The virtualized and converged central office/cable headend

When the first telephone exchanges were built in the 1870s, switchboard operators sitting in a "central office" manually connected two copper wires, allowing people to converse using Alexander Graham Bell's invention - the telephone. Today it's mostly fiber optics instead of copper wires—and data switches instead of operators—but the function of the central office or cable headend as an access aggregation point remains essentially the same.

While this aspect is unlikely to change, more is expected from a central office in the coming years.

Networks are being upgraded to multi-gigabit access speeds and ultra-low latency performance to support applications ranging from virtual reality to connected cars. 5G will drive new services and business models. The cost of CPU processing power is rapidly declining due to commodity servers, and virtualization technologies are maturing. To reduce latency and improve the user experience, servers will be increasingly deployed in the central office and further out in the access network.

This white paper explores these trends and their impact on the central office and headend.

Four trends that are redefining the central office

- Evolution of access networks
- Convergence of wireless and wireline networks
- Virtualization through NFV and SDN
- Moving from central office to edge data center

The evolution of access networks

Copper access networks are the ubiquitous legacy of the analog telephone networks that began in the 1870s. From the telephone to the fax to the xDSL (digital subscriber line), the majority of the world's fixed internet services are delivered via the copper last mile. Cable TV (CATV) systems, originating in the 1950s, have since evolved to the HFC (hybrid fiber coax) networks of today. More recent is GPON and EPON, also known as fiber to the home (FTTH). In these networks, fiber-optic cables run all the way from the central office to the subscribers' premises.

Today, we are on the threshold of a new generation of high-bandwidth, low-latency access technologies that advances the user experience, promises new services and business models, and will drive changes in network architectures:

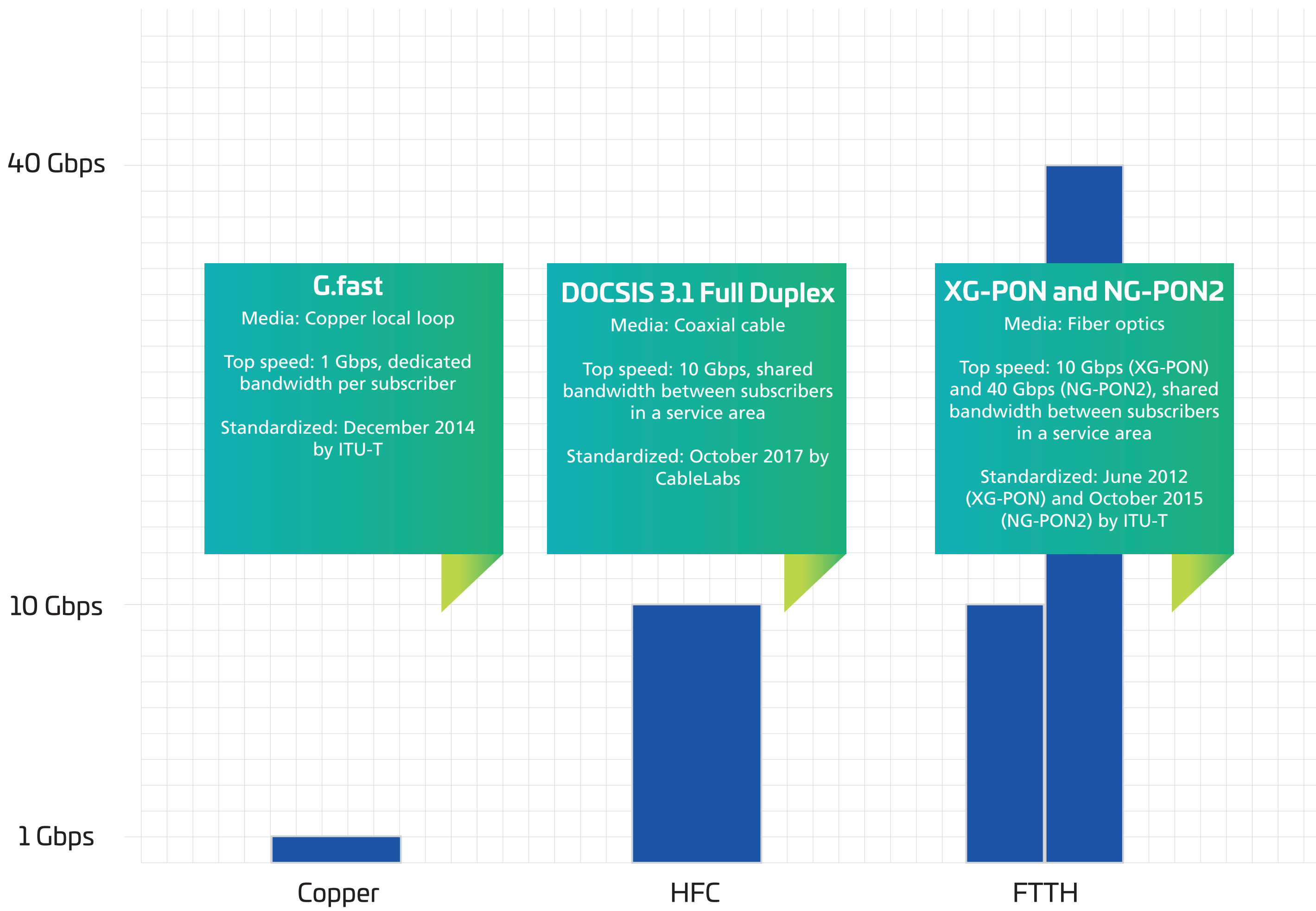

Figure 1: Next generation access technologies

For most service providers these technologies are at the trial and early deployment stage, and already we can see the implications for the central office and headend:

More ports and wavelengths to manage

The new access technologies will necessitate either a new OLT (optical line terminal) in the central office or a new CMTS (cable modem termination system) in the cable headend. Since space is a limited resource, higher density fiber connectivity solutions will clearly be preferable. Fiber in the access network is also a limited resource and therefore service providers will leverage wavelength division multiplexing (WDM) technologies to get the most out of the outside plant (OSP) fiber cables. This will require high-density optical modules in the CO to multiplex and de-multiplex the wavelengths, as well as WDM units packaged for the OSP at the far end. WDM for fronthaul between BBU's (baseband units) and RRU's (remote radio heads) is a key example of how this solution is leveraged. Some PON technologies include the ability to multiplex multiple wavelengths. This may create an expanded role for WDM, with an emphasis on efficient use of fiber in the access network, as well as space-saving in the CO.

Virtualization

NFV, or network functions virtualization, is starting to make its way to access networking equipment. Virtualized OLT and CMTS systems are becoming available. This architecture, where access networking equipment is emulated with software that runs on commodity servers and often combined with white-box SDN (software defined networking) switches, is similar to that of cloud data centers. The CORD (central office re-architected as a data center) initiative offers a framework for implementation.

Distributed access architectures

In distributed architectures, some network functions are moved from the central office or headend to locations closer to the consumer in the access portion of the network:

- xDSL: Higher speeds are achieved when copper pairs are terminated at a remote DSLAM (Digital Subscriber Line Access Terminal), closer to the subscriber. The fiber from the DSLAM to the central office then carries packetized Ethernet traffic.
- PON: A similar distributed architecture exists for remote OLTs, comparable to a remote DSLAM.
- HFC: The emerging remote PHY (physical RF layer) and remote MAC (Medium Access Control)-PHY architectures relocate layer 1 and/or layer 2 functions from the headend to the optical node, resulting in Ethernet traffic from the optical node to the headend.

In the long term, Ethernet traffic will gain an increased share of access network traffic. As this occurs the benefit of SDN will enhance service delivery across the entire network.

The convergence of wireless and wireline networks

Fiber optics is the backbone and transport infrastructure for both fixed and mobile services. Regulatory, organizational and operational priorities have traditionally driven these networks to evolve separately. As the need for increased capacity and lower latency presents new business opportunities, new design paradigms are emerging.

Cell densification

Today service providers are bringing their wireline and wireless networks together. They're adding small cells in high-demand areas to significantly boost capacity – a technique known as cell densification. In a December 2017 survey conducted by the Small Cell Forum, 40% of service providers expect to deploy 100-350 small cells per square kilometer in the areas where improved coverage and capacity are required. This is a key demand driver for new fiber in the access network.

C-RAN hubs

As part of cell densification, service providers are building C-RAN (centralized/cloud radio access network) hubs in centralized locations, e.g. in the central office. Service providers are removing processing functions (part of the BBU or Base Band Unit) and centralizing them - this is referred to as C-RAN (Centralized or Cloud Radio Access Network). These C-RAN hubs are then imbedded in the access network with the ability to increase the cell site density (densification). In the process, power consumption and site leasing costs can be reduced. Wireless capacity and performance improves and new features can be enabled once the BBUs are co-located and inter-cell latency is reduced.

Wireless and wireline services over one network

Instead of using dedicated and separate fibers, the convergence of mobile, residential, and business services over the same fiber takes advantage of a common fiber footprint. For example, fronthaul circuits between the BBUs and small-cell RRUs (remote radio units) may be on the same fiber cables from the central office or MSC (mobile switching center). If those RRUs are on top of a building, Metro Ethernet services to the customers in the building can also be riding on those cables. And soon, fronthaul to 5G fixed wireless access radios may be transported over the same PON network that's also providing services to residences and businesses.

Achieving operational efficiencies

Since large providers have both wireline and wireless operations, converging them onto a single access network to maximize coverage and minimize lead times for connecting new sites can significantly reduce overall fiber construction costs.

Impact on the central office and headend

A converged fiber network – compared to point-to-point networks carrying dedicated traffic – means that more wireless traffic will be terminating at the central office. With C-RAN hubs, some of the functionality that used to be performed at the MSC is now located inside the central office. Hence, an expanded role for the central office is expected as wireless networks expand.

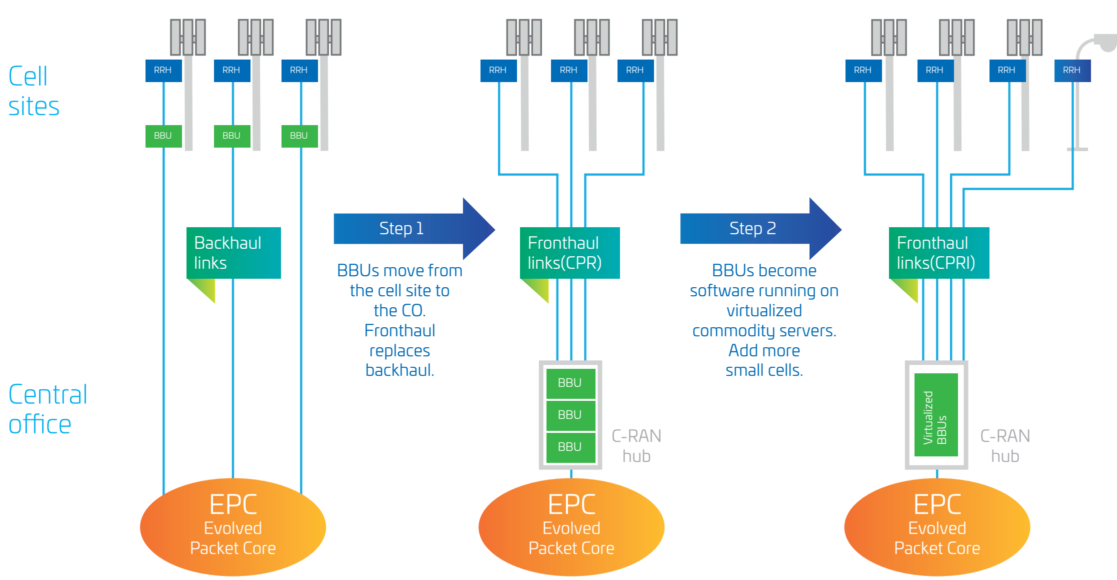

Figure 2: Creating a C-RAN hub

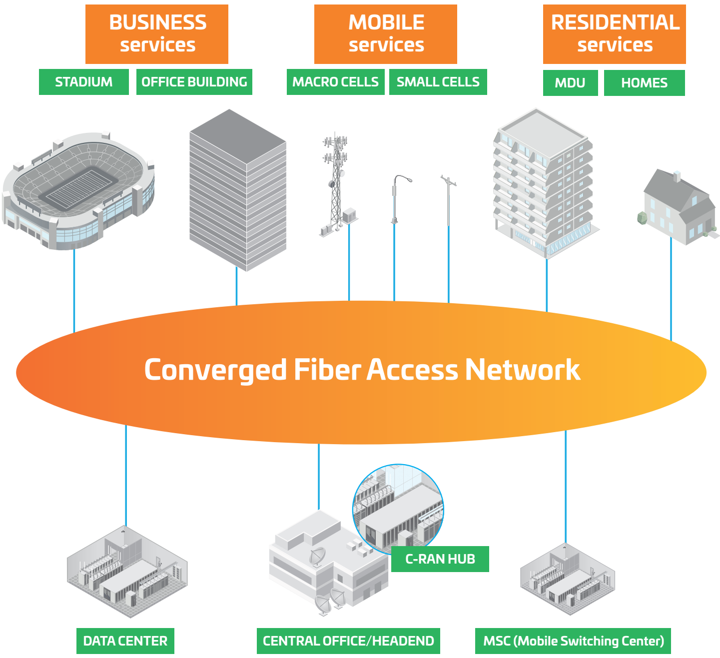

Fig. 3: Converged wireless and wireline network

Virtualization through NFV and SDN

The idea of virtualization in the telecommunications network is simple: network functions performed by actual equipment are replaced by software programs. In the central office this idea is expressed by the terms "network functions virtualization" (NFV). Just as the smartphone made devices like cameras, calculators, and watches obsolete—they were all replaced by software that runs on one device—so NFV will have a substantial impact on the deployment of network services and applications.

SDN (software defined networking) is vital to the changes to the network architecture by introducing concepts of centrally orchestrated networking, enabling agile traffic rerouting depending on network conditions, and making optimized use of the available capacity.

Reducing costs and optimizing capacity

Traditionally, network functions like routing, firewalls, deep packet inspection, and session border controls have been performed by dedicated pieces of equipment. For providers this has been expensive, since the devices must be procured, deployed, and maintained during their service life. NFV and SDN circumvent some of these expenses by implementing network functions with software, which operates on low-cost x86 servers deployed in data center network architectures.

For example, a provider could more easily allocate equipment and bandwidth to deal with demand from a large sporting event. In the longer term, providers will have increased their ability to scale up network capacity and increase the speed of deployments of new applications and services based on actual customer demand.

New architecture for new services

The development of NFV and SDN parallels the convergence of wireline and wireless networks. Just as the central office will see added equipment to support C-RAN, service providers are deploying equipment to leverage NFV and SDN: servers, switches, routers, and SDN controllers and orchestrators. This new architecture of the central office will allow providers to deliver a wider range of services, adopt new business models, and enter new markets. This brings us to another important trend: CORD, or central offices re-architected as data centers.

> Network functions traditionally performed by actual equipment is replaced by software allowing service providers to reduce hardware costs and better allocate bandwidth.

CORD (central office re-architected as a data center) combines NFV, SDN, and the elasticity of commodity clouds to bring data center economics and cloud agility to the telco central office. CORD lets the operator manage central offices using declarative modeling languages for agile, real-time configuration of new customer services.

https://opencord.org/

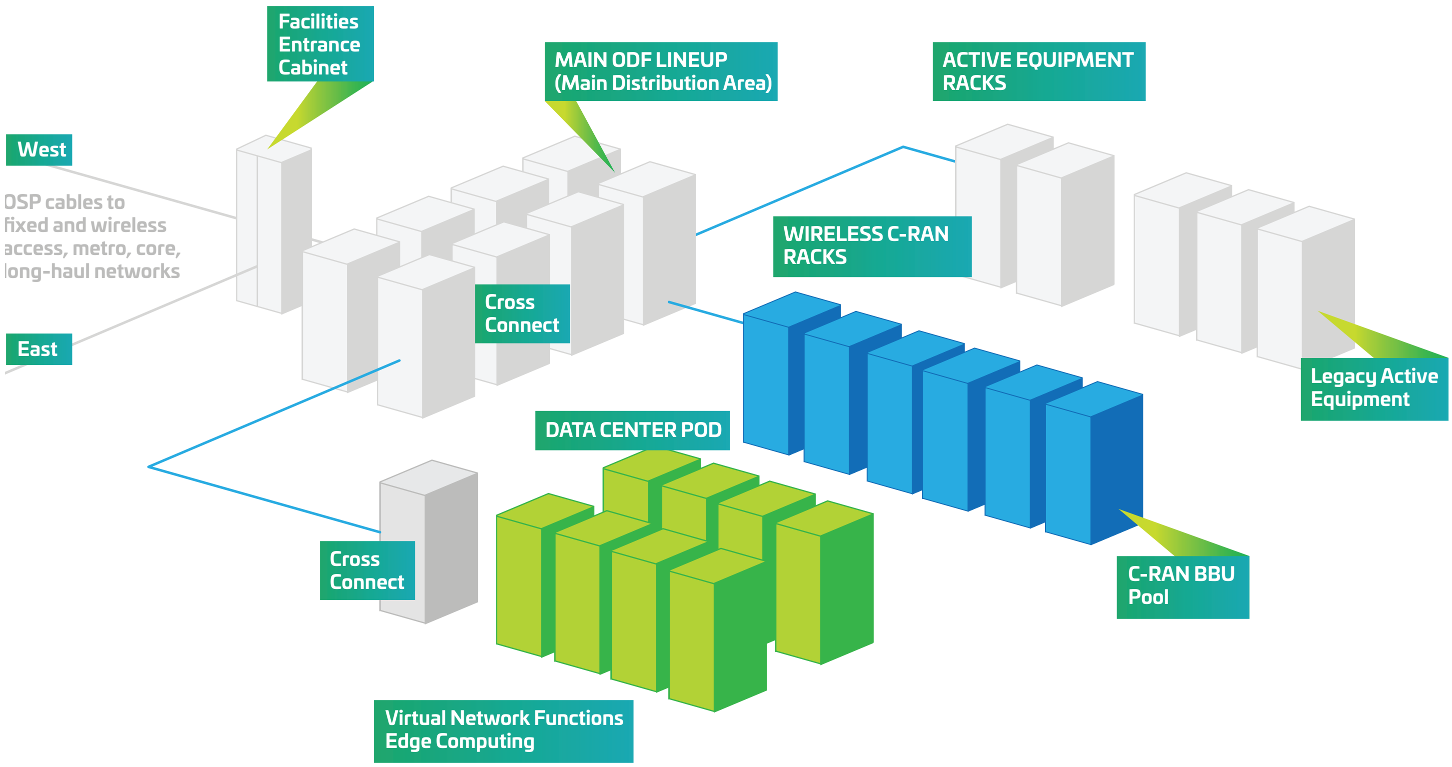

Figure 4: New additions to the central office/headend

Moving from central office to edge data center

Like the other trends, the move to edge data centers is prompted by the huge increase in data network traffic from mobile devices, the internet of things (IoT) and streaming media. In a traditional scenario, a cloud data center might be located far from the systems' users, possibly even on another continent. This distance could produce an unacceptable response time, or latency, in processing information requests and providing content to a network.

Bringing content closer to end-user

By establishing smaller data centers at the "edge" of the internet—far from huge hubs like New York City and Silicon Valley but close to the users—large providers like Netflix and YouTube can deliver content faster because they can cache the most popular content and web-application data on servers closer to their customers. These closer data centers not only make customers happy—by providing, for example, high-def video without buffering—they can save providers millions of dollars in backbone transport costs because of their proximity to the customers they serve.

Central offices ideal to house edge data centers

Service providers are well positioned to take advantage of the edge data center development, since they already have thousands of central offices in their existing networks with suitable carrier-grade facilities infrastructure and operational practices to incorporate data center equipment. By implementing small edge data centers in these locations, they can create facilities that function as both data centers and central offices.

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Offering better services and preparing for the future

Edge data centers sit at the demarcation between the core and access networks, so they allow cloud service and web content providers to keep up with increasing consumer demand because they can give quicker response times in streaming content, surfing the internet, and processing data for IoT devices. By positioning computing power and storage on the edge of the network, they can bring large advantages to providers:

- Bandwidth-intensive content is closer to the users
- Latency-sensitive applications are closer to the data source
- Data transport time is lower, with availability increased
- Dramatically reduced latency improves the user experience
- Edge data centers are minimally staffed or even run autonomously

These small facilities can also serve as a PoP, or point of presence—an interface point where a provider can have a local presence much closer to internet users. Furthermore, the development of edge data centers better positions network providers for the predicted growth of the IoT and the low-latency computing and storage demands posed by technologies like autonomous vehicles.

The CommScope view

As the world's networks rapidly move to a more virtualized, edge-based delivery model, a higher-performance fiber-optic infrastructure is a pre-requisite.

What will that infrastructure look like, and what will these changes mean for the central office? Since service providers will have different migration and upgrade strategies—possibly one for each geographic market—forecasting demand is challenging. The mix of current and new technologies, timing, and ramp-up speed all factor into the equation, so a flexible and adaptive infrastructure that allows providers to quickly tailor their services to customer demands, as well as react to developments in technology, will prove essential to creating a successful plan of action.

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