UNLEASH THE
POWER OF LIMITLESS
CONNECTIVITY
Wireline Access Network

Developing the DOCSIS 4.0 Playbook for the Season of 10G

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Agenda

Finally Tackling Upstream
FDX Overview
FDD Overview
HFC Migration to DOCSIS 4.0
Synergistic Elements
Attributes and Key Qs: Side-by-Side
Summary
It's Time!

Upstream Spectrum is Finally Getting its Shot

A little spectrum has gone a looooooooooong way.

It has not changed since the launch of HSD!

Another looooooooooong capacity runway is ahead – powered by DOCSIS 3.1 OFDMA and Mid-Split BW and speeds.

The recipe for capacity and Gigabit speed starts with High Split bandwidth.
Speaking of Upstream Speeds.....

The Two Flavors of DOCSIS 4.0 Deliver it

DOCSIS 4.0 Full Duplex (FDX)

DOCSIS 4.0 Extended Spectrum

Both are powered by the proven DOCSIS 3.1 PHY foundation of DS OFDM and US OFDMA
The Two Big Ideas

1. Simultaneous use of spectrum without interference
   - Massive new upstream without vacating downstream
   - More efficient use of existing spectrum
   - Configurable US BW/Speed by FDX band allocation

2. Where interference is unavoidable, schedule around potential conflicts
   - New technology (for Cable) to manage overlapping spectrum
   - Echo Cancellation
   - DS/US-Aware Scheduling in CMTS
Extending FDX to N+x

Amplifier contains DSP function
DSP is the same EC used in the RPD
New traffic engineering aspects

1) % of Total Capacity is Shared
   • FDX US is mostly idle – peak rate US bursts are statistically rare

2) Node Seg for Capacity threshold → “Network” Seg for Speed threshold
An FDX RPD is Born!

EC effect modeled

Measured US on “Model 1” (SFU) plant segment
Extended Spectrum as a Natural HFC Next Step

Massive new upstream available by moving the diplex split further out
- New US bands identical to FDX: 108MHz + K x 96MHz up to 684MHz
- Start of downstream shifts with increasing UHS upstream BW allocation
- DS extensible to 1.8GHz to offset BW allocated to UHS
- Four UHS options to balance DS/US allocation by market needs
- DOCSIS 4.0 FDD SoCs now in lab testing
Distributed Access Architecture (DAA) is the foundation for DOCSIS 4.0 solutions

- Greatly improves signal fidelity
- More efficient use of fiber
- Longer reach of digital optics
- Major space and power efficiencies at Hubs, supporting continued traffic increases
- Ethernet-based ecosystem for connectivity to Digital nodes
- Opportunities for deeper real-time telemetry

DOCSIS 4.0 will be implemented into a majority of the node platforms that exists today
YAY
1. Common design rules
2. Network performance consistency
3. Reduce lowest-common denominator impacts of aged and stretched cases

BUT
As-built variables impact migration Cost of (for example) “N+5 Max”
- Original network bandwidth / spacing
- MDU, SDU mix – density in hhp/mile
- Properly engineered Node splits
- Aerial or Underground; conduit / no conduit
- Regional and Muni regulatory differences
- Implications to network powering
Elements of Synergy: Specsmanship

Common Extension of “DOCSIS 3.1” Resources

<table>
<thead>
<tr>
<th>Item</th>
<th>Device</th>
<th>OFDM/OFDMA</th>
<th>SC-QAM</th>
</tr>
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<tbody>
<tr>
<td><strong>Downstream Channel Support</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CM</td>
<td></td>
<td>5 total OFDM channels;</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 channels capable of FDX operation;</td>
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<td></td>
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</table>

| **Upstream Channel Support** |        | At least 7 total OFDMA channels; | 4 (or 8) SC-QAM channels, operating within the legacy diplexer configuration |
| CM                    |        | 6 channels capable of FDX operation; | 4 (or 8) SC-QAM channels, operating within the legacy diplexer configuration |
|                       |        | 2 channels capable of non-FDX operation within the legacy diplexer configuration. (Some channels can be configurable to support either FDX or non-FDX operation. When supporting 6 FDX OFDMA channels, only 1 non-FDX OFDMA channel is required.) | 4 (or 8) SC-QAM channels, operation dependent on operator deployment requirements |
| CMTS                  |        | 8 total OFDMA channels;           | 4 (or 8) SC-QAM channels, operation dependent on operator deployment requirements |
|                       |        | 6 channels with FDX operation;   |        |
|                       |        | 2 channels capable of non-FDX operation based on operator deployment requirements. |        |

| **FDD**              |        |                                   |        |
| Downstream Channel Support |        | 5 OFDM channels                   | 32     |
| CM                    |        | 6 OFDM channels                   | 32     |
| CMTS                  |        | 7 OFDMA channels                  | 4 (upstream SC-QAM channels, operating within the diplex filter configuration. Optional support for up to 8 SC-QAM channels) |
|                       |        | 8 OFDMA channels                  | 4 (upstream SC-QAM channels, operation dependent on operator deployment requirements. Optional support for up to 8 upstream SC-QAM channels) |

1.2 GHz Full Duplex DOCSIS

1.8 GHz Extended Spectrum DOCSIS

Specifically targeting a large increase in US OFDMA
DOCSIS 4.0 Technologies are Complementary

\[
[FDD \text{ DS BW} + \text{ US BW}] = [FDX \text{ DS BW} + \text{ US BW}]
\]

US Allocation flexible to Speed Demand
- FDX → SW to configure FDX US allocation, existing DS BW intact
- FDD → SW to select a HW option with different DS/US ratios

Path to 10 Gbps of upstream capacity
Elements of Synergy: In the Home

Point-of-Entry Termination Part to DOCSIS 4.0

Why PoE?

FDX
- No splitter loss
- Predictable echo environment
- Can operate deep in home with a 15% US capacity penalty

FDD
- No splitter loss
- No replacing in-home passives for 1.8GHz

<table>
<thead>
<tr>
<th>Single Box Solution</th>
<th>Two-Box Solution</th>
</tr>
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<tbody>
<tr>
<td>Lower Cost</td>
<td>DOCSIS 4.0 CM demarc to Common GW</td>
</tr>
<tr>
<td>Simple provisioning and mgmt</td>
<td>Optimize WiFi location</td>
</tr>
<tr>
<td>Self-install Kit (SIK) model</td>
<td>WAN</td>
</tr>
<tr>
<td>WiFi + Mesh – GW location less critical</td>
<td>Outdoor CM Oppt’y @ PoE</td>
</tr>
<tr>
<td>GW turnover with LAN (WiFi) pace</td>
<td>Ethernet WAN and Link Security</td>
</tr>
<tr>
<td></td>
<td>Voice port location</td>
</tr>
</tbody>
</table>
### Attributes Summary & iFAQs

<table>
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<th>Attribute</th>
<th>FDD/ESD</th>
<th>FDX</th>
</tr>
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</table>
| **Strategy/Philosophy to 10G** | • Based on access network BW extension upgrade, up to 1.8GHz, for existing actives and passives  
• Introduction of DAA to migrate to 10G, similar to previous HFC plant upgrades with a choice of diplex split configurations | • Based on access network technology upgrades to introduce new DSP (EC) into RPHY nodes and Amplifier platforms  
• Build on DAA production and scaling of vCMTS as the foundation for 10G |
| **Migration Factors**         | • 1.8 GHz DOCSIS 4.0 DAA Nodes, Amps, Taps and Passives  
• Allows for cascade of amplifiers  
• New CPE | • RPD Nodes with DOCSIS 4.0 EC function  
• FDX-capable amps with DSP  
• New CPE |
| **Complexity**                | • New tech challenges – BW and TCP extension  
• Use of "low power" amp extender for edge cases | • New tech challenges – EC function, CMTS scheduler, DSP-based amps  
• New capacity mgmt rule for IG/TG size for peak speed |
| **Spectrum/Capacity**         | • 1536 MHz DS/656 MHz US (see Figure 13 and Table 1)  
• Up to 15G/5G (all-DOCSIS 3.1)  
• DS/US: BW and Capacity per diplex selection | • 1110 MHz DS / 656 MHz US (see Figure 2)  
• Up to 11G/5G (simultaneous, all-DOCSIS 3.1)  
• FDX BW/speed by SW config |
| **Operations**                | • Utilize existing common operational practices – FDD system with different possible split choices  
• New field tools | • New operational practices for handling of spectrum overlap and amplifier installations  
• New field tools |
| **Network**                   | • N+X  
• Cascade reduction/trade-off based market capabilities | • N+0 (optimal)  
• N+X – Cascade reduction/trade-off based on market speeds |
| **As-Built Migration**        | • Continue node split and introduce DAA node splits, leverage for HFC migration activity, introducing components of FDD over time  
• Migration path and timing considerations for Underground vs Aerial and MDU vs SDU cost implications | • Introduce DAA for node splits with vCMTS, leverage for HFC migration activity and platforms that enable FDX activation  
• Migration path and timing considerations for Underground vs Aerial and MDU vs SDU cost implications |

### Pivots On......

- **Adopting new technology vs Extending existing paradigms**
- **FDX and FDD HW premiums and projected network upgrade costs**
- **Risk assessment of key tech features and magnitude of plant upgrade**
- **Extending current practice to new freqs vs new digital metrics and practices**
- **Limitations to system performance imposed by existing N+x**
- **Relative limitations (or advantages) of as-built**
## Debate Kindling Top 3?

<table>
<thead>
<tr>
<th>Challenges</th>
<th>FDD/ESD</th>
<th>FDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Composite Power limitations for 1.8 GHz</td>
<td>N+0 foundation implications for cost</td>
</tr>
<tr>
<td>2</td>
<td>As-built frequency response over N+x</td>
<td>New technology risk</td>
</tr>
<tr>
<td>3</td>
<td>Upgrade and replacement of all taps and passives</td>
<td>FDX amp and N+x operation</td>
</tr>
</tbody>
</table>
DOCSIS 4.0 has Moved from Slideware to Hardware!

Addressing upstream for capacity and speed is the primary objective
• FDX brings technology new to HFC to increase efficiency in the existing D3.1 band by adding new US channels without vacating DS BW
• FDD brings new total spectrum to HFC to add new US channels above existing D3.1 US, and creates new bands to support ample DS BW

2021 is a year of component level development and early results
In the not too distance future, there will be a year of integration of components and field validation

Network upgrade planned timing is WIP with several key factors
• Market speed targets
• Alignment to planned network upgrade cycle (i.e. next node splits)
• Business factors balancing pro-active network prep vs JIT launches

Charter and Comcast are committed to bringing the 10G vision to life, and will continue to share experiences with one another and with the industry along the way
Thank You!

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