IPTV over Cable

Ariel Szternberg
Agenda

- Market Drivers for Cable IPTV
- Technical Enablers for Cable IPTV
- Deployment Strategies
Why are Cable Operators interested in IPTV?
What is Driving Cable to Look at IPTV?

1. **Adjacent Market Opportunities**
   Deliver services where there is no HFC (MDUs, college campuses, new fiber-based residential communities, etc.)

2. **Multi-Network Video Delivery**
   Deploy the same service, same CPE, in cable, wireline, FTTx, WiMax, etc.

3. **Cheaper, more varied CPE**
   IP-based client devices eliminate tuner costs and enable delivery to a wider range of CE devices

4. **Overlay Deployment**
   An IPTV Video Service can be deployed alongside an existing legacy service with modest incremental spectrum demands

5. **Service Velocity**
   IPTV systems leverage Web 2.0 technologies, enabling rapid application/service development
The competitive environment is only getting more challenging…

Broadcast

Satellite/Wireless
Public IP Network
Closed IP Network
Cable

Telecoms

3G Video
Video Alliances
IPTV
Digitalization
Voice & VOIP

Content Production
Live Broadcast
Time-Shift Multicast
VoD Streaming
Internet Downloads
Internet Access/Data/OIP
Satellite Weapon of Choice - HD
Telco Weapon of Choice - Innovation

- Multi-room DVR
- Remote Programming
- HD
- PIP, Fast Channel Change
- Personalized Weather/Sports/Traffic/etc.
- Photos
- VOD, Clips
- “Other Cool Stuff”
IPTV = Service Velocity
Application development much easier when “direct IP” connection present

Instant Channel Change

Feature Velocity

Ubiquitous connectivity

Cross Platform Applications

Web service interface

One platform for all applications

Slideshow on TV
Caller ID on TV
Video/voice mail on TV
Remote DVR programming

And more…

Video Mosaic
Multi-Vendor, Multi-Device Application Framework

- Compact, highly optimized and reliable
- The latest Internet standards
  - HTML4.01, XHTML, DHTML, DVB-HTML, AJAX
  - CSS 2.1, CSS TV, CSS 3
  - DOM 2, JavaScript 1.5, SSL 2 and 3
- Compatible with latest Access Gateway technologies and protocols
- Full control over style
  - Easy branding and theme changes
  - Quickly change style sheet for new look on demand
- Opportunity to personalize
- Rapid prototyping environment
Enables Fast Service Authoring
For Rapid Prototyping and Launch of Advanced Services

UI Design & Layout
- Wire-frame for look and usability analysis

Authoring Tools
- HTML/Web tools used to develop UI and input into previewing

HTML Output
- Debug Tools
  - Refine & Debug

Preview
- Package for deployment

Deployment

Low skill set needed, Faster turn around, Easy deployment
Native IP Delivery of Set-Top Applications
Reduces Complexity and Increasing Service Velocity

Traditional Cable Set-Top
Complex Ecosystem
for Existing Set-Tops

IP or Hybrid Set-Top
Simple Ecosystem
Utilizes IP capabilities
Value Proposition
Delivery of services is changing...

Yesterday – Analog channels moved to digital

- Analog Video
- Digital Video
- High Speed Internet
- Digital Voice

DOCSIS 1.X / 2.0

HFC Plant
Delivery of services is changing...

Today – Further HFC Plant Segmentation

- Analog Video
- Digital Video
- High Speed Internet
- Digital Voice
- 2\textsuperscript{nd} and 3\textsuperscript{rd} Screen Video
- Business VPN’s
- Managed Services

DOCSIS 3.0

HFC Plant
Changing Delivery of Services

Tomorrow – Digital channels moving to IPTV

- Analog Video
- Digital Video
- High Speed Internet
- Digital Voice
- 2nd and 3rd Screen Video
- Business VPN’s
- Managed Services

DOCSIS 3.0

DOCSIS 3.0 leverages IP for all “On Net” Services

Leveraging IP allows services to also go “Off Net”
IP Centric Headend
Broadcast Video + HS Data

Mux / Splicer
Broadcast Video

Data, Voice

MPEG2-TS

Edge QAM

CMTS

Main HE

Local HE

Network

Home

DVB-C STB
Cable Modem

TV

Data, Voice

Mux / Splicer

Broadcast Video

Data, Voice

CMTS

Main HE

Local HE

Network

Home

DVB-C STB
Cable Modem

TV
IP Centric Headend
Broadcast Video + HS Data + VoD

- Asset Video
  - Asset Distribution System Ingest
  - VOD Vault
  - MPEG2-TS
  - nPVR

- Back office
  - VOD Session Manager
  - VOD Streamer
  - On-Demand Video
  - MPEG2-TS

- Broadcast Video
  - Edge QAM
  - Broadcast Video
  - CMTS
  - Data, Voice

- Main HE
  - Network
  - Local HE

- Home
  - TV
  - DVB-C STB
  - Cable Modem

- Data, Voice
  - Mux / Splicer
IP Centric Headend
Broadcast Video + HS Data + VoD + DPI

- Asset Video
- Asset Distribution System Ingest
- Back office
- VOD Session Manager
- VOD Vault
- VOD Streamer
- Edge QAM
- On-Demand Video
- MPEG2-TS
- Broadcast Video
- Mux / Splicer
- Ad Server
- DPI
- nPVR
- Data, Voice
- CMTS
- Main HE
- Local HE
- Network
- Home
- TV
- DVB-C STB
- Cable Modem
- Data, Voice

Broadcast Video + HS Data + VoD + DPI
IP Centric Headend
Broadcast Video + HS Data + VoD + DPI + SDV
IP Centric Headend
BC Video + HS Data + VoD + DPI + SDV + VDOC
What makes Docsis 3.0 suitable for IPTV
Integrated and Modular CMTS Architecture

- MAC, DS PHY and US PHY functions are co-located on the same Line Card
- Fixed ratio between DS and US Ports

- External DS PHY (separate MAC and PHY)
- Flexible ratio between DS and US Ports
- Timing server to keep the two boxes in synch

I-CMTS

- DOCSIS MAC + upper layer protocols
- DS PHY
- US PHY

CMTS Core

- DOCSIS MAC + upper layer protocols
- US PHY

EQAM

- DS PHY

Network Side Interface (NSI)

Radio Frequency Interface (RFI)

Network Side Interface (NSI)

Radio Frequency Interface (RFI)
Cable Labs M-CMTS Architecture

Downstream External Phy Interface: DEPI
DOCSIS Timing Interface: DTI
Downstream RF Interface: DRFI
Edge Resource Management Interface: ERMI
Cable IPTV System Reference Architecture
Making the Transition to Cable IPTV

- XoD, nPVR
- Linear Video
- Niche Programming
- VoD
- On Demand
- Personal Channels
- Linear TV
- Universal Edge QAMs
- CMTS
- Packet Shelf
- Router
- PacketCable
- STB
- Cable Modem
- Phone
- HSD
- VoIP
Making the Transition to Cable IPTV

XoD, nPVR

Linear Video
Niche Programming

HSD

VoIP

VoD

On Demand

Personal Channels

Linear TV

Universal Edge QAMs

CMTS Packet Shelf

Router

PacketCable

M-CMTS

Cable Modem

Phone

IP STB
## IPTV CPE Options

<table>
<thead>
<tr>
<th>Pure IP STB</th>
<th>IP Video Gateway + IP STB</th>
<th>Hybrid STB</th>
</tr>
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<tbody>
<tr>
<td>Maximum STB cost savings</td>
<td>Nominal STB cost savings</td>
<td>Higher STB cost</td>
</tr>
<tr>
<td>One CM is shared among all IP capable devices</td>
<td>One IP service gateway is shared among all IP capable devices</td>
<td>One CM is shared among all IP capable devices</td>
</tr>
<tr>
<td>Easy to upgrade to latest in CM bonding capability</td>
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<tr>
<td>Spectrum utilization is not optimal – duplication of broadcast</td>
<td>Improved broadcast spectrum utilization</td>
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**Notes:**
- **Pure IP STB**
  - Maximum STB cost savings
  - One CM is shared among all IP capable devices
  - Easy to upgrade to latest in CM bonding capability
  - Spectrum utilization is not optimal – duplication of broadcast

- **IP Video Gateway + IP STB**
  - Nominal STB cost savings
  - One IP service gateway is shared among all IP capable devices
  - Easy to upgrade to latest in CM bonding capability
  - Improved broadcast spectrum utilization

- **Hybrid STB**
  - Higher STB cost
  - One CM is shared among all IP capable devices
  - Easy to upgrade to latest in CM bonding capability
  - Improved broadcast spectrum utilization

**Diagram Notes:**
- **Cable Modem**
  - IPTV Client Platform
  - CAS/DRM
  - IP STB

- **IP Services Gateway**
  - IPTV Client Platform
  - CAS/DRM
  - IP STB

- **Hybrid STB**
  - Hybrid Client Platform
  - CAS/DRM
  - Hybrid STB
Compounding Efficiency Gains From IPTV

- **Variable Bitrate**
  - VBR improves bandwidth 40-60% percent
  - Use VBR for all broadcast content
  - The only bandwidth solution for MPEG2 only box
  - IPTV is the best choice for narrowcast statmux and AVC statmux

- **Switched Video**
  - Switching is the way to offer unlimited channels
  - IPTV provides built-in switching functionality

- **Advanced Coding**
  - Advanced encoding improves bandwidth by 50%
  - The solution for HD channels
  - Even better when combined with VBR and statmux
  - IPTV solves the problem of slow channel change with AVC

- **QAM Sharing**
  - Convergence provides further bandwidth savings
  - QAM sharing for VoD and SDV
  - QAM sharing for video and DOCSIS
  - IPTV provides the convergence of data, voice and video
Channel Bonding creates efficiency gains
Big Channel “Packing Advantage”

- Unbonded channels create inefficient boundaries
- Bonding drives efficient “Packing”
- Benefit varies
  - MPEG2/4 HD/SD mix
  - Bonding group size

Channel capacity

4 separate QAM channels

10 SD + 5 HD streams

4-channel bonding group

10 SD + 5 HD streams

No more room for HD

2 additional HD streams
Efficiency Gains from VBR Video – 40-60%

- VBR streams provide equivalent/better quality at lower avg BR
- Law of large numbers favors simple VBR multiplexing in large pipe
Cable IPTV Network
Multiple Bonding Groups for Video/Data/Voice

- Video Headend
- IPTV System
- Internet
- VoIP System

CMTS
Integrated or Modular

HSD/VoIP
RF Spanning
IPTV

Service Group 1
CM
PC
CM
PC
CM
STB / PC

Service Group n
CM
PC
CM
PC
CM
STB / PC
DOCSIS Transport Design

- Video Control
- IP Network
- Video Source

- M-CMTS Core
  - Downstream Channels
  - Upstream Channels

- EQAM
  - DOCSIS DS (HSD)
  - DOCSIS US
  - DOCSIS DS (IPTV)
  - DOCSIS IPTV

- DTI Server
- Bonding Group
  - HSD only subscriber
  - HSD + IPTV subscriber
  - STB

- Bonding Group IPTV

- CM
  - f1
  - f2
  - f3
  - f4
  - f5
  - f6
  - f7
  - f8

- Do not hallucinate.
Spectrum Design with 4x4 CM

- Multicast and unicast service flows must fit modem tuner capture window
  - One tuner block with 80MHz tuning range
- 10 unbonded multicast channels and 3 bonded unicast channels max (Annex B)
  - 87 CBR streams (2Mbps SD and 8Mbps HD with 33% HD percentage)
  - Assume 10% DOCSIS overhead
- Dynamic Bonding Change (DBC) is used to tune to different multicast channels

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![Diagram showing static multicast channels and dynamic multicast and unicast channels within a 80 MHz capture range.](attachment:image.png)
Dynamic Bonding Change (DBC)

- Broadcast channels are delivered by the CMTS to broadcast QAMs B1... Bn via static multicast
- The STB sends IGMP to the CMTS to tune to a broadcast channel
- The CMTS looks up the multicast address and finds out the broadcast QAM that carries the channel
- The CMTS sends the DBC message to CM and gives the RCC for tuning
- The CM tunes to the RCC and the media flows to the STB

Receiving Channel Configuration (RCC) for CM
- Q1/Q2/Q3/B1
- Q1/Q2/Q3/B2
- ...
Spectrum Design with 8x4 CM

- 4 channel bonded multicast and 4 channel bonded unicast
  - static multicast and RF spanning
  - two independent tuner blocks, 32MHz each

- One 4-channel bonding group for static multicast (Annex B)
  - 35 CBR streams (2Mbps SD, 8Mbps HD at 33% HD percentage)
  - 56 VBR streams with 40% VBR encoding gain and 87% VBR statmux efficiency

- One 4-channel bonding group for dynamic multicast and unicast
RF Spanning

- Use static multicast to broadcast most popular content
- Use dynamic multicast to narrowcast less popular content
- Apply RF spanning to further reduce the cost for broadcast
When the initial IPTV penetration is extremely low, this configuration can further reduce the startup cost.

- One bonded QAM channel group can feed CMs from more than a single fiber node.
- Fully switched linear content.
The critical multicast features for IPTV: multicast QoS, multicast fast leave, SSM

The regional network is SSM network, the CMTS needs to support SSM mapping to support migration from ASM to SSM on the CPE side

The SSM mapping should support both single sender and multiple senders

Multicast fast leave is needed to support basic IPTV channel change and rapid channel change

In DOCSIS 3.0 multicast, the fast leave is achieved by CMTS explicit CPE tracking. IGMPv3 on the CPE side is the requirement for fast leave

IGMP join latency and latency variation are critical for VQE RCC operation

DOCSIS 3.0 CM will NOT do IGMP snooping, the forwarding is fully controlled by the CMTS
DOCSIS Multicast Admission Control

- Dynamic multicast with QoS is subjected to admission control
- Static multicast can be used for critical multicast flows
- Admission control is triggered by IGMP
- Bandwidth configuration at the source and CMTS must match
- STB must handle silent IGMP failure gracefully
**DOCSIS Quality of Service**

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>DSCP Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Voice</td>
<td>EF 0b101110</td>
</tr>
<tr>
<td>Broadcast Video and dynamic multicast</td>
<td>AF41 0b100010</td>
</tr>
<tr>
<td>Interactive video (VoD)</td>
<td>AF42 0b100110</td>
</tr>
<tr>
<td>All control traffic</td>
<td>CS3 0b011000</td>
</tr>
<tr>
<td>VQE RCC</td>
<td>CS4 0b100000</td>
</tr>
<tr>
<td>Data (Internet Access)</td>
<td>BE 0b000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>DOCSIS QoS Priority</th>
<th>Bonding Group</th>
<th>CIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Voice</td>
<td>Any</td>
<td>HSD BD</td>
<td>CIR with PCMM signaling and low latency</td>
</tr>
<tr>
<td>Broadcast Video</td>
<td>Any</td>
<td>Broadcast BD</td>
<td>Separate bonding group</td>
</tr>
<tr>
<td>Interactive video (VoD)</td>
<td>Any</td>
<td>Video BD</td>
<td>CIR w. signaling for admission control</td>
</tr>
<tr>
<td>Dynamic Multicast Video</td>
<td>Any</td>
<td>Video BD</td>
<td>Or non-CIR best effort</td>
</tr>
<tr>
<td>All control traffic</td>
<td>Any</td>
<td>Video BD</td>
<td>CIR with IGMP signaling for admission control</td>
</tr>
<tr>
<td>VQE RCC</td>
<td>Any</td>
<td>RCC BD</td>
<td>No CIR</td>
</tr>
<tr>
<td>Data (Internet Access)</td>
<td>Any</td>
<td>HSD BD</td>
<td>No CIR</td>
</tr>
</tbody>
</table>

- **DSCP marking for various traffic type**
  - Downstream marking done at first hop routers closest to source
  - Upstream marking is done by the STB (configured on ISDS)
- **CIR admission control: SDV**
QoS with Overlapping Bonding Groups

Three overlapping bonding groups:
- VoD, SDV, Control
- Rapid channel change
- HSD, Gaming, Voice

Non-overlapping broadcast bonding group:
- Broadcast Video
Dynamic Bandwidth Sharing

Dynamic bandwidth sharing among overlapping bonding groups

- Attributed based forwarding is used to direct traffic to different bonding group
- Bonding group is associated with attributes
- Service flow is configured with attributes
- CMTS matches the SF attributes with bonding group attributes when directing SF

<table>
<thead>
<tr>
<th>Bonding Group</th>
<th>Fixed BW (%)</th>
<th>Remaining ratio</th>
<th>Effective Guaranteed BW (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDV &amp; VoD &amp; multicast control</td>
<td>85</td>
<td>1</td>
<td>68% if VoD flows are CIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85% if VoD flows are non-CIR</td>
</tr>
<tr>
<td>Rapid channel change</td>
<td>5</td>
<td>100</td>
<td>22% if VoD flows are CIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5% if VoD flows are non-CIR</td>
</tr>
<tr>
<td>HSD</td>
<td>10</td>
<td>1</td>
<td>10%</td>
</tr>
</tbody>
</table>
IPTV feature requirements
## IPTV Middleware Systems

<table>
<thead>
<tr>
<th>Middleware Servers</th>
<th>IP Transport Networks</th>
<th>Middleware Clients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device &amp; Service Management</strong></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Device" /></td>
</tr>
<tr>
<td><strong>VoD System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content Protection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Error Recovery</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fast Channel Change</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Middleware system enables the IPTV service
  - linear video is delivered via multicast
  - on-demand video is delivered via unicast
- Middleware is access independent
- Middleware can be optimized for cable access
Middleware and Adaptation

Cable Access Characteristics
- Shared last mile
- Wideband access
- Low bit error rate

Admission Control:
- Network based instead of subscriber based
- Middleware admission control signaling

Fast Channel Change:
- Use high burst rate to optimize performance
- Network congestion and QoS

Error Recovery:
- Avoid application level FEC, use error retransmission

Multicast Control Flow:
- IGMPv3 and SSM
- Static vs. dynamic and broadcast vs. narrowcast

Any Middleware
Ensuring Video Quality w. Admission Control

- What happens when demand exceeds design assumptions in shared access such as cable?
- Oversubscription leads to packet loss for many
- For shared cable access, admission control should be done at the access node instead of subscriber home
- DOCSIS access support admission control based on PCMM. For multicast, IGMP could also be leveraged for admission control
- Middleware must provide the signaling trigger for DOCSIS admission control
Error Concealment and Recovery

- Middleware error concealment and recover is divided into two categories
  - **Error retransmission**: retransmitting lost packet to client
  - **Application level forward error correction (FEC)**: sending duplicate error repair packet

- DOCSIS access has FEC at QAM level using RS coding. This contributes to low BER, e.g. in the order of 1E-8

- The low BER characteristics of DOCSIS does not justify the use of FEC at application level because of the higher bandwidth overhead

- Error retransmission covers packet loss in home network as well
Middleware and Multicast

- SSM is the multicast choice of SP networks. If a middleware does not support SSM, the ASM to SSM conversion can be applied at the network edge (CMTS).
- Middleware needs to support IGMPv3 for IPTV channel change operation.
- Middleware may apply multicast to control signaling. The multicast usage should be optimized in cable access with the following options.

<table>
<thead>
<tr>
<th>Delivery Methods</th>
<th>DOCSIS delivery</th>
<th>Multicast Method</th>
<th>Subject to Admission</th>
<th>Recommended Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td>Static multicast</td>
<td>No</td>
<td>System wide scoping</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low bandwidth control flow</td>
<td></td>
</tr>
<tr>
<td>Narrowcast</td>
<td>Dynamic multicast</td>
<td>Yes</td>
<td>Per service group scoping</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Graceful handling of admission failure required</td>
<td></td>
</tr>
<tr>
<td>Narrowcast</td>
<td>Static multicast</td>
<td>No</td>
<td>Per service group scoping</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Critical control flow</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low bandwidth flow</td>
<td></td>
</tr>
</tbody>
</table>
Channel Change Delay Contributing Factors

<table>
<thead>
<tr>
<th>Channel Change Latency Factor</th>
<th>T=0</th>
<th>Channel Change Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multicast Join for New Channel</td>
<td>50 ms</td>
<td>500 ms or greater*</td>
</tr>
<tr>
<td>Dynamic Multicast Set Up Delay</td>
<td>75 ms</td>
<td>500 ms or greater*</td>
</tr>
<tr>
<td>System Information</td>
<td>100 ms</td>
<td></td>
</tr>
<tr>
<td>Encryption Key</td>
<td></td>
<td></td>
</tr>
<tr>
<td>De-Jitter Buffer Fill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-Frame Delay</td>
<td>100 ms</td>
<td></td>
</tr>
<tr>
<td>*depends on compression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPEG (decoder) Buffering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*depends on STB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Main culprits
- I-frame delay and decoder buffer fill

Typical fast channel change technique
- Unicast bursting the I-frame at speed faster than nominal play speed
- Seamless switch back to multicast stream after channel change event
Fast Channel Change in Cable Access

- DOCSIS access has higher bandwidth in the access
- Bursting at a higher rate delivers better channel change performance in cable access than in DSL access

Example:
- Bursting SD channel at 3 times the nominal rate
- Bursting HD channel at 2 times the nominal rate

- In shared access as DOCSIS, fast channel change burst should be given high priority than BE data service via QoS design
- Middleware must gracefully handle network congestion and resort to un-accelerated channel change if congestion happens during the unicast burst
Summary
Key IPTV Takeaways

- IPTV Technology/Innovation ecosystem is happening no matter what the cable industry does
  Ignore vs. fight vs. adopt

- DOCSIS 3.0 rollout opens the window to port this ecosystem to cable industry
  Multicast, Channel Bonding, M-CMTS

- Cable IPTV allows cable operators to access “innovation pool” developing in IPTV ecosystem

- Cable IPTV completes end-to-end IP connection from headend to home, enabling delivery to any IP-connected device
Thank You