BSG
Broadband
Stakeholder
Group

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Out-of-home use of the internet

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About the author

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Disclaimer

The opinions offered in this report are purely those of the author. They do not necessarily represent the views of the BSG or its members, nor do they represent a corporate opinion of Communications Chambers.

BSG Foreword

For the past two years a key theme of the BSG's work programme has been to inform and raise the profile of demand side issues in the broadband policy debate.

Policy-makers have focused on how to deliver the government speeds and coverage targets given the differing costs and capabilities of technologies. Although this work must continue, we believe that the primary focus should now be on demand and usage side of the UK's broadband infrastructure.

In November 2013 we therefore published Domestic Demand for Bandwidth which sought to create an application based model for domestic bandwidth to 2023. During this work it became apparent that a necessary and complementary piece of work would be to assess out-of-home internet usage.

Accordingly, the BSG commissioned Communication Chambers to conduct a study into this area as a further input to the demand-side debate. The report explores patterns and trends in internet use out of the home – naturally focusing on cellular and public WiFi use – without attempting, due to the paucity of data available, to quantitatively model future demand.

In commissioning this work we were influenced by a number of factors. A year on from the widespread launch of 4G networks, coupled with increasingly prevalent public WiFi networks, represents a timely opportunity to look at this area which has historically received less attention than the fixed network. We were also keen for the work to be completed in time to inform the Digital Communications Infrastructure Strategy.

Communications Chambers examined usage today, looking at the opportunities for using the internet out-of-the home, where that opportunity matches cellular and WiFi coverage and examining how best to measure demand. Based on a variety of sources the report estimates that total network out-of-home traffic is 35.6 PB/month, with a 2:1 split across cellular and WiFi networks. To place this in

context, the report examines residential broadband demand which is placed at 650 PB/month.

The report looks at this relationship between in-home and out-of-home use, with video content playing a key role in driving demand in both settings. The difference in usage is explained by human factors, such as the lack of contiguous idle time, which is when viewing of long form video usually takes place, when out of the home, and network constraints, such as coverage and bandwidth, to explain different usage patterns between the two. Whilst some of these constraints will ease over time, others are likely to be fixed meaning that full convergence between the two is unlikely.

In looking at usage, the report also raises the issue of traffic intensity – that is the mean average level of data consumed per user per waking hour – for out-of-home this is calculated to be an average of 7.7 MB whilst in home usage has an average traffic intensity of 71.8 MB.

The study also places the UK in an international context with countries which started their LTE deployments far earlier – South Korea, Japan and the US. This allows us to compare the UK's use of cellular networks against countries which are already utilising 4G services – and offers an indication of the likely future trajectory of cellular use in the UK.

Four limitations to users accessing the internet out of the home are identified. Firstly, there are natural limits to the size and technical limitations to the battery life of devices. Secondly, many consumers are influenced in their usage by the level of their data allowance – which is rarely exceeded, regardless of its size. Thirdly, there is the bandwidth constraint, and variability, of mobile networks which has a significant impact on the performance of demanding applications. Finally, there is the challenge in accessing WiFi networks, where there is a need to manually log-in.

Future out-of-home use is explored from a total network traffic and per user basis. Increased adoption of smart phones, the lessening of some constraints such as network availability and coverage (such as the rollout of 4G and an increase in easy to log-in WiFi hotspots), along with a maturing ecosystem are all factors in the likely growth of out-of-home internet use. This concurs with evidence on the international scene which shows an exponential 'uptick' in mobile traffic as consumers move to 4G (tariffs of which generally have

higher data allowances). However, the report highlights the difficulties that cellular and WiFi networks may have in meeting this demand.

In coming to making the following recommendations the BSG, drawing on the conclusions of the report, have tried to answer the question of *'how do we retain flexibility in the out-of-home system whilst ensuring that we address consumers' demands to do what they want, where they want?'*

A combination of cellular and WiFi networks are essential components of a system that allows us to meet consumers demand and the growth in mobile traffic. In the search for greater capacity, both small cells and WiFi hotspots are important in offering offload for congested macro-cellular networks. In order to facilitate this system:

- **Government should ensure better access to public sector land and street furniture** for both WiFi and cellular providers. Actions could include a presumption in favour of land held by public bodies, the promotion of concession contracts and ensuring that new public structures and furniture have connectivity built in.
- Subject to international spectrum negotiations, the work of the Spectrum Policy Forum and the requirements of other wireless services, **Government and Ofcom should work to ensure that both forms of technology have access to sufficient, and affordable, spectrum to meet demand.**

As outlined in the report, cellular is incredibly important in providing increasing levels of, and in the future, a level of 'ubiquitous', coverage across the country. In order to expand coverage of the network:

- **The Government should seek to reform the Electronic Communications Code** which could significantly lower the cost of land for new sites.
- The Government should carry out further **reforms to the planning system to shift the focus from whether to where mobile infrastructure (both macro-cellular and small cells) should be deployed** – this includes encouraging the sharing of infrastructure, access to roof-tops and considering the use of taller masts, which would possibly reduce the total amount of masts needed.
- **Ofcom should ensure that the cost of backhaul is not excessive.**

In high footfall areas, particularly where those are indoors, WiFi plays a greater role in providing both coverage and capacity. Therefore we believe:

- **Industry should work with Government to place a greater strategic emphasis on WiFi provision;** one of the goals of which should be to drive better coordination of WiFi at a local level in order to prevent interference.
- **Industry should prioritise the rollout of Passpoint 2.0** to ensure that access at the local level requires minimal user interaction.
- OOH WiFi usage has had a lower profile in comparison to cellular than it perhaps deserves, partly because of the fragmented nature of the market. In order to increase understanding of its importance, **Ofcom should consider conducting more research into OOH WiFi usage via device-level monitoring.**

This report brings new insights to this policy area and the BSG looks forward to continuing this debate.

Contents

1. Executive Summary

This paper offers a survey of out-of-home use of the internet, exploring patterns and drivers of consumption. Out-of-home usage is important not least because adults spend 48% of their waking hours away from home. As internet usage has grown, it has been natural for consumers to want to extend it into this portion of their lives, and at least 58% now use the internet on their mobiles.[1]

This has been enabled by the availability of affordable smartphones; mobile data network coverage that now reaches 99% of premises; and the expanding availability of wifi hotspots. We estimate that approximately one-third of out-of-home use is via wifi and two-thirds via cellular. (Overall mobile device traffic may be 75% wifi, but this includes substantial wifi use in-home).

As of June 2013, we estimate out-of-home traffic (mobile and hotspot, but excluding workplace wifi) at 33.6 PB per month. This is substantial, but still far below residential fixed broadband use of 650 PB. On a per-waking-hour basis, we estimate in-home use at 72MB, and out-of-home use at 7.7MB.

This difference will in part be due to differing network capabilities – surfing has typically been slower on cellular networks, mobile bandwidths do not always support video and so on. However, there are some fundamental reasons why levels of usage in- and out-of-home will always differ. These include the implications of mobile devices (such as smaller screens, limited ability to multitask and so on), lower propensity for video use, less idle time when out-of-home and so on.

While traffic levels are lower out-of-home, traffic mix is actually surprisingly similar. P2P traffic (such as Bittorrent) is much less common on cellular than home broadband, but setting this aside, the main difference is video, which comprises 54% of fixed and 43% of cellular traffic. While lesser, this substantial amount of video on suggests that the network does not represent a material barrier to consumption. The mix of traffic for users on 3G and 4G is also very similar, again suggesting that 3G network capabilities have not been a particular barrier to certain types of consumption.

Concerns over cost do appear to be an issue. Consumers typically greatly underutilise their data allowances, suggesting a desire to avoid bill-shock (or perhaps poor choice of plan). Consumer

[1] . ONS, *Internet Access - Households and Individuals, 2014*, 7 August 2013

responses include side-loading[2] content instead of streaming, delaying consumption until wifi is available, and use of hotspots when out-of-home (though this last is a minority activity). Content and service providers too are seeking to minimise cellular traffic requirements, via apps, improved video and image compression, lower resolution video streams and so on.

Clearly internet usage overall (in- and out-of-home) continues to grow. However, while the mobile internet is less mature than in-home, it may be that it is now 'mature enough' that its per user growth rates are converging with in-home – they were 39% and 30% respectively in the year to June 2013. That said, out-of-home use will likely accelerate as 4G phones and coverage become widespread (Japan, Korea and the US have already seen such an uplift).

Future growth will primarily come from greater per-user consumption, since the number of people using smartphones to access the internet appears to be approaching saturation.

In addition to the continuing development of the internet ecosystem, with ever more applications and use cases, future out-of-home growth will be underpinned by two effective price reductions for consumers. For cellular, the roll-out of 4G networks and adoption of 4G devices greatly increase the supply of cellular capacity, and will lead to a reduction in per-MB pricing. For wifi, the enablement of auto-login (without a username or splashscreen) will remove a key time-cost to the usage of wifi, and effectively reduce to zero the cost of traffic when within range of a relevant hotspot.

As traffic costs to users drop, they will both do more and new things with their smartphones, but also they may do the same things differently. For instance, they may choose to stream content rather than side-loading it, or choose higher definition video streams (or content providers may choose higher definition streams for them).

Such interactions are just one example of complex and dynamic nature of the out-of-home ecosystem. Networks (of two very distinct types), content and application providers, consumers and regulators all interact, each responding to the decisions of the others.

The dynamic nature of the system suggests that standalone traffic forecasts need to be treated circumspectly as an input to policy decisions.

[2] Loading media files onto a device at home for consumption while on-the-go later

That said, OOH growth is certain, and both cellular and wifi each have a vital role to play in meeting this. While locally they can sometimes substitute for each other, at a strategic level both are essential.

Of the two, wifi is perhaps less understood in policy terms, largely due to its decentralised nature. Better knowledge here may throw up opportunities to meet OOH demand more efficiently.

2. Usage today

In this section we look at current out-of-home usage. We consider, in terms of available time and network, how large is the scope for out-of-home internet use. We then estimate today's actual out-of-home traffic, building on an analysis of cellular and wifi consumption by time of day. We compare out-of-home and in-home traffic, exploring the reasons for differences between the two.

We then turn to different types of usage and applications, which we consider both from a traffic basis and on the basis of time spent. We also look at the range of devices deployed for out-of-home use.

Finally we look at UK usage in an international context, with particular reference to markets which are futher ahead in deployment of 4G networks.

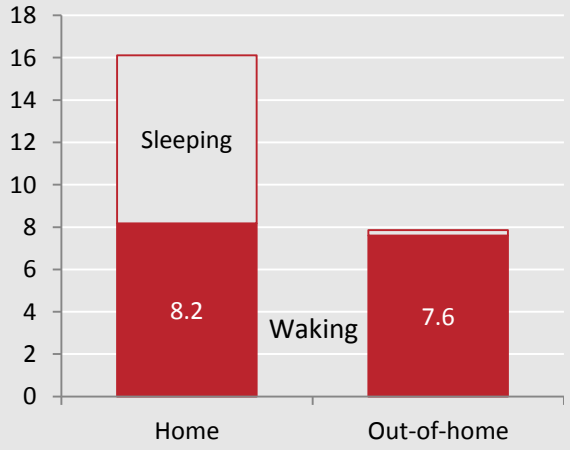
Opportunities for usage

Time out-of-home

Out-of-home usage is important for many reasons – not least because adults spend 48% of their waking usage away from home, according to the ONS Time Use Survey (Figure 1).

As the internet has become an integral part of both entertainment and productivity at home, it has been natural for consumers to extend its use outside. For a smaller group, the mobile internet was initially an extension of their office use of the internet – for example, corporate users who were early users of Blackberries for email.

Figure 1: Time spent by location (hrs/day) (weighted per age mix of smartphone users)[3]



[3] Communications Chambers analysis of ONS, *The Time Use Survey, 2005*, July 2006. Time split includes adjustments to match age profile of smartphone users. Excludes 50 minutes of time unallocated in the survey results between home and out-of-home

Employment comprises 3.0 hours[5] or 30% of time spent out of home (Figure 2). For some, hours spend on paid work will leave little or no time for internet use (waiters and bus drivers, to take just two examples). Conversely, for many white-collar workers, internet use will be integral to their employment. Internet usage may be via office wifi, or via macrocellular, particularly for mobile workers.

Figure 2: Out-of-home time by activity (hrs/day)[4]

During work hours people may have less time to kill, and their internet usage is likely more purposeful, with less video. While video accounts for over half of internet traffic, it typically is just 20% of corporate network traffic.[6]

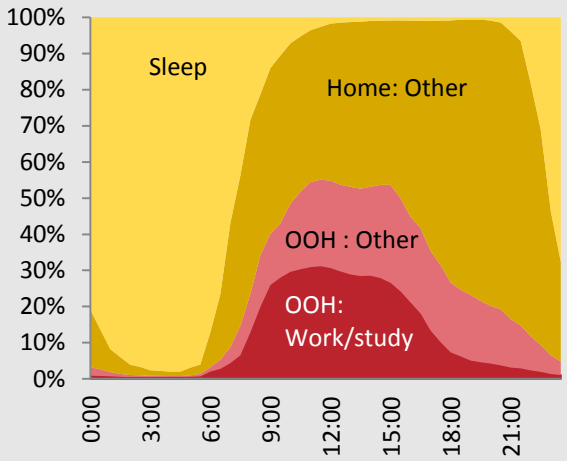
A further 1.5 hours per day is spent on travel. For journeys to work, 64% drive or cycle, presumably giving limited opportunity for rich-media internet use, at least until driverless cars become widespread.[7] (Though note that in the meantime an increasing number of cars sold will have embedded connectivity of some type – Analysys Mason forecast this will rise from 15% today to 66% by 2020).[8] A further 11% of journeys to work are on foot.

However, 18% of journeys are by public transport and 5% as a passenger in a car or van, and such journeys will present substantial opportunity for use of mobile devices and the mobile internet. While such usage may be via the transport provider's wifi, in most cases the connection will ultimately be via the macrocellular network.[9]

[4] Ibid
[5] This figure is an average across those in paid work and not, and across work days and non-work days
[6] Blue Coat Systems, *Online Video Habits of Employees*, 2011
[7] ONS, *2011 Census: Method of travel to work, local authorities in England and Wales*, 30 January 2013
[8] Analysys Mason, *Connected cars: worldwide trends, forecasts and strategies 2014–2024*, June 2014
[9] Though note wifi coverage on the London Underground and an increasing number of rail stations, connected to the internet via fixed broadband

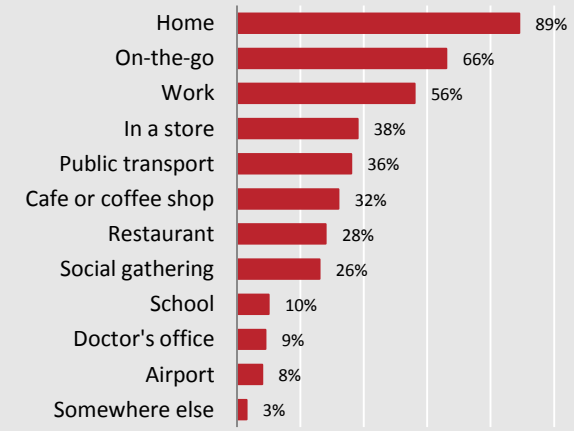
Data from Ofcom's study *The Consumer's Digital Day* shows when during the day consumers are out-of-home (Figure 3). Between 10.30am and 4pm, over 50% of adults are away from home, but there are relatively steep drop-offs both before and after this period

Figure 3: Activity by time of day[10]



This mix of time spent is, perhaps unsurprisingly, consistent with where people report using their smartphones. The vast majority use them at home, and most use them on-the-go (commuting or walking) and at work. Of those employed, 80% use them at work. Note that this usage includes both online and offline apps – the latter category would include games, pre-loaded map applications, watching side loaded video and so on.

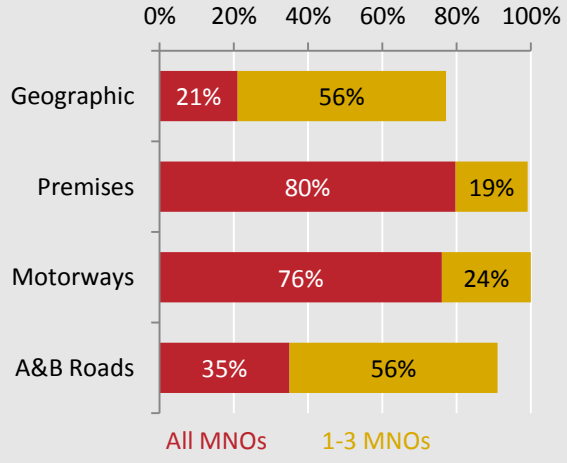
Figure 4: Places smartphone used in last week[11]



Cellular coverage out-of-home

As Figure 5 shows, coverage for mobile broadband is already high – 99% of premises have 3G coverage from at least one mobile operator, and 80% have coverage from all four. On motorways coverage is almost as high. While it is lower on A and B roads and on a geographic basis, this in itself is unlikely to result in a material reduction in overall mobile internet use – people spend less time away from premises, and when they are on a road they may well be driving and unable to use the internet for most purposes

Figure 5: 3G Mobile coverage[12]



[10] Communications Chambers analysis of underlying data for Ofcom, *The Consumer's Digital Day*, 14 December 2010
[11] Google, *Our mobile planet*, 2013. 'On-the-go' includes use while commuting or on foot
[12] Ofcom, *Infrastructure Report - 2013 Update*, 6 December 2013

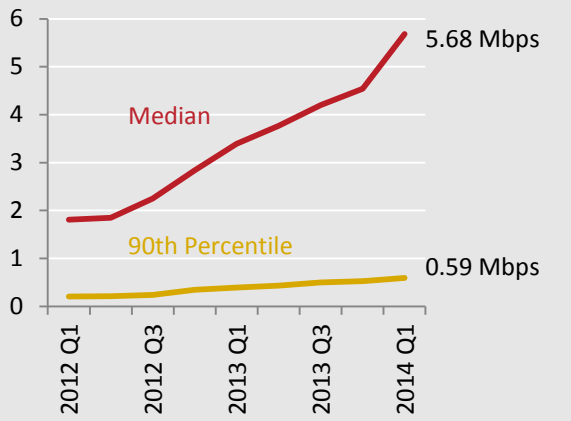
(streaming radio and internet based sat-nav would be two possible exceptions).

The roll-out of 4G coverage is ongoing, but all operators anticipate premises coverage of around 98% by end-2015.[13]

While coverage is high, this does not necessarily mean that network capabilities are no barrier to usage. For example, at the edge of cells or during periods of high usage, per-user bandwidth may be too low to sustain streaming video. Situations where a user is outside 'application coverage' for what they need at that point in time may result in significant frustration.

However, Ericsson - based on Ookla data[15] - report that the speeds available to UK users within coverage areas are steadily increasing (Figure 6). Even 90th percentile speeds, that is those that can expect to be bettered 90% of the time, have now reached 0.59 Mbps, a rate above that which might typically be used by broadcasters to stream video to a smartphone on a mobile network.[16]

Figure 6: UK cellular downlink speeds (Mbps)[14]



Continued roll-out of 4G (and its adoption by consumers) will further improve speeds, though this will be counterbalanced by increasing usage of the network (which divides available cell bandwidth between more concurrent users).

Wifi coverage out-of-home

Wifi *in* the home has been widespread for some time. As of Q1 2014, Ofcom found that 93% of those with fixed broadband had a wireless router at home.[17] The Oxford Internet Institute found an even higher figure, at 96%.[18] Ofcom estimate 17.5m households with wifi.[19] For individuals visiting friends and family, use of such wifi will represent out-of-home use. (Note however that there will

[13] Ibid
[14] Ericsson, *Mobility Report Appendix : Europe*, June 2014
[15] Note that Ookla speed testers are a self-selected sample, and may not be representative. For instance, those experiencing network problems or conversely those wishing to test the performance of a new 4G phone may be over-represented. Moreover, if a consumer was in a location with insufficient coverage to run a test, then by definition they will not be included in Ookla's dataset
[16] Such rates are adjusted both according to the actual performance of the user's connection, and according to the device and network. Typical streaming rates to a tablets or devices on wifi networks would be higher, for example
[17] Ofcom, *Communications Market Report 2014*, 7 August 2014
[18] OII, *Cultures of the Internet: The Internet in Britain*, 1 October 2013
[19] Ofcom, *Technical coexistence issues for the 2.3 and 3.4 GHz award (annexes 7-14)*, 19 February 2014

be a small number of households with mobile internet but no fixed broadband).

Recent years have seen an increase in availability of wifi outside homes also. In the year to June 2013, public wifi hotspots reported to Ofcom grew from 16,000 to 34,000.[20] Coverage includes retail chains, coffee shops, hotels, stations and so on. However, this figure is only for hotspots provided by commercial operators such as BT and The Cloud (owned by Sky). Ofcom estimate a further 44,000 indoor public hotspots are operated by business owners, and another 4,000 outdoor hotspots (such as those provided by some city councils.[21] In most cases such wifi is available free of charge, at least for limited periods – in the early days of hotspots, wifi was often offered as a paid service, but this model was abandoned by most retailers by 2011.

Ofcom also assume that all workplaces with 10 or more employees – 680,000 in the UK – are likely to also provide wifi. Cisco research found that 57% of smartphone owning employees in the UK had access to workplace wifi. [22] However, one fifth of those with such access said they chose not to use it. In some cases security policies may forbid the connection of outside devices, employees may prefer cellular for privacy or convenience, wifi may not be available throughout that workplace and so on.

In addition, many jobs may not involve a single place of work, or may involve substantial time away from that 'home base'. In these cases, the availability of wifi in workplaces may have little relevance to those workers' ability to use wifi during work hours.

To get an understanding of the scope of these issues, we have undertaken a rough analysis of the jobs of the UK workforce, as set out in the Labour Force Survey. We have split the 369 roles quantified in the LFS into desk vs non-desk, and fixed vs mobile. Desk jobs are those with heavy information content and a desk to which the employee returns to work. Mobile jobs are those that involve substantial time on the road or out of doors – that is, away from any (own) workplace wifi.

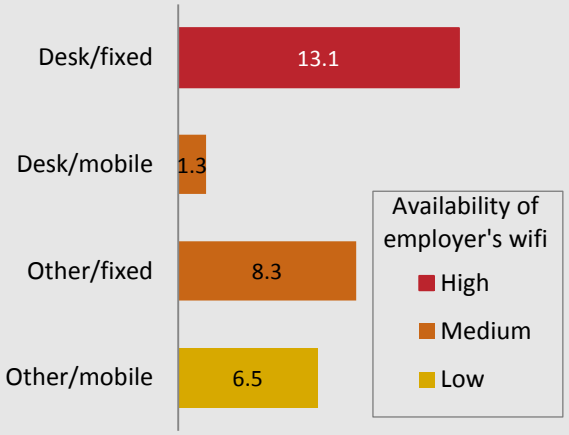
Figure 7: Sample job categorisations

	Fixed	Mobile
Desk	Secretarial Accounting	Sales execs Architects
Non-Desk	Retail assistants Nurses	Drivers Farm workers

[20] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013. Note that this increase was in part due to the inclusion of Arqiva in 2013, which was not included in 2012
[21] Ofcom, *Technical coexistence issues for the 2.3 and 3.4 GHz award (annexes 7-14)*, 19 February 2014
[22] Cisco, *Global 2013 Wifi Survey*, February 2013

Our categorisation inevitably is approximate, and there will be significant variation between individuals with the same job title, but it nonetheless offers a broad picture of the mix of roles – see Figure 8. Of the total workforce of 29m, just under half (13.1m) are in desk-based roles with relatively little time away. It seems likely most such individuals have access to wifi, and if they do not, they likely have internet access via their work computer. Over a quarter (8.3m) have a fixed place of work, but are not in office roles – as such, they may be less likely to have access to a wifi signal (though many certainly will).

Figure 8: Workers by category (m)[23]



The third largest category (6.5m) is non-desk, mobile workers who spend most of their time away from base or outdoors. Such individuals will only be able to make limited use of any workplace wifi.

Thus this analysis suggests that even if the great majority of workplaces have wifi available, there will be a substantial minority of workers – perhaps a third – who will not be able to make ready use of their employer's wifi. As such, they will depend on macrocellular or third party wifi for their day-time data needs. (This finding is broadly consistent with the Cisco research noted above which found that 57% of full-time employees currently have wifi access at work).[24]

Note that even if smartphone users use their phones *at* work, this doesn't mean they use them *for* work. Indeed, 74% of UK smartphone users (and rising) report that they *only* use their phones for personal reasons.[25]

Levels of out-of-home traffic

We now consider various metrics of today's volume of use. We start with network traffic.

Network traffic

In practice, it is impossible to precisely identify out-of-home traffic. While Ofcom reports residential fixed, mobile network and wifi hotspot traffic, these categories do not map directly onto an in-

[23] Communications Chambers analysis of ONS, *Labour Force Survey Employment status by occupation - April - June 2012*, 15 August 2012
[24] Cisco, *Global 2013 Wifi Survey*, February 2013
[25] Google, *Our mobile planet*, 2013

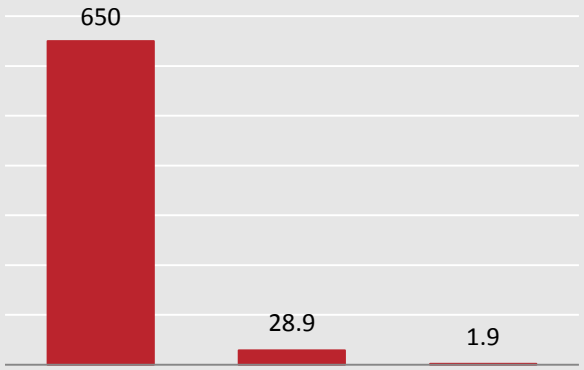
home/out-of-home split. At least some of residential fixed traffic will be from visiting friends and family using a host's wifi (either by being given the home password, or through home hotspots such as BT's Openzone). Conversely, some of the mobile network traffic will be in-home. Finally, some hotspot usage may in fact be in-home. Per-user hotspot data shows, for a small number of users, very heavy usage of individual hotspots. This at least suggests that these users may happen to have visibility of these hotspots from home.

Entirely excluded from Ofcom's categories is workplace internet traffic, which would include both out-of-home personal use via office computers, but also via mobile devices accessing workplace wifi.

Nonetheless, a comparison of Ofcom's categories of traffic is illuminating (Figure 9). Clearly the 650 PB of residential fixed usage in June 2013 dwarfs mobile and hot spot usage combined. These 650PB will be from a range of devices – computers, internet connected TVs and set top boxes, and mobile devices used in-home.

Note that the hot spot traffic shown is just that from commercial providers such as BT and The Cloud – independent hotspots might perhaps double this traffic. Workplace wifi would be in addition, but is unquantified.

Figure 9: Internet traffic by access type (PB/month, Jun 2013)[26]



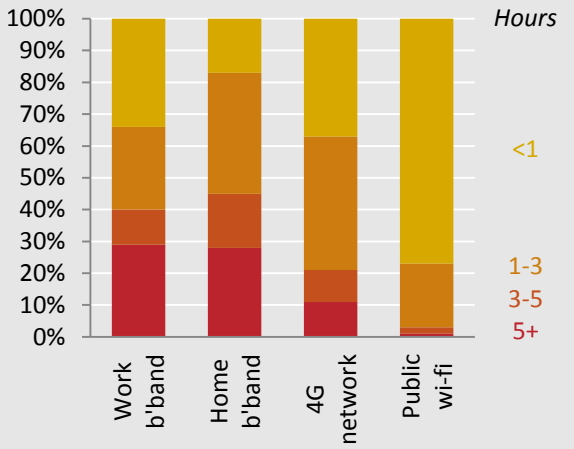
One reason for the heavier use of fixed is that more adults use fixed broadband (72% compared to 51% with smartphones). On a per-capita basis, fixed broadband users used 17.6GB that month, and mobile data users 1.26GB.[27]

[26] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013

[27] We assume that the number of smartphone users is a good proxy for the number of mobile data users – that is, the number people using dongles or tablets but *not* smartphones is small. Figure includes commercial HS usage and an estimate of independent HS, but not workplace wifi usage

EE survey data, in which 4G users reported their time spent using different networks, tells a similar story. Both home and work broadband see significantly more extended use than the 4G network, with roughly 40% of respondents spending three hours or more per day using each, compared to 21% using 4G for this amount of time. (This despite the fact that early adopters of 4G may be heavier users of mobile internet than most, though this will be counter-balanced by incomplete EE 4G coverage at the time of the survey – at May 2014 it was a little over 70%).[29]

Figure 10: 4G users time on internet by network[28]



However, cellular usage dwarfs hotspot usage – only 6% spend three of more hours on public wifi.

Note that while fixed networks dominate, mobile devices (used in part on those fixed networks) are increasingly important. They now represent 33% of UK page views (up from 2% in January 2010),[30] 48% of iPlayer TV requests[31] and 30-40% of most eGov interactions.[32] From the consumer's perspective, the internet is well on the way to being a 'mobile device first' activity.

Offload

'Offload' is the use of wifi instead of cellular by mobile devices. While we will use this term, it is perhaps slightly misleading, since it may suggest that by default the traffic would be on a cellular network. There are two issues with such a presumption. First, the traffic in question might not have occurred on a cellular network – for instance, the consumer might regard extended video consumption as too expensive on the cellular network but would be happy to consume the same video on wifi; or cellular might not be able to provide video streaming at that time and place. Second, the great majority of mobile device usage is on wifi, not cellular – in this sense, wifi is the default, not cellular.

Estimates of offload vary (see Figure 11) but 75% might be a reasonable expectation for the UK for smartphones. (We discuss tablets and other mobile devices later - these are likely to see a much higher percentage, since they are mainly used in home).

[28] EE, *4GEE Mobile Living Index, First half report 2014*, 7 August 2014
[29] EE, *EE unveils plans to increase 4G accessibility and transform the user experience as 4G overtakes 3G*, 21 May 2014
[30] Statcounter [Accessed 4 June 2014]
[31] BBC, *iPlayer Monthly Performance Pack, April 2014*,4 June 2014
[32] Tom Loosemore (GDS), *When will more people visit GOV.UK using a mobile or tablet than a PC?*, 8 January 2014

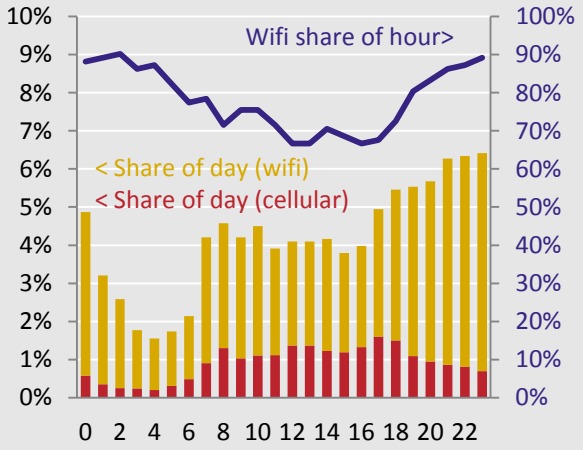
Figure 11: Wifi offload

Study	Date[33]	Coverage	Offload	Notes
Lee et al[34]	2010	Korea, urban iPhone	65%	Wifi availability drops from 80% to ~50% in working hours
Liu & Striegel[35]	2012	US, students	30%	
Fukuda & Nagami[36]	2012	Japan, Android	64%	Over 50% of users turn off wifi during business hours
Nielsen[37]	2012	UK, 3G Android	78%	
Cisco[38]	2013	Global	45%	
Analysys Mason[39]	2013	Global	65%	Expected to rise to 70% by 2018
WIK/Aegis[40]	2013	UK	74%	
Informa[41]	2014	UK, 4G Android	84%	Self-selected participants may be unusually active data managers

However, this 75% figure is an average across the day – in practice offload varies by hour. Because wifi is readily available at home, it is particularly likely to be used during evening hours and during the night, when offload is in the region of 85 to 90%.[43].

Between 9am and 5pm, this drops to around 70%. Those at work or out of the home for other reasons are less likely to have wifi available (though it is notable that even during this period, wifi traffic is more than double cellular traffic).

Figure 12: Smartphone traffic mix by hour (2012)[42]



This high day-time usage of wifi will be for a number of reasons. Firstly, it likely reflects substantial in-home use. As we saw above (Figure 3), even in the middle of the day, just under 50% of adults are at home, though this figure includes retirees, who (currently) are far less likely to use a smartphone. Of those aged 18-65,

[33] Date of estimate or of fieldwork – publication dates generally different
[34] Lee et al, *Mobile Data Offloading: How Much Can WiFi Deliver?*, April 2013
[35] Shu Liu & Aaron Striegel, *Casting Doubts on the Viability of WiFi Offloading*, August 2012
[36] Kensuke Fukuda & Kenichi Nagami, *A Measurement of Mobile Traffic Offloading*, March 2013
[37] Nielsen, *Wi-Fi delivers over three-quarters of all UK smartphone data*, 15 November 2012
[38] Cisco, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018*, 5 February 2014
[39] Analysys Mason, *Wireless network traffic worldwide: forecasts and analysis 2013–2018*, October 2013
[40] WIK & Aegis (for European Commission), *Study on Impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum*, 21 May 2013
[41] Informa for Mobidia, *Smartphone use transforming with the rise of 4G and wifi*, 24 February 2014
[42] Nielsen, *Wi-Fi delivers over three-quarters of all UK smartphone data*, 15 November 2012. See also Informa for Mobidia, *Understanding today's smartphone user: Demystifying data usage trends on cellular & Wi-Fi networks*, February 2012; analysis of this data leads to a very similar pattern of offload during the day
[43] Note that for this particular sample, overall offload was 78%

approximately 73% are in paid work. For those in paid work, approximately 64% of days are spent working.[44] This implies that overall, just under half of this age group are working on the average day. Of course, non-working days are not spent entirely at home, but nonetheless enough time will be spent at home such as to contribute meaningfully to daytime wifi consumption.

Secondly, wifi may be used out-of-home via workplace access (or, less significantly, hotspot access). On a typical day approximately one quarter of smartphone users will have access to workplace wifi.[45] However, 54% of 4G users report that they make less use of hotspots since moving from 3G, which may reduce future growth in this form of day-time wifi.[46]

Thirdly behaviour may be very different for those with a wifi connection which generally does not carry traffic charges.[47] The costs of wifi connections may be bundled into a broadband or wifi offer, or covered by a retailer. In some cases it may be bought from an aggregator such as iPass. However, if there are usage limits (and often there are not), they are generally by time not traffic.

Thus wifi generally has little or no marginal traffic cost at the point of use (and potentially higher bandwidth) so users may be more inclined to use services such as video when wifi is available, generating more traffic per hour. Thus the 70% of traffic that is on wifi during the day may represent a rather lower percentage of users and/or time spent online.

Looking specifically at the spread of cellular traffic during the day in Figure 12, it is notable that 31% of it is between 7pm and 7am, hours when people will frequently be at home. It may be that the cellular traffic during these hours is derived particularly from those who happen to be out-of-home in this period, but conversely at least some of the (more substantial) cellular daytime traffic between 7am and 7pm is in fact from individuals at home. Thus it seems likely that a material portion of cellular traffic does in fact derive from the home – for the purposes of this study, we estimate this at 20%.

[44] Allowing for weekends, bank holidays and personal holidays. Figure is for days spent in the UK, and reflects a small adjustment for time spent out of the country

[45] Based on one half working on an average day and the Cisco finding that 57% of employees have access to workplace wifi and four-fifths of this group make use of it

[46] EE, *4GEE Mobile Living Index, First half report 2014*, 7 August 2014

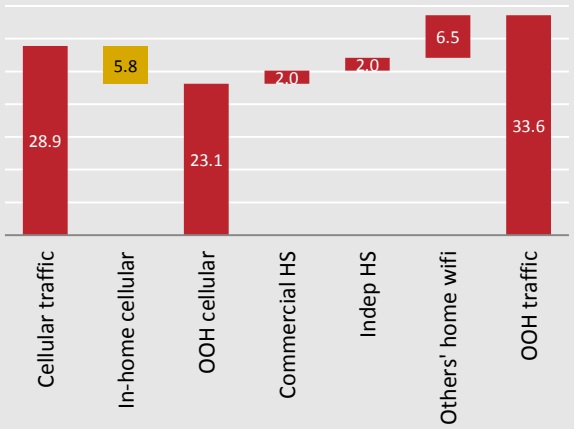
[47] Home broadband (and hence home wifi traffic) is increasingly uncapped. Virgin and Talk Talk no longer promote traffic-limited products, for instance. Hotspot wifi is, in most locations, also uncharged. Starbucks, one of the last major chains which charged, moved to free in 2011

Estimated Out-of-Home traffic

Based on the above, we are in a position to make a rough estimate of out-of-home use. This estimate depends on three key assumptions. The first is our estimate that 20% of cellular traffic is in-home. The second is an assumption that the 44,000 non-commercial hotspots provide as much traffic as the 34,000 commercial hotspots. The third is an arbitrary estimate that 1% of residential fixed traffic is in fact from visitors to the household in question, accessing that link either through a service such as BT Openzone, or with the explicit permission of their host.

Based on these assumptions, we estimate out-of-home usage at 33.6 PB (for June 2013), excluding workplace wifi (Figure 13). Of this, approximately two-thirds are delivered by cellular, and one third by wifi. Wifi in others' homes represents 19% of the total. This compares to the 9% of out-of-home hours spent at friends and families' homes.[49] However, the availability of wifi and greater free time may increase per-hour data utilisation in these locations.

Figure 13: Estimated out-of-home traffic, PB/m (excl workplace wifi)[48]



As noted, this analysis excludes workplace wifi. This may or may not be significant. Only on one man-day in three will 18-65 year olds have access to workplace wifi. Moreover, many of those with wifi access at work will also have access to a fixed computer, and in many use cases, this may be their device of choice.

There is extremely little data in the public domain on traffic volumes associated with workplace wifi. However, one proxy comes from usage of the British Library's wifi. The Library provides free wifi to its readers, and records 58 MB per device per day.[50] This seems likely to be significantly above volumes for a typical employee. By definition, visitors to the Library are knowledge workers. Moreover, the Library provides no fixed internet connectivity, unlike a typical office, so all visitors' traffic flows via wifi.

This 58 MB per person per day of traffic is equivalent to monthly workplace usage of 580 MB (on the basis of one man-day in three

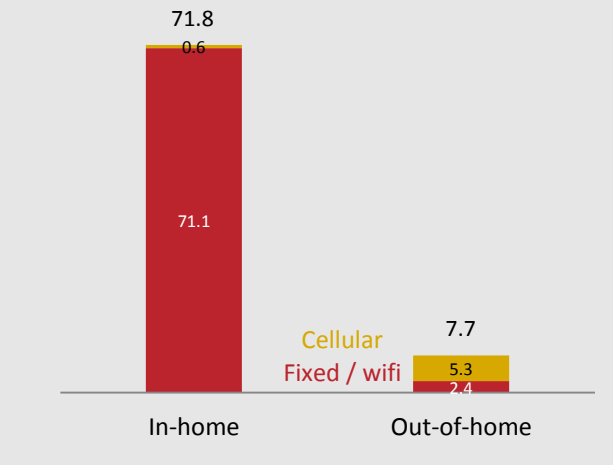
[48] Communications Chambers analysis
[49] Communications Chambers analysis of ONS, *The Time Use Survey, 2005*, July 2006. Note that for consistency hours spent within workplace wifi coverage have been excluded, since the associated traffic is also excluded
[50] British Library, *British Library Wifi Upgrade*, 11 April 2013

being in the workplace). This is less than half the 1.26 GB in June 2013 of smartphone cellular traffic. This suggests that an upper bound for total UK workplace wifi is therefore 13.3 PB/month. This would be a 40% uplift to our 33.6 PB of out-of-home usage, though in reality the figure may be much less. Given the uncertainty around workplace usage, we will set it aside in the following discussion.

Traffic intensity

With these estimates of a split of in- and out-of-home traffic, we can assess the 'data intensity' of time spent in the two locations. At an average rate of 71.8 MB per user per waking hour, in-home usage is substantially higher than the 7.7 MB per waking hour out-of-home (excluding time and associated data in workplace wifi coverage). Note that these are mean figures - given that in-home traffic is particularly driven by heavier users, it may be that the gap between median in- and out-of-home usage would be narrower.[52]

Figure 14: Traffic (MB) per adult per waking hour[51]



While this difference in traffic per hour suggests there is substantial room for out-of-home usage to grow (and in-home usage is itself a moving target, since it too is growing), there is no particular reason to expect these two figures to converge. There are a number of fixed constraints, reasons why out-of-home traffic intensity will always be lower than in-home. That said, there are also 'easing' constraints – current impediments to use out-of-home which will fall away. Figure 15 sets out key examples of each.

[51] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013
[52] See page 20 for a more detailed discussion of traffic distribution

Figure 15: Constraints on out-of-home traffic intensity (compared to fixed broadband)

'Easing' constraint	'Fixed' constraint

• Higher cost per GB (when on cellular)
• OOH use less mature than in-home
• Network availability and bandwidth lower
• Substantially smaller screen size
	• Lower data for same use case on mobiles
	  ○ Lower res video
	  ○ Mobile web pages
	  ○ Use of apps
	• Lower percentage of time 'available' OOH (eg limited mobile use in some workplaces)
	• Little contiguous time available OOH, making some use cases (eg long-form video) less likely
	• Lesser ability to multi-task on mobile devices
	• Limited passive apps on mobiles (eg Bittorrent)

However, there are also some factors that might act to increase usage out-of-home relative to in-home. For instance, pictures and videos taken with smartphones are perhaps more likely to be captured out-of-home, and users may wish to upload them immediately.

'Human factors' in out-of-home use

Some of the key fixed constraints set out above are 'human factors' – that is, not issues of technology, but rather more fundamental issues of human behaviour and society. These are certainly not immutable, but are likely to change more gradually. In this section we look at these human factors in more detail.

A key factor in the step up from dial-up internet to broadband at home was, in addition to increased bandwidth, 'always on'. Dial-up had required an extended 'handshake' between the consumer's and the ISP's modem. This only took minutes, but nonetheless was an annoyance and a significant barrier to consumption. With broadband, one could sit down at a computer and be online immediately.

That said, even with broadband the internet was only 'always on' at the PC. If you were in another room, there was the need to go to the PC and potentially boot up the computer before getting online – perhaps as inconvenient as dial-up once was. Wifi combined with laptops and mobile devices has made the internet 'always on' throughout the home. The 'inconvenience barriers' to consumption are very low.

The importance of these inconvenience barriers is evident in the level of smartphone and tablet consumption in the home. In one sense these are sub-optimal devices compared to a PC – a touch screen can be a slower interface than a keyboard and mouse, a smartphone screen is far smaller than a PC's and so on. Nonetheless, mobile devices are heavily used in the home environment – as we have seen, 48% of iPlayer TV requests are from mobile devices - and convenience effectively trumps form factor. (US research into the reasons for using mobile devices for video found 'convenience' was almost twice as important as any other driver, with 49% reporting it as their main reason).[53]

The mobile internet has extended 'always on' out of home. Usage no longer needs to wait until the user is at home, and this both relocates usage and grows it (since the 'cost' of the inconvenience barrier is removed). Instant gratification is possible for discovering football scores, friends' Facebook updates and the latest weather forecast.

Thus out-of-home internet taps into a substantial pool of latent demand, in much the same way that broadband did by enabling 'always on'.

That said, out-of-home is a very different environment. While being at home might be regarded as a 'default state', people are usually out-of-home with a purpose in mind – meeting friends, going to work, shopping and so on. Crudely we can categorise time spent out-of-home into 'purposeful' (doing whatever prompted the trip out); 'travel' and 'idle' (spare time between other activities).

Purposeful time

For much purposeful time, the users' focus of attention may elsewhere than on their internet connection – doing their work, selecting groceries and so on. This is not to say that the internet has no role. Work might involve checking emails, shopping might require checking prices online and so on. However, such usage is likely primarily informational – more driven by web pages than streaming media for example. There are exceptions of course – a video call for work, or a YouTube video shared with friends in the pub.

Travel time

As discussed above, travel time is significant at 1.5 hours per day, but only 23% of commutes are as a passenger and so for most

[53] CRE, *Following the Mobile Path of TV Content*, 24 July 2013

commuters travel time represents a limited opportunity for immersive media consumption. That said, data intensity may be high for the 23% who are free to use the mobile internet.

Idle time

Idle time clearly can be used for the full range of a mobile device's capabilities, and the substantial time spent with games applications suggests that killing time is an important use case. Equally, video can readily be used in this situation (assuming sufficient bandwidth) We surmise however that out-of-home video consumption will skew towards short form content.

While out-of-home idle time may be material during the day, it is unlikely to be contiguous, simply because a person with (say) an hour to kill might well go home (or to their office). While long form content certainly can be consumed in multiple sessions, there is likely to be a skew towards content which can be fully consumed in the available time. (Of course, whether an idle half hour is spent consuming part of an episode of *Top Gear* or multiple YouTube videos makes little difference from a network perspective).

Given that the above human factors suggest that video is perhaps less likely in both purposeful and work time out-of-home, this suggests that out-of-home traffic intensity will remain well below that of out-of-home. That said, serving current levels of out-of-home traffic has required substantial investment, and (as noted above) this traffic has significant room for growth.

Distribution of usage

Use of mobile data remains relatively concentrated – for those on postpaid plans, just under 10% of users generate 50% of cellular traffic.[54] However, this is less concentrated than fixed broadband usage, where less than 5% of households generate 50% of traffic. Two likely explanations for this are that:

- While a mobile subscription is almost always associated with one person, a fixed subscription can be associated with one or many people, dependent on household size – this creates a wider spread of traffic volumes for fixed
- P2P, which is a key driver of traffic for many heavy fixed users, is far less common on mobile

[54] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013

Traffic mix

We now turn to traffic mix. We are not able to estimate traffic mix purely for out-of-home. We therefore consider the mix for both fixed and mobile, with an emphasis on the latter, which likely represents the majority of OOH usage.

Figure 16: UK Traffic mix, fixed vs mobile, 2013[55]

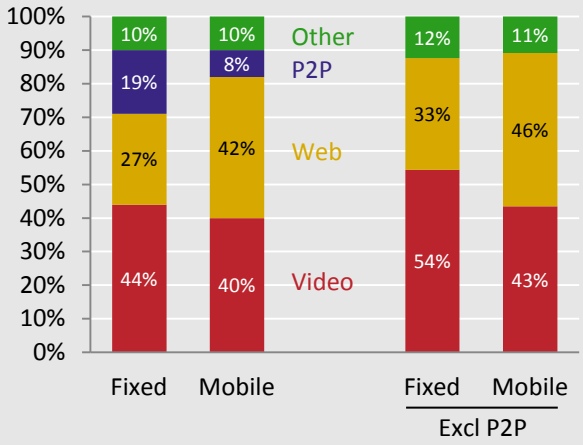


Figure 16 shows Ofcom data on the mix of traffic by application type, fixed versus mobile. In both cases video is approximately 40% of traffic. This might suggest that users are not discouraged from using video by the cost or bandwidth of cellular. However, the picture is somewhat distorted by P2P traffic, which is much lower on mobile devices. On smartphones in particular, torrenting is challenging – there is no app for iOS, and for all mobile devices storage may be a challenge for the large files typically involved.

If we set aside P2P traffic and look at the mix of other traffic types (the right hand two columns), it is clear that web usage is relatively more popular via cellular networks, and video less so.

Mobidia data (for 2012) on variations in smartphone usage depending on access type tells a similar story:

Figure 17: Top UK smartphone uses by traffic (MB) by net, 2012[56]

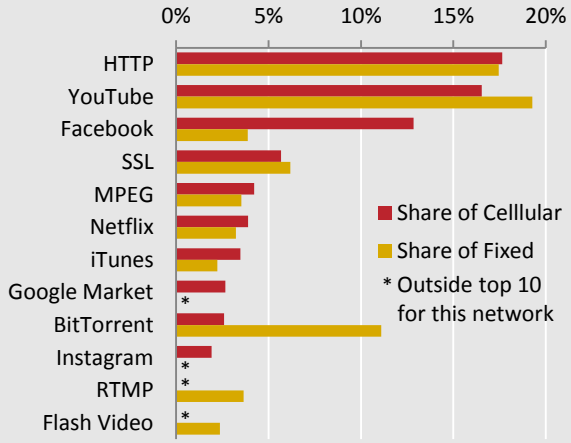
Rank	Cellular	Wifi	Roaming
1	Browsing	Browsing	Browsing
2	Facebook app	YouTube	Facebook app
3	Tethering	Video & audio streaming	Google Maps
4	YouTube	Downloads	E-mail
5	Downloads	iPlayer	Tethering

When a smartphone is connected to wifi, three of the top five applications in terms of traffic are forms of video (YouTube, other video and audio streaming and iPlayer). Conversely, when used on a cellular connection, only YouTube makes the top 5.

[55] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013
[56] Informa for Mobidia, *Understanding today's smartphone user: Demystifying data usage trends on cellular & Wi-Fi networks*, February 2012

Sandvine data offers another detailed perspective, albeit at a European level. HTTP (the web) and YouTube are the most important applications by peak downstream traffic for both mobile and fixed. However, Facebook is far more important on cellular, highlighting mobile's role in supporting engagement with social media throughout the day. (Facebook is the single most important application for *upstream* mobile traffic in Europe).

Figure 18: Share of fixed and mobile peak downstream traffic, top 10 applications (2014)[57]



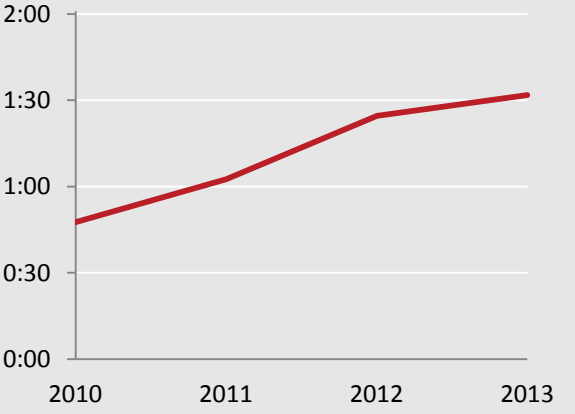
The Sandvine data also confirms the relative absence of BitTorrent on mobile networks.

The above discussion refers to the mix of traffic on cellular networks. As we have noted, perhaps 20% of this traffic will be in-home, and it may be that the mix of such traffic is different. For instance, cellular video usage may heavier in-home, where the user is static (and hence may have more reliable connectivity) and has the time to consume longer form video. However, we believe the overall traffic mix is broadly representative of out-of-home use.

Application mix

While traffic levels are important from the network perspective, different applications have very different bandwidths, and as a result equal traffic for two applications can represent very different minutes of usage. Time spent, and reach (the percentage of smartphone users using a particular application) are more descriptive of the consumer's experience of smartphone use. In this section we consider these issues.

Figure 19: Hours per user per day spent with smartphones[58]



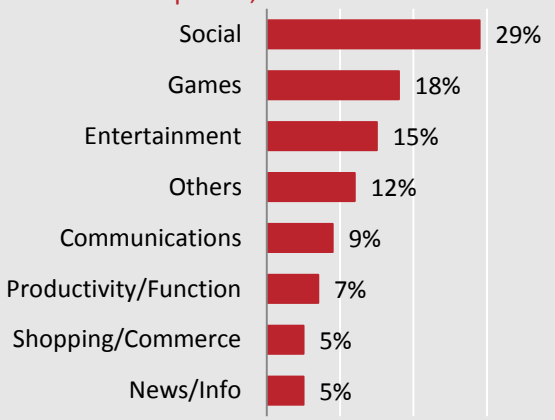
Across all applications, time spent with smartphones by owners is increasing, although the rate of increase may be slowing – in the year to 2013, the increase was 9%, to 1 hour 31 minutes (Figure 19). This time includes applications involving no data transfer at all, such as many games, the clock and so on.

[57] Sandvine, *Global Internet Phenomena Report: 1H 2014*, 13 May 2014. SSL is encrypted traffic; MPEG is video; RTMP is a protocol primarily used for streaming

[58] eMarketer, *Digital Set to Surpass TV in Time Spent with Media in the UK*, 18 March 2014, Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013, Communications Chambers analysis

Nielsen estimate that consumers reached for their smartphones nine times per day as of December 2013, up from 5.5 at the beginning of the year.[60] The IAB, based footage from cameras worn by smartphone users, estimated a higher figure, with 34 uses of a connected device per day.[61] (Note that even without consumer interaction, smartphones can generate traffic - applications may check for updates for instance - and these frequent, brief interactions can be a significant driver of signalling traffic).

Figure 20: UK share of time spent with smartphone, December 2013[59]



In terms of time spent, Nielsen report that social media is the most important application. (It ranks only third in terms of traffic – see Figure 20).

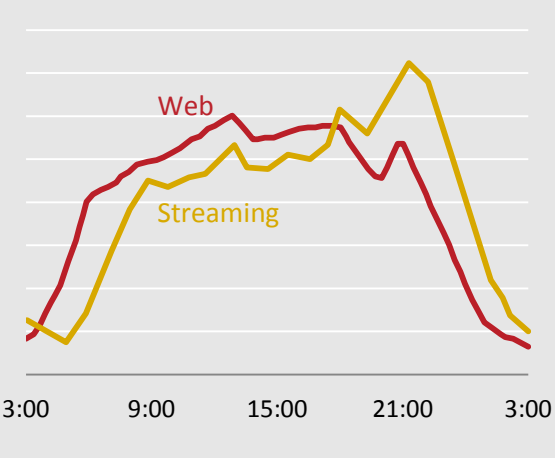
Games rank second in terms of time. From the user's perspective, the 'games console' aspect of smartphones is very important, but this requires little or no bandwidth.

Entertainment, ranked third in time, includes video, a leading driver of traffic.

The Nielsen figures are for all device usage, and as such include both in- and out-of-home usage, and cellular and wifi usage (and apps requiring no bandwidth at all).

However, the mix of place of usage will vary by application. For instance, mapping applications are more likely to be used out of home. Figure 21 shows distribution across the day of web and streaming (primarily video) traffic for EE's 4G customers. Despite the likely availability of wifi at home, it is nonetheless the evening hours that see the heaviest use of streaming, peaking at 9pm. (Note that given this traffic is averaged across multiple days, and the day-time usage likely includes much in-home usage also). By contrast, web usage is relatively steady

Figure 21: EE 4G traffic by time of day (index)[62]



[59] Nielsen, *How Smartphones are Changing Consumers' Daily Routines Around the Globe*, 24 February 2014
[60] ibid
[61] IAB, *One in six smartphone owners use them for purchasing*, 16 October 2013. 'Connected device' includes laptops and tablets
[62] EE, *4GEE Mobile Living Index, Second half 2013 report*, 9 December 2013

during the day, with a lunch time peak and declining use in the evening.

Given that (today at least) the 4G network can provide ample bandwidth, this usage pattern suggests that there are fundamental reasons why video is being consumed primarily in the home, and is consistent with the 'human factors' discussed above[63] which mean that video is less likely to be used to be used out-of-home - it is not simply that home is where the bandwidth is.

Device mix

This report focuses primarily on smarthphones, which are the most widely used devices out-of-home. However, while less widely used, both tablets and laptops are important, not least because per device traffic is higher for such devices than for smartphones. Cisco estimates that a tablet generates 2.6x the traffic of a smartphone, and a laptop (via a dongle) 4.6x.[64]

Dongles

As of Q4 2013, there were 4.9m mobile data dongles for laptops in use in the UK – a figure which has been slightly declining since the end of 2011.[65] There is likely some substitution by smartphones, either because laptop users no longer feel obliged to carry them to stay in touch, or because tethering a laptop to a mobile phone is directly substituting for dongles. Moreover, it appears that many of these dongles may be dormant. According to an Ofcom sample, the least-used 72% generate just 10% of total mobile broadband traffic, suggesting a long tail of little- or unused devices.[66]

Tablets

Adoption of tablets is rising rapidly. As of Q2 2014, it stood at 41% of households, up from 24% a year prior. [67] Individual adoption is lower – Ofcom found it to be 30% as of Q4 2013.[68] (Note that while the UK tablet market has recently contracted, [69] this is a drop in the rate of growth of adoption, not a decline).

Tablets have quite distinct usage patterns from smartphones. They are more likely to be used at home – 49% of UK tablet owners use

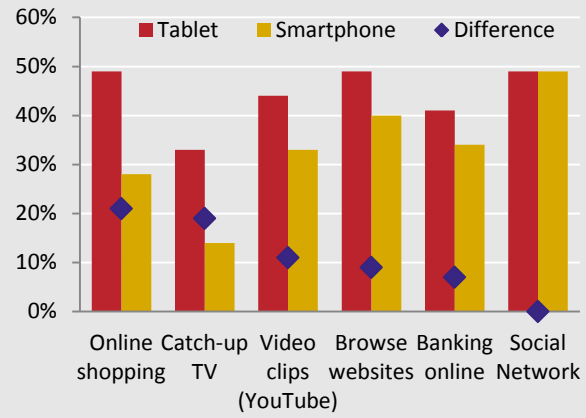
[63] See page 15
[64] Cisco, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018*, 5 February 2014
[65] Ofcom, *Telecommunications market data tables Q4 2013*, 24 April 2014
[66] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013
[67] Ipsos Media CT, *Tech Tracker Q2 2014*, 9 May 2014
[68] Ofcom, *Adults' Media Use and Attitudes Report 2014*, April 2014
[69] Telegraph, *Tablet market suffers dramatic slowdown as users keep older models*, 14 July 2014

them at home every day, while only 7% do so out of home.[70] For out-of-home use, Analysys Mason comment:

> "Tablets will become the most important element in public Wi-Fi traffic. They are nomadic rather than mobile devices, requiring multiple static locations more than full mobility".[71]

Amongst those who have access to a tablet, usage (regardless of location) is heavier across a wide range of applications (Figure 22), the main exception being social networking, which is as widely used on mobiles as on tablets. Video services, in particular catch-up TV, are appreciably more widely used by tablet owners. It is plausible that catch-up TV is primarily consumed at home, where tablet owners have a choice between the larger screen of the tablet or the smaller screen of the smartphone and (unsurprisingly) choose the former. Note that the difference between tablet and smartphone usage is less for YouTube. Such 'snackable' content is perhaps more heavily consumed out-of-home, where consumers may not have access to their tablet, boosting smartphones' relative performance.

Figure 22 Uses of tablets and smartphones[72]

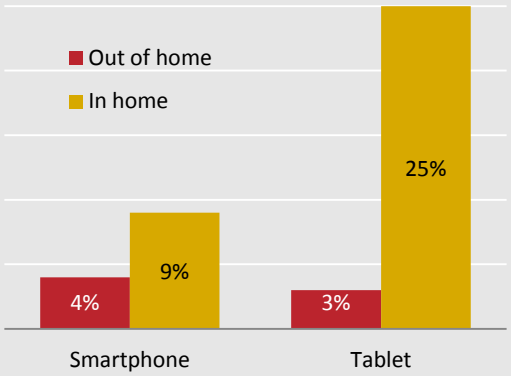


Consumers certainly report proportionately lesser usage of tablets for video out-of-home (Figure 23). Smartphone usage is roughly similar in- and out-of-home, at 3-4%. But while 25% of tablet owners report using for video at home, just 9% report video use out-of-home.

[70] Kantar Media, *Is the tablet a knock out?,* May 2013
[71] Analysys Mason, *Wireless network traffic worldwide: forecasts and analysis 2013–2018*, October 2013
[72] Ways device used in past 3 months; Ipsos Media CT, *Tech Tracker Q2 2014*, 9 May 2014

This difference in relative usage may be because tablets are simply not carried out of the home so much, or perhaps because many tablets lack cellular connectivity and therefore are less convenient to use OOH, even when they're present. According to Cisco, just 20% of UK tablets have cellular connectivity.[74] (Though such devices may be tethered to the user's smartphone for indirect cellular usage). Moreover, the trend is away from cellular connectivity. In the year to Q1 2014, UK sales of cellular enabled tablets fell by 34%, while wifi only tablet sales grew by 36%.[75]

Figure 23 Where device used for AV content in past week[73]

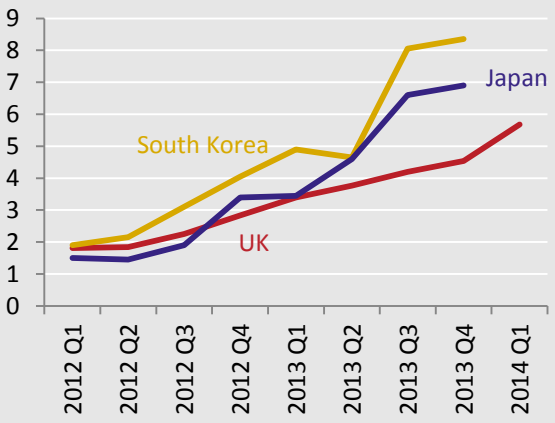


UK usage in an international context

Finally in our discussion of usage we consider how the UK compares to select overseas markets. In particular, we look at those who have deployed LTE earlier and have heavier usage (though note the two are not synonymous), since these may be leading indicators of future UK usage. We use as our comparators South Korea, Japan and the US. These countries had per capita LTE penetration of 57%, 31% and 31% at end-2013, compared to the UK's 3%.[76]

While speed data is not available for the US, Figure 24 shows how South Korea and Japan's cellular downlink rates compare to the UK's. Since mid-2012 they have been pulling ahead, and are now roughly 75-100% higher. However, note that measured by time, this is not a dramatic lead. The UK's Q1 2014 speeds are roughly equivalent to Korea and Japan's in mid-2013. Thus while these markets may be leading indicators for the impact of rising speeds in the UK, they are not necessarily long term guides.

Figure 24: Cellular downlink speeds (Mbps)[77]



[73] Ofcom, *Communications Market Report 2014*, 7 August 2014
[74] Cisco, *Global 2013 Wifi Survey*, February 2013
[75] Context, *3G tablet sales plummet as consumers choose Wi-Fi only models*, 22 May 2014
[76] Informa for Mobidia, *Smartphone use transforming with the rise of 4G and wifi*, 24 February 2014
[77] Ericsson, *Mobility Report Appendix : Europe*, June 2014; Ericsson, *Mobility Report Appendix : North East Asia*, June 2014

Volumes of cellular usage are higher in each of these countries, both amongst 4G users and 3G users. While there is some variance, across these four markets 4G users consume roughly twice as much data as 3G users. However, for both technologies usage is appreciably higher in the three comparators versus the UK. They have 2.7x the 3G usage of the UK, and 2.0x the 4G usage. This suggests that while the earlier roll-out of 4G has certainly contributed to growth in these markets, there is also an underlying factor of greater mobile data intensity in these markets. There are several possible explanations. For example, Japan has a very strong history of mobile data use, dating back to the launch of iMode in 1999. The US has a particularly mobile population and a history of uncapped data offers.

Figure 25 Android smartphone usage (GB) Dec 2013[78]

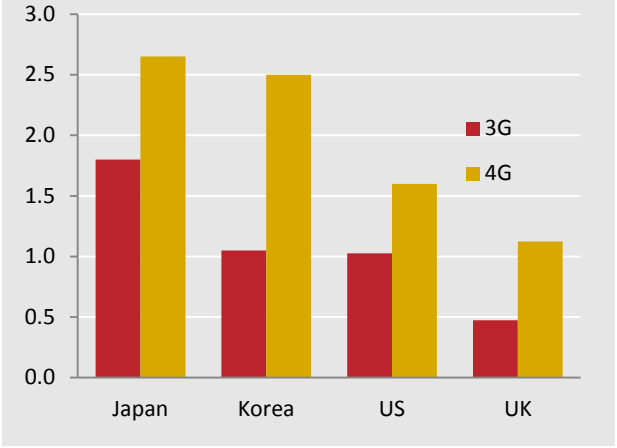
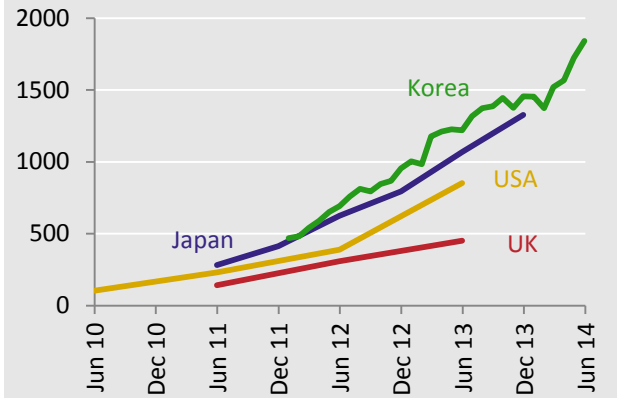


Figure 26: Mobile network traffic (MB/capita/m)[79]



However, while UK usage lags these other markets, in time terms, the lag is again not that great. As Figure 26 shows, the UK's mobile traffic per capita is approximately 12 to 18 months behind that of Korea, the US and Japan. That said, these countries have had rapid growth in recent months (perhaps due to 4G), which the UK may mirror based on its own, later 4G roll-out. Certainly the growth of Korea's traffic is primarily due to the shift to 4G. Overall per subscriber traffic is up 47% over the 12 months to June 2014, but per 4G subscriber traffic is only up 29%, and per 3G subscriber traffic is up 2%.[80] The overall growth is driven by the shift to 4G, which has twice the per-subscriber usage of 3G.

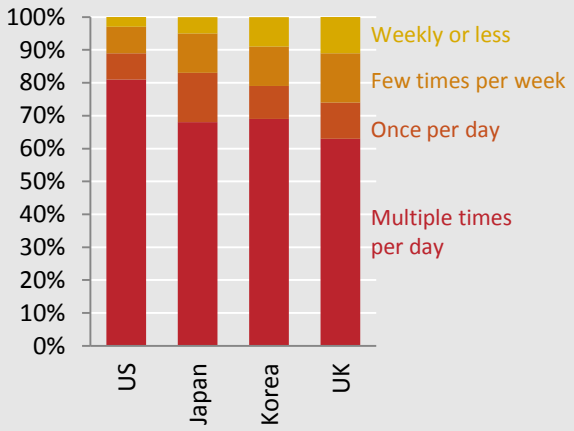
[78] Informa for Mobidia, *Smartphone use transforming with the rise of 4G and wifi*, 24 February 2014

[79] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013; CTIA, *Wireless Industry Survey*, 2014; MIC, *我が国のインターネットにおけるトラヒック総量の把握*, 6 March 2014; MSIP, *무선데이터 트래픽 통계*, 30 July 2014; Communications Chambers analysis. Korean figures exclude operator provided wifi and WiBro

[80] Communications Chambers analysis of MSIP, ibid

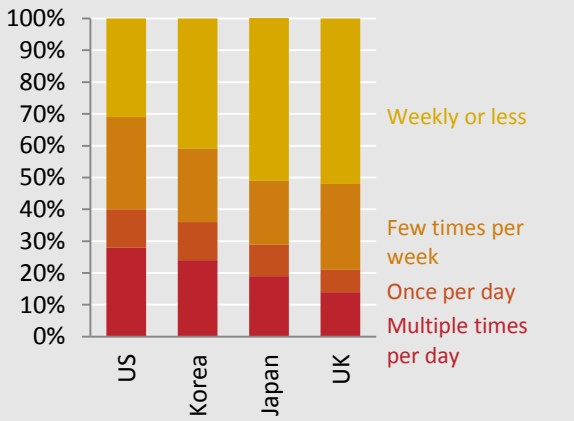
Technology aside, one factor driving heavier traffic in these other markers is simply more frequent use. Over 80% of American smartphone users report using the browser on their phone multiple times per day, compared to 63% in the UK (Figure 27). That said, clearly frequency of web usage is high in all markets.

Figure 27: Frequency of smartphone web use[81]



Looking at video usage, the contrast between different countries is starker. Americans are twice as likely as those in the UK to consume video via smartphones. However, note that for all countries, video usage is much less common than web usage – the number reporting multiple uses per day for video is roughly one third of those reporting similar rates of use for the web.

Figure 28: Frequency of smartphone video use[82]



Certainly usage of all types is still not mature, even in these advanced markets, but at least as of yet, the availability of higher bandwidths and traffic caps has not brought video usage up to the level of web usage.

Summary

People spend roughly the same number of waking hours in- and out-of-home. However, OOH data intensity (in MB per waking hour) is a little over one-tenth that in-home. This is in part due to network and device limits (discussed in the next section), but also due to fundamental human factors. People have more free time available for internet use in-home, and in particular have a greater propensity there to use bandwidth intense applications such as video.

[81] Google, *Our mobile planet*, 2013
[82] Google, *Our mobile planet*, 2013

Wifi represents roughly one-third of OOH traffic, though this is a much lower figure than total wifi offload (approximately 75%), since so much wifi usage for mobile devices takes place in the home.

Measured by traffic, mobile network usage (representative of OOH) is broadly similar to fixed usage, but with lower video and P2P traffic and greater web traffic. However, some important uses for mobile devices, such as gaming (the second heaviest in terms of time) use very little traffic.

UK patterns of consumption appear to lag leading markets such as Japan, the US and South Korea by 12-18 months. These markets would suggest that the UK is likely to see an appreciable uplift in traffic due to the transition to 4G. This will result from more frequent use of high and low bandwidth apps, such as video and web respectively.

3. Limitations of the out-of-home internet and responses

From users' perspective, there are four primary limitations to the internet access they receive via mobile devices and via cellular in particular. Firstly, mobile devices have some inherent physical limits. Secondly, (for most consumers) cellular usage is limited, with an allowance of a certain number of MB per month. Thirdly, speeds available are variable, and often lower than those available on fixed connections (though the roll-out of 4G is of course improving wireless speeds). Fourthly, wifi can be challenging to access.

In this section we set out these issues in more detail, and discuss how users and application providers have adapted their behaviour or used work-arounds to deal with these limits.

Device limits

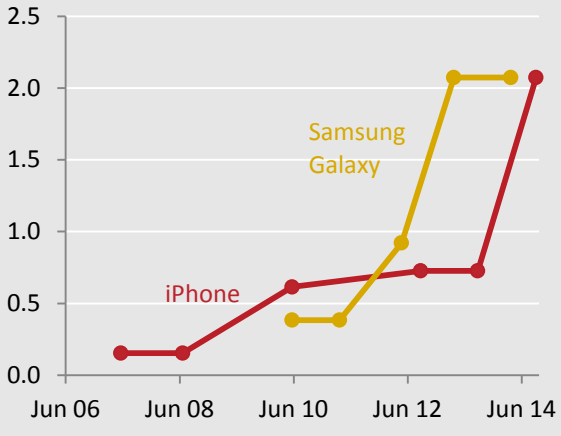
Mobile devices have inherent limits that derive from their portability, in particular size and battery life.

Screen size

Devices which are small enough to fit into a pocket and which have a touch screen which can be conveniently be used one-handed have a natural physical limit to their screen size. While phone screens have grown appreciably (from an average of 2.6" in 2007 to 4.9" in 2014),[83] this trend seems to be slowing. Of Europeans who previously had a 5" or greater screen, 42% chose a smaller device for their next phone.[84]

Note that smaller screens need not imply low resolution. The latest models of the Samsung Galaxy have resolutions of 1080x1920, roughly comparable to a typical 24" desktop monitor. However, this resolution is essentially undistinguishable at comfortable viewing distances for a mobile device, and it *may* be that device manufacturers shift their attention elsewhere (now that Apple has caught up with Samsung - Figure 29).

Figure 29: Screen resolution of iPhone and Samsung Galaxy phones (megapixels)[85]



Thus the limits of screen size and viewing distances mean that screen 'real estate' is

[83] PhoneArena.com, *Did you know that smartphone screens nearly doubled in size since 2007?*, 31 January 2014
[84] Kantar, *Mobile Trends that Matter Tomorrow*, 26 February 2014
[85] Communications Chambers analysis

limited, which narrows the range of applications that are fully practical or enjoyable on mobile devices.

There are however exceptions to this screen size constraint. While a minority, some users will carry a larger screened device out-of-home, such as a tablet or laptop. This may have its own cellular connectivity, may be used at hotspots, or may be used via tethering to a smartphone.

Battery life

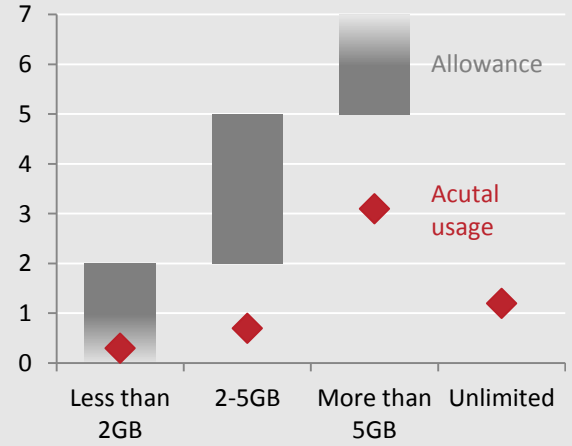
While battery capacities have increased steadily, battery life has not. Indeed, smartphones typically have shorter battery lives than feature phones of a decade ago. This is because evermore powerful processers, large colour screens, the increasing array of wireless interfaces (cellular, wifi, Bluetooth) and on-board sensors (such as GPS) all require ever more power. Data intense applications, such as streaming video over a cellular network, are particularly demanding, making heavy use of the radio interface, the screen and the processor simultaneously.

Users may respond to such constraints by limiting use of certain apps, turning off radio interfaces (Bluetooth or wifi, for example) and so on. In time this constraint may be eased by standardisation of chargers, recharging mats in coffee-shops and the like, which will provide more opportunities to top up batteries while out-of-home.

Cellular data allowances

A critical network constraint is the data allowance. Only 22% of UK consumers report that they are on fully unlimited mobile data plans.[87] The great majority face overage charges beyond a certain level. However Figure 30 shows that most consumers are dramatically under-using their allowance. This may be because consumers value the peace of mind that ample headroom brings, and thus are choosing larger allowances than they strictly need.

Figure 30: Mobile data use by Allowance[86]



UK consumers have lower data allowances than some other markets. For instance, we estimate (based on Mobidia data) that the average UK smartphone user has a data

[86] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013
[87] Google, *Our mobile planet*, 2013

allowance less than half that of average users in the US, South Korea or Japan.[88] That said, UK allowances are broadly comparable to Germany, the other European market tracked by Mobidia.

The reason for this does not appear to be related to pricing however. Ofcom research found that UK prices were well below US prices for both smartphone and mobile broadband (and also below other European tariffs in almost all categories).[89]

This doesn't mean, of course, that price is not a concern for UK mobile users (and a factor in their usage choices). Rather, it means that price is not a likely reason for UK usage in certain categories being lower than that overseas. Other more fundamental factors are likely at play, such as market maturity, network coverage or population mobility.

A typical data allowance in the UK today is 1 GB, with 86% of 3G and 66% of 4G on such plans or smaller as of December 2013 (though there is an ongoing migration to larger allowances).[91] Such an allowance is ample when used for low bandwidth activities such as browsing and email, but can easily be a binding constraint for heavier applications such as audio and video streaming (Figure 31). For example, if a 1 GB allowance was used entirely for iPlayer, it might enable 6 minutes per day of video consumption. Even this understates the effect of allowances, since (as we have seen) consumers significantly undershoot their allowance.

Figure 31: Use volumes possible with 1 GB per month[90]

Application	Data requirement	Usage (per day)
Email	35 KB	952 units
Web pages	180 KB	185 units
Radio	128 Kbps	35 minutes
iPlayer	800 Kbps	6 minutes

If we assume that customers will on average use 50% of their data allowance, and that 1GB of data costs £10,[93] then we can estimate the unit costs of the various applications (Figure 32). At 12p per minute, consumers' caution about using video on limited cellular tariffs is understandable. Of course, those on above average data allowance will generally face lower unit costs than this.

Figure 32: Implied unit cost of applications, 1GB cellular pack[92]

Application	Cost (p)
One email	0.07
One web page	0.36
One minute of radio	1.92
One minute of iPlayer	12.00

[88] Informa for Mobidia, *Smartphone use transforming with the rise of 4G and wifi*, 24 February 2014
[89] Ofcom, *International Communications Market Report 2013*, 12 December 2013
[90] Communications Chambers analysis. Data requirements are indicative only, and in practice will vary considerably
[91] Informa for Mobidia, *Smartphone use transforming with the rise of 4G and wifi*, 24 February 2014. Note that Mobidia's sample is Android users only
[92] Communications Chambers analysis
[93] Vodafone tariff for 1GB SIM-only 12 month plan. [Accessed 4 July 2014]

Thus unlimited packages (or allowances large enough to feel unlimited from the consumer's perspective) can have the effect of enabling previously latent usage, parallel to the increase in fixed broadband usage as those tariffs migrated away from data allowances.

Bandwidth limits

A user's experience of mobile bandwidth is appreciably more variable than fixed bandwidth. It can vary based on the users' proximity to a base station, the number of other active users in a cell, whether the user is indoors, whether 4G is available in that location (and to that user) and so on. This means that while email, a low bandwidth application, may be viable almost everywhere there is 3G coverage or better, more demanding applications such as streaming video may have appreciably narrower effective coverage, particularly at peak times.

Thus there may be times and places where users are simply unable to access the application they'd like to, or where the experience is so slow (for instance, for web browsing) that it becomes effectively unworkable.

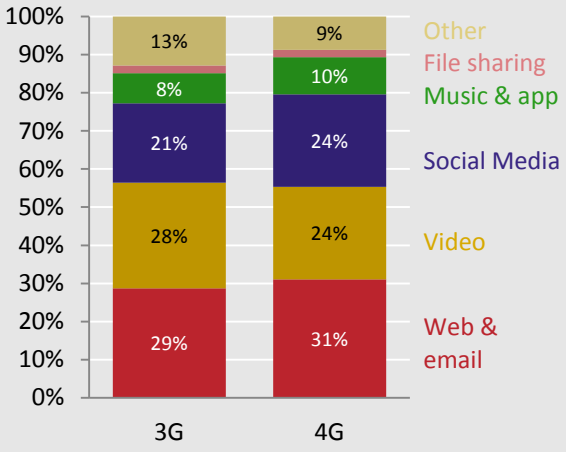
This effect is undoubtedly real, but its impact on overall traffic may not be massive. Mobile devices have a single user; they are not easy to use to multitask (compared to, say, having a YouTube window and a browser open on a PC); and they have small screens which generally require lower resolution video and other content. As a consequence, per active user bandwidth requirements can be moderate compared to fixed use environments.

Practical evidence of this comes from the traffic mix of 3G and 4G users. 3G offers lower bandwidths to users, and if this was a substantial constraint we might expect the traffic mix to be very different for 4G users, with high bandwidth applications being more prevalent – for instance, we might expect much more video. Certainly 4G users report greater consumption of video, with 29% reporting at least twice-weekly usage compared to 19% for non-4G users (according to an Ofcom survey).[94]

[94] Ofcom, *Communications Market Report 2014*, 7 August 2014

However, using EE as an example, the measured traffic mix for their 3G and 4G customers is in fact remarkably similar (Figure 33).[96] When EE users were asked what they were doing more of since switching to 4G, the most popular answer by a clear margin was web browsing.[97]

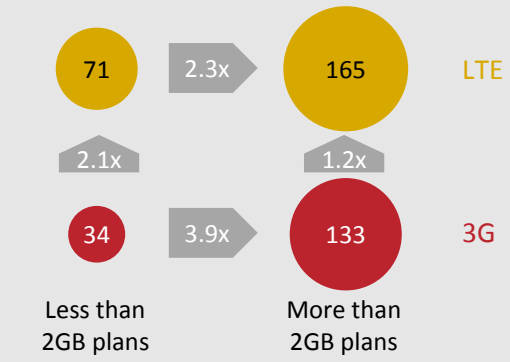
Figure 33: EE Traffic mix, 3G vs 4G, Jun 2014[95]



While the traffic mix is the same, 4G users do generally have higher usage than 3G users. Vodafone, for instance, reports that after an upgrade to a 4G handset, data usage is 2.3x what it was prior to the upgrade.[98] However, it is at least possible that the impact is in part from the shift to larger data plans typical of 4G, rather than simply from the increase in speed.

Evidence for the importance of larger data plans (in addition to higher speeds) comes from the US. Figure 34 shows YouTube usage for US customers (in MB of cellular traffic), split by whether or not they were on an LTE (4G) plan, and by the data allowance of that plan. YouTube is of course a relatively demanding application in terms of bandwidth.

Figure 34: US Android cellular usage (MB) for YouTube, by plan and network, 2012[99]



While those on LTE did have heavier usage than those on 3G, this difference was significantly smaller than the delta between those with data allowances above and below 2GB. Indeed, those on the slower network but with the higher data allowance had almost twice the usage of those on the faster network but the lower allowance.

[95] EE, *4GEE Mobile Living Index, First half report 2014*, 7 August 2014. Note that this mix of traffic shows appreciably less video than in the national figures offered in Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013. This may in part be because EE includes some embedded media within social networking, such as Facebook video

[96] Note that one other mobile operator has told the author that they see a greater share of video traffic on 4G than on 3G

[97] EE, *4GEE Mobile Living Index, Second half 2013 report*, 9 December 2013. There is an apparent conflict between users reporting relatively more time spent surfing, but no relative increase in surfing traffic. This may perhaps be explained by higher bandwidths enabling higher quality video streams, increasing relative video traffic even though relative video time has not increased

[98] Vodafone, *Vodafone Group Plc Preliminary results - For the year ended 31 March 2014*, 20 May 2014

[99] Mobidia, *Understanding today's smartphone user: Demystifying data usage trends on cellular & Wi-Fi networks*, February 2012

Note that in suggesting that increased per-user speeds may only have moderate impact on user behaviour, we are certainly *not* suggesting that the increased bandwidth of 4G cells is not valuable – this bandwidth is shared across all active users in a cell, and as use of mobile data becomes more frequent and widespread, increased cell bandwidth (or greater cell density) will be required simply to maintain today's per-user bandwidths.

Further, higher speeds on 4G can lead to greater traffic even with no change in user behaviour at all. For instance, Adaptive Bit Rate streaming adjusts video quality according to the available bandwidth. Thus a 4G and a 3G user may be watching exactly the same video, but the 4G user would be using more traffic as a result of receiving a higher resolution stream.

Wifi access challenges

Users spend much of their time within range of a wifi signal. In many environments, users may be able to see multiple signals. To take an extreme case, many locations in the Covent Garden area have 30 or more wifi access points visible.[100]

However, 'visible' is not the same as 'accessible'. Amongst public wifi users, 42% in a Cisco survey said that availability and coverage is one of the biggest challenges (the most popular response).[101]

Some hotspots may only be available if the consumer has a relevant subscription. Most BT hotspots are only available to those with BT broadband or a specific BT Wifi subscription, for example. Enterprise networks may have no reason to offer wifi access to passers-by – on the contrary, they likely have strong security reasons not to.

Both hotspots and, potentially, home wifi routers (via services such as BT Openzone[102]) will be theoretically open to visitors. However, in practice authentication – logging in – can be a material barrier to usage. This takes several forms:

- Absent auto-login, the user must know wifi is available and actively seek to connect
- For some services, the user may need a password or ID he doesn't recall

[100] Aegis & Quotient Associates [for Ofcom], *Study on the use of Wi-Fi for Metropolitan Area applications*, 22 April 2013
[101] Cisco, *Global 2013 Wifi Survey*, February 2013
[102] Openzone partitions part of a BT customer's home broadband and wifi for use by other BT customers, though the home customer's traffic takes priority

- There may be a charge for usage, which the user is unwilling to pay
- For some services, interaction with a splash screen in a browser is required, but this may not be evident to the user
- Even if the user knows exactly how to login, he may decide it isn't worth the bother.

Such barriers to login are one reason why 38% of mobile device users say they never use hotspots, and a further 27% say they do so once a month or less.[103] (Other reasons for non-use include that some users may simply not spend time at hotspots, or may be satisfied with cellular connectivity)

A number of moves are in hand to address the login challenge. For example, SIM-based authentication, enabled by the new Hotspot 2.0 initiative, will enable a smartphone's SIM to act as logon credentials for relevant wifi hotspots, entirely automating the procedure. Certain public wifi operators are also offering apps that facilitate logon to their network, such as The Cloud's FastConnect.

Such approaches have the potential to shift all mobile data use for relevant users onto wifi, without intervention by the user. Moreover, if the user then notices they have access to a wifi signal, they may change their usage to be more bandwidth intense. Thus there is a potential impact on both mix and volume of traffic. As a secondary effect, if users have 'saved' some of their cellular data allowance via wifi, they may 'spend' some of it elsewhere, leaving overall cellular usage unchanged.

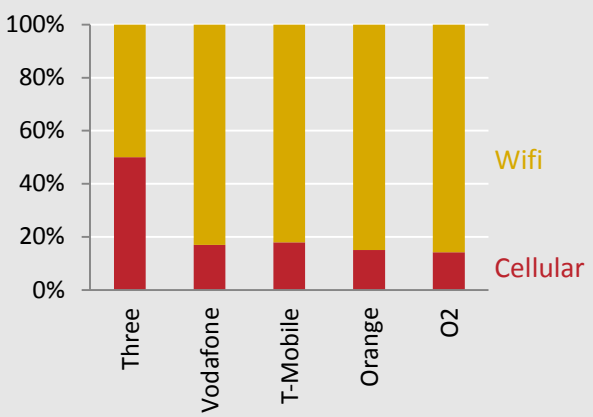
Two other perception issues constrain traffic on wifi networks. Cisco's survey found that 9% of respondents did not use public wifi because they were concerned about security.[104] Conversely, a Purple Wifi survey found that 54% believe they were automatically logged in to wifi in a venue that offered it[105] – since this is unlikely to be true in many cases, it suggests that more users believe they are using wifi than actually are.

[103] Cisco, *Global 2013 Wifi Survey*, February 2013
[104] Ibid
[105] Purple Wifi, *Our latest survey: how do people use WiFi in public places?*, 13 June 2014

Consumer Responses

It is intuitive that consumers react to higher prices for traffic on cellular by shifting their use to wifi if possible. Evidence that price plays a part in driving usage of wifi comes from differential levels of offload between different operators. According to Mobidia, customers of Three - which has traditionally been more aggressive with unlimited data bundles - had a much lower percentage of wifi traffic than other MNOs (as of 2012). This needn't mean such customers are making less use of wifi in absolute terms – it may simply be they are increasing levels of usage when reliant on cellular.

Figure 35: Smartphone traffic mix by MNO (UK, 2012)[106]



Consumers also perceive that wifi offers higher speeds, which it often does (though certainly not always).

Shifting usage to wifi can take several forms. It can be as simple as waiting to consume (say) a video until a wifi signal is available. It can be sideloading of content, putting a media file onto a smartphone at home in the evening for consumption the next day while out-of-home. An equivalent use case is the 'make available offline' option in some music streaming services. By setting this switch for a playlist on Spotify, for example, a user can download the relevant tracks once and store them on the device for multiple playbacks later. (This approach can of course also be used to download tracks when in good cellular coverage for later consumption in patchier coverage).

Apps represent another way of time-shifting consumption. For instance, the Copilot map app comes with map data pre-loaded, obviating the need for data download on the move (as required by the Apple and Google map apps).

Application Provider Responses

Application providers have an interest in making their services work both within data caps and potentially limited bandwidth. This is particularly true for global players, who are designing their apps not just for the relatively high bandwidth and caps of the developed

[106] Mobidia, *Understanding today's smartphone user: Demystifying data usage trends on cellular & Wi-Fi networks*, February 2012

world, but also for the much more constrained environment of the developed world.

For just this reason, Facebook (for example) is using a variety of techniques to reduce the average daily data usage of its mobile app from 12 MB per day currently to 1 MB per day.[107] Tools include:[108]

- Deployment of WebP, a more efficient form of image compression than JPEG or PNG, developed by Google
- Substantial compression of pictures taken on the device before upload
- Customising image sizes for the mobile screen in question
- Prefetching content when wifi is available
- Reordering stories in low data situations
- More sophisticated caching of images on the phone

Applications are themselves a method to make a provider's service work more widely and use less data. For instance, mobile banking via a browser requires images (such as the bank's logo) to be downloaded each time the site is used.[109] Via an app, the images are downloaded once and stored locally – all that is transmitted when the app is used is the very small amounts of data required for latest transactions, balances and so on. One result of this is that much high-value use of the mobile internet is nearly invisible in the traffic statistics, precisely because such apps use so little data.

Streaming providers also generally stream lower resolution / lower bandwidth video when their content is accessed via mobile networks.

Summary

In addition to the human factors driving different in- and out-of-home usage, there are several practical factors that constrain OOH use. Some, such as battery life and screen size, are inherent to mobile devices

Others are related more to networks. While cellular data charges continue to fall, a perceived marginal cost of traffic will remain a constraint on usage for many consumers. In some cases, bandwidth may be unavailable for the application in question, though 4G roll-out and adoption is reducing this challenge. Wifi networks' biggest constraint on usage today (where they are available) is ease-of-

[107] Facebook, *Is connectivity a human right?*, 21 August 2013
[108] Facebook, Ericsson & Qualcomm, *A Focus on Efficiency*, 16 September 2013
[109] An exception is if the relevant image is already stored in the local cache of the mobile browser. However, smartphone caches are generally relatively small

access. Automatic login is not widespread, and manual login can be complex for many users. Developments such as SIM-authentication have the potential to dramatically ease this constraint.

Users have responded to these constraints in a variety of ways. For example, they may use side-loading, to shift their usage to a time when they have certain and low-cost connectivity, rather than rely on streaming when OOH. Application providers too have sought work-arounds for the limitations of OOH networks, using apps and other techniques to minimise the data requirements of their services.

4. Usage tomorrow

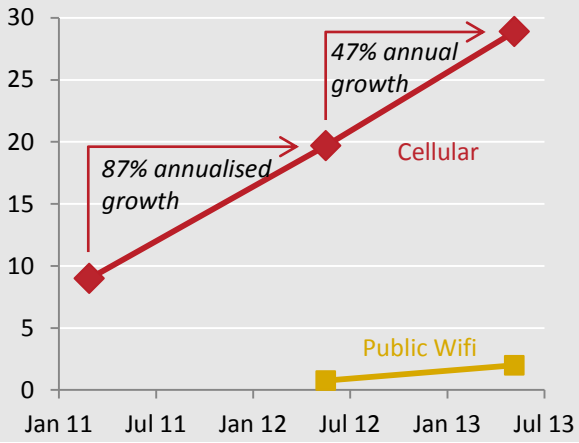
In this section we consider recent growth trends for out-of-home use, and consider what are likely to be the primary drivers of future growth, and finally briefly look at how that demand will be met.

Recent growth

Total traffic

Cellular growth is robust, but from 2011 to 2013 was linear rather than exponential (Figure 36). 4G adoption and roll-out is likely to provide a boost to growth from 2014.

Figure 36: Data use on mobile and public wifi networks (PB/month)[110]



Public wifi, albeit from a much lower base, is experiencing greater growth. Note that this traffic volume covers smartphone, tablet and laptop use (via a dongle), and includes some in-home use.

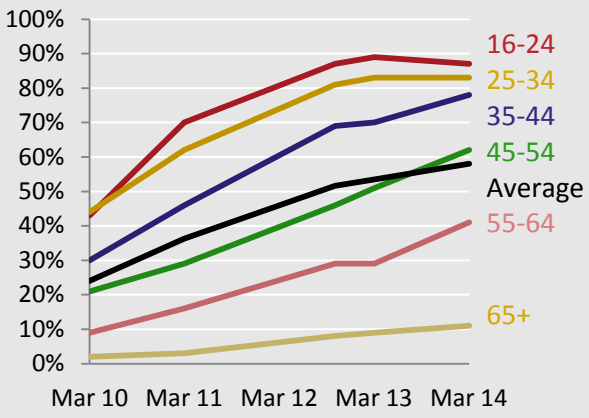
Cellular traffic growth stems from more users; more time per user; and more data per time spent online. The growth in reported public wifi is primarily due to a 114% increase in hot spots (in part due to the inclusion in 2013 of Arqiva's hotspots for the first time). Per-HS growth has been 26%. (Underlying growth per-HS on a like-for-like basis was likely higher – the average figure may have been diluted by the addition of new, more marginal sites.)

[110] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013

Users

Adoption of the internet on mobile phones has been rapid, and according to ONS as of Q1 2014 stood at 58% of adults (Figure 37).[112] Out-of-home use also takes place on tablets and via dongles. However, we believe that the number of people using such devices out-of-home but not also using a smartphone is likely relatively small. In other words, 58% is probably close to overall penetration of out-of-home mobile internet use (excluding workplace usage).

Figure 37: Users of internet on a mobile, by age[111]



[111] Any usage in last three months. ONS, *Internet Access - Households and Individuals, 2014*, 7 August 2013; Communications Chambers analysis

[112] Ofcom figures for mobile internet use, based on a differently worded question, give lower levels of usage, but higher recent growth - see page 366 of Ofcom, *Communications Market Report 2014*, 7 August 2014

This adoption is very unevenly spread. Amongst those aged 44 and younger, adoption is over 80% and is be approaching saturation. For those aged 55 and older adoption is just 23%, with growth primarily driven by those aged 55-64.

Smartphone adoption is likely some distance from saturation. Of adults, 93% have a mobile phone,[113] and natural replacement cycles will likely result in remaining feature phones being replaced with smartphones – as the costs of basic smartphones continue to fall, they will be the natural choice for most (though some may prefer the simplicity of feature phones).

However, smartphone and mobile internet use are not the same thing. Already, a proportion of smartphone owners say that they do not use them to connect to the internet - Deloitte report 23%, Ipsos Media 11%.[114]

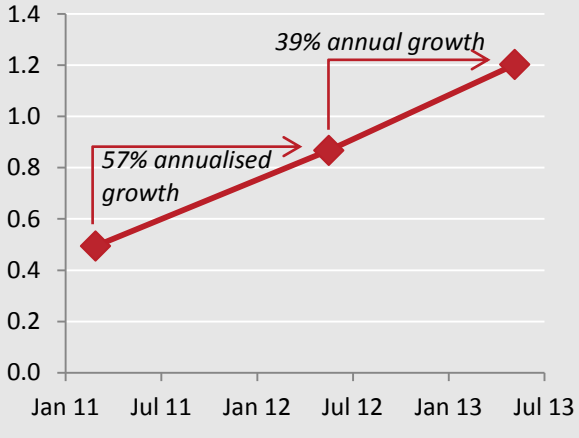
Home broadband penetration (fixed and mobile) stands at 77%.[115] As mobile internet adoption approaches this figure, it will increasingly have to draw on users who have not previously used the internet. While there are reasons to believe mobile may be effective as a tool for bringing people across the digital divide,[116] this is likely to be a slower process than persuading those who already use the internet to extend its use out-of-home. Moreover, new mobile internet users who have not previously been online may be more likely to be light users.

Traffic per user

Out-of-home traffic per smartphone user (across devices and networks) grew by 39% in the year to June 2013. This was substantially greater than the 9% increase in time spent with smartphones, pointing to increasingly data-intense use of phones.

This 39% growth is more than the 30% growth in traffic per fixed broadband line in the same period, but not dramatically so.[118] If these growth rates are converging, this may suggest that out-of-home growth is increasingly driven by general internet

Figure 38: Out-of-home usage (excl workplace wifi) per smartphone user (GB/month)[117]



[113] Ofcom, *Communications Market Report 2014*, 7 August 2014
[114] Deloitte, *The State of the Global Mobile Consumer*, January 2014; Ipsos Media CT, *Tech Tracker Q2 2014*, 9 May 2014
[115] Ofcom, *Communications Market Report 2014*, 7 August 2014
[116] Robert Kenny & Claire Milne [for Vodafone], *Mobile : A powerful tool for Digital Inclusion*, 12 May 2014
[117] Communications Chambers analysis
[118] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013

trends, rather than by 'catching up' to the in-home experience. However, as noted above, 4G is likely to provide a boost to cellular growth, though it is uncertain how much of this additional growth is at the expense of wifi and how much is completely new OOH traffic.

Future growth

A number of factors will drive continuing growth in out-of-home usage of the internet. We discuss these in turn.

Figure 39: Drivers of future out-of-home use

Major	Minor
• Lessening 'bill fear' • Maturing ecosystem • Better application coverage	• Increased adoption • M2M • Higher resolution devices

Lessening 'bill fear'

Consumers' wariness of the cost of out-of-home will be eased for two reasons. Firstly, the actual and perceived price of cellular data will continue to fall, and this will drive traffic. (Plum go as far as to suggest that a broadly fixed consumer willingness-to-pay for data should be divided by declining unit costs to forecast cellular traffic, rather than starting from a traffic estimate).[119] Cellular price reductions will in part be driven by continuing investment in future generations of technology such as LTE Advanced and 5G, which will enable more capacity to be delivered from the same spectrum.

The second reason for declinging bill-fear is that, as discussed above, wifi will be ever more widely available and (more importantly) *readily* available via SIM-authentication and apps. When consumers are within range of a relevant hotspot, this will reduce their marginal cost of traffic to zero.

If consumers' bill fear lessens, their behaviour will change in two ways. They may start to consume different content, for instance using more video while out-of-home. But they may also consume the same content differently. For instance, rather than using Spotify's 'make available offline' feature, they may instead choose to simply stream all music, saving storage space on their phones for other uses. Put another way, some of the work-arounds prompted by historically expensive mobile data may become less necessary.

[119] This is a highly simplified description of Plum's more subtle approach – see Plum, *Do you need a mobile data forecast to estimate spectrum demand?*, June 2014

Maturing ecosystem

The entire smartphone ecosystem is only 7 years old – the iPhone first went on sale in June 2007. Usage is still developing rapidly, and both application developers and consumers are finding new ways to make use of smartphone capabilities. Major applications that today drive significant traffic are even younger. Instagram for example was launched in October 2010.

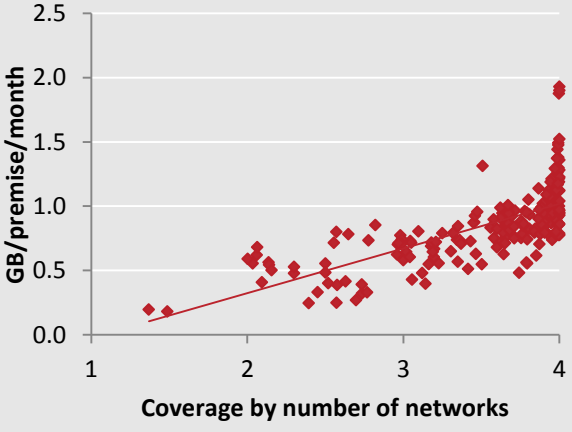
Innovation will continue, both based on the current capabilities of smartphones and on the enhancements that continue to be incorporated. Sensors are one example, with ever more in successive generations of phones. Gyroscopes, accelerometers, light sensors and proximity sensors are all now standard, with some newer phones incorporating pressure, temperature and humidity measurements, for example. These developments will spur new categories of applications.

Better application coverage

The roll-out of 4G, the adoption of 4G (which Analysys Mason predict will reach 47% of UK devices by 2017)[120] and wider availability of wifi will enable consumers to use more applications in more places. In-building coverage (perhaps addressed primarily by wifi) and use while moving (necessarily cellular) are two scenarios where connection quality may be insufficient for some purposes today. Video is the prime example of a demanding application, but video calls, VoIP and music streaming could all see their growth rates enhanced by improved application coverage.[121]

Data on 3G usage by local authority does suggest that coverage is linked to usage – authorities with more operators providing coverage to a higher percentage of premises have higher traffic per premise (Figure 40). Of course, this is in part likely to be because fewer operators choose to serve lower traffic areas – that is, low traffic causes low coverage, not vice versa.

Figure 40: 3G Network coverage and Mobile data traffic per premise, all local authority areas[122]



However, as an extreme case, if we assume all the lower usage of lower coverage areas were due to that lower coverage, we can estimate the potential uplift in traffic if all local authority areas

[120] Analysys Mason, *The Role of 4G in Mobile Data Monetisation*, 8 May 2013
[121] For a more detailed discussion of app coverage, see Ericsson, *App Coverage*, September 2013
[122] Communications Chambers analysis of Ofcom data. Coverage is based on combined coverage of the four networks. For instance, if two MNOs serve a local authority area, both with 75% coverage, then total coverage is 1.5

were to have 100% coverage from all four areas. We estimate this would lead to a 10.6% uplift in usage. (Note that this is the maximum uplift associated with expanding 3G coverage – the benefit of overlaying 4G network coverage is a separate issue).

Increased adoption

Take-up of the mobile internet continues to increase. However, as discussed above, this is unlikely to be a major driver of total consumption. The rate of take-up appears to be slowing, and those who are not yet users are unlikely to be heavy consumers once they do move online.

M2M[123]

Machine to machine communication has enormous societal and economic potential. For instance, in the event of a car accident eCall-enabled cars can use the cellular network to automatically notify emergency services of location, direction of travel and vehicle ID; smart meters can improve energy efficiency; agricultural monitors can ensure that fields are watered at the optimal time; and so on.

However, we believe the impact on cellular networks of such telemetry services will not be dramatic. Firstly, necessary data rates are frequently low (though signalling overhead can be high for such applications). Secondly, the devices in question may not make use of the cellular network. For instance, smart meters will make use of specific spectrum at 870-876 MHz for in home connectivity and (amongst other solutions) may use 400 MHz spectrum for wide area connectivity, rather than relying on the mobile network. Other connected devices may make use of a range of protocols and spectrum allocations, including Zigbee, Bluetooth, wifi and so on.

Higher resolution devices

As older, lower resolution devices are gradually replaced with more recent models with higher resolutions, data consumption will increase, both because they will require higher-resolution video streams and because some use cases (such as web-surfing) will become more comfortable.

However, as many devices in the market already appear to be at the limit of constraints such as the human eye and the pocket, this will not be an important driver in the long term.

[123] Note that much M2M use, such as smart-metering, is in fact in-home

The challenges of meeting this growth

Both cellular and wifi will contribute to meeting this growth, but each faces different challenges in so doing.

Cellular

For cellular networks, the key challenge is one of cost. Broadly speaking, MNOs can expand their capacity in three ways: through increased spectrum allocation; through network densification (more, smaller cells) and through improved technology (for instance, 4G LTE instead of 3G, and, in time, 5G). Each of these approaches comes at a cost, and traffic growth will also require increased spend on backhaul to carry traffic to and from base stations.

Thus for mobile operators, the primary challenge is not how technically to meet traffic growth, but rather how to do so profitably, particularly in an environment where ongoing price declines have become expected. In 2012 the aggregate return on net fixed assets of the industry was just 1.6% (down from 3.4% a year prior).[124] Such low returns make it harder to justify additional investment.

One perspective on this is that consumers are not currently paying the full economic cost of the traffic they're using, which could be said to mean that current usage overstates the demand that would occur at 'true' cost.

Wifi

For wifi, the challenges of meeting growth are rather different. Network densification is not a problem - wifi already has far more 'cells' that cellular ever will - there are 22m broadband connections,[125] of which the great majority have wifi attached (if not necessarily available to all, as discussed above). This compares to 52,500 cellular base stations (at end 2011).[126] Cost is often less of an issue because a premise may have wifi anyway, and the marginal cost of making it available to visitors is thus low. (That said, for a premise which attracts heavier usage, an upgrade for the access point or the fixed broadband connection may become necessary).

Instead, wifi's challenges stem primarily from its unplanned nature, both in a local and a strategic sense. In a local sense, wifi is unplanned in that there is generally no co-ordination between

[124] Communications Chambers analysis of MNO annual accounts. Vodafone figures are for year to March 2013, other operators are calendar year 2012. EE goodwill resulting from acquisition excluded from NFA
[125] Ofcom, *Infrastructure Report 2013 Update*, 24 October 2013
[126] Mobile Operators Association, *Base Stations and Masts* [Accessed 16 July 2014

access points. For example, neighbours may both have their routers set to the same frequency, reducing capacity for both, even if there is vacant spectrum available (a problem made worse by wifi's lack of power management, a standard feature of cellular networks).

Such conflicts are already problematic in highly dense urban environments with numerous independent hotspots.[127] In large, managed environments such as a shopping mall, conflicts will be less likely, though in areas with very heavy traffic, such as transportation hubs, spectrum may become a constraint within ten years.[128]

At a strategic level, there is no entity with an objective to provide nationwide wifi coverage, or anything close to it.

Some MNOs do offer wifi as part of their service, but this is (perfectly legitimately) as an adjunct to their cellular offer, not something that in itself aims for ubiquity. As Coleago (for the GSMA) put it:

> "For cultural, economic or strategic reasons, it is unlikely that MNOs will see Wi-Fi as a replacement technology for licensed spectrum and networks. As a replacement, Wi-Fi is disruptive for MNO's as it challenges its legacy business models, alters core assets of their balance sheets such as commercial margins, investments in core and access networks, as well as the spectrum licences."[129]

Pure wifi providers such as The Cloud are generally not charging end users, who might require ubiquitous coverage. Rather, they are serving public venues who are interested in their own locations in order (for instance) to drive end-customer visits. However, such venues have relatively little interest in coverage beyond their own doors. Thus there is also no central imperative for these wifi providers to address wifi 'not spots'.

Summary

OOH traffic growth is driven by more users and more traffic per user. Growth in the number of users is inevitably slowing, as mobile internet adoption approaches saturation. Recently traffic per user growth has slowed, but is likely to accelerate again due to 4G.

[127] See for instance the discussion of Covent Garden in Aegis & Quotient (for Ofcom), *Study on the use of Wi-Fi for Metropolitan Area applications*, 22 April 2013
[128] Plum (for Cisco), *Future proofing Wi-Fi – the case for more spectrum*, January 2013
[129] Coleago (for GSMA), *Will Wi-Fi relieve congestion on cellular networks?*, 5 May 2014

Key drivers of growth will include:

- Lessening 'bill fear', as 4G enables larger data allowances for cellular, and as 'free' wifi becomes more readily accessible
- A maturing ecosystem, as both application developers and device manufacturers continue to increase the capabilities of the OOH internet
- Better application coverage (from both cellular and wifi networks), enabling more apps to be used in more places

Subsidiary drivers of growth will include increased adoption, M2M (important, but bandwidth-light) and higher resolution devices.

Both cellular and wifi will be vital to meeting this growth. Each faces different challenges in doing so. For cellular, the key challenge is to accommodate growth profitably. Returns are already low, and while capacity can be increased via network densification, technology upgrades or spectrum acquisition, each comes at significant cost.

Wifi's challenges relate to its decentralised nature. No one operator is seeking to provide ubiquitous coverage, at a local level there is no radio-planning to avoid interference, and so on.

5. Conclusions

Out-of-home internet has seen robust growth. Near-ubiquitous availability of the internet is now an expectation for a majority of people, and out-of-home usage is embedded in their daily lives. The mix of traffic and applications out-of-home is already surprisingly similar to that in-home, and while video is somewhat less prevalent, this may be more due to human factors than network limitations.

Growth will certainly continue, but how best to meet it is a serious challenge both for industry and policy makers. We believe the 'out-of-home' perspective taken in this paper has a number of implications, as follows:

- Wifi is an important contributor to out-of-home use, and needs to be recognised as such. While wifi's share of OOH traffic is not as high as its overall share of mobile device traffic, it is nonetheless significant at over 30% based on our estimates (excluding employer wifi).

- This usage has, from a policy perspective, been low profile. Its providers are highly fragmented, and have generally have little reason to measure usage. While Ofcom now tracks commercial hotspot traffic, this leaves unmeasured use of independent hotspots, employer wifi, friends' wifi, and so on. Thus OOH wifi usage is an area worthy of further investigation, likely by Ofcom. In practice such usage will only be measurable via device-based monitoring.

- OOH use is an area where consumer decisions are often based on limited understanding, and (by extension) price signals may operate poorly. Examples include the fact that many users appear to be subscribed to a significantly higher data plan than they need (though they may simply be paying a premium for peace of mind), and the large number of users who believe they are automatically logged into hotspots when this generally not the case. The sub-normal returns of the cellular players also suggest that price signals may be operating somewhat ineffectively.

- Negative externalities are widely possible. For example, a new wireless router (or increased usage of an existing one) can degrade performance for others within its signal range,

or a user switching to 4G from wifi can potentially degrade performance for all other users within that 4G cell.[130]

The issues of externalities are particularly acute if users carry over their behaviour from fixed broadband. For fixed, the marginal cost of traffic is low, and constraints of last mile capacity primarily create externalities within a household. (A low bandwidth connection may mean your video inconveniences your housemate, but the rest of your neighbourhood is unaffected). Thus in a fixed context, the impact of 'heavy' applications is somewhat constrained. In a mobile context, the triggered costs are more material, as are the implications for other users in the same cell.

- Wifi and cellular are not strategic substitutes, but *are* often local substitutes. Both networks are vital, with each having unique roles. Cellular is the only option for much outside use (particularly while on the move), offers ubiquitous security and is immediately available. Wifi can offer better coverage in-building, and for price sensitive customers may be the only practical option for data intense usage. However, there are clearly many situations where the two are, locally, substitutes. A user may choose to use wifi in a hotspot instead of cellular (and thereby free up cellular capacity to better serve the users who depend on it, such as those on the move).

- OOH demand is not exogenous, but is highly dependent on a range of factors. This is evident in the impact of 4G. This has enabled faster speeds and lower unit prices, and these have spurred growth. Material swings are also possible as user behaviour changes between (for instance) side-loading and streaming. What is true for OOH demand as a whole is doubly true for individual networks serving OOH need – traffic can migrate between wifi and cellular for instance, and all the more readily as cellular application coverage improves and wifi autologin becomes more common.

- By extension, standalone traffic forecasts, particularly for one network type, are slippery grounds on which to reach policy conclusions. Such forecasts beg at least two questions. The first is 'what consumer pricing is implicit in

[130] If the user's increased consumption brings extra revenue to enable the MNO to upgrade the cell, then the negative externality is transient only. However, this presumes that the extra traffic triggers extra charges for the user, which is not a given, and that those charges are sufficient to cover the full economic cost of traffic. This too isn't a given, in light of the sub-normal returns of the MNOs

such forecasts, and is this credible (both from the perspective of consumer willingness-to-pay, and operator profitability)?'. The second is 'must this traffic demand be met on this network, or can the same user need be met more efficiently via a different network?'

- As a related point, societal value is grown by increasing application usage, not simply by traffic growth or traffic redistribution. To take one example, 4G may be encouraging users to move traffic from wifi to cellular, but this extra cellular traffic is likely to have appreciably less incremental societal value than the same amount of completely new traffic. In another example, increased tablet adoption may increase video traffic at wifi hotspots, but this may only bring marginal public benefit.

- Expectations of application coverage will inevitably rise, as what was remarkable becomes standard. The rise in coverage will in itself make not-spots all the more noticeable, particularly as mission-critical applications become dependent on OOH connectivity (as has already happened in mobile voice). Diverse networks and increased capacity will both contribute to meeting these expectations.

- In rural areas both wifi and cellular face particular challenges in providing application coverage. Lower premise density makes wifi less relevant. Cellular economics are worsened by lower traffic density and the cost of backhaul. Given that MNO profitability is under pressure even in more benign environments, this suggests rural application coverage will need government support.

- A key challenge to widespread, reliable coverage for mission-critical application coverage is the use of the network for lower value applications. The shared nature of OOH and in particular cellular networks is such that high-volume, relatively low-value traffic can materially degrade the performance of higher-value applications.

As we have seen, the OOH internet is a complex and interlinked ecosystem, creating substantial challenges for network operators and policy makers alike as they seek to meet users' ever-rising expectations. However, the very richness of the OOH system creates flexibility and opportunity in how to meet users' needs, to ensure OOH continues to make its substantial contribution to society.