4 Motivation for NG-EPON

4.1 Background and market drivers

With the first trials of first generation of EPON (1G-EPON) taking place in 2005, EPON quickly emerged as the market-leading optical access technology in multiple application areas in different countries around the world.

Editorial Note (to be removed prior to publication): Glen K. to update market figures and provide necessary revisions to the text. the following three paragraphs were copied from text of the article: "IEEE 1904.1 standard: SIEPON Architecture and Model"

In Japan, as of the end of September 2011, there were 21.4 million EPON subscribers, of which 12.9 million represented single family units (SFU) and 8.5 million represented multi-dwelling units (MDU). The SFU/MDU distinction in this context represents not the actual housing configuration, but rather a networking configuration: in SFU configuration, an optical fiber reaches a network unit that serves a single family (subscriber), whereas in MDU configuration, a network unit serves multiple subscribers and is typically located in the basement or in a cabinet.

NTT has 74.4% share of EPON subscribers in Japan. Most of the rest are served by KDDI, the second largest carrier in Japan. Generally, 100 Mb/s or 200 Mb/s services are offered, with KDDI offering 1 Gb/s service in some areas. The immediate target of NTT is to achieve 20 million FTTH subscribers [XXX].

Editorial Note (to be removed prior to publication): reference needed

Korea Telecom (KT) began EPON deployments in Korea in 2006. As of April 2012, EPON serves more than 3.2 million FTTH, and 1 million FTTB subscribers, which together represent 53% of all KT's broadband customers. EPON service contracts generally provide 50-100 Mb/s of bandwidth and may include IPTV and VoIP services [XXX].

Editorial Note (to be removed prior to publication): reference needed

China Telecom started a comprehensive EPON interoperability program in 2006. Interoperability tests were first conducted among the chip vendors and then among the system vendors. As part of the interop tests, China Telecom demonstrated in 2007 a large-scale, comprehensive chip-level and system-level interoperability among EPON devices. With more than 60 million households passed and 20 million active broadband subscribers, China Telecom is today the largest and fastest growing FTTx network operator. They are on track to deploy fiber within reach of 30 million subscribers in 2012, of which half are expected to subscribe to the new fiber-based services [XXX].

Editorial Note (to be removed prior to publication): Do we have updated information on this? We are referring to 2012 as a present/future time, but it's in the past. Glen K. to update market figures and provide necessary revisions to the text.

Editorial Note (to be removed prior to publication): reference needed

In July 2009, China Telecom launched a new interoperability testing program, this time focused on 10G-EPON, including both symmetric (10G/10G) and asymmetric (10G/1G) EPON ASICs and systems. This sustained and extensive program continued through 2011 and culminated in the introduction of fully interoperable, commercial quality equipment from a large number of suppliers.

In December of 2011 NTT demonstrated a field trial of long-reach dual-rate 10G-EPON in Japan. The demonstrated technology supported both 10G/10G ONUs and 1G/1G ONUs, between the cities of Sapporo and Chitose [ma2].

Responding to the increasing bandwidth demand from its customers in Korea, Korea Telecom is planning a pilot deployment of 10G-EPON by the end of 2012 [ma3].

Editorial Note (to be removed prior to publication): We are referring to something in the past as a future event. Where do we get updated information. Glen K. to update market figures and provide necessary revisions to the text.

Intending to significantly enhance access to broadband applications and extend mobile Internet penetration, China [bcnp] has plans to introduce FTTB for urban households and broadband access by 2015 in rural districts. Expected take rates for fixed broadband reaching 50% and the fraction of villages provided with broadband services is expected to reach 95%. Public institutions such as schools, libraries, hospitals, etc., are expected to have nearly universal broadband access. The minimum offered broadband access rates for urban and rural families are set at 20 Mb/s and 4 Mb/s, respectively, while they can reach 100 Mbps in some developed cities.

Expecting broadband applications to be deeply integrated into day-to-day life, mobile Internet access to be universally popular by 2020, under the same strategy, China plans for take rates of fixed broadband access and mobile 3G/LTE broadband access to reach 70% and 85%, respectively. The fraction of villages provided with broadband services is expected to reach 98%. The minimum offered broadband access rates for urban and rural families are set at 50 Mb/s and 12 Mb/s, respectively, while they can reach 1 Gb/s in some developed cities.

Bandwidth targets for individual types of FTTx subscribers and adoption timelines are included in [bcnp].

~~**Figure 06: Targets and Timetable of the Broadband China National Plan [bcnp]**~~

~~**Indicators**~~	~~**Units**~~	~~**2013**~~	~~**2015**~~	~~**2020**~~
~~1. Scale of broadband users~~				
~~Fixed broadband access users~~	~~100M~~	~~2.1~~	~~2.7~~	~~4.0~~
~~Among them: FTTH users~~	~~100M~~	~~0.3~~	~~0.7~~	~~–~~
~~Among them: Urban users~~	~~100M~~	~~1.6~~	~~2.0~~	~~–~~
~~Among them: Rural users~~	~~100M~~	~~0.5~~	~~0.7~~	~~–~~
~~3G/LTE users~~	~~100M~~	~~3.3~~	~~4.5~~	~~12~~
~~2. Degree/Level of broadband penetration~~				
~~Fixed broadband household penetration~~	~~%~~	~~40~~	~~50~~	~~70~~
~~Among them: Urban~~	~~%~~	~~55~~	~~65~~	~~–~~
~~Among them: Rural~~	~~%~~	~~20~~	~~30~~	~~–~~
~~3G/LTE~~	~~%~~	~~25~~	~~32.5~~	~~85~~

Commented [MH1]: Table contains no useful information – summarized via reference to the table in the report – any interested party can go and read figures there. Without broader context, table is not very useful

~~3. Broadband network capabilities~~				
~~Urban~~	~~Mbps~~	~~20 (80% users)~~	~~20~~	~~50~~
~~Among them: developed cities[1]~~	~~Mbps~~	~~–~~	~~100~~	~~1000[2]~~
~~Rural~~	~~Mbps~~	~~4 (85% users)~~	~~4~~	~~12~~
~~Large enterprises~~	~~Mbps~~	~~–~~	~~>100~~	~~>1000~~
~~International outlet~~	~~Gbps~~	~~2500~~	~~6500~~	~~–~~
~~FTTH coverage family~~	~~100M~~	~~1.3~~	~~2.0~~	~~3.0~~
~~Scale of 3G/LTE base station~~	~~100M~~	~~95~~	~~120~~	~~–~~
~~Villages~~	~~%~~	~~90~~	~~95~~	~~>98~~
~~4. Broadband information applications~~				
~~Number of internet users~~	~~100M~~	~~7.0~~	~~8.5~~	~~11.0~~
~~Among them: rural users~~	~~100M~~	~~1.8~~	~~2.0~~	~~——~~
~~Internet data~~	~~Terabytes~~	~~7800~~	~~15000~~	

~~4.2 Bandwidth Consumption Trends~~

~~4.3~~4.2 Bandwidth consumption around the world – current situation

By the end of the H1 2014 [sand], in North America, the median bandwidth usage (per subscriber) in the fixed access network is on the order of 17.4 GB downstream and 1.4 GB upstream per month, while the mean reaches almost 43.8 GB downstream and around 7.6 GB upstream. Top users (also sometimes referred to as *power users*) consistently exceeded 5 TB of monthly bandwidth usage, typically shared among multiple devices at home. Note that there is a steady bandwidth consumption growth of more than 30% per year, observed by most of the service providers, irrespective of the access technology they use in their first mile networks. What is even more interesting is the fact that the large growth in the mean and median bandwidth consumption in fixed access networks (when compared with 2011 numbers as published by the same source) is mainly attributed to the growing use of Real-Time Entertainment (RTE) services. RTE services are responsible for about 63% of peak bandwidth consumption during busy hours [sand].

In NA (see Figure 7), Netflix continues to be the main contributor to downstream bandwidth consumption, accounting for more than 34% of downstream traffic during the peak period. Moreover, with the introduction of 4K Super HD content, Netflix is expected to continue~~s~~ to drive bandwidth consumption in the downstream, ~~and is likely to continue to increase~~ increasing its overall share as 4K TVs become more popular. When combined with other similar services (YouTube, Amazon Video, ~~and~~ Hulu, etc.), more than 65% of downstream traffic is consumed by RTE services focused on video delivery.

[1] ~~Chinese first-tier cities with relatively highest level of economic development and income of residents, such as Shanghai, Beijing and Guangzhou.~~

[2] ~~Including users in developed cities who have demand for offered rates above 1 Gb/s and good economic conditions~~

The same source [sand] also provides numbers for bandwidth consumption in fixed access networks in Europe, Africa, Latin America, and APAC regions.

In Europe the median values are smaller than in NA (around 7 GB downstream and less than 1 GB upstream), with the mean values reaching roughly half of the bandwidth consumption reported for NA-based fixed access subscribers. This fact is mostly attributed to pervasive xDSL access in Europe, and slower adoption of higher-speed copper and fiber-based access technologies. European countries with limited access to RTE content have typically higher volume of file-sharing traffic (see Figure 8), the fact that ~~which has been~~ was observed before in NA~~,~~ when the RTE services were ~~at~~ in their infancy. It is expected that as Over The Top (OTT) RTE services become more generally accessible (both technically, as well as economically), the traffic distribution becomes more similar to the one observed in NA, decreasing the share of file sharing services and increasing the share of RTE services.

Commented [MH2]: Language fixes

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	36.35%	Netflix	31.62%	Netflix	28.18%
2	HTTP	6.03%	YouTube	18.69%	YouTube	16.78%
3	SSL	5.87%	HTTP	9.74%	HTTP	9.26%
4	Netflix	4.44%	BitTorrent	4.05%	BitTorrent	7.39%
5	YouTube	3.63%	iTunes	3.27%	iTunes	2.91%
6	Skype	2.76%	MPEG - Other	2.60%	SSL	2.54%
7	QVoD	2.55%	SSL	2.05%	MPEG - Other	2.32%
8	Facebook	1.54%	Amazon Video	1.61%	Amazon Video	1.48%
9	FaceTime	1.44%	Facebook	1.31%	Facebook	1.34%
10	Dropbox	1.39%	Hulu	1.29%	Hulu	1.15%
		66.00%		76.23%		73.35%

sandvine

Figure 7: Top 10 peak period applications - NA, fixed access [sand]

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	48.10%	YouTube	28.73%	YouTube	24.21%
2	YouTube	7.12%	HTTP	15.64%	BitTorrent	17.99%
3	HTTP	5.74%	BitTorrent	10.10%	HTTP	13.59%
4	Skype	4.96%	Facebook	4.94%	Facebook	4.65%
5	Facebook	3.54%	Netflix	3.45%	Netflix	3.33%
6	Netflix	2.83%	MPEG - Other	3.10%	MPEG - Other	2.57%
7	SSL	2.47%	RTMP	2.82%	RTMP	2.42%
8	eDonkey	1.12%	Flash Video	2.56%	Skype	2.32%
9	Dropbox	1.12%	SSL	1.91%	Flash Video	2.16%
10	RTMP	0.85%	PutLocker	1.25%	SSL	2.03%
		77.83%		73.23%		75.25%

sandvine

Figure 8: Top 10 peak period applications - Europe, fixed access [sand]

Interestingly enough, these numbers for Latin America are only around 25% lower when compared to NA, indicating that local service providers are quickly closing the technology gap and migrating their customers to higher speed links. When compared with NA, the average bandwidth consumption in the APAC region is lower. It is also interesting to note that the upstream bandwidth consumption is larger, implying that more digital content is being created and shared online. Despite this lower overall bandwidth usage per subscriber, the habits of the digital content consumption in Latin America are very similar to that observed in NA and in Europe. Unsurprisingly, RTE services generate the majority of the downstream traffic during peak hours, while the share of web browsing and file sharing services is dropping continuously as RTE OTT services become more available and accessible to an average consumer. At this time YouTube dominates downstream bandwidth consumption. The recent emergence of proxy caches allowing Netflix streaming to areas without the official support for Netflix drove the large (5%) increase in Netflix traffic in Latin America, which was previously observed at <1% range as of the end of the H1 2013, as reported by the same source.

Commented [MH3]: Clarification on what "lower" really means here

Commented [MH4]: Reference for the data

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	29.70%	YouTube	36.82%	YouTube	33.29%
2	YouTube	14.70%	HTTP	20.01%	HTTP	18.10%
3	Facebook	8.55%	BitTorrent	7.63%	BitTorrent	11.14%
4	HTTP	8.01%	Facebook	6.22%	Facebook	6.59%
5	Ares	5.61%	SSL	2.81%	SSL	2.88%
6	SSL	3.22%	MPEG - Other	2.68%	MPEG - Other	2.36%
7	Skype	2.81%	Flash Video	2.23%	Flash Video	1.99%
8	SPDY	1.00%	Netflix	2.17%	Netflix	1.94%
9	RTMP	0.97%	RTMP	1.79%	RTMP	1.66%
10	eDonkey	0.77%	SPDY	1.22%	Ares	1.64%
		75.34%		83.57%		81.60%

Figure 9: Top 10 peak period applications – Latin America, fixed access [sand]

A unique characteristic of the APAC region is the popularity of peer casting applications, such as PPStream and QVoD that are not used anywhere else around the world at a similar scale. These applications allow users to stream live events. Simultaneously, users participate in distribution of other data streams to viewers, providing distributed caching capabilities. Both of these features of peer casting applications drive the observed high upstream bandwidth consumption. File sharing applications remain strong, especially in the upstream, contributing to roughly 45% of the volume of transmitted data. Similar to other regions, the lack of well-established OTT RTE services skews the traffic distribution towards free YouTube content and file sharing applications, providing access to video content not available through other digital channels.

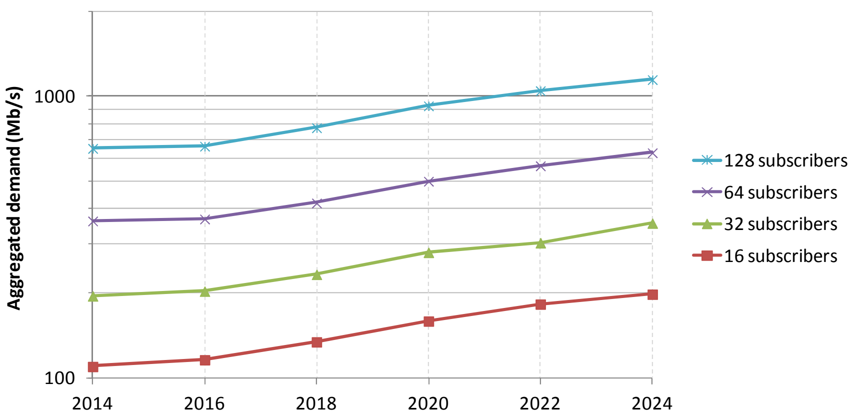
	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	35.72%	YouTube	31.22%	YouTube	23.30%
2	QVoD	14.10%	BitTorrent	14.25%	BitTorrent	21.18%
3	YouTube	6.65%	HTTP	10.48%	HTTP	8.08%
4	RTSP	5.00%	QVoD	4.51%	QVoD	7.61%
5	Thunder	4.03%	Facebook	4.45%	Facebook	3.57%
6	HTTP	3.04%	MPEG - Other	3.65%	RTSP	3.24%
7	Skype	2.03%	RTSP	2.40%	MPEG - Other	2.62%
8	Facebook	1.74%	iTunes	1.70%	Thunder	2.20%
9	PPStream	1.30%	Dailymotion	1.69%	iTunes	1.28%
10	Funshion	1.17%	Flash Video	1.67%	Dailymotion	1.21%
		74.78%		76.03%	0.00%	74.28%

Figure 10: Top 10 peak period applications – APAC, fixed access [sand]

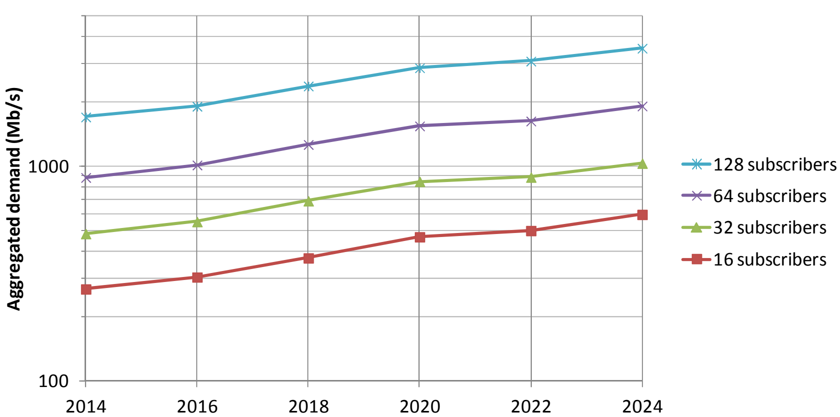
~~4.4~~4.3 ~~Forecasting Bandwidth~~ Bandwidth consumption forecast – residential access

The bandwidth requirement for a TDM-PON is a function of the aggregated bandwidth demand of all the subscribers on that PON. A statistical model, described in [eh1] and [eh3], forecasts aggregate residential downstream bandwidth demands. ~~Since it is not possible to predict the future with certainty, t~~The model attempts to bound the forecast with a “moderate” set of inputs and a “heavy” set of inputs. The heavy inputs, in relation to the moderate inputs, assume ~~more~~ a larger number of concurrent video streams per home, relatively higher penetration of HD and UHD displays and higher availability of HD and UHD content, ~~lighter~~ lower video compression ratio for improved video quality, and ~~larger and~~ faster ~~growing~~ growth in bursty traffic. In both examined scenarios, ~~it is most appropriate for~~ NG-EPON needs to be able to support the ~~“~~worst~~-~~-case~~”~~ bandwidth consumption, where all video traffic, including all linear TV (i.e., traditional scheduled non-time-shifted television service), is ~~unicasted in band~~transmitted as unicast to individual subscribers. The forecasts for aggregate bandwidth demand at ~~Peak~~peak-hours ~~forecasts~~ for both the moderate and heavy demand scenarios are presented in Figure 11. ~~By far, most of the demand results from managed plus OTT video traffic.~~

Commented [MH5]: Language simplification and removal of fluff



(a) Moderate demand scenario



(b) Heavy demand scenario

Figure 11: Forecasted demand vs. the number of aggregated subscribers, peak hour

The aggregated bandwidth demand~~s~~ shown in Figure 11 includes peak-hour sustained bandwidth demand and peak-hour average burst bandwidth demand. To complete the demand picture, it is necessary to add the maximum individual peak burst demand, which requires additional bandwidth for headroom, the size of which ~~. The magnitude of this headroom must at least~~ needs to accommodate a least one successful speed test run by a subscriber already receiving the maximum offered service level~~ offered~~. This extra bandwidth is ~~required~~ necessary because subscribers ~~will~~ expect to be able to successfully ~~pass~~ complete a speed test even during peak hour traffic. The probability of ~~(the case where~~ multiple subscribers ~~run~~ executing simultaneous ~~a~~ speed tests ~~simultaneously~~ is ~~neglected)~~negligible. For example, in 2024, it is expected that under ~~in~~ the heavy demand scenario and with ~~, for~~ 32 subscribers~~ on a TDM PON~~, ~~there will be~~ consume approximately 1 Gb/s of downstream peak hour traffic~~ in the year 2024~~. If 1 Gb/s service is ~~to be~~ offered over this PON, then 1 Gb/s of bandwidth headroom is required to support peak bursts of ~~1~~ 1 Gb/s, ~~for~~ resulting in the ~~a~~ total aggregate downstream bandwidth demand of 2 Gb/s during peak hours.

Commented [MH6]: Language simplification and removal of fluff

~~The above forecast~~Using the model described above, it can be concluded ~~indicates~~ that 10G-EPON can support bandwidth demand in residential ~~bandwidth~~ access ~~demands plus a 1 Gb/s service offer~~ up to the year 2024[3]. ~~WDM-PON FTTH systems, with at least 1 Gb/s dedicated bandwidth per wavelength, could also support 1 Gb/s service. There is no differentiation on this point among these FTTH technologies.~~

~~Therefore, perhaps the most important bandwidth differentiation that can be offered by NG-EPON for residential services is the peak hour bandwidth headroom, which determines the maximum burst demand that can be supported and therefore the maximum service level that an operator can offer. For TDM-PON MAC domains, this can be determined by simply subtracting the forecasted aggregate demand in Figure 11 from the TDM-PON MAC downstream bandwidth capacity (less overheads). For existing and NG-EPON candidate FTTH technologies, t~~The maximum service levels ~~that can be offered~~ supported by different FTTH technologies (both existing and emerging) by~~in~~ the year 2024 are ~~indicated~~ shown in Figure 12.

Commented [MH7]: Lots of unnecessary words – we need to state just facts we observe based on the model: 10G-EPON is sufficient until 2024 (likely) and then blend in Figure 12 and conclusions from it.

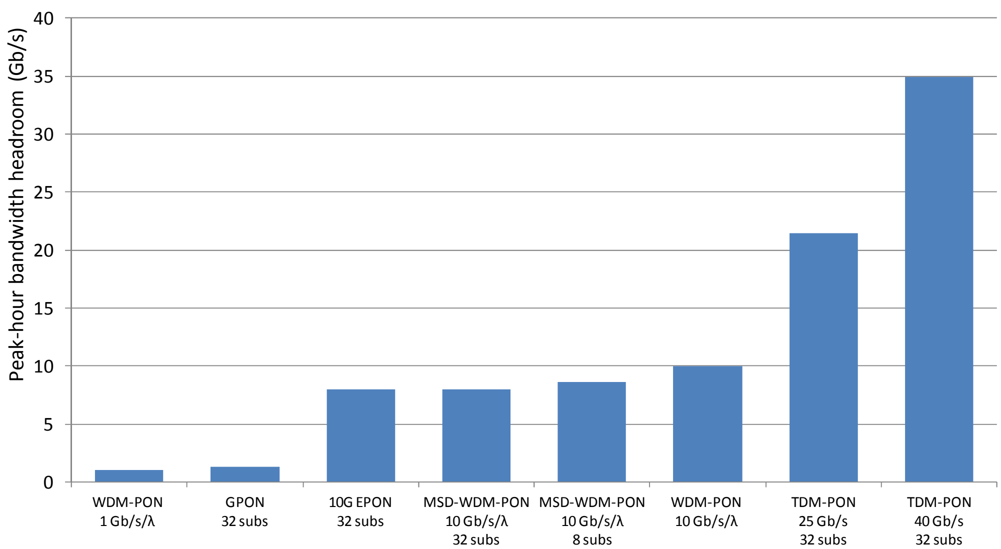


Figure 12: Peak-hour bandwidth headroom = maximum service level that can be offered for existing and NG-EPON candidate access technologies in year 2024 (~~*~~32 subscribers per PON).

~~Figure 12 indicates, from a residential bandwidth point of view, that to significantly differentiate itself from existing 10G EPON, an NG-EPON system will need to support more than 10 Gb/s service. In other words, a~~

[3] If, instead of a statistical view a "worst-case" view is preferred, a 10G-EPON could support 32 subscribers, each streaming four simultaneous streams of UHD-2 "8k" video at 50 Mb/s each, and still have enough headroom to support bursts, and therefore a service offer, of more than 2 Gb/s.

~~TDM-PON MAC must support an aggregate bit rate or a WDM-PON must support a per-wavelength bit rate of more than 10 Gb/s.~~

Commented [MH8]: Not clear why this statement is needed in the first place – the point is not to build something different for the sake of being different but to address the operator demand in the following years

~~4.5~~4.4 Bit Rate Trends

Over the last few years, there has been a clear trend for a steady increase in bandwidth consumption for residential and business customers, as shown in Figure 13, with an example of data rates for ~~for~~ cable modems. Similar curves could be also drawn for other access media, including twisted pair, as well as fiber. The observed increase is primarily motivated by both evolutionary and revolutionary end-user applications, requiring online connectivity, and attracting larger quantities of individual consumers as well as driving the bandwidth consumption per single user.

Commented [MH9]: Make sure that the cable modems are just an example here for other devices.

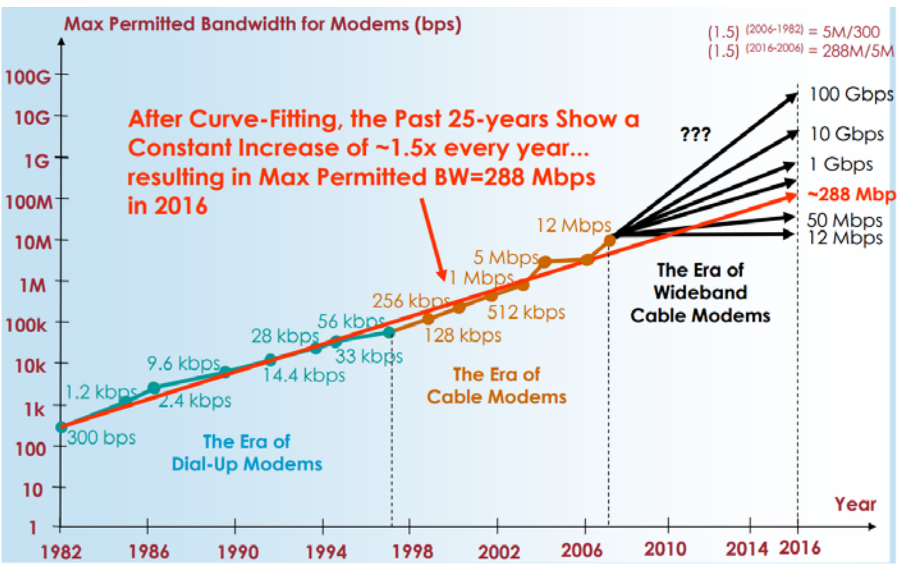


Figure 13: Maximum permitted bandwidth for cable modems [XXX]

Web 2.0 with its video-oriented and interactive content is one good example of a revolutionary change in the online services consumed by a large pool of users. The transition from SD to HD quality for streaming video services is an example of evolutionary change in the online services. Today (in 2014) we observe this transition as well, with some streaming platforms ~~(http://www.cnet.com/news/netflix-begins-4k-streams/)~~(for example, Netflix) beginning to offer 4K resolution content to their subscribers. It is expected that with the increasing popularity of 4K-compatible TV sets, the volume of 4K content is expected to become much larger, ~~driving higher~~ further increasing the average bandwidth consumption observed in the access network.

Formatted: No underline, Font color: Auto

Commented [MH10]: Netflix is just an example here

Commented [MH11]: Language improvement

However, it is also necessary to remember that the number of simultaneous sessions established between the subscriber LAN and individual services, as well as the duration of such sessions also affect the total bandwidth consumed in the access network. In the era of dial-up modems, connections were typically made on demand, when the user needed to download and/or upload some data, resulting in short sessions, and typically very few simultaneous sessions established during such a connection. Along with the start of the era of broadband access devices and always-on network connectivity, the number and duration of individual data sessions increased substantially. Individual users started streaming data (music, video, and other content) directly off the web, rather than from local storage. There are also many more users online at any point of time, sharing a single access link and generating much more traffic on average than in the case of on-demand dial-up connections. Various studies forecast that the average number of devices connected to Internet (at any time) per household can reach 5 by 2017 and 10 by 2020, comprising mostly portable personal electronic devices (tablets, smartphones, etc.) and smart home systems (home appliances, air conditioning, home security systems, etc.) [ictrl] [npd]. The rapidly emerging trends for the use of cloud storage and cloud computing systems [appi] only add to bandwidth demand both in downstream and upstream directions, as content is now not only consumed by devices connected to the subscriber LAN, but also generated by subscribers and uploaded to the remote cloud storage for distribution to other connected devices.

Commented [MH12]: Added text on average number of connected devices (always on) per home and projections of these numbers.

Commented [MH13]: Added text on cloud computing and storage trends. There are no good studies to rely on here, though.

More recently, even more content is being stored in the cloud (not on local LAN storage devices), requiring more downstream bandwidth, as well as improved upload capabilities, when compared to the previous generation of access networks. The increase in quality / resolution of multimedia content stored in the cloud, as well as close integration of cloud-based storage services with newer generations of computer operating systems provides a clear view of the always-connected future, where local storage would be mostly used for caching purposes only.

The current projections, shown in Figure 13, in terms of bandwidth demand per household (in residential applications) calls for approximately 300 Mbps around end of year 2016. Should the same trend in bandwidth consumption (~1.5 increase per year, ~~tracing~~ following closely Nielsen's Law [~~reference needed~~niel]) be observed in the following years close to 600 Mbps per subscriber is expected to be ~~called for~~ demanded around 2020. For NG-EPON to be suitable to provide services around 2020 and beyond, it is necessary to support delivery of at least 1 Gb/s (on average) per household (in a residential scenario), as well as the ability to scale up to 10 Gb/s per household (burstable) to support the possibility that consumer-grade electronics with either a single 10 Gb/s or multiple 1 Gb/s interfaces become commonplace in the following years.

Commented [MH14]: Reference added

Commented [MH15]: Minor rewording to eliminate clumsy wording

In the business application space, bandwidth requirements are typically quite different when compared to residential scenarios. This is primarily due to:

- delivery of bandwidth symmetric services, where downstream and upstream bandwidth available to a connected customer is the same.
- delivery of guaranteed bandwidth, where the purchased amount of bandwidth is allocated exclusively to the given customer and not shared with other customers.
- more stringent frame delay and frame delay variation requirements, especially for advanced applications like cellular backhaul and fronthaul.

It is worth noting that with the rapid adoption of FTTx services, the distinction between residential and business services is quickly disappearing as far as bandwidth symmetry and quality requirements are concerned. With FTTH, it is not uncommon for operators to provide symmetric bandwidth, especially to higher subscriber tiers, to allow more streamlined usage of cloud-based services. There are also new business application products, where only part of provisioned bandwidth is guaranteed, and the remainder is provided on a shared and best-effort basis.

~~4.6~~4.5 User Population/Split Ratio

At this time, there are no consistent studies of the average number of subscribers connected to a single OLT port in FTTx architectures around in the world. Using data on ONU and OLT port shipments around the world [~~reference to OVUM report?~~ovum], it is possible to conclude that a rather low split ratio is most commonly used, ranging from 1:4 to 1:16, depending on the number of actual OLT ports brought into service. Most new FTTx projects assume 1:16 or 1:32 split ratios, primarily to offset CAPEX (electronics and fiber infrastructure) and future OPEX related primarily with fiber infrastructure. The number of actual connected and active subscribers is typically lower than the number of splits in the ODN connected to a single OLT port. Depending on the adopted deployment model, demographics, and local competition, take rates between 20% and 90% are common. Take rates of 100% can only be achieved in communities where fiber is connected to all homes in the community and included in a contractual package for residents [~~reference to MDG property announcement~~mdg]. It is, therefore, typically very hard to predict with any level of confidence how many active subscribers are present on the access platform once it is deployed, at least as far as residential access is concerned. This deployment model also requires the operators to deploy the capacity first (most of CAPEX up front) and add customers on demand, as services are requested.

Commented [MH16]: Reference added

Commented [MH17]: Reference added

In the case of business services, the deployment model is typically different. Dark fiber is deployed first in the given area and when customer demand dictates individual dark fiber trunks are activated and new OLT ports are put into operation. This allows operators to adopt a pay-as-you-grow approach, adding capacity to the access platform along with the increase in take ratios and number of connected customers.

[ictrl] iControl Networks, “2014 State of Smart Home”, report available online at: http://www.icontrol.com/insights/2014-state-smart-home/

[npd] “Internet Connected Devices Surpass Half a Billion in U.S. Homes”, available online at https://www.npd.com/wps/portal/npd/us/news/press-releases/internet-connected-devices-surpass-half-a-billion-in-u-s-homes-according-to-the-npd-group/

[mdg] Shalini Ramachandran, “Bright House to Build Ultrafast Broadband Network”, available online at: http://www.myultrafi.com/wp-content/uploads/2014/03/Wall-Street-Journal-Article_03-12-14.pdf, Wall Street Journal, March 2014

[appi] APPIRIO, “State of the Public Cloud: The Cloud Adopters ’ Perspective”, available online at: http://thecloud.appirio.com/rs/appirio/images/State_of_the_Public_Cloud_Results_FINAL-102910.pdf, October 2010

[niel] J. Nielsen, “Nielsen's Law of Internet Bandwidth”, available online at: http://www.nngroup.com/articles/law-of-bandwidth/