An Introduction to D3.1*Enhanced*

Learn about how D3.1*Enhanced* can optimize the performance of mid-split and high-split HFC cable access networks.

Not all optimization scenarios for HFC cable access networks are equally viable, and not all network architectures need to evolve at the same pace. Indeed, many unique factors—such as geographic location, network traffic, or homes passed—may mitigate the urgency or even the need to make the leap from a 1 GHz sub-split network architecture to full 1.8 GHz DOCSIS® 4.0 operation.

COMMSCOPE®

SOLUTIONS BRIEF

Overview

For some cable operators, network improvements are a matter of timing, pace, and scope. Upgrading a network for DOCSIS 4.0 operation, for example, is a considerable undertaking that involves virtualizing the headend, deploying DAA architectures, replacing network passives, and committing to significant construction in older parts of the network—to say nothing of the potential for significant service outages during the upgrade process. To further complicate upgrade scenarios, what constitutes an "obsolete" operating system is, in many instances, really a matter of context. The same can be said of optimizing an "obsolete" HFC cable access network. That's why a "one-size fits all" approach to improving network performance is simply not realistic. Instead, cable operators should determine which areas of their network need to be updated or improved and why, the cost benefits of the improvement options that are currently available to them, and the impact these improvements will have on their business—and their subscribers—in five or even ten years.

For networks (or targeted areas of an existing network) that merit a fiscally conservative, more measured approach to optimized performance—but which can also benefit from increased downstream capacities and throughput speeds—CommScope® offers the D3.1*Enhanced* (D3.1*E*) solution, a cost-effective, surgical approach to enhancing the performance of existing network deployments by increasing the spectrum available on mid-split or high-split networks. D3.1*E* supports the introduction (or expansion) of premium, gigabit service tiers and helps to establish a foundation for future plant upgrades by replacing current generation DOCSIS 3.0 and 3.1 CPE devices with next-generation DOCSIS 3.1+ or DOCSIS 4.0 CPE devices. Best of all, D3.1*E* can provide these benefits with either no upgrades or minimal upgrades to an existing network architecture, depending on its current operating capacities.

D3.1*E* is part of CommScope's *evolutionary* approach to optimizing, improving, and enhancing current HFC cable access network performance. Cable providers with a more conservative, incremental plan to evolve their networks can keep their current operating systems in place for the foreseeable future, install DOCSIS 3.1+ CPE devices, and still achieve a significant uptick in downstream bandwidth capacity and speed—with up to five bonded OFDM channel blocks and 8 Gbps throughput speeds —in mid-split or high-split networks. Cable providers who have more immediate plans for DOCSIS 4.0 network operation can deploy DOCSIS 4.0 CPE devices in their D3.1*E* networks now and prepare for DOCSIS 4.0 operation ahead of any future headend and outside plant upgrades.

D3.1*E* Explained

D3.1*E* uses DOCSIS 3.1+ or DOCSIS 4.0 CPE devices to expand downstream capacity and increase network throughput speeds without the need for significant upgrades to existing network infrastructures. D3.1*E* immediately enables cable providers to introduce upgraded, higher-speed service tiers to their portfolio of services and surgically target these upgrades to those subscribers who order them.

The performance capabilities of current generation DOCSIS 3.1 devices, DOCSIS 3.1+ or DOCSIS 4.0 devices, and D3.1*E* deployments depend primarily on the number of OFDM (in the downstream) and OFDMA (in the upstream) channels the device supports. This support, in turn, depends on the switches and diplex filters the device uses to operate in a specific network configuration. Current generation DOCSIS 3.1 modems, for example, support up to two OFDM blocks at up to 192 MHz each in the downstream and up to two OFDMA blocks at up to 96 MHz each in the upstream in an 85/108 MHz mid-split or a 204/258 MHz high-split network.

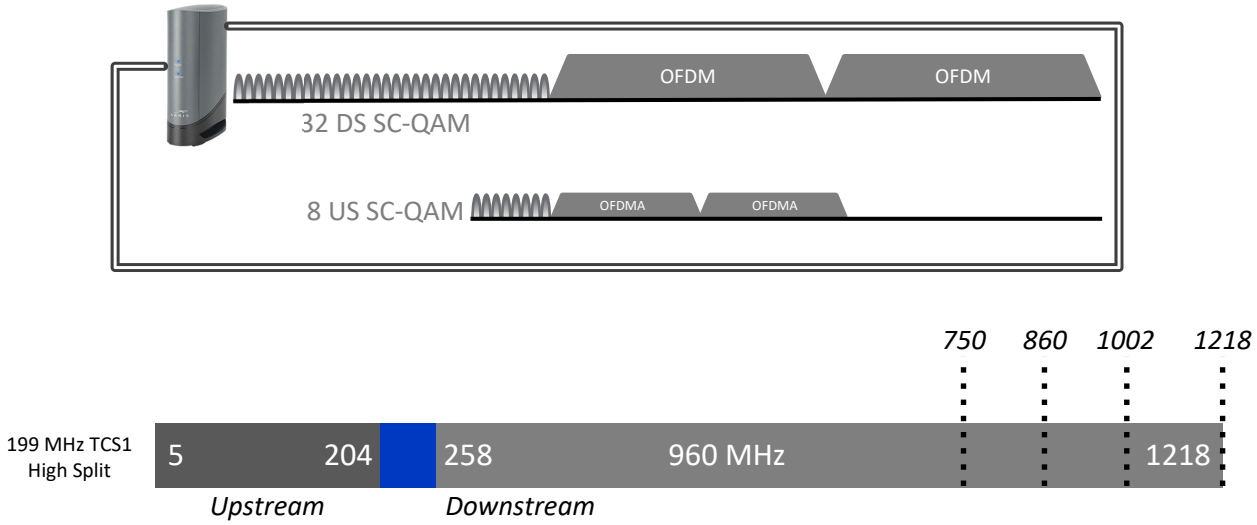

Figure 1. Current Generation DOCSIS 3.1 CPE OFDM/A Capacity with 32 Downstream SC-QAMs

Next-generation DOCSIS 4.0 CPE devices, on the other hand, can support up to five OFDM blocks at up to 192 MHz each in the downstream and up to seven OFDMA blocks at up to 96 MHz each in the upstream in an ultra-high split network.

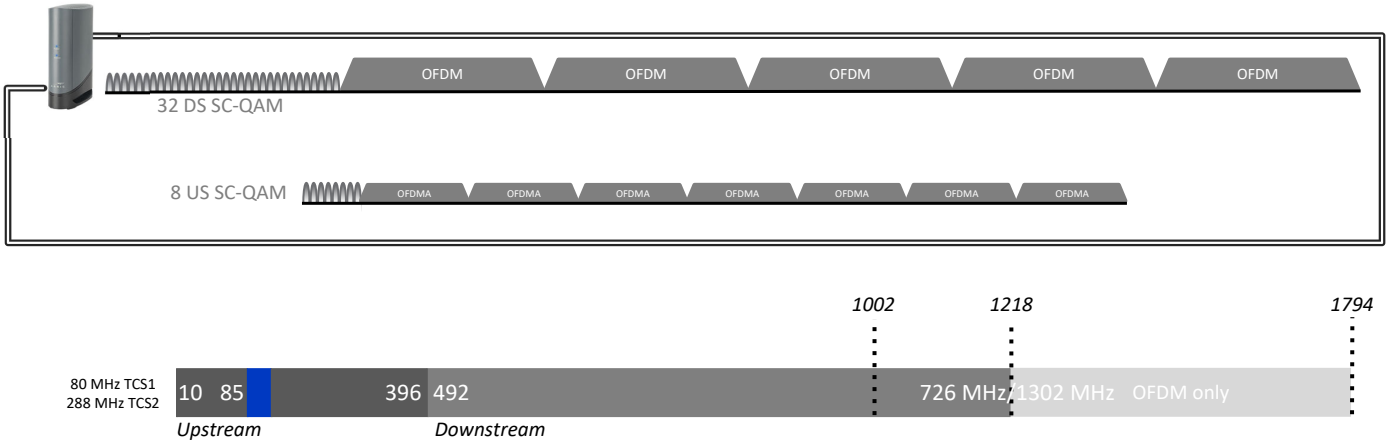

Figure 2. DOCSIS 4.0 CPE OFDM/A Capacity with 32 Downstream SC-QAMs

Next-generation DOCSIS 3.1+ CPE devices utilize an advanced chipset that supports up to four OFDM blocks at up to 192 MHz each (with 32 SC-QAM channels) or five OFDM blocks at up to 192 MHz each in the downstream and up to two OFDMA blocks at 92 MHz each in the upstream. This same OFDM/A capacity is also supported by DOCSIS 4.0 CPE devices operating in a DOCSIS 3.1 mid-split or high-split network.

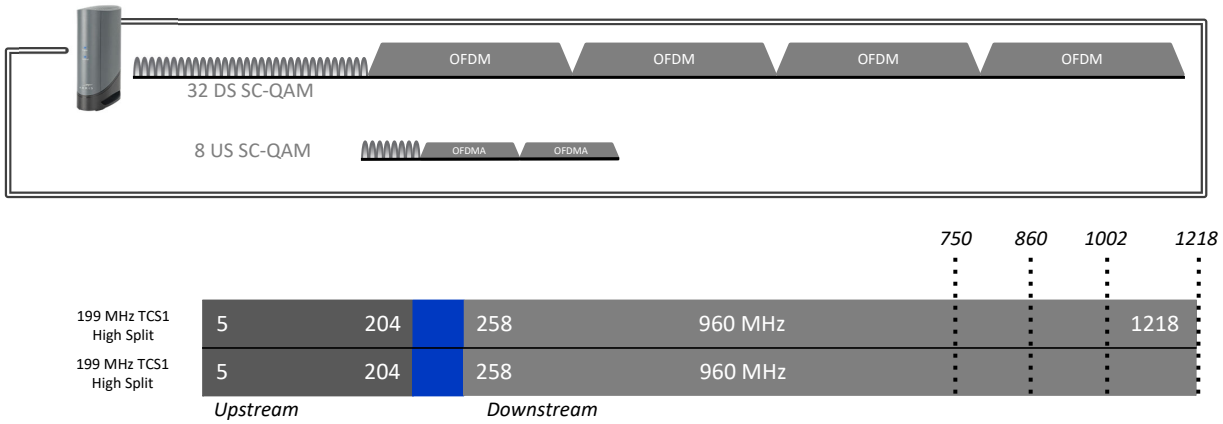

Figure 3. Next-Generation DOCSIS 3.1+ CPE OFDM/A Capacity with 32 Downstream SC-QAMs

DOCSIS 4.0 CPE devices can operate on either current DOCSIS 3.1 mid-split and high-split networks (when equipped with the proper diplex filters and switches) or ultra-high split DOCSIS 4.0 networks; next-generation DOCSIS 3.1+ CPE devices can operate on any system with a DOCSIS 3.0 or DOCSIS 3.1 CMTS architecture. D3.1*E* leverages the increased OFDM/A capabilities of these devices to boost the network capacity of a variety of network architectures. Cable operators, however, will achieve maximum gains in mid-split and high-split networks. Thus, cable operators can deploy D3.1*E* to expand the downstream capacity of their current network to a maximum of 5 OFDM blocks at up to 192 MHz each.

Besides these increases in downstream speed and capacity, D3.1*E* can also provide additional operational benefits. For example, D3.1*E* can help to accelerate the adoption of IPTV services. As the industry pivots toward DAA, Node PON, and virtualized headend operation, many cable operators are now beginning to plan for a transition from legacy MPEG-QAM video channels to IPTV. By eliminating MPEG QAM video channels, cable operators can reclaim either 6 or 8 MHz per channel (depending on their current channel configurations) in the downstream band. Leveraging D3.1*E*'s expanded OFDM downstream capacity, cable operators can then reassign that portion of the downstream spectrum to an OFDM carrier. This modification isn't possible with standard DOCSIS 3.1 CPE devices, because the devices are already operating at maximum downstream capacity—that is, two OFDM blocks and 32 SC-QAM channels.

Additionally, many D3.1*E* CPE devices support improved or enhanced Wi-Fi® features, which further support a transition to IPTV. D3.1*E* gateways, for example, may feature the latest dual-band or tri-band Wi-Fi 7® capability. By accelerating throughput, reducing latency, and improving reliability (among other features), Wi-Fi 7 delivers improved bandwidth performance throughout the home to network-connected end user devices.

An Economical Way to Optimize Network Performance

Plant upgrades incur a variety of immediate and on-going costs. Besides the obvious costs of upgrading and/or replacing equipment in the field, there's also costs associated with:

- Outside plant construction, including replacing cable and splicing in actives to support increased spans
- Inside plant construction, including adding and/or expanding chassis, increased powering requirements, and software, firmware, and licensing upgrades
- On-going plant maintenance, the costs of which typically increase by ~5% for each plant upgrade. For example, upgrading a plant for 1.2 GHz operation can increase maintenance costs associated with current 1 GHz plants by ~5%; a plant upgrade from 1.2 GHz to 1.8 GHz can increase maintenance costs by ~10%.

D3.1*E* is an economical way to get the most out of current HFC cable access network architectures. It allows cable operators to enhance and optimize their networks now and defer costly construction and next-generation plant upgrades for some time in the future. Rather than immediately incurring new expenses, cable operators can choose instead to deploy next-generation DOCSIS 3.1 or DOCSIS 4.0 CPE devices in conjunction with mid-split or high-split plant upgrades while they budget for more comprehensive network rebuilds later. An added benefit is having a population of next-generation CPE devices in place to continually achieve optimal capacities and speeds as the network spectrum expands and plant upgrades are deployed.

Eventually, most HFC cable access networks will evolve to support high-split, 1.2 GHz operation. But it's with that next step to full 1.8 GHz DOCSIS 4.0 operation that the most substantial costs and service disruptions will come into play. While the costs of upgrading from sub-split to mid- or high-split operation will vary depending on several factors that are unique to each operator, it's a given that any transition from a high-split, 1.2 GHz D3.1*E* network to a 1.8 GHz ultra-high split plant will incur quite substantial expenditures of capital and labor in all upgrade scenarios—reiterating the long-term value that cable operators can derive from D3.1*E* deployments.

CommScope Network Upgrade Options

- Mid-split and high-split frequency split upgrade kits for CommScope amplifiers and nodes
- Factory-configured mid-split and high-split 1.2 GHz STARLINE® Amplifiers
- Factory-configured mid-split and high-split 1.2 GHz OM and NC series HFC/DAA nodes
- 1.8 GHz STARLINE Amplifiers configured for operation in 1.2 GHz networks
- 1.8 GHz OM and NC series DAA nodes configured for operation in 1.2 GHz networks

Optimizing Today's Network: D3.1*E* and Current Iterations of DOCSIS

Cable operators can deploy D3.1*E* in a variety of current DOCSIS network architectures. The maximum gains in downstream capacity and throughput speeds, however, will vary based on bandsplits, CMTS configurations, and other factors; cable operators will see the biggest improvement in network performance in mid-split and high-split architectures. While D3.1*E* is technically viable in sub-split architectures—assuming the cable operator can reclaim sufficient bandwidth from the downstream path to support either one OFDM block (by reclaiming 192 MHz) or two OFDM blocks (by reclaiming 384 MHz)—the gains in network performance will be negligible because of the inherent limitations in sub-split downstream capacity. It therefore makes the most sense for cable operators with sub-split plants to upgrade for mid-split operation in conjunction with their D3.1*E* deployments.

D3.1+ CPE devices can support bonding of up to four OFDM channels and 32 SC-QAMs in 1 GHz and 1.2 GHz mid-split networks and 1.2 GHz high-split networks, with maximum throughput speeds of up to 8 Gbps; the devices also support speeds of up to 1.25 Gbps in the upstream in this network configuration. These improvements are accomplished by bonding OFDM channels from existing CMTS and/or Remote MACPHY equipment, resulting in a 4x2 solution that is fully supported by DOCSIS 3.1+ and DOCSIS 4.0 CPE devices.

Note that mid-split networks provide an additional 150 MHz of downstream bandwidth when compared to high-split networks; mid-split upstream bandwidth is, however, more limited than high-split upstream bandwidth, which provides an extra 119 MHz of bandwidth.

Table 1 shows the potential gains with D3.1*E* deployments in mid- and high-split DOCSIS 3.1 networks.

D3.1 Mid-Split Spectrum	DOCSIS 3.1 CMTS Channels		Max. DOCSIS 3.0 SG Configuration Examples		Max. D3.1/ D3.1*E* SG Configuration Examples		
	SC-QAM (6 MHZ)	OFDM	Max. D3.0 Subs	Max. D3.0 DS Tier	Max. 3.0 + 3.1 Subs	Max. D3.1 DS Tier	Est. D3.1*E* DS Tier
108 – 684 MHz	32	2 x192	100	500 Mbps	274	3 Gbps	3 Gbps
	0	3 x 192	0	—	226	3 Gbps	4 Gbps
108 – 876 MHz	32	3 x 192	100	500 Mbps	255	4 Gbps	5 Gbps
	0	4 x 192	0	—	206	3 Gbps	6 Gbps
108 – 1068 MHz	32	4 x 192	100	500 Mbps	235	4 Gbps	7 Gbps
	0	4 x 192	0	—	187	3 Gbps	8 Gbps
D3.1 High-Split Spectrum	**DOCSIS 3.1 CMTS Channels**		**Max. DOCSIS 3.0 SG Configuration Examples**		**Max. D3.1/D3.1*E* SG Configuration Examples**		
	SC-QAM (6 MHZ)	OFDM	Max. D3.0 Subs	Max. D3.0 DS Tier	Max. 3.0 + 3.1 Subs	Max. D3.1 DS Tier	Est. D3.1*E* DS Tier
258 – 834 MHz	32	2 x 192	100	500 Mbps	274	3 Gbps	3 Gbps
	0	3 x 192	0	—	226	3 Gbps	4 Gbps
258 – 1026 MHz	32	3 x 192	100	500 Mbps	255	4 Gbps	5 Gbps
	0	4 x 192	0	—	206	3 Gbps	6 Gbps
258 – 1218 MHz	32	4 x 192	100	500 Mbps	235	4 Gbps	7 Gbps
	0	4 x 192	0	—	187	3 Gbps	8 Gbps

Table 1. Potential Capacity and Throughput Improvements with D3.1*E* Mid- or High-split Network Deployments

Looking to the Future: D3.1*E* as a First Step Toward DOCSIS 4.0

D3.1*E* can also be deployed as an intermediate step between high-split DOCSIS 3.1 and full DOCSIS 4.0 operation. Cable operators who plan to make the transition to DOCSIS 4.0, but who wish to optimize high-speed service tiers in the interim, can deploy DOCSIS 4.0 CPE devices to future-proof the network for full DOCSIS 4.0 deployments.

D3.1*E* deployments with DOCSIS 4.0 CPE devices can immediately support even higher service tiers than a D3.1*E* deployment in a DOCSIS 3.1 mid- or high-split network, with enhanced throughput speeds of up to 9 Gbps. Unlike mid-split of high-split DOCSIS 3.1 operation, however, cable operators also will see a significant upgrade in upstream channel capacity and speeds with the DOCSIS 4.0 CPE devices, from a maximum of two OFDMA channel blocks in a high-split DOCSIS 3.1 network to a maximum of seven OFDMA channel blocks in an ultra-high split network.

Basic Upgrade Considerations for D3.1*E*

D3.1*E*'s most noticeable performance improvements begin with mid-split 85/102 MHz operation. Cable operators can easily upgrade 1 GHz sub-split networks for mid-split operation by performing a frequency split upgrade. CommScope's legacy 1 GHz amplifiers and nodes all support mid-split upgrades, typically via a frequency split upgrade kit.

Product Family	Models that Support Mid-Split Upgrades
STARLINE® 1 GHz Amplifiers	BT100 Trunk/Bridger
	MB100 MiniBridger®
	BLE100 Line Extender
	MBV3
Flex Max® 1 GHz Amplifiers	FM321/FM321e
	FM331LE
	FM601/FM601e Trunk/Bridger
	FM901e Trunk/Bridger
Opti Max® 1 GHz Nodes	OM2741
	OM3100
	OM4100
Legacy 1 GHz Nodes	NC2 Series
	NC4 Series
	SG4000

Table 3. 1 GHz CommScope Products Upgradable for D3.1*E* Mid-Split Operation

Cable operators currently running a 1.2 GHz mid-split network can easily upgrade CommScope products for high-split operation by again using frequency split upgrade kits. Besides providing the maximum performance improvements from a D3.1*E* deployment, 1.2 GHz high-split operation saves power, provides additional gain, and—with CommScope 1.2 GHz amplifiers configured for high-split operation and operating with a 711 MHz ADU—optimizes downstream and upstream performance. These operational improvements can therefore provide both cost savings and enhanced network performance.

While high splits can provide maximum D3.1*E* capacity and throughput gains, there are several potential operating issues related to the expanded, high-split upstream spectrum. These include relocating downstream channels that exist at sub-258 MHz frequencies, addressing potential ingress or leakage issues at frequencies above 85 MHz, and moving legacy Out-of-Band (OOB) set-top channels to higher frequencies.

In sub-split networks, the OOB channel resides at a sub-102 MHz frequency. A cable operator's base of legacy set-top boxes will probably include a mix that:

- Cannot receive OOB signals of 102 MHz or higher
- Can receive OOB signals of 102 MHz or higher
- Cannot receive signals at the lower edge of a high-split 258 MHz downstream bandwidth

A cable operator should therefore consider the effort and cost involved in evaluating and, if necessary, replacing legacy set-top boxes that cannot receive OOB signals above either 102 MHz or 258 MHz. Typically, most current set-top boxes can operate above the 102 MHz lower edge of mid-split downstream band, but if the cable operator opts for a high-split upgrade, then a targeted deployment of DOCSIS Set-top Gateway (DSG) set-top boxes—which can fully support >258 MHz frequencies—will need to be part of any upgrade plan.

Traditional leakage detection signal choices also become an issue in high-split networks. In sub- or mid-split networks, the leakage detection frequency is typically located between 135 and 138 MHz in the downstream band. But a high-split downstream band begins at 258 MHz, which requires the leakage detection frequency to be moved into the upstream band. While high-split upstream leakage

detection is extremely complex, CommScope has worked with leading vendors to successfully implement leakage detection in I-CCAP, R-PHY, and R-MACPHY CMTS architectures.

D3.1*E* support varies by vendor and likely requires a software upgrade from your currently deployed access network versions. CommScope has already demonstrated support for D3.1*E* on I-CCAP, with support for D3.1*E* on CommScope's vCMTS and QAM video solution coming later in 2024.

In the headend, cable operators using Gen 2 E6000 Converged Edge Router (CER) devices will need to upgrade to E6000 Software Release 13, which supports D3.1*E* channel bonding for additional OFDM blocks in the downstream. Software Release 13 also supports next-generation cable modems, including DOCSIS 4.0 devices running in DOCSIS 3.1 mode, allowing cable operators to deploy next-generation CPE devices for D3.1*E* operation. Software Release 13 also supports other enhanced network services that are related to D3.1*E* operation, including Remote PHY DAA deployments and enhanced support for IPTV operation, allowing operators to transition from traditional SC-QAM video delivery and reclaim bandwidth for extended D3.1*E* network capacities and speed tiers.

CommScope is also developing new software releases that will support D3.1*E* on both the C100G and its highly anticipated, virtualized CCAP, which are part of the recent acquisition of the cable business unit assets of Casa Systems. C100G Software Release 8.12 will support four OFDM channel blocks and two OFDMA channel blocks for D3.1*E* operation. Software Release 8.12 will also provide support for DOCSIS 4.0 CPE devices running in DOCSIS 3.1 mode. vCCAP Software Release 10.8.2 will support these same D3.1*E* features on a virtual platform.

Conclusion: Enhance and Optimize Network Performance Today

D3.1*E* offers a quick, cost-effective path to premium, gigabit high-speed data services for subscribers without having to commit significant resources to extensive and costly infrastructure improvements. D3.1*E* also supports multiple strategies for optimizing and evolving HFC cable access networks. Cable Operators can deploy D3.1*E* as an intermediate step towards full DOCSIS 4.0 operation, or they can deploy D3.1*E* to optimize the current (and future) downstream capacities and speeds of their existing network architectures. No matter what approach to improving their networks cable operators take, D3.1*E* has significant current and future operational and business benefits that cable operators can leverage to improve their subscribers' experiences, keep pace with competitors' service offerings, and expand their premium service tiers. Why wait for tomorrow to deploy high-speed, premium services? D3.1*E* is here today.

CommScope offers a full, end-to-end portfolio of DOCSIS 3.1 and DOCSIS 4.0 products and solutions for inside and outside plant operation. For further information about DOCSIS 3.1E, contact your CommScope Sales Representative.

CommScope pushes the boundaries of communications technology with game-changing ideas and ground-breaking discoveries that spark profound human achievement. We collaborate with our customers and partners to design, create and build the world's most advanced networks. It is our passion and commitment to identify the next opportunity and realize a better tomorrow. Discover more at commscope.com

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