Beyond 1G

Access networks have reached an inflection point where monoliths such as the macrocell networks and HFC plants that were built in developed markets over the past decades just can't scale economically. In some cases, no amount of money could scale them to where they need to be. As a result, companies are turning to more distributed, heterogeneous and flexible solutions to meet customer demands.

Getting to a Gig – Foundational Principles

"Getting to a gig" is a phrase we've heard a lot in the cable and telecom industries in the past few years. But with no reprieve from consumer and enterprise demand for communication, data and media services, we have our sights set on the fundamental solutions that will make it economically feasible for our customers to get beyond a gigabit per second (1Gbps) and prepare for a world in which billions of devices will access millions of services.

Our initial focus is on access network solutions that will make services beyond 1G economically viable for service providers. This concentration on the network edge gives us a mandate to re-imagine and develop access and aggregation solutions more rapidly than our competitors. In this journey, we have developed a few fundamental design principles from which we operate.

- **Simplification:** converge access and aggregation functions into common platforms where it makes sense to do so, in order to reduce operating expenses (OPEX) and improve manageability. This is why we were the first to launch a commercial Converged Cable Access Platform (CCAP) – to combine Cable Modem Termination System (CMTS), Edge Quadrature Amplitude Modulation (QAM), routing, Multiprotocol Label Switching (MPLS) and subscriber/traffic management functions into one platform. Our C100G CCAP chassis enables us to continue developing new functionality at a fast pace, and to add new access solutions into the chassis with ease. The C100G chassis will be around for a very long time because it's just that flexible. We are also independent from application-specific integrated circuit (ASIC) vendors so our own software development is performed in advance of chip readiness. This agility is what let us be first to achieve DOCSIS 3.0 certification by CableLabs and continues to be our competitive edge. It provides longer life to hardware, allowing new features to be introduced as software-only upgrades, including the DOCSIS 3.1 US and DS solution, which launched in 2015.
- **Separation/Distribution:** separate functions that need to scale independently. This is the inverse of the simplification point above, and helps avoid convergence for convergence's sake. For example, our Remote-PHY solution allows more cost-efficient densification by keeping the media access control (MAC) functions (which do not scale in line with the PHY) in the headend/hub. Distributing network functions into the most optimum physical location via distributed access architectures, like Remote-PHY, allows providers to realize better quality of experience (QoE) and simultaneously reduce costs.
- **Virtualization:** virtualize network functions so they can be software defined and controlled in order to speed time to market for new services, put capacity where needed, when needed, and assure QoE. Virtualization is on the roadmap for all of our solutions as part of a dual development path in which we will continue to enhance existing hardware platforms to provide more functionality and density, while simultaneously building virtualized solutions.

- **Integration:** integrate functionality across access types. Consumers and enterprises are increasingly frustrated by constraints on their ability to access any service from any device, wherever they are and by differences in their experiences when doing so. Providers who gain a competitive edge will look for solutions that cross technology platform silos. We have a distinct

advantage because our cable, wireless and Wi-Fi product and engineering teams sit within a few feet of each other. The product team bullpen is always active with discussions and ideas that cross access technologies. This fosters integrated design and development and enables us to bring new solutions to market that innovatively combine access types (e.g., our Wi-Fi/CMTS solution).

Roadmap to 1G and Beyond

Getting to gigabit services in a cable network requires providers to take a hard look at not only the equipment in their headend and hub sites, but also the HFC plant, customer premises equipment (CPE) and, in light of DOCSIS 3.1, the move to all IP transport and distributed access architectures (DAA).

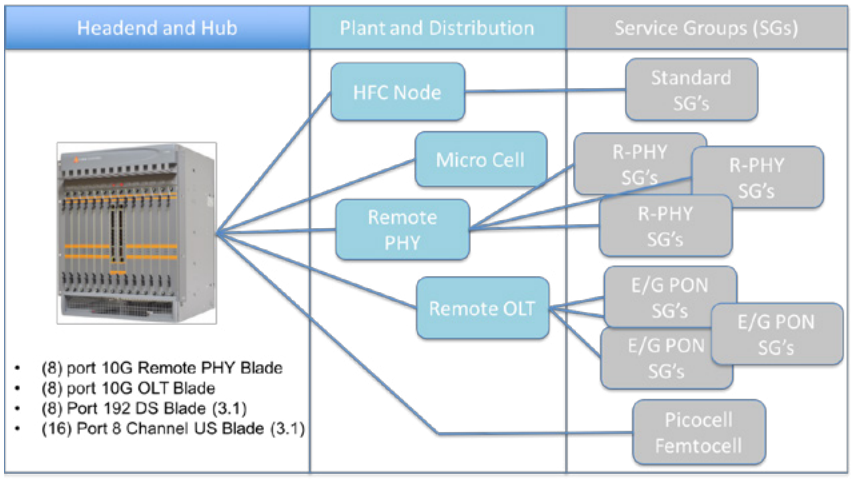
1Gbps Services Today

Our solutions for providers on this journey start with the industry's first CCAP, our C100G converged services platform, illustrated in Figure 1. Providers using our C100G can implement 1G DS services today, using DOCSIS 3.0, without any additional hardware or software by simply acquiring additional licenses for extra DS channels per port and taking advantage of our 32-channel bonding features (see Figure 2).

Assuming 16 DS channels in use, an additional 16 DOCSIS channels per port will push the bandwidth over 1Gbps. This is dependent on the cable modems in use, however, 32-channel bonding cable modems (CMs) are required. If CPE vendors can deliver higher channel bonding solutions, the C100G can support them without any hardware or software changes.

A unique feature of our US module is the ability to support two logical channels (each with its own channel width, receive power

Figure 1. Casa Systems C100G Converged Services Platform



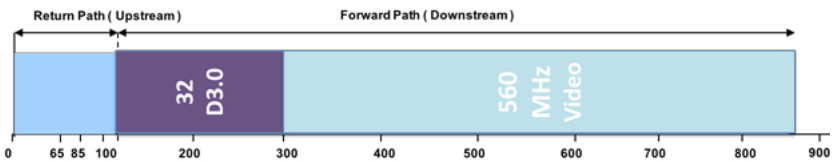
level and modulation) on one upstream channel. This can be used to support legacy CMs in the network, or to provide different upstream profiles for DOCSIS 3.0 and 3.1 CMs on the same physical channel. Or, highly attenuated CMs can be aggregated onto a logical channel with a lower modulation level, while CMs with good signal-to-noise (SNR) ratio can be aggregated onto a second logical channel with a higher modulation level (and thus, more bandwidth). In addition to providing greater service flexibility, support for logical channels allows a reduction of OPEX without any additional capital expenditure (CAPEX).

DOCSIS 3.1: Services Beyond 1Gbps Now

Figure 3 illustrates a solution that allows 2.5Gbps services to be offered, using a mixture of DOCSIS 3.1 and DOCSIS 3.0 for US and DS channels.

Alternatively, a provider might choose to use all the traditional channels below 800 MHz for DOCSIS 3.0, and use the channels between 800 MHz – 1GHz for a full orthogonal frequency-division multiplexing (OFDM) block. With a 192MHz OFDM block and running QAM4K, the bandwidth can go up to 1.8 Gbps.

Figure 2.



Phase 1

- I Gbps DS services can be offered
- Maximum bandwidth 1.3 Gbps
  - (32) D3.0 channels * 40 Mbps (256-QAM)

Video

- 560 MHz of traditional QAM video is available

If a provider is unable to deploy a full OFDM channel, they can still use the DOCSIS 3.0 channels plus a partial OFDM block to achieve 1Gbps with our ability to bond OFDM and SC-QAM channels.

Our CCAP supports DOCSIS 3.1 now

Ramping up to provide 5Gbps services with our C100G CCAP platform can be accomplished via additional D3.1 channels as shown in figure 4. With a total of four D3.1 channels, the maximum bandwidth reaches 6.08 Gbps. Figure 5 illustrates 10Gbps services, using six D3.1 channels, 2048 QAM and the full 1.2MHz of spectrum.

With one chassis that can support 1Gbps services today and scale smoothly and flexibly to 10Gbps services in the future, we expect our C100G CCAP to be a workhorse for service providers for years to come.

Distributed Access Architectures

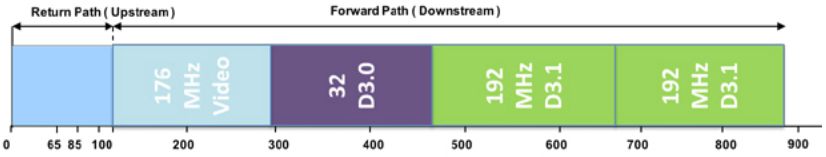
One of our design principles is to create network solutions that allow the right functions to be distributed to the right physical locations. There is much discussion in the industry about DAA in cable networks, analogous to heterogeneous network densification in wireless networks. We will lead the way with new solutions for both.

After careful consideration of the realities of cable networks today, and the most straight forward path to achieving the cost and QoE benefits of distributed access while mitigating operational and service risks, our approach is to enable a Remote PHY solution, as shown in Figure 6.

Cable DAAs

In cable networks, providers are faced with several DAA alternatives including Remote-PHY and Remote- MAC/PHY.

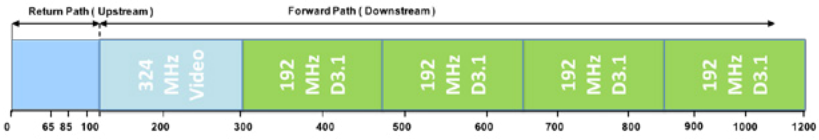
Figure 3.



Phase 2
- 2.5 Gbps DS services can be offered
- Maximum bandwidth 4.3 Gbps
  - (32) D3.0 channels * 40 Mbps (256-QAM) = 1.3 Gbps
  - (2) D3.1 channels * 1.52 Gbps (1024-QAM) = 3.0 Gbps

Video
- 560 MHz of traditional QAM video is available

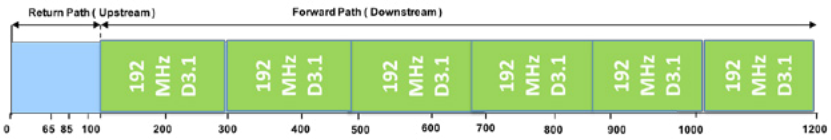
Figure 4.



Phase 3
- 5.0 Gbps DS services can be offered
- Maximum bandwidth 6.08 Gbps
  - (4) D3.1 channels * 1.52 Gbps (1024 -QAM) = 6.08 Gbps

Video
- 324 MHz of traditional QAM video is available

Figure 5.



Phase 4
- I0.0 Gbps DS services can be offered
- Maximum bandwidth 10.02 Gbps
  - (6) D3.1 channels * 1.67 Gbps (2048-QAM) = 10.02 Gbps

By moving the DOCSIS and EdgeQAM PHY to a fiber node, allowing the MAC and higher layer functions to stay in the headend/ hub, providers can scale bandwidth and reduce space and power needs without costly changes to cable modems/set-top boxes, while continuing to use their existing CCAP management tools to provide all the services supported by CCAP today.

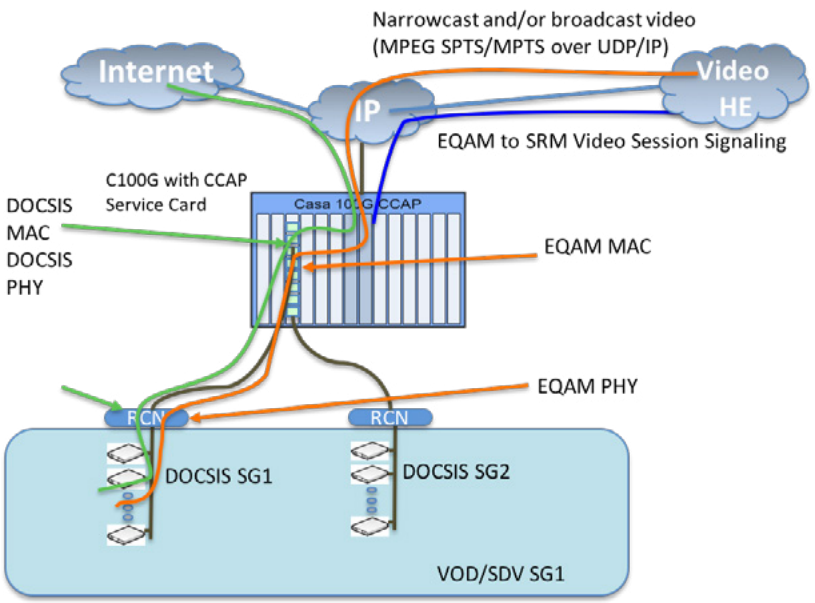
Further, by retaining the MAC functions in the headend, the Remote PHY architecture reduces the potential complexity and costs of the optical node in the network. Such reduced complexity will translate into fewer operational failures and, thus, fewer truck rolls for cable service providers to carry out.

Consider the following migration scenario involving our Remote CCAP Node (RCN) and the corresponding CCAP services card (CSC) in the headend which aggregates the remode nodes. A single HFC node can be cut over very simply to an RCN (presuming the RCN is already positioned and the corresponding CSC card is already in the CCAP core) by upgrading the fiber cable in the headend and at the node. Then, if needed, more RCNs can be added to reduce service group sizes within a cluster.

In our solution, because a single RCN can support two RPHY modules, a 2x node split can be carried out by deploying one RCN. DOCSIS service can be switched over to the node independently of video services. A mixture of DOCSIS 3.0, DOCSIS 3.1 and RCN FN can be supported. There's no requirement that DOCSIS and VOD service group sizes be the same, so service rollouts can be incremental, down to the node level.

Our RCN aggregation module will support 8x10 GbE ports, 10G ethernet and PON pluggable optics, and US and DS out-of-band signals to/from legacy set-top boxes. Fully backward compatible with existing CCAP modules, the RCN module is available now and deployable as a shelf or node.

Figure 6.



The line cards available enable very high density DS (8x192) and are industry-leading in US density (16x8). With full fiber functionality in the node, migration is simple and straightforward.

Wireless Networks

Cable remote PHY moves IP/RF conversion closer to the network edge to improve capacity and performance. In wireless networks, we see the RF functions being separated from the baseband processing functions, following a similar line of logic as is being pursued in Remote-PHY discussions. Providers need to place access end points as close to users as possible in order to keep up with bandwidth demand and QoE expectations.

We have launched our first mobile access solutions (multi-standard 3/4G small cells and mobile edge computing platform) and our first Wi-Fi access solutions (for trusted and untrusted Wi-Fi), stand alone or integrated with CMTS. Leveraging our experience with handling massive numbers of access connections between cable aggregation points and cable modems, and the RF expertise that comes with that, our roadmap calls for a similar trajectory to the one we have taken in cable access networks: simplify the functions, separate functions that need to scale independently, distribute functions closer to users and ultimately create virtual solutions.

For Multi-System Operators (MSOs), we offer an unparalleled roadmap for leveraging existing cable assets to capitalize on burgeoning wireless demands, both on a retail and wholesale level.

Cable providers are already deploying Wi-Fi access to complete their quad-play offering by providing a mobility service to their customers. New strategies for leveraging those assets are continuing to take shape.

- MSOs can provide services to their customers by making use of their Wi-Fi deployments. A popular example is voice over Wi-Fi ("Wi-Fi Calling"), but this is not the only mobile service that can be delivered over Wi-Fi.
- MSOs can also lease the Wi-Fi coverage they have created to other operators who need it, most obviously the mobile operators. Standards for trusted Wi-Fi access to 3GPP networks make this model for leveraging their assets a clear path for cable operators.
- MSOs can be the savior of mobile operators interested in densifying their mobile networks using small cells. Small cell deployments are hampered by lack of access to sites, power and backhaul, and with their existing assets, cable operators can address all of these. Using their HFC plant, with DOCSIS 3.1 upgrades, deploying small cells as a service to mobile operators can be an attractive opportunity for MSOs.

Our vision doesn't stop at the network edge. We aim to be the ultra-broadband leader at the edge, in the core and at the services layer. From our point of view, by simplifying, separating, distributing and virtualizing the edge, the potential for scalable performance and economically viable innovation in services expands exponentially.

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