WHITE PAPER

Cable
Connected Home

Multigigabit Speed and Symmetrical Data Service with Full Duplex DOCSIS*

Full Duplex DOCSIS 3.1 standard helps cable service operators evolve networks for next-generation access

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The fast-growing need for speed

The growing number and diversity of connected devices within the home and the desire for bandwidth-hungry online experiences, such as 4K video streaming and VR, are fueling exponential growth in the demand for faster home connectivity. Nielsen's Law of Internet Bandwidth states that users' data demands grow by 50 percent every year—meaning demand more than triples every three years.[1]

Operators are continuously challenged to cost-effectively deliver data rates that keep up with this exponential growth in demand. In 2012, Intel partnered with leading cable modem termination system (CMTS) vendors and proposed an evolution of DOCSIS* 3.0 standards to allow operators to offer gigabit-speed data rates.[2] DOCSIS 3.1 showed a path to 10 Gbps downstream using existing hybrid fiber-coaxial (HFC) infrastructure, which enabled cable operators to compete with fiber and twisted-pair alternatives—since DOCSIS 3.1 is less expensive to deploy than fiber to the home (FTTH) and offering higher speeds than twisted-pair networks.

DOCSIS 3.1 on traditional HFC does have its limitations, however. The upstream band is usually limited to low frequencies, such as 42 MHz and 85 MHz, and even the 204 MHz option introduced by DOCSIS 3.1 requires significant network upgrades (and still does not deliver true gigabit upstream service). While widespread consumer demand for gigabit-speed upstream is not here yet, operators need to be prepared as applications that require high-speed upstream bandwidth come to market.

The future is symmetrical

Announced in February 2016, Full Duplex DOCSIS 3.1 (FDX) improves upon the DOCSIS 3.1 standard to use a large part of the cable plant spectrum simultaneously in both upstream and downstream directions—enabling symmetrical multigigabit services.

The key ingredient in FDX connectivity is the echo canceller, a technology that removes the self-transmitted signal from the received signal. The transmitted signal is usually much stronger than the received signal, and it travels to the receiver through a linear channel consisting of near end (device) and far end (network) reflections (also called echoes). Although the original transmitted signal is known to the receiver, the received signal includes unknown noise and distortion, and the echo canceller must be able to estimate all these impairments with high enough accuracy to cancel out the artifacts of the transmitted signal imposed on the received signal.

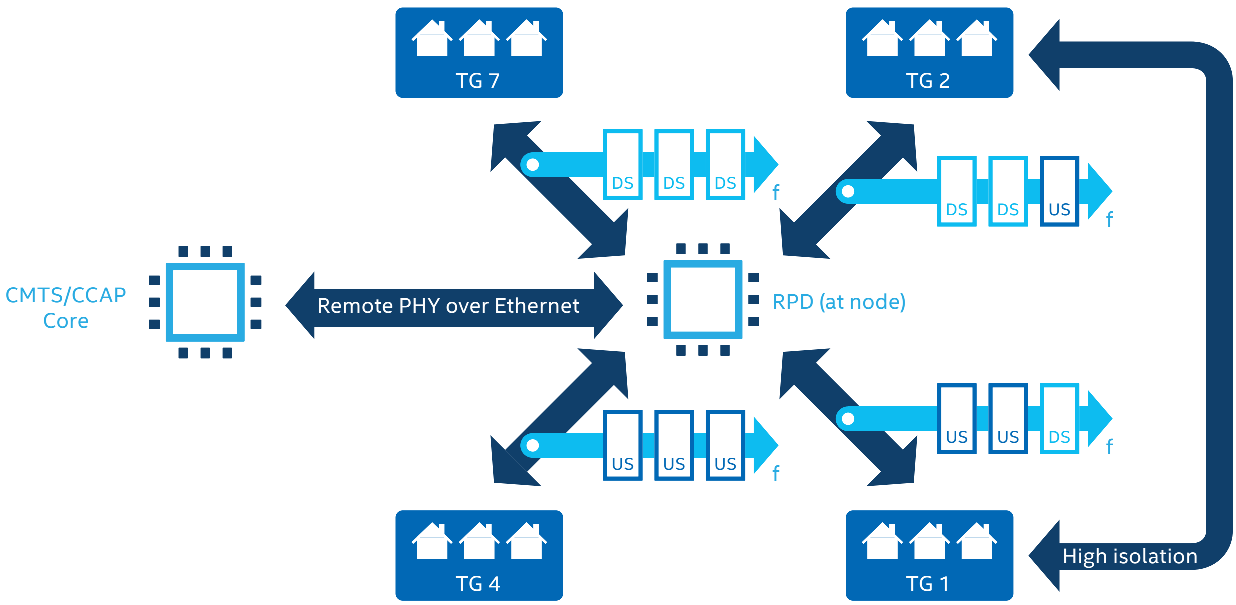

Figure 1. Full duplex communication in an N+0 node

In addition, when cable modem clients transmit they may interfere with other clients on the network receiving on the same frequency. The Full Duplex DOCSIS architecture can work around the limitations of sharing media in a point-to-multipoint system while still offering high network utilization in both upstream and downstream directions. Even though network design ensures a "good" link budget between any consumer premises equipment (CPE) and head-end transceiver, there are still groups of CPE devices that exhibit high loss in between each other. This tends to be higher than the link budget loss to the head-end transceiver, which means full duplex communication is possible on a group basis instead of individual CPE basis by allowing groups with high isolation between each other to transmit and receive simultaneously (Figure 1). With smart allocation of upstream and downstream resources to a group, the network is still fully utilized, and traffic simultaneously flows over the same frequency to and from the head-end transceiver.

Full duplex requires an all-passive architecture since HFC amplifiers are unidirectional when they operate on a given frequency band. This means that full duplex is only possible on an N+0 architecture (a node with no amplifiers in the network). Fortunately, the process of migrating HFC networks to all-passive coax and digital nodes is already underway.

Remote PHY (RPHY) architecture has emerged as the leading distributed network access approach. It allows the separation of the medium access control/physical (MAC/PHY) interface and can transfer it over IP networks from the CMTS core at the hub to the digital node in the field (Figure 2). This "fiber deep" architecture also provides advantages beyond full duplex. RPHY increases the signal to noise ratio (SNR) due to its lack of analog optics, and it provides better real estate and power utilization at the hub. It also allows virtualizing all MAC and upper layers of the CMTS.[3,4]

Making FDX reality

The Full Duplex DOCSIS standard is evolving through the specification process as Intel progresses with real-world validation in the lab. However, challenges remain, and several issues that have been discovered in Full Duplex DOCSIS are not isolated to individual technologies as they were in previous technology upgrades.

For example, one longstanding benefit of HFC networks is transparency. An MSO could build out its network using a certain amount of bandwidth and allocate it for upstream and downstream, along with a certain level of signal fidelity. The operator can employ any technology within that envelope, and increase efficiency through higher modulation, improved forward error correction (FEC), and better frequency utilization. Problems with upstream and downstream pipes could also be isolated and solved independently.

With FDX, the system must be designed as a complete entity and some issues, which were previously solved individually, must now be solved within the larger system.

Solving FDX challenges

Intel and node vendors are aggressively working on solving the new challenges that Full Duplex DOCSIS presents. New technologies must be developed for FDX to deliver new effects within the node—for example, transmit power leakage into the receiver including both the deterministic transmitted signal and noise from the PA. While challenging, these problems are constrained to the node and can be addressed through the coordinated efforts of chipset and node vendors.

Research engineers are developing new approaches for isolating the transmit (TX) and receive (RX) paths, and investigating unique sources of noise, such as the noise from the power amplifiers.

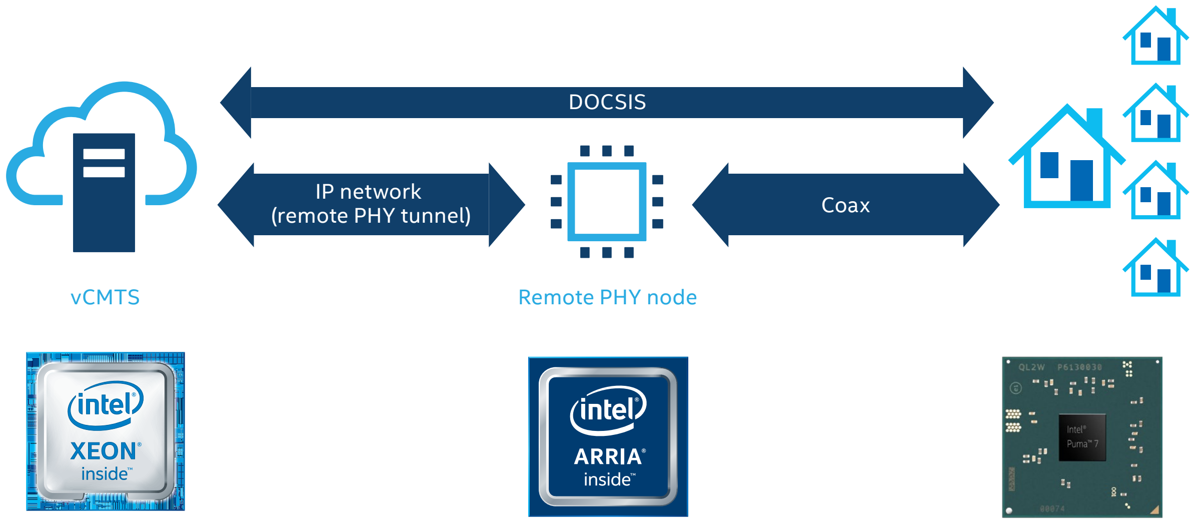

Figure 2. Distributed access architecture with programmable node

The plant presents an additional set of challenges. For example, RPHY nodes and CPE must be able to handle:

1. Unknown plant topologies and echo responses, plus a wide range of received power levels and delays
2. Echo drift over time due to temperature or wind variations in aerial plants
3. TX versus RX capacity trade-offs: a certain amount of net performance is possible in each node for a given amount of echo cancellation and can be split between the upstream and downstream paths
4. Transmission degradation due to common plant impairments
5. A broad assortment of in-home environments and self-install scenarios

The RPHY primarily needs to address challenges 1–4 above, and since it operates with significant co-channel interference (potentially 20 db higher than the received signal), the margin for error is quite small. While various topologies can be planned for in advance, the ways the plant can change over time can vary considerably. These variables require a highly flexible and adaptive echo-cancellation design that can ensure operation in unforeseen scenarios. With respect to challenges 3–5, CPE also needs to operate in dynamic environments, and ensuring safe operation of FDX in plants with legacy equipment is vital for success.

Despite these challenges, FDX works today and is a key technology for providing new levels of performance on HFC networks. It does, however, require new system-level design and higher intelligence and adaptability in the network than with previous standards.

The Intel approach

With a focus on the future, Intel invests in technologies that increase bandwidth and maximize the value of existing wiring infrastructures—including DOCSIS 3.1, Full Duplex DOCSIS, programmable digital nodes with FPGAs, and virtualization. Intel participates in the standards committee for Full Duplex DOCSIS and is collaborating with industry leaders to develop proofs of concept for the new standard.

These efforts allow MSOs to harness Full Duplex DOCSIS and deliver significantly faster upstream and downstream speeds, while extending the life and value of existing infrastructure. While FDX is changing the rules across the cable industry, it is also part of a larger trend toward virtualization that sets the stage for future transformations, such as backhaul for 5G networks.

From client to cloud, Intel provides cable network operators with high-performance, cost-effective solutions for meeting fast-growing demands for bandwidth and achieving new levels of high-velocity, agile service delivery. With a breadth of solutions across the connected home, access network, service provider edge, and data center, Intel is helping MSOs meet demands for bandwidth, enhance flexibility, simplify upgrades, and manage costs today—and prepare for the next-generation access technologies of the future.

Learn more: intel.com/connectedhome

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