A User Centred Approach to Evaluating the Future Demand for Bandwidth from Consumers

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Abstract. This paper estimates bandwidth demand for consumers using a user-centred model including an extension of the persona concept to describe complete households. Peak demand is calculated by describing when different applications and services are used within each household during the day and by summing the concurrent demands for bandwidth from each concurrent application or service. The value of the peak demand calculation to capacity planning is discussed.

Keywords: Broadband, consumer.

1 Introduction

This paper explores the factors that affect the bandwidth required by, and offered to, residential consumers. Broadband is popular with and valued by consumers: adoption rates have risen approximately 20% in the last 6 years and now stand at about 70% [1]; and in a July 2011 survey 32% of respondents claimed Internet would be the last thing they would give up to save money [2]. The industry is keen, through advertising and through lobbying, to explain benefits of the service. One study measures the net benefit[1] to US households at between $23Bn and $32Bn per year [3]. The market for such a commodity is valuable and competitive. Over the last 13 years, a key feature of connectivity that has been used to attract consumers is speed[2]. Technology investments have allowed broadband speeds to increase and this is mirrored by the press announcements relating to the speed (capacity) of broadband products in the UK (see Table 1). But do current products offer enough bandwidth to satisfy consumer demand? And will they in the future?

The primary goal of this paper is to describe a methodology that can be used to predict bandwidth demand of different household types. The paper goes go on to critically appraise the method and to explore its limitations and to unpack some of the other factors that affect the determination of broadband speed as a design parameter.

[1] Net benefit is a measure of the value perceived by US customers, minus the cost.
[2] Speed is a widely used marketing term for broadband data transmission rate.

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Table 1. A timeline of UK broadband product launch dates since 1999

Year	Broadband launch announcement
1999	First consumer broadband launched
2000	BT[3] offers 512kb/s broadband
2001	NTL[4] launch 128kb/s 'broadband' service
2002	NTL launch 1Mb/s broadband
2004	NTL[4] and Telewest launch 750kb/s broadband and 1.5Mb/s
2005	BT launch 2Mb/s broadband
2006	BT offers ADSL Max (up to 8Mb/s product launched)
2007	BT offers ADSL 2+ (up to 24Mb/s) Virgin launch 20Mb/s broadband product
2008	Virgin launch 50Mb/s broadband product
2010	BT Infinity 36Mb/s launched
2010	Virgin 100Mb/s launched
2011	BT announces 110Mb/s FTTH product
2012	BT Infinity 2 launched with 76Mb/s download speeds.

2 Method

The methodology for estimating household bandwidth demand involves three steps; defining the bandwidth requirements of different applications and services; defining the users and finally defining the time-delimited usage of applications and services throughout the day which when summed will give an overall peak demand in any given time interval.

The approach demands an understanding of the range of applications and services that people use. The choice of services we select is supported from results from: deep packet inspection within the core network (which allows us to understand, for applications that have a recognized signature, the applications and services that create most of the bandwidth demand today); from user studies and surveys [3]; and from market surveys (which give some insight into take up applications and surveys); from our own and others experience. In addition, we made some predictions about services that we thought might be available in 2015 that were not readily available at the time of the study (2011). The minimum bandwidth required to support each of the identified services is defined at a level that does not, in and of itself, deleteriously affect the user experience of the service or application. These bandwidth levels are defined as the minimum acceptable bandwidth per service.

The second step is to describe the users. For broadband services it is important to consider households, not isolated individuals, as it is the aggregated demand from

[3] BT (British Telecommunications plc.) is the largest UK broadband provider www.btplc.com

[4] NTL and Telewest were cable companies offering cable television, cable internet and fixed-line cable telephone services in the UK up until 2006 when NTL, Telewest and Virgin all merged to form Virgin media.

within a household that will drive the peak demand. In this work we adopt the notion of *familia*. Familia [4] is a relatively new concept, essentially an extension of persona descriptions [5], that describes a complete household rather than an individual. Familia are useful in this context as they describe not only the individual users but also encourage you to consider the impact of household dynamics which will greatly impact the aggregated peak demand from a household.

The third step involves describing the pattern of usage, during the course of the day, of the applications and services by the different familia we have defined. By summing the minimum acceptable bandwidth requirements of all the applications used at any given time, we can estimate the peak bandwidth demand generated by these familia. The times of day in which particular applications and services are used is informed by a consideration of family life using understood behaviours like TV-atching [6] (BARB, 2013), the need to eat, and the known patterns of internet traffic during the day in our core network.

3 Results

3.1 The Applications and Their Bandwidth Requirements

It is not easy to predict which applications and services will be used in the future. We have chosen a relatively short time horizon, 2-3 years ahead, which should make things easier. Even so this leaves significant margin for error as some applications and services have become important very quickly. Facebook[5] for example has a reported a global membership of 1 billion people, with a market penetration in some countries of over 50%, but started less than 10 years ago. At the time of the study expectations were very high about the acceptance of 3D video services by users; judgements had to be made about whether 3D content delivered to the home would become common place or not.

The list of applications and services (shown in Table 2 was agreed by augmenting current understood usage (from core network logs) and other studies with other possible applications that might become popular in the future. Applications like 3D gaming, 3D video, ultra high definition TV, and HD video calling were all considered. This longer list was then refined to exclude applications that we judged would not be widely available in 2015, for example ultra-high definition (4k) TV services that are being trialled now [7] will probably not be widely available in 2015.

The key applications/services were defined iteratively with the patterns of usage defined for each familia and were rationalised based on the fact that some, apparently different, activities required (essentially) the same underlying application. For example, trialling a game from Xbox; and opening a large file attachment on an email all broadly require a large file to be downloaded in a 'reasonable' time frame. By rationalising the applications requirements in this way we found we needed to describe only eleven different service/application types, and defined for each of them the range of bandwidth demand (both upstream and downstream) created by the service.

[5] Key data on the growth of Facebook are reported on the web sites of Facebook and `http://newsroom.fb.com/content/default.aspx?NewsAreaId=20`

Table 2. An incomplete list of the services and applications that consumers may be using that will drive bandwidth in 2015

Application	Description
File sharing, Cloud Back up and Software Updates	Fast download (and upload) of content to sharing websites (YouTube, Facebook) and personal cloud storage (DropBox) and for software back-up and restore will drive the need for fast file transfer. Uses will include: Software Updates (e.g. OS Service Packs); Games demo download (e.g. Xbox Live); Burst back-up and restore for home PC; Rapid sync of media players with Net Store; Cloud media sharing; Email attachments **Bandwidth Requirements:** • 2GB Xbox Live game demos downloaded over 100Mbit/sec ~ 3 mins • 500GB Back-up and restore time - 29 hours (40Mb/s) and 12 hours (100Mb/s)
Usage of BT WiFi by those not in the house	BT Broadband customers are, by default, opted-in to a scheme that shares (via WiFi) a small portion of their home broadband capacity and allows them to access broadband when away from home whenever they are in range of a BT Wi-Fi signal from another consumers' broadband router. There are currently over 2 million home-hubs sharing their WiFi capacity. Users can use this free WiFi to perform mobile offload whenever they are in range of such Wi-Fi. **Bandwidth Requirements:** The BT WiFi capacity available in 2015 is uncertain. In 2011 it was restricted to 0.5Mbit/sec and is expected to increase though the upgrade roadmap is not certain.
Multicast linear TV	BT provides a TV service using channels delivered over the air with additional VoD and catch up TV content available online. In the future channels will also be delivered using multicast technology over the wired network infrastructure. Consumers will use bandwidth every time they watch or record this channel content and will be able to do so on many different device types including Smartphones, Smart TVs, tablets and Set-top boxes. **Bandwidth Requirements:** Multicast HD streams will require between 8Mbits/sec and 11Mbits/sec for HD content [8].
Multi-screen concurrent entertainment	The use of 'companion screen' devices to 'social network' and participate in shows while watching TV is prompting many broadcasters, producers, and TV service providers to creatively merge Content and Comms into new and compelling hybrid entertainment experiences; video 'mash-ups' that combine broadcast with personalised video (e.g. Bingo with friends) or HD video chat with friends while watching same programme. **Bandwidth Requirements:** HD multicast stream to TV will use 8-11Mb/s, additional downstream bandwidth of 4Mb/s is anticipated to support the media and comms on the second screen. Upstream bandwidth requirements are dominated by comms; HD voice will require about 100kB/s and video could use up to 4Mb/s.

Table 2. *(Continued)*

Application	Description
Streamed multiplayer gaming	The next generation of games consoles (PS4 and the replacement for the Xbox) together with some recent entrants such as OnLive will support streamed gaming in which scenes are rendered in the net and streamed to the screen via the console. Increased rendering capacity and fast networks should support up to 1080p 3D gaming **Bandwidth Requirements:** HD gaming would require 8-11Mb/s at 1080p for the downstream bandwidth. Upstream requirements will be dominated by VoIP requirements for team speak like communications, for which 100kb/should suffice.
Cloud media editing and sharing service	Some consumers choose to edit both photographs and video using on line editing tools such as You Tube Video Editor. Many more then go on to share their video and photos using applications like Picasa, Facebook, Flickr, YouTube etc. For such applications, fast upload speeds that minimise the delay associated with uploading media are desirable. Playback should be sufficient to replay media smoothly and at high quality. **Bandwidth Requirements:** Uploading 30 20MB high resolution photos over 10Mbit/sec takes about 8 minutes. HD video (H264 encoded) will require about 10Mb/s to upload in real time – the same to preview. Playback will depend on the video resolution and quality and may be up to 11Mb/s for high quality 1080p content.
Video on Demand OTT video streaming	Consumers are turning to Over the Top service providers such as NetFlix, and LoveFilm to watch films and TV series. Video quality is currently up to HD quality today; in time, but not before 2015 in our estimation, Ultra HD (4k) video will also be supported. VoD content can be viewed on a wide range of devices including computers, Smart TVs, TV streaming devices, games consoles, iPads, etc. **Bandwidth Requirements:** HD streamed video require 8-11Mb/s (Kim, 2010). Download-to-own video – a typical blockbuster film could be downloaded in under 20 minutes over a 100Mb/s connection.
Multiparty HD video calling	Skype and Google+ hangouts both support multi-way video chat enabling groups of people to chat on line together. Services are available on personal and tablet computers but also games consoles, Smart TVs and as a TV accessory from providers like Logitech, TelyLabs HD and Biscotti. **Bandwidth Requirements:** HD video conferencing requires from about 800kb/s to a few MB/s (symmetrical)
Home monitoring and security	Remote home video monitoring using IP cameras can be used to offer peace of mind and added security. Whilst some system can be self-contained others allow the images captured to be viewed over the net from remote places[6]. Always on video chat connection could also be used to provide a window into the lives of a loved one or to provide a reassuring connection for a vulnerable relative. **Bandwidth Requirements:** Upstream bandwidth 100Kbits/sec to 2 Mb/s

[6] In 2011 services were available from Intamac, AlertMe and from Verizon.

Table 2. *(Continued)*

Application	Description
High definition VoIP call	Voice remains essential component in our communications mix. Recently mobile providers have been differentiating their services based on the availability of 'HD voice'[6]. As voice chat migrates to WiFi there will be ample opportunity for service providers to allow users to experience HD voice and for users to start appreciating the benefits of higher bandwidth voice codecs. **Bandwidth Requirements** Codecs like AAC-ELD, and Skype's SILK (available as an open source codec) provide excellent (CD like) quality for voice at 48Kbits/sec per channel

It also possible that the bandwidth required for such activities will become lower in 2015 than they are today. Advances in coding capability, and possibly in the development of new codecs[7] may in time reduce (by as much as a factor of two) the bandwidth required to deliver a given video quality. In this work we chose a specific date, 2015, and made the assumption that no new codecs were in widespread use and that coding efficiency based on the current H.264 based codecs would not improve significantly in the intervening time period.

It is not clear how many hours a week of video we will watch via video on demand services; neither is it clear the extent to which we will use video based calling to routinely communicate. For peak use though we do not have to model average or total usage during the week – the key is the concurrent use of different applications and it is this which has to be modelled.

3.2 Users

Personas [5] have been found to be very useful tool for software design. They provide a mechanism for developers to discuss and hopefully satisfy the needs of the user. In the provision of bandwidth it is not the demands and activity of a single user that need to be met but the aggregated demand caused by concurrent use. The persona idea remains a useful one, in grounding the imagined use of the broadband capacity. The idea of 'familia' [4] - an extension of the persona idea to describe a household - helps guide the work. Broadband capacity will be different for different households and for this reason we chose to model four household segments: young adults; older adults; family and empty nesters

Segmentation models can be many things (geographic, demographic, psychographic or behaviour based). Since our goal is to identify *maximum* realistic levels of bandwidth demand (unconstrained by bandwidth availability) we sought to model segments that we anticipate would develop more demand. Our chosen segments were not (therefore) significantly constrained by wealth (a demographic characteristic), nor

[6] In 2011 Orange have launched a HiQ voice service on their mobile phones using the G722. AMR codec.

[7] H264 based of codecs are expected to be replaced by HEVC "High Efficiency Video Codec" based codecs and these are expected to deliver the same subjective quality with approximately half the bandwidth.

by attitudes to technology (a psychographic characteristic). So in each case we assume our segments are reasonably affluent and inclined to use technology.

The familia descriptions we used to develop our understanding of bandwidth usage are in Table 3. Within our working documents we also used photographs of the household members.

Table 3. The familia descriptions, showing the level of detail used to develop the pen pictures of household activity and thence bandwidth use

Young Adults. (6.7M Individuals) James (25) and Sophie (24) live together. They work in the city and have busy work and social lives. They have a wide circle of social and work friends, and use social networks to help manage their relationships. They love entertaining and like to keep up to date with the latest TV shows, films and games. They want to be the 'first to have seen' in their social network.
Older Adults (7.4M Individuals) Jenny (39) and David (42) both have busy jobs. They are technically savvy and value products and services that save them time. They have a high disposable income and watch little TV during the week. They are heavy internet users. On an evening Jenny relaxes watching TV while David uploads the summer holiday video for friends to see on YouTube.
Empty Nesters (12.3M Individuals) Jim (61) and Jane (62). Their daughter Claire lives quite locally. She is taking a career break while she raises a young family. They love BT. The need some help with new technologies and need them to be simple. They each have mobiles and share a home PC. They regularly use the Internet. They have weekly video calls with relatives abroad and have OnLive games for when the grandchildren usually visit on Sundays.
Family (17.4M Individuals) Amy (42), Dave (43), Lucy (11), Emma (16) and Andy (18) live in a busy house with visits from family and the kids' friends over to play. Amy has a sister who is married but has no kids. Amy's Mum has arthritis and perhaps some early dementia or age related forgetfulness. Amy's Mum's prime carer is Susan (Amy's sister). Dave's has a brother who lives in Aberdeen. Dave's parents are well off and spend a lot of time away from their home on holidays.

3.3 Time Based Bandwidth Demand

We developed time based usage models based on evidence from sources like British Audience Research Board [6], BARB, (for TV watching) and to the known aggregated bandwidth capacity recorded in our core network. The models we developed also tried to honour factors like the times at which people return from school, eat, sleep and the propensity to adopt certain services (like catch-up TV). For sources like BARB and the BBC iPlayer briefing packs [9] these behaviours can also be correlated with certain demographics.

A short narrative was provided to explain who was involved and the application or service that was being used. A few examples of the activity descriptions are shown in Table 4. Predicted bandwidth demand was plotted by summing the instantaneous demands from each of the different applications throughout the day. Totals were calculated using both the maximum and minimum bandwidth estimates of the required bandwidth per application/service. A typical plot, for the period between 15:00 and 01:45, is shown in Fig. 1.

The overall peak bandwidths we calculated, for each of the four familia is shown in Fig. 2. According to this analysis the familia that is likely to demand most bandwidth

is a busy family and the bandwidth demand they will create will be between 38Mb/s and 55Mb/s downstream and between 18Mb/s and 5Mb/s upstream.

Table 4. Example of the level of detail used in developing the time based usage pictures for the Family familia. Overall there were 19 activities described for this household.

User	Application in use	Narrative
Amy	HD Video Calling - 720P (SKYPE)	1700-1715: Amy uses Skype video to chat to a friend using the lap top on the kitchen table whilst having a cup of coffee sometimes Dave (43) joins in too - they have been discussing going on holiday together.
Amy	Remote HD Video Monitoring - 720P	1730-1745: Amy helps care for her Mum who has arthritis. Amy's sister does most of the day to day caring but Amy tries to do what she can and tries to video chat with her Mum most evenings.
Amy	HD Video Calling - 720P (SKYPE)	2030-2300: Amy and Dave's friends, who live just up the street, have a date night. Their kids are just about old enough to leave by themselves. Amy agrees to leave a Skype session to her friend's house open - just to make sure there are no problems.
Amy Emma	Multicast Linear TV - HD 1080i	1930-2030: Amy and Emma watch Million Pound Drop.
Amy Emma	Multi-Party HD Video Calling - 720P	1930-2030: Amy and Emma play along with Million pound drop, watching video thumbnails of their friends on their tablet and chatting to them as they try and out-do each other on the popular game show

The peak downstream bandwidth occurs at 20:15 on a weekday. This is caused largely by 4 simultaneous instances of streamed video (Amy and Emma watching Million Pound Drop whilst playing along with the associated app; Dave watching a film with Lucy; Dave recording a stream of Mad Men he has on series record; Andy watching SkySports on a tablet).

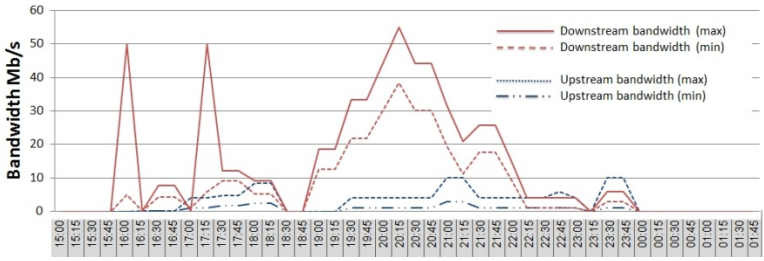

Fig. 1. Bandwidth demand plot for the family familia between 15:00 and 01:45 showing peak bandwidth demand both upstream and downstream using both maximum and minumum estimates of the bandwidth required per application.

The peak upstream bandwidth demand occurs at 21:00 hrs, due to Dave using a Skype video chat session while also holding open a Skype video session to remotely monitor a neighbouring property and, at a later time (23:30), using on online video editing/sharing site that requires fast upload bandwidths to make the upload delays short enough for its use to be practical.

	Download Speeds		Upload Speeds	
Familia	Mb/s (min)	Mb/s (max)	Mb/s (min)	Mb/s (max)
Family	38	55	5	18
Young adults	22	32	2	10
Older adults	25	34	1	12
Empty nesters	29	38	2	14

Fig. 2. Peak bandwidth estimates for the different familia

4 Discussion

The use of familia has proved a useful tool in the formulation of these estimates of peak bandwidth demand. The authors found themselves looking critically at the pen pictures and arguing about whether 'Dave would be doing that' and arguing about whether the level of individual vs joint activity within the households was plausible. This helped to generate a set of pen pictures that the authors were happy to defend.

Further the familia idea has proved useful in communicating to others the causes of this bandwidth demand, it is easy to quickly see the assumptions that have led to the peak demand figures. The use of additional aggregate information in the formulation of the pen pictures (such as TV viewing and Internet traffic pattern) further provides confidence that the imagined behaviours are plausible. Whilst the use cases at some levels seem aggressive (a family of five receiving four simultaneous streams of TV seems a little unusual) the painted pen picture explains why such demand is plausible (if unusual).

Such information is not sufficient to drive multi billion pound/dollar investment decisions about network roll out on its own. Such a decision is an important strategic one made in a regulated and competitive environment. Profitability, ultimately, is the driver. This has two often conflicting effects: the need to save money (and so to not invest), and the need to attract and retain customers with alluring promises of fast internet access; this latter effect can result in over specification against the real needs of users.

To suggest then that the use of familia can determine bandwidth capacity that a company should provide is to over-state the case. Capacity, like speed and performance with cars, can be used to seduce customers into using one product over another. Strategists and marketers will negotiate with these attributes as well as the cost of the proposed investment plans as well as the need to satisfy what the customer demands for bandwidth.

5 Conclusion

The bandwidth demand from residential consumers in 2015 has been calculated. A user centred approach has been adopted based on the use of familia which are an extension to the persona idea that help describe a household.

Four familia were described: young adults, older adults, family and empty nesters. Estimates of the peak bandwidth demand are calculated by combining estimates for the bandwidth demand created by specific applications and services with the imagined use of these applications and services by the familia through the day. The familia we expect to have the greatest demand for bandwidth is the Family, with demand largely created by concurrent streams of HD video peaking at between 38 and 55Mb/s upstream (depending on the assumptions about bandwidth demand for individual services and applications) and between 5Mb/s and 18Mb/s upstream. Whilst the information is useful input to strategic decisions concerning capacity planning in access networks, factors like the marketing attractiveness of the capacity available and of the costs of different technology options will have equal or greater impact on the design choices.

References

1. OFCOM, Internations Communications Market Report. OFCOM (2012)
2. NFCC (National Foundation for Credit Cousellors) (July 2011), http://www.nfcc.org/Newsroom/newsreleases/, http://www.nfcc.org, http://www.nfcc.org/Newsroom/newsreleases/cellphone.cfm (retrieved February 15, 2013)
3. Dutz, M.O.: The Substantial Consumer Benefits of Broadband connectivity for U.S Households. Mark Dutz, Jonathan Orszag and Robert Willig Commissioned by the Internet Innovation Alliance and available from (2009)
4. Kort, J.S.: D8.4 Evaluations of TA2 Concepts (2010)
5. Cooper, A.: The Inmates are Running the Asylum. SAMS (1999) ISBN 0-672-31649-8
6. BARB (2013). BARB. from BARB: Broadcast Audience Research Board, http://www.barb.co.uk/ (retrieved February 27, 2013)
7. UHD TV Terrestrial Test Transmissions (February 24, 2013), from InformITV: Connected TV: News, http://informitv.com/news/2013/02/24/uhdtvterrestrialtest/ (retrieved March 1, 2013)
8. Kim, H.J.: A Study on a QoS/QoE Correlation Model for QoE Evaluation on IPTV Service. Advanced Communication Technology (ICACT) (2010)
9. BBC (November 2012) BBC Media Centre, from BBC iPlayer Performance Pack, http://downloads.bbc.co.uk/mediacentre/iplayer/iplayer-performance-nov12.pdf (retrieved March 1, 2013)