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HAS THE TIME COME FOR REMOTE PHY IN THE HFC NETWORK?

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NOTE: The concepts and proposals presented in this paper are those of the author and presented for discussion purposes only, and do not reflect any actual plans from Comcast. Similarly, all examples presented are only provided for illustrative purposes.

Rationale for Digital Forward

DOCSIS 3.1 enables the most bits/Hz/sec on HFC to date

- 1,024/2,048/4,096 for DS and 256/512/1,024 US

But not all CMs will be able to achieve the highest performance

- Performance will vary with plant conditions (e.g., SNR)

DOCSIS 3.1 includes a new feature: Multiple Modulation Profiles

- Before DOCSIS 3.1, CMs listened to all DS transmissions
- With MMP the CMTS transmits in 4 MPs
- One profile is set-up for the lowest modulation that all CMs can hear, and is used for communication to some modems and all MAC, multicast, etc.)
- MMP allows CMs to operate at their individual maximum performance within each of the 4 profiles

Rationale for Digital Forward – cont.

The downstream AM optical link becomes a limiting factor

- Signals from HE can be launched with >47 dB MER today
  - Newer EQAMs and CCAP equipment is even better
- AM link in average with 40 wavelengths is at ~38-39 dB MER
- Therefore, EOL performance is typically at 35-38 dB MER

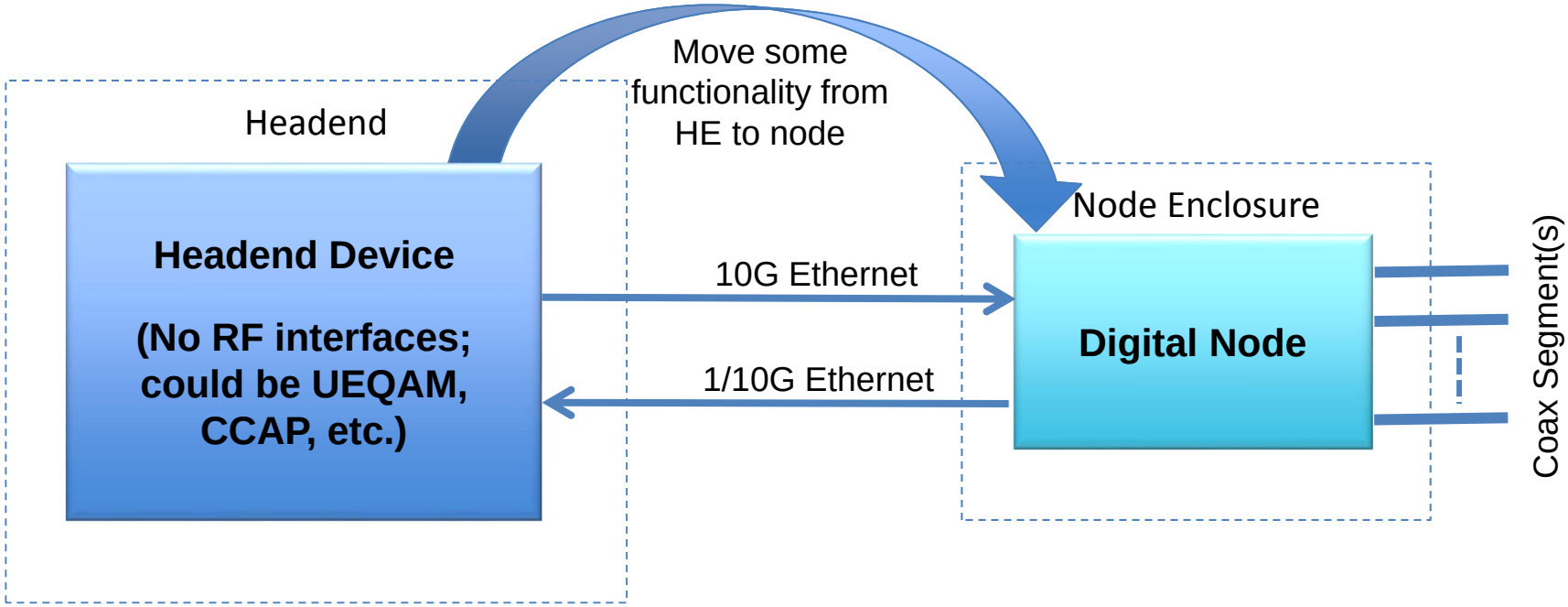
A digital downstream link could improve MER to ~HE quality

- Larger MER would allow most CMs to operate at best MP

As MSOs continue segmenting the network and deploying additional nodes, it might be possible to migrate to digital forward

- Should not be more expensive or more complex
- Instead, it could be more reliable and need less maintenance

Digital Forward High Level Architecture

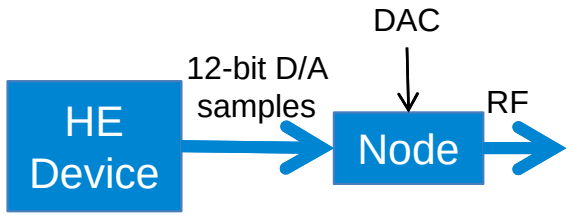
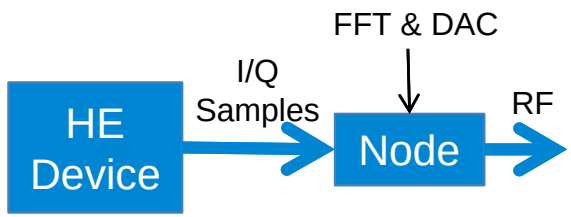
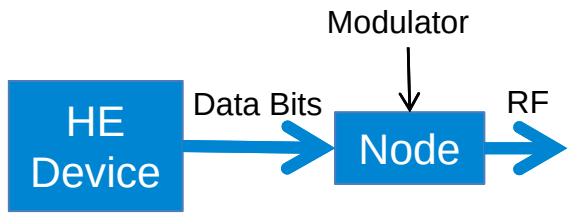


5 Options for Digital Forward

1. **Maintain RF** in the headend
   - Headend equipment remains unchanged
   - RF is digitized, transported, and regenerated in the node
2. Remote **DAC**
   - Analogous to Digital Return
   - Only the D/A is placed in the node
3. Remote **Lower PHY**
   - PHY is split between the headend and the node
4. Remote **Entire PHY**
   - Entire modulator is moved to node
5. Remote the **Entire PHY and MAC**
   - Miniaturize service group and placed in the node

Focus of this presentation

DS and US Options for Remote PHY

	Option 2: DAC in node	Option 3: "Lower PHY"	Option 4: Entire PHY
Key Trade-offs	• Requires separation of the DAC from the rest of PHY • Lowest intelligence in node • Very high bitrate over the fiber link • Requires P2P link (one port and one fiber per node) • Industry specific interface	• The PHY needs to be split between HE and node • A little more intelligence in the node than Option 2 • Still high bitrate over fiber • Also requires P2P link • Industry proprietary and highest complexity link • Requires special silicon	• More intelligence in node (all PHY modulation and demod) • Lowest bitrate over fiber (multiple nodes fit in 10GE) • Uses existing/planned silicon • Enables packet-based link • Allows reuse of common capacity (broadcast)
Block Diagram			

Regardless of implementation, Digital Forward will improve MER

Proposed Tenets for Digital Forward Link

1. Headend and node devices for digital forward link should be interoperable
2. Limit interface specifications to the areas that are absolutely needed for interoperability
3. Minimize electronics housed in the node
4. Minimize software in the node
5. Minimize the amount of capacity needed in the optical link
6. Keep as much of the higher layers as possible in the headend

Proposed Tenets for Digital Forward Link

7. Make the timing requirements for the node as simple as possible
8. Keep the independence between the DS and US as much as possible
9. Maintain the digital forward link independent from the DOCSIS version

Proposed Additional Objectives for Digital FWD

A. Develop an architecture that enables scalability as capacity is needed over time

B. Minimize the need for replacing the node components as additional capacity is needed

C. Leave system components that scale with capacity in the headend

D. Use technologies used in other communications protocols when possible

E. Minimize space and power requirements in the headend

Proposed Additional Objectives for Digital FWD

F. Minimize power requirements in the node, targeting the power consumption of a line extender as the maximum power requirement

G. Enable the use of the digital forward link for other networking functions

Comparison of Digital FWD Options

		Option 2	Option 3	Option 4
Basic Tenets	Interoperable	Should be	Should be	✓
	Limit specs	✓	✓	✓
	Minimize electronics	✓	✓	✓
	Minimize software	✓	✓	✓
	Minimize link capacity	✗	Not likely	✓
	Minimize high layers	✓	✓	✓
	Simple timing	Should be	Should be	Should be
	US/DS independence	✓	✓	✓
	DOCSIS ver independence	Should be	Should be	Should be
Additional Objectives	Scalability	✓	✓	✓
	Minimize replacement	✓	✓	✓
	Leave scaling in HE	✓	✓	✓
	Common tech comp	✗	✗	✓
	Minimize HE space/power	Not likely	Not likely	✓
	Minimize power in node	✓	✓	Should be
	Use link for other net functions	✗	✗	✓

Conclusions

- The analog forward link in HFC networks will become a limiting factor in the performance of DOCSIS 3.1
- Replacing the analog forward optical link with a digital link will enable the highest orders of modulation in D3.1
- Options for implementing a digital forward optical links can be broken down into 5 categories; 3 included in presentation
- A series of tenets and additional objectives are proposed
- The 3 categories of options are compared versus the proposed tenets/objectives to understand the trade-offs
- Time will tell if there aren't other options for implementing digital forward in HFC and/or if the tenets outlined are those considered appropriate by operators and vendors alike

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