



Executive Summary

Residential fixed broadband usage has evolved from static search and information retrieval to multimedia content delivery on a wide variety of devices. In particular, it offers an attractive alternative to subscription TV services because it provides a more flexible and intuitive user interface, personalized on-demand access to video content, a broader choice of viewing platforms, and lower cost. A new multiscreen household usage pattern is emerging where each resident simultaneously employs multiple devices and interacts with broadband as well as subscription TV services. This pattern is not a simple substitution of broadband service for subscription TV service.

The bandwidth capacity of the metro network must be engineered to meet the bandwidth requirement of an average household with usage averaged during the busy period (7 p.m. to 11 p.m.). Today, the average household views more than 40 hours of broadcast subscription TV service per week versus a couple hours per week of Internet TV service. The move from broadcast service, which is multicast across the metro network, to broadband video service, which is unicast, and the use of many more devices in each household will have a massive impact on the required bandwidth capacity of the metro network.

ACG Research presents a five-year projection of average household bandwidth requirements. The prediction is built bottom-up by projecting the bandwidth requirements for individual applications running on PCs, smartphones, tablets, Internet video consoles and smart TVs, gaming consoles, future technologies, and for subscription video on-demand services. Average household bandwidth requirements are estimated to be 2.5 Mbps in 2014 and will grow at a five-year Compound Annual Growth Rate (CAGR) in a range from 19 percent to 44 percent with a most likely value of 31 percent. At the metro network level this suggests that typical 2018 bandwidth requirements will be 7.3 Gbps at the end office, 145 Gbps at the video serving office, and 725 Gbps at the video headend office for a metro area with one million total households. Bandwidth requirements at the video headend in 2018 will be moderated by moving computing and video streaming resources closer to residences.

KEY FINDINGS

Increasing streaming video residential is driving average household bandwidth requirements. It is projected to grow:

- 31% CAGR from 2.5 Mbps in 2014 to 7.3 Mbps in 2018
- 36% CAGR for fixed broadband
- 16% CAGR for subscription VoD
- 56% CAGR for tablets and Internet video consoles
- In 2018 55% of bandwidth will be due to Internet connected large-screen TVs
- 4K TVs will capture a significant share of total bandwidth by 2018

Introduction

Residences are dramatically changing their use of broadband¹ and subscription video² services as broadband has become capable of delivering not only data services but also high-quality large-screen video services. Broadband use also extends to a diverse mix of devices: laptops, smartphones, tablets, gaming consoles, Internet video consoles, and machine to machine (M2M) devices. Subscription video services, in contrast, remain tethered to slow-to-change set-top boxes linked to TV sets. The increased versatility and use of broadband, however, is not causing a simple substitution of broadband service for subscription video service. Synergistic effects between these service offerings are spawning increased network usage and more integrated service provider business models.

These new residential bandwidth growth and usage patterns have different effects on network operators' access, metro, and long-haul networks. Household fixed broadband and subscription video access connections must provide adequate bandwidth to support the simultaneous use of connected devices for the entire household. Subscription video and broadband services are typically provided as a bundle by the same service provider so shifts from subscription video to broadband service do not greatly affect the bandwidth requirement at the residential/network interface point.

The role of the metro network is to aggregate the individual bandwidth requirements of 1,000s to 100,000s of households. Here the shift from subscription video broadcast (multicast) distribution model to the Internet on-demand (unicast) service delivery model has the potential to drive massive increases in the required bandwidth capacity of the metro network. For example, only five percent of broadcast video viewing has shifted to the Internet, but this streaming TV accounts for 67 percent of peak period fixed access traffic³ in North America.

Similar traffic volume increases are not expected to impact the long-haul network as severely. Network operators and content providers are dispersing caches, cloud data centers, and video serving offices down to and within metro areas to reduce costly long-haul traffic requirements.

Methodology

The purpose of the residential broadband and subscription video bandwidth projection is to predict capacity requirements for the metro network⁴. The total bandwidth demand requirement at the metro area reflects the effect of statistical multiplexing traffic from 10,000s to 100,000s of households. Because this projection is built bottom-up from individual devices and applications running within each household two levels of averaging are employed to calculate bandwidth requirements that reflect the effects of statistical multiplexing.

1. Average bandwidth usage is calculated for all households within the metro area. This includes those households that do not use broadband services.

¹ Study analyzes residential fixed broadband services delivered over hybrid fiber/coax, DSL and PON.

² Subscription video is multichannel video subscription service such as cable TV or telco TV.

³ "Global Internet Phenomena Report," 2H 2013, Sandvine.

⁴ U.S. statistical data is used to support the projection. This data is believed to be representative of much usage in developed countries since the U.S.'s broadband speed rating rank is 33rd place, midway among the results for developed countries. See Ookla speed ratings.

2. Average bandwidth usage during the 7 p.m. to 11 p.m. peak period is calculated. This can be calculated by using a concurrency rate, where concurrency rate is defined to be the hours of use during the peak period divided by the number of hours in the peak period. Average peak period bandwidth required is equal to the concurrency rate multiplied by the bandwidth required by the active application.

For example, assume a metro area has 100,000 households and that the average household uses 10 Mbps of bandwidth for one hour during the four-hour peak period. This implies a concurrency rate of 0.25, and it therefore follows that the average peak period bandwidth usage is 2.5 Mbps per average household. The total metro area residential peak period bandwidth requirement is $2.5 \times 100,000/1,000 = 250$ Gbps. A particular service provider would serve a fraction of this total since most metro areas are served by multiple service providers.

The following bandwidth demand segmentation is used to predict bandwidth demand contributions by device, application, and where applicable subtending TV sets (Figure 1).

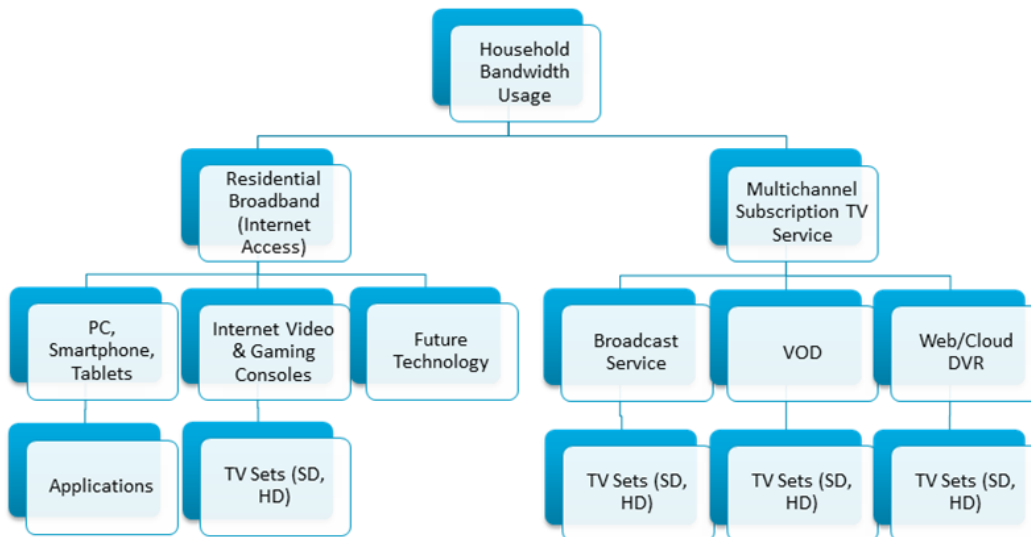


Figure 1 – Segmentation of Household Bandwidth Usage

Total household fixed bandwidth demand consists of broadband (Internet access) and multichannel subscription TV service (cable and telecom TV); direct broadcast satellite service is excluded. Broadband bandwidth requirements are then classified by the type of device used to access the service. PCs, smartphone, and tablet usage is restricted to fixed access only. The devices typically use a Wi-Fi router to access the fixed broadband service. Smartphone and tablet broadband access via mobile data service is excluded from the analysis. Internet video and gaming consoles provide an interface that is used to view Internet video on TV sets. This category also includes smart TVs where the Internet video console function is integral to the TV. Future technologies include 4K TV, 3D TV, M2M devices, and wearables.

The lowest level in the figure includes individual Internet applications such as Email or social networking and in the case of Internet video and gaming consoles the types of subtending TV sets that are used to view the content.

Multichannel subscription TV service is segmented by broadcast service (typically up to 200 channels); Video on Demand (VoD), a unicast service; and web or cloud digital video recorder, an emerging service. VoD service is the only subscription TV service that will increase metro network bandwidth requirements. TV sets are at the lowest segmentation level where the video format (standard definition or high definition) determines the bandwidth requirement. These services use a set-top box to provide the TV connection.

The total bandwidth requirement is calculated for each device and application combination. It is then averaged for the peak usage period by applying concurrency rates (as previously discussed). These individual bandwidth contributions are totaled to produce the average per household requirement.

Application-Specific Bandwidth Requirements

Each broadband application has a unique bandwidth requirement that depends on its function and may also depend on the screen size of the device used to access the application. For example, Twitter requires 50 Kbps while a Netflix HD movie viewed on a laptop requires 5.1 Mbps. The same Netflix movie viewed on a smartphone requires 500 Kbps. In this section application bandwidth requirements using the PC/laptop⁵ are discussed; the next section describes how the device type affects the bandwidth requirement.

Figure 2 presents 10 classes of broadband applications used on PCs and provides examples of some of the most popular applications.

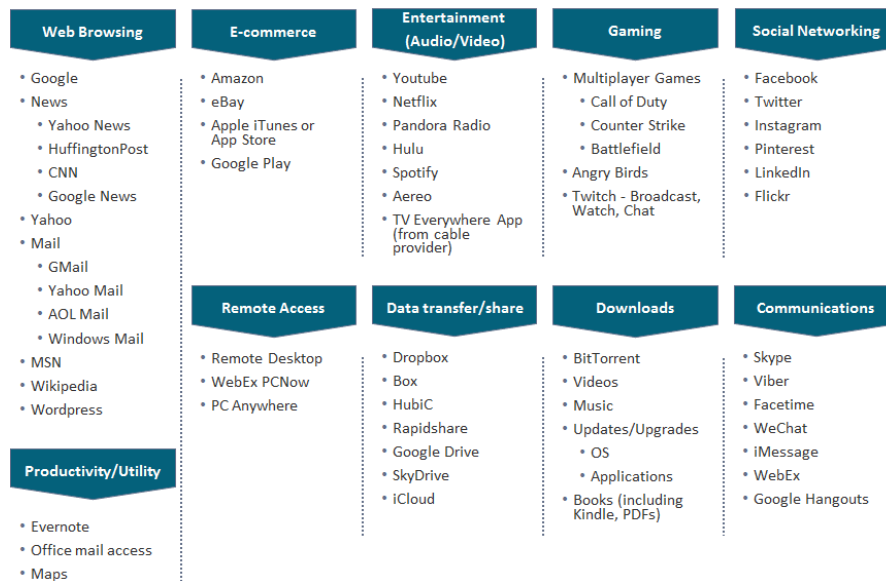


Figure 2 – Popular Applications for PC/Laptop

In general, text and fixed image applications such as Wikipedia, Facebook, and eBay have the lowest bandwidth requirements; big high-resolution videos, downloads, and data transfer applications such as Netflix, Dropbox, and application upgrades have the largest bandwidth requirements.

⁵ The analysis uses separate applications lists and bandwidth allocations for PCs, tablets, and smartphones.

Figure 3 shows the current and projected bandwidth requirements when accessed from a PC for the 10 application categories. The values are weighted to reflect the relative hours of use of each application.

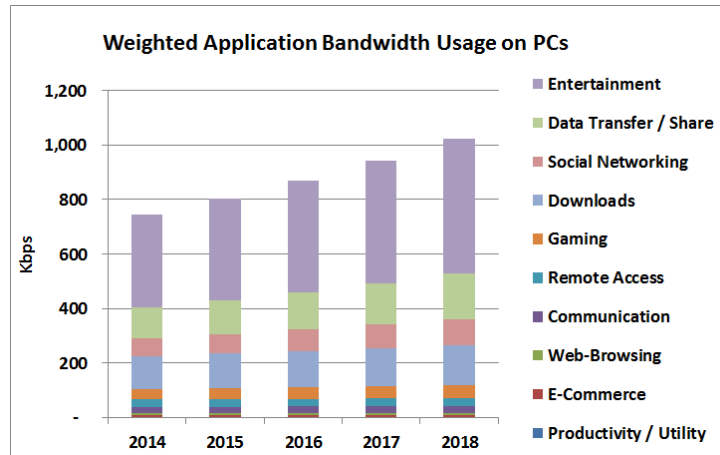


Figure 3 – Weighted Application Bandwidth Usage on PCs

Entertainment has substantially higher bandwidth requirements than the other categories and is projected to further increase its total bandwidth share. This is caused by the shift from subscription video services to online video. Today, Netflix and YouTube are the leading online video services. Data transfer/share is projected to move up from the third largest to the second largest bandwidth source. This is caused by the aggressive marketing of and consumer buy-in to cloud services. The need to share data across multiple devices is a root cause of this demand growth. All other application categories will also see bandwidth increases because streaming video is becoming pervasive.

Device Penetration

Figure 4 projects household device penetration.

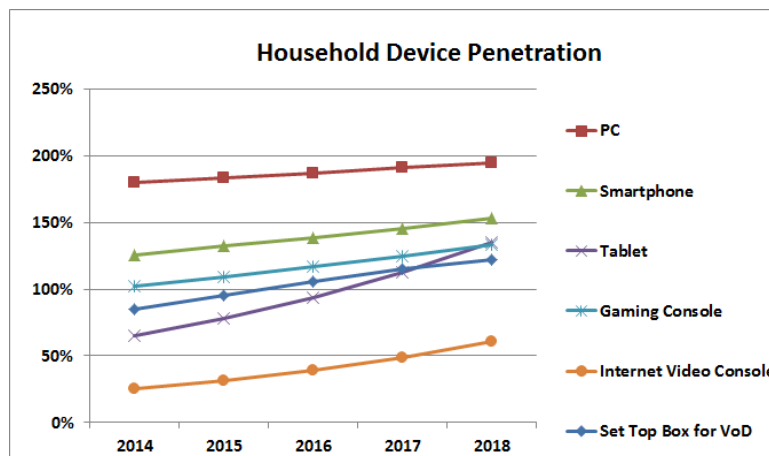


Figure 4 – Household Penetration of Devices

PC/Laptop penetration is nearly two PCs per household, and though sales are slowing because of increased smartphone and tablet purchases the saturation point has not yet been reached. Smartphone

penetration also has slowed but is not yet saturated. Gaming consoles are now in their eighth generation but continue to penetrate the market because of the new interest generated by online gaming and their Internet video capabilities. Tablets are the hottest consumer electronics item and are finding a niche that offers a larger screen than a smartphone, simpler user interface, and increased portability than a laptop.

Set-top boxes that are used to connect HDTVs to subscription TV services (especially VoD) are continuing to penetrate the market because subscription video providers are providing more free content and modernizing their user interfaces to work more like those of over-the-top (OTT) providers.

The Internet video console, which includes smart TVs, holds the greatest potential for rapid future growth and is making the transition from the early adaptor phase to the mainstream growth phase. Recent events that seem likely to fuel its gains include:

- Amazon introduction of Fire TV: This brings another major retailer into the market to compete with early entrants such as Roku, Apple TV, and Google Chromecast.
- Streaming TV as a standard feature on widely deployed BlueRay players, including those of Panasonic, Samsung, and Sony.
- New TVs called smart TVs integrate the Internet video function into the TV set. This makes Internet video easier to use and will aid Internet video adoption since the buyer will not be required to make a separate purchase of an Internet video console.
- Increased cooperation between broadband and content providers: The agreement between Comcast, the largest cable TV company, and Netflix, the largest streaming video provider, to improve the delivery of Netflix videos over Comcast's broadband network provides an important industry precedent and business model for further streaming TV development.
- The successful Verizon court challenge to the network neutrality rules and the FCC's plan to revise the rules will provide broadband providers with the legal means and financial incentives to support (rather than hinder) the development of streaming TV.

Device Screen Size

Device screen size is a major factor in determining bandwidth requirements. Figure 5 compares the bandwidth requirements of devices with widely varying screen sizes.

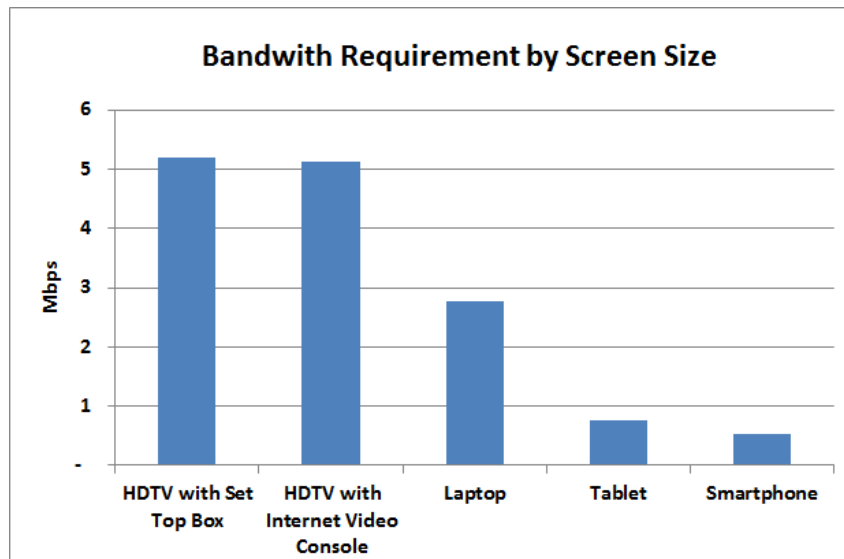


Figure 5 – Bandwidth Requirement by Screen Size

Large-screen TVs require much more bandwidth to deliver an image of comparable quality to that of small-screen devices.

Figure 5 also suggests that as viewers shift from watching subscription TV on large TVs to small portable devices bandwidth requirements within the home will be reduced. However, at the metro network level the shift from multicast viewing to unicast viewing will much more than offset this effect.

Future Technology

Some of the most promising technologies likely to impact residential fixed broadband requirements include:

- M2M: Home security and automation, smart utility metering, maintenance, building automation, healthcare and consumer electronics.
- Wearables: Smart watches and glasses, heads-up displays, health and fitness trackers, wearable scanners and navigation devices, and smart clothing.
- 3D TV: 3D TV sets are sold by LG, Vizio, Panasonic, Samsung, and others. The 3D video stream requires about 12 Mbps bandwidth.
- 4K TV: 4K Ultra-high definition TV sets have 4,000 lines per frame video format. The improved resolution becomes apparent at screen sizes in excess of 40 inches. This format is being rapidly adopted by cinemas as a means of differentiating themselves from TV offerings. The 4K video stream requires at least 20 Mbps bandwidth.

Figure 6 shows the total bandwidth requirement for the three most likely future technologies.

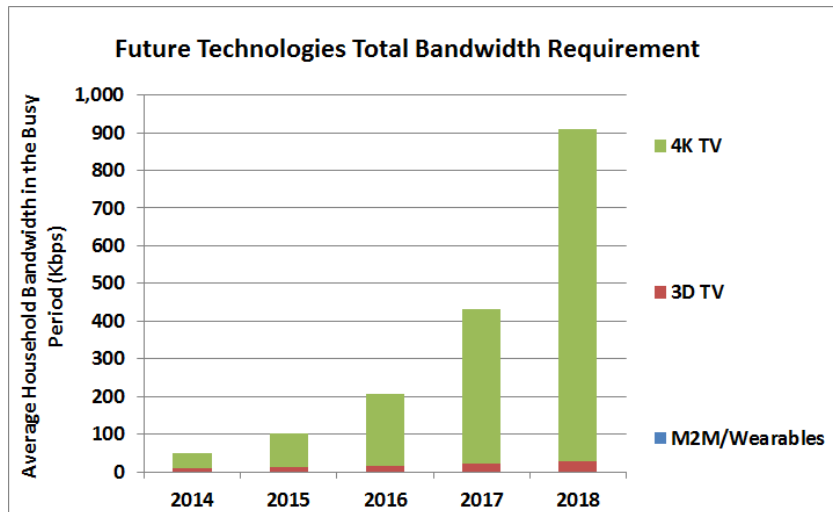


Figure 6 – Average Bandwidth Requirement in the Busy Period for Future Technologies

4K TV is being introduced this year. 4K infrastructure is deployed in many studios as is projection equipment in 10,000s of cinemas worldwide. This provides the basis for rapid consumer uptake of 4K TV sets once consumer electronics companies reduce their cost. Consequently, 4K TV is likely to become a mainstream offering within five years⁶. 3D TV, however, has not met with strong acceptance by consumers, and the necessary production infrastructure is not widely deployed. It seems unlikely that 3D TV will become a mainstream offering. M2M and wearables are already being deployed. Home security and energy management seems to be the most successful offering. These devices require only about 30 Kbps of bandwidth and transmit data in intermittent short bursts; their average bandwidth requirement averaged over the busy period is infinitesimal compare to 3D TV or 4K TV.

Concurrency⁷

Measuring the bandwidth requirement on the metro network requires consideration of the concurrency factor. More usage hours during the busy period will boost the metro network bandwidth requirement. Figure 7 shows the concurrency factors for all device types and subscription video on demand (VoD) services.

⁶ 4K TV makes bandwidth contributions to the Set Top Box for VoD and Internet Video Console categories. 41% of 4K TV is attributable to Set Top Box usage and 59 percent is attributable to the Internet Video Console category in 2018.

⁷ See the methodology section for a definition of concurrency and a discussion of its importance in measuring bandwidth requirements of metro networks.

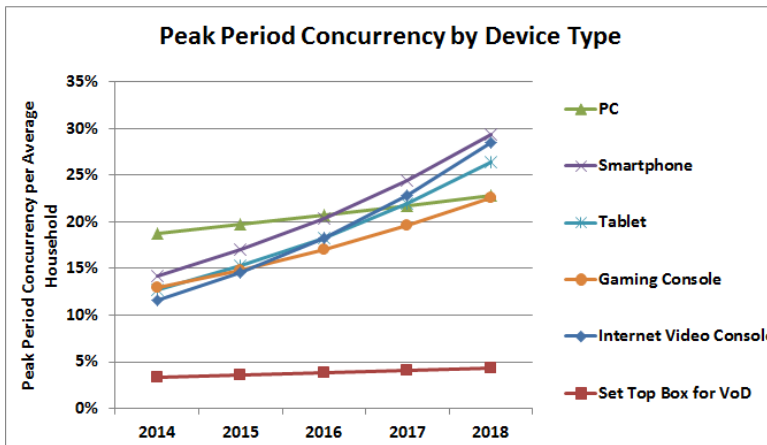


Figure 7 – Peak Period Concurrency by Device Type for the Average Household

Internet viewing habits are expected to become much like those of broadcast TV as the technology becomes mainstream. This will boost concurrency of all broadband device types because average weekly online video use is currently only two hours per week compared to about 40 hours per week for broadcast TV. Internet video console concurrency will rise fastest because the Internet video console acts much like a substitute for the set-top box of subscription TV. The chart also shows concurrency for set-top boxes used to deliver subscription VoD. Even though subscription services will be negatively impacted by the increased use of broadband video, modest increases in concurrency are projected because subscription video providers are moving aggressively to make their VoD offerings easier to use by introducing new user interfaces that look and feel more like those of OTT services.

Smartphones and tablets connected via home Wi-Fi will see steadily increasing usage as content providers continue to redesign their offerings to be more suitable for small-screen use and subscription video providers pursue their TV Everywhere initiatives.

Household Bandwidth Usage

Error! Reference source not found. summarizes total average household bandwidth requirements with usage by device type averaged over the busy period.

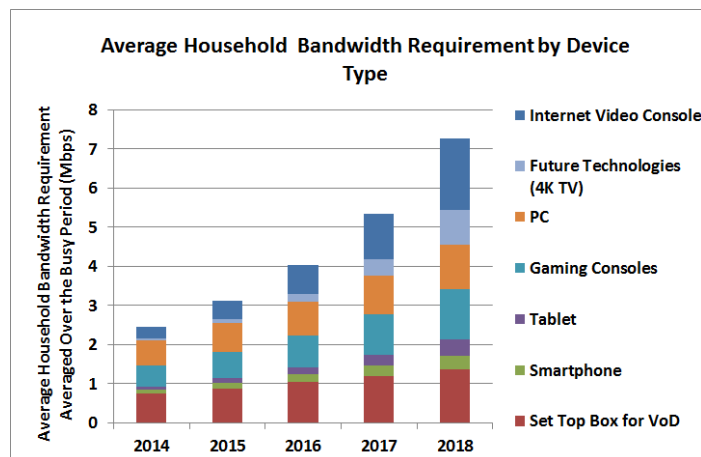


Figure 8 – Total Average Household Broadband and Subscription VoD Bandwidth Requirement

Total average household bandwidth requirements are projected to grow at 31 percent CAGR from 2.5 Mbps in 2014 to 7.3 Mbps in 2018. The shift from viewing TV over multichannel video subscription services to Internet video is a root cause driving increased bandwidth requirements. Streaming video applications account for the majority of the bandwidth requirement for all device types⁸. Other factors driving increasing bandwidth requirements include multiscreen use that is producing a synergistic effect where new devices, especially smartphones and tablets, are supplementing subscription video services rather than replacing them; the strong growth in large screen TVs; increasing penetration of HDTV; and the emergence of ultra-high definition TV.

Error! Reference source not found. also shows that though the bandwidth requirements of smartphones and tablets connected to home Wi-Fi will rapidly increase their bandwidth requirements in the next five years; their relative contribution to the total home bandwidth requirement will be small because of screen sizes that are small compared to devices that use large-screen HDTV for video displays.

Though subscription VoD bandwidth requirements also will rise during the next five years, its growth will be inhibited by the shift to Internet-based video.

Forecast Sensitivity

Sensitivity studies were performed to test the robustness of the forecast to changes in the modeling assumptions. Detailed pessimistic, most likely, and optimistic assumptions were made for the amount of time PCs, smartphones, and tablets are used for high-bandwidth entertainment applications versus low-bandwidth social networking, E-commerce, and web-browsing applications. Table 1 shows a range of assumptions judged to be most critical to the development of Internet-based, large-screen video entertainment.

Sensitivity Factors	CAGR (%)		
	Pessimistic	Most Likely	Optimistic
4K TV Adoption	50%	96%	150%
VoD Concurrency	4%	7%	10%
Internet Video Console Adoption and Concurrency	15%	25%	30%
Gaming Console Adoption	0%	7%	10%
Gaming Console Concurrency	5%	15%	20%
PC Concurrency	0%	5%	10%

Table 1 – Large-Screen Video Forecast Sensitivity Factors

Figure 9 shows total household bandwidth requirements for each of the three scenarios.

⁸ Subscription VoD also is a type of unicast streaming video.

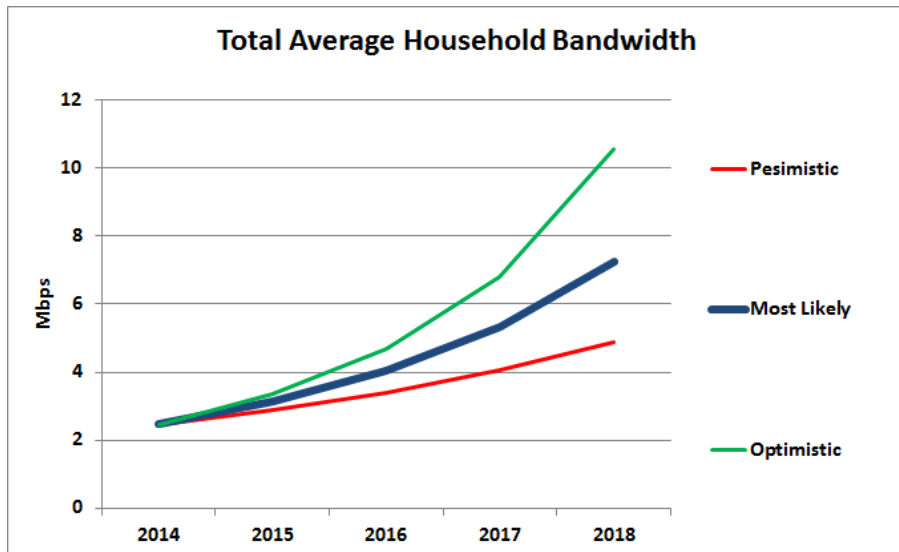


Figure 9 – Total Household Bandwidth Requirements Sensitivity Analysis

The figure shows that there is more upside than downside uncertainty in the projection of average household bandwidth requirement. Five-year CAGR is estimated to range from a low of 19 percent to a high of 44 percent with a most likely value of 31 percent. Double-digit growth in residential fixed bandwidth requirements seems certain with only the degree of growth in doubt.

Figure 10 shows that most of the uncertainty is caused by the assumptions affecting the development of large-screen Internet TV usage.

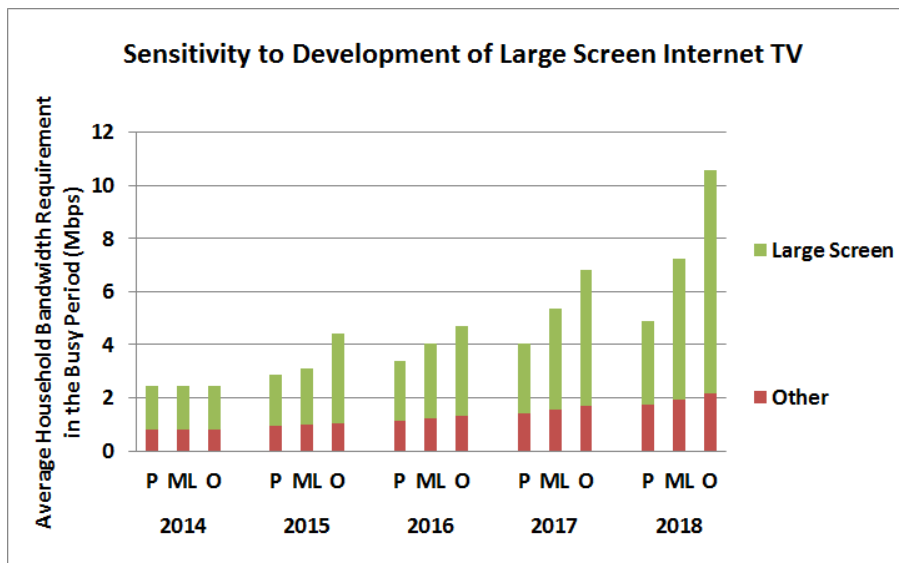


Figure 10 – Sensitivity of Bandwidth Projection to Large-Screen Internet TV Usage

Comparison of **Error! Reference source not found.** with Figure 10 shows that the increasing bandwidth requirements for Internet video consoles and 4K TV in 2017 and 2018 have major impacts on the overall five-year household bandwidth requirements.

Network Implications

Table 2 shows bandwidth requirements within the metro network for a typical residential fixed broadband service provider.

Network Segment	Total Households	Share of Addressable Market	Addressable Market (Households)	Bandwidth Requirement (Gbps)		CAGR
				2014	2018	
End Office	5,000	20%	1,000	2.5	7.3	31%
Video Serving Office	100,000	20%	20,000	49	145	31%
Video Headend Office	1,000,000	20%	200,000	491	725	10%

Table 2 – Metro Network Fixed Residential Bandwidth Requirements for a Typical Broadband Provider

Under the present mode of operations on-net computing resources and video streaming content are located at the video headend office. Bandwidth requirements therefore scale linearly across the three-level hierarchy of end offices, video serving offices, and video headend office. Service providers are beginning to exploit the economics of virtualized computing and storage to move content, caching, and video transcoders closer to households to reduce metro network costs. The 2018 bandwidth requirements shown in Table 2 assume that content, caching, and video transcoding resources are established at the video serving offices. The table reflects an estimate that traffic flows between the video headend and video serving offices are reduced by 50 percent of the projected capacity requirement. This reduces the capacity requirement CAGR on the video serving office to video headend from 31 percent to 10 percent. There is a further opportunity to reduce network capacity requirements by establishing content, caching, and video transcoding capabilities at the end offices.

Conclusion

Residences are dramatically changing their use of broadband and subscription video services as broadband has gained the capability to stream high-quality video and support varied devices. Subscription video service is tethered to the set-top box, and its user interface has not kept pace with that of Internet streamed video. However, broadband is not a simple substitute for subscription video service because multiscreen use is spawning synergism between the two services. This is increasing fixed residential service usage and driving strong growth in residential bandwidth demand requirements.

Average household fixed broadband and subscription video bandwidth requirements with usage averaged during 7 p.m. to 11 p.m. (busy period) is estimated to be 2.5 Mbps today and projected to grow at a five-year CAGR in a range from 19 percent to 44 percent with a most likely value of 31 percent. The shift from viewing TV over multichannel subscription video services to Internet video is a root cause of this growth. Multiscreen use of large-screen TVs, PCs, tablets, and smartphones also is an important driver of this growth.

The bandwidth requirements of the metro network will be impacted most heavily by this increase in residential fixed access bandwidth requirements growth. For example, within a metro area of one million households a typical service provider will see its end office residential traffic requirement

increase from 2.5 Gbps in 2014 to 7.3 Gbps in 2018; its video serving office residential bandwidth requirement increase from 49 Gbps to 145 Gbps; and its video headend office residential bandwidth requirement increase from 491 Gbps to 725 Gbps during the same period. The increase in the traffic requirement at the video headend office will be less severe because service providers are responding to these large traffic increases by moving computing and video streaming resources closer to residences.

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