Keeping Up with Bandwidth Demand – the Upstream Challenge

by Viavi Solutions

Planning for future disruptors as we emerge out of the pandemic means learning from the extremes faced over the last year and the introduction of new industry-wide means, metrics and responses.

The Upstream Bandwidth Challenge

In March of 2020, the impact of the emerging global pandemic hit home for many regions around the world. Lockdown orders drove a seemingly overnight transition to working from home for parents and e-learning for children. This caused a rapid adoption of videoconferencing with its nearly symmetrical downstream/upstream usage and created real problems for cable operators globally to keep up. The downstream had the surge capacity to absorb the shock, but the traditionally tight upstream was stretched to its limits. Operators took heroic measures to keep up, in some cases completing all planned 2020 node splits in the first 4 months of the year. Overall networks held up to this demand shock, but how operators carry out capacity planning going forward will be forever changed.

Planning for capacity growth is not new for cable operators; they have traditionally relied on a mix of three reliable methods to grow available bandwidth:

- More Nodes – Reducing service group sizes via node segmentation or node splits
- More Hz – Using more upstream spectrum by adding carriers
- More Bits/Hz – Passing more data through available spectrum by increasing modulation orders

How these three methods are applied is changing as new challenges to their use emerge:

- More Nodes – Distributed Access Architectures (DAA) like Remote PHY enable node splits to continue by eliminating the need for more power/cooling and rack space in overstuffed hubs that traditional node splits require
- More Hz – Most 42MHz and some 65MHz systems already utilize all usable spectrum – moving the split to 85MHz (Mid-Split) or 204MHz (High Split) enable the addition of SC-QAM and/or OFDM-A carriers
- More Bits/Hz – Most of the world is already heavily deployed with 64QAM in the upstream, so increasing spectral efficiency requires adoption of OFDMA enabling modulation orders of 1024 or even 4096QAM

The adaptations to the three primary methods certainly extend their applicability but also create new challenges for each. Some examples are explained below.

More Nodes

One obvious operational challenge for DAA is the removal of RF from hubs, impacting return path monitoring, forward and return sweep, signal leakage, and other systems. Solutions have been developed to address these challenges, with a common thread being virtualisation of the legacy HW-based solutions and leveraging the Remote PHY device (RPD) as an RF receiver and/or transmitter. Some of these solutions have been engineered to use the same deployed sweep and leakage meters and established workflows for both legacy and DAA nodes, minimising disruption to established workflows and processes for technicians.

Other Challenges with more Nodes

- **Video Verification** – RF video is created for the first time at the RPD and given that each service group may have unique configurations there is a lot that can go wrong. In addition to typical physical layer problems, you have to check for missing programmes/PID's, stalled PID's, out of band (OOB) carrier operation and more. In the beginning, operators would load up a truck with a variety of set top boxes with a monitor, run a temporary drop down to the truck, and manually flip through the channels to check each programme on each node. Recently, field meter-based capabilities exist to automate this testing and shrink test times from 30 minutes or more per node to 5 minutes.
- **New (to Cable) Technologies** – there are many technologies that have been used elsewhere in telecom and enterprise businesses that are being introduced to cable access networks via DAA. Examples include Multi-fibre Push On (MPO) connectors, Active Automated Cables (AOC), IEEE 1588/PTP Timing and more. Personnel must learn how to work with these technologies and troubleshoot when problems arise.

More Hz

Transitioning to mid or high-split architectures creates some daunting challenges. For operators with 860MHz or 1GHz downstreams, enough spectrum can be cleared by analogue reclamation and increased compression for digital video. For others a downstream expansion may be required to go to 204MHz in the upstream. Another big obstacle is the need to touch every active and some passives in the outside plant. This is a heavy lift for operators, some choose to take a "big bang" approach and after clearing downstream spectrum deploy an army of technicians to a node and knock it all out during a maintenance window. Others will take an iterative approach requiring multiple trips to each active. In addition to the volume of outside plant work required, there are several other challenges created by split changes:

Other Challenges with more Hz

- **Adjacent Channel Interference** - high-power upstream signals now present above the previous diplex split bleeding into the downstream of legacy CPE through splitter or potentially tap port isolation can impair downstream carriers. Primary symptom of this problem are video issues on the lowest video carriers.
- **Signal Leakage** – When moving to the high split, the aeronautical band moves from the downstream to the upstream. Injection of CW-based downstream leakage tags at 138MHz is no longer possible, and while many alternative techniques are being proposed, the leading candidate is to detect OFDMA test signals that DOCSIS 3.1 CPE are already capable of transmitting in the upstream. Modern FPGA-based signal leakage detectors are essentially highly sensitive software defined radios, so transitioning to detecting different leakage signatures should be possible. Stay tuned for much more on this

Headend/Hub Construction	Fiber Construction	RPHY Installation and Cutover	Maintenance
Network Equipment Installation Connector end face inspection DWDM Ethernet and Transport test MPO and AOC test GPS antenna test **Shelf RPD Verification** Characterize RF DOCSIS service test Video test Voice test	**Deploy new fiber link/Upgrade existing plant** Connector end face inspection Fiber Characterization (IL/ORL/OTDR/CD/PMD) **Install DWDM passive components** Connector end face inspection End-to-end channel loss and continuity (DWDM OTDR)	**RPD Install** Connector end face inspection SFP+ Optics test Ethernet test PTP test **RPD Configuration** Characterize RF DOCSIS service test Sweep	Leakage Ingress suppression PTP wander tests Video test DWDM Optical Power levels Fiber fault location • Break, bend Service Assurance Tests • Fiber, HFC, Ethernet **All construction and installation tests potentially applicable**

Figure 1: DAA Test Considerations

topic as the industry converges on how this will be handled, especially in countries with governmental regulations around harmful interference. Even where mandates don't exist, operators are motivated to retain low-end visibility into where shielding weaknesses are allowing ingress into their networks.

- **FM Ingress** – Similar to leakage – FM ingress moves from a downstream problem to the upstream with the high split. FM ingress is so problematic as FM signals are always present in the air just looking for shielding weaknesses to sneak into cable plants. Since only OFDMA is specified for use above 85MHz, by definition they will frequently be hidden beneath wide and seemingly always-on OFDMA carriers. Early adopters are seeing success using heatmap-based spectral analysis in monitoring systems and meters to detect FM ingress in high-split plants.

More Bits/Hz

Compared to the other two methods this one sounds easy – right? Just flip a few bits on the network endpoints (CCAP, CPE), and instantly squeeze more bits through your existing spectrum without touching the outside plant. Like everything in cable, the devil is in the detail with OFDMA. All deployed DOCSIS 3.1 CPE should be at most a FW update away from being ready and getting CCAP's equipped/configured/licenced to support OFDMA is generally not overly challenging. Maintaining and troubleshooting networks with OFDMA is where many of the challenges emerge.

Operational Challenges with more Bits/Hz

Ingress detection and troubleshooting

Upstream ingress is a fact of life for cable operators, and while OFDMA and LDPC can be more robust against it, operators still need to be able to detect and troubleshoot ingress.

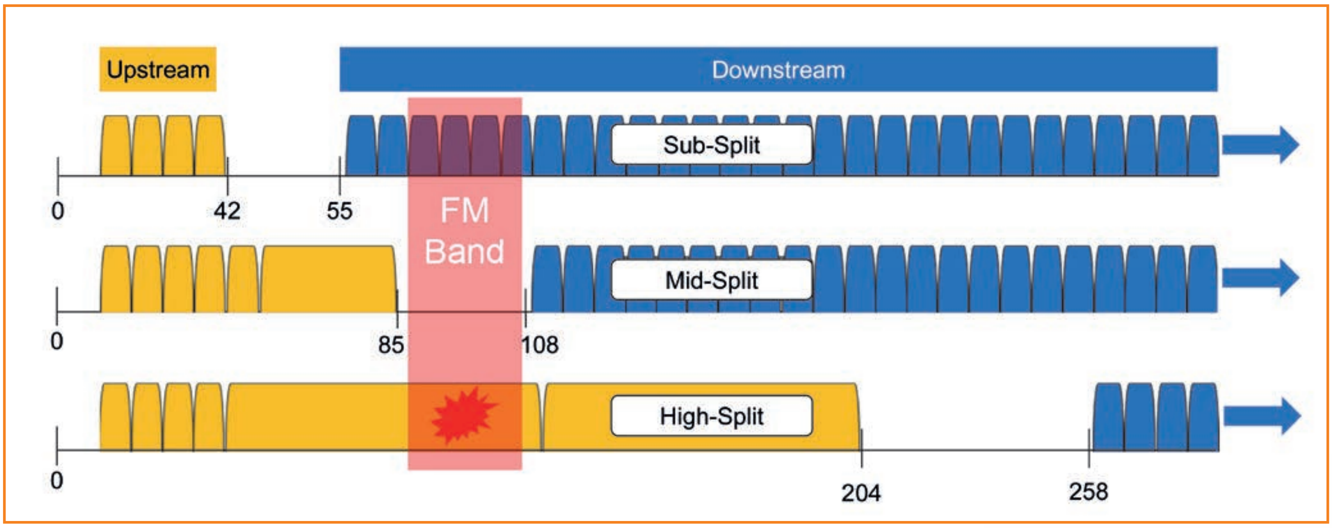

Figure 2: FM Ingress with High Split

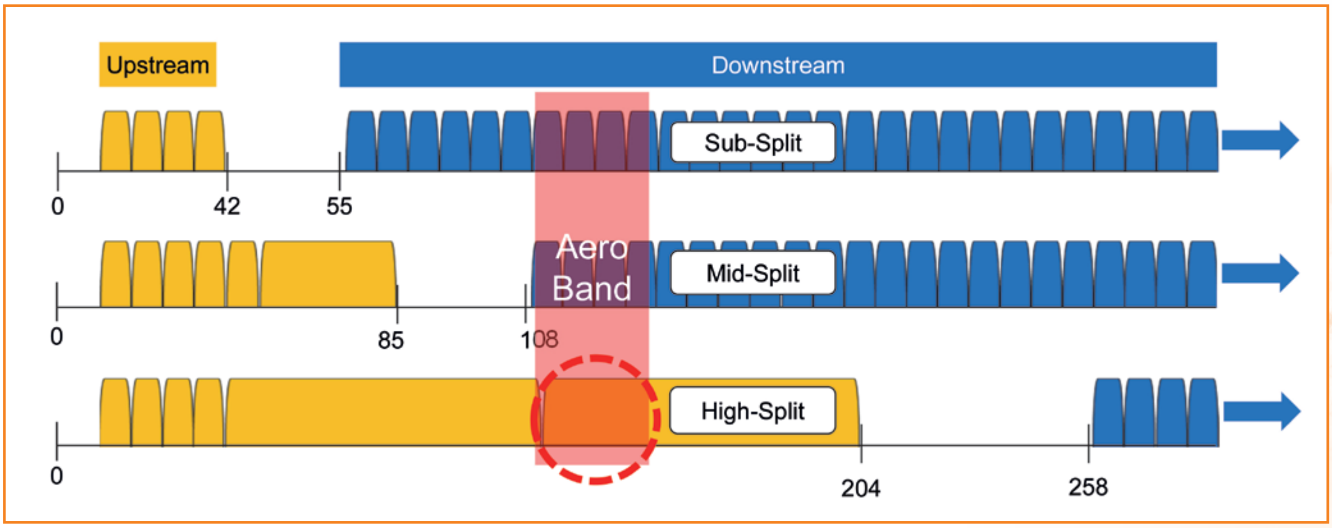

Figure 3: Signal Leakage with High Split

OFDMA carriers can be much wider than SC-QAM carriers, so looking for ingress in the guard bands is not possible. Heatmap analysers can show both steady ingress under wide OFDMA carriers as well as intermittent/bursty impulse noise signatures.

Reverse Sweep

Wide OFDMA carriers don't just hamper ingress remediation, but also disallow placing sweep points every 6.4MHz between carriers. There are multiple solutions to address this challenge; which is used depends on the driver for sweep. For troubleshooting critical outages, operators will sweep right through OFDMA carriers using traditional sweep processes. There is potential for minor service disruptions doing this, but the benefit of clearing an outage quickly outweighs this risk. There is now a refined version which uses shorter sweep pulses to minimise chances of service disruption while retaining the responsiveness of traditional sweep. Finally, sweepless return sweep can be used on field meters to provide the highest resolution view of upstream response, which has the added bonus of not requiring any hub-based gear or management of sweep plans. The primary downside to return sweepless sweep is that it is not as responsive as traditional sweep variants, nor is it well suited for real-time amplifier alignment and balance.

New Metrics/Paradigms

OFDMA introduces new metrics that must be incorporated into monitoring algorithms and technician process, including how to respond to them. Unlike with SC-QAM, correctable codeword errors aren't a bad thing with OFDMA for example. Fortunately, many of the changes are similar to the more-established OFDM downstream, so learning curves can be minimised.

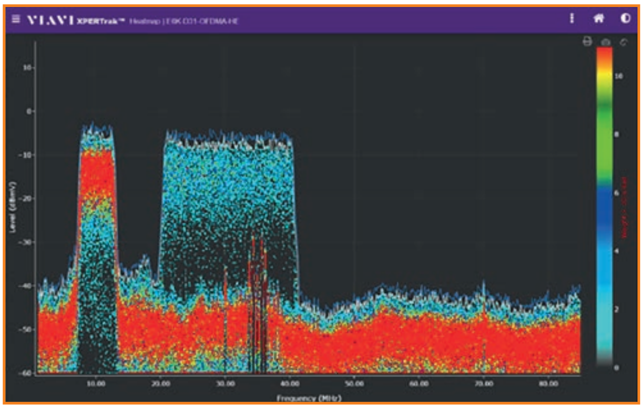

Figure 4 - Heatmap Spectrum Analysis

Conclusion

Strategic technology development and disciplined capacity planning have been hallmarks of the cable industry, enabling HFC networks to stay ahead of ever-growing broadband demand. The shock to the system caused by the pandemic and its disruption of steady growth models challenged the standard methods and processed that operators had relied on for decades, especially in the upstream. But as with past disruptive events and technologies, the industry showed innovation and dedication to overcome these challenges. The future looks bright for HFC to continue on as the broadband service delivery architecture of choice for many years to come.

For more information, see http://viavisolutions.com/AdvancedUpstream