Network Convergence

Building a smart, simple infrastructure with advanced network capabilities

COMMSCOPE®

Network Convergence

Convergence: a single, unified infrastructure to serve the needs of multiple kinds of network traffic

Advance Planning Today Empowers Advanced Possibilities Tomorrow

The need is now

For wireless operators and other network service providers, rapid change has always been a central pillar of the business model. Each day the number of users is increasing, tapping into more applications, exponentially growing the demand for bandwidth and mobility.

Never before has the "connected life" lived up to its name so literally.

Add to all this the incredible proliferation of connected devices, services and other IoT innovations, and you begin to see how growth is driven not only by coverage and capacity, but by network complexity as well. By embracing a future-focused strategic approach of network convergence, operators can solve for all these challenges in one smart, simple network architecture which provides a common network to handle today's demand. With a little forward thinking, it can provide a solid foundation for the anticipated network demand of tomorrow. By adopting such a strategy, an operator even has the option of leasing currently unused excess capacity to other providers, creating a low-touch but extremely valuable incremental revenue stream that can accelerate CapEx offsets.

Never before has the "connected life" lived up to its name so literally.

Network convergence as strategy

"Convergence" is simply a general name for using a single, unified infrastructure to serve the needs of multiple kinds of network traffic.

Many operators are pursuing converged service offerings already in fixed and mobile bundled services. To maximize revenue, these operators must flatten their wired and wireless networks through a converged physical network architecture that handles both high-bandwidth applications as well as wireless backhaul.

In the process of deploying the fiber-optic infrastructure to power this converged network, the inclusion of dark fiber in the strategic plan provides insurance against the uncertainties of tomorrow's demand, while providing a potential source of revenue in the meantime—and it can all be done today for far less than the cost of upgrading infrastructure at the moment market demand compels it.

Building 5G for the future

The net cost of fiber-optic crosshaul and backhaul can be reduced by 65 to 96 percent by deploying an optimized converged fiber network in advance.

Fiber to the Home Council Europe

Hyperconnectivity and fiber

The single biggest market driver in wireless today is of course the ongoing rollout of 5G in markets all over the world. 5G presents a number of unique advantages in speed and latency—but also comes with some very specific challenges that can only be solved by a high-capacity, future-ready converged network built on high-performance fiber infrastructure.

As 5G is rolled out in stages, operators are deploying more sites in more unusual places—not only small cell sites hidden away in street furniture, but also in dedicated indoor 5G deployments based on small cell or DAS technologies. This need for higher network density is driven by its limited range and restrictions on radio power levels used in populated areas, forcing densities to increase in a way that LTE deployment strategies were rarely forced to confront.

This elevates the importance of crosshaul and backhaul, as many smart building applications and other 5G services depend on extremely low latency, an advantage only found in advanced fiber infrastructure.

The long-term economics point to convergence

As many operators have already found, the total cost of ownership of more advanced converged fiber networks has continued to shrink relative to the potential revenue gains. Fiber continues to extend further out into the network, and fiber to the home (FTTH) has now become commonplace, unlocking a vast range of new service offerings, dark fiber lease opportunities and others.

Convergence is the network strategy of the future—and the future is already here. This eBook will explore some of the details of convergence as an architecture, as a business model, and as a profound opportunity for today's networks to prepare for tomorrow's demand.

Convergence is the network strategy of the future—and the future is already here.

Enhanced Mobile Broadband and the Journey to Convergence

Welcome to the world of wireless innovation

If convergence is an evolutionary journey, then enhanced mobile broadband is the destination that justifies that journey. In many applications, that will take the shape of 5G connectivity that extends far beyond the conventional ideas of clearer mobile calls and faster refreshes on social media pages. In fact, services like 5G and IoT form the foundation for a dizzying array of new technologies, services and applications that will affect daily life at work, at home, at play and on the go.

Physical networks must continue to evolve

The number of mobile network applications is virtually unlimited, with millions of connected users and billions of connected sensors and other devices. Yet, without a robust physical infrastructure in place to reliably carry the vast amounts of data involved, the 5G promise would end at the antenna.

Enhanced wireless networks will connect these vital innovations in our daily lives

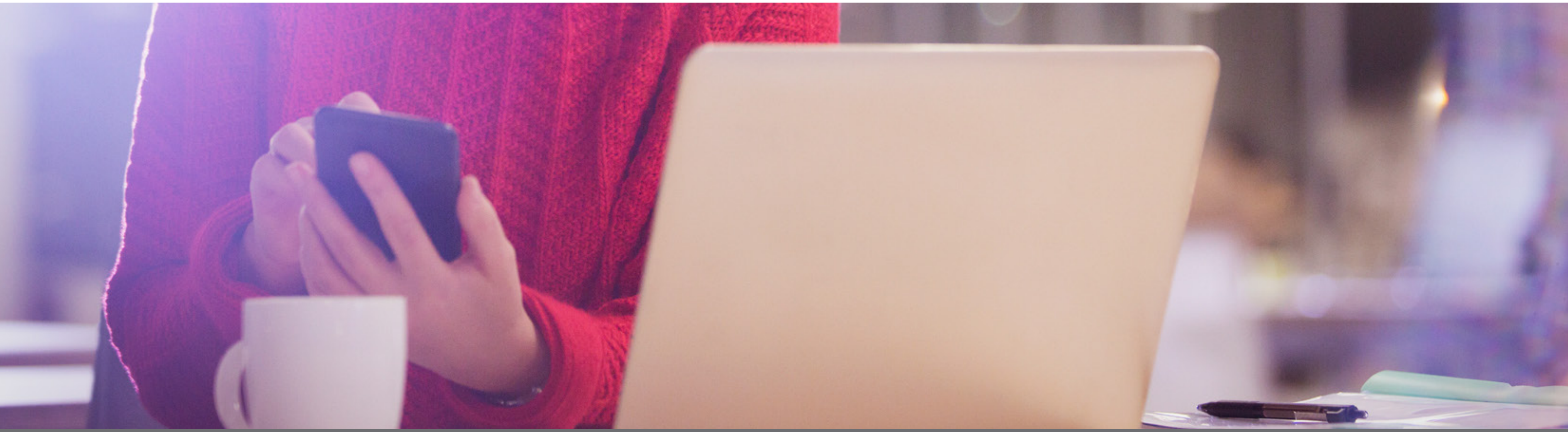
- Smart homes and buildings
- Self-driving automobiles
- Industrial automation
- 8k video
- Augmented Reality (AR)/Virtual Reality (VR)
- Video calling/ conferencing
- Telemedicine and remote surgeries
- Smart cities
- Universal cloud access
- *And countless others*

What's required is nothing less than a quantum leap in terms of the capacity, flexibility and speed of the physical network, which can be delivered through three evolutionary changes:

1. **Increased network density.** A denser radio access network (RAN) means more small cell sites, in more places, with more antennas employing MIMO and other capacity-boosting technologies. This allows more thorough coverage with lower power levels, as well as improved spectrum reuse for greater capacity.

How much denser? A lot

The highest-frequency bands in the 5G spectrum provide the most bandwidth, but also require the most antennas—*up to 10 times the number used for traditional LTE.*



2. **Centralized RAN (C-RAN) and Cloud RAN.** C-RAN architectures centralize the baseband units (BBUs) in a central location removed from the remote radio heads (RRHs) located on the sites they serve. This aggregation point can be miles away, connected via high-speed, high-capacity, low-latency fiber fronthaul. This enables more compact small cell sites and simpler DAS deployments for indoor wireless networks. It also streamlines the maintenance and upkeep of the radio equipment by co-locating multiple site head-ends under one roof. This arrangement also promotes efficient load-sharing and more effective spectrum reuse among BBUs to flex with variable demand.

   The next evolution of this architecture, Cloud RAN, will see the BBU equipment itself replaced by virtualized head-ends operating in a more traditional data center environment. This will further reduce operational costs, requiring less power and space, as well as simplify maintenance and administration. Here, the need for converged fiber infrastructure extends all the way into the data center itself.

The need for speed

It takes a converged fiber network infrastructure to deliver the speed needed by 5G connectivity. LTE delivers about 10Mbps, fast enough for email and web browsing, but not enough for various 5G applications.

5G speeds will range up to 2Gbps, up to 200 times current LTE standards

3. **Multi-Access Edge Computing (MEC).** The architecture of converged networks also requires that cloud-based application hosting must move closer to both the source and destination of network traffic. This practice, generally called edge computing, is a key component of delivering the high speeds, high bandwidths and low latencies required by 5G's most demanding applications.

   By moving computing and storage resources toward the edges of the network, service providers can leverage fiber fronthaul and backhaul to provide the performance needed to meet this need.

Without the physical infrastructure, none of it is possible

The one thing that these three transformative architectures have in common is the fact that they all depend on a powerful, flexible fiber-optic physical infrastructure to tie them all together. In the next chapter, we'll take a deeper look at the role converged network infrastructure plays in these architectures, and how the latest practices can help service providers leverage increased capacity and performance.

What low latency really looks like

Latency—the time it takes for a signal to reach its destination—is key to 5G performance. LTE has a theoretical latency of about 30ms and a real-world latency of about 50ms. Pretty fast—but not fast enough for 5G.

To reach its full potential, 5G network latency must be close to 1ms.

Planning and Building the Converged Network

Cooperation and competition

A converged network is, by definition, built on a versatile, high-performance infrastructure capable of handling multiple kinds of services and applications simultaneously. That means, in to build a converged network, one must secure the interest and cooperation of other communications network providers and operators. In some cases, these relationships are complementary; in others, they may be competitive, requiring some salesmanship to overcome assorted institutional obstacles common to proprietary networks.

Structural convergence offers something for everyone

Fiber networks offer the performance and flexibility to easily handle both fixed and wireless services; support commercial, industrial and residential customers; and enable both increased network densification and improved connectivity at the network edge. The sheer number of applications available means that most operators and service providers can find a compelling reason to engage in some level or degree of network convergence, as the benefits are virtually universal.

Convergence takes more than technology—it takes cooperation

Sharing infrastructure among different service providers and operators can be fraught with complications such as differing SLAs and maintenance responsibilities. However, the incentives are at least as strong:

- Lower per-operator deployment costs
- Competitive advantage over other operators on non-converged infrastructure
- Better coverage in remote areas
- Streamlined, standardized infrastructure

Convergence made easier, thanks to fiber flexibility

Sharing fiber infrastructure is an inherently easy thing to do because of the various operational levels at which the sharing can be done. Passive optical network (PON) architecture has a number of capacity-increasing practices associated with it that allow multiple services or modes to operate on the same platform without interference. This has particular value in C-RAN deployments.

As discussed in Chapter 1, C-RAN architectures connect a cluster of distributed connection points—such as cellular sites, Wi-Fi access points or similar—and centralizes their baseband functions at a remote location. The head-end can be on premise, or miles away. Employing fiber fronthaul that uses a WDM technology (either CWDM or DWDM) allows vast amounts of network traffic to flow without compromising latency or bandwidth.

Fiber backhaul is key to converging wired and wireless networks in a C-RAN environment because it provides the bandwidth, speed and scalability to empower ongoing C-RAN evolution, including Cloud RAN that allows operators to move the head-end even further toward the edge.

Multiplexing multiplies capacity

Using techniques like wavelength-division multiplexing (WDM), operators can increase their PON network capacity at no additional cost. WDM transmits multiple wavelengths at different frequencies along the same fiber. Within WDM, there is coarse and dense wavelength division multiplexing (CWDM and DWDM).

Building for the future: dark fiber

Dark fiber is unused capacity available in fiber infrastructure—in essence, it's convergence waiting to happen. This can take the form of extra parallel fiber infrastructure installed alongside a network's new deployments, or it can be higher fiber counts in a single cable run, giving the infrastructure more capacity than its owner needs. Sometimes this is done to build in redundancy or extra capacity for future needs, but it can also provide a valuable resource for sharing network resources with other operators.

Virtual dark fiber

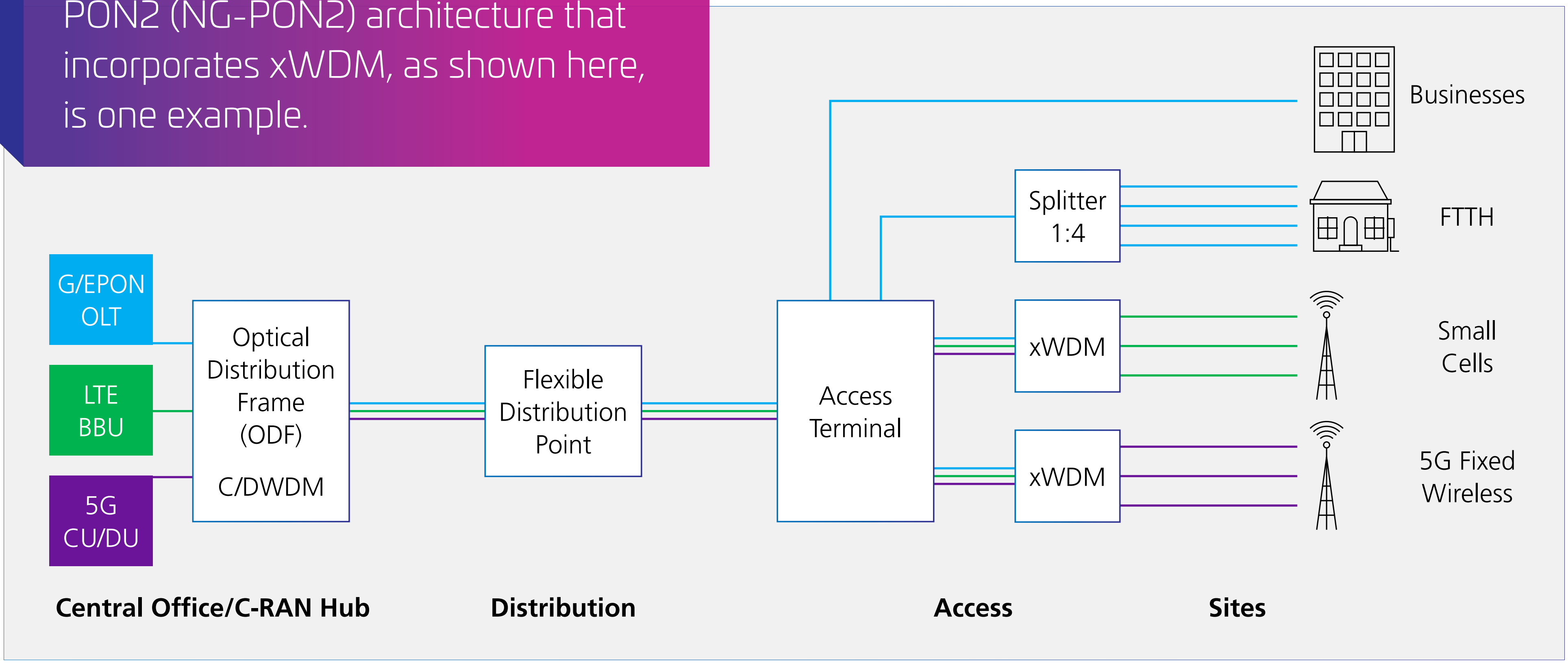
Dark fiber doesn't necessarily have to be extra physical infrastructure or surplus fibers included in a deployment, however; due to WDM, most PON have "dark fiber" already built into the infrastructure that's already in use.

Most fiber-to-the-home (FTTH) networks only use two or three wavelengths, typically one for downstream, one for upstream and one for RF video signals. This leaves a vast range of coarse or dense WDM (C/DWDM) wavelengths available for other uses and other operators—at a fraction of the cost required for those providers to lay their own fiber network. This represents an incredibly valuable opportunity for otherwise unrelated networks (such as cable TV and cellular) to share bandwidth via quick and inexpensive WDM sharing.

Multiplexing multiplies capacity

- **CWDM** transmits up to 18 wavelength channels spaced 20nm apart. For shorter runs, under about 70 kms, it's a great way to maximize existing fiber and reduce cost.
- **DWDM** can support up to 80 individual channels, spaced just 0.8nm apart. Plus, DWDM can be amplified, making it great for heavier traffic over longer distances.

A shared infrastructure can take many forms. Using a next-generation PON2 (NG-PON2) architecture that incorporates xWDM, as shown here, is one example.



Other levels of shared infrastructure

C-RAN, dark fiber and virtual dark fiber are just some of the ways to combine multiple networks onto a single infrastructure. Others include:

- **IP-level virtualization** that eliminates specialized head-end equipment in favor of more flexible virtualized functions in the data center
- **Layer 2 NG-PON2** architecture that improves reutilization of network resources via P2P WDM overlay channels

Convergence is worth the investment

The opportunities available with a convergence-ready fiber network can be realized with relatively minor incremental cost over a straight deployment. From extra capacity to redundancy to leased bandwidth revenue, network owners who pay a little more today and realize incredible returns tomorrow—on multiple fronts.

How to leverage existing networks

- NG-PON2 / XGS-PON / 10GEPON and future PON standards
- Coexistence elements
- WDM overlays
- Push PON splitters out further to free up fiber

The Many Ways Convergence Transforms Your Network

Greater demand—and greater opportunities

Converged networks are a natural response to two key business realities: the ever-increasing demand for bandwidth, and the need to reduce CapEx and OpEx costs. Because they offer cost-efficient on-ramps for multiple communications modes, fiber networks offer exceptional opportunities to better manage both priorities.

The fact is that convergent fiber infrastructure has the capacity to transform every level of your network, allowing cellular backhaul networks to carry distributed broadband traffic or vice-versa. To implement a convergent strategy, however, it's smart to consider all the factors that affect network capabilities at various physical levels.

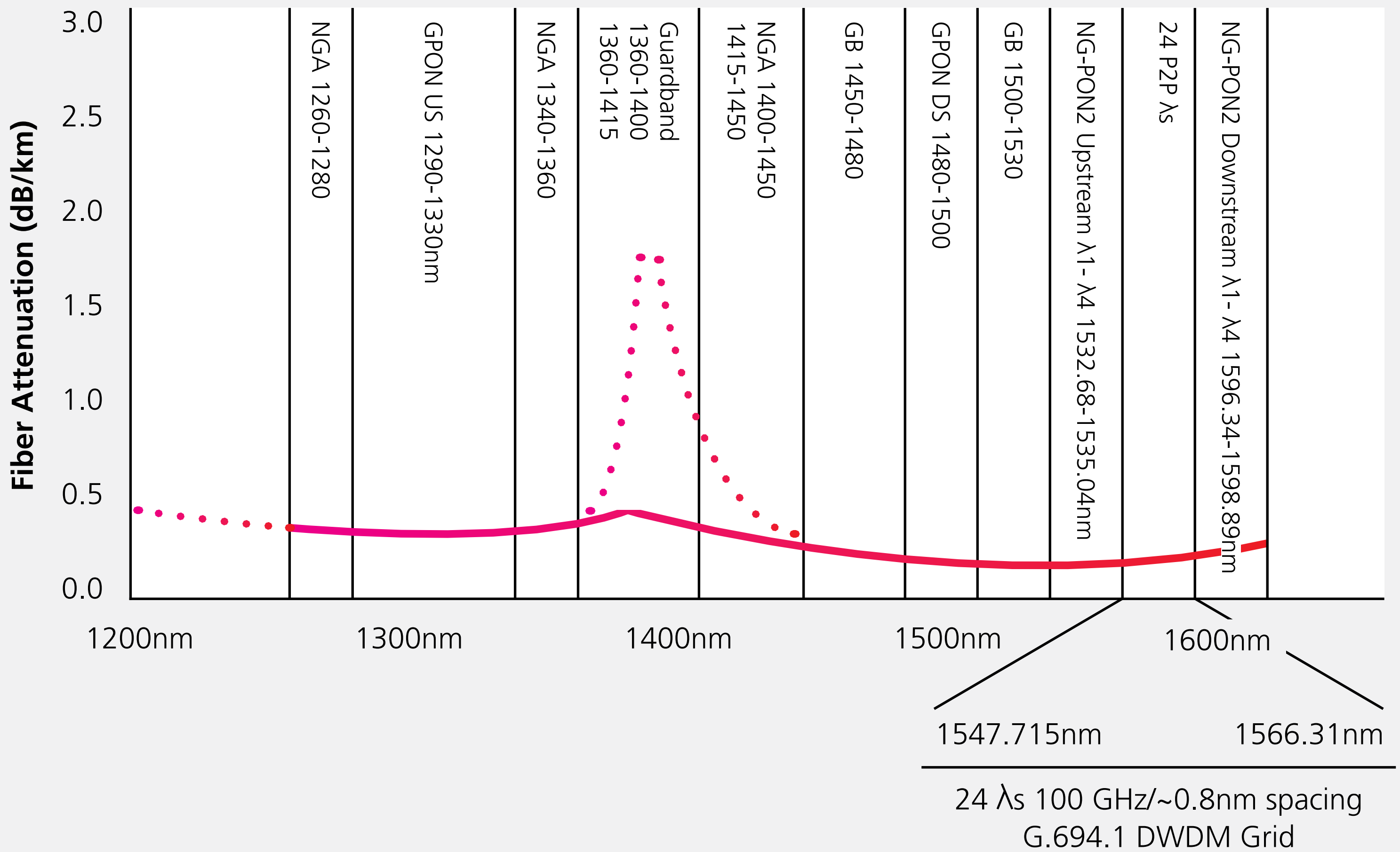
New deployment considerations

Depending on the location and function of each part of the network, new fiber deployments should be designed to best address their main priorities.

Convergent fiber infrastructure has the capacity to transform every level of your network.

The untapped potential of fiber

Thanks to wavelength-division multiplexing (WDM) opportunities, most fiber installations—particularly new installation—have greater capacity than any single mode can likely use. Since WDM can be employed in new installations or retrofitted to existing fiber networks, this valuable surplus capacity is literally there for the taking—and the selling.



1. **Central Office (CO) or C-RAN Hub.** The most important factor in these deployments is one of density to support virtualization. Key considerations include:
    - Managing high fiber counts
    - Providing flexible connectivity for multiple services
    - Integration of optical components
2. **Distribution Points.** Because of the rapidly-changing face of the business and constant addition of new services, applications and connection points, change tolerance and flexibility are foremost priorities at this level. Key considerations here include:
    - Cross-connect capabilities
    - Efficient management of high fiber counts
    - Documentation for management of various SLAs on different services

3. **Access Points.** Whether fiber to the home (FTTH) or other termination points, network speed and access are critical factors to manage. Key considerations at this level include:

- Various fiber counts in drop cables
- Drops to different locations
- Integration of power infrastructure
- Changes, adds and upgrades to drops

A worthwhile investment in future-ready capacity

All these convergence touchpoints can be implemented in new deployments with relatively modest CapEx. They can also be implemented in existing fiber infrastructure through the addition of WDM and the ability to support coexistence of multiple services even to multi-fiber connectors.

In the next chapter, we'll look at the wholesale and open access models for tapping new revenue streams in a converged network—so you can see what the extra five percent deployment costs can offer your network in return.

Convergence for Wholesale/Open Access

From an infrastructure perspective, network convergence consolidates the system buildout and management while enabling network operators to take advantage of efficiencies in backhaul. When paired with a wholesale open access network (WOAN) model, the business model for convergence grows even stronger.

The value of enhanced, converged services

In addition to minimizing risk, network convergence can also be a financial boon, especially for wholesalers who adapt their networks earlier rather than later. The service benefits of a converged network—improved latency, more bandwidth, greater reliability—have significant monetary value for end-users and service providers, by extension. In other words, infrastructure providers who invest in network convergence stand to reap the financial benefits of their investment.

While the upfront cost for network convergence is in addition to normal network expenditures, the cost to operate and maintain it is significantly lower than discrete wireline/wireless networks. Not only do wholesale operators save on network operations and maintenance, there is the potential to realize higher revenues from improved services.

Benefits for Wholesale Open Access Networks (WOANs)

The WOAN model decouples the infrastructure from the service delivery. One of the attractive aspects of the model is that it spreads risk and reward among those who build and maintain the infrastructure and those who retail it to the end users. Infrastructure wholesalers are somewhat insulated from the effects of shrinking ARPU, while service providers can lower their overall investment in network modernization.

More competitive landscape

Until recently, residential and, to a lesser extent, commercial subscribers have had limited options when it comes to selecting a service provider. The cost of building and maintaining a modernized network has prevented all but the largest, best-funded vertically integrated ISPs from competing. The up-take of 5G, along with the requisite investment in small cell and IoT deployment, will only deepen the divide.

The WOAN model completely rewrites the rules of entry for retail-focused ISPs. With infrastructure sharing on the rise, the wholesaling network can support multiple service partners to create a variety of revenue streams from the same infrastructure.

Opportunities for incremental revenue

The wholesale market is projected to be a key supplier to telecom service providers. In some markets, the service providers will look to shift all traffic onto the wholesaler's network. In other areas, they may only need selected resources, such as storage and extra bandwidth in high-density urban areas. Needless to say, 5G services and IoT deployment will be among the capabilities the WOANs will be asked to provide on an as-needed basis.

The WOAN model completely rewrites the rules of entry for retail-focused ISPs.

Private investors getting on board

For wholesale network providers looking to make the jump to a pure IP converged infrastructure, opportunities are also coming from unexpected sources, namely private investors. According to James Wagar, Managing Director of Thomas Capital Group, investors are now contributing to large pools of capital in order to fund networks on a project-by-project basis. Once the model is tested and the investment has been proven to be fruitful, Wagar predicts investors are more likely to give network owners funding with more leeway, which will result in increased efficiency.[i]

Differentiation through innovation

The WOAN model is not particularly new. In Europe and Asia, open access models appear more regularly, but in the U.S., the open access arrangement has primarily been adopted by local governments offering wholesale service to ISPs. As it continues to mainstream, and services such as Gigabit internet become commoditized, suppliers must be able to differentiate their capabilities. A converged network provides a more flexible and efficient way to do that.

Converge incrementally to better manage the process

It is important to remember that switching to a converged network does not have to happen all at once. Many elements of current 5G technology build on 4G networks. So, rather than having to engineer and manage a complete cut-over at once, mobile operators can take an evolutionary approach to infrastructure investment.[ii]

However you decide to approach the migration to a converged network, getting the infrastructure right is perhaps the most critical requirement. Not only will it dictate your level of success in the short-term, it will ensure you have the agility and scalability to support the bandwidth, applications and user expectations in the future.

Mobile operators can take an evolutionary approach to infrastructure investment.

i Open Access Networks Increasingly Attract Private Investment; Community Networks, blogpost; November 15, 2019
ii The road to 5G: The inevitable growth of infrastructure cost; McKinsey & Company, article; February 23, 2018

HFC Network Convergence

HFC: the original converged network

Hybrid Fiber Coaxial (HFC) has long served as a backbone for cable networks. Developed as a bridge from legacy coax to fiber, it has enabled network owners to move gradually toward a fiber-rich network. This inherent flexibility has proven valuable as network owners look to provide 10G multi-gigabit service delivery while still monetizing their investment in coax.

HFC enables the use of fiber from the head-end or central office to deep in the access network, then transition to high-speed copper for last-mile distribution. When it comes to network convergence, some characteristics of an HFC network not only make it well-suited for the task, they provide the operator with some competitive advantages.

With its hybrid structure, an HFC network is well suited for network convergence.

In fact, an argument could be made that the HFC network is already a converged network.

The convergence benefits of HFC cabling

As network operators work through the details of network convergence, the physical characteristics of HFC cabling provide some unique capabilities. These include bringing power to small cells and other devices, as well as backhaul and enhanced siting options:

Power: In addition to its fiber/coax composition, HFC has the inherent ability to provide AC power via the coaxial cabling. Typically, 15-amp service at 90 V is available, delivering more than enough power for wireless APs (Wi-Fi or LTE) and 5G small cells.

Backhaul: In an HFC network, backhaul can be provided in several ways. DOCSIS provides connectivity over the cable's coax or fiber links. Additionally, many HFC installations provide direct fiber connectivity over previously installed dark fiber.

Enhanced siting options: Going forward, the majority of wireless mobility to be deployed for LTE densification or 5G will be implemented in urban and suburban areas. In an HFC network, which is typically more aerial in these areas, many of the challenges of site acquisition and permitting can be alleviated.

> **"The evolution of 5G networks from LTE/LTE-A will need higher capacity backhaul links per cell site: while LTE/LTE-A networks need hundreds of Mbps, 5G network will need to support tens of Gbps."**
>
> 5G Backhaul: Requirements, Challenges, and Emerging Technologies; Intechopen.com; November 2018

HFC is a stepping stone to full convergence

Looking ahead, HFC operators face many significant infrastructure challenges as they continue to move toward a fully converged network model. Their network infrastructure plays a role in many, if not most, of those challenges. Here are just a few:

Increasing xhaul capacity: To support the surge in data demand, HFC networks will rely heavily on current and future DOCSIS versions for additional capacity and capabilities. DOCSIS 3.1 already allows for the move to 1.2 GHz and includes low-latency DOCSIS (LLD) in the specifications. DOCSIS 4.0 will eventually enable the jump to 3.0 GHz—but is still a few years off. In the mean time, DOCSIS 4.0 also provides for 1.8 GHz of spectrum as a part of the Extended Spectrum DOCSIS feature, which provides a good bridge to increased capacity.

Establishing new MNO partnerships: In the search for additional revenue, HFC operators must continue to expand their footprint without accumulating significantly more debt. Partnering with mobile network operators (MNOs) is a smart way to accomplish this.

Extending the value of legacy copper: While convergence suggests an all-fiber or fiber-to-wireless architecture, there is still a lot of value in the copper portion of the HFC network. By merely improving their xhaul capabilities, operators can extend the service life of their copper plant up to ten years or more. One way to do this is by combining the benefits of frequency modulation and multiplexing. For example, by applying orthogonal frequency division multiplexing (OFDM) to existing quadrature amplitude modulation (QAM) techniques, HFC networks can increase upstream capacity. The takeaway? No need to rush, there's 10-15 years of capacity runway in existing HFC networks.

Why HFC networks are well-positioned for convergence

Given the physical characteristics of hybrid fiber coax cabling and the emerging technologies to enable improved capacity, performance and cost-efficiency, operators of HFC networks are in an ideal position regarding network convergence. With much of North America still underserved, new subscriber growth, via partnerships with MNOs, there are plenty of opportunities to grow revenue without overhauls their networks. Taking a deliberate and planful approach will yield the highest return on your investment.

Time to Ask the Hard Questions

Now that we've outlined some of the key issues and potential strategies for network convergence, it's time to start asking the hard questions. Before embarking on a convergence initiative, you need to assess where you are, where you want to go and what are the roadblocks standing in the way. The following is a list of just some of the many questions you need to consider before beginning your network convergence.

Begin with the end in mind

A successful convergence demands a clear understanding of where you are and where you want to be.

Start with what you know:

- How many of your current macro sites have fiber backhaul?
- How much of that fiber do you own vs lease, and what is the cost difference?
- What are your plans for expanding fiber backhaul and fiber ownership?
- How does the footprint of your fixed network compare your mobile network?

Before embarking on a convergence initiative, you need to assess where you are, where you want to go and what are the roadblocks standing in the way.

Envision where you need to go:

- How many cell sites do you anticipate adding in next 5-10-20-50 years?
- What does cell densification look like?
- What is the long-term impact of your fixed network assets on cost and performance?

Convergence is not only a network issue, it's an organizational mindset.

Internal resources and planning

Convergence is not only a network issue, it's an organizational mindset. Consider if your organization is already set up for convergence by evaluating how closely fixed network and mobile network teams work together.

- Are your fixed and wireless teams integrated and aware of each other's plans and activities?
- Does the wireless team consider the fixed team as an internal supplier?
- Do fixed and wireless cooperate to avoid inefficiencies like trenching the same street twice?
- Is your fixed team aware of the wireless team's plans for densification/5G?

Creating a collaborative mindset begins at the top, with those responsible for strategizing and planning the network's roadmap. Ask yourself:

- When planning fixed network infrastructure do you consider the impact on your future wireless needs?
- Do you design your access networks with decades of excess capacity that can be tapped when needed?

Convergence is not only a network issue, it's an organizational mindset.

Cost and efficiency considerations

As discussed in Chapter 2, one of the most significant advantages of network convergence are the potential cost synergies. These savings can be realized on multiple levels within the network. These financial benefits help to assess the business case for convergence. The following are some of the many issues to consider as you evaluate your options.

What are your CapEx and OpEx costs for building, maintaining and operating separate fixed access and wireless networks compared to a single converge network?

- How many node locations, like central offices, do you need to achieve good geographical coverage for both wireline and wireless networks and at what cost?
- How small is the extra investment in few additional fibers compared to the total build cost and civils?

Convergence is not only a network issue, it's an organizational mindset.

Revenue potential

On the other side of the business case is the added revenue you stand to gain from a more efficient and streamlined converged network. Ask yourself:

- What is the revenue potential of next gen access technologies like XGS-PON and improved x-haul capabilities?
- What effect will a single, easier-to-manage network have on subscriber churn and ARPU?

How an experienced guide can help

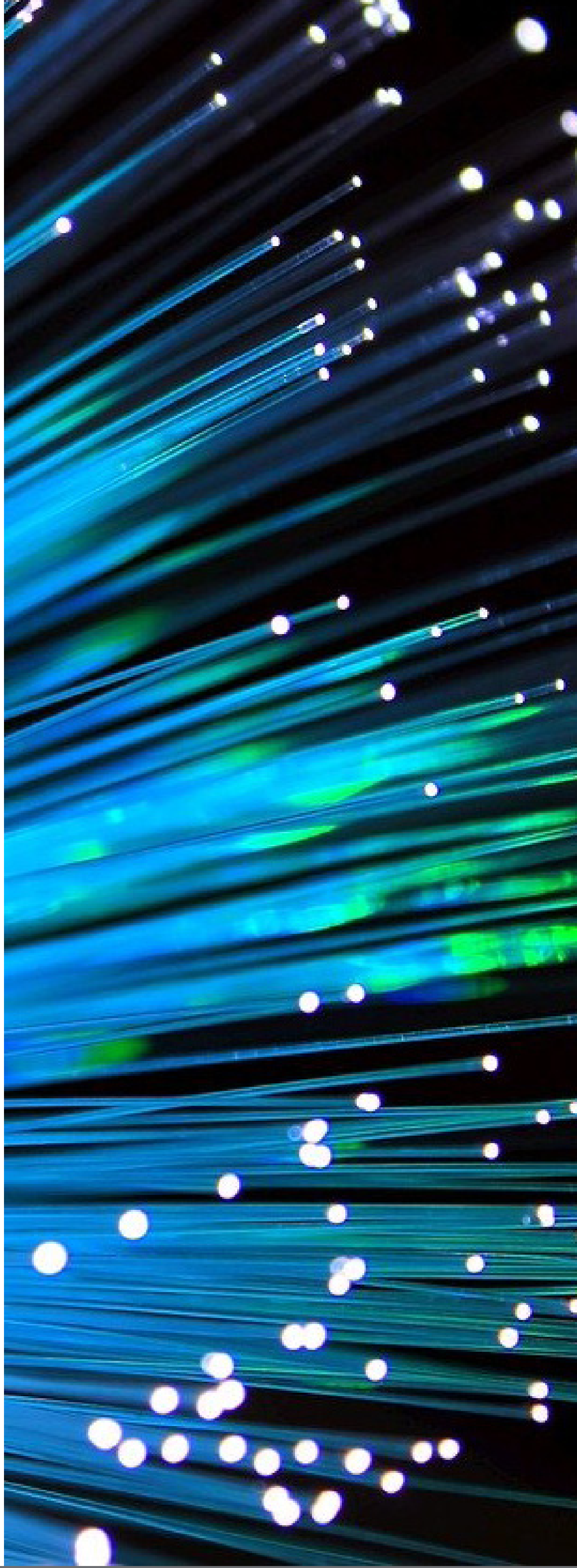
As you've figured out by now, the process of network convergence is less of a sprint and more of a deliberate journey. It helps to have someone beside you who knows the way forward—the potential pitfalls as well as quickest way from here to there. This experience is critical, even before you set out. An expert guide can help you:

- Identify the right convergence approach and solution(s) for your network.
- Get a lay of the land, understand the process and where to begin.
- Define the challenges by answering your questions, providing deeper discussion and providing insight based on experience.

Convergence is not only a network issue, it's an organizational mindset.

This is where CommScope's experience and vision, adds value and insight. Backed by 30 years of global fixed network and wireless experience, CommScope network architects can advise the best network topology and the right selection of technologies to ensure a streamlined, agile and future-ready converged network. With our Professional Services team, we give you the experience, partnerships and proven methodology to design, plan, manage and construct your converged network architecture project.

Now that you know, the future—quite literally—is in your hands. What's your next move?



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EB-114605.1-EN (08/20)