DOCSIS 3.1
High Level Overview at NANOG 59

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Oct 09, 2013
Agenda

DOCSIS 3.1 Overview

• Key Objectives
• PHY & MAC layer choices
• Evolution of the DOCSIS network architecture
• Summary
DOCSIS Network Architecture

Data Over Cable Service Interface Specification

- DOCSIS is a global standard deployed on all continents
  - Over 180 million units shipped worldwide
- Data services over the Hybrid Fiber Coax Plant

Video Services
IP Services
Voice Services

Aggregation Network
MSO Core

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DOCSIS Evolution

~1996… to… 2013… to…

• DOCSIS 1.0
  – High Speed Internet Access
• DOCSIS 1.1
  – Voice, Gaming, Streaming
• DOCSIS 2.0
  – Capacity for Symmetric Services
• DOCSIS 3.0
  – Channel Bonding, IPv6
• DOCSIS 3.1
  – OFDM, Wideband Channel
DOCSIS 3.1 Key
Project Objectives
DOCSIS® 3.1: Key Objectives

Develop new version of DOCSIS Specifications/Technology

- Higher Capacity:
  - Efficient 10+ Gbps downstream, 2+ Gbps upstream
- Cost Reduction:
  - Significant cost per bit reduction w.r.t. DOCSIS 3.0
- Plant Adaptation:
  - Adapt to different spectrum, plant conditions
- Effective Migration Strategy:
  - Allow “success based” migration, investment
- Existing HFC Network Operation:
  - Operates without modification of network, actives
DOCSIS 3.1: Higher Capacity

New FEC and More Spectrum

- New Forward Error Correction (FEC)
  - Low Density Parity Check (LDPC) enables higher order modulation (e.g. 1024, 4096 QAM)
  - Greater spectral efficiency (bits/second/Hz)
    - 256 QAM to 4096 QAM = 50% ↑
- Operation across large bands of spectrum
  - Multi-Gigabit speeds require larger spectrum bands
  - E.g. ~500 MHz of downstream spectrum at 10 bits/symbol (net) for ~5 Gbps
    - Note: DOCSIS 3.0 would require ~780 MHz for 5 Gbps
DOCSIS 3.1: Cost Reduction & Plant Adaptation
Orthogonal Frequency Division Multiplexing (OFDM)

- OFDM for upstream, downstream
  - Robust operation, efficient use of spectrum
  - Multiple narrow sub-carriers transmitted together in a block
  - No more 6/8 MHz channel restrictions
- Enables plant adaptation
  - Adjustment to channel conditions with 25-50 kHz resolution
  - Operation into band edge
  - Easy expansion into available spectrum
DOCSIS 3.1 Effective Migration Strategy

Backward compatibility requirements

• DOCSIS 3.1 CMs will operate on DOCSIS 3.0 CMTSs
  – Deploy on existing CMTS/CCAP, incrementally activate new PHY capabilities when upgraded
• DOCSIS 3.1 CMTSs will support DOCSIS 3.0 CMs
  – Can continue to use DOCSIS 2.0 & 3.0 CMs after DOCSIS 3.1 upgrades
• CMs and CMTSs will support bonding
  – 24 downstream SC-QAM channels
  – 8 upstream SC-QAM channels
• CMs and CMTSs will support bonding between D3.0 and D3.1 channels
DOCSIS 3.1 Existing HFC Network Operation

Achieving Project Objectives

- Upstream spectrum remains below downstream
- CPE devices support existing splits (42/65 MHz) and higher splits (85 and 200 MHz)
  - Activate OFDM sub-carriers to increase capacity as needed
- CPE devices operate in existing downstream and higher spectrum enabled by network and passive elements, up to ~1.2 GHz
- No plant changes required to deploy DOCSIS 3.1 equipment
- Future proof - If MSOs chose to expand HFC spectrum in the future, no CPE or infrastructure swap required to increase capacity
PHY Layer Notes

D3.1 is a completely new Physical Layer

- OFDM Numerology
  - Max Channel BW, varied channel sizes, Num of subcarriers
  - Downstream and Upstream, Number of OFDM channels
  - Varied FFT Sizes and Subcarrier spacing
- New Frequency Ranges, Splits
- Higher Modulation orders
- US/DS TX/RX
- New Fidelity requirements
- Proactive Network Maintenance
- New Convergence Layer
Channel Bonding
Adopted packet bonding process from D3.0 MAC Layer

• OFDM “channel” treated like a SC-QAM channel
  – Provides flexibility to the scheduler for optimizing service
• Support for bonding between:
  – OFDM channels
  – SC-QAM (DOCSIS 3.0) channels
  – Between each type of channel
• Works along with Simultaneous Time and Frequency Division Multiplexing
New MAC Concepts & features

New to DOCSIS 3.1

- Ranging and Probing
- Profile Testing and assignment
- Larger MTU Size : 2000 bytes
- Energy Management : Light sleep mode
- Timing & Synchronization : Higher precision and accuracy
- Active Queue Management
- Hierarchical QoS : Advanced Bandwidth Management
D3.1 Migration and Network Evolution
Termination Technology Evolution

DOCSIS 3.1

**DOCSIS 3.0 CPE**
- Few 1.0/1.1
- Lots of 2.0
- Some 3.0

**DOCSIS 3.0 HE**
- 5-42/65 MHz US
- 3.0 CMTS
- DS Bonding

**Today**
- Remove 1.0/1.1?
- More 3.0

**Soon**
- Many 3.0
- Begin deploy 3.1

**3.1 CPE**
- 3.0 DS CCAP
- More DS Bonding
- US Bonding
- S-CDMA?

**3.1 DS / US CCAP**
- 3.1 CCAP
- Begin 3.1 DS and/or US OFDM
- Expand DS OFDM spectrum

**3.1 DS / US CCAP**
- Expand US Split
- Expand DS
- HE upgrade

**Augment HFC**
- CPE Leverages Spectrum
- CPE Refresh

**DOCSIS 3.1 HE**
- Lots of 3.0
- More 3.1
- Lots of 3.1
- Cap 3.0

CPE Devices

HE Equipment

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Network Architecture Evolution

**DOCSIS 3.1**

**Today – some US bonding, 8 target DS**

- Legacy OOB US
- 1-3 LD Channels
- Analog
- Legacy OOB DS
- 4-8 LD Channels

**Tomorrow – Full US bonding (<8), 500 Mbps+ DS D3, D3.1 CPE in D3 mode**

- Legacy OOB US
- 1-4 LD Channels
- Analog
- Legacy OOB DS
- 4-24/32 LD Channels

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Network Architecture Evolution

DOCSIS 3.1

2015/16 – Add D3.1 signals in available spectrum

Future – Change split, expand BW

Bond D3 and D3.1 groups for high rate tier

* Potential 1700 MHz w/tap face plate changes
DOCSIS 3.1 Network Implications

**Spectrum**
- Operates on and increases efficiency on existing HFC
- Top speeds and capacity require more IP spectrum
- Start with a small block and bond to DOCSIS 3.0 channels
- Video optimization and all IP migration to free spectrum
- Optimize to high BW customers
- HFC upgrades can also benefit efficiency and opex
- Core network investments made with BW growth
Summary of Technical Direction

DOCSIS 3.1

- New LDPC FEC and higher order modulation
- OFDM upstream and downstream
- Backward compatibility with DOCSIS 3.0 system
  - Channel Bonding (24x8 SC-QAM channel minimum)
- Upstream below downstream (no “top split”)
- Operates on existing plant without changes
Evolving Cable Technology
Investing in the best broadband experience for all consumers

• DOCSIS 3.1 technology enables faster services
  – Capital investment can be made per customer demand
• DOCSIS 3.1 specifications are latest in the series that has evolved to meet anticipated future demand and facilitate new applications
  – Cost-effectively scale to multi-gigabit services
  – Works in and further optimizes existing HFC plant
  – Options for new spectrum usage; increasing capacity
  – State-of-the-Art technologies and innovation
Questions?

Thanks!

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