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RETHINK

# LTE and HSPA device availability in UK-relevant frequency bands

## *Current availability and future evolution*


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# Executive summary

This report has been prepared on behalf of Ofcom, the UK communications regulator, by Real Wireless in collaboration with Rethink Research.

This report presents the latest research of HSPA+, DC-HSPA+ and LTE commercial device availability and a survey of device vendor roadmaps up to 2016. The research covers the latest publicly available information of device launches, commercial network launches in frequency bands that are/will become available in the UK.

**Commercial device availability**

This report provides an update of the commercial activity that has taken place since the last report [1] produced by Real Wireless on commercial device availability and shows how availability of HSPA+ and LTE devices has changed across the frequency bands of interest in the UK. The report identifies the trends in device types that are now emerging on the market such as smartphones and tablets, dual FDD/TDD mode devices and the latest high speed 150+ Mbps devices (e.g. category 4).

The following chart illustrates how the number of new LTE devices introduced to the market has changed over the six month period from October 2011 to April 2012. The largest increase in the number of LTE devices can be seen across the three European frequency bands 800 MHz, 1800 MHz and 2600 MHz. There is also a nine-fold increase in the number of TDD devices supporting the 2600 MHz band over the period.

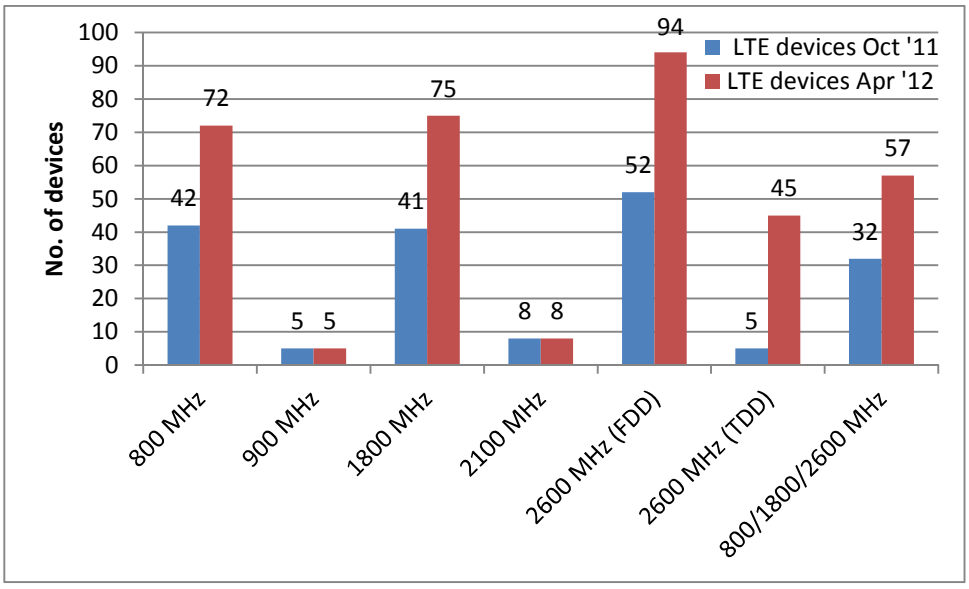


**Figure 0-1 Growth in LTE devices across frequency bands between October 2011 and April 2012**

The report also illustrates the growth in the number of HSPA+ devices in the 900 MHz and 2100 MHz bands. Figure 0-2 shows the maturity of the HSPA device market from the relatively smaller growth in devices compared to LTE. There continues to be an increase of HSPA+ devices coming to market but the most significant growth has been the number of DC-HSPA+ devices, which has doubled in the nine month period from June 2011 to February 2012.

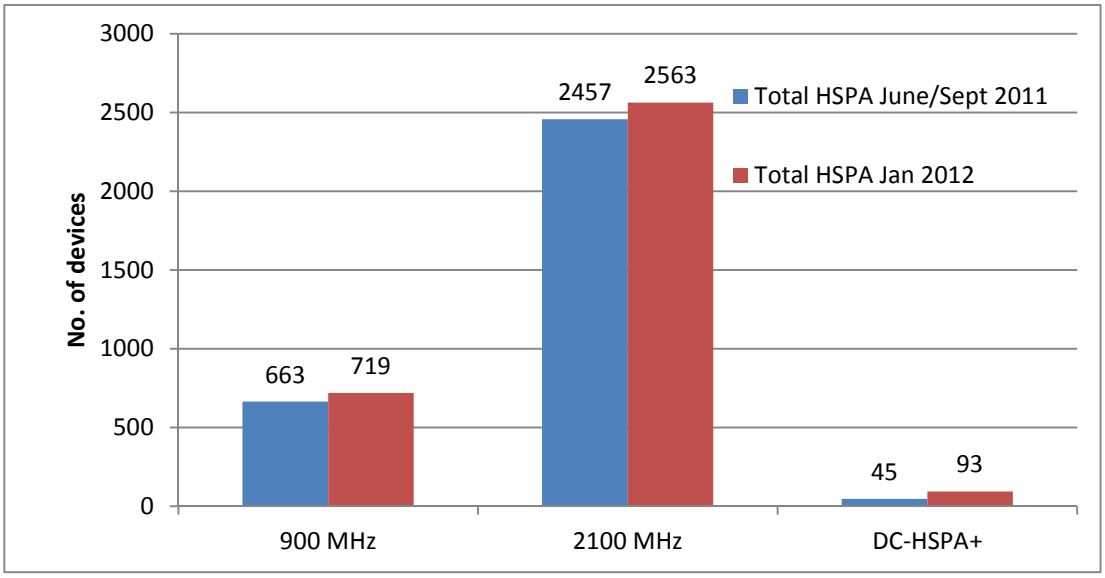


**Figure 0-2 Growth in HSPA devices across frequency bands in the last six to nine months**

Overall the growth trends in commercial LTE device availability have been significant across the smartphone and tablet form factors with vendors such as HTC, ZTE, Huawei and Samsung dominating device launches since mid-2011. We note that 2012 will be an important year for device vendors as both sales increase, a predicted 10-fold increase in shipments of LTE devices in 2012 and new smartphone and tablet launches will be announced particularly for devices supporting the European bands.

**Survey of device vendor roadmaps for various European LTE and HSPA+ bands 2012-2016**

We surveyed 16 device manufacturers, 42 European operators and numerous suppliers of key components to understand their roadmaps for new devices over the next few years. The main data refers to five-year product roadmaps of branded mobile device OEMs. These reflect the band combinations they expect to support, as of Q112, based on their reading of operator plans to the end of 2016.

Our research suggests there will be two tiers of LTE frequencies in device procurement terms which will consist of 3-4 universally supported bands per region. In Europe these include the 800 MHz, 1800 MHz and 2600 MHz bands with 900 MHz initially falling into the second tier in Europe. 900 MHz will start to feature as a tier one LTE band, likely to be around 2015/2016, once global volumes for OEMs, roaming and pricing have reached a level similar to that of other bands notably the 1800 MHz band.

The support for LTE in the 900 MHz band is gaining momentum in a similar way to that seen in in the 1800 MHz band a few years ago. However, there are still no European tier one operators fully supporting LTE900 with devices being driven by Middle East operators and parts of the Asia Pacific. Nevertheless, 60% of operators surveyed, were considering using 900 MHz for LTE. This shift in perception is due to the accelerated deployment of wide-scale roll-out plans of LTE and the spectrum options available to operators holding a variety of bands that can support it.

Operators also indicated LTE900 scales better than HSPA and offers a better migration path to LTE-Advanced. There is considerable carrier interest, even among those confident of securing 800MHz licences, in refarming 900MHz in 2014 or later as a way to move directly to LTE-A. The deployment of LTE-A itself has moved forward on many carriers' timescales, compared to 2009.

**Selected forecasts**

Figure 0-3 shows the relative prevalence of 24 different band combinations between the end of 2012 and 2016. This means that many bands will be in play worldwide during the first phase of LTE, with a significant impact on the device ecosystem. The chart illustrates how the balance between frequency combinations change between 2012 and 2016 with the largest shift occurring from a single band 2100 MHz HSPA device with 30% of device variants in 2012 down to only 7% by 2016. This is overtaken by the 800 MHz LTE/2600 MHz LTE and 2100 MHz HSPA band combination in 2016 with 11% share of device variants.

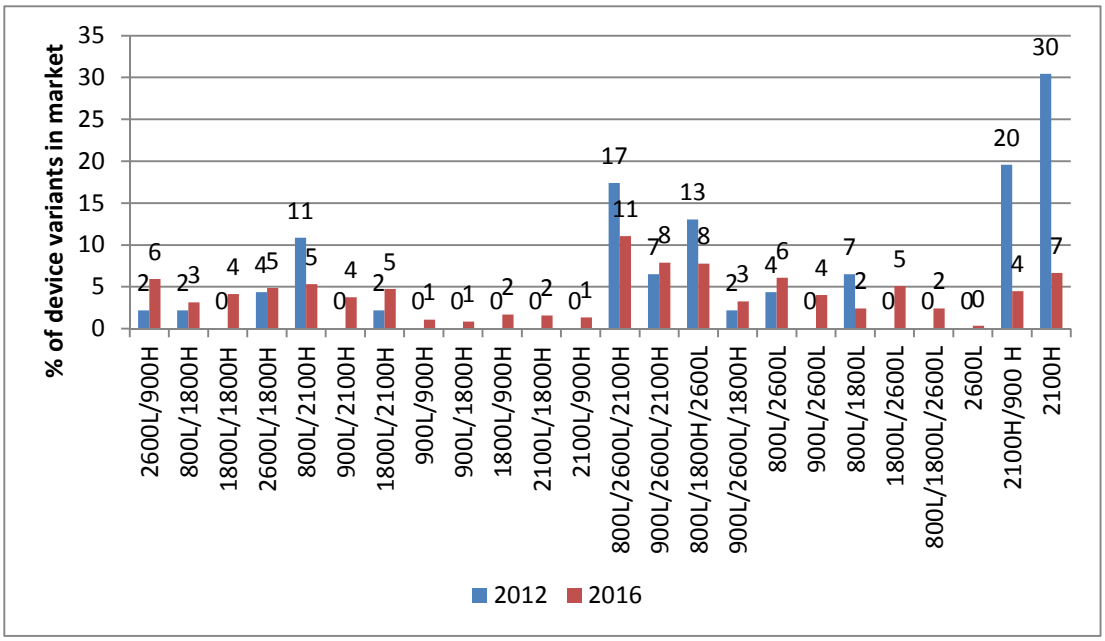


**Figure 0-3 Band combinations supported by device variants appropriate to Europe, as a percentage of the total base (56 variants in 2012, 824 in 2016).**

The changes in how the 3G+/4G device market is divided between different frequency combinations indicates fragmentation as LTE gains scale, after the relatively homogenized environment of European HSPA. Although it will be cheaper and easier for OEMs to support a larger number of combinations, willingness will be moderated by pressure on device prices.

By 2016, the profile is expected to change significantly, with OEMs pulling back from HSPA+-only devices as even the second wave of 4G operators start to activate their LTE services. At this point, HSPA+-only combinations account for only 11% of a far larger total. LTE-only models are more common, totalling 19% of variants. Within these, 2.6GHz support is almost universal, and the most common accompaniment is 800MHz, followed by 1800MHz and then 900MHz. Only 2% of the total base supports LTE-only but without 2.6GHz included.

Our research found that changes in the device ecosystem will also be driven by the growth in the machine-to-machine devices and the fragmentation of mobile device branding, service and content providers and the increasing use of LTE embedded in devices such as e-readers.

TD-LTE is also likely to influence the shape and growth of the LTE device ecosystem. OEMs generally have a 'wait and see' attitude to European TD-LTE. Asian devices can be converted relatively easily for the European spectrum as the market demands, but most do not expect a TD/FD-LTE smartphone to be a mainstream option until after 2016. In the meantime roll-outs will rely mainly on data-only devices or customized handsets. These will be driven mainly by the vendors which had WiMAX smartphone business – HTC, Samsung, ZTE – as well as Huawei.

# Contents

# 1. Introduction

In January 2012 [1] we compiled a report which Ofcom published alongside their consultation on proposals for award of the 800 MHz and 2.6 GHz spectrum in the UK. The report covered the following areas:

1. LTE and HSPA technical features based on 3GPP standards
2. Device availability based on public sources versus frequency band and technology
3. Future evolution of device availability based on a survey of vendors

While the data in 1 above is relatively stable due to 3GPP's approximately annual release cycle, both 2 and 3 are rapidly evolving as LTE and HSPA deployments progress internationally. In order to provide Ofcom with the latest relevant data for their policy considerations, we have updated our view of both current commercial announcements of mobile devices and on current vendor roadmaps for device evolution over 5 years. The particular focus of this report is on the relative availability of devices supporting the frequency band and technology combinations listed in Table 1-1, as well as combinations of those bands where appropriate. To a lesser extent we have also provided information about support for other international bands where this is useful to give context to the developments, notably the US 700 MHz band.

**Table 1-1: Frequency band and technology combinations of prime interest in this report**

| Frequency band and technology | 3GPP band designation for UTRA (i.e. UMTS/HSPA) and E-UTRA (i.e. LTE) |
|---|---|
| 800MHz LTE | 20 |
| 800MHz HSPA+ | 20 |
| 900MHz LTE | 8 |
| 900MHz HSPA+ | 8 |
| 1800MHz LTE | 3 |
| 1800MHz HSPA+ | 3 |
| 2100MHz LTE | 1 |
| 2100MHz HSPA+ | 1 |
| 2300 MHz TD-LTE | 40 |
| 2600MHz LTE | 7 |
| 2600MHz TD-LTE | 38 |
| 3500MHz TD-LTE | 42 |
| 3700 MHz TD-LTE | 43 |

Section 2 provides a view of current commercial device availability based on public sources, highlighting changes since our previous report, while section 3 reports on device manufacturer roadmaps for devices over the next five years.

# 2. Current commercial device availability and frequency band support

## 2.1 Introduction

In this section we present the latest device releases from industry including an update on the number of devices commercially available across the main European frequency bands that support LTE. We also highlight the change between the data from the January report and the data gathered for this report to provide a sense of the rate of change over the period.

## 2.2 HSPA and LTE devices available in current and upcoming UK frequency bands

Ofcom's last Communications Market Report indicated [2] that UK mobile data traffic volumes increased by 390 times over three years (Q4 2007 to Q4 2010). In those few years there has been an increasing penetration and proliferation of mobile devices on operators' networks with the emergence of mobile broadband USB modems, smartphones and tablet PCs.

The technology, features and functionality has also evolved from 'quad band' phones to devices now supporting a greater number of licensed mobile bands. Figure 2-1 shows the 3GPP frequency bands (3GPP band designations given in brackets) and the designated bandwidths compared to the UK frequency allocations. It can be seen that in some cases the quantity of UK frequency allocations do not exactly match the total available quantity which could impact the use of some devices in the UK.

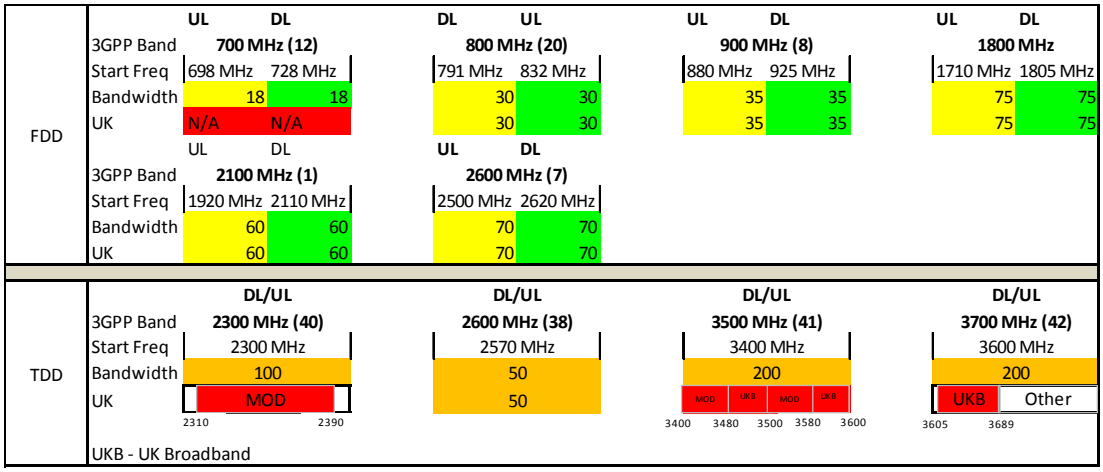


**Figure 2-1 FDD/TDD frequency bands and bandwidths compared with UK spectrum allocations**

The 2100 MHz band was the first frequency band to support HSPA technology in the UK and early devices required only a single band to support this in uptake.

Since the 900 MHz and 1800 MHz bands became liberalised in 2009, HSPA devices across Europe have progressively supported 900 MHz but not 1800 MHz. The 1800 MHz band has tended to be supported for the deployment of LTE rather than HSPA/HSPA+, despite the same level of support for both bands in the 3GPP standards.

This section presents each band in ascending order of frequency, providing factual data on the number of devices, specific device launches and the frequencies they support and the different form factors that are available on the market.

Five main form factors are examined:

- Handsets/Smartphones
- Tablets
- USB modems
- Embedded modules (Laptops/Netbooks)
- Routers

However, other form factors are also considered in this section that form part of the wider ecosystems and these include:

- PEM (PC Express Mini) cards
- Chipset modules (for phones, tablets and other consumer devices)

In this updated report two more frequency bands have been added for review of device availability which were not covered in the previous report:

- 2300 MHz (TD-LTE)
- 3500 MHz (TD-LTE)

## 2.3 Timeline for LTE device availability

Since October 2011 there has been a 76% increase in new devices released for LTE in the form factors listed above. The total number of LTE-enabled user devices now available is 347 (as of April 2012) compared to 197 six months ago. These devices span all standard frequency bands from 700 MHz to 2600 MHz. A breakdown of the devices now available per frequency band is given in the table below based on the GSA's report in April 2012 [3]:

| Band | Total number of devices Oct 11 | Total number of devices Apr '12 |
|---|---|---|
| 700 MHz | 106 | 170 |
| 800 MHz | 42 | 72 |
| 900 MHz | 5 (June '11) | >5 |
| 1800 MHz | 41 | 75 |
| 2100 MHz | 8 (June '11) | 8 |
| 2600 MHz (FDD) | 52 | 94 |
| 800/1800/2600 MHz | 32 | 57 |
| 1700/2100 MHz AWS | 35 | 72 |

**Table 2-1 Change in the number of LTE devices supporting each frequency band between October 2011 and April 2012** Note that device numbers for 800/1800/2600 MHz combined are included in the individual bands

It can be seen that significant growth (>80%) in the number of devices occurs in the core European frequency bands. This means there is an expanding ecosystem of capable devices supporting a wider choice of frequency bands.

Additionally, the number of TDD devices has increased across frequency bands since the last report. A summary list of the number of TDD devices is now available from the GSA report and includes:

- 2300 MHz (band 40) 43 devices
- 2600 MHz (band 38) 45 devices
- 2600 MHz (band 41) 5 devices

Figure 2-2provides a breakdown of the devices by form factor type which can be seen in. It shows that routers are the dominant form factor produced for LTE at 34% of all devices followed by dongles and smartphones at 18%. Modules and tablets represent 12% and 9% respectively of all commercial LTE devices.

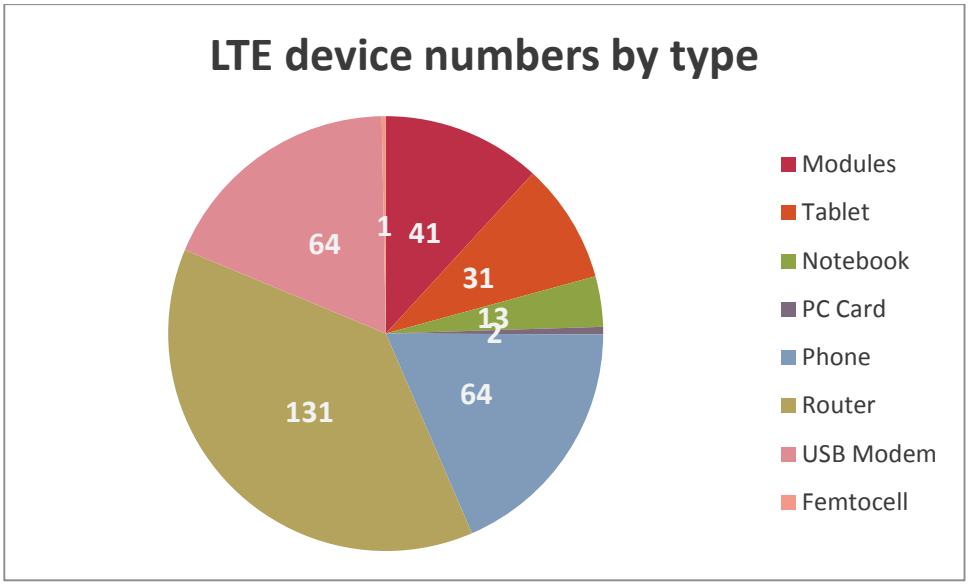


**Figure 2-2 Number of LTE devices by form factor** Source: GSA [3] statistics

It is noted that out of these devices 118 also support HSPA and 167 now support the 800, 1800 MHz and 2600 MHz bands compared to 135 devices (supporting the 800, 1800 and 2600 MHz bands) as reported by the GSA in October 2011 [4].

Growth in the number of devices for supporting LTE, over the same period [4], has mainly been in tablets (281%) and smartphones (137%) with routers (87%) and USB modems (36%) showing lower but still significant growth.

This is consistent with a trend we noted in the previous report [1] for the rate of development of devices which can support multiple bands and multiple technologies to increase for LTE relative to previous technologies.

## 2.4 Details of LTE handsets and tablets and device evolution

There has been a surge in the number of smartphones released on the market with a 33% increase in the three month period from Jan'12 to Mar '12. There has also been growth in the number of LTE enabled tablets which has seen an increase of 72% in the 3 month period from Jan'12 – Mar'12. Below we outline a selection of the latest LTE smartphones and tablets that have been launched on the market since summer 2011:

| Example handsets and tablets now available with LTE | |
|---|---|
|  |  |
| HTC Velocity 4G [5] (1800 MHz) | Samsung Galaxy S II LTE [6] (800/1800/2600 MHz) |
|  |  |
| Asus Transformer Pad Infinity [7] (700 MHz) | RIM LTE Playbook [8] (700 MHz) |
|  |  |
| Apple the new iPad US [9] (700 MHz) | Nokia Lumia 900 [10] (700 MHz) |
|  | |
| Samsung Galaxy S3 [11] (800/1800/2600 MHz) | |

**Table 2-2 Selection of LTE handsets and tablets commercially available**

According to Strategy Analytics [12] 2012 will be an important year for device vendors with a predicted ten-fold increase in LTE device shipments in 2012. This includes planned launches of new smartphones and tablets from LG, Nokia, Samsung and HTC.

The majority of devices expected to be launched in the course of 2012 will be for the US market in the 700 MHz band. However more devices will start to emerge that support the growing number of European LTE network deployments. The devices currently supporting the European bands include a variety of portable Wi-Fi routers, and USB dongles with a selection of only a few smartphones and tablets. For example, the HTC Velocity 4G supports LTE1800 and HSPA+ (42 Mbps) in the 850 and 2100 MHz bands [13] and the Samsung Galaxy S2 supports European bands 800, 1800 MHz and 2600 MHz for LTE and 900/2100 MHz for HSDPA [14]. These devices are now available on Vodafone [15] in Germany.

The latest LTE devices also support interworking and fallback to other technology modes, most notably HSPA and HSPA+. The following statistics from the GSA [3] show the technology capability of the latest LTE devices:

- 217 LTE devices operate on either HSPA, HSPA+ or 42 Mbps DC-HSPA+ networks
- 91 LTE devices support 42 Mbps DC-HSPA+
- 108 LTE devices support EV-DO networks

LTE support generally has increased, with 319 operators investing in LTE in 97 countries and with 72 commercial networks now launched globally in 37 countries [16].

The maximum downlink speed of an LTE device depends on the device category. All current commercial LTE devices are category 3, which allows up to 100 Mbps in the downlink. However, the first category 4 commercial LTE device, supporting up to 150 Mbps, was launched in H1 2012 by Huawei. Their E3276 [17]Cat 4 150Mbps DL USB modem supports 800 MHz, 1800 MHz and 2600 MHz frequency bands for LTE and falls back to GSM and UMTS.

## 2.5 HSPA and LTE mobile device availability

### 2.5.1 800 MHz HSPA devices

There is still only one device available which supports HSPA at 800 MHz which is a PC Mini Express Card [18]. Besides this device no further published information was found on devices which support HSPA in this band.

There continues to be little commercial investment from vendors, device development and support in the 800 MHz band has been predominantly focused on LTE technology.

### 2.5.2 800 MHz LTE devices

There continues to be increasingly significant vendor support for LTE devices in the 800 MHz band with 72 devices commercially available compared to 42 devices since the October 2011 GSA report [4]. Form factors supported include chipsets, dongles, phones, tablets and routers. 57 of the devices also support other frequency bands including 1800 MHz and 2600 MHz.

Particular LTE 800 devices include:

- The Altair FourGee 3100 [19] is a baseband processor which can be incorporated into handsets, dongles and other consumer electronic devices.
- ZTE have launched a multimode USB modem MF880 [20] which supports LTE 800, 2300 and 2600 MHz
- The Samsung GT-B 3740 USB modem [21] was the first device to be certified by the Global Certification Forum in March 2011 and supports the 800 MHz band
- Samsung and ZTE have produced tablets and smartphones that can operate on the 800 MHz band and the 1800 MHz and 2600 MHz bands. The Samsung Galaxy S2 [6] LTE and ZTE V5L [22] are two example handsets and the Samsung Galaxy Tab 8.9 [23] and ZTE V11L [22] are two example tablets. These devices also fall back to HSPA and form the first devices of this type supported in the band.
- Nokia's LTE-capable multi-mode multi-band Internet USB Modem RD-3 was commonly used in 800 MHz trials such as the first test call conducted in Finland [24].
- Huawei [25]have announced two smartphones that operate in the 800 MHz, 1800 MHz and 2600 MHz band (See section 2.5.6 for details)

The growth in the number of devices for this band is likely to have been driven by both the planned and commercial deployment of 800 MHz LTE networks in Europe. In Germany, for example, 800 MHz network operators [26] now offer a selection of smartphones, USB dongles and personal Wi-Fi devices.

### 2.5.3 900 MHz HSPA devices

Devices that support this band continue to grow rapidly. They usually also support the 2100 MHz band as increasing number of operators begin to deploy 3G in the 900 MHz spectrum. There are more than 750 UMTS900 devices [27] that have been announced to support the growing number of commercial networks being launched across the world.

According to the GSA's May 2012 report [27] on the status of UMTS 900 it confirmed 42 commercial network deployments in 29 countries as of May 2012.

The report also includes a list of operators that have launched 900 MHz HSPA commercially 31. The following operators are those who have commercially launched since October 2011

- Slovenia Si Mobile
- Spain Telefonica Movistar
- Germany E-Plus
- Poland Polkomtel
- Russia MTS
- Russia, Megafon
- Russia, Vimpelcom

Devices used in these deployments support at least 3GPP Release 6 with some operators, notably 3 in Sweden, supporting HSPA Release 8 with DC-HSPA [28]. The number of devices supporting HSPA in this band has grown to 750 [27] from 663 since June 2011. This includes: ZTE PF112 [29], the new iPad [9], Samsung Galaxy S2 [6], Nokia Lumia 900 [10].

There were 245 HSPA+ 900 MHz devices as of January 2012 [27] including BandRich PR40 series pocket router, Novatel Wireless USB modem Ovation MC545 capable of supporting 42 Mbps. This was compared to 182 devices in mid-2011. There are now 93 devices which support DC-HSPA+ as of February 2012 with this number expected to grow as more manufacturers add DC-HSPA+ to their product portfolio. Table 2-3 lists devices which support UMTS 900 MHz and 2100 MHz, alongside LTE connectivity [30].

| Manufacturer | Model | Type | European bands supported (MHz) |
|---|---|---|---|
| BandRich | BandLuxe C501 | USB Modem | 800/1800/2600 |
| BandRich | BandLuxe C502 | USB Modem | 800/1800/2600 |
| BandRich | BandLuxe C509 with TDD LTE | USB Modem | 800/1800/2600 |
| Franklin Wireless | U700 | USB Modem | N/A |
| Huawei | E392 with optional TDD support | USB Modem | 800/1800/2600 |
| Huawei | E397 | USB Modem | 800/1800/2600 |
| Huawei | E398 | USB Modem | 800/1800/2600 |
| Huawei | E398 Cyfrowy Polsat model | USB Modem | 800/1800/2600 |
| Huawei | Vodafone Connect Pen K5005 | USB Modem | 800/1800/2600 |
| Yota Devices | Pearl | USB Modem | 800/1800/2600 |
| ZTE | AL621 | USB Modem | 1800 |
| ZTE | MF820 | USB Modem | 1800 |
| ZTE | MF820D | USB Modem | 800/1800/2600 |
| ZTE | MF880 with LTE FDD and TDD | USB Modem | 800/1800/2600 |

**Table 2-3 Devices which support UMTS 900/2100 and LTE connectivity April 2012. Source: GSA [3]**

It can be seen from Table 2-3 that these devices are all USB modems and support a mix of the key European bands. There are a number of example smartphones which now support HSPA900 with LTE connectivity according to the GSA [30]. The Samsung Galaxy S II LTE, however, is the only smartphone that supports HSPA in the 900 MHz and 2100 MHz with LTE in European bands - the other available smartphones support US LTE frequencies.

### 2.5.4 900 MHz LTE devices

Our previous report suggested based on vendor roadmaps that there would be growth in LTE devices in the 900 MHz band, despite there being few commercial devices at the time. It suggested by 2015 there would be around 30-40 devices supporting this band. One report [31] from Informa Telecoms and Media has suggested LTE in the 900 MHz band would be driven initially by deployments in the Middle East. Mobile penetration in general in the Middle East (101%) is now greater than North America (93%) but less than Western Europe (129%) according to Ericsson [32] which is also likely to impact on growth of mobile broadband penetration as new networks are deployed.

Devices that will support LTE900 in the near future are mainly USB dongles, the Option Beemo [33], for example, is due for launch in 2012. This is a quad band LTE device which supports 800 MHz, 900 MHz, 1800 MHz and 2600 MHz. which means it will be ready for the launch of LTE services in the UK. Amongst other LTE 900 devices are portable Wi-Fi routers and embedded modules such as the Sierra Wireless Airprime MC7719 [34].

Reports suggest [27] operators continue to focus their resources on WCDMA/HSPA/HSPA+ deployments in the 900 MHz band rather than LTE in this band. This means there are still as many as 40 (April 2012) operators globally that are upgrading their GSM networks to 3G in this band and not upgrading straight to LTE.

However, Value Partners [35], forecast a timeline for mass market adoption of LTE900 over the next 5 to 10 years. LTE chipsets being developed are beginning to support 900 MHz, such as those from Infineon, ST Ericsson, Altair. Some example trials of LTE use in the 900 MHz band include, Cosmote in Greece and Magyar Telecom in Hungary who are each testing and trialling LTE technology [36]. Additionally, Cell C [37] in South Africa are conducting LTE trials in existing 900 MHz spectrum. Telstra in Australia is an operator that more recently (March 2012) been investigating the use of LTE in its 900 MHz spectrum according to one report [38]. Although it has not made any firm commitments the operator is in dialogue with chipset vendors and device manufacturers to build up support for devices in this band.

### 2.5.5 1800 MHz HSPA devices

As with the previous report, no commercially available HSPA devices that support the 1800 MHz band have been found. One UMTS/HSPA 1800 trial network has been identified in France, Orange have trialled HSPA in the 1800 MHz band using Ericsson BTS and Qualcomm devices [39].

The trial commenced in November 2010 using a Qualcomm RTR 8600 chipset which supports DC-HSPA, LTE, EDGE and GPS.

### 2.5.6 1800 MHz LTE devices

As at May 2012 there were 18 LTE1800 commercial networks deployed across the globe as [40] provides some insights and contributions from operators and vendors that are involved with trials and deployments of LTE in the 1800 MHz band. There is significant interest from operators globally for use in this band with 35 operators either trialling or in deployment. This is compared to 23 firm deployment commitments since November 2011.

As of May 2012 there were 10 LTE1800 networks commercially launched in Europe, compared to 6 at the end of 2011:

- Mobyland, Poland
- Omnitel, Lithuania
- Deutsche Telekom, Germany
- LMT, Latvia
- Teliasonera, Finland
- Telia, Denmark
- Elisa, Finland (2600/1800 MHz and DC-HSPA+)
- DNA, Finland (2600/1800 MHz)
- T-Mobile, Hungary
- T-Hrvatski, Croatia

There is vendor support for 75 LTE 1800 devices currently compared to 50 since the October 2011 GSA report [4]. These include a mixture of form factors such as chipsets, routers, tablets, dongles and smartphones as seen in Figure 2-3. The majority of these devices fall back to HSPA/HSPA+ and in some cases support DC-HSPA+. The majority of the devices supporting this band also support other frequency bands such as 800 and 2600 MHz for LTE.

It can be seen that routers form the most popular form factor for devices in this band which include personal hotspots at 36%. There are also dongles and modules which represent 24% and 23% respectively. Smartphones represent 12% of all devices in this band and tablets under 5%.

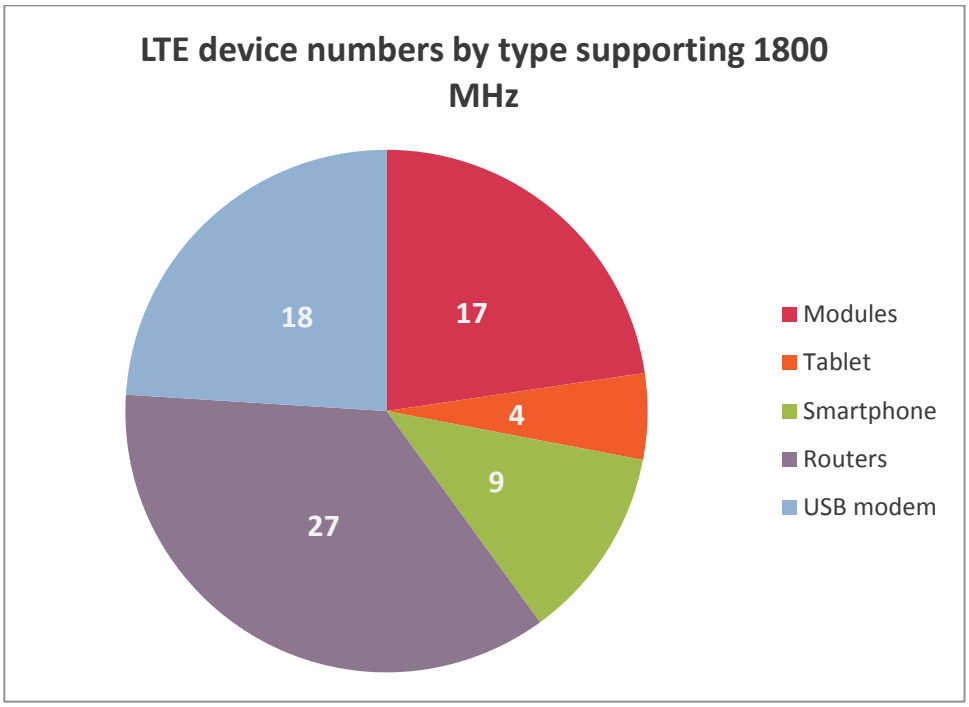


**Figure 2-3 Number of LTE1800 devices by form factor.** Source: GSA [**3**]

In the previous report we noted that Samsung and ZTE had produced tablets and smartphones that can operate on the 1800 MHz band (and the 800 MHz and 2600 MHz bands). The Samsung Galaxy S2 LTE [6] and ZTE V5L [22] were the two example handsets and the Samsung Galaxy Tab 8.9 [41] and ZTE V11L [22] were the two example tablets that were commercially available. However, there is now evidence of European operators deploying these types of devices.

The HTC Velocity [5] was launched in February 2012 and supports LTE in the 1800 MHz band and is offered by Vodafone [15] in Germany. This multimode handset also supports HSPA in 2100 MHz. However, one report [42] suggests this particular model was aimed at the Australian/Asian market and will not work on the European 1800 MHz band. Huawei [43] also plan to launch two smartphones in second half of 2012 which support 800 MHz, 1800 MHz and 2600 MHz, the Huawei Ascend P1 and the Ascend D. These smartphones are multimode also supporting GSM and UMTS. The Ascend P1 will also support TD-LTE in 2600 MHz band.

### 2.5.7 2100 MHz HSPA devices

The 2100 MHz band is still one of the most widely supported bands for mobile broadband devices. This is based on the number of operator deployments of networks in this band with over 172 operators across Europe (including approximately 40 UMTS900 deployments in Europe) who have deployed HSPA networks. The GSA reported [27] around 3362 HSPA devices are available, as of January 2012, from over 271 suppliers with 2563 HSPA devices operating in this band. This is compared to 3227 devices in total, 264 suppliers and 2457 devices in this band in September 2011.

All mobile operators in the UK have deployed HSPA in their 2100 MHz networks with minimum DL speeds of at least 7.2 Mbps. According to a GSA market analysis [44] 3 and O2 has already deployed HSPA+ with O2's network reaching maximum download speeds of 42 Mbps in 2011.

### 2.5.8 2100 MHz LTE devices

There is still currently no evidence of any European countries supporting LTE in this band. The contrary evidence from the GSA and GSMA suggests that European countries are predominantly planning to deploy LTE in new spectrum such as 2.6 GHz rather than 2100 MHz [45].

The previous report noted NTT DoCoMo had deployed LTE in the Japanese version of this band and they and some analysts suggest this should be the global roaming band for LTE [46]. In February 2012 NTT DoCoMo published a newsletter [47] with an update on its operations using LTE in the 2.1 GHz band. The company has been encouraging global to upgrade their 2.1 GHz spectrum for LTE use. The operator has also developed a radio frequency amplifier that can support up to six frequency bands in the range 1.5 GHz to 2.5 GHz and designed to be smaller than conventional single band modules.

### 2.5.9 2300 MHz devices

The 2300 MHz band is a designated IMT band with majority of the network deployments taking place in Asia and the far-east markets such as India, China, Korea and Malaysia. The band is standardised by 3GPP and designated as band 40 according to the list of harmonised mobile bands (See section 2.2). In the UK the Ministry of Defence [48] holds the majority of this spectrum and it is currently working on plans to release 80 MHz of spectrum in this band by 2015.

Research for our previous report mainly indicated trials with no commercial deployments and little evidence of commercial devices. Since January 2012 there has been a growing number of devices available on the market which use TD-LTE technology, due mainly to the increasing deployments in Asian and far-eastern markets. According to the GSA [3] there are 43 devices now commercially available supporting the 2300 MHz TDD band (many also support the 2600 MHz band):

- NSN TD-LTE Mi-Fi (2.3 GHz and 2.6 GHz)
- Huawei E589 [49]Mobile Wi-Fi (2.3 GHz and 2.6 GHz)
- Huawei E392 multi-mode USB dongle (2.3 GHz and 2.6 GHz)
- ZTE [50]LTE smartphone (2.3 GHz and 2.6 GHz)
- Nokia TD-LTE booklet (2.3 GHz and 2.6 GHz)

According to one South African web site ZTE [51] are due to launch the first TD-LTE tablet V11T supporting 2.3 GHz and 2.6 GHz in Q2 2012.

The Global TD-LTE Initiative (GTI) [52] has been influential in supporting vendors and operators in adopting the use of this band and incorporating it into devices. As noted in the list above both ZTE and Huawei are supporting devices in this band with smartphones and USB dongles. However Nokia has produced a device in this band with a booklet and personal mobile Wi-Fi device. Additionally, these devices also support multi-mode such as UMTS 900/2100 which is incorporated in the Huawei E589 for example.

### 2.5.10 2600 MHz HSPA devices

The 2600 MHz band was originally designated as the '3G expansion band' by the ITU configured with (3G) systems in mind. However, there is little evidence of HSPA being deployed in the 2600 MHz band. Operators holding fresh 2600 MHz spectrum have either already deployed LTE or are planning to deploy LTE [53] in future. The 3GPP standards do support HSPA at 2600 MHz but no commercially available devices that offer HSPA in this band have been found to date.

### 2.5.11 2600 MHz FDD LTE devices

In Europe, the 2600 MHz band was the first to have LTE technology deployed by Teliasonera in Sweden at the end of 2009. A single mode/band USB modem (Samsung GT-B3710 USB modem [54]) was the only device available at launch to access the network. There are currently (April 2012) 94 devices that support the 2600 MHz band compared to 52 six months ago [3].

Device types available for this band include embedded modules, tablets, phones, PC Cards, notebooks, routers, and USB dongles. More than 50% of the devices support multiple bands including 800 MHz and 1800 MHz and also support other technologies such as HSPA/HSPA+.

There has been an 81% increase in the number of devices in this band since the October 2011 GSA report [4] and across the different form factors. Based on the total number of LTE devices (all types) the main increase has been from tablets (281%) and handsets (137%). This is because there were so few tablets and handsets that supported any of the European bands. For example Huawei is due to launch a smartphone which supports 800 MHz and 2600 MHz later in 2012 [55], no exact date has been specified. The GSA June 2011 report revealed ZTE [22] were the only vendor to offer a tablet and phone in this frequency band. However, since then Samsung and HTC [5] also offer smartphones and tablets in this frequency band. As discussed in section 2.5.5 Samsung released the Galaxy S II [6] and the Galaxy Tab 8.9 [22] to widen the choice of vendor handsets and tablets in this band.

This increase in device support can be attributed to the increase in the number of commercial network launches. There have been 2 live commercial network launches in Europe in this band since the end of 2011. These include Telenor in Montenegro and Vodafone in Portugal which is in addition to the 14 or so networks already launched.

**Commercial 2600 MHz FDD LTE networks in Europe [3]:**

- Austria (3) – One new network deployment since Oct '11
- Sweden (2) – No change since Oct '11
- Finland (2) – No change since Oct '11
- Estonia – No change since Oct '11
- Denmark – No change since Oct '11
- Norway – No change since Oct '11
- Germany –New network deployment since Oct '11
- Portugal (2) – Two new network deployments since Oct '11
- Hungary – New network deployment since Oct '11
- Lithuania – New network deployment since Oct '11

- Montenegro – New network deployment since Oct '11

Trial networks also continue to operate in this band but are mainly in countries whose frequencies are yet to be awarded.

**Trial networks in Europe [3]:**

- France
- Italy
- UK

### 2.5.12 2600 MHz TD-LTE devices and TD-LTE in general

According to the GSA [3] there are now (April 2012) 45 terminal devices commercially available that support TD-LTE in the 2.6 GHz band. These devices include mobile Wi-Fi, CPE, laptops, handsets, tablets and embedded modules. An example list extracted from the Global TD-LTE Initiative (GTI) [20] web site is given below:

- NSN TD-LTE Mi-Fi (2.3 GHz and 2.6 GHz)
- Huawei E589 Mobile Wi-Fi (2.3 GHz and 2.6 GHz)
- Huawei E392 multi-mode USB dongle (2.3 GHz and 2.6 GHz)
- ZTE MF880 dual mode (FDD/TDD) USB modem supporting 800/2600 FDD and 2600 TDD
- ZTE LTE smartphone (2.3 GHz and 2.6 GHz)
- Nokia TD-LTE booklet (2.3 GHz and 2.6 GHz)

ZTE [50] are reportedly due to launch the first TD-LTE tablet V11T supporting 2.3 GHz and 2.6 GHz in Q2 2012. Additionally, Gemtek and Sequans announced at Mobile World Congress in 2012 [56] a category 4 USB modem which supports bands 38, 40 and 41 and downlink throughput of up to 150 Mbps. This device also supports 4 x 2 MIMO with transmit diversity. Some of the devices, notably the Huawei E589 also support UMTS 900 and 2100 so can be used on 3G networks in the UK and across other European markets.

China Mobile continues to promote the development of TD-LTE with its on-going trial network, but one report suggests this network will not be launched commercially until 2014 [57]. A number of the 16 TD-LTE trials presented in the previous report are now migrating to commercial deployments as presented below [3]:

- Australia (commercial launch expected in 2012)
- Denmark (dual mode (FDD/TDD) deployment underway)
- France (trial on-going)
- Germany (trial on-going)
- India (numerous TD-LTE deployments)
- Ireland (trial concluded)
- Malaysia (2) (planned overlay of TD-LTE onto WiMAX network sites)
- Japan (Softbank launched Feb 2012)
- Oman (showcase network)
- Poland (Aero 2 launched)
- Russia (Rostelecom approval to deploy 2.3 GHz network)
- Taiwan (numerous tests and trials completed)

- USA (Clearwire plans to deploy TD-LTE as an overlay to its WiMAX network)

In Europe support for TD-LTE has continued to evolve with one operator has launched a commercial service in the last 12 months. Aero 2 in Poland launched [58] its dual FDD-TDD network using its 2.6 GHz TDD spectrum. The TD-LTE trials that have been taking place in Europe, notably Spain, Sweden and Germany are either still on-going or completed with the exception of Sweden, which has now launched a commercial network. We provide an outline overview from the three markets:

- Vodafone Spain has been conducting TD-LTE trials in their 2600 MHz spectrum achieving DL speeds of 60 Mbps and UL speeds of 25 Mbps [59]
- Hi3G in Sweden has started to deploy a dual mode TDD/FDD LTE network at 2600 MHz with support from ZTE [58]
- E-Plus [60] in Germany launched a TD-LTE field trial in their 2.6 GHz spectrum in Q1 of 2011. This trial is being supported by ZTE and China Mobile

Since the previous report chipset vendors have continued to conduct interoperability testing. In January 2012 Clearwire in the US and China Mobile [61] signed a Memorandum of Understanding to collaborate jointly for interoperability testing of devices in the 2.3 GHz and 2.6 GHz bands. The aim of the partnership was to accelerate the development and testing of TDD variant devices that support multi-mode and multi band capability.

We noted in the previous report two independent analyses that had also forecast the deployment and growth of TD-LTE in the next 2 to 3 years, notably Ovum's forecast [62] of 89 million TD-LTE connections by 2015. However, a report [63] published by Rethink Research and Maravedis in April 2012 forecast that 458 million dual-mode (FDD and TDD) devices will be activated by 2016.

The recent growth in TD-LTE devices has been generated from collaboration amongst vendors and operators investing in the TDD variant of LTE. The Global TD-LTE Initiative (GTI) [52] which was founded in 2011 has been facilitating the promotion of the LTE-TDD in order meet demand for growing mobile broadband services. Furthermore, the transition from TDD variants of 3G networks has influenced the use of TD-LTE as an evolutionary upgrade path.

### 2.5.13 3500 MHz LTE devices Band 42

3GPP Release 10, frozen in March 2011, included support for the 3.5 GHz band for LTE and HSPA. 3GPP TR 37.801 [64] is a new work Item that incorporated UMTS/LTE technology in the 3500 MHz band and a frequency band arrangement to allow support for both FDD and TDD operation. Given general trends [65], devices supporting this band could be available 12-18 months after standards. In the previous report, no specific evidence of vendors developing 3500 MHz LTE devices was found.

However, UK Broadband [66] launched its TD-LTE wholesale network in 3500 MHz in London in February 2012. According to UK Broadband the first devices will be Customer Premises Equipment (CPE) from Huawei available for indoor and outdoor use at homes and businesses. The first mobile devices that will support both FDD and TDD LTE and 3G will be available in September 2012.

The 2012 Mobile World Congress [67] hosted the first 3.5 GHz TD-LTE summit which included key players, from operators and vendors from across the ecosystem such as Huawei, Huawei HiSilicon, Sequans and Altair. However, the ecosystem for standard devices in this band is still in its infancy. There is growing support for the utilisation of TD-LTE in the 3.5 GHz band as indicated by announcements from Mobile World Congress but little evidence of commercially available devices supporting this band was found.

The FCC announced [68] at CTIA Wireless in May 2012 it would make available 100MHz of 3.5 GHz for small cell applications as part of an unprecedented push to enhance mobile broadband services.

### 2.5.14 3700 MHz LTE devices Band 43

In the UK, mobile broadband operator, UK Broadband holds 82 MHz spectrum in the band 3600 MHz- 3800 MHz. Additionally, this frequency band has become a recognised 3GPP band supporting TD-LTE. Research has found no evidence of commercial TD-LTE devices operating in this band. However, Mobile WiMAX vendor Alvarion [69] has developed products that do operate in this frequency band including base station equipment and CPE. This suggests that silicon and other RF components are commercially available which could potentially be used to develop TD-LTE devices in this band.

## 2.6 Summary of update in mobile device availability for LTE and HSPA

Figure 2-4 captures the growth in LTE devices across the key frequency bands of interest between October 2011 and April 2012. The top three bands supported in October 2011 were the 800, 1800 and 2600 MHz bands:

- 42 devices supported in 800 MHz
- 41 devices supported in 1800 MHz
- 52 devices supported in 2600 MHz

Since then, the trend has continued in available devices supported across these bands and the latest figures (April 2012) show up to an 80% increase in that time in some cases, and a switch to 1800 MHz being more popular than 800 MHz:

- 72 devices supported in 800 MHz
- 75 devices supported in 1800 MHz
- 94 devices supported in 2600 MHz

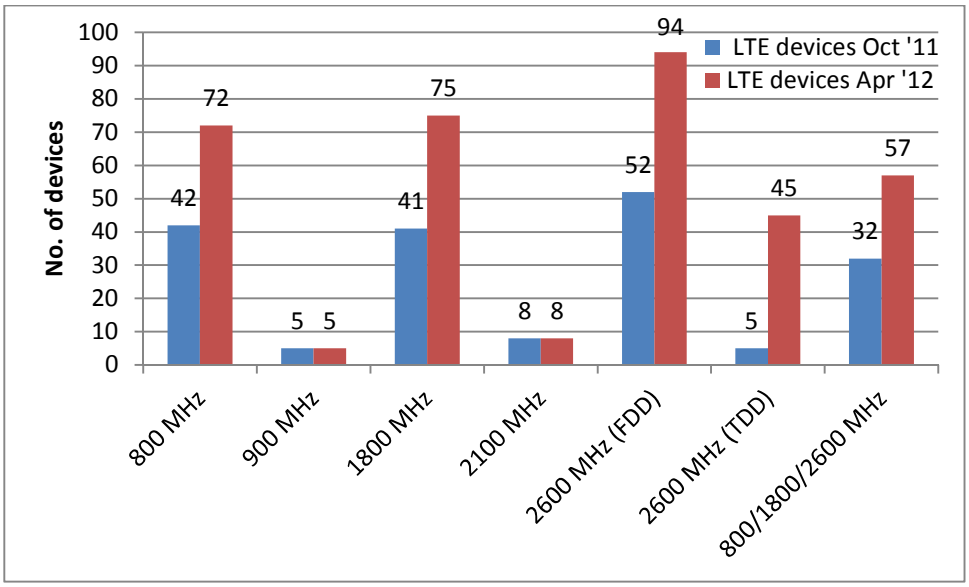


**Figure 2-4 Growth in LTE devices across frequency bands between October 2011 and April 2012**

The 2600 MHz band continues to lead in total available devices across all three bands. In terms of form factor, USB modems and routers are the two leading device types emerging on the market that support all three frequency bands. There are currently two smartphones and two tablets available that support these frequency bands.

However, there has been a significant increase in general LTE device availability, with a six fold increase in handsets and a doubling in tablets according to[3]. The majority of these devices have been produced for the US market to support the 700 MHz and AWS frequency bands. It is expected that more devices will be launched in 2012 to support the European harmonised LTE bands as more networks are deployed.

The growth in HSPA devices across 900 MHz and 2100 MHz can be seen in Figure 2-5. Device manufacturing and development has reached maturity in terms of HSPA and HSPA+ in these bands. However, there has been growing development in DC-HSPA+ devices which have doubled in availability since our last report.

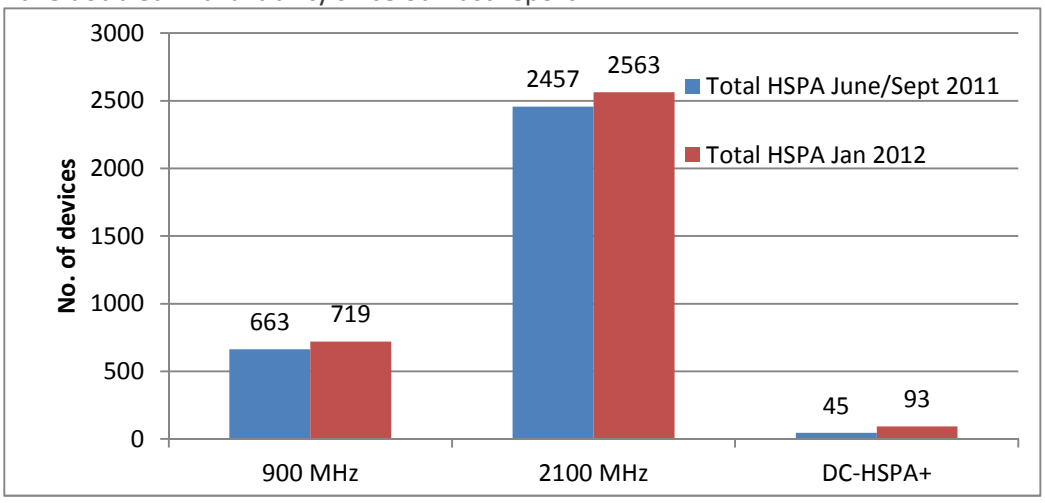


**Figure 2-5 Growth in HSPA devices across frequency band in the last six to nine months**

## 2.7 Summary of devices by frequency band and technology

### HSPA 2600 MHz band summary

- No evidence of 2.6 GHz devices found

### HSPA 2100 MHz band summary

- 3362 HSPA devices from 271 suppliers
- 2563 HSPA devices operate in this band
- Device types include USB dongles, smartphones, embedded laptops, data cards and routers including personal MiFi

### HSPA 1800 MHz band summary

- 1 UMTS/HSPA 1800 trial network identified in France
- No commercial services found

### HSPA 900 MHz band summary

- 32 Global and 20 European UMTS900 commercial networks in operation as of June 2011
- 719 HSPA devices available for use in this band which includes: Apple iPhone 4 S, iPad2 and iPad3, Samsung Galaxy S, Blackberry Playbook, Nokia N8, HTC HD7 etc.
- 93 DC-HSPA+ devices available from January 2012 including BandRich PR40 series pocket router, Novatel Wireless USB modem Ovation MC545 capable of supporting 42 Mbps. This number has doubled in the last 6 months
- Number of UMTS900-HSPA user devices launched has increased slightly by 10% in the last 6 months
- O2 has upgraded to HSPA+ in 2012 delivering speeds up to 42 Mbps

### HSPA 800 MHz band summary

- 1 device from Qualcomm PC Mini Express Card was found
- No commercial services found

### LTE 3500 MHz band summary

- UK Broadband launched a TD-LTE network in March 2012 expected go live in May 2012 with mobile devices available in September 2012
- Standards supporting the band were published in March 2011.

### LTE 2600 MHz band summary

- Currently supports the largest selection and mix of commercial devices with 94 FDD and 45 TDD in total including USB modems, tablets and handsets
- More than 57 out of 139 devices support multi-frequency
- More than half of 139 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

## LTE 2300 MHz band summary

- There is growing support for this band and 2600 MHz in various devices
- There are 43 devices in total including USB modems, tablets and handsets
- Majority of vendors are supporting deployments in Asian and Far Eastern markets

## LTE 2100 MHz band

- Currently supports a collection of 8 different devices
- 6 out of the 8 devices support multi-frequency
- All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

## LTE 1800 MHz band summary

- Supports a well-established mix of devices with a total of 75 different devices including dongles, tablets and handsets
- All devices support multi frequency
- More than half out of the 75 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

## LTE 900 MHz band summary

- Currently supports more than 6 devices with a small mix of modules, routers and USB modems
- All devices support multi frequency
- All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

## LTE 800 MHz band summary

- Currently supports a growing mix of devices with a total 72 different devices including dongles, tablets and handsets
- More than 57 out of the72 devices support multi frequency
- More than half out of the 72 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

# 3. Survey of device vendor roadmaps for various European LTE and HSPA+ bands 2012-2016

## 3.1 Some key general conclusions from the survey

The following predictions and forecasts are based on a survey carried out by Rethink Technology Research in March-April 2012, examining carrier and OEM plans to support various spectrum bands for LTE and/or HSPA+. The research base consisted of:

- Branded mobile device makers (16)
- SoC/baseband/RF suppliers (15)
- ODMs and contract device makers (12)
- Non-handset mobile device makers (6)
- Other handset component makers (10)
- European operators (42)

The study addressed frequency support in smartphones and tablets, which are the key deciders of consumer adoption of a new network or service. It excluded data-only devices such as dongles, cellular PCs, mobile hotspots and CPE. New networks usually launch first with data-only devices, but significant uptake is driven by handset introduction.

One of the most important contrasts between the evolution of 3G services and that of LTE is an entirely different spectrum situation. This, in turn, has been driven by the explosion of mobile data traffic, which is only expected to accelerate further in the period of the study, to 2016. In the early years of European 3G, mobile data usage was in its infancy and there was little squeeze on spectrum availability. As with GSM, the W-CDMA bands were largely harmonized across the region and were capable of supporting the data levels required. Carriers prioritized on the standard bands and aimed to support as few as possible to improve device and infrastructure economics.

Towards the end of the last decade, it was clear that 3G(+) data would soon outgrow the available capacity in areas of high usage, and there was a race for new spectrum capacity combined with more spectrally efficient technologies (HSPA+ and LTE). Offload to Wi-Fi also came into play, and will remain an important factor in keeping the data load on available 3G and 4G spectrum manageable during the study period. This is not examined in detail in this report, but we assume that virtually all the smartphones and tablets referred to will contain dual-band Wi-Fi plus Bluetooth along with the cellular connections. In addition, many will have additional radios such as GPS, NFC or FM. There is no difference in the level of Wi-Fi integration according to LTE or 3G band.

Wi-Fi offload and upgrades to HSPA+ were the first phase tactics, followed by acquisition of new spectrum for LTE. Next will come refarming of GSM frequencies for 3G+ or LTE. From 2013 operators will employ various additional strategies to maximize data capacity and coverage at manageable cost, notably:

- Further air interface upgrades, to LTE-Advanced and/or HSPA+ Advanced
- Harnessing of additional spectrum capacity such as TDD
- Adoption of HetNets, which combine multiple layers of cells in different spectrum bands and potentially combining different air interfaces plus Wi-Fi

All this creates a situation where carriers prioritize the spectrum capacity they can procure, even if this covers many bands, over harmonization, leading to a highly fragmented spectrum picture.

### 3.1.1 The pressure to support a wider range of frequencies

To add a little more detail to the above point, the LTE bands are highly fragmented worldwide because:

- The 3GPP has taken a flexible approach to approved bands
- Various factors are driving many cellcos to use whatever spectrum they have to hand for LTE rather than relying entirely on newly allocated frequencies. Reasons include:
  - The desire to make an early market move, in a faster timescale than the country's auction e.g.China Mobile refarming its 3G band at 1.9GHz
  - The need for more spectrum than is available at auction, to support expected mobile data growth rates. Many operators will combine deployments in both new and refarmed bands within the first three years of commercial activity to increase overall capacity e.g. Telstra is already supporting 42Mbps HSPA+ in 850MHz (which it will upgrade to 84Mbps) with LTE in 1.8GHz, and plans to add HSPA+ capacity by upgrading legacy 2.1GHz services, plus running LTE in new 2.6GHz and 700MHz allocations (post-auction) and eventually in 900MHz too.
  - Limited numbers of licences, especially in the lower frequencies. Operators like E-Plus in Germany or 3 Italia missed out on 800MHz licences so are examining other spectrum options such as 900MHz and TDD.
- In some countries, the premier bands are not yet available. An extreme example is Brazil, which will open up 450MHz for wide area/rural LTE rather than 700MHz or 800MHz in the first round of auctions.
- Even when operators have acquired new spectrum at auction, they will often need additional capacity to support mobile data needs, therefore they will deploy in several bands over the next few years (e.g. Verizon will extend its 700MHz network into refarmed CDMA bands; longer term many carriers will look to TDD offload).
- This is the first generation of mobile technology where there will be extensive refarming. In addition to the virgin bands, which are relatively harmonized within regions (e.g. Europe 2.6GHz and 800MHz), many operators will be using spectrum they originally acquired for GSM or, in rarer cases, WiMAX. There will even be some refarming of 3G spectrum during the period though this is less common in Europe than in areas where operators want to leap straight from 2G to 4G (e.g. China Mobile; T-Mobile USA's 'double refarm', moving its HSPA+ service from AWS to PCS, and then deploying LTE in AWS).

All this means that many bands will be in play worldwide during the first phase of LTE, with a significant impact on the device ecosystem.

### 3.1.2 There will be two tiers of LTE frequencies in device procurement terms

Most device OEMs and operators believe a two-tier system will emerge, with 3-4 universally supported bands per region. In Europe these will certainly include 2.6GHz, 1.8GHz and 800MHz for LTE. Operators running LTE in second tier bands will have two main options:

- Offer incentives to branded OEMs to produce a variant supporting their frequencies. This will usually involve significant concessions to the vendor, such as minimum sales commitment, marketing budget commitment, higher subsidies. The balance of power will, of course, depend on the weight of the operator and the size of its subscriber base. Some large carriers can drive an ecosystem single-handed, the extreme example being China Mobile, but this requires heavy investment. Among the Europe-based majors, Vodafone, Orange and Telefónica are particularly well placed because they buy across multiple regions (increasing their negotiating power with their suppliers, even for non-standard devices), and they are part of huge buying clubs e.g. Telefónica and NTT DoCoMo.
- Commission handsets from an OEM or ODM. This is common practice at the low end of the cellphone market, and is starting to become more visible in smartphones, though usually for branding rather than frequency reasons (e.g. Google Nexus). Simple ODM handsets do not represent a high investment but lack the 'pulling power' of the big brands. However, there is a rise in the high end commissioned handset, and this will be accelerated by LTE's fragmentation. This may be branded by the operator or the vendor, but is a one-off variant for that particular carrier. An example is the HTC J for Japan's KDDI, which is a version of the new HTC One S, supporting WiMAX, the local mobile TV service and the Japanese One-Seg m-wallet.

In other words, handsets will be available for all bands, but some will be more commercially viable. A major issue is whether 900MHz will fall on the universally supported side of the fence or not in Europe. The research indicates that it will, though it will not appear in as large a number of devices as 800MHz LTE. Its growth is initially being driven by the Middle East but by 2015 also by some European operators and parts of Asia. As we have seen, the intense pressure to acquire spectrum capacity wherever it is available means that many bands will be supported in LTE, and there will be limited consolidation of this number – indeed, new ones are already under consideration. The EU's RSPP, chasing its target of opening up an additional 500MHz to 600MHz of mobile broadband spectrum by the end of 2015, is considering 1.4GHz L-Band, 2GHz MSS band, 700MHz and 2.3GHz TDD.

Most device OEMs and operators believe a two-tier system will emerge in terms of LTE bands. The total number of bands will not decrease, indeed it will grow over the course of the decade, but a few 'premium' bands will achieve very widespread support and move to the top of the OEMs' priority lists. This is important because although, as we will see, most tier one and tier two vendors will support most LTE bands and combinations to some extent, they will prioritize on those with the greatest volumes, which can lead to:

- A wider choice of models supporting a premium band
- A leadtime to market, typically of nine months or even more in some cases, in favour of the more popular band, with consequent impact for carriers without access to that band. This factor has been particularly true of Apple.

The top tier bands will be:

- Those supported by one of the top 10 global procurers by volume because of their buying power. These players can 'promote' a band even if they only use it in certain markets, because of their overall ability to influence their suppliers and the ecosystem as a whole. This factor becomes even more important when several of these super-operators work together to influence the device industry to support their needs, and then to purchase as a 'club'. Examples include China Mobile/Verizon Wireless/Vodafone, which have worked together to shape the early LTE device industry, notably by calling for broad support for dual-mode TDD/FDD; Telefónica, with its reach across Latin America and Europe, and also with its NTT DoCoMo device partnership; Orange.
- Those adopted in areas of early and high value LTE adoption, driving an immediate kick-start to device sales in that band. This has mainly been seen in Verizon's 700MHz band so far, a single-operator roll-out (incompatible with other 700MHz deployments) which has been heavily supported by OEMs, in order to gain profile and a head start in LTE sales. In Europe this early mover effect will mainly be seen in 800MHz and 2.6GHz.
- Those supported on a broad geographical basis around the world, and so widely adopted for roaming (even by operators without access to the band themselves). More details on roaming bands below.

Each region will end up with 3-4 tier one bands, which are almost universally supported by mainstream device makers. Based on the criteria above, in Europe these will certainly include 2.6GHz, 1.8GHz and 800MHz for LTE. There are rising indications that 900MHz will also fall into this category, though with a lower level of support than the other three, as this report will analyse below.

### 3.1.3 Will 900MHz be a tier one LTE band?

The attractiveness of 900MHz and 1.8GHz for LTE, as opposed to HSPA+, will partly be driven by global considerations – volume for the OEMs, roaming and pricing for the carriers. Internationally, there is more advanced support for 1800LTE but 900LTE is also seeing momentum in the Middle East and parts of Asia-Pacific.

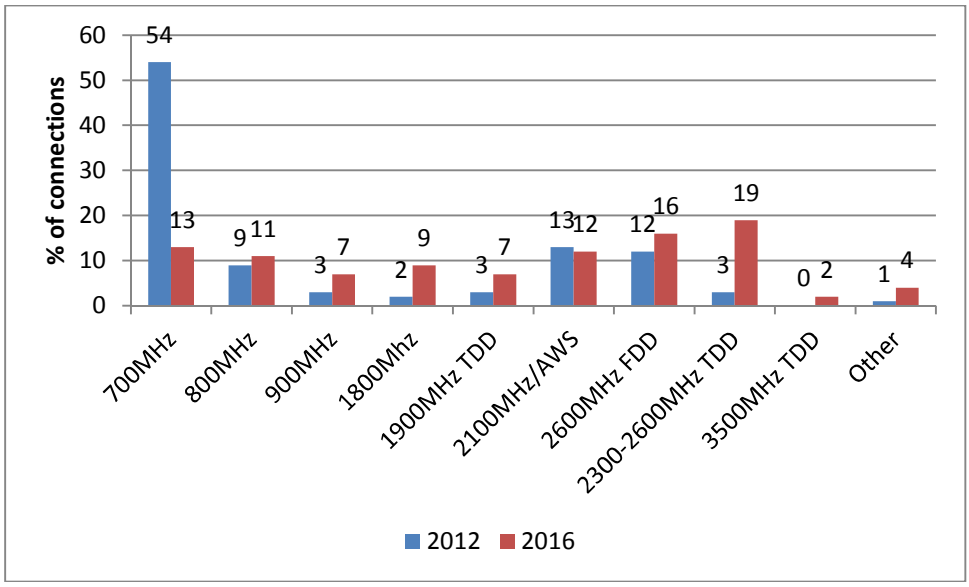


**Figure 3-1 LTE connections by frequency band by 2016, global. This indicates the key volume bands**

The figure indicates the key LTE bands which will attract heavy device volume during the study period. In 2012, connections are dominated by 700MHz because of the rapid progress of US roll-outs in that band. It accounts for over half of the total number of LTE connections in the world, about 43m. The rapid progress in North America is also highlighted by the strength of the US AWS band, the only other one to account for more than 10% of total connections. While there are many LTE networks operational in other parts of the world, these have generally been less broad-based, so far, than those in the US, and more generally in the CDMA community.

The importance of 700MHz will decline as a percentage over the period as the US operators additionally deploy other bands and as the total base grows larger. LTE connections will rise from 43m at the end of 2012 to 480m by the end of 2016 (consensus forecasts) and by this stage, the high level of fragmentation is clearly seen, with only five bands accounting for more than 10% of connections each. These are the 2.3GHz-2.6GHz TDD frequencies, heavily driven by Asia, especially China and India; 2.6GHz, which remains the primary FDD roaming band; 700MHz, boosted by Latin America and some Asian countries, though itself fragmented; AWS; and 800MHz.

The weighting towards higher bands by 2016 is driven by their capacity, so that they will be supporting more connections at any one time than the lower frequencies. They are also boosted by their roaming role, but the majority of devices will support at least one sub-1GHz and one higher frequency (as will most operators).

In other words, handsets will be available for all bands, but some will be more commercially viable than others. A major issue is whether 900MHz will fall on the universally supported side of the fence or not in Europe. The research indicates that it will, though it will not appear in as large a number of devices as 800MHz LTE. In a recent survey of over 40 European mobile operators, nearly all respondents identified 2.6GHz, 1.8GHz and 800MHz as the tier one LTE bands in the EU, but almost 60% (59%) also believed 900MHz would fall into this category and were considering using this frequency for 4G in future.

This confidence level has doubled since a similar survey in 2009, when 900MHz was expected to be refarmed almost entirely for HSPA. The perception of the 900MHz band is going through a similar process to that of the 1.8GHz spectrum, which was also initially assumed to be a future 3G expansion band, but is now more commonly treated as an LTE option. The change of heart on 1.8GHz has reached such a level that groups such as the GSM Association now regard the spectrum as one of the most attractive for global LTE roaming, and have brought considerable pressure to bear on the device industry to that end. Similar momentum is starting to build behind 900LTE.

The shift of opinion on the two GSM bands reflects a general acceleration of wide scale LTE roll-out plans even in regions, like Europe, where there will still be heavy reliance on HSPA+ expansion for the next five years or more. The new views of 900MHz are driven by:

- A change of perspective on LTE build-out as a whole in Europe. More operators plan to achieve wide coverage with LTE by 2016, rather than keeping it mainly for hotzones of high mobile data usage, such as city centres. This means they will need more LTE spectrum at an earlier stage. Although HSPA(+) will remain the most commonly used technology at most EU carriers throughout the study period, LTE will spread well beyond the hotzones in most countries, and the 2.1GHz band will suffice for the HSPA+ expansion needs of many carriers (about 35% indicated this while others are undecided on this issue). The accelerated roll-out plans have partly been driven by greater than expected rates of mobile data growth, looking ahead, and by increased confidence that there will be attractive and affordable LTE devices at an early stage – the proof point being Verizon. By contrast, in 2009 most operators did not believe they would be able to access such handsets until 2013 or later and so were cautious about investing too heavily in LTE at an early stage.
- The focus on using LTE alongside HSPA+ for wider area coverage has put more pressure on sub-1GHz bands, which better support less densely populated areas, broad coverage and indoor penetration. This has put a new spotlight on 900MHz, especially for carriers which have failed to secure licences in the 800MHz spectrum auctions, like E-Plus in Germany. Other carriers may be driven to take 900MHz more seriously by their fear that 800MHz spectrum prices will be unaffordable.
- With some operators leading the way with deployments and trials, there is greater confidence that device vendors will support the 900MHz LTE band, and for OEMs, it is a minor challenge to produce 900MHz versions of their LTE800 devices.
- Supporters of LTE900 argue that it scales better than HSPA and has a forward path to LTE-Advanced, and therefore to being combined with LTE in other bands. There is considerable carrier interest, even among those confident of securing 800MHz licences, in refarming 900MHz in 2014 or later as a way to move directly to LTE-A. The move to LTE-A itself has moved forward on many carriers' timescales, compared to 2009. An example is Telstra in Australia, which is conducting tests and holding talks with its device suppliers with a view to using its 900MHz spectrum for a second wave of 4G deployment. This would join its networks in 850MHz (HSPA+), 2.1GHz (HSPA), and three LTE bands (700MHz, 1.8GHz and 2.5GHz). The example is somewhat extreme but indicates the kind of band complexity which some operators will support in the pursuit of capacity. By contrast, Telstra's Hong Kong unit, CSL, has refarmed its own 900MHz spectrum for DC-HSPA+ and also launched LTE in 1.8GHz and 2.6GHz.

While many European carriers are now weighing the pros and cons of HSPA+ versus LTE for future refarming in their 900MHz spectrum, few have made a firm decision, the main exception being Net4Mobility in Sweden, which is deploying LTE in 900MHz and 2.6GHz. The very early use of the band for 4G is currently mainly driven by the Middle East region. Option recently introduced one of the first LTE devices, the Beemo dongle (see section 2.5.4 for more details), to support the three main European LTE bands (800MHz, 1.8GHz and 2.6GHz) plus 900MHz for roaming in the Middle East and, in future, other countries.

However, there remain risks associated with LTE900 and most carriers remain open-minded on how to use this band, with no short term plans. Of the 59% which are considering this as an LTE band, only one in five expect to refarm 900MHz before 2014. This creates a (probably) temporary but real disadvantage for operators which want to roll out LTE more quickly in 900MHz, perhaps because they have failed to secure 800MHz. Achieving a critical mass of devices will take 12-18 months longer than for 800MHz. No tier one operator has yet thrown its full weight behind supporting a 900MHz ecosystem and though all the major OEMs plan to support 900LTE in at least some of their products, this is likely to be at a later date and with fewer models than for other bands, at least for the next few years.

Other risks concern the complexity of refarming and turning off GSM services, as well as the limited capacity below 1GHz. These issues also lend weight to the argument for waiting for LTE-A, which will have additional spectral efficiencies, although new techniques such as configurable carrier bandwidth add flexibility in refarming 900MHz.

### 3.1.4 Roaming

Roaming is not a major issue in the first phase as most operators are focused on their own LTE bands, relying on 3G for roaming with other carriers or internationally. However, by 2016 there will be far more pressure to support major international LTE bands also. This issue has already hit the headlines with the controversy over Apple's '4G' iPad, which only supports US 700MHz and AWS bands for LTE (plus DC-HSPA+ in 2.1GHz, 1.9GHz, 900MHz, 800MHz and 850MHz).

The 2.6GHz band is already being identified by most OEMs as the most likely international LTE roaming band and is supported in a huge proportion of devices for that reason. There is also discussion over possible use of 3.5GHz for 'small cell roaming' in future as carriers build additional layers of coverage, using small base stations and often in different spectrum bands. ZTE is leading the charge to support 3.5GHz as a major international TD-LTE band. Some of the tier one bands appear to offer the prospect of greater global harmonization, which is important to the device ecosystem and to roaming, but this factor can be exaggerated e.g. the US 700MHz and 2.3GHz band plans not only differ from those in other parts of the world, notably Asia, but are inconsistent within the country itself. This is also likely to be the case if the US proceeds on its preliminary discussions about opening up the 1.8GHz band in that country, although there is significant impetus behind moves to make this a global roaming band. In the US it is occupied by military and public sector bodies but in March 2012, Lawrence Strickling, administrator of the government technology agency the NTIA, proposed that those incumbents should harness modern cognitive radio and spectrum database techniques to share their spectrum with commercial providers [70].

### 3.1.5 Contrasting issues in HSPA and LTE

Bands for HSPA+ are more harmonized with most carriers upgrading their existing 3G networks (in 2.1GHz in Europe). However, there will be some refarming of 2G spectrum for HSPA+. This will give rise to a situation where operators may have either HSPA+ or LTE in the GSM bands (900MHz and 1.8GHz), further complicating the device combinations. This situation is less confused in Europe than some regions like the US, but will still add to the variations device makers must consider. Many are looking to Telstra/CSL's 'ideal platform' as their end point, integrating 1800 DC-HSPA+ with dual-mode LTE in 850MHz and 2.6GHz, and in future, 2.1GHz HSPA and 900MHz LTE-Advanced. Such plans show the challenges that will face most large carriers and their OEMs in future.

LTE-only devices are not common except in the dongle or PC card segments. They will start to feature more heavily towards 2016 as some operators switch off older networks but this will be uncommon in Europe and mainly seen among CDMA carriers.

DC-HSPA has mainly been prevalent in data devices but in 2012 is becoming a common option in high end smartphones and tablets e.g. iPad HD, Lumia 800, Galaxy S3 etc. There was a shortage of granular data on how DC-HSPA+ bands will differ from those for non-DC networks, with most OEMs assuming most HSPA+ upgrades during this period will stay within the existing bands. Thus they expect to incorporate DC-HSPA+ in nearly all their device families by the end of 2012, but almost entirely in 2.1GHz. Precise timings and individual device details for DC-HSPA+, HSPA Advanced and LTE Advanced are hard to secure as they are regarded as critical competitive information at this stage.

However, 2.1GHz continues to be the highest volume band throughout the study period because it is the main focus for HSPA+ in all its iterations. That effect will be intensified if many operators turn away from running HSPA+ in refarmed GSM bands. Despite that, there is also a surprisingly high level of support for 1.8GHz HSPA+, despite the shift of carrier interest towards using this band for LTE instead. That is being driven partly by the ecosystem itself, particularly by Qualcomm, which sees dual-mode LTE/HSPA+ devices for the 1.8GHz band appearing this year. There are also a few important operators which retain significant interest and trials of 1800HSPA+, such as Orange.

The volume potential of HSPA+ devices remains far higher throughout the period than for LTE devices. This is partly because of the greater harmony in frequencies, and partly because the HSPA family will account for more than 20 times more connections than LTE at the end of 2012 in Europe, and more than 10 times more than LTE at the end of 2016. By 2016, over 75% of those connections in Europe will be HSPA+.

### 3.1.6 OEM strategies and the iPhone effect

As the preceding points indicate, carriers' attitudes to supporting multiple frequencies have changed dramatically since Rethink first conducted these surveys three years ago. They are far more willing to support multiple bands since they need to maximize their spectrum capacity to support mobile data volumes. In the carrier survey, three-quarters of respondents expect to be using five HSPA+/LTE bands by 2016 (plus Wi-Fi, and usually still with GSM) to achieve their data requirements by 2016.

This is, to some extent, a necessary evil, but a complex multiband strategy is far more commercially viable than it would have been a few years ago. Multiband devices are becoming cheaper, and with fewer problems such as battery drain and interference. And as competition mounts among handset makers, and the devices commoditize, operators are in a far stronger position to negotiate and to influence pricing and future design, than they were at the start of the 3G era. Most vendors are now chasing volume rather than margin in the handset business in order to gain the necessary economies of scale for a commoditizing sector, and looking for premium prices elsewhere, notably in tablets. The current exception is Apple but even that vendor is coming under new pressure.

Fragmentation of operator build-outs is also driving a very different approach to OEM strategies on how many bands to support. To be competitive, most will have to be far more flexible and support a wide variety of combinations at a reasonable cost. For them, advances in component technology will help make this commercially viable.

Increasingly, the decision by an OEM to support a particular band or combination of bands is down to marketing rather than cost considerations. The cost of creating a variation of a device with a different combination of radios is falling rapidly but it remains a valuable bargaining chip when negotiating deals with carriers. However, there the most mainstream bands (or those supported by a particularly valuable operator) will still take priority in R&D and roll-out plans.

Rethink conducted a survey of mobile device OEMs, ODMs and their suppliers, and found that the average vendor of branded mobile devices (i.e. not commissioned by the carrier) expects to support 4x more band combinations in 2013 than in 2008, but still expects the bill of materials for the RF/connectivity elements of the smartphone to be less than half, as a percentage of total device cost. That is because the most expensive elements in a modern mobile device are the processor, screen and memory rather than the connectivity.

One important factor is that sourcing multiband chipsets is becoming easier. According to chip suppliers 19 combinations of 3G+/4G will have sufficient volume in 2013 (global figure) to justify product release. For example, the Qualcomm chipset family supports five HSPA bands, five LTE bands, four EDGE bands and integrated GPS. Typically the firm expects its customers to activate three or four HSPA/LTE bands but sees a rise in worldphones of five or more 3G/4G bands.

The need to support many bands for 3G/4G has prompted the adoption of RF architectures in phones in which it is intrinsically more straightforward to add bands or change bands (e.g. between 800MHz and 900MHz). Given the large aggregate volumes involved, such architectures carry a rather lower cost penalty now over "traditional" approaches, so adding a band to an existing phone design is in principle relatively straightforward and low cost.

Most baseband/RF suppliers are working on architectures which scale to five bands and more, with a declining incremental cost per frequency as more are added. In future, techniques like agile or cognitive radios should add to the flexibility further, but these remain commercially unproven.

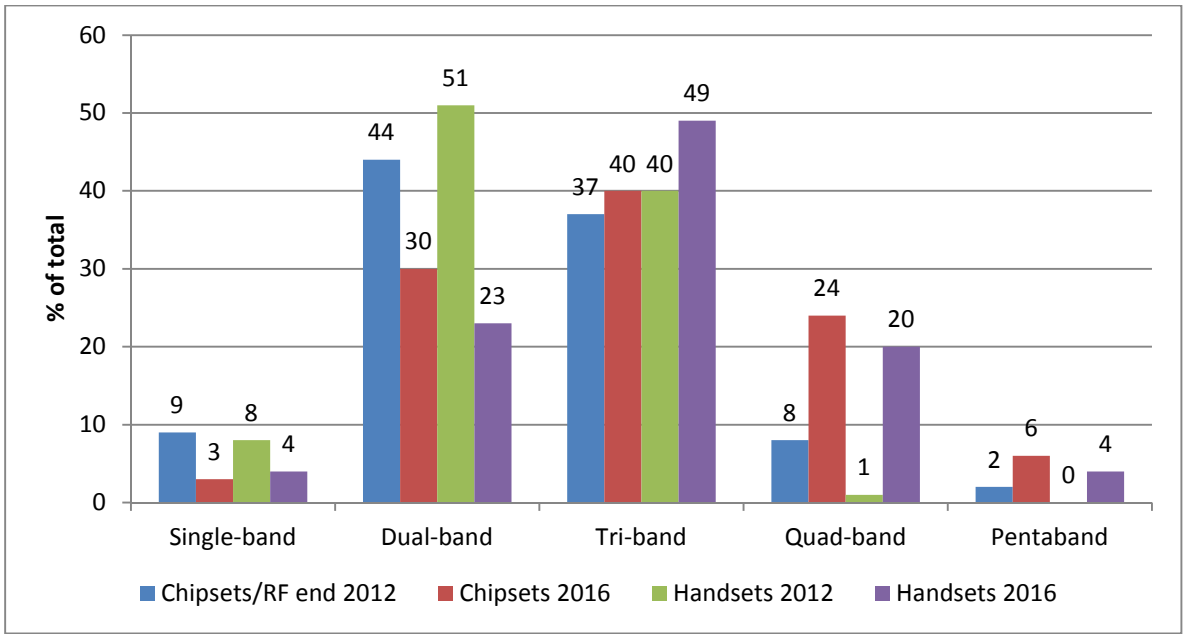


**Figure 3-2 The number of chipsets and handsets supporting multiple 3G+/4G bands (most will also have quad-band GSM/EDGE until these networks start to be switched off later in the decade)**

However, while there is a move towards five-band support across LTE and HSPA+, as seen in the figure above, the greater significance of these flexible architectures is that they reduce the time, cost and risk for OEMs to support many different combinations of band combinations within a single device family, and to exchange one frequency for another without significant effort. The overall result is that the difficulty of sourcing devices for unusual frequencies becomes a far less important issue when deciding on the value of a particular piece of spectrum.

Nonetheless, it is important not to exaggerate the point. While multiband devices are more common and easier to procure than in the past, there is still a penalty for using bands with relatively low commercial support, and for increasing the total number of bands supported by a given phone. In particular:

- Adding a band incurs a substantial and lengthy process of testing to deal with regulatory and operator requirements. This testing is the biggest element of time in bringing a new band to market (much longer than the basic R&D to get the design done) and may mean that a given model with 'special' bands is available much later than the 'mainstream' variant. Much of this testing effort is taken on by the operator and must be factored into cost considerations for a non-standard band.
- The appetite of a manufacturer to address bands (and band combinations) which are not supported by a large number of operators (with large associated volumes) will be limited. Some manufacturers (though not Apple) will contemplate such cases, but will have a limited number of such cases which they are prepared to take on, will still prioritise them as to scale and strategic impact, and will charge a premium

In summary, an operator attempting to gain manufacturer support for phones in a non-mainstream band will still incur cost, time, choice and (potentially) performance penalties, even though the differential has reduced significantly.

In addition, individual OEMs have different policies towards band proliferation:

- support only volume bands (e.g. Apple)
- support customized combinations in return for major operator incentives (e.g. HTC, Samsung, probably Nokia)
- produce many variations to get market share (Samsung, ZTE)

Certain OEM strategies can have a distorting effect on the market. In particular, the impact of the iPhone on the uptake of new services is currently higher than any other device, so its availability for a given band combination (or lack of) will be more important to operator frequency decisions than other phones. For instance, despite all the marketing Verizon has put behind its LTE services, it still sees higher uptake of the iPhone, which remains confined to the CDMA network. Failure to secure an iPhone and iPad for a particular band, when rivals in another band could offer one, would be a significant competitive disadvantage in current market conditions. That has already been seen in the US, where Apple has refused to support T-Mobile's unusual AWS band for HSPA+, putting that network at a disadvantage to AT&T's rival HSPA offering, which has lower speeds and overall quality.

Apple is highly secretive about specific product plans but traditionally it is conservative about supporting non-mainstream frequencies, unless it can secure very significant operator incentives (e.g. Sprint). It also often supports US bands first.

The LTE iPhone is assumed to be scheduled for October 2012. We believe it will support European bands immediately or at least by year end and will choose 800MHz and 2.6GHz in the first model (plus HSPA+). It may raise the profile of the launch by initiating roll-out with a return to its old policy of partnering with a few exclusive partners. We would then expect it to add a 1.8GHz iteration later in 2013 but 900MHz LTE support is unlikely to follow until 2014. Apple is heavily secretive about its plans so these assumptions are based on supply chain intelligence and the OEM's relatively predictable frequency strategies in the past.

If these assumptions prove correct, a 900MHz LTE operator will have plenty of device choice by the end of 2013, but no iPhone (unless a major player is willing to offer Apple major incentives. The top tier European cellcos have generally been less willing to do this than their US counterparts). The importance of the iPhone effect is likely to diminish over time as Apple comes under rising competitive pressure from high impact rivals like the Samsung Galaxy S family, and as operators bite back against the firm's heavy subsidy requirements. However, potential lack of an iPhone remains a risk factor for unusual bands.

Beyond Apple, the choice of devices for operators in all bands will increase at a rapid rate during the study period, as seen in the figure below. The graph shows that, while the total number of device models available for EU-supported HSPA+ or LTE bands will rise fivefold by the end of 2016, the number of different 3G/4G band combinations (variants of those devices) will rise by almost 15 times, from 56 to 824 – or from almost three frequency combinations per model, to almost eight per model. The figures do not include additional support for GSM/EDGE and Wi-Fi.

There will be more LTE variants of most given models, because of the fragmentation of the band. However, there will be very few LTE-only devices with no HSPA support at all, with dual-mode products being the most common at almost 70% of the 2016 total. In addition, the variants which incorporate HSPA+ will attract greater volumes in many cases in Europe because this network will still be the backbone system for most carriers, and the spectrum is highly harmonized – even more so since many cellcos are planning to use 1.8GHz and possibly 900MHz for LTE rather than HSPA+ once they are able to refarm.

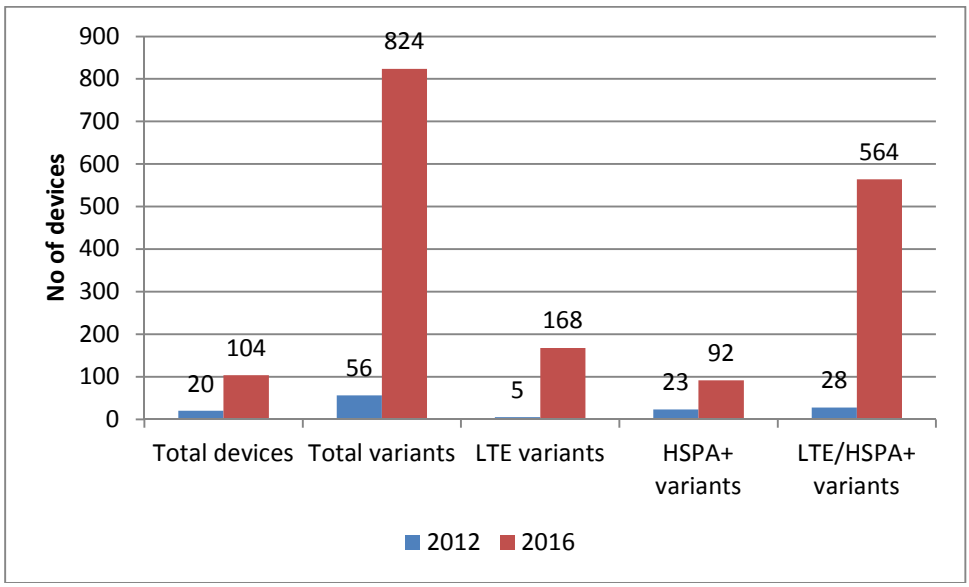


**Figure 3-3 The number of branded mobile smartphones and tablets with LTE and/or HSPA+ support, and with support for European bands, at the end of 2012 and the end of 2016**

## 3.2 Selected forecasts

### Notes on forecasts:

- The forecasts refer to commercial handsets, not those commissioned specifically by an operator
- They only deal with HSPA+ and LTE support but assume most devices also have GSM/EDGE and/or UMTS
- Forecasts are based on plans by currently actively device makers and do not take account of any new entrants that might arrive by 2016, or the failure of any of the current players.
- Forecasts include smartphones and mobile tablets but not dongles, PC cards, netbooks or cellular PCs.
- The main data refers to five-year product roadmaps of branded mobile device OEMs. These reflect the band combinations they expect to support, as of Q112, based on their reading of operator plans to the end of 2016. However, all these plans are subject to change depending on real world operator decisions. Most OEMs decide whether to trigger commercial launch of a device on their roadmap about nine months before shipment.

- Each device model has multiple variants supporting different band combinations. The following graphs all refer to the percentage of those variants which support various bands or combinations. E.g. one device such as the Galaxy S3 may come in six EU-relevant variants, each with a different set of bands. In the forecasts this would appear as six separate options.
- The total base of device variants is 56 at the end of 2012 (after the Christmas launch period) and 824 at the same stage in 2016.

### 3.2.1 The key bands supported in European devices 2012-2016

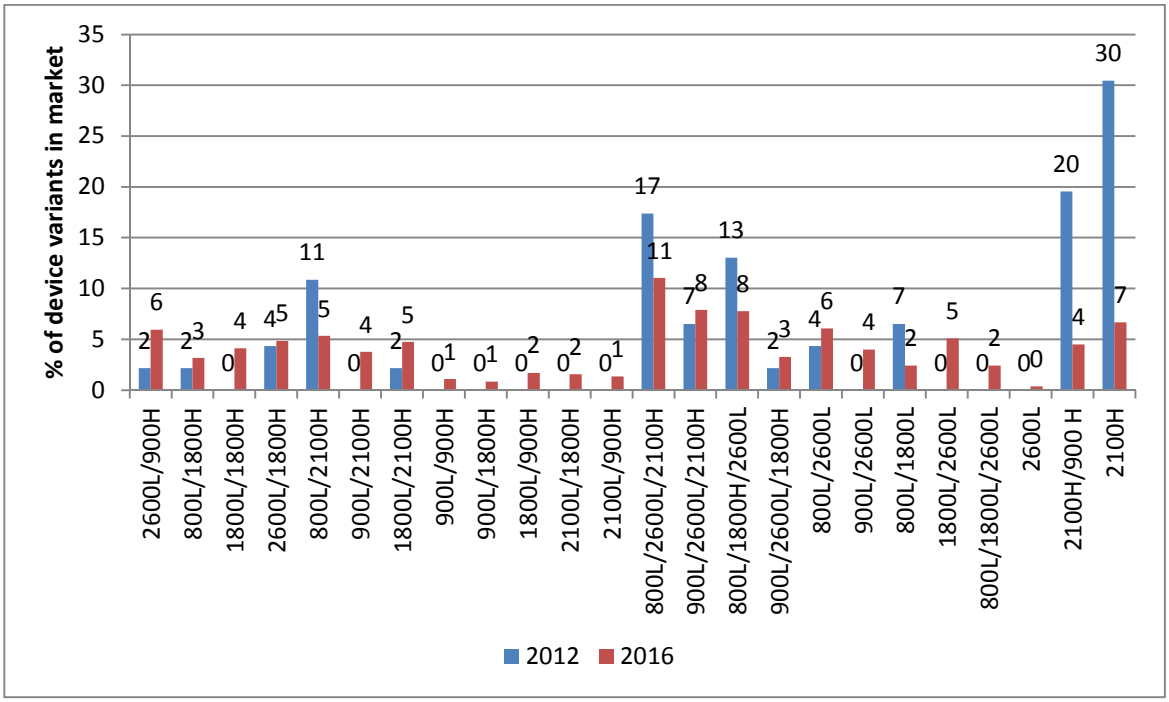


**Figure 3-4 Band combinations supported by device variants appropriate to Europe, as a percentage of the total base (56 variants in 2012, 824 in 2016).**

The changes in how the 3G+/4G device market is divided between different frequency combinations indicates fragmentation as LTE gains scale, after the relatively homogenized environment of European HSPA. Although it will be cheaper and easier for OEMs to support a larger number of combinations, willingness will be moderated by pressure on device prices.

At the end of 2012, the largest percentage of device variants available to EU carriers will support 2.1GHz, either on its own or combined with 900MHz HSPA+. Single- or dual-band HSPA+ will account for half the models available at this stage. Smartphone roll-out remains immature in Europe during 2012, and HSPA+ will remain the dominant mobile broadband technology. Therefore, among the models supporting LTE, only 11% will be LTE-only (plus 2G/3G). Some of these models will have been primarily targeted at non-EU markets, notably those supporting 1.8GHz LTE. While these will be available and relevant to Europe

at the end of 2012, it is doubtful whether an operator will be in a position to launch them until a later date. The primary combinations including LTE will support 800MHz and 2.6GHz with HSPA+ in 2.1GHz. Several models include 1.8GHz HSPA+, but as the next graph will show, these will not achieve high volumes in Europe and most of their sales in 2012 are likely to be in other regions where 1800LTE roll-out is more advanced.

By 2016, the picture has changed significantly, with OEMs pulling back from HSPA+-only devices as even the second wave of 4G operators start to activate their LTE services. At this point, HSPA+-only combinations account for only 11% of a far larger total. LTE-only models are more common, totalling 19% of variants. Within these, 2.6GHz support is almost universal, and the most common accompaniment is 800MHz, followed by 1800MHz and then 900MHz. Only 2% of the total base supports LTE-only but without 2.6GHz included.

The greatest range of variants is found in dual-mode LTE/HSPA+. The most common options are triband devices with 2.6GHz LTE plus a sub-1GHz LTE plus HSPA+. Within these, 2600/800MHz LTE plus HSPA+ is the best represented, accounting for 19% of the total variants available to EU carriers. By contrast, 2600/900MHz LTE plus HSPA+ accounts for 11%.

Some quad-band and pentaband LTE/HSPA+ combinations will start to emerge towards the end of this period but they remain an insignificant percentage until the second half of the decade, except in the case of devices specifically marketed as 'worldphones'.

The next two graphs offer snapshots of the most mainstream band combinations in commercial devices in 2012 and 2016.

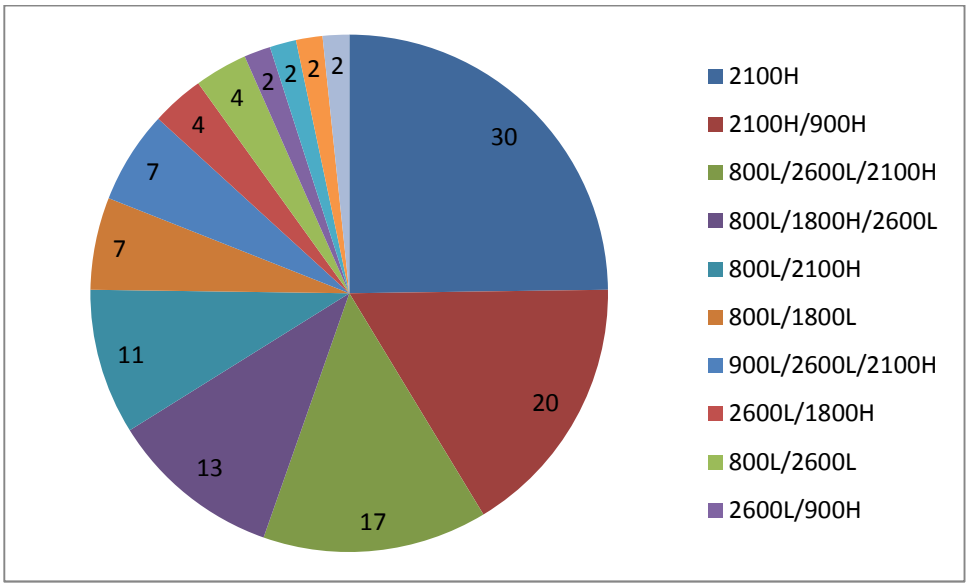


**Figure 3-5 Main band combinations in commercial devices end 2012 (% of 56 variants)**

Initially most carriers in Europe are building LTE in the new 2.6GHz band and preparing for 800MHz roll-out too, but are still relying primarily on HSPA+ upgrade and expansion for universal data coverage. That puts the 2.1GHz and the classic triband combination (2.6/800 LTE plus HSPA) in the lead, but by year end OEMs are also looking to less common options

such as dual-band HSPA+; combinations including 900MHz LTE; and even some devices without 2.6GHz. The main change from 2013 onwards, they believe, will be refarming of 900MHz for LTE or HSPA.

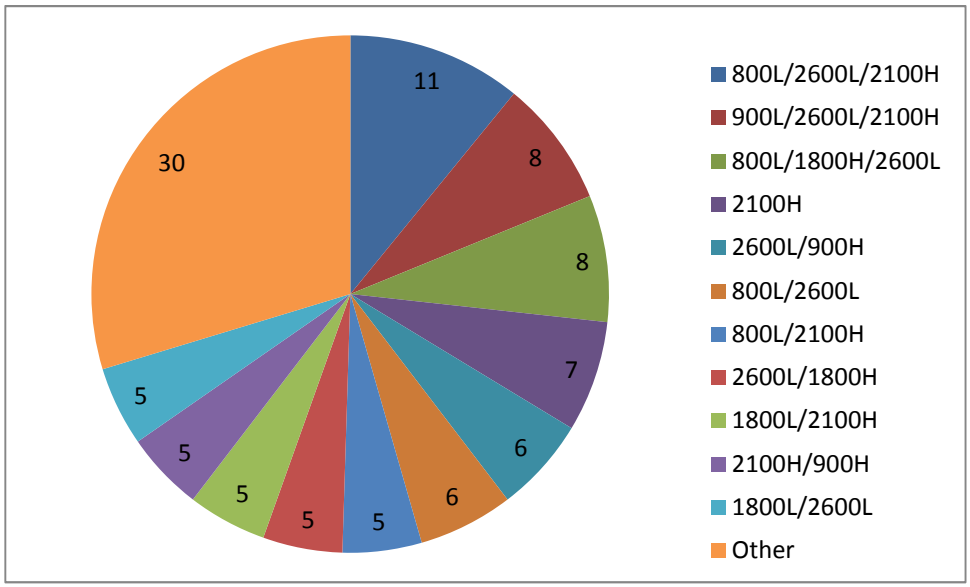


**Figure 3-6 Main band combinations in commercial devices 2016 (% of 824 variants)**

By the end of 2016, the clearest change is fragmentation, with 'other' accounting for more than a quarter of devices. The prevalence of non-LTE devices has dropped dramatically while 900MHz LTE has become a mainstream element, though still less common than 800MHz LTE. Both are commonly combined with 2.6GHz LTE and 2.1GHz HSPA. There will be some demand by this stage for roaming phones which can move between 800MHz and 900MHz LTE networks but these will remain uncommon because of the cost and interference implications of packing more than three LTE radios into one device.

One somewhat surprising finding was the surviving strength of 1.8GHz HSPA+ at this point, with the option supported in 13% of variants, in assorted combinations. Given the continuing shift in operator sentiment towards seeing this as an LTE band, and the political impetus behind it, we suspect the real commercial support for 1.8GHz HSPA+ in 2016 will be lower than this indicates. However, at this stage, most OEMs remain convinced that there will be sufficient carrier support to justify making devices with this option, though these may not be primarily targeted at the EU. By contrast, 1.8GHz LTE will appear in about 20% of variants and in a wider range of combinations than any other LTE option, because of its potential to complement either low frequency or high frequency bands. Many of these 1.8GHz LTE variants fall within the 'other' category in terms of the number of different models on offer, but will still attract significant volumes.

The two figures below indicates the level of support for each band, either on its own or in combination – as a percentage of the total device base available to EU operators, and in terms of numbers of models. The 2.6GHz LTE band emerges as the most commonly supported by 2016, appearing in 58% of all device variants and surpassing the number of models supporting the key HSPA+ band 2.1GHz (though this will continue to have higher volume).

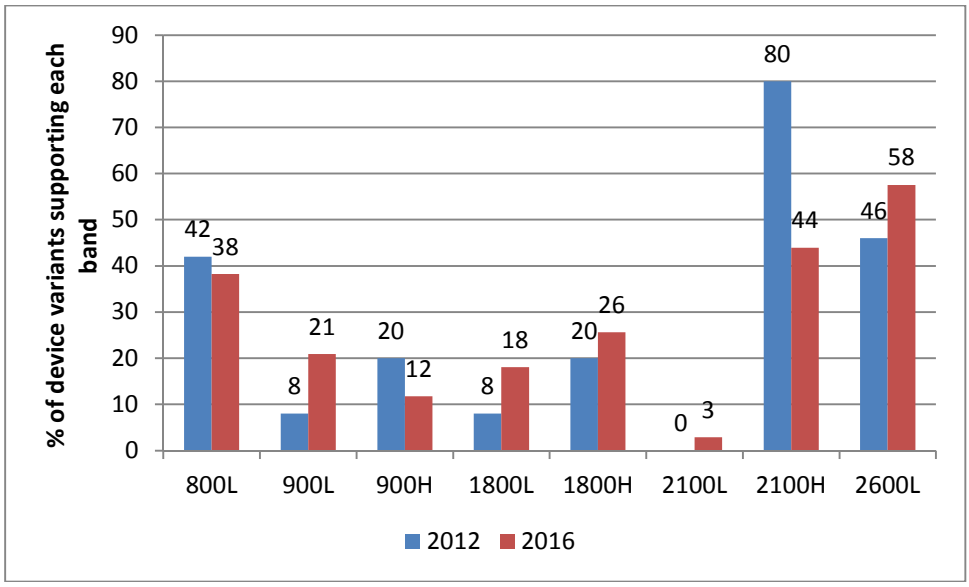


**Figure 3-7 Support for each main band, whether alone or in combination, as a percentage of the total device base**

The graphs indicate that 900MHz LTE grows as a percentage of an enlarged total, though remains less common than 800MHz or 2.6GHz. It is more commonly supported than 900MHz HSPA by 2016, with the crossover coming at the start of 2016. There is a minor showing for 2.1GHz LTE by 2016 as a few carriers start to refarm the 3G band and move towards a 4G-only strategy but this remains a less common strategy in Europe during this period than in other regions.

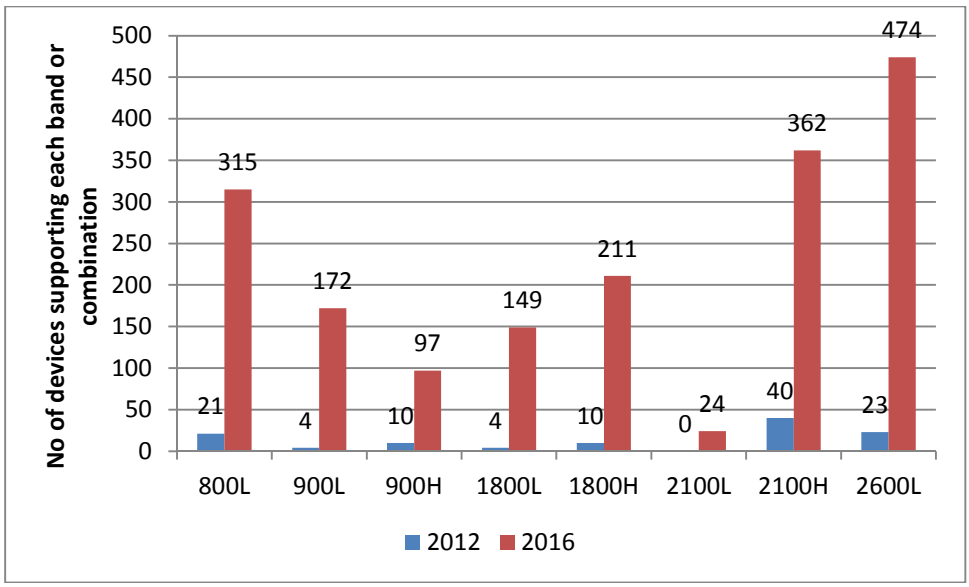


**Figure 3-8 Numbers of mobile devices for each band, alone or in combination**

The graph above shows that, in terms of the numbers of models available, by 2016 LTE and HSPA+ are both gaining scale but the huge numbers of frequency combinations has not consolidated significantly. About 100 branded devices are available but with many variants for different band combinations (totalling more than 800).

Competitive edge for OEMs is being achieved partly through extreme flexibility in frequency support. Only a few OEMs, notably Apple, can afford to ignore this fact as they battle for market share.

There is an interesting contrast between the number of models available for each band combination, and the volume of sales which OEMs expect to accrue from each combination. As stated before, vendors are increasingly willing to support relatively minor bands, but clearly the more widely adopted bands and combinations will deliver greater volumes, and this will impact pricing negotiations. This is particularly extreme when it comes to HSPA+ versus LTE bands, since the HSPA family will continue to account for the majority of mobile broadband connections in 2016 in Europe – about 10 times the volume of LTE, and in far fewer bands. Thus 2.1GHz HSPA+ has genuine critical mass in terms of the volumes of handsets which will be sold including this band, alone or in combination.

By the end of 2012, devices supporting HSPA+ but not LTE will account for half the available mobile broadband models, but 85% of volumes shipped to Europe. By contrast, LTE-only models will account for 11% of the device variants available but only 3% of shipments, with dual-mode LTE/HSPA+ totalling 12% (these figures exclude any devices which support only 7Mbps HSPA, UMTS or below, which will retain even higher volumes).

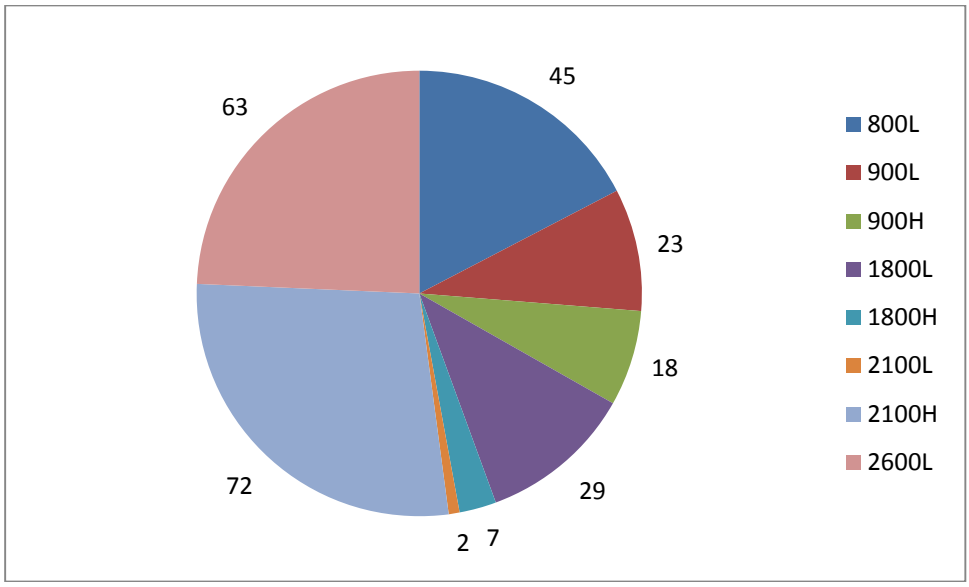


**Figure 3-9 Percentage of device shipments by volume incorporating each major band, alone or in combination, 2016. Source: Rethink OEM survey, consensus forecasts**

By the end of 2016, LTE-only products will account for 19% of the device variants on offer, but just 9% of volumes. Within that category, 90% of shipped devices will include 2.6GHz support, two-thirds will include 800MHz, 55% LTE1800 and 42% LTE900. There will be some triband LTE devices seen.

HSPA+-only models will still have significant volume at one-third of total shipments, though they will account for only 11% of variants. Their volumes will still be overwhelmingly driven by 2.1GHz – 88% of single-mode HSPA+ shipments, alone or in combination with 900MHz.

Dual-mode LTE/HSPA+ devices will have become the norm by this stage, supported in 70% of device variants available to EU operators, and driving 58% of volumes. Within that figure, the dominant combination in volume terms will be 800/2600MHz LTE + 2100MHz HSPA+, accounting for 51% of dual-mode shipments by volume. Overall in terms of volumes, 2.1GHz HSPA+ retains the lead across all kinds of 3G+/4G variants, appearing in 72% of devices shipped, while 2.6GHz LTE appears in 63%, 800MHz LTE in 45%, 1.8GHz LTE in 29% and 900MHz LTE in 23%. All these bands can therefore be said to have critical mass in terms of sales potential, though there are clear contrasts in volume between them, with resulting impact on pricing and OEM enthusiasm.

### 3.2.2 Note on data-only devices

LTE and HSPA+ services are generally launched with data-only devices such as dongles and PC products, with handsets coming about a year later. Smartphones are the main driver of consumer uptake of new services and have a significant impact on commercial success, so although they are the most complex devices to adapt and test for new bands, they are vital to the business model if consumers are involved.

There are changes taking place in this pattern:

- During the course of the study period, the importance of dongles among data-only devices will fall as cellular connectivity becomes embedded in more devices such as notebooks, cloudbooks, and tablets. Other important categories are personal routers, media players, tablets and there is also some fixed CPE where LTE is used for rural coverage.
- This will boost the importance of the module makers in the device ecosystem. Modules often represent a relatively quick and affordable way for device makers to support new band combinations. Modules have mainly been used in notebooks, dongles etc. but vendors are pushing them into smartphones, media players and other devices, enabling a new wave of devices for customized or tier two OEMs. This trend will make support for secondary bands even easier over time.
- The time lag between data-only devices and the launch of smartphones is contracting, partly driven by Verizon's efforts in the US, and will shrink to an average of six months by 2016.
- In the same time frame, the tablet will become almost as important as the smartphone for driving uptake of a new network or service. Although slightly simpler to execute than the multiband, multimode handset (because of the secondary importance of voice roaming), the tablet leverages most of the same components and commands a higher premium price/lower operator subsidy. Availability of tablets, even while this remains a minority category compared to handsets, will be increasingly important to the success of deployment in a given band.

The device ecosystem will become further diversified by the emergence of machine-to-machine and 'internet of things' products, and by the fragmentation of mobile device branding – not just between OEMs and carriers, but also service or content providers (Amazon Kindle) and a far wider variety of MVNOs.

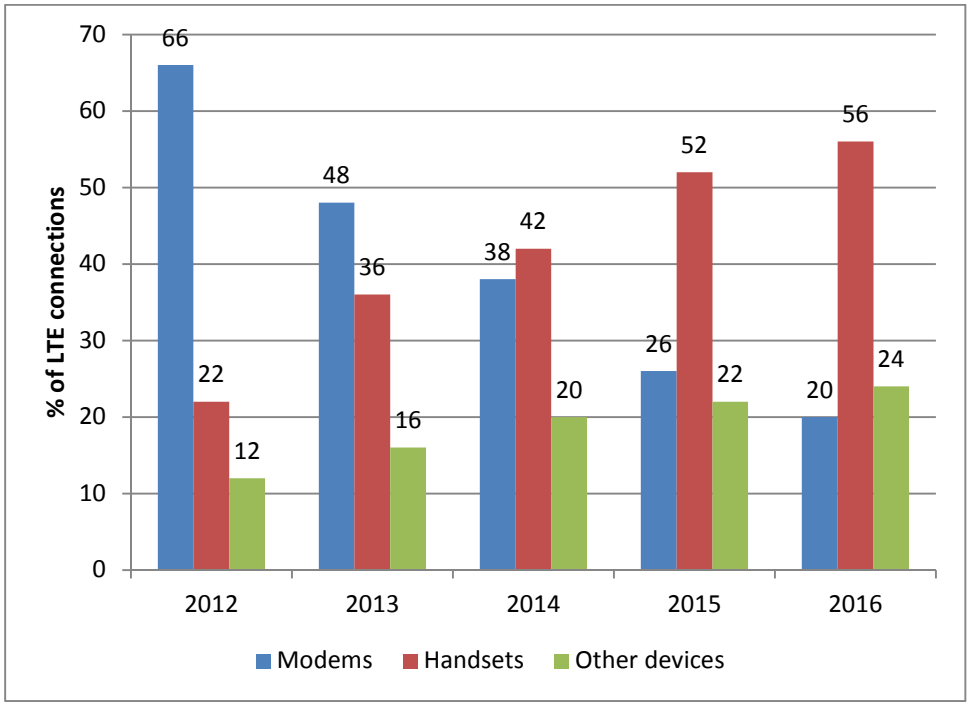


**Figure 3-10 LTE connections by device type. Modems = dongles, PCs, modules (not included in preceding forecasts). Other = emerging categories e.g. tablets, cloudbooks, media players, games consoles**

### 3.2.3 TDD support in Europe

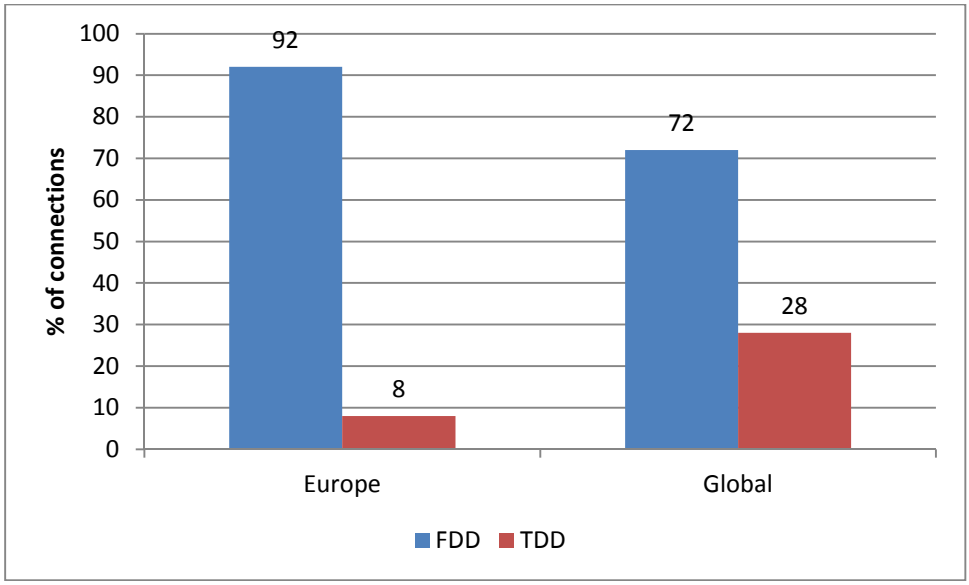


**Figure 3-11 FDD/TDD support in Europe and Worldwide**

As the figure indicates, the importance of TD-LTE will be far lower in Europe than in other regions, most notably parts of Asia. There is significant momentum behind creating a TD-LTE device ecosystem – or primarily, a multimode TDD/FDD platform which can support roaming. The first smartphones are appearing this year (at Softbank in Japan). However, these activities are heavily driven by the early adopters notably China Mobile, which has the most urgent requirement to move to TD-LTE, but will initially use the refarmed 1.9GHz band. Other important early movers are Reliance Infotel and Bharti in India in 2.3/2.5GHz (though mainly focused on fixed access); Softbank in 2.5GHz; WiMAX migrations like Clearwire's in the US and Packet One's in Malaysia (2.5GHz).

European operators mainly regard TDD spectrum as a second wave option, to add capacity when their initial deployments start to hit a ceiling. This has been seen in the generally low interest in 2.6GHz TDD spectrum in the auctions to date. The Rethink carrier study indicates that almost half the operators expect to add TDD capacity, but generally not until 2015 or later, and they anticipate being able to acquire the spectrum cheaply off interim holders, or to offer the services via a partnership.

TD-LTE interest is limited in Europe by the continuing vital importance of HSPA and the relatively good availability of mobile broadband spectrum, both in contrast to CDMA bases. Also, Europe has never had a major WiMAX base to migrate to the newer TDD standard.

The main TD-LTE activity in Europe is taking place at 3 Group, which has acquired 2.6GHz TDD spectrum in Italy, Sweden and Denmark and is pursuing a TDD/FDD strategy which it may extend in its other territories. Hutchison 3 does not have China Mobile's ability to drive an ecosystem but it has extensive supply chain influence and even its own handset unit, and its initiatives will be closely watched by other European cellcos. Most significant will be the attitude of Orange, which has been working closely with China Mobile on TD-LTE trials and device projects for several years.

Most dual-mode roll-outs in Europe are by minor players, like Aero2 in Poland and UK Broadband (in 3.5GHz) in the UK. There is also a somewhat unified device and R&D ecosystem evolving across Europe and Middle East – TD-LTE is a more common option in the latter, which remains spectrum starved.

OEMs generally have a 'wait and see' attitude to European TD-LTE. They can convert Asian devices relatively easily for the European spectrum as the market demands, but most do not expect a TD/FD-LTE smartphone to be a mainstream option until after 2016. In addition, it is harder technically to add TDD capability to an FDD only device and it also adds more cost, than adding another FDD band to a device.

In the meantime roll-outs will rely mainly on data-only devices or customized handsets. These will be driven mainly by the vendors which had WiMAX smartphone business – HTC, Samsung, ZTE – as well as Huawei.

When there is demand for TD-LTE or dual-mode TD/FD-LTE devices, the chipsets to support this will be readily available. TDD/FDD chipsets are already available and will be common by the end of 2013, driven by China Mobile and its partners, and their campaign to have all mobile silicon providers support dual-mode by default.

### 3.2.4 Other potential bands for UK LTE

The 3.3GHz-3.6GHz spectrum is widely used round the world for WiMAX and fixed broadband wireless, and increasingly mobile hand-off is also permitted by regulators. There is some interest in migrating WiMAX to TD-LTE in this band, as seen at UK Broadband. Such deployments are likely to target fixed and nomadic access, and so devices such as gateways or portable hotspots will be more significant than handsets. There is also interest in the use of the global 3.5GHz band to support small cell roaming, and to backhaul Wi-Fi.

Ofcom is consulting on the 700MHz band as a future option for LTE, which would add to the store of sub-1GHz spectrum, so valuable for coverage and rural access. This is unlikely to be commercial until 2016 or later and so will target LTE-Advanced at that stage, which will support capacity and performance advantages compared to the initial 700LTE deployments in the US. Opening up 700MHz would bring the UK into the device ecosystem for this band, but although 700MHz is currently the dominant LTE frequency, it is problematic in terms of roaming or universal handsets. The US band plan is different to that of Asia-Pacific, and even different US carriers' devices are non-interoperable. Latin America is splitting over whether to support the US or Asian approach. The result is that there will have to be 'multiband' devices even within the 700MHz spectrum.

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