HFC Cable Architecture

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[all images from CableLabs, Cisco, Arris or otherwise noted]
Agenda

• Overview of Cable as a technology: what the future holds
• Architecture overview and terminology
• The PHY layer
  • Hybrid Fiber Coaxial (HFC) system
  • Spectrum allocation, division, FDD
• The MAC layer
  • DOCSIS, symbols, modulation
• CPE
  • Products, speeds, performance in practice
• Operations and Maintenance
Cable is generally not a popular topic..
Why Cable matters (even if we don’t like it)

- HFC can deliver speeds in excess of 10gb/s on existing infrastructure
- Franchise agreements in place, power, right of way, fiber-deep
## Version and Speed Evolution

<table>
<thead>
<tr>
<th>Broadband Generation</th>
<th>DOCSIS 1.0</th>
<th>DOCSIS 1.1</th>
<th>DOCSIS 2.0</th>
<th>DOCSIS 3.0</th>
<th>DOCSIS 3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highlights</td>
<td>Initial cable broadband technology</td>
<td>Added voice over IP service</td>
<td>Higher upstream speed</td>
<td>Greatly enhanced capacity</td>
<td>Capacity and efficiency progression</td>
</tr>
<tr>
<td>Downstream Capacity</td>
<td>40 Mbps</td>
<td>40 Mbps</td>
<td>40 Mbps</td>
<td>1 Gbps</td>
<td>10 Gbps</td>
</tr>
<tr>
<td>Upstream Capacity</td>
<td>10 Mbps</td>
<td>10 Mbps</td>
<td>30 Mbps</td>
<td>100 Mbps</td>
<td>1-2 Gbps</td>
</tr>
</tbody>
</table>

Cable Broadband Technology Evolution, 1990s to Present
Future of Cable broadband is bright

- DOCSIS 3.1 in early phases with 10-15 year useful life in current form
- Full duplex DOCSIS emerging (FDX) which allows for 10gb symmetric
- Fiber-deep architecture enables FTTH and node+0 technology
- OFDM/OFDMA allows for highly efficient use of spectrum
- LDCP replaces FEC in 3.1, adding efficiency
- LTE can run over HFC, and it is headed that way with FDX
- DOCSIS has been used over unlicensed wireless to add robustness
Terminology and Equipment

- CMTS: Cable Modem Termination System
- DOCSIS: Data over cable system interface standard
- Cable Modem: Customer premise cable termination device
- Node: a passive (but powered) optical to radio frequency transceiver
- HFC: Hybrid fiber coaxial: a blend of optical and RF for distribution
- Amplifier: a passive device to perform non-linear RF amplification
- Spectrum: the RF band from 0-1.2GHz (typical) used in Cable
- SC-QAM: single-channel QAM, normally 6.0 MHz (DS), 6.4 MHz (US)
- Node+: Number of nodes in cascade
- Upstream / Downstream: direction of RF amplification and data flow
Simplistic view of DOCSIS Network
Basics of Cable Network
The HFC Reference Architecture
DOCSIS requires 4 management areas

CMTS  Spectrum  Plant  Customer
Roles in a Cable network

• RF Engineer
• Network Engineer
• Headend Tech
• Maintenance Tech
• Field Tech
• OSS Solution Engineer
• BSS Integration
• Customer Support (inside tech)
Cable Modem Termination System (i-CCAP)

Cisco cBR8

Arris E6000

- DCAM Physical Interface Card (PIC)
  - 8 F-connectors per DCAM (in rear)
  - Spare in highest numbered slot

- Power Entry Modules (PEMs)
  - Two -48V DC feeds per PEM
  - Hitless failover between PEMs

- UCAM PIC
  - 24 MCX-Connectors per UCAM (in rear)
  - Spare in lowest numbered slot
Remote PHY
# Sample Output on CMTS

<table>
<thead>
<tr>
<th>Upstream Service Group</th>
<th>Downstream Service Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Router# show cable mac-domain cable 7/1/0 upstream-service-group</strong></td>
<td><strong>router#show cable mac-domain cable 7/0/0 rcc 5 simplified</strong></td>
</tr>
<tr>
<td>Cable MD 7/1/0</td>
<td>RCC ID                  : 5</td>
</tr>
<tr>
<td>US-SG-ID : 1</td>
<td>Created Via             : Wideband - Wi7/0/0:1</td>
</tr>
<tr>
<td>US-Chan : U0,1,2,3,4</td>
<td>CM attribute mask       : 0x80000000</td>
</tr>
<tr>
<td>Primary-DS: 5/1/0:0</td>
<td><strong>RCC ID                  : 5</strong></td>
</tr>
<tr>
<td>US-SG-ID: 1</td>
<td><strong>Created Via             : Wideband - Wi7/0/0:1</strong></td>
</tr>
<tr>
<td>MDD US-List : U0,1,2,3</td>
<td><strong>CM attribute mask       : 0x80000000</strong></td>
</tr>
<tr>
<td>MDD Ambiguity : U0,1,2,3</td>
<td><strong>Primary Receive Channel List:</strong></td>
</tr>
<tr>
<td><strong>Primary-DS: 3/0/0:0</strong></td>
<td>Chan Idx RF Chan DCID Freq</td>
</tr>
<tr>
<td>US-SG-ID: 1</td>
<td>1 ln7/0/0:0 1 453000000</td>
</tr>
<tr>
<td>MDD US-List : U0,1,2,3,4</td>
<td>Non-Primary Receive Channel List:</td>
</tr>
<tr>
<td>MDD Ambiguity : U0,1,2,3,4</td>
<td>Chan Idx RF Chan DCID Freq</td>
</tr>
<tr>
<td><strong>Primary-DS: 3/0/0:1</strong></td>
<td>2 ln7/0/0:1 2 459000000</td>
</tr>
<tr>
<td>US-SG-ID: 1</td>
<td>3 ln7/0/0:2 3 465000000</td>
</tr>
<tr>
<td>MDD US-List : U0,1,2,3,4</td>
<td>4 ln7/0/0:3 4 471000000</td>
</tr>
<tr>
<td>MDD Ambiguity : U0,1,2,3,4</td>
<td>5 ln7/0/0:4 5 477000000</td>
</tr>
<tr>
<td><strong>Primary-DS: 3/0/0:2</strong></td>
<td>6 ln7/0/0:5 6 483000000</td>
</tr>
<tr>
<td>US-SG-ID: 1</td>
<td>...</td>
</tr>
<tr>
<td>MDD US-List : U0,1,2,3,4</td>
<td>24 ln7/0/0:23 24 591000000</td>
</tr>
<tr>
<td>MDD Ambiguity : U0,1,2,3,4</td>
<td>25 ln7/0/0:158 159 663000000</td>
</tr>
<tr>
<td><strong>Primary-DS: 3/0/0:3</strong></td>
<td>OFDM Receive Channel List:</td>
</tr>
<tr>
<td>US-SG-ID: 1</td>
<td>Chan Idx RF Channel DCID PLC-Freq Profiles</td>
</tr>
<tr>
<td>MDD US-List : U0,1,2,3,4</td>
<td>25 ln7/0/0:158 159 663000000 0 1 2</td>
</tr>
</tbody>
</table>
Return and Forward split at 42, 85 or 200MHz

Frequency Division Duplex,

- Different downstream and upstream spectrum, transmit simultaneously
- Example: DOCSIS 3.1

Frequency Division Duplex, used in current cable networks
Spectrum Allocation, Channels, Noise

Upstream, single 6.4Mhz carrier

Downstream, single 6.0Mhz carrier
Outside Plant
<table>
<thead>
<tr>
<th>Mhz</th>
<th>EIA</th>
<th>256-QAM 5.33 b/Hz</th>
<th>512-QAM 5.63 b/Hz</th>
<th>1024-QAM 6.39 b/Hz</th>
<th>2048-QAM 6.99 b/Hz</th>
<th>4096-QAM 7.60 b/Hz</th>
<th>8192-QAM 8.20 b/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>384</td>
<td>64</td>
<td>2.04</td>
<td>2.16</td>
<td>2.45</td>
<td>2.68</td>
<td>2.91</td>
<td>3.14</td>
</tr>
<tr>
<td>336</td>
<td>56</td>
<td>1.79</td>
<td>1.89</td>
<td>2.14</td>
<td>2.34</td>
<td>2.55</td>
<td>2.75</td>
</tr>
<tr>
<td>288</td>
<td>48</td>
<td>1.53</td>
<td>1.62</td>
<td>1.84</td>
<td>2.01</td>
<td>2.18</td>
<td>2.36</td>
</tr>
<tr>
<td>240</td>
<td>40</td>
<td>1.27</td>
<td>1.35</td>
<td>1.53</td>
<td>1.67</td>
<td>1.82</td>
<td>1.96</td>
</tr>
<tr>
<td>192</td>
<td>32</td>
<td>1.02</td>
<td>1.08</td>
<td>1.22</td>
<td>1.34</td>
<td>1.45</td>
<td>1.57</td>
</tr>
<tr>
<td>144</td>
<td>24</td>
<td>0.76</td>
<td>0.81</td>
<td>0.92</td>
<td>1.00</td>
<td>1.09</td>
<td>1.18</td>
</tr>
<tr>
<td>96</td>
<td>16</td>
<td>0.51</td>
<td>0.54</td>
<td>0.61</td>
<td>0.67</td>
<td>0.72</td>
<td>0.78</td>
</tr>
<tr>
<td>48</td>
<td>8</td>
<td>0.25</td>
<td>0.27</td>
<td>0.30</td>
<td>0.33</td>
<td>0.36</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Effort and cost increase with higher modulation.
Plant Performance

% Weighted average Improvement over Max D3.0: 8K FFT: 30%
4K FFT: 20%

SNR (dB)
Physical Layer

Two-Way Plant, commonly a “service group”

Graphic adapted from: Kevin Keaner, Aurora Networks
Another view of HFC

Graphic: Kevin Keaner, Aurora Networks
CPE Options

Bridge

Gateway
DOCSIS Frame (w/ LDPC)
Other Notes

• Plant power for nodes and amplifiers is 90v, field supplied
• Leakage, flyover, sweeps
• Unity Gain and RF maintenance
• PNM
• RDK, areas of industry leadership
Excellent Resources

- Return Path Optimization from Aurora
- CableLabs
- Arris and Cisco, largest CMTS manufacturers
- SCTE – Society of Cable and Telecommunications Engineers
- Spectral Efficiency of DOCIS 3.1
Distributed Port Design

1 OLT port per 64 HP

OLT

Fusion Spliced

1 OLT port per 64 HP

Port Distribution

Ports 1-8

Ports 9-16

Ports 17-24

Ports 25-36

Ports 37-42

Ports 43-48

Ports 49-52

Ports 53-64

Port Access