Lady Giga Takes the Stage

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Abstract

The insatiable appetite for rich content, ubiquitous connectivity, and sharing of experiences through social media has kept the battle for high-speed data supremacy alive and highly competitive. There does not appear to be an end in sight to the growth of IP-capable devices in the home. A single household may have a dozen or more devices with connectivity. Most of them are video capable and part of an emerging pattern of behavior of simultaneous use. "Lean Back" viewing is a decaying consumer segment.

With so many video-capable devices, today's "killer app" remains streaming video, and its impacts have been widely felt. And, video evolution itself is not complete, as 4kHD clearly shows. Meanwhile, the consumer market has barely scratched the service on the Smart Home, Telemedicine, or other potentially bandwidth-consumptive, non-media related applications. An end to IP data growth does not yet appear to be in sight.

So, while the debate continues about whether year-on-year capacity growth is permanent or becomes a gradual tapering over time, every service provider knows it is not sufficient to simply look at the demand side of capacity. It has long been considered table stakes to keep pace with persistent year-on-year data growth by adding IP resources. Operators have to simultaneously focus on the service speed offering, also referred to as "billboard speed." In this category, the latest market buzz that Operators are answering the bell for is delivering the Gigabit service tier.

In this paper, we will explore the delivery of a Gigabit from the operator's perspective. We will look at the marketing aspects that have driven the message into industry and consumer lexicon. We will compare the buzz created to realities of common usage, aggregate demand, and traffic engineering. We will consider the obstacles to delivery and consumption and the relationship to application benefits. We will describe the "layers" of the Giga-Ask, and identify the solution possibilities and service capabilities enabled by these solutions. We will take on the technical details of these solutions and project where they can take us down the road. Lastly, we will articulate the key messages that the Cable industry should focus on as Lady Giga takes the stage.

PERSISTENT AGGRESSIVE CAGR

Consumer data capacity demand has advanced steadily in a compounding fashion since the introduction of broadband Internet services. The commonly accepted Compound Annual Growth Rate (CAGR) of downstream traffic is 40-50% per year. Various approaches have been taken to chart the growth of downstream traffic as it relates to HFC capacity to guide network investment strategy, including the insightful Capacity Management Timeline approach, an example of which is shown in Figure 1 and described in [5]. The 1 Gbps capacity requirement, from a demand perspective, is based on a hypothetical DOCSIS allocation and scenario in 2014, as identified on the chart.

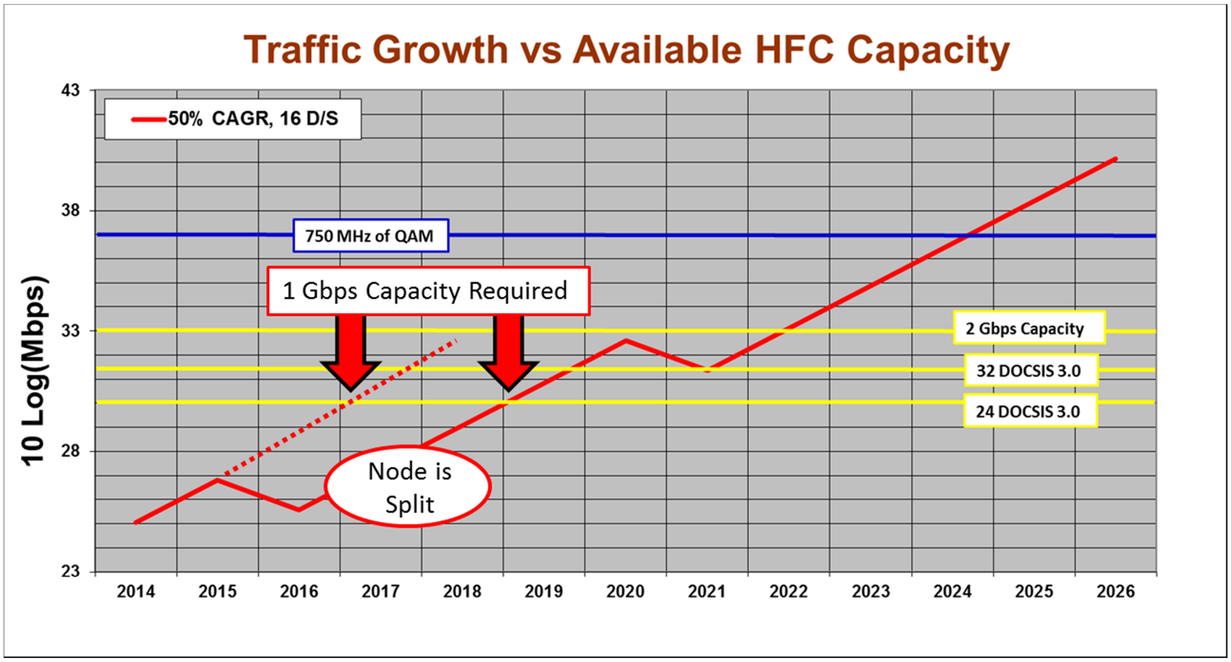


Figure 1 – Capacity Management Timeline Approach to Traffic Growth

It is sometimes more convenient in practice to consider growth in terms of Traffic Doubling Periods (TDPs), or how much time passes before the traffic is 2x the current amount. Conveniently, 40% is a doubling of approximately every two years (50% is about 21 months). Other convenient rules of thumb, in particular as we evaluate options for the upstream, are a TDP of 3 years for a 25% CAGR and 4 years for a 20% CAGR.

Doubling periods are useful because we can then easily frame the problem in terms of DOCSIS channels, CMTS ports, Headend combining, or nodes splits or segmentations. These are all known tools in the toolkit that are used regularly to manage capacity growth of HFC networks. And, they are also well-understood in terms of financial, facilities, and network bandwidth implications. There are other tools available, such as video encoding technology (HEVC) and the move to an all-IP network.

As an example of TDP use, Comcast has raised Internet data speeds on average once a year for over a decade to keep pace with capacity demand and the applications that require sustained broadband speeds, such as over-the-top (OTT) video and file sharing services. It wasn't that long ago that 10 Mbps was a tremendous breakthrough, one that enabled strong market share against DSL-based Internet providers in North America in the early years of DOCSIS.

Using the simple TDP rules above, going from 10 Mbps speeds to 100 Mbps speeds at 40% CAGR is just over 3 TDPs, or about 6 years. Coincidentally, DOCSIS 3.0, which enabled 100 Mbps of per-user capacity, was completed in 2006. This crude "10x" analysis applies also for the case of going from 100 Mbps to 1 Gbps. The 100 Mbps target was a major consideration for the channel bonding approach used in DOCSIS 3.0, since single 6 MHz QAM slots were limited to about 40 Mbps. Just as DOCSIS 3.0 development began and completed in advance of the 100 Mbps expected need, the DOCSIS answer to Gigabit speed – DOCSIS 3.1 – has been developed in advance of the projected need, and appears to be arriving just in time to deliver on this emerging market target.

(Note that throughout the paper, we will use the word "Gigabit" as synonymous with Gigabit per second or 1 Gbps).

GO GIG OR GO HOME

In the data-centric world of Ethernet, cost effective connectivity advanced to support residential broadband speeds, but more so because the computer era drove data technology for businesses, and businesses had internal data needs before demand growth of Internet access was a driving factor. Today, business services Internet requirements tend to be more symmetric, while residential services tend to be more asymmetric. In short, Ethernet connectivity preceded and lay in wait of access speeds capable of using 100BaseT connections.

Eventually, as residential speed wars reached beyond 100 Mbps, the steady battle to claim the fastest Internet meant continually increasing top tiers….200 Mbps, 250 Mbps, 300 Mbps, and even 505 Mbps, despite modest impacts to the overall Quality of Experience (QoE) for most users. While not necessarily tied to user experience for the majority of Internet subscribers, there is certainly marketing value to being the fastest service provider in an era when the Internet is no longer a luxury, but an essential service at the top of the list of what consumers find important. And, of course, business advantage could be had in some cases by deploying a service speed that put a different access technology and architecture at a competitive disadvantage.

As speeds worked their way through the Nx100 Mbps range, the "Gig" moniker came into view. Now, rather than just bigger numbers, an entirely new language and branding opportunity was in play. As such, compared to other speed war thresholds, "Gig" arrived perhaps sooner, in part spurred on by new competitors taking advantage of the nature of the linguistic change, but also by marketing of fiber-based solutions as the answer to having a network that is deemed "future-proof." Google Fiber, though modest in actual customers served and limited to only a small number of select cities, has aggressively marketed FTTH deployments around Gigabit capability. Gigabit is showcased through a host of futuristic applications that presumably could drive CAGR trends long into the future.

On the Rebound

The economic recovery took many years to get underway, and only relatively recently has new construction become robust. Over that period of time, technology has only become more infused into everyday life through social media and a variety of other applications available on smartphones and tablets. Builders and property owners recognize the importance of High Speed Internet (HSI) to potential new residents. In fact, on surveying, it is the MOST important amenity selected [6]. Showing new potential residents that the property is committed to the best technology and Internet experience is a major part of a successful business model for property owners. As a result, these owners have become aggressive in marketing the technology aspects of their properties to potential residents.

While there is a general awareness that Gigabit service has primarily marketing value today as opposed to being necessary for actual traffic demand, the "future proof" component of Gigabit has significant value, and for good reason. This is particularly so when considering properties that forge a bulk services agreement with an operator based on a multi-year contract. Given the CAGR trends discussed above, it makes sense that property owners prepare their property for what the Internet service demands will look like at the *end* of their contract, and to do what they can to prevent disruption due to rewiring on the property during the course of the contract.

Lastly, trends in new housing growth indicate that multiple dwelling unit (MDU) living, often in downtown cores and/or live-work-play model village-towns are a larger weighting of new homes than was the case prior to the real estate crash. The demographic in the MDU environments tends to be younger than the average US adult. This trend can be attributed to the economic recovery that is allowing 5+ years of underemployed but relatively recent college graduates to become fully employed and begin to seek better living conditions.

New customer opportunities are great news for cable companies. It has been quite some time since there has been any significant new construction. However, this emerging generation of potential new customers do not have longstanding ties to major operators. The "triple play" has less value, voice service is often mobile-only, and viewing habits weigh the convenience of access and devices on par with, if not above, content volume. High speed Internet is a must-have, while hundreds of cable channels of programming is not – and cable voice service is even less so. This allows data-only services to be sufficient for these consumers, which is a business model a wider range of service providers can support than just large full-service providers.

In summary, the emergence of a "Go Gig or Go Home" mindset has arisen out of a combination of:

- Real-estate growth weighted towards MDUs and young adults
- High profile Fiber-to-the-Home (FTTH) deployments in North America
- New competition focused on an "easier" to deploy data services model
- Everyday lifestyles with heavy reliance on technology and Internet access
- Years of uninterrupted CAGR and rapid change in technology
- Desire of builders and owners of complexes to market competitively to potential residents

LAYERS OF THE GIGABIT ASK

The DOCSIS 3.0 standard was issued in August of 2006. The most significant component that this 4th version of the standard introduced was the concept of "channel bonding." Bonding allowed multiple 6 MHz channels in the downstream to be used as a single "wideband" channel from a user's perspective. Whereby a user might have been assigned one of four downstream CMTS channels in DOCSIS 2.0, DOCSIS 3.0 allowed a user to receive traffic on all four channels at once. Therefore, instead of the approximately 40 Mbps of downstream peak rate of a single channel, now N x 40 Mbps was possible, with N as high as 32. While the network itself does not change actual capacity without adding new channels altogether, any single user could be allocated more capacity and also would be able to achieve much higher service tier speeds.

Bonding in the upstream was also introduced in DOCSIS 3.0. Upstream channel widths vary and the upstream is a time-division-multiple-access (TDMA) approach for each upstream carrier, so the specifics of how bonding is done are very different. However, conceptually, upstream bonding serves the same purpose as the downstream – more bandwidth can be provided to an individual user, and higher speeds are possible.

Not coincidentally, N = 32 downstream channels means that a full-size downstream bonding group is more than a Gigabit of IP/DOCSIS capacity. By 2006, cable had been operating DOCSIS networks for about a decade, and the compounding growth of data traffic through the early era of broadband had become well known and understood. The projected need for a Gigabit was clearly on the horizon, and operators reacted by ensuring that the standard for their latest version enabled bonding enough channels to reach Gigabit capability.

While the above described the demand-side expectation driving DOCSIS 3.0 parameters, another competitive driver at that time was the relatively recent introduction of FTTH services in North America using Broadband Passive Optical Networks (BPON) technology (622/155 Mbps), and a few years later using Gigabit Passive Optical Networks (GPON) technology (2.5/1.5 Gbps).

We're Heeeeeere

Now, in 2015, the Gigabit that was on the horizon in 2006 is now officially at the doorstep. The DOCSIS technology put in place at that time, and the emerging DOCSIS technology – DOCSIS 3.1 – has been and is still being evolved and deployed with a keen awareness of competitive capacity and speeds. Capacity, speed and also fiber connectivity are all component parts of today's Gigabit discussion. A convenient way to describe the "asks" of a service provider in this new age is to view modern requirements as "Layers" as shown in Table 1.

Table 1 – "Layers" of the Gigabit Ask

- ❑ Is it a Fiber Network ?
- ❑ Is it a 1 Gig Network ?
- ❑ Is there a Path to a 1 Gig Network ?
- ❑ Is it 1 Gig Speed ?
- ❑ Is it 1 Gig Symmetrical Speed ?

As cable operators bring DOCSIS 3.1 to life to deliver Gigabit speeds, fiber-based providers have campaigned to link Gigabit to fiber solutions. Because of cable's long history of deploying fiber and pulling it deeper and deeper into neighborhoods*, cable operators alone are well-position to deliver Gigabit solutions over either coaxial or fiber last miles.* Many cable operators today already deliver Gigabit services over point-to-point Ethernet connections using fiber to business customers.

Nonetheless, it is quite common for a Request for Information (RFI) from a potential customer to begin with a preference for a fiber-to-the-premises (FTTP) network. There are multiple technology approaches available to fulfill this as a requirement, and all are Gigabit capable.

Beyond simply the infrastructure to install, the complex ownerships or homeowner associations responsible for telecommunications services, per the second and third bullets in Table 1, want to understand whether the proposed system is a Gigabit network, or has an evolution path to become Gigabit capable. Specific fiber and Gigabit interest began in earnest in 2013, as the economy emerged out of the long recession, hiring ramped up, and new home construction took a turn for the better. Indeed, new construction "Greenfield" accelerated throughout 2014 and is projected to continue to grow. As mentioned, this represents an exciting new opportunity for operators, as business growth associated with adding new customers had been difficult to obtain during difficult economic years.

More recently, "Gigabit" has evolved to the next bullet in Table 1, to a speed or a *service rate* of 1 Gbps. This is where the possibility of gamesmanship in advertisement and marketing, as well as legal language, can make it difficult to compare solutions and offerings apples-to-apples. This often has to do with how providers define Gigabit given that such a speed is impossible to achieve at the payload level from a GbE port or practical WiFi connection, and also that "proof" of achieving the Gigabit threshold is not uniform across providers.

Lastly, Gigabit service rates have migrated to a considering Gigabit *symmetrical* service rates.

GIGABIT ASK: SOLUTION OPTIONS

First and foremost, it is important to note that *DOCSIS 3.1 over HFC enables all of the Gigabit scenarios* in Table 1. It does not, in most typical single family neighborhood cases, meet the "all-fiber network" criteria, although it can. DOCSIS is typically delivered, of course, over an existing coax – to-the-home (CTTH) solution. The requirements set forth in the DOCSIS 3.1 standard were developed with the understanding that it would operate over existing HFC plant today without any changes required, and also that Gigabit services were a primary objective.

It is the case, and has always been the case, that the coaxial capacity is capable of such high capacity services [5]. This is because, historically, the HFC network was designed to meet requirements that support a high number of analog video services. Analog video is very sensitive to channel impairments, and as such network requirements demanded very high CNR, very low distortion, and very wide bandwidth because of the inefficient way that analog video uses spectrum. Therefore, the HFC network was made to be broadband, extremely high fidelity, and extremely linear – characteristics that modern communications systems can exploit to tremendous capacity effect. DOCSIS 3.1 is simply the first version of the standard to ensure that this latent capacity is exploited fully and for the purpose of Gigabit. Cable operators have invested wisely and in a timely manner to keep pace with the growth of capacity and demands for higher speed, and DOCSIS 3.1 is the latest example of this.

We will detail some common variations emerging for HFC network evolution in the next section. First, however, we consider the fiber-based possibilities associated with Gigabit.

Gigabit Multi-Path

DOSCIS 3.1 is not limited to coaxial deployments, as technology based on SCTE 174 2010 [7], commonly referred to as RF-Over-Glass (RFoG), enables DOCSIS over FTTH networks. This SCTE standard's key value is that it defines an all-fiber optical distribution network (ODN), but which is consistent with current cable services, back-offices, and practices.

All-fiber networks can also be implemented with point-to-point Ethernet – as mentioned, this is common today in cable networks for commercial customers – as well as Passive Optical Network technologies such as those previously described. Many cable operators have based their PON architectures on Ethernet Passive Optical Network (EPON). While both PON approaches have merit, EPON has been augmented by standardization that allows compatibility with cable provisioning, as well as other features that attract cable providers. Both PON technology families are implemented worldwide.

For PON, some North American deployments are capable of Gigabit, but a large percentage of existing FTTH deployments use BPON technology. BPON, of course, is unable to deliver Gigabit capacity or speeds, as it is based on 622/155 Mbps total capacity. GPON and EPON families are available that support Gigabit, however.

Ethernet support for Gigabit services is enabled by dedicated Gigabit Ethernet circuits, typically on a DWDM network, and no or minimal aggregation on the network side, depending on specific service terms. It can also be enabled via 10 Gbe circuits that enable more sharing of the circuit/wavelength.

Table 2 summarizes the architecture capabilities of various operator options when considering the features described in Table 1. Rather than compare HFC and DOCSIS variants to dated options for PON technology of more limited capability, a comparison based on emerging 10G EPON technology is used since this is what DOCSIS 3.1 aims to enable.

Note that Fiber-to-the-Premises (FTTP) is used to accommodate both SDU (fiber-to-the-home) and MDUs (fiber-to-the-building) within a single table in Table 2, using the color coded checkmark identified in the note at the bottom of the table.

Table 2 – “Layers” of the Giga-Ask Versus Architecture Options

	HFC-Based				FTTP		
	Standard		Fiber Deep (N+0) DOCSIS 3.1		SCTE 174 2010 DOCSIS 3.1		PON
Network Feature ↓	**DOCSIS 3.0**	**DOCSIS 3.1**	**Mid-Split 85 MHz**	**High-Split 212 MHz**	**Mid-Split 85 MHz**	**High-Split 212 MHz**	**10G EPON**
Fiber			√	√	√	√	√
Gbps Network	√	√	√	√	√	√	√
Fiber AND Gbps Network			√	√	√	√	√
1 Gbps Service		√	√	√	√	√	√
Symmetric 300 Mbps Service			√	√	√	√	√
Symmetric 1 Gbps Service				√		√	√

√ = Applies to MDU Only

HFC Evolutionary Variants

As mentioned in the previous section, there are several evolutionary architectures for HFC, some of which are called out in Table 2 and described in more detail below.

The “Fiber Deep” approach, which can be thought of as “Fiber Deepest” in that it is a passive coax last mile following the amplifier, is an approach described in [5] based on striking a balance between optimizing an N+0 network design for maximum coverage (hhp), but with considerations to the existing installed fiber, coax, and powering infrastructure. The core principles of this approach are shown in Figure 2.

Fiber deep conveniently addresses one of the nagging obstacles to service evolution of classic HFC – the currently defined boundary of allocated upstream spectrum. DOCSIS 3.1 itself – without new consideration of upstream spectrum – will add significant new capacity potential to the HFC upstream in two ways.

First, as in the downstream, the DOCSIS 3.1 standard calls out more spectrally efficient QAM formats. The increased spectral efficiency attributable to this alone is 66-100%.

Second, the DOCSIS 3.1 signal format based on OFDM will enable efficient use of formerly difficult spectrum below 20 MHz, which standard QAM/TDMA tools often found impossible to traverse. When combined, more than a doubling of upstream capacity is expected from these two components.

Upstream CAGR has historically been inconsistent, but generally significantly lower than the downstream. Using TDPs, for example, and a 20% upstream CAGR on a healthy upstream network today, upgrading to DOCSIS 3.1 and implementing a node split would deliver capacity that lasts 4 + 4 = 8 years, where 20% CAGR means a doubling of traffic after four years.

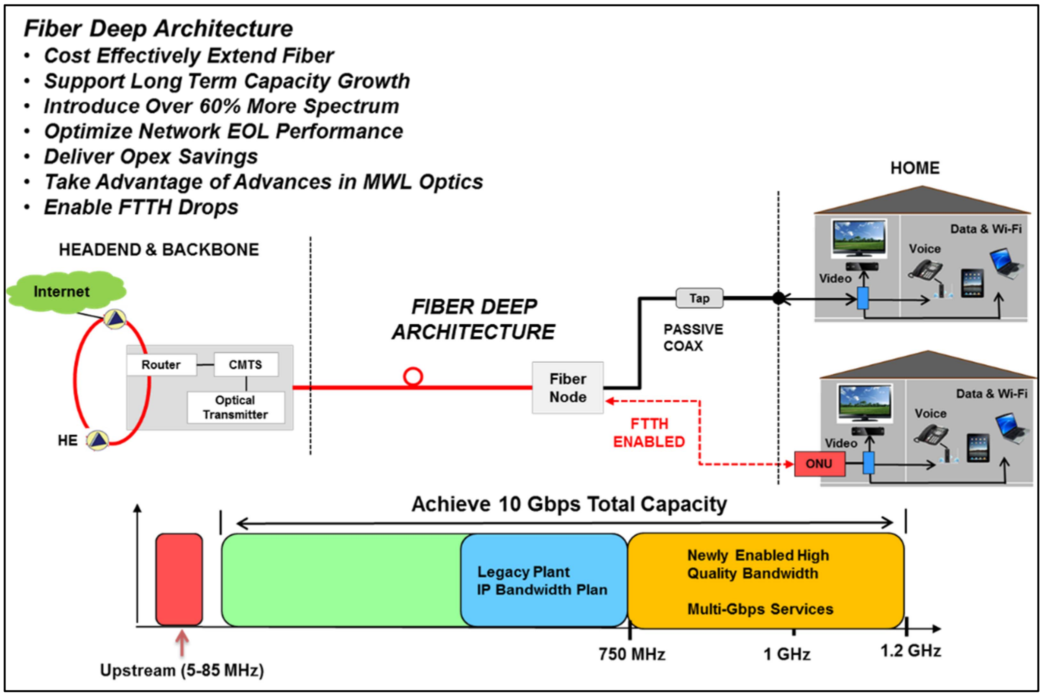


Figure 2 – Fiber Deep Principles [5]

Nonetheless, under continued growth of data traffic, the 42 MHz allocation may become insufficient over time, and perhaps more importantly it places speed limits on the upstream service tiers that cannot be solved by node splitting alone. When this spectrum becomes insufficient is relatively predictable as shown in the coarse TDP analysis above, but with the uncertainty that comes with what has been inconsistent upstream traffic growth year-on-year. The "Napster Moment" in the early 2000's, ushering in peer-to-peer file sharing services, is the reference example for a step function upstream growth scenario, but it has not been repeated since.

Figure 3 is a an example of analysis of upstream capacity [5] that represent the information content of Figure 1 in a different format, recognizing that a fixed CAGR analysis such as is shown for the downstream is less insightful for the upstream.

Returning to the topic of upstream spectrum allocation, the fiber deep approach, because it eliminates amplifiers, makes the expansion of the return to 85 MHz relatively simple in the network itself. Installation of an 85 MHz capable node is all that is required in the plant. There are other elements of the conversion (spectrum clearing of 54-108 MHz, home architecture, CPE out-of-band compatibility [OOB], HE signaling), but none that are technology barriers.

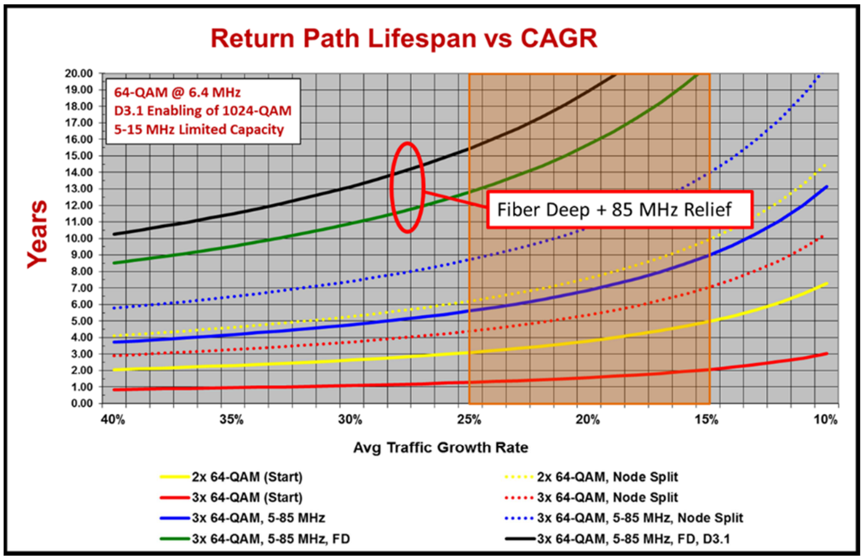


Figure 3 – Comparison of Options for Managing Upstream Growth

What 85 MHz provides is Nx100 Mbps services (i.e. 100 Mbps, 200 Mbps, and 300 Mbps) while allowing the continued support of the vast majority of STBs in the field that use a legacy narrowband downstream OOB channel for STB communications, such as VOD. What the 85 MHz return does *not* provide is a path to Gigabit capability in the upstream. It is simply not enough spectrum to do that. However, this is specifically why the DOCSIS 3.1 standard calls also for the possibility of a *higher* bandwidth return, with an upper edge of 212 MHz. This bandwidth and the corresponding definition of the OFDM and underlying QAM parameters enables Gigabit services. In the case of the high split, it comes with the trade-off of the loss of significantly more downstream bandwidth, as well as the inability to easily support OOB communications for most legacy STBs in the field.

In summary then, DOCSIS 3.1 with an 85 MHz mid-split enables asymmetrical services with Gigabit or multi-Gigabit downstream. It does so while preserving legacy video services, and with a very modest impact to downstream spectrum. The Internet service tiers for this case could be, for example 1G/300M (asymmetrical). With a 212 MHz upstream split, DOCSIS 3.1 will enable symmetrical Gigabit speeds, as well as asymmetrical services such as 1G/300M or 2G/1G. Table 2 summarizes the service coverage for each of these permutations of network and spectrum for different access architectures.

Revisiting Spectrum Allocation

While we have focused on the upstream implications above on the way to symmetrical Gigabit, note that the Fiber Deep approach enables extended downstream possibilities as well. By defining a single active driving the last mile coax, the potential to extend the downstream to 1.218 GHz per the DOCSIS 3.1 standard also exists. In so doing, DOCSIS 3.1 technology can deliver up to 10 Gbps of downstream capacity while simultaneously delivering over 2 Gbps of upstream capacity.

An element of the Fiber Deep architecture that ensures that the "up to" 10 Gbps and beyond is enabled fully and robustly is the emerging architecture approach based on distributed DOCSIS technology. Similar to how telco providers push digital fiber deep to squeeze the most capacity possible out of the very limited twisted pair last mile, cable operators can implement a logically similar architecture [4]. In the case of telcos, limiting the distance from the DSL Access Multiplexer (DSLAM) to the home was essential for reasonably useful broadband capacity, and they have been forced to continue to get closer to the home as part of the strategy to keep pace with CAGR.

By contrast, cable operators do not have such a prevalent last mile bandwidth constraint to overcome. Instead, however, by deploying distributed systems based on digital fiber, the end-of-line (EOL) SNR performance at the home is optimized. Linear fiber optics and RF amplifiers contribute SNR loss from the Headend CMTS transmission point to cable modem receiver in the home, and also from the home cable modem transmitter upstream to the HE CMTS. A Distributed Architecture with a digital optical basis, of which there are several possibilities, and a Fiber Deep system that eliminates amplifiers remove both of these RF channel performance degradations. The maximum DOCSSI 3.1 QAM profiles – the most spectrally efficient "MUST" format being 4096-QAM – are thereby most robustly enabled.

The 1.218 GHz extension also plays the important role of "replacing" the bandwidth that is lost to the downstream by a 212 MHz upstream high split. Of course, only DOCSIS 3.1 can use this bandwidth above 1 GHz. In this way, the 212 MHz architecture is connected to the all-IP transition based on DOCSIS 3.1 as cable's IP pipe. Looked at another way, even in traditional HFC networks (750 MHz, 860 MHz, or 1 GHz), which will exist for many, many years, use of the 212 MHz upstream bandwidth will *essentially* be tied to a full IP conversion – one that implements the IP delivery but that also retires QAM delivery. The latter removes the video simulcast that inefficiently uses spectrum, and allows the full all-IP conversion to take place.

CONTEMPORARY TRAFFIC SNAPSHOTS

"Who needs a Gigabit?" is a common question as the market matures around Gigabit solutions and consumers look for the value that the extreme speeds bring – asking themselves what is it that they actually get for the price. No doubt, one of the more popular applications initially will be the speed test itself, but consumers engaged in large peer-to-peer file sharing and commercial services customers are the most likely to notice the benefits of Gigabit in comparison to, for example, more common peak speeds such as 50 Mbps or 100 Mbps.

Commercial enterprises commonly have more symmetric demands, since the majority of the traffic is email, data, and file both to and from the enterprise. The size of the enterprise sets the bandwidth required for the enterprise to efficiently execute its business.

The residential space, however, is less likely to have symmetric demands. The file sharing user case is the nearest exception. In relative terms, it is how the early "Napster" days were turbo charged by broadband speeds for what was, at that time, large music files exchanged over dial-up connections. Over time, it is anticipated that perhaps the Internet of Things (IoT) and the associated machine-to-machine (M2M) traffic may swing the pendulum back towards more symmetry of consumer traffic.

Gigafy Me

Outside of the measureable time savings that Gigabit may bring to an HD movie transfer, applications for Gigabit today are limited. Furthermore, with most consumer's receiving their data over WiFi, the bottleneck to the client device is often the wireless connectivity of the Home LAN. That is, even should a Gigabit get to the home, getting that Gigabit throughout the home has other constraints to consider.

Not signing on the Gigabit tier, and even the impacts of localized bottlenecks should not affect over the top (OTT) streaming video services in a properly engineered network if the wireless network is properly within range. Table 3 shows the range of average video rates as a function of video format and encoding technology [1].

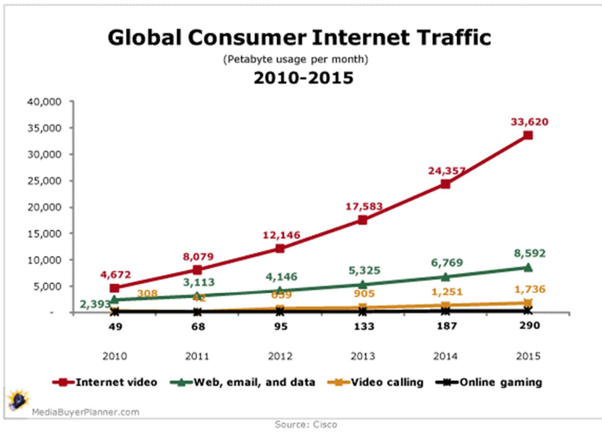
Table 3 – Video Streaming Rates

Resolution		Digital Compression Method and Bit Rate		
Resolution Terms	Frame Size / Scanning System / Frame Rate	MPEG2	H.264	HEVC
SDTV	480 / i / 30	3.7 Mbps	2 Mbps	1 Mbps
HDTV	720 / p / 30	6 Mbps	3 Mbps	1.5 Mbps
HDTV	720 / p / 60 (or 1080 / i /60)	12 Mbps	6 Mbps	3 Mbps
HDTV	1080 / p / 60	20 Mbps	10 Mbps	5 Mbps
4K UHDTV	4Kx2K / p / 60	80 Mbps	40 Mbps	20 Mbps
8K UHDTV	8Kx4K/ p / 60	320 Mbps	160 Mbps	80 Mbps

While volumes of streaming video from cable operators themselves, or from OTT providers have had a significant role in keep the CAGR train moving forward at a 50% per year clip for new capacity, even 1080p HD streams based on MPEG-4 (H.264) encoding are on the order of 10 Mbps average bit rate. Multiply this by 2-3x for action-packed movies during peak bursting periods. Thus, Gigabit service is not necessary for supporting a high quality streaming video experience. However, what is very critical for streaming services, because it is sustained rates that must be met for long periods of time (versus web browsing sessions, for example) is that operators have allocated sufficient capacity to handle the growing number of streaming users at peak busy hour (pbh). Operators that offer Gigabit service should have traffic engineered the network around well-understood rules guiding the distribution of peak speeds, concurrency of use, and total capacity. This fundamental traffic engineering tenet applies whether the capacity or speed number is followed by a "G" or an "M."

Figure 4 shows how the growth of streaming video has come to dominate the traffic demand [2,3]. The top figure shows actual data through 2013 and projections through 2105, while the bottom extends the projection through 2018, with the addition of file sharing. The file sharing application is insightful in that it represents an application associated with potential high growth upstream traffic, as common email and web-surfing applications are limited in upstream demand.

What is clear from the bottom chart of Figure 4 is that streaming video is expected to grow at a more rapid pace than file sharing or normal web use. As such, while market messages around symmetrical data services are growing in the residential space, the trends are headed to increased asymmetry of actual demand.



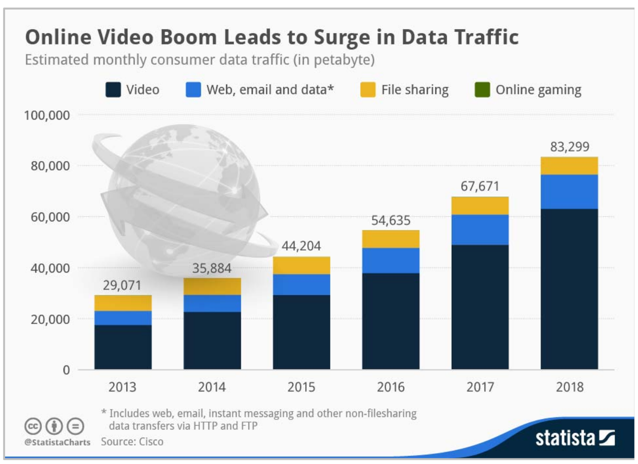


Figure 4 – Downstream Traffic Growth is Dominating Recent Trends [2,3]

Figure 5 shows the state of modern consumer traffic imbalance over the course of 24 hours. It is consistent at peak busy hour (pbh) with Figure 4 where video streaming tends to emerge as the dominant application in "primetime." Network engineering practices are built around managing through the peak periods. As noted in [1], in the early 2000's, as peer-to-peer file sharing became a dominant application of the time, asymmetry ratios during peak periods were closer to 2:1.

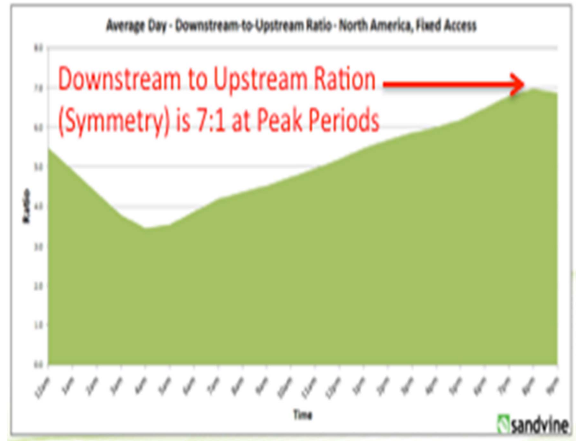


Figure 5 – Traffic Asymmetry has Increased with Streaming Video

STRIKING THE RIGHT TONE

While Gigabit is an important and relevant 2015 buzzword storming the marketplace, it is important to remember that cable operators foresaw this as far back as 2006 with DOCSIS 3.0, and upped the ante further in developing the DOCSIS 3.1 specification which began in 2012, with deployment beginning in 2016. Furthermore, DOCSIS 3.1 anticipated a multi-gigabit era in developing the requirements, ensuring that 10 Gbps of downstream capacity was possible on the coax in an all-DOCSIS 3.1 system. Even in the face of continued data growth, this creates a long-term, sustainable network, whose power is multiplied by the additional levers of spectrum re-allocation, business-as-usual service group splitting, distributed DOCSIS architectures, and an all-IP transition.

Cable operators have consistently raised capacity and speeds as demand has continued to grow. This is testament to the flexibility of the HFC architecture, since cable is well into the second decade of DOCSIS data services which, all the while, has undergone compounding data growth year on year. It is important to articulate and balance the excitement of the Gigabit momentum with the reality of practical data demand downstream and upstream, and the proven ability that cable has shown in keeping ahead of this demand for the entire life of the broadband Internet.

It is rarely a good idea to be debating whether there is a need for higher bandwidth from the side of the more conservative perspective. The archives are littered with quotes of technology leaders of the past whose predictions are unattractively juxtaposed against the reality that has come to pass. However, the volumes of extremely granular data that operators have on actual usage and trends, and the track record of cable operators to meet the demand as it arises, lend unmatched credibility to matching broadband bandwidth and speeds to solutions that satisfy subscribers.

Importantly, while marketing and competition has affected perceptions around the capability of cable networks, it is clearly demonstrable that "Gigabit" is not a number tied to fiber-based access. The notion that fiber is necessary for Gigabit services is pure mythology. Indeed, even today's 750 MHz digital cable systems are delivering over 4 Gbps of traffic all day, every day. The allocation of those bits has simply weighted to video services historically, and mostly broadcast video services. That mix is constantly changing as both data technology and video technology become more efficient, and more and more services migrate to IP. It will be demonstrably and explicitly true that coaxial infrastructure enables Gigabit when DOCSIS 3.1 hits the field in 2016.

CONCLUSION

Gigabit is the latest target in the continuing race to the highest "billboard" speed. Applications for Gigabit today may be limited, but if the history of data growth is any guide, it will not be too long before "multi-Gigabit" is the word of the day, and eventually Gigabit becomes insufficient. CAGR simply always wins out to a fixed target if it persists unabated.

Talking about Gigabit now perhaps seems to be a massive leap forward, in part because we are officially leaving the "Megabit" era, and the shift in language can be imposing. However, DOCSIS capacity and speeds have been steadily marching forward year after year, keeping pace with the compounding way that demand has behaved, and since inception of the service. Gigabit is simply the next, logical emerging threshold. It is perhaps a bit ahead of its projected timeline based on CAGR because of market forces and the aforementioned language threshold, but with the persistent CAGR at 50%, this modest acceleration of timeline does not significantly alter the continuing evolution challenge cable operators continue to face head-on.

Not surprisingly given the flexibility of HFC, there are a range of options that meet the criteria of Gigabit, including media-specific requirements such as fiber only – something common in new developments – or coax only, which is often preferred in existing MDUs in order to the major intrusiveness that building rewiring can entail.

All in all, Lady Giga is not an intimidating presence to cable operators. Cable, in fact, is an ideal dance partner, with its message on Gigabit crystal clear:

- Speed is nothing new to cable. This is the industry that invented broadband Internet and put the "High Speed" in high speed Internet, displacing dial-up and racing past DSL.
- Gig is just the next speed tier that the 5th iteration of DOCSIS will accomplish.
- Cable operators have increased speeds since the inception of DOCSIS, at every turn meeting customer demand for increased bandwidth. "Gigabit" does not change this dynamic.
- Cable operators can deliver Gigabit over coax OR over fiber, and no other provider has this flexibility
- Cable operators are delivering Gigabit via FTTP today to thousands of businesses
- Cable operators are carrying multi-Gigabit to the home everyplace an all-digital system operates today
- Quality of Experience is more than just the speed to the home, it is also the speed to the devices within the home and access outside the home. Operators deploy leading edge WiFi, and taking advantage of a powered access network to deliver coverage outside the home

Cable welcomes Lady Giga to the stage. She may sound shiny and new, but for cable operators with 15+ years of DOCSIS and HIS under their belt, she is really just an old friend wearing a new dress.

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