In watts, what is the maximum power required by your home?

In litres per minute, what is the maximum flow of water your house requires?

Does exploding data drive a demand for Gigabit connections?

Doug Williams (doug.williams@bt.com)

Does exploding data drive a demand for Gigabit connections?

- Find the gap
- Modelling approach
- Characterising bandwidth

- Estimating the bandwidth we'll need
  - Key drivers and trends
    - Browsing
    - VoD
    - Live Sport
    - Mobile Apps
    - OS updates
    - IoT
    - Gaming
- A sort of prediction

Find the gap

A Trabant is capable of achieving the normal levels of occupancy, speed and acceleration; but they are not good enough. Provision of bandwidth is like cars, there is a gap between ‘normally good enough’ and excessive, we need to find that gap.

Find the gap

A Trabant is capable of achieving the normal levels of occupancy, speed and acceleration; but they are not good enough. Provision of bandwidth is like cars, there is a gap between ‘normally good enough’ and excessive, we need to find that gap.

The Gap

“Normally good enough” is normally, not good enough.
But what’s excessive? We need to find the gap.

Modelling approach

The narrative model tries to understand the causes of bandwidth, trends in those causes and tries to anticipate sensible levels of simultaneous use that may occur with households. Answers are provided as a narrative, not just a number.

BT

Household types

Distribution of HH types across the UK
(assumed fixed over the years)

Typical make up and behaviours within each HH type

Number of users, in each household type, that use each of the possible services

Frequency of use

Duration of use

Bandwidth requirement per application /service

Browsing behaviour
Page size evolution

TV
HD, 4k, HDR, HFR, 8k, H.265, H.266?

Large file downloads
Sizes, mitigating strategies

Gaming;
Resolution, Stream vs DL, mitigation strategies
In game Downloads

'You'll regularly require X Mbps on occasion you'll appreciate Y Mbps'

Household types

We use a segmentation from Personicx which uses life-stage amongst other parameters to define households. We segment against key behaviour traits that the model suggest will contribute significantly to bandwidth usage, eg premium online sports, gaming.

2017

	18-34 (16% of all HH)	35-54, 36% of all HH	55-64, 16% of all HH	65+, 32% of all HH
	 LAGER...	 AGA...	 SAGA...	 CAGA...
	~90%	16% (100%)	34% (94%)	14% (88%)	22% (69%)
BBC iPlayer	~60%	13% (82%)	24% (67%)	8% (50%)	13% (40%)
	~40%	9% (56%)	21% (58%)	6% (38%)	3% (9%)
4K ULTRA HD	1%	0.1% (0.6%)	0.3% (0.8%)	0.4% (2.5%)	0.2% (0.6%)

Characterising Bandwidth

Symmetry

- Down >> Up
- Down > Up
- Down ~ Up
- Down < Up
- Down << Up

Duration

- Few seconds
- < 1 minute
- Few minutes
- 10s minutes
- Hour or more

Frequency

- Each year
- Each month
- Each week
- Each day
- Each hour
- Several times / hour

Autonomy

- Human driven
- Mix
- Autonomous

Adaptability

- Responsive
- Rate ladder

Criticality

- Latency – short ping times
- Tolerant
- Urgent (but tolerant) - ASAP
- Persistency – can't fail
- Constancy – Requirements MUST be maintained

Web browsing

Web pages have been growing steadily, as images, video and scripts become more common. Pages should be readable within about a second and based on these assumptions 16Mb/s will be sufficient out to 2035. Increasingly use of video impacts hold time more than speed.

Symmetry

- Down >> Up
- Down > Up
- Down ~ Up
- Down < Up
- Down << Up

Duration

- Few seconds
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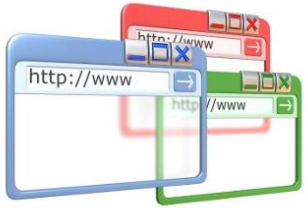
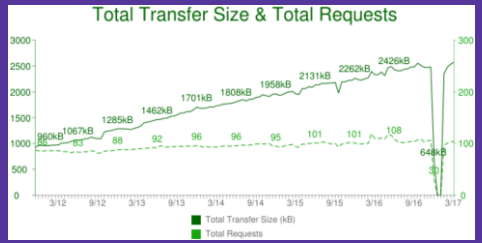
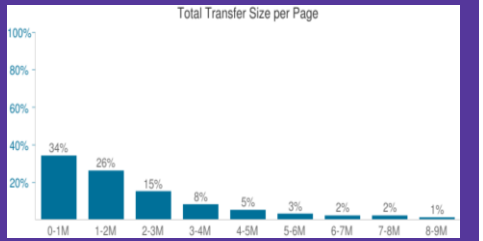


Bandwidth trend – 3Mb/s growing to about 16Mb/s

Pages are getting bigger (2MB per page in 2017), should still *display* within a few seconds (pages download as you read) and may persist longer (video).





Source: https://www.nngroup.com/articles/response-times-3-important-limits/
Source: http://httparchive.org

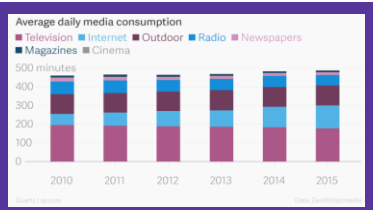
Usage trend - increasing

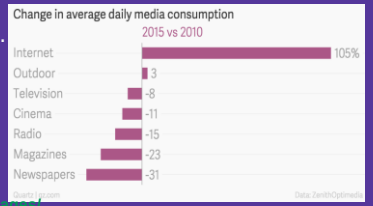
Total media time (Minutes per day)	*2010* 460	*2017* 509

Mobile devices leading increase

In-home media time: Internet time substituting TV, magazines, newspapers, cinema.

Clicks per minute 2011 – a little over 1





Source: https://qz.com/416416/
Source: https://www.nngroup.com/articles/how-long-do-users-stay-on-web-pages/

Video on demand

Increasing efficiency of codecs means that we see decreases in the bandwidth required to encode a video, to a given perceptual quality, of about 5% per year.

Symmetry

- Down >> Up
- Down > Up
- Down ~ Up
- Down < Up
- Down << Up

Duration

- Few seconds
- < 1 minute
- Few minutes
- 10s minutes
- Hour or more

Frequency

- Each year
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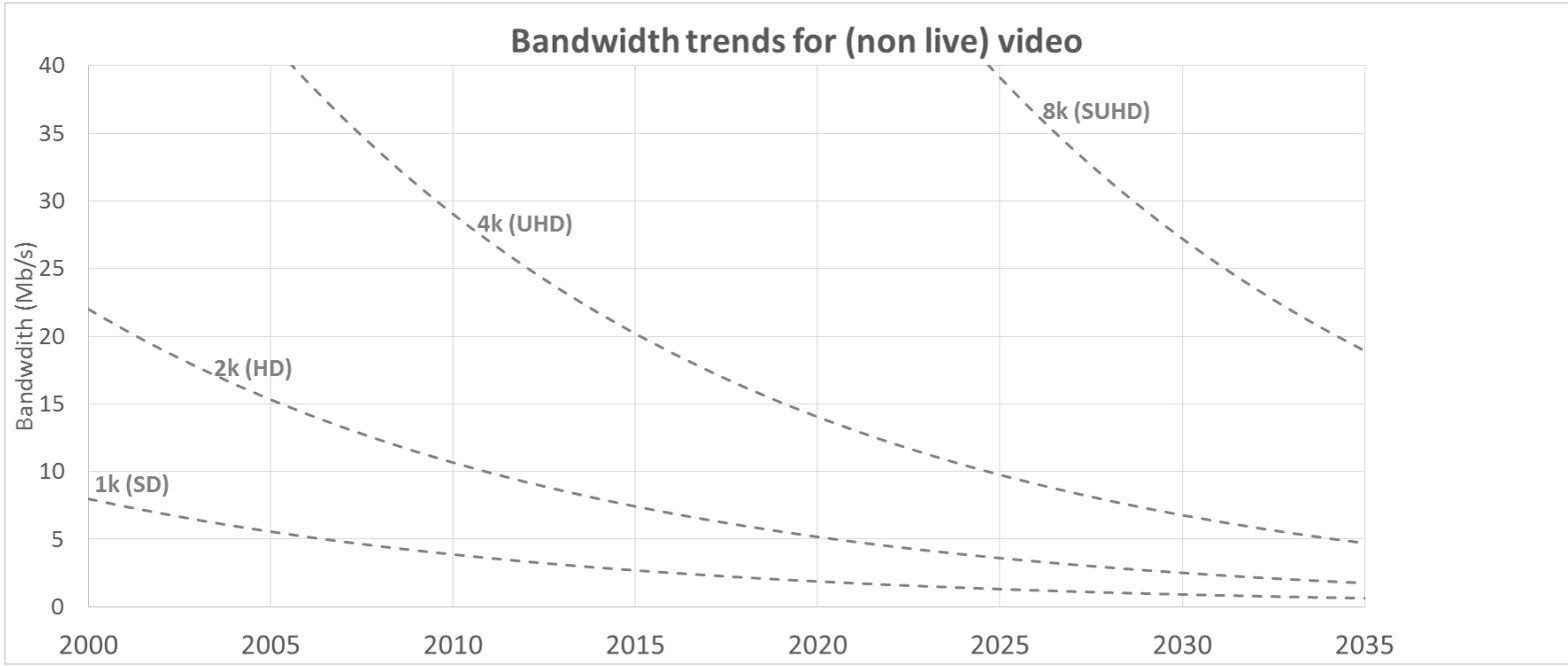

Video on demand

In a given year the bandwidth required to deliver a form of video that viewers would describe as acceptable, very good or for which they would pay a premium, increases.

Symmetry

- Down >> Up
- Down > Up
- Down ~ Up
- Down < Up
- Down << Up

Duration

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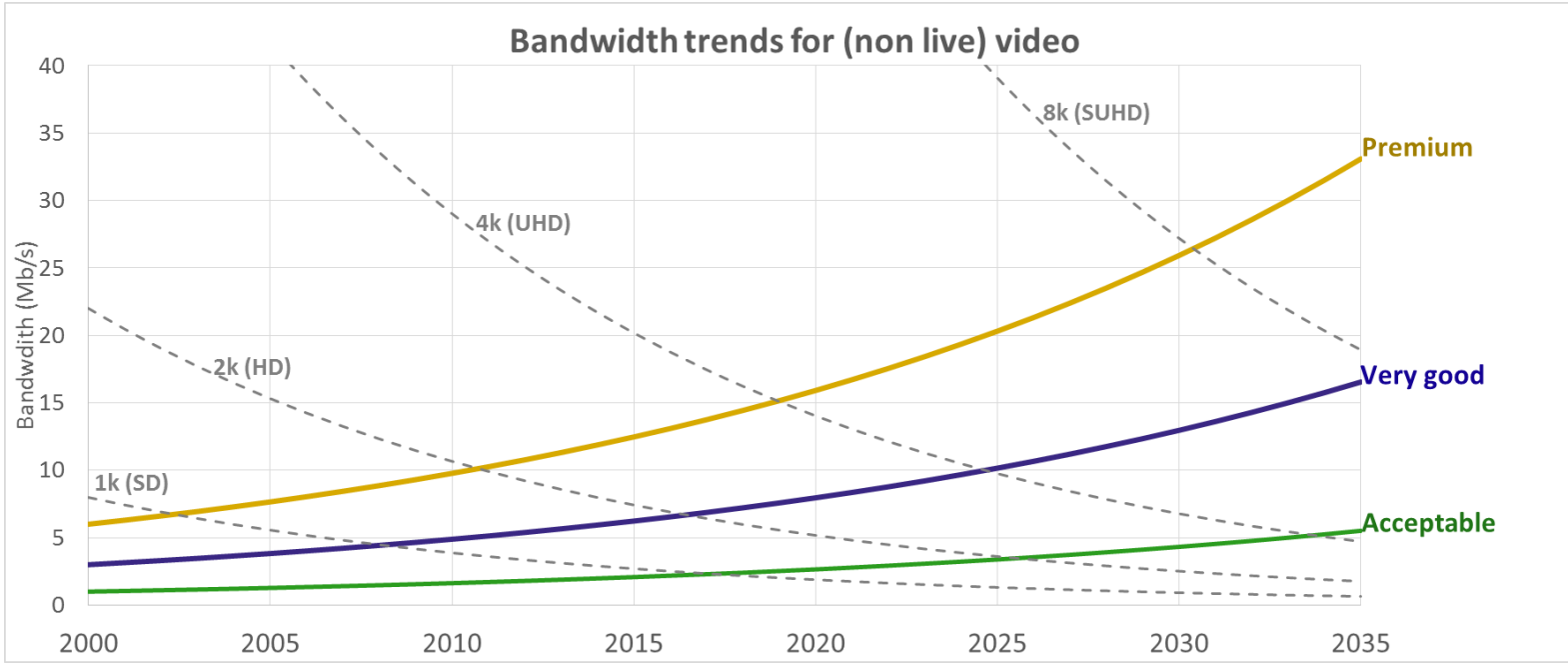

Video on demand

2018 11-18Mb/s is required for premium services
3-5Mb/s is required for very good quality video
2Mb/s is required for an acceptable quality of video

Symmetry

- Down >> Up
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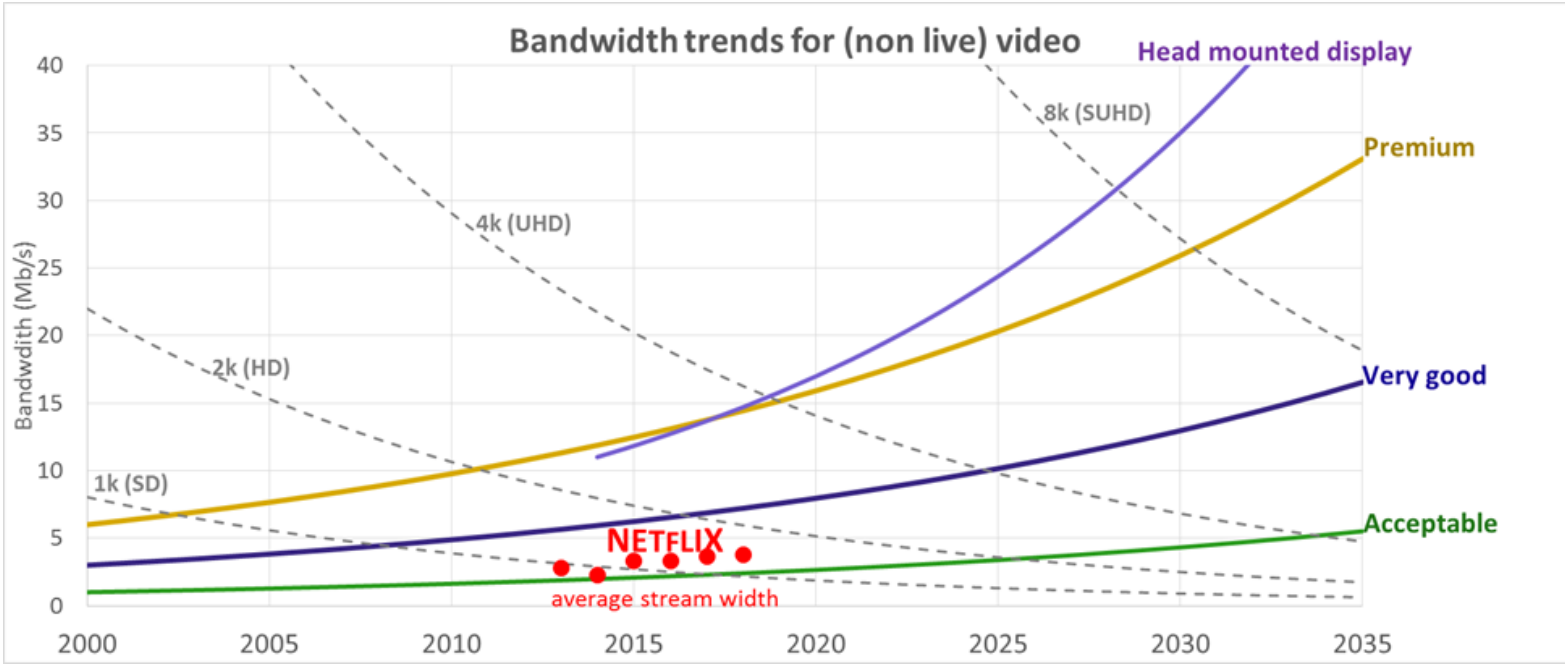

Video on demand

There is tussle between picture quality, screen size, and coding efficiency that dictates the bandwidth required per stream. The net effect is a slowly increasing bandwidth requirement, Premium VoD services require ~15Mb/s in 2017 and may rise to 30Mb/s by 2030.

Symmetry

- Down >> Up
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- Down ~ Up
- Down < Up
- Down << Up

Duration

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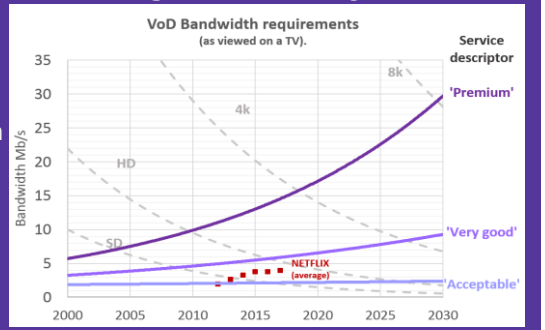
Max bandwidth requirement rising; 30Mb/s by 2030

- Coding efficiency improves a few %/yr
- Pixel count quadruples every 10yrs
- TVs get bigger about 1" per year
- Netflix bits per stream is increasing

Net: bandwidth required to achieve given subjective quality level is rising

	2017	2030
Acceptable	2 Mb/s	2.3Mb/s
Very Good	**6** Mb/s	9 Mb/s
Premium	15 Mb/s	30Mb/s



Source: https://ispspeedindex.netflix.com/country/uk/
Source: http://techblog.netflix.com/2015/12/per-title-encode-optimization.html
Source: https://www.ofcom.org.uk/__data/assets/pdf_file/0017/72242/video.pdf?la=cy-gb

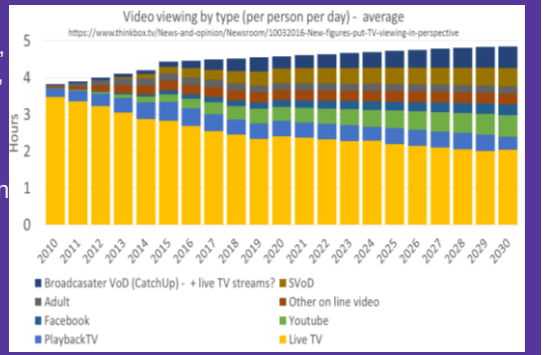
Usage trend

Time watching broadcast TV is in decline, particularly amongst younger age groups, but news, sport, and event TV will remain an important component in our watching habits.

Video delivered over IP is enabling growth in total video consumption in particular.

	2017	2030
IPTV (VoD+live)	1.2	1.9
Broadcast TV	2.55	2.05

(Hours per person per day)



Source: https://www.thinkbox.tv/News-and-opinion/Newsroom/10032016-New-figures-put-TV-viewing-in-perspective

Premium live video

The display format most likely to create high instantaneous bandwidth demand is head-mounted displays. They create images that include a field of view about 20 to 30 times that of televisions, clever encoding approaches will limit bandwidth required to about 100Mb/s

Symmetry

- Down >> Up
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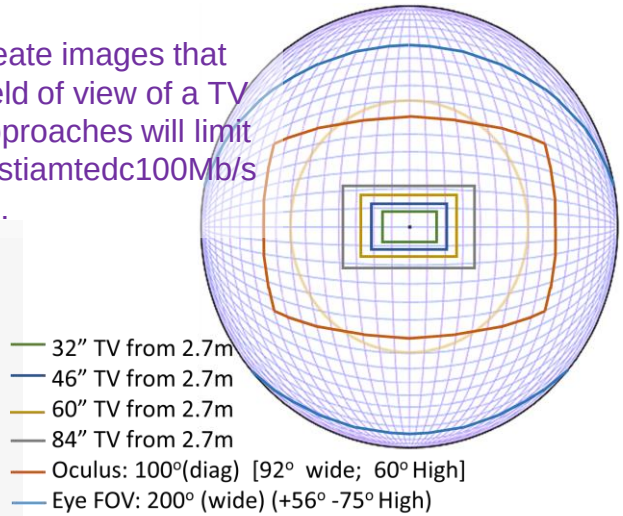
Head-mounted displays create images that cover 20 to 30 times the field of view of a TV set, but clever encoding approaches will limit bandwidth required to an estiamtedc100Mb/s in 2030…for a few minutes.



Demanding video services

- 2016: UHD4k Champions league (30Mb/s)
- 2017: Netflix launch UHD HDR (~18Mb/s)
- 2017: BT: UHD/4k HDR boxing/football (30Mb/s)
- 2017: BT 6 off 360 video Champions league final
- 2020: Olympics in SUHDTV 8K, (80-100Mb/s)
- >2020: VR headsets: deserve a pixel count; >>>8k; 60-600Mb/s
- >2030 Free space hologram (Obi Wan Kanobe).

Source: http://www.swift.ac.uk/about/files/vision.pdf

Mobile apps

Apps, on phones, tablets and TVs create an infrequent demand for downloads that users would want to complete ASAP. We think the bandwidth rate required will grow at about 18% per annum creating, infrequent demand, for short periods, of 300Mb/s by 2030.

Symmetry

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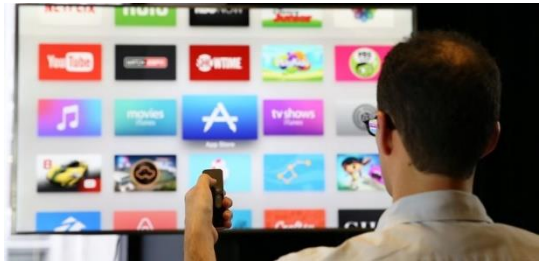
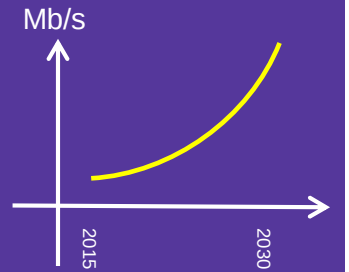


Bandwidth: depends on file size and your patience

- No. of apps on a phone ~25-30
- App sizes are related to device storage (growing at 25% p.a.)
- Max app size currently controlled to be 4GB

- **2016** 10% apps >35MB; 120sec download time
  - **2.5 Mb/s**
- **2030**: 10% apps >800MB; 20sec download time
  - **300 Mb/s**



Source: http://www.nielsen.com/us/en/insights/news/2015/so-many-apps-so-much-more-time-for-entertainment.html
Source: http://blog.scottlogic.com/2014/03/20/app-store-analysis.html

Usage trend

- New apps rarely downloaded
- No. of Apps per device growing slowly
- Time spent using mobile device growing
- Developers may nudge back to browser based interaction
- Updates are important, quite frequent, but increasingly automated

- Automation of app downloads means downloads will become urgent less often but when urgent bandwidth requirement to achieve a pleasingly fast download of a new app will grow at 18% year on year

Operating system updates

Operating system updates will require large file downloads a few times a year. If such updates are 'attended' they may require download speeds of a few hundred Mb/s for a few minutes, but providers will seek to allow downloads occur as background, hidden activities.

Symmetry

- Down >> Up
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Duration

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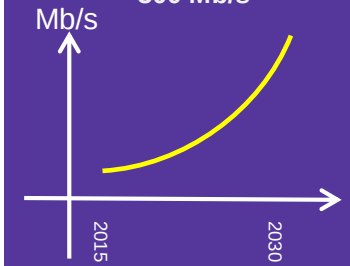
Bandwidth trend

- OS updates - a special case of file and app downloads
- Tend to be larger and have to negotiate customer frustration when install sizes disrupt normal use of the devices, (particularly true for mobile devices)
- Becoming more automatic as providers pursue a 'software as a service' model with subscription based payment.
- Providers profess to pursue "smaller and more frequent" updates.
- Growth in OS size, nevertheless, seems inevitable, we assume a 10% CAGR mirroring growth over the last 10 years.
- A reduction in users patience is also a given. Providers/users will seek to hide the download event – by allowing it download in the background or to see it complete quickly.

- **2016** 6GB, 30 minute download time
  - **28 Mb/s**
- **2030**: 23GB, 5 minute download time
  - **300 Mb/s**



But how long is too long to wait? If 10 minutes is acceptable wait time in 2030, halve the bandwidth

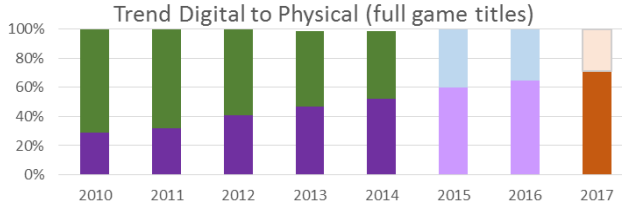
Operating system file sizes (GBytes)			
	2016	CAGR	2030
iOS	0.7GB	10%	2.7 GB
Android (for Samsung)	0.6 GB	10%	2.3GB
Windows 10	6 GB	10%	23GB
MacOS 10	6 GB	10%	23GB

Gaming

It isn't clear which form of game distribution will become dominant. This chart outlines the different methods by which games are distributed. Subsequent charts will outline the bandwidths each method may require.

Physical sales

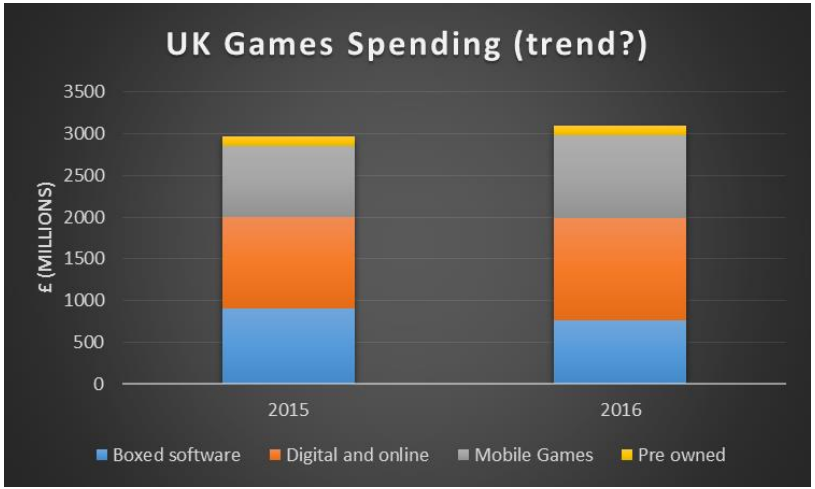
Microsoft	**Sony**	**Nintendo**	**Sony**	**Nintendo**	**PC**
XBoxONE	PS4	WiiU	PSVita	3DS XL	
DISCS	DISCS	DISCS	CARDS	CARDS	DISCS
Digital	Digital	Digital	Digital	Digital	Digital
XBox Live, X Box Store	PSNetwok	eShopWii Wii Store	PS Network	Nintendo eShop	Steam



Streamed video gaming

Whole games, Patches and Upgrades, PDLC - Paid Downloadable Content
+
Cloud gaming/ file streaming/progressive downloading
Game files downloaded to a thin client on the user's gaming device, such as a mobile device, a PC or a console. Gameplay is enabled after downloading about 10% of the total game size.
+
Video/Pixel streaming
The game is stored, executed, and rendered on the remote operator's or game company's servers and the video results are streamed directly to a consumer's computers over the internet.

Streamed file gaming



Sources:
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http://www.bbc.co.uk/news/business-36854291
http://ukie.org.uk/news/2017/03/uk-games-market-worth-record-%C2%A3433bn-2016

Cloud gaming

If games file sizes increase at 20% CAGR and a move to Games-As-A-Service Model, with subscriptions offering access to wide range of game titles that can be downloaded on impulse, a requirement for download speeds approaching 1Gb/s in 2030 may emerge.

Symmetry

- Down >> Up
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- Down ~ Up
- Down < Up
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Duration

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NINTENDO SWITCH™

STEAM®

XBOX LIVE

PlayStation®Store

Trends

- Fewer physical, more digital sales (30:70 in 2017)
- Sales via Games as A Service 'All you can eat' subscription models
- Games getting bigger - 23% CAGR in game size, tracking optical disc storage capacity.
  - 10% are larger than 25GBytes in 2016
- 'Time to playable' is key metric (Suggest: 45mins in 2016; 10-20 in 2030)
  - AAA games can be pre downloaded before the release date
  - All games can be designed to be playable before the whole game has downloaded

Issues

- GAAS model encourages impulse downloads and means pre downloading to mitigate wait time s are not possible
- The inevitability of Day One patches, which can be a significant fraction of the whole game DL size, means even physical games have a DL requirement.

Outcome

Fast bandwidths, up to 1Gb/s, are predicted to be necessary to support fast-enough download speeds in 2030.

How long is too long? Faster will always be better

Full Game Downloads			
	2016	CAGR	2030
Largest 10% games (GB)	25	23%	450
Wait time before playable (mins)	45	-	10-20
Fraction of game before playable	10%	10%	10%
Bandwidth required	12Mb/s		0.5-1Gb/s

Video/pixel streaming of games

Pixel streaming of games (network rendering) requires low latency networks but, bandwidth-wise has requirements similar to video; bandwidths of 6 to 100Mb/s may be required by 2030 depending on the fidelity (HD 720p or 1080, 4k or 8k) the industry is using.

Symmetry

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LIQUIDSKY

Bandwidth

Streaming of appears a successful option, now with PlayStation Now operating at the vanguard. Streams have a requirement for low latency and often have higher frame rates than for film but the bandwidth requirements are broadly similar. HD at 720p is the chosen resolution in 2016/17, whilst streaming games services cope with 5Mb/s today the manufacturers use 40Mb/s straight from the disc – and we can expect those numbers to go north as we move to full HD, 4k and beyond.

	2017	2030
Acceptable	5 Mb/s	6 Mb/s
Premium	40 Mb/s	100 Mb/s

Trends

- Usage & money are moving away from traditional physical retail
- Pixel streaming games is currently niche: PlayStation Now works and will accommodate PS4 titles: Sony appears committed.
- Liquid Sky's approach to cloud rendering (using bespoke PS4 based servers) appears more financially efficient than previous attempts based on generic cloud capabilities
- Microsoft's hybrid cloud rendering, proposed for use with Crackdown 3 (Nov 17), offers another method to help deal with lag; split the rendering so that only non time-critical tasks are performed in the cloud.

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https://www.giantbomb.com/forums/xbox-one-8450/nvidia-demos-hybrid-cloud-rendered-lighting-1446867/
http://www.bbc.co.uk/news/business-36854291

A sort of prediction

The distribution of ‘lo’ and ‘hi’ levels of demand in different household types will vary. Most outcomes suggest the capacity of G.Fast technology (200-350MB/s) will be sufficient to 2030. The highest levels of bandwidth demand relate to game downloads; but are the assumptions valid?

		2017	2030
Regularly require (weekly peak)	Lo	3Mb/s to 30Mb/s	30Mb/s to 70Mb/s
	Hi		
Occasionally appreciate (monthly peak)	Lo	20Mb/s to 70Mb/s	60Mb/s to 0.5-1Gb/s
	Hi		

Assumptions for 2030

1. Games will be downloaded
2. File sizes will grow 20% CAGR
3. We will be happy if the biggest games download in 20 minutes in 2030

Conclusion

1. For most applications including streamed video, bandwidths available through G.Fast technologies (eg 250Mb/s) look like they are enough until 2030.

2. Users downloading (AAA console) games may well appreciate download speeds faster than those offered by G.Fast, we think this will become a particularly apparent around 2030
…but changes in gaming delivery (streaming) would soften this demand considerably.

End.

Thank you

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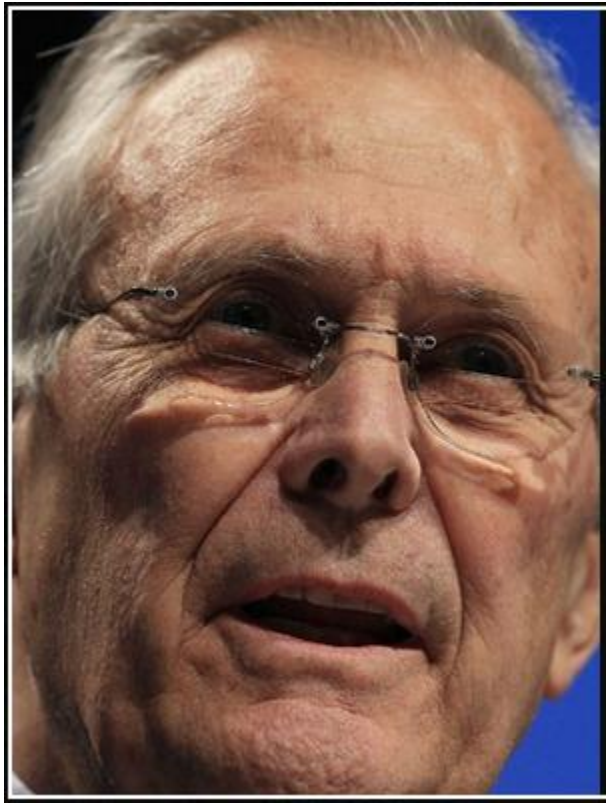

There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.

— Donald Rumsfeld —

AZ QUOTES