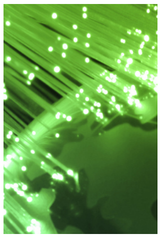


FULL GIG SPEED AHEAD

Next generation access technologies fueling the rise of a gigabit future.

Not so very long ago, gigabit capable access networks were limited to discussions on PowerPoint slides. Today, telcos, cable companies, cooperatives and municipalities are actively deploying gig-capable networks across the U.S. These ultra-high-speed, low-latency networks are serving urban, suburban and rural areas alike because everyone, everywhere can benefit from their capabilities, including the service providers who operate them.

Existing and ever increasing demand for bandwidth to meet today's needs provide network operators more than enough justification to upgrade their networks or build new ones that are gig-capable. However, many broadband service providers are well aware of the capacity and performance required by true gigabit applications and services, which are already under development and poised to eclipse what we are currently accustomed to using.

The emerging network technologies and specifications/standards that have been created to meet existing and future networking challenges include:

- G.fast (ITU-T G.9701 Fast Access to Subscriber Terminals) for hybrid copper-fiber networks
- Next Generation-Passive Optical Network2 (NG-PON2) for Fiber to the Home (FTTH) networks
- Data Over Cable Service Interface Specification (DOCSIS) 3.1 for hybrid fiber-coax (HFC) networks

Each offers unique benefits, and all are well on the way to becoming tangible, go-to solutions for broadband carriers.

This white paper presents a high-level overview of these solutions and their necessity in the marketplace, as well as a concise snapshot of each technology, its applications, and the role it will play bringing broadband service providers towards a gig-capable future.

The Case for Gig Networks

Next Stop: The Future

It is impossible to overstate the fact that demand for bandwidth is surging among end-users across the U.S. and creating unprecedented demand for bandwidth on existing networks of all types. While this challenge would be more than enough for most network operators to handle, it is not the only reason that broadband service providers are focusing on upgrading to, and deploying, new gig-capable infrastructures. What today's apps and services require of broadband networks soon will pale in comparison to what lies just around the bend. Many gigabit apps and services are still being incubated and developed, but broadband providers know they will require ubiquitous, low-latency, gig-capable networks to compete and thrive.

Pending demand of tomorrow combined with skyrocketing demand for bandwidth on their existing networks is spurring broadband providers into action sooner rather than later. According to a recent CIO magazine article, which cites research by RVA LLC [1], at present, 11.6 American homes are connected to FTTH networks. Those networks pass by a total of 25 million homes. The article also notes that new subscribers are signing up for FTTH services at an annualized growth rate of 480 percent per year. It goes on to say that this growth has much to do with the fact that the cost of transporting data across FTTH networks has steadily fallen over the years. This coincides with the increased efficiency of, and ability to, distribute high-bandwidth transmissions inside the home thanks to recent improvements in Wi-Fi equipment and standards.

However, the article points out that this is only the beginning of what is to come. "At its current stage, gigabit Internet access isn't much different than the early iPhone," writes article author Steven Max Patterson.

Exponentially Speaking

Because so many residential customers connect to the Internet using Wi-Fi connected mobile devices and smartphones in their homes, the demand those devices place on FTTH networks at present is significant and it looms even larger for gig-capable networks in the near term. For example, the mobile video explosion continues to boom. Total mobile video traffic over the next six years will balloon to 22 times that of the prior six years, according to the Ericsson Mobility Report, June 2015. [2] Granularly speaking, mobile devices created a total of 25 ExaBytes worth of data traffic from 2009 to 2014. They are expected to create 570 ExaBytes from 2015 to 2020.

Last year alone, mobile operators experienced a 55 percent growth in overall mobile data traffic (Q1-2014 to Q1-2015). The Ericsson report also forecasts a huge jump in the number of smartphone subscriptions – from 2.6 billion in 2014 to 6.1 billion in 2020. Those subscriptions will be accompanied by 7.7 billion mobile broadband subscriptions in the same time frame.

Keeping the above in mind, today there are typically five or more data-centric devices connected to the Internet in people's homes. As a result, multiple applications are in "play" at all times on home networks. This typically includes near continuous use of social networking, sporadic video downloads, Over The Top (OTT) video and streaming media, multi-player gaming and an increasing number of "things" appropriating bandwidth in order to communicate in the Machine-to-Machine (M2M)/Internet of Things (IoT) sphere. How many more devices will vie for connection in the home in the future is not yet known, but that there may be fewer seems an unlikely option.

On a more granular level, the size of files being uploaded and downloaded onto today's ultra-high bandwidth networks are growing, too – digital photos (5 MB), song downloads from iTunes (5 MB), CDs (560 MB), Netflix movies (3.8 GB) and Sony 4K HD movies (50 GB uncompressed)

Of course the file sizes of gigabit applications currently under development have yet to be determined. Volume of use may be just as important as file size. However, these apps are really what broadband service providers are putting gig-capable networks in place to support. While existing applications and services primarily need a lot of downstream bandwidth, gig-capable networks can offer symmetrical data transmission, low-latency and management capabilities that make a direct comparison difficult.

Setting the Bar

To date, broadband service providers have rolled out gigabit-capable networks in more than 100 markets across the U.S. In addition, more and more app developers, innovators and financial backers are working to create an ecosystem that will enable the next networking sea change. Glimpses of the gigabit future are being demonstrated at hackathons such as GigHacks and other gatherings that are taking place across the U.S. Fortunately, most of the developers creating future apps are too young to remember living in a non-connected world. Instead of being encumbered by limitations of legacy "broadband" networks, they are enlivened by the sheer potential of an equally and ubiquitously connected gigabit world.

THE SOLUTIONS

While many of the opportunities that gig-capable networks provide are new, the bulk of the networks that will be used to support them initially are not. Greenfield gig-capable networks are going to be the exception, not the rule, in the near term. More often than not, broadband service providers are upgrading legacy networks that ultimately will incorporate both older and newer standards-based technology as they are transformed. There are three basic specifications created to enable solutions that allow broadband service providers to upgrade their legacy networks, or build new ones if they so choose. Wisely, backwards compatibility has been built-in to each of them.

Copper: G.fast

G.fast networks are designed to be quickly and easily deployed by broadband service providers with a goal to leverage the voluminous amounts of twisted pair copper infrastructure installed in residential dwellings and small businesses. Developed by the International Telecommunications Union ITU-T[3], the specification combines the best aspects of optical fiber networks and Digital Subscriber Line (DSL) technology to support access speeds of up to 1 Gbps via existing copper twisted pair. G.fast can help broadband service providers serve subscribers located in areas where it is not cost-effective to deploy fiber or where it cannot physically reach. The technology is designed to provide service to locations within 400 meters of a fiber-fed distribution point. Like DSL, the closer end-users are to the distribution terminal, the faster the speeds they will be able to attain. G.fast also enables speedier deployment because customers can self-install their terminal devices.

In addition to these benefits, G.fast has the potential to help broadband providers meet pressing demand for bandwidth required of emerging video applications such as Ultra-HD '4K' or '8K' streaming and next-generation IPTV. They have a big bandwidth gap to cover in a hurry. Sony's 4K Ultra HD requires four times the bandwidth of HD signals, while 8K Ultra High Digital TV (UHDTC) requires 16 times as much bandwidth as HD.

G.fast also can support advanced cloud-based storage and communication via HD video, according to the ITU-T, allowing G. fast to serve both residential customers and small-to-medium sized businesses within reach. This in turn enables broadband service providers to broaden their customer base for the service and begin providing gig-capable services to customers that do not want to wait for fiber to make its way past their doorways.

On the operations side, G.fast facilitates remote management of user connections. Its co-existence With VDSL2 also enables service providers to switch customers between G.fast and VDSL2 as needed.

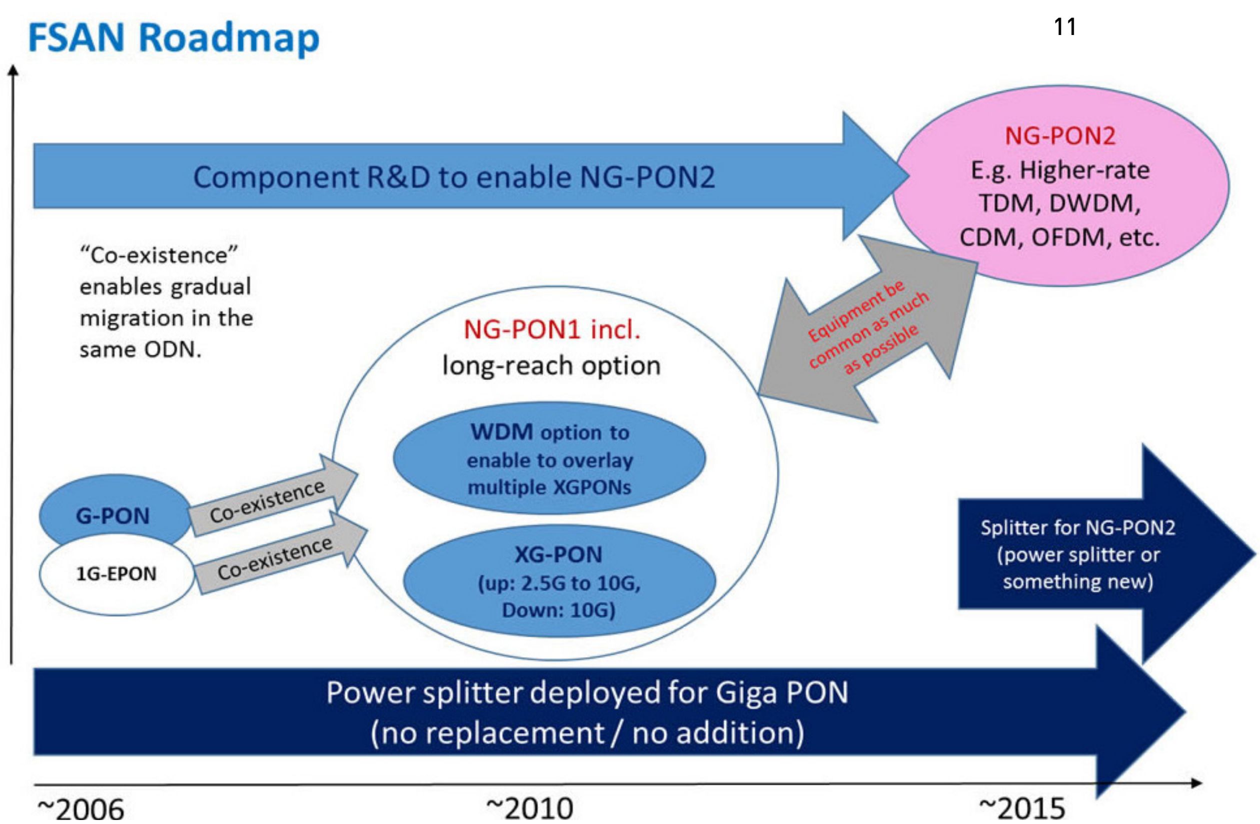
The development of G.fast has been coordinated with the Broadband Forum's FTTdp system architecture project. Both organizations have worked together to ensure that G.fast solutions can be quickly placed into FTTdp deployments. The two organizations also developed a test suite and certification program for G.fast systems. The test suite provided for interoperability, functional and performance testing at two plugfests held so far this year.

In January 2015, seven companies implementing chipsets based on new G.fast specifications met and performed interoperability testing at the University of New Hampshire InterOperability Laboratory (UNH-IOL)[4]. The lab also hosted the first G.fast equipment plugfest and presentation of reference designs in June, with 14 companies in attendance [5]. The Broadband Forum and ITU-T expect certified G.fast implementations to appear on the market before the end of 2015[6].

Fiber: NG-PON2

While there are many types of passive optical networks (PONs) deployed across the U.S., most are based on decades' old technology and provide what used to be considered plenty of bandwidth. Just as copper infrastructure can be upgraded to support 1 Gbps apps and services, PONs can, too. Broadband service providers are preparing to upgrade their optical networks with equipment based on the ITU/FSAN Next Generation – Passive Optical Network2 (NG-PON2) specification[7].

Flexibility and the ability to cost-effectively deploy needed upgrades are key (Figure 1). The NG-PON2 equipment being introduced this year supports up to 10 Gbps of bandwidth per customer, which allows broadband service providers to serve residential and business customers cost-effectively and via the same platform[8]. It also saves them even more money and time since NG-PON2 enables upgraded networks to coexist with legacy, standards-based optical networks. The standard also supports smooth migration from legacy PONs on a per ONU basis[9]. Adtran, Calix, and Alcatel-Lucent, among others, have announced NG-PON2 offerings, to date[10].



Unlike legacy PONs, NG-PON2 utilizes a combination of time and dense wavelength division multiplexing called TWDM. This multiplexing technique enables each wavelength to easily be shared between multiple ONUs. NG-PON2 also supports a "pay as you grow" strategy, as not all channel pairs need to be active at once on a system.

NG-PON2 systems can provide up to 40 Gbps of downstream capacity, which is shared by all subscribers on a system. By comparison, legacy GPON subscribers share 2.5 Gbps[12] of bandwidth. Additional NG-PON2 features that pave the way for the gigabit future include colorless/tunable optics, increased reliability, multiple redundancy options and features, as well as lower power consumption. Verizon recently conducted a NG-PON2 field trial, leveraging different wavelengths to achieve 40+ Gbps throughput[13]. NG-PON2 systems also have a reach of 40 to 60 km. These important features and flexibility will enable broadband service providers that deploy NG-PON2 technology to succeed and thrive, in the near- and long-term.

Hybrid Fiber Coax: DOCSIS 3.1

Like the copper and fiber networks described above, cable multiple service operators' (MSOs) HFC networks need to be upgraded and expanded to accommodate existing and future demand for bandwidth and performance. Released in 2013 and updated several times since then, DOCSIS 3.1[14] supports capacities of at least 10 Gbps downstream and 1 Gbps upstream for each end user.

MSOs that upgrade to DOCSIS 3.1 will immediately improve network efficiency by 25%. This means that networks that are currently at 100% capacity can be utilized for more bandwidth[15]. This facilitated in part because the new specification uses extremely efficient Orthogonal Frequency Division Multiplexing (OFDM) subcarriers; instead of 6 MHz and 8MHz wide channel spacing used in DOCSIS 3.0. OFDM enables 4096 Quadrature Amplitude Modulation (QAM), as opposed to the previous 256 QAM limit. The spec also uses 20-50 KHz wide carriers for significantly enhanced upstream speed capability.

Simply put, whereas DOCSIS 3.0 required 780 MHz of spectrum to support 5 Gbps of bandwidth, DOCSIS 3.1's efficiency requires only 500 MHz. DOCSIS 3.1 also envisions upgrading the CATC system to a 1.2 GHz CATV system bandwidth up from previous systems bandwidth of 750 MHz, 860 MHz and 1 GHz.

Additionally, the new specification incorporates new energy management features that reduce cost of operation and wear and tear on equipment. Like the other technologies, this backwards-compatible specification works with cable modem termination systems (CMTS) as far back as DOCSIS 1.0, which was released in 1997[16].

As for actual movement toward deployment, 2015 has been a very busy year for DOCIS 3.1. CableLabs is hosting an interoperability plugfest [17] for vendors to test their products in September. Broadcom began sampling its first DOCSIS 3.1 chip earlier this year and STMicroelectronics unveiled its new DOCSIS 3.1 chipset in August [18]. Meanwhile, Comcast and Liberty Global have announced DOCSIS 3.1 roll-out plans for 2015[19] . Comcast also recently announced that its market trial of a 10-Gbps network will begin in 4Q [20].

MOVING FORWARD

Integrate to Innovate

Broadband service providers have more than enough reason to plan their gig-capable strategies and begin implementing them as next-generation software upgrades and equipment become available. The ever increasing need for bandwidth is not going to change anytime soon. However, gigabit apps and services in the development pipeline are poised to revolutionize today's networks in terms of their operation and how people use them.

Gigabit apps and services are bound to pack a few surprises (á la mobile video) in the not-so-distant future. In addition to needing more bandwidth, they will require low- latency and symmetrical bandwidth to fulfill their promise. All of this must be made available on legacy networks as well as greenfield opportunities. What is in place today is staying in place.

The specifications have been written and past experience has been taken into consideration. However, engineering gig-capability and implementing upgrades to copper, fiber and HFC networks is going to rely on first-hand experience with legacy technologies, understanding of new network technologies, and dedication to the end result. Finley Engineering offers all of the above and more to broadband service providers that are looking to get their gig-capable networks up and running ahead of their competitors.

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Steve Senne is Chief Technology Officer and Vice President for Finley Engineering Company. For over 25 years Mr. Senne has held leadership roles in projects involving FTTH, next-generation switches, VOIP, network upgrades, cybersecurity and other work for the communications, IP services and energy markets.

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