Discussion of DOCSIS 3.1 Deployment Migration

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Abstract

As DOCSIS 3.1 prepares to begin its rollout over the next several years, many questions have to be analyzed to determine the most efficient transition methodologies. This paper considers the problem of network transition. It will look at the services currently deployed and consider how to overlay new D3.1 services. The factors considered in the model will include the HSD usage of current customers over D3.0 and D2.0 modems, and several different models of new D3.1 customers and their potential usage patterns. The D3.1 usage patterns could include commercial customers like small businesses or larger customers that might use D3.1 tiers for data backups off-hours. Another group of potential D3.1 users could be IPTV subscribers. The different D3.1 user groups would potentially have different performance expectations and different usage patterns that might allow a more efficient deployment alongside the current customers. Finally, the long-term transition of existing customers should be considered.

The modeling of various scenarios would also consider the different modes of deploying the new D3.3 tier, overlay or new spectrum, as a part of the modeling process.

Introduction

After months of standards committee work, DOCSIS3.1 specifications have been released, and the cable industry's vendor community is hard at work developing chips, software and systems for the coming deployments. But, what form will those deployments take? This paper explores some options available to operators as they consider how to roll out this new technology.

DOCSIS 3.1 Considerations

DOCSIS 3.1 incorporates some fundamentally new technologies to enable superior throughput over the cable plant. Orthogonal Frequency Division Multiplexing, or OFDM, is used instead of traditional single carrier Quadrature Amplitude Modulation, SC-QAM.

Downstream Details

The Media Access Control layer has also changed from a general broadcast downstream to a more complex and efficient directed transmission. Broadcast mode is still possible, but now subsets of cable modems sharing transmit path characteristics can be addressed as well. This allows modems which are experiencing less noise impairment to use higher modulation orders for higher throughput. The channel width for a D3.1 Downstream (DS) channel has changed as well. A D3.1 channel can range in size from 24MHz up to a maximum size for a single channel of 192 MHz. The Downstream spectrum range for D3.1 is changed from an earlier version. The required lower end is moved to 258 MHz, and the high end can now reach up to 1.218 GHz, with an option to reach to 1.794 GHz.

An additional feature is that data flows destined for D3.1 modems can be bonded across D3.0 and D3.1 channels. This capability can allow a new D3.1 section to be opened up for use while still allowing D3.1 modems to potentially utilize some or all of the D3.0 band to pass additional content.

Since D.31 modems are also required to be able to access D3.0 channels, multicast content present on D3.0 channels does not have to be repeated in the D3.1 band.

Upstream Details

In the upstream direction, the MAC changes have been less dramatic than in the DS, but the PHY changes are still significant. OFDM has also been adopted in the US, and the minimum and maximum channel widths have been changed to 6.4 MHz and 96 MHz. The required frequency range has also shifted. A D3.1 CM and CMTS are required to support an US that can reach at least 85MHz, with an option to go up to 204 MHz.

Current Traffic Behavior and Predictions

The possibilities for user migration onto D3.1 are potentially shaped by usage patterns. In a recent study by Sandvine®, they described upstream and downstream usage patterns on wired links.[i] This section examines some of the recent studies and reports on bandwidth usage to provide an informed basis for speculation about future trends.

Downstream Traffic

An important finding was that downstream usage is more homogeneous that it had been in the past. In some previous years, a small percentage of users accounted for a disproportionate proportion of bandwidth use, for example in 2011, 1% of the users accounted for about 25% of the downstream traffic.[ii] The latest report shows that now 1% of the users only account for about 10% of overall downstream traffic.

This shift in the concentration of users' traffic can be partially explained by the increase in streaming video. The same Sandvine report also showed that Netflix® users accounted for over 30% of the bandwidth usage during primetime peak hours. YouTube users accounted for almost 19% of the peak bandwidth. In fact the overall estimate for streaming video during primetime was over 67% of the downstream bandwidth. This percentage has been steadily increasing over the years (graph here). Currently Netflix subscribers are between 30% and 40% of the general population depending on whether you rely on PriceWaterhouseCoopers' July 2013 study or USA Today in September of 2013, so their use of 30% of primetime bandwidth seems roughly proportional.

Based on the trends seen in the marketplace, the consumer preference for streaming media in the home is likely to keep growing. The only disputed area of streaming media is whether bandwidth streaming to applications loaded onto multi-purpose devices will surpass that streaming to consoles and smart TVs. The bandwidth for the mobile devices is usually smaller due to the smaller form factor, but there are many more of those devices in the consumers' hands.

Upstream Traffic

Turning to upstream bandwidth usage, the peer to peer traffic surge that dominated upstream traffic engineering has begun to decline. BitTorrent and other file sharing applications are now about 42% of the total upstream traffic at peak in the latest Sandvine report references earlier. This level represents a substantial decline over years past, for example in the Sandvine 2011 report BitTorrent alone represented 52% of the upstream traffic at during primetime.

The slow decline of file sharing applications has also decreased the level of user asymmetry in the upstream, though it is still greater than it is in the downstream. The top 1% of upstream users still account for over 40% of traffic.

Looking toward the future, the upstream traffic mix may continue to fragment. Some real-time applications have been growing,

such as FaceTime. Cloud storage applications, such as Dropbox, have also been growing. As the trend toward cloud everything continues, the consumer will expect to be able to use the cloud for storage and processing of personal information, as they become used to working with that sort of technology in their businesses. That trend will undoubtedly increase the variety of application consuming upstream bandwidth.

D3.1 Migration Strategies

The new features incorporated into D3.1 allow much flexibility in designing a network migration strategy and also present many options for the end configuration of the target network after the migration is complete. As a first principle, this paper assumes that as much as possible a new D3.1 deployment should not disrupt existing customers, while still enabling the operator to take advantage of the higher bandwidth services that can be provided by deploying D3.1.

Contention between services is already intense for all available upstream and downstream spectrum. To squeeze in new D3.1 spectrum into the current bandwidth in most systems is challenging. We will discuss some options for spectrum selection in the Upstream and Downstream sections, since the available choices for each band differ significantly and have profound implications in the amount of upfront work needed to enable the expanded spectrum selections of D3.1.

Aside from the spectrum allocation and availability questions, another question will be explored, what services and customers can be most profitably be used to drive the deployment of D3.1? The changing dynamics of customer traffic profiles discussed earlier play into consideration of what customers can be most advantageously targeted for D3.1 modem deployment.

D3.1 Upstream Migration Strategies

Migration strategies possible for upstream D3.1 present some interesting challenges. The D3.1 specification implicitly assumed that substantial changes can be made to the current HFC network. To accomplish the changes, downstream subscriber services will also be affected.

In order for a D3.1 upgrade to be most effective, the outside plant needs to be upgraded to support at least 85 MHz of upstream spectrum, a substantial increase from the current 42MHz in North American and 65MHz in Europe. The specification supports an expansion of upstream spectrum up to 200MHz, though at this point few operators are convinced that upstream spectrum needs that much expansion. The upstream upgrade will involve moving any existing downstream channels out of the new expanded upstream band, and may also drive the need for DTA deployment if they are not already in place. When the downstream channels, usually video, are removed, a consumer education campaign may be required if DTAs are not in use, since the lowest video channels have for many years been preferentially used for basic tier service. Any outside plant elements with a diplexer or any form of two way active operation may need modification or replacement. This change will include fiber nodes, amplifiers, line extenders and even the humble house amplifier.

Since D3.1 allows exclusion regions in the middle of a channel, the existing legacy DOCSIS channels can be left in place in the upstream to allow legacy modems to continue to operate effectively. A single D3.1 channel can be defined encompassing the spectrum occupied by the legacy channels without disturbing them. In this manner, the D3.1 channel can make use of both the lower portion of the spectrum which is typically unusable by SC-QAM channels and the

higher portion of the spectrum made available by the expansion to 85 MHz.

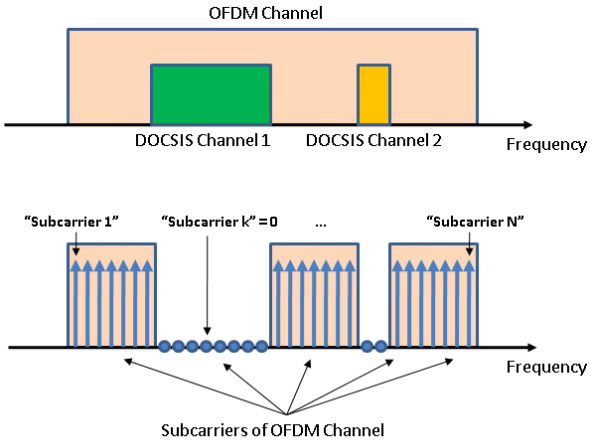

Figure 1 Illustration of OFDM Overlap with Legacy Channels[iii]

As part of a migration strategy to D3.1, customers on the highest speed tier could be moved to the new D3.1 channel once the plant modifications are completed. A D3.1 channel can provide more data throughput than legacy DOCSIS channels, and moving the highest bandwidth customers to the new channel will provide them with more available bandwidth, and will free up bandwidth for the other customers left on the legacy channels. It is expected that initially only a small number of customers will need to be moved to the D3.1 channel. Alternatively, higher usage customers could be identified and invited move to the new channel. As an example, if a substantial fraction of the BitTorrent users in a service group could be moved, it would have an out-sized impact in the bandwidth available to the customers remaining on the older channels since 30% or more of the primetime traffic would move with them.

As more customers are migrated over to the D3.1 channel, available bandwidth on that channel may become an issue. In order to make more bandwidth available to those customers, a next step would be to channel bond those customer modems across the D3.1 and legacy channels. This change will make more bandwidth available to the D3.1 modems. Since the number of legacy customers is also decreasing as they are slowly moved to D3.1 devices, the subscribers remaining on older modems should not be adversely impacted by this change.

It is likely that the D3.1 channel will support a higher modulation order in the spectrum used by the legacy channels. D3.1 offers an alternative to using channel bonding to make use of the spectrum occupied by the legacy channels. D3.1 allows that spectrum to be time multiplexed between the SC-QAM channels and the OFDM channel. However, due to the D3.1 OFDM framing structure, this mechanism will likely not be an efficient use of bandwidth until a sufficient number of D3.1 modems is present to assure that the majority of OFDM frames are filled with data. Before the number of D3.1 modems are available to make this method efficient, the channel bonding of OFDM and SC-QAM channels can continue to be used.

Longer term, as bandwidth demands continue to increase, the plant can be upgraded to support a 204 MHz upstream split and a second OFDM upstream channel added. The two OFDM channels can be channel bonded together, and provide a customer with a 1Gbps upstream service. The second upgrade will again require migration of affected downstream channels, and an upgrade of active elements in the network. Hopefully, network elements developed for the 85MHz upgrade can incorporate simple cost-effective methods to support a later 200MHz upgrade. Alternatively, an operator may elect to make only a single upgrade but push up to the 200MHz boundary. This decision will probably be motivated by the demographics and demand predictions seen by the individual operator.

D3.1 Downstream Migration Strategies

The Downstream features within D3.1 provide the same channel bonding and channel squelching that were discussed in the US migration section. The potential use of the squelch feature may not be as widespread in the DS as it promises to be in the US since there are few, if any, areas of vacant channel in the current DS bands. The channel bonding feature may be used to allow traffic spreading between D3.0 channels and D3.1 channels if new D3.1 spectrum is used to augment the current DS bandwidth available, but without sufficient bandwidth within just the D3.1 spectrum to support new service tiers that may be targeted to receive D3.1 CPE (Customer Premises Equipment) devices.

A more expedient course may be to place a new D3.1 band above the current services, above 750MHz. Using this spectrum may be precluded if there are network elements such as fiber systems or amplifiers that will block these frequencies, but the standard choice for most HFC outside plant deployments for some time has been 1GHz elements, even if no STBs or CMs deployed are capable of using this spectrum. If the new D3.1 band is deployed without having to work around existing services by using previously unused spectrum, it may be possible to deploy a D3.1 channel with sufficient bandwidth to avoid the complication of effectively requiring some portion of the D3.0 bandwidth to be reserved for new D3.1 users.

Turning to potential subscriber migration issues, many MSOs have been pursuing business services with increasing success in the past few years, but to provide competitive service, MSOs have often had to run fiber drops, which may not be cost effective for small to medium business (SMB) opportunities. The higher modulation rates of D3.1 offer new service capabilities that can dovetail well into the SMB market segment. New CPE units for D3.1 will probably be more expensive than standard D3.0 modems at least until volumes become large because a D3.1 modem is defined in the specifications as a D3.0 modem with an additional D3.1 Media Access Control layer (MAC) and Physical layer (PHY). Though many MSOs would like to aggressively deploy the new units, similar to the way the D2.0 and D3.0 CPE units were deployed in advance of the widespread availability of headend equipment and frequency allocation, the additional cost may pose an obstacle in early deployments. SMB customers can offer an excellent target for those early deployments. Their bandwidth requirements will fit well within the expected D3.1 performance and can be used to justify a higher price for the higher performing service.

Another group that may be advantageously deployed with new D3.1 modems could be comprised of the heaviest users within the residential ranks. With the shifting of traffic patterns for DS users, the candidate users are not as simple to target as they might have been in years past. Users who make frequent use of high resolution streaming media may be a useful group to consider for the first migration, but their ranks are fairly large. Additionally, streaming media protocols typically shift their resolutions in response to the presence or absence of bandwidth. Moving some streaming users to the new D3.1 band may not provide much bandwidth relief to the legacy band if the remaining users' streaming clients soak up much of that newly available bandwidth. If the majority of the heavy streaming users are shifted to the new band, then the legacy users will have substantial bandwidth relief during prime time.

Conclusions

After several years of discussing and debating D3.1 features, the first CPE and headend units will arrive soon. Migration planning needs to begin in earnest informed by the latest trends in user behavior as well as technical and financial feasibility. The greatest challenges to deployment of D3.1 services are found in the new upstream since extensive plant work will be needed – downstream deployments may be simpler.

On the customer migration side, business customers, since they may have both increased upstream and downstream bandwidth requirements, are excellent targets for the first D3.1 customer deployments. Assuming streaming media continues to gain in popularity, its residential users can only increase their domination of the downstream bitstream which will tend to create a broad class of users that may be good candidates for a D3.1 transition group in the downstream.

Overall D3.1 presents challenges and opportunities as the industry tries to deploy new technology while keeping ahead of the consumers whose bandwidth uses are constantly changing.

References

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