DOCSIS 4.0 and PON compared

White paper

Contents

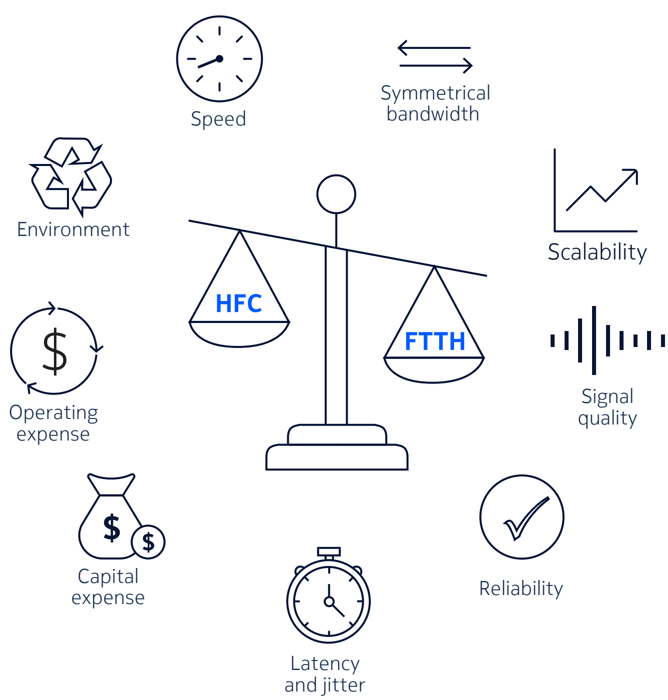
Introduction

For decades, cable operators have successfully relied on their hybrid fiber-coaxial networks and DOCSIS to satisfy their customers' broadband requirements. Since DOCSIS 1.0 in 1997, industry vendors and operators have continuously evolved the technology, adding capacity and capabilities to address the increasing and changing needs of the market. The latest and forthcoming versions of DOCSIS are no exception, taking capacities to gigabit and multi-gigabit.

But as customer wants and needs increase, and as competitive pressures from service providers deploying fiber-to-the-home (FTTH) networks mount, will it be enough? How does a DOCSIS 4.0 (D.4.0) hybrid fiber-coaxial (HFC) network stack up against a PON fiber-to-the-home (FTTH) network? Which is best for a cable operator's next-gen network?

There are many aspects to consider in evaluating network technologies and architectures, and there are many variables that come into play, so there is not a single, absolute answer. However, on almost every metric – speed, symmetrical bandwidth, scalability, signal quality, latency, jitter, reliability, CAPEX, OPEX, and environmental impact – a PON FTTH network is superior to DOCSIS 4.0.

Figure 1. Network characteristics



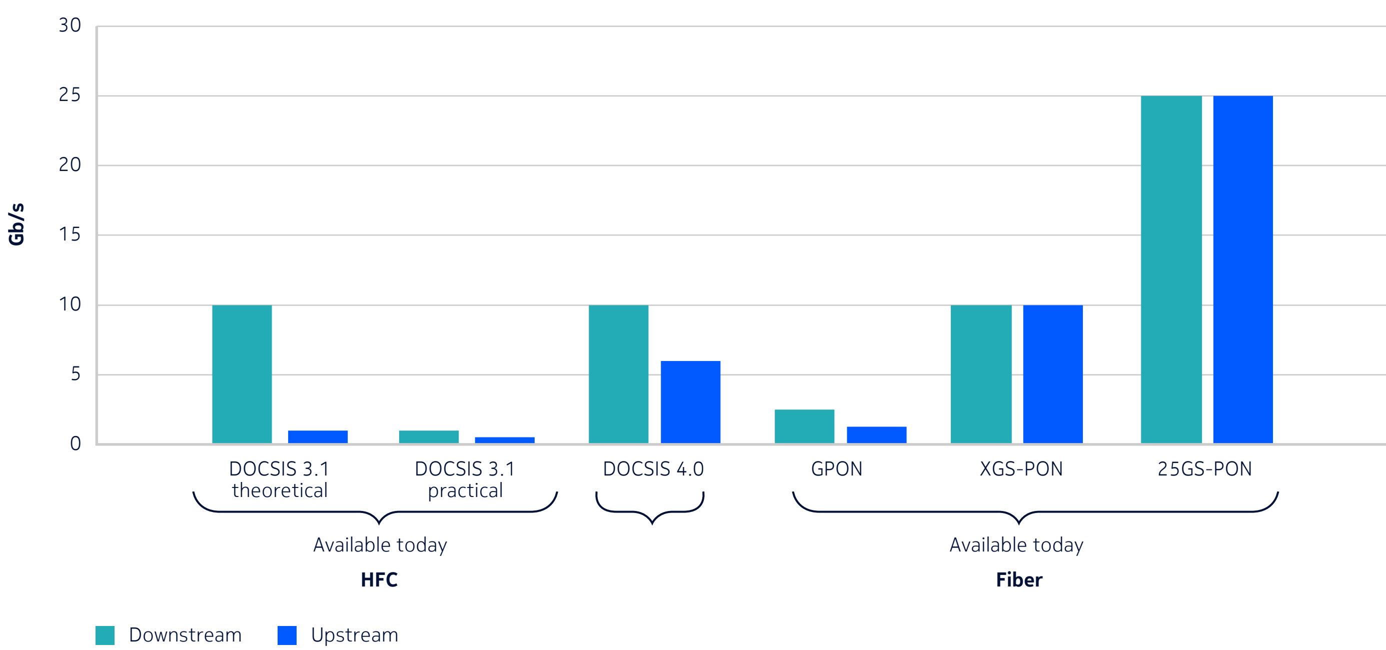
Speed

DOCSIS 3.1 specifies downstream bandwidth of up to 10 Gb/s and upstream bandwidth of 1 Gb/s. In reality, no cable operator is delivering anything close to that. Practically speaking, it will deliver up to 1 Gb/s downstream and 100 Mb/s to 1 Gb/s upstream depending on the split and whether the outside plant is capable. Most cable networks today are maxing at around 100-300 Mb/s downstream and 35-50 Mb/s upstream. The specification for DOCSIS 4.0 keeps the maximum downstream speed at 10 Gb/s and increases the upstream to 6 Gb/s, but broad commercial deployments are likely still a couple of years away.

On the other hand, today, GPON delivers 2.5 Gb/s downstream and 1.25 Gb/s upstream, and XGS-PON delivers 10 Gb/s symmetrical (i.e., both downstream and upstream). Also available today, and able to operate on the same fiber network, is 25 Gb/s PON.

In other words, in a couple of years, a DOCSIS network may be able to provide bandwidth approaching what XGS-PON delivers, but 2.5 times less than what 25GS-PON delivers, today.

Figure 2. Technology speeds

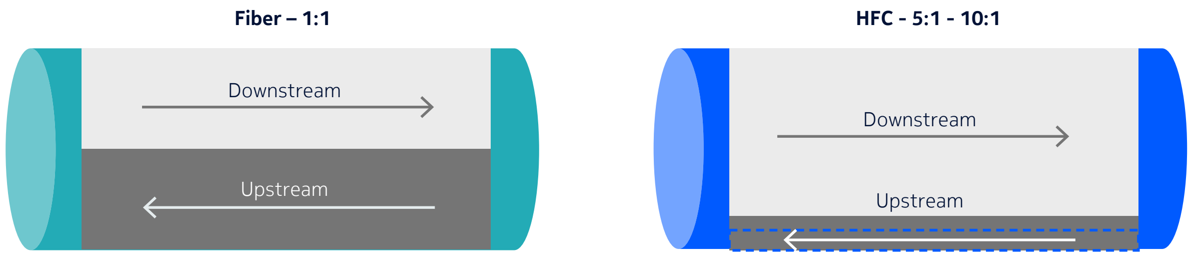


Symmetrical bandwidth

Cable networks have historically allocated the great majority of their bandwidth to downstream traffic. Fiber networks take a symmetrical approach, with most service offerings providing equal upstream/downstream performance. This is because fiber inherently has significantly more capacity than coax and can more easily be designed to provide symmetric speeds. Numerically speaking, where fiber typically has a 1:1 downstream/upstream ratio, cable DOCSIS networks are more in the 5:1 or 10:1 range.

In the past, these asymmetric speeds were not a major issue for most users; they were reflective of the typical consumer's usage. However, that's changing. As more people work remotely, participate in video calls, and attend virtual events and classes, the upstream network is experiencing more prolonged and more frequent periods of high demand. Consequently, it is increasingly important to configure networks with symmetrical bandwidth. Symmetrical bandwidth is even more critical for businesses which upload more and larger files as well as rely more greatly on cloud computing.

Figure 3. Symmetrical bandwidth

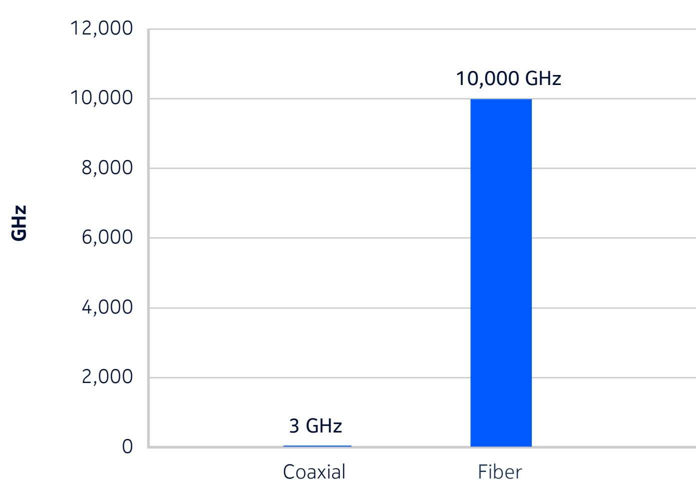


Scalability

The maximum speed delivered over a network is limited by the physics of the medium. An HFC network has quite a bit of fiber, but the last part of the connection to the customer is coaxial cable. Today, the coaxial portions of most cable networks are generally limited to less than 1 GHz of usable spectrum in total. Even DOCSIS 4.0 Extended Spectrum will only reach 1.8-3.0 GHz. By comparison, the available capacity of fiber optic cable is in excess of 10,000 GHz: 5,000 to 10,000 times greater. This allows for virtually limitless scalability in the future.

The process of scaling an HFC network can be far more complex than for a fiber network. For example, when needing to leverage more spectrum, as in the case of DOCSIS 4.0, cable operators will likely have to replace or upgrade existing nodes, add additional nodes, add power, replace the taps, reduce the number of amplifiers and replace those remaining, possibly upgrade parts of the coax itself, and more. On the other hand, fiber networks require only upgrading the network electronics.

Figure 4. Bandwidth and scalability



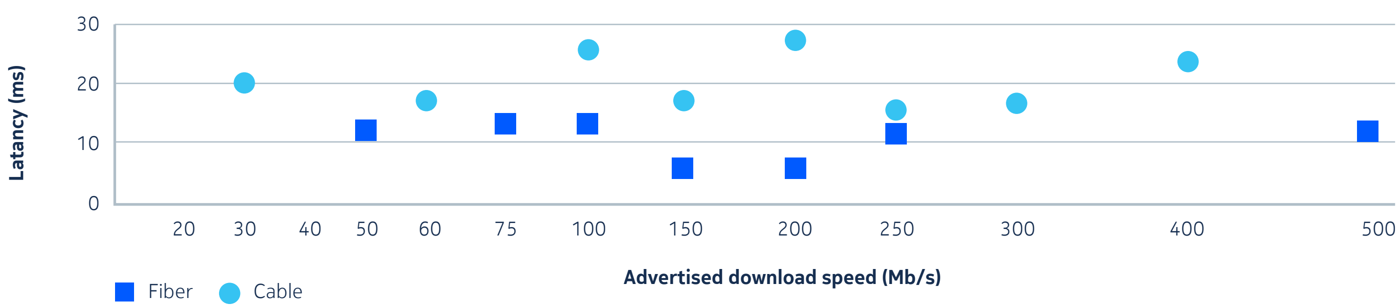
Signal quality, latency and jitter

DOCSIS deployments exhibit higher latency and jitter than fiber networks. There are several related reasons for this. First, the degradation in older cable results in higher noise rates and greater signal attenuation. To contend with this, DOCSIS uses advanced encoding schemes which result in additional latency. Cable operators can use simpler encoding schemes to minimize the impact, but that will result in lower noise reduction which in turn leads to more dropped packets and greater jitter.

A new development called “Low Latency DOCSIS” (LLD) came out with DOCSIS 3.1. LLD aims to reduce latency by targeting specific flows/applications (e.g., gaming, video) that are greatly impacted by latency. It is not a comprehensive, systemic latency reduction, it won’t address the delays caused by encoding and decoding traffic, and it is complicated. LLD requires several hardware and software components to work together, so successful implementation will depend on multiple vendors.

Signals on fiber, on the other hand, contain very little noise, so fiber protocols require less overhead for error correction, ultimately meaning lower latency and jitter. The chart, part of an FCC study, shows the weighted median latencies, by technology and by advertised download speed for terrestrial technologies. At every speed, fiber delivered lower latency.

Figure 5. Latency for terrestrial ISPs, by technology, and by advertised download speed



Source: U.S. Federal Communications Commission, January 2021

Reliability

HFC networks have significantly more active electronics, such as nodes and amplifiers, in the outside plant than fiber networks. As DOCSIS networks upgrade and take fiber deeper, there will be more nodes installed. These active elements are dependent on power from the electrical grid or, in the event of a power outage, backup batteries. Being in the outside plant, these components are at risk of water damage from rain and snow. Passive elements can also be physically damaged. Furthermore, as discussed above, HFC networks are subject to considerable noise and signal degradation, and the network needs regular maintenance to preserve performance levels. All these factors reduce HFC network reliability.

FTTH networks have no active outside plant components, except in the case of a network that includes remote OLTs. The only real physical risk is fiber breakage if, for example, someone hits the fiber while digging (e.g., during construction). Fiber inherently has less noise and does not require regular maintenance. Verizon found repair rates dropped by as much as 50 percent compared to their copper-based networks. Fiber is durable; once in the ground, a fiber will endure for more than 75 years.

Capital expense

The most common argument against going FTTH, at least in a brownfield environment, is the capital expense. In a greenfield deployment, there is not a great deal of difference. The largest costs are in laying the network infrastructure, and in a modern HFC network, fiber would be taken nearly as deep as in an FTTH network. In this case, most operators will opt for FTTH for all the reasons discussed in this paper.

In a brownfield environment, it is very likely that an operator could upgrade their HFC network to DOCSIS 3.1 with a mid- or high-split ratio for less than an overbuild and transition to FTTH. While this could get an operator to gigabit services, it does not have a long-term multi-gigabit future. Taking the current HFC network to multi-gigabit would involve going to DOCSIS 4.0. In addition to node changes and additions, cable operators will likely have to replace or upgrade tap plates, tap housings, drop cables, power plant, amplifiers, and possibly fiber trunk infrastructure. At this point, depending on the deployment density, the capital expense is likely comparable to an FTTH transition, if not more.

Operating expense

Whereas capital expense is a one-time cost, operating expense is ongoing. Consequently, over the life of a network, a significantly lower OPEX can offset a higher CAPEX, potentially leading to a lower total cost of ownership. And that is arguably the case with FTTH vs HFC networks.

Anecdotal evidence from cable operators as well as a detailed study published in mid-2020 show that OPEX for FTTH networks is about 50% that of an HFC network.

Looking at this in a bit more detail, there are several components to OPEX. Some of these include explicit items like power and maintenance, but related items such as customer churn should also be considered.

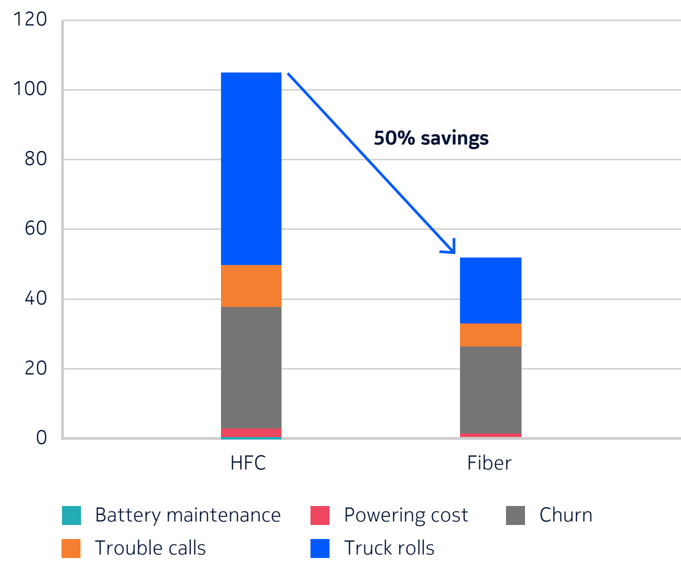
HFC networks typically have far more active electronics in the outside plant than FTTH networks. HFC active electronics include a large number of nodes and multiple coax line amplifiers per node. The nodes also require back-up batteries in the event of grid power failure. As cable operators offer higher-speed services, they will need to increase the number of nodes (i.e., decrease the number of households on each node), and thus increase power consumption, in the network.

A centralized PON network has no active electronics in the outside plant. If remote OLTs are used, they will require power and standby power.

HFC networks require careful signal quality and leakage detection monitoring. HFC network are also subject to damage from rain or snow. Signal quality issues or damage to outside plant elements may lead to a trouble call from a customer and, if not able to be resolved remotely, a truck roll. Ultimately, more issues lead to lower customer satisfaction and a higher churn rate.

With so many fewer active outside plant components, FTTH networks have much lower maintenance requirements. In combination with the superior signal quality delivered over fiber, FTTH networks also enjoy a higher level of customer satisfaction.

Figure 6. Total annual operating expense per home passed



Source: Fiber Broadband Association, June 2020

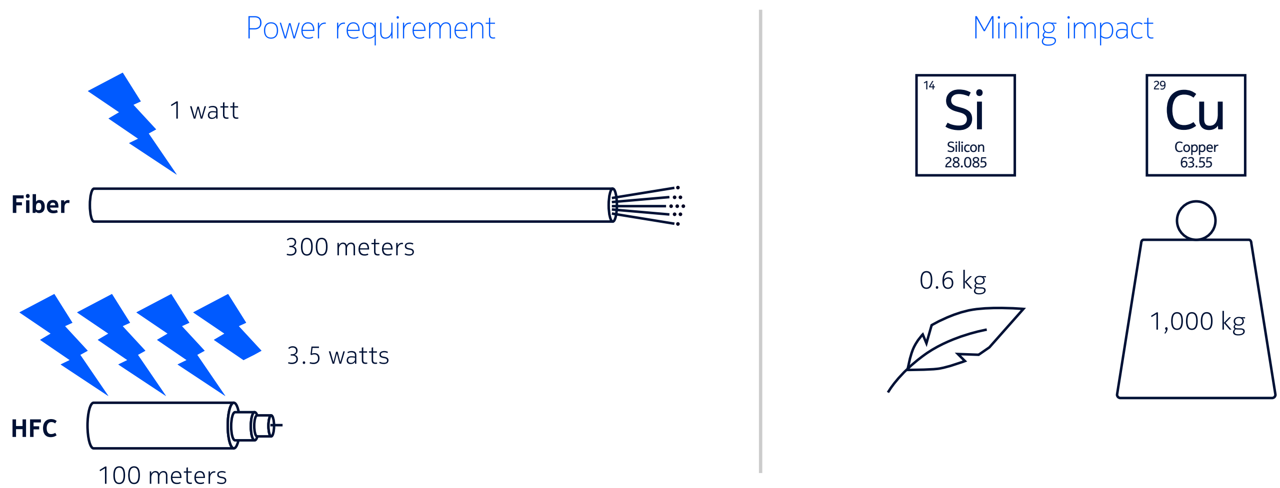
Environmental

As global concern for our environment has increased, whole industries have made moves and commitments to becoming carbon neutral. The information and communications technology (ICT) industry is one that has stepped forward and acknowledged the importance of making sustainability a key agenda item. It is estimated that the ICT sector is responsible for 2% of global CO2 emissions, the same as the aviation sector.

Power consumption is an important part of this, and it is generally accepted that fiber uses less energy than copper, with calculations ranging from seven to twelve times less. A fiber network requires just 1 watt to transmit data 300 meters while a cable network uses 3.5 watts to send the same data just 100 meters.

As discussed above, fiber requires far less maintenance and fewer truck rolls, all of which reduces total carbon emissions. Even fiber's higher bandwidth and speed contribute to a reduced footprint as it enables more effective telecommuting and school-from-home. Perhaps greatest of all is that coax uses copper, which must be mined from the earth – a huge environmental impact. Fiber is created from silicon dioxide (SiO2). Silicon is the second most common element on earth, naturally occurring in sand, clay and rocks, and extracted with no damage to the environment or harmful byproducts. According to Corning, a leading producer of fiber, "the mining required to provide two kilograms of copper wire (roughly the amount you would need for a 200-foot length of copper cable) translates into about 1,000 kilograms of environmental impact. The creation of that same length of fiber requires only about 0.06 of a kilogram of environmental impact."

Figure 7. Environmental impact



Conclusion

Fiber offers clear advantages over HFC in speed, symmetrical bandwidth, scalability, signal quality, latency, jitter, reliability, CAPEX, OPEX, and environmental impact. Given ever-growing network capacity and performance demands, as well as increasing competitive pressures, cable operators must consider both a short-term and long-term strategy. In greenfield deployments, FTTH is generally accepted as the default approach. In many brownfield networks, even where a DOCSIS-upgrade is enough near-term, it is a stepping-stone to an eventual FTTH deployment. Thus, FTTH is almost always the right choice.

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