TOMORROW starts here.

IPTV and Over-the-Top Video: Managed and Unmanaged Video Delivery

BRKSPV-1999

Ali C. Begen

Video and Content Platforms Research and Advanced Development

Cisco live!

Presenter Today – Ali C. Begen

Visit http://ali.begen.net for Publications, Presentations, etc.

- Have a Ph.D. degree from Georgia Tech, joined Cisco in 2007
- Works in the area of architectures for next-generation video transport and distribution over IP networks
- Interested in
  - Networked entertainment
  - Internet multimedia
  - Transport protocols
  - Content distribution
- Senior member of the IEEE and ACM

Agenda

- Part I: IPTV
  - IPTV – Architecture, Protocols and SLAs
  - Video Transport in the Core Networks
  - Video Distribution in the Access Networks
  - Improving Viewer Quality of Experience

- Part II: Internet Video and Adaptive Streaming
  - Example Over-the-Top (OTT) Services
  - Media Delivery over the Internet
  - Adaptive Streaming over HTTP
  - MPEG DASH Standard

First Things First

IPTV vs. IP (Over-the-Top) Video

IPTV	IP Video
Managed delivery	Best-effort delivery
Emphasis on quality	Quality not guaranteed
Linear TV plus VoD	Mostly on demand
Paid service	Paid or free service

Experiences Consumers Want Now

Yet Service Providers Struggle to Deliver

Online Content on TV/STB

Intuitive Unified Navigation for All Content

Multi-screen TV Experience

Web 2.0 Experiences on TV/STB

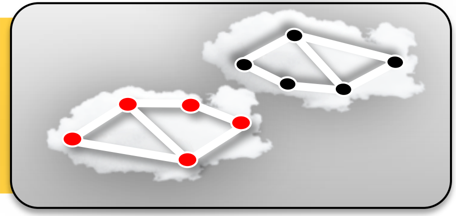
Support an increasing variety of services on an any device and deliver a common experience everywhere

Three Dimensions of the Problem

Content, Transport and Devices

Managed and Unmanaged Content

Managed and Unmanaged Transport



Managed and Unmanaged Devices

From Totally Best-Effort to Fully-Managed Offerings

Challenge is to Provide a Solution that Covers All

Design to the most general case
Optimise where appropriate



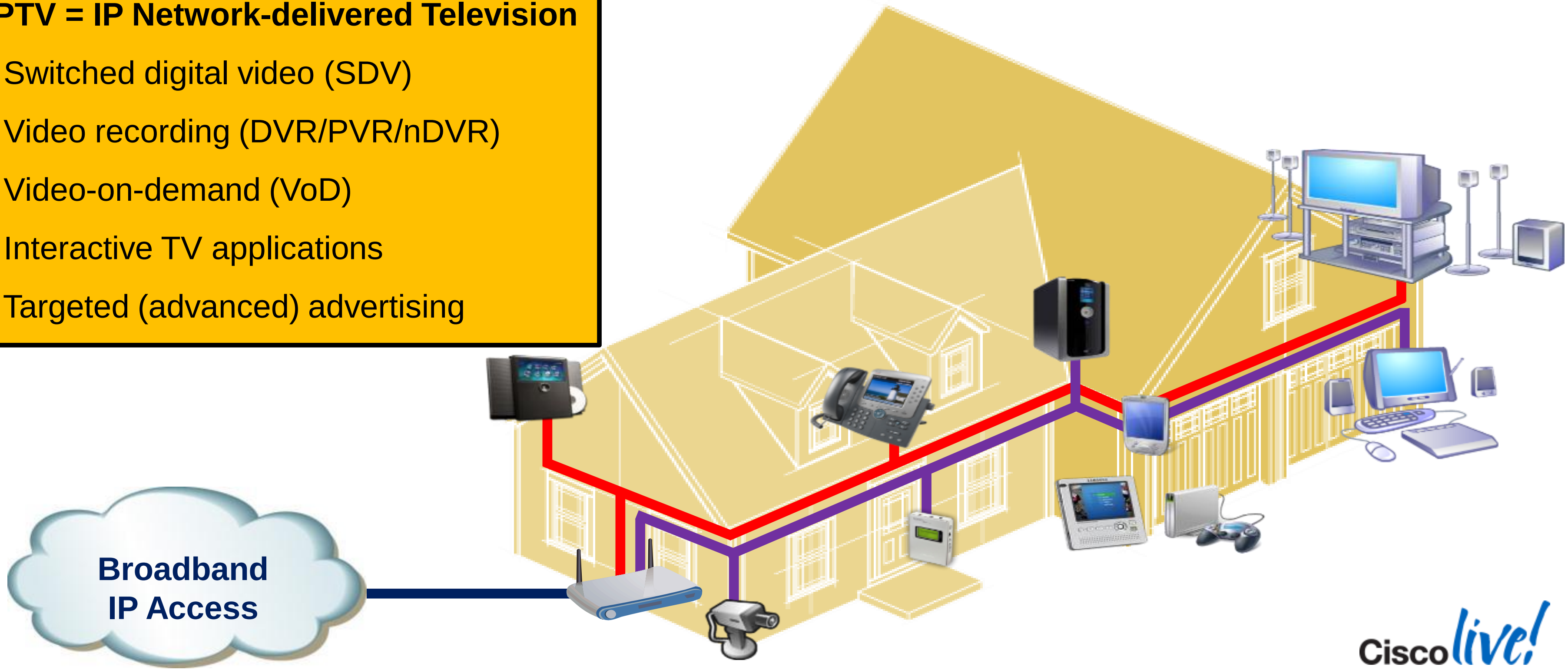

Part I: IPTV

What is IPTV?

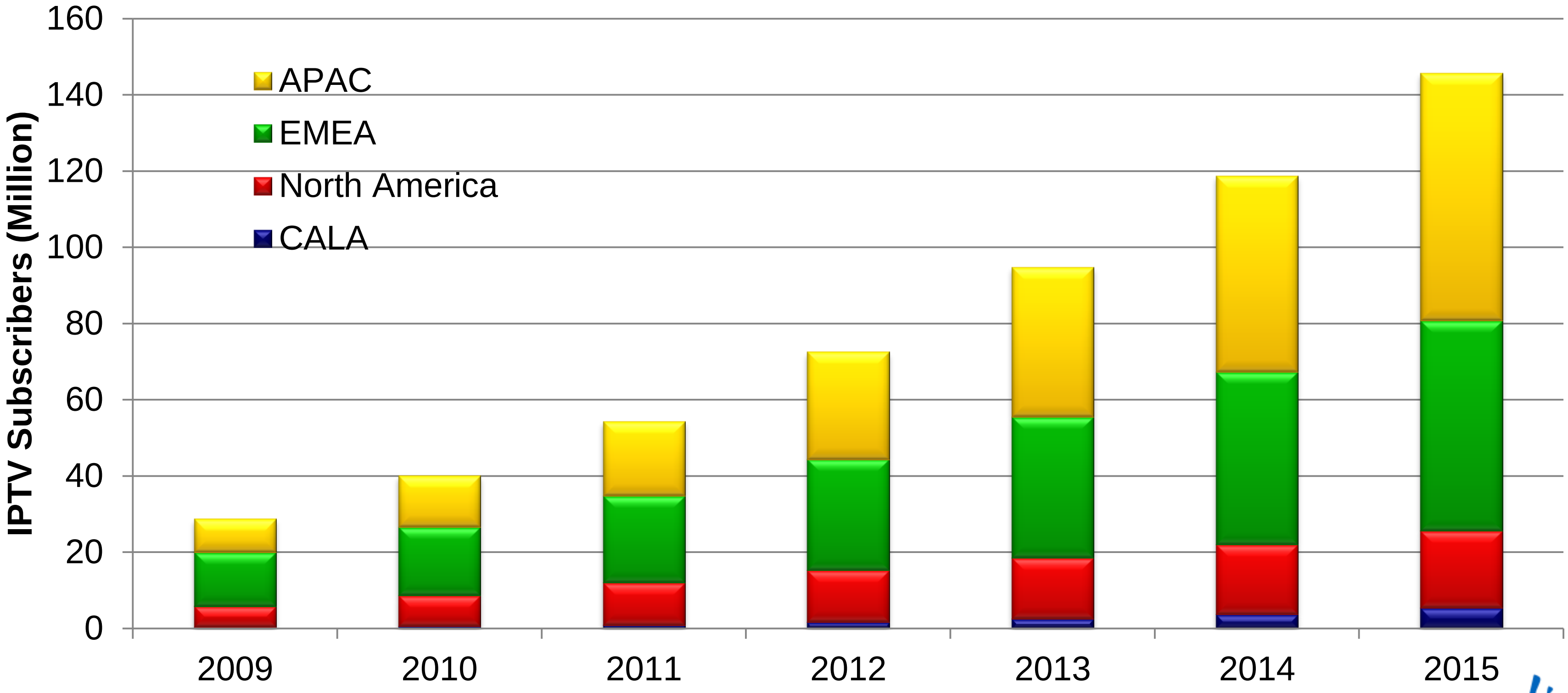
The Fundamental Component for Connected Homes

IPTV = IP Network-delivered Television

- Switched digital video (SDV)
- Video recording (DVR/PVR/nDVR)
- Video-on-demand (VoD)
- Interactive TV applications
- Targeted (advanced) advertising



Growth for IPTV



Source: Infonetics Research, 2011

Trends Driving IPTV Adoption

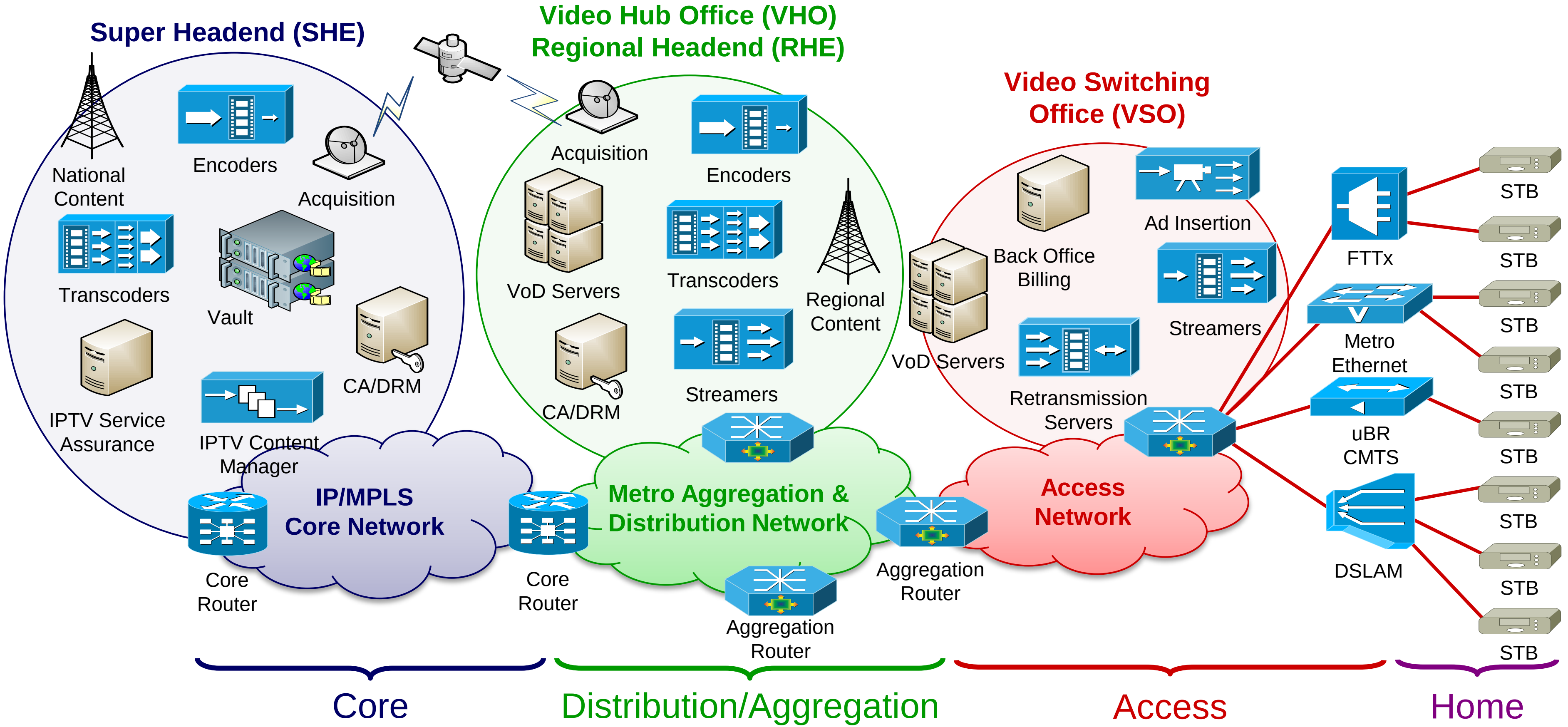
- **Subscribers want more choice and control**
  - New generation grew up computer/Internet savvy
  - Customised for me – One bill, one provider, integrated services
- **Codec, access, server and CPE technologies are improving**
  - MPEG-4 AVC (H.264) improvements, new xDSL, FTTx, DOCSIS 3.0 access technologies
  - Moore's law advancements in processing and memory
- **Competition is increasing among service providers**
  - No longer limited by access
  - Traditional markets are going away, e.g., VoIP is almost free

Video is driving next generation service provider network designs

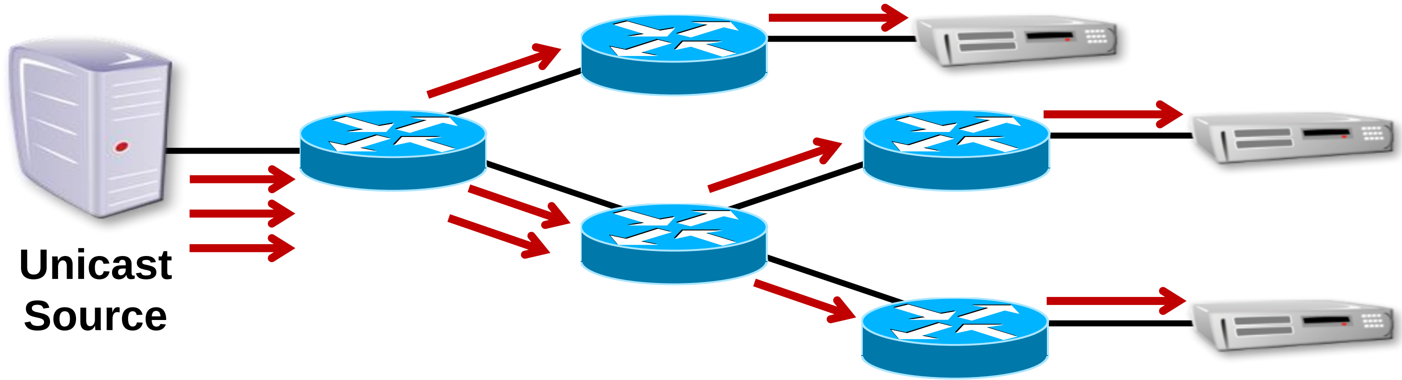


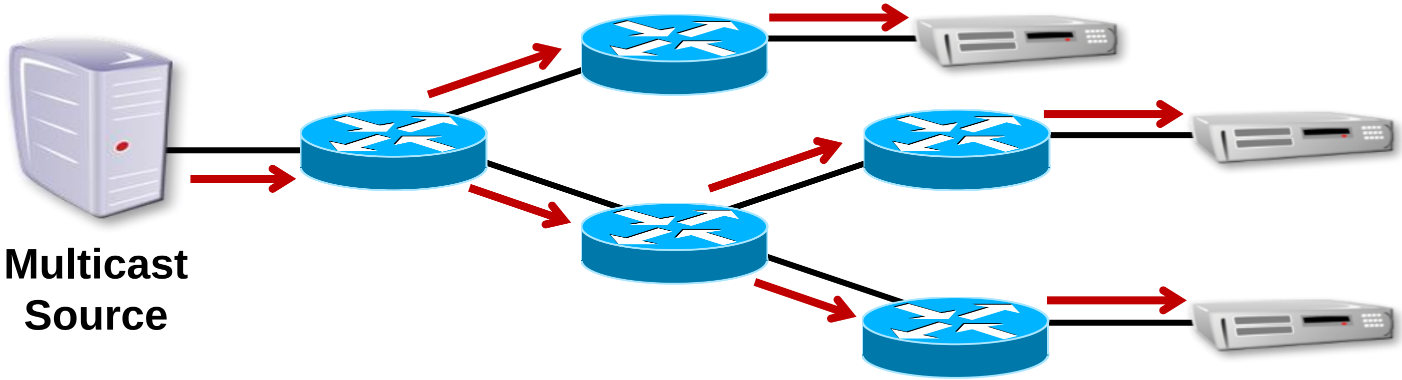

IPTV – Architecture, Protocols and SLAs

End-to-End IPTV Network Architecture



Unicast vs. Multicast





Broadcast IPTV = IP Multicast

- **Various Transports**
  - Native IP multicast, MPLS, L2, optical
- **SSM: Source-Specific Multicast (RFCs 4604 and 4607)**
  - Receivers subscribe (S,G) channels to receive traffic only from source S sent to group G
  - Primarily introduced (by IETF) for IPTV-like services
- **IP Multicast Endpoints**
  - Sources: Encoder, transcoder, groomer, ad-splicer
  - Receivers: Transcoder, groomer, ad-splicer, eQAM, IP STB
- **IETF standardised**
  - Receiver-to-Router Protocols: IGMPv3 (IPv4) and MLDv2 (IPv6) with (S,G) signalling
  - Router-to-Router Protocols: PIM-SSM, IGMPv3 Proxy Routing, Snooping on HAG and L2 devices
- **Transport Challenges**
  - Packet loss, out-of-order delivery, packet duplication

    (We cannot use TCP for IP multicast)

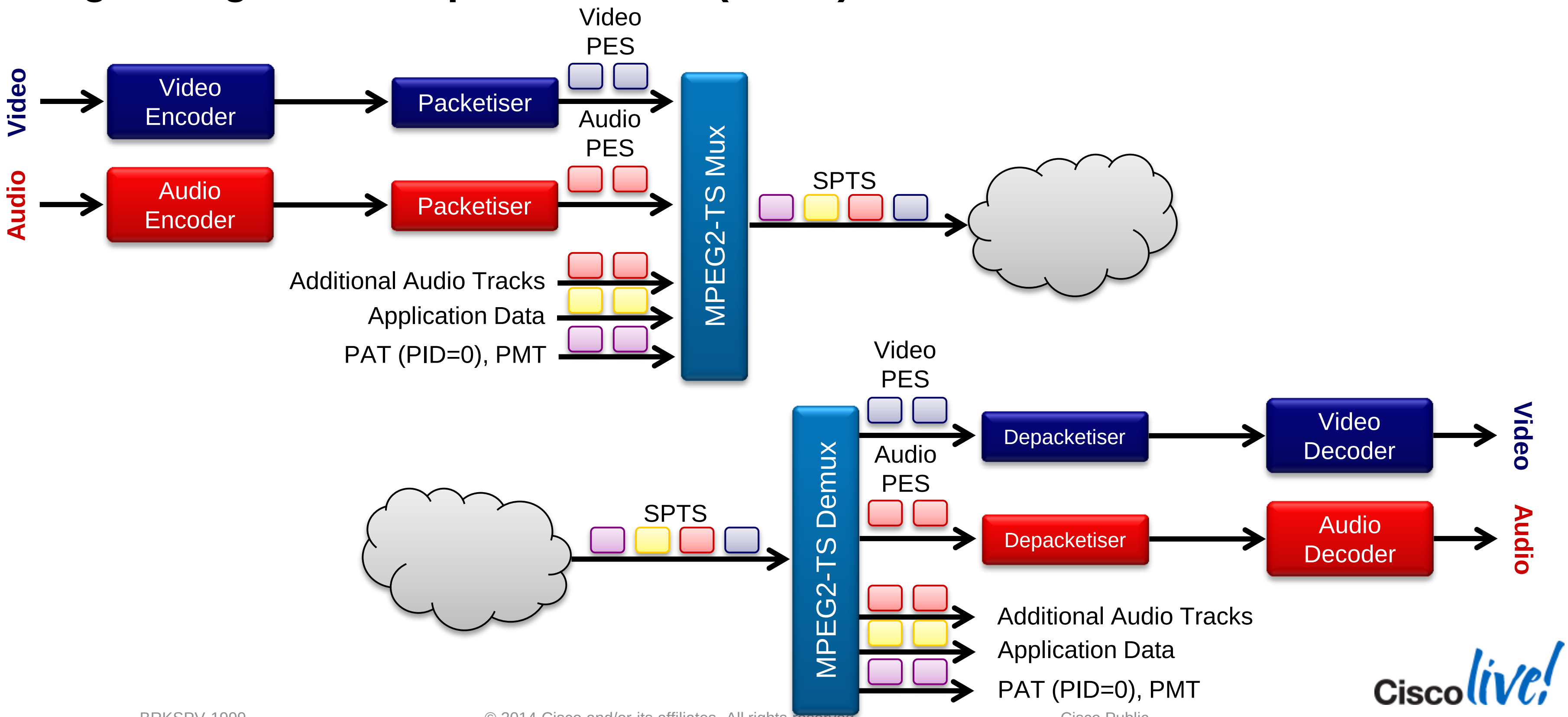
Real-Time Transport Protocol (RTP)

http://tools.ietf.org/html/rfc3550

- **Basics**
  - First specified by IETF in 1996, later updated in 2003 (RFC 3550)
  - Runs over any transport-layer protocol (Typically over UDP)
  - Runs over both unicast and multicast
  - No built-in reliability
- **Main Services**
  - Payload type identification
  - Sequence numbering
  - Timestamping
- **Extensions**
  - Basic RTP functionality uses a 12-byte header
  - RFC 5285 defines an RTP header extension mechanism
- **Control Plane – RTCP**
  - Provides minimal control and identification functionality
  - Enables a scalable monitoring functionality (Sender, receiver, extended reports)

Packetisation into MPEG2 Transport Streams

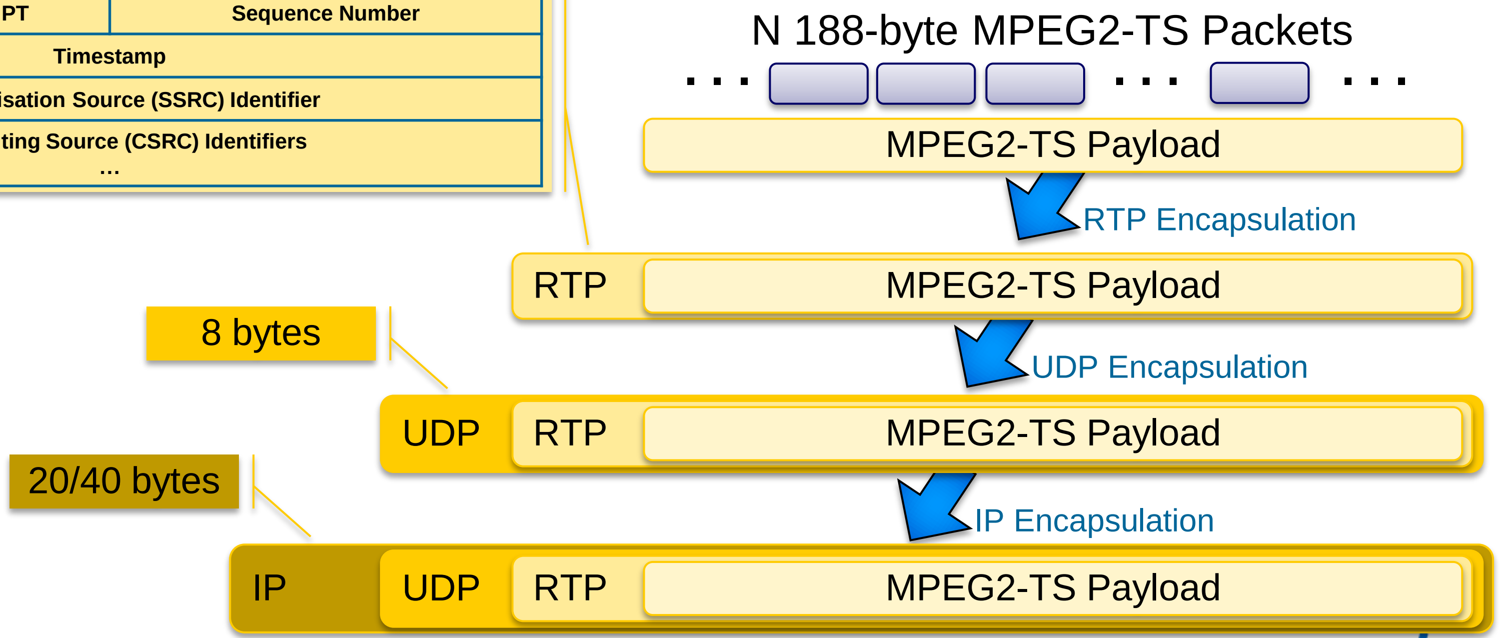
Single Program Transport Streams (SPTS)



RTP Transport of MPEG2 Transport Streams

http://tools.ietf.org/html/rfc2250

V=2	P	X	CC	M	PT	Sequence Number
Timestamp						
Synchronisation Source (SSRC) Identifier						
Contributing Source (CSRC) Identifiers …						



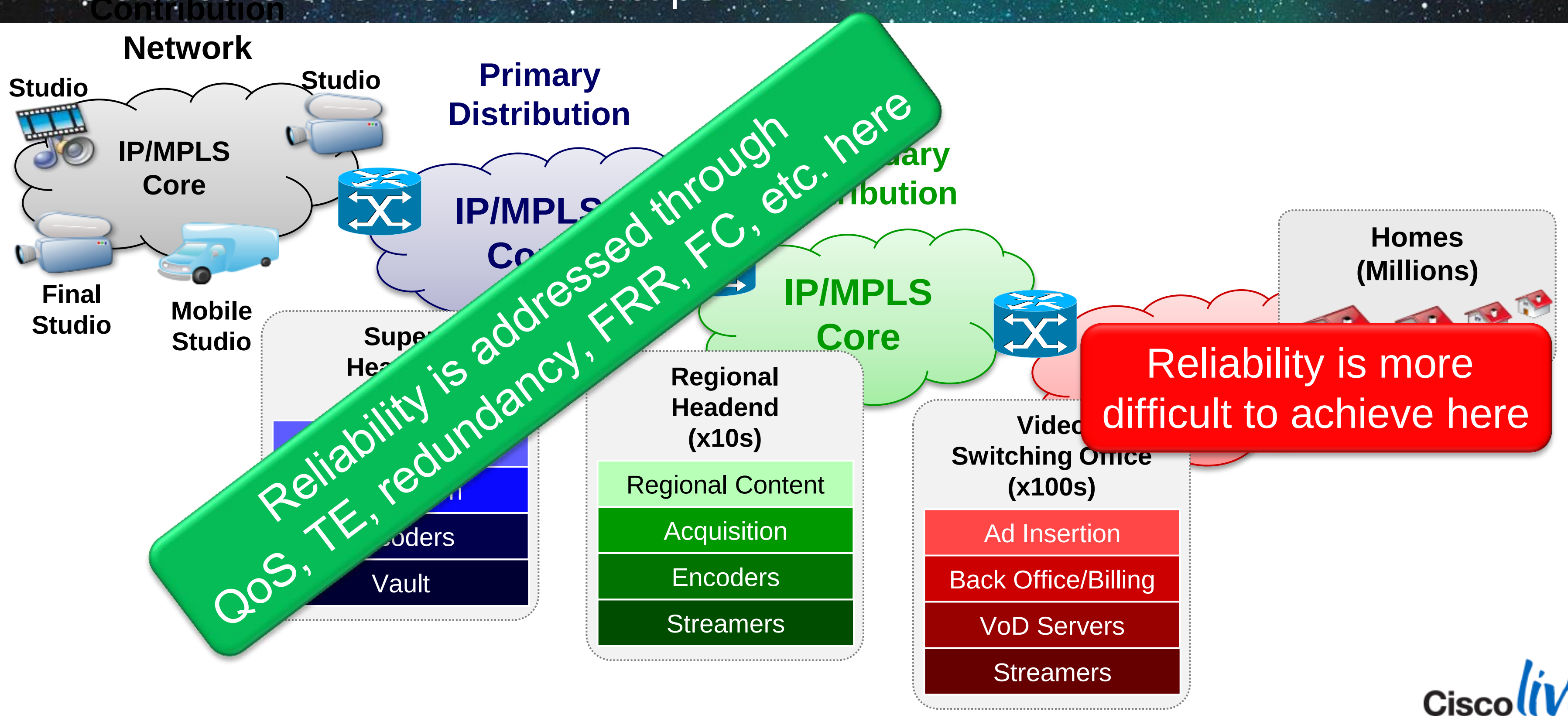
Default IP header size is 20 and 40 bytes for IPv4 and IPv6, respectively

Types of Video Services

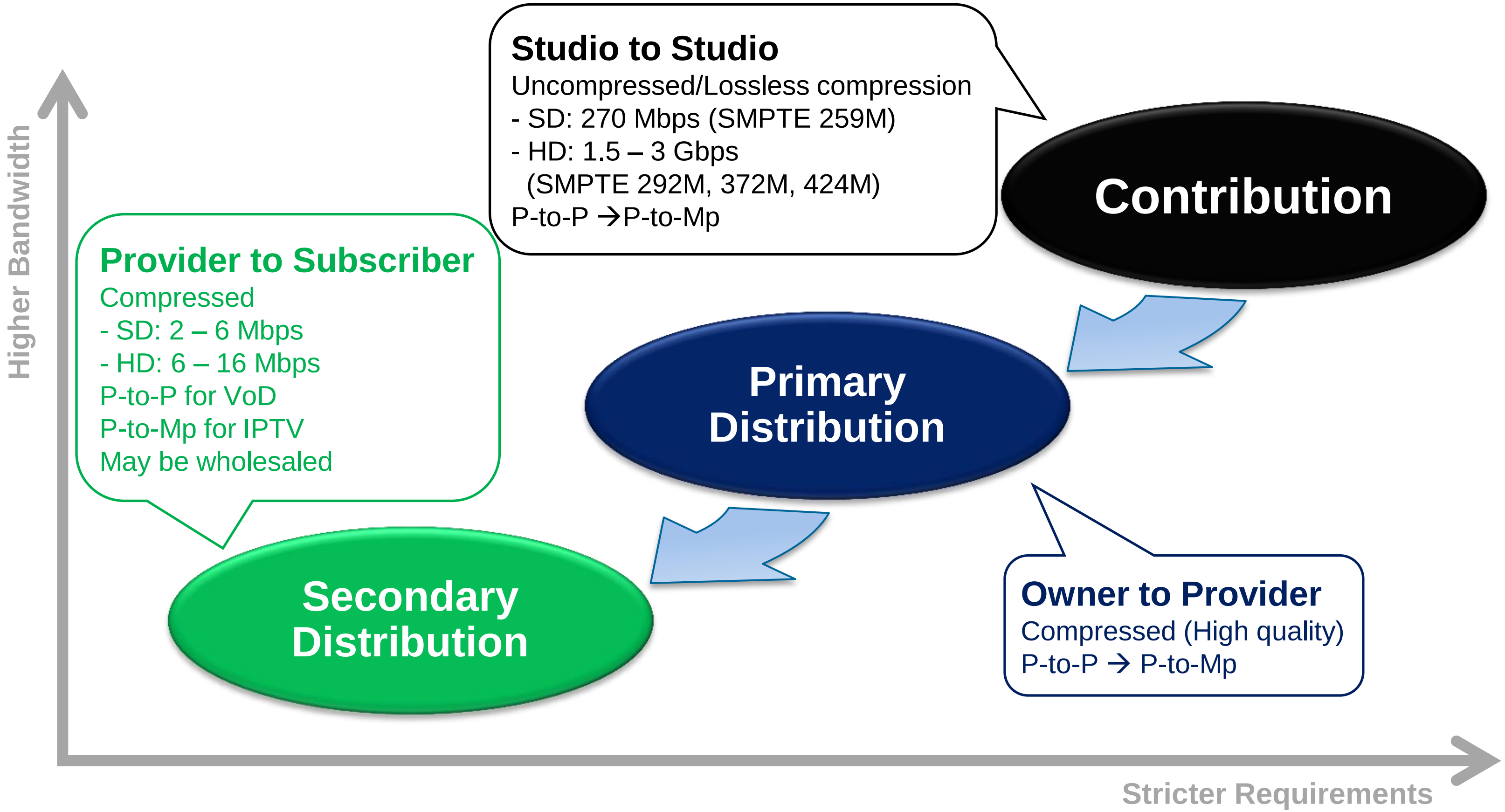
- **Transport (Contribution and Primary Distribution)**
- **IPTV /CATV (Secondary Distribution)**
  - IP multicast distribution from centralised super headends
  - (Driving enhanced multicast features and functions)
- **VoD (Secondary Distribution)**
  - Distributed architecture for better scalability
  - Non-real-time content distribution to caches
- **Enterprise**
  - mVPN based
- **Over-the-Top (e.g., Hulu, Apple TV, Netflix)**
  - Adaptive streaming methods are ubiquitous

IPTV *must* Deliver Entertainment-Calibre Video

Tolerance is One Visible Artefact per Movie



Taxonomy of Video Service Providers



Video SLA Requirements

- **Throughput**
  - Addressed through capacity planning and QoS (i.e., Diffserv)
- **Delay/Jitter**
  - Controlled with QoS
  - Absorbed by de-jittering buffer at IP STB
    - We desire to minimise buffer sizes to improve responsiveness
    - Jitter originating in the core is rather insignificant
- **Packet Loss**
  - Controlling loss is the main challenge
- **Service Availability**
  - Proportion of time for which the specified throughput is available within the bounds of the defined delay and loss




Video Transport in the Core Networks

Four Primary Causes for Packet Loss

- **Excess Delay**
  - Renders media packets essentially lost beyond an acceptable bound
  - Can be prevented with appropriate QoS (i.e., Diffserv)
- **Congestion**
  - Considered as a catastrophic case, i.e., fundamental failure of service
  - Must be prevented with appropriate QoS and admission control
- **PHY-Layer Errors**
  - Apply to core and access – Occurrence in core is far less
  - Considered insignificant compared to losses due to network failures
- **Network Reconvergence Events**
  - Occur at different scales based on topology, components and traffic
  - Can be eliminated with high availability (HA) techniques

What are the Core Impairment Contributors?

	Impairment Rate
Trunk failures	.0010 /2h
Hardware failures	.0003 /2h
Software failures	.0012 /2h
Non-stop forwarding (NSF) and Stateful switch-over (SSO) help here	
Software upgrades (Maintenance)	.0037 /2h
Modular code (IOS-XR) helps here	
Total	.0062 /2h (One every two weeks)

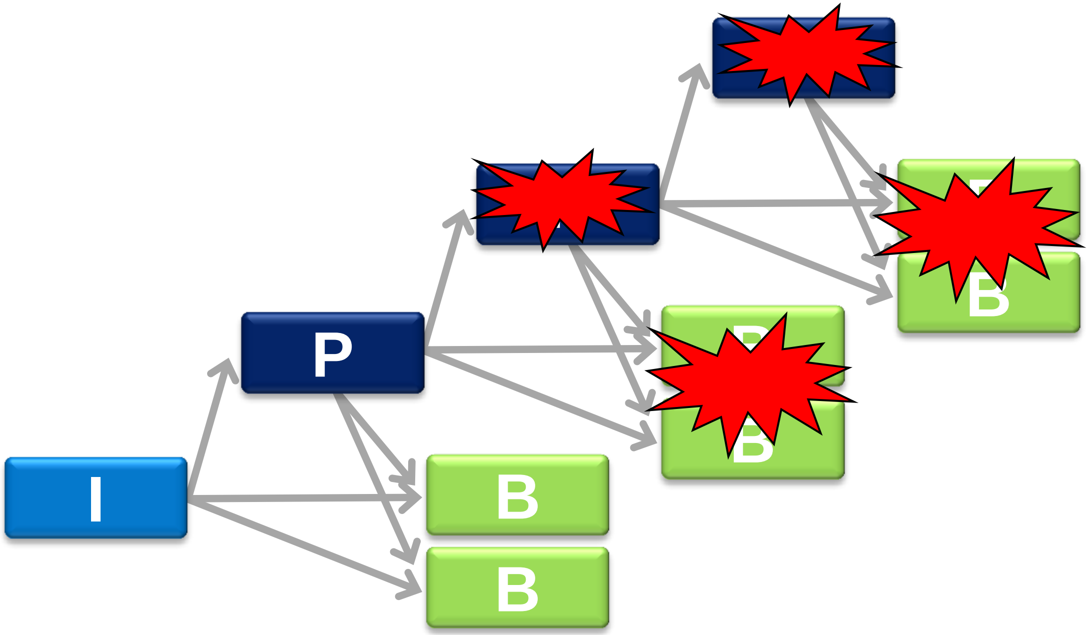
Note that average mean time between errors on a DSL line is in the order of minutes when no protection is applied

Back of envelope calculations across several SPs show mean time between core failures affecting video is > 100 hours

Source: Data from industry standards, customers and assumptions

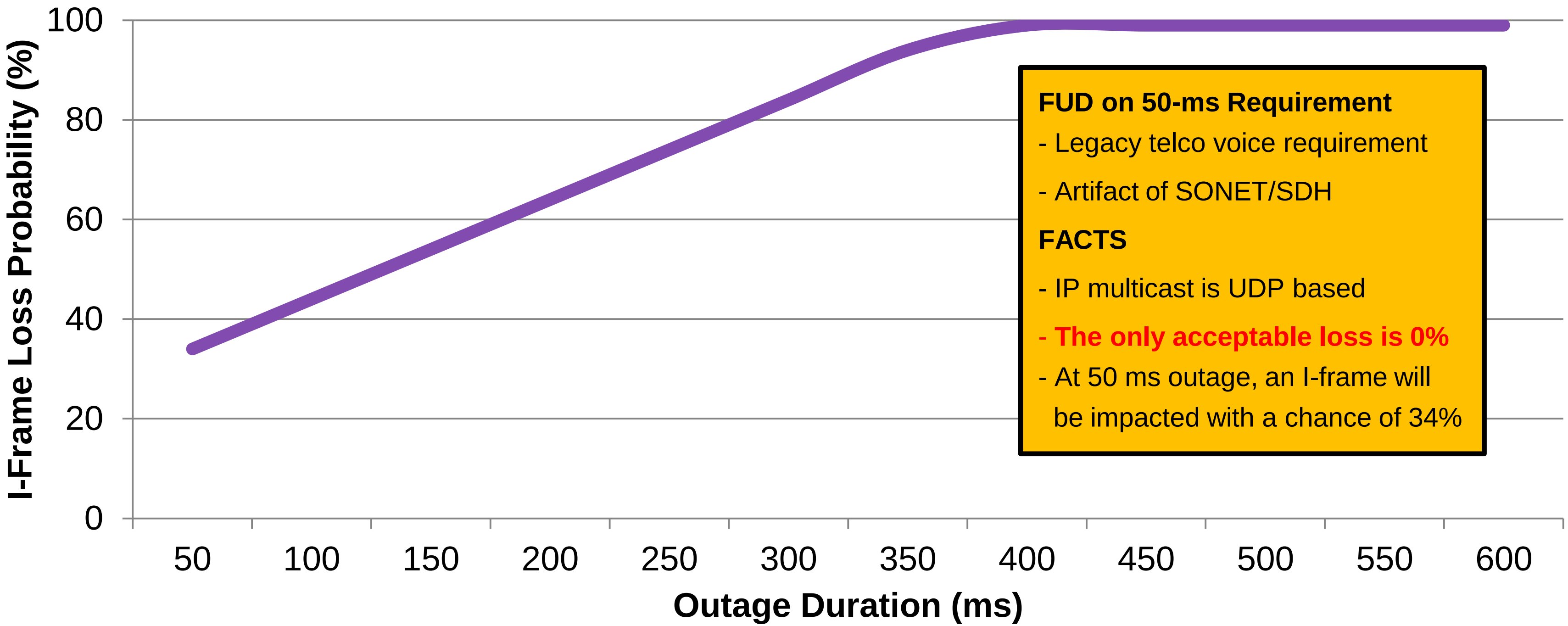
Unequal Importance of Video Packets

A Simple MPEG Video Group of Pictures (GoP)

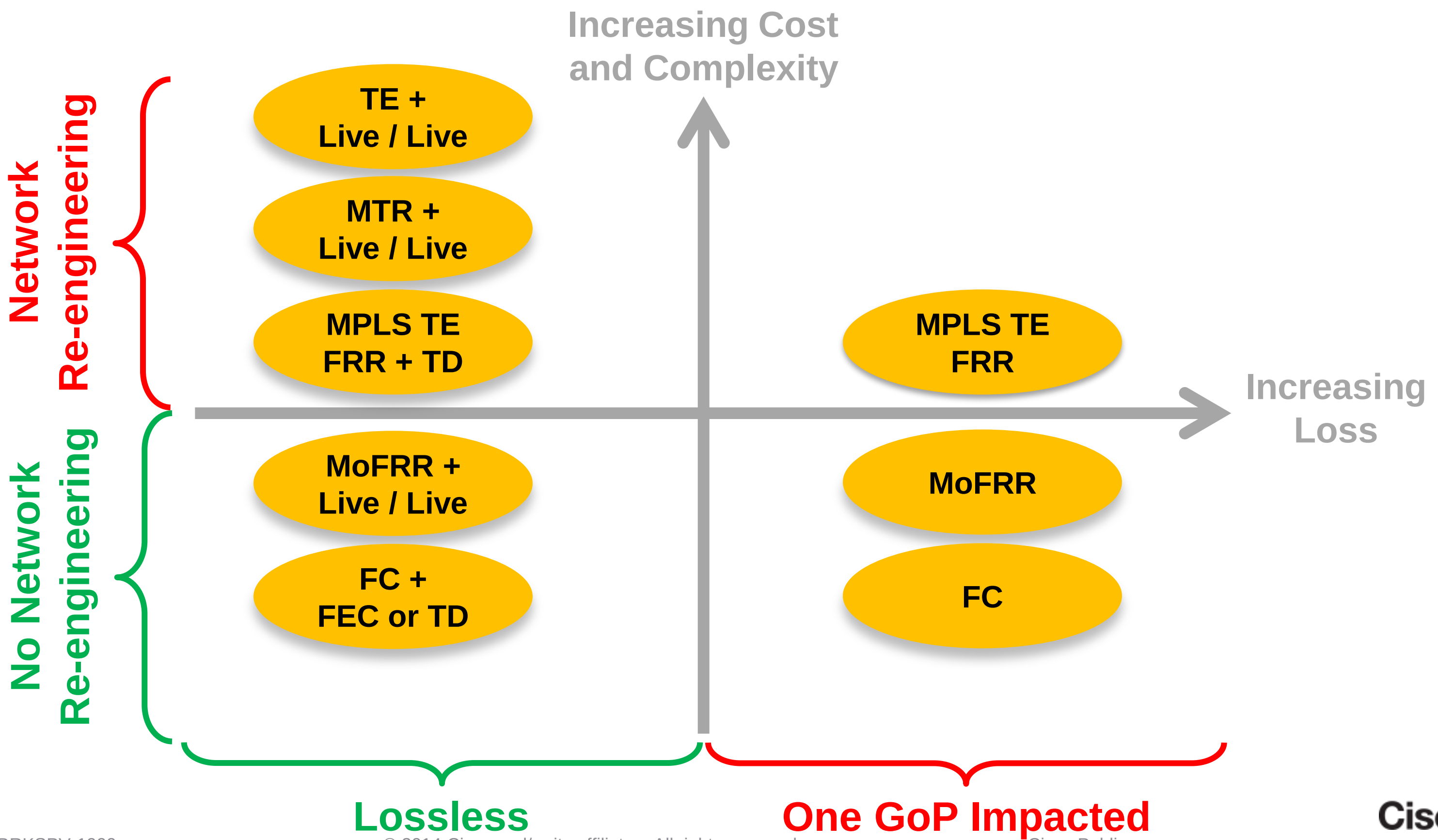


MPEG Frame Impact from Packet Loss

GoP Size: 500 ms (I:P:B = 7:3:1)



Toward Lossless IPTV Transport



Toward Lossless IPTV Transport

Reading

“Toward lossless video transport,”
IEEE Internet Computing, Nov./Dec. 2011

“Designing a reliable IPTV network,”
IEEE Internet Computing, May/June 2009



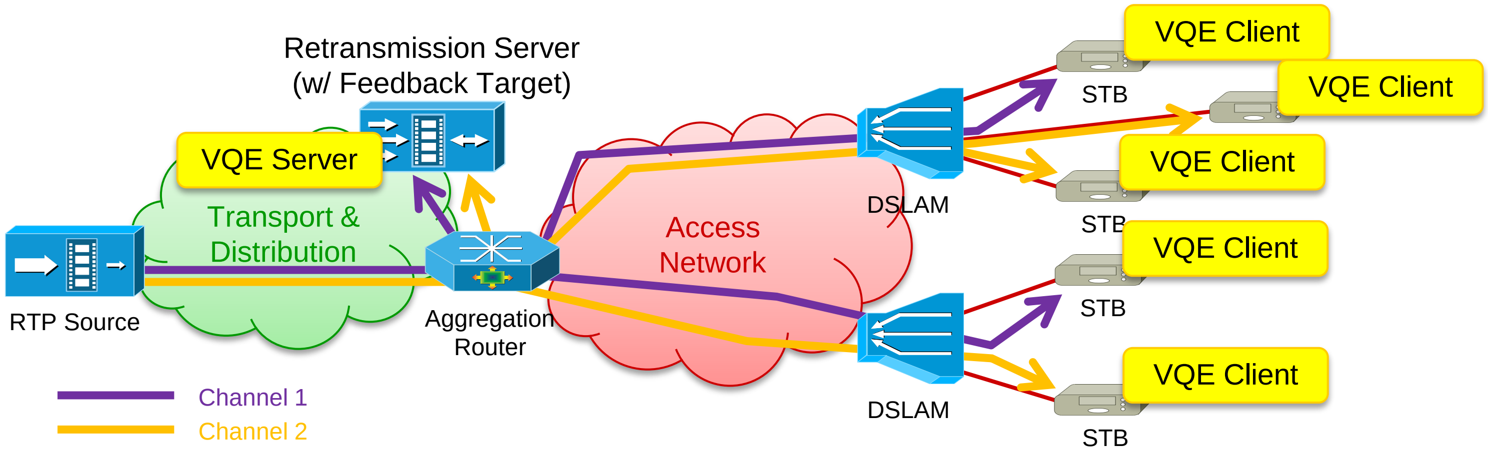

Video Distribution in the Access Networks

VQE – A Unified QoE Solution

Glitch-Free Audiovisual Quality, Short and Consistent Zapping

- **IPTV viewers have two criteria to judge their service**
  - Artefact-free audiovisual quality
    - Loss may be correlated in spatial and/or temporal domain, must be recovered quickly
    - Loss-repair methods must be multicast friendly
  - Short and consistent zapping times
    - Compression and encryption used in digital TV increase the zapping times
    - Multicasting in IPTV increases the zapping times
- **Service providers need a scalable unified solution that**
  - Is standards-based and interoperable with their infrastructure
  - Enables versatility, quick deployment and visibility into the network
  - Extends the service coverage area, and keeps CapEx and OpEx low

A Simplified Model



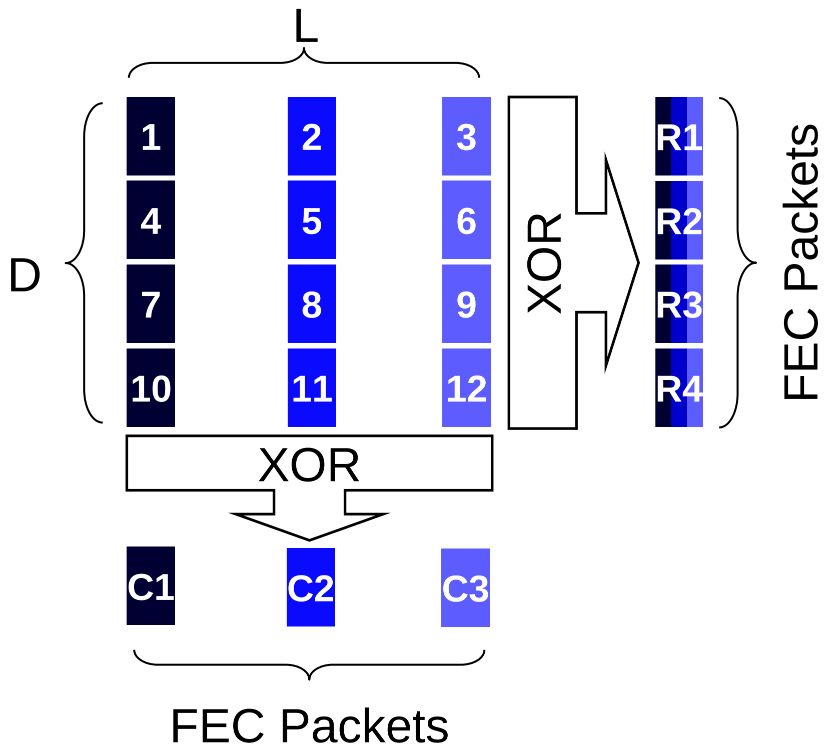
- **Each TV channel is served in a unique (SSM) multicast session**
  - IP STBs join the respective multicast session for the desired TV channel
  - Retransmission servers join all multicast sessions
- **Unicast feedback from IP STBs are collected by the feedback target**
  - NACK messages reporting missing packets, rapid channel change requests
  - RTCP receiver and extended reports reporting reception quality

Impairments in xDSL Networks

- **Twisted pair is subject to**
  - Signal attenuation: Use shorter loops
  - Cross talk: Use Trellis Coding and RS-based FEC
  - Impulse noise: Use RS-based FEC with interleaving
- **There are three types of DSL impulse noise**
  - REIN: Short burst of noises (< 1 ms)
  - PEIN: Individual impulse noise (> 1 ms, < 10 ms)
  - SHINE: Individual impulse noise (> 10 ms)
- **We observe different noise characteristics**
  - Among different SP networks
  - Among different loops in the same SP network

First-Line of Defence in Loss Repair

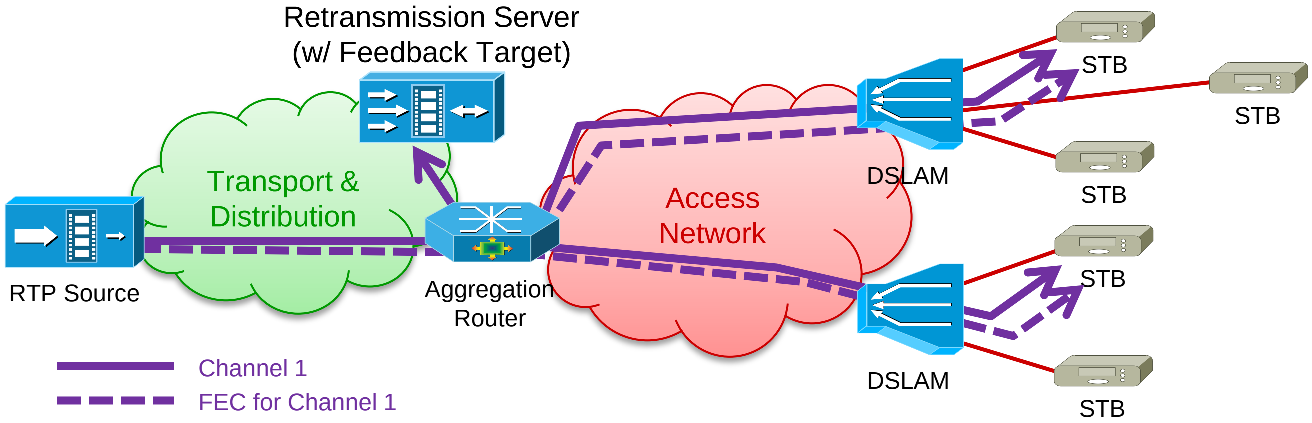
1-D/2-D Parity Forward Error Correction



- **Source Block Size: D x L**
- **1-D Column FEC (for Bursty Losses)**
  - Each column produces a single packet
  - Overhead = 1 / D
  - L-packet duration should be larger than the (target) burst duration
- **1-D Row FEC (for Random Losses)**
  - Each row produces a single packet
  - Overhead = 1 / L
- **2-D Column + Row FEC**
  - Overhead = (D+L)/(DxL)

First-Line of Defence in Loss Repair

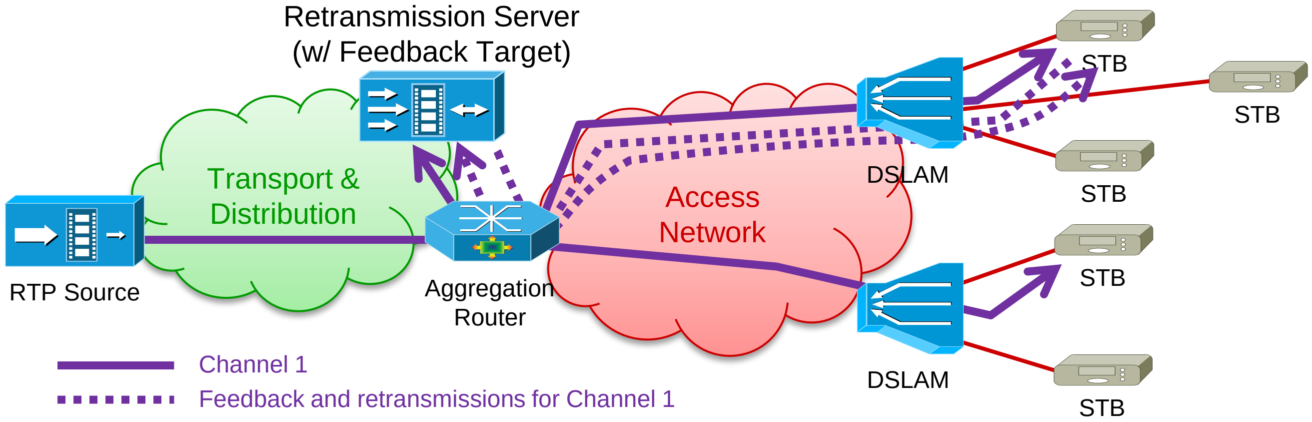
1-D/2-D Parity Forward Error Correction



- **Each TV channel may be associated with one or more FEC streams**
  - FEC streams may have different repair capabilities
  - IP STBs may join the respective multicast sessions to receive FEC stream(s)
- **General Remarks**
  - ✓ FEC scales extremely well with upfront planning, easily repairs spatially correlated losses
  - × Longer outages require larger overhead or larger block sizes (More delay)
  - × FEC requires encoding/decoding operations

Second-Line of Defence in Loss Repair

RTP Retransmissions



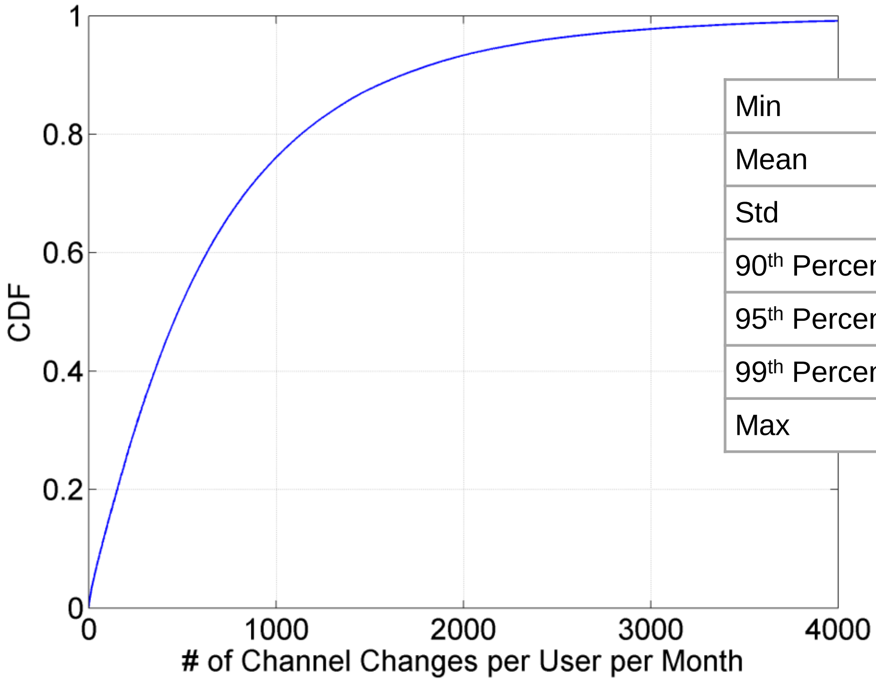
- **There is a (logical) feedback target for each TV channel on the retransmission server**
  - If optional FEC cannot repair missing packets, IP STB sends an RTCP NACK to report missing packets
  - Retransmission server pulls the requested packets out of the cache and retransmits them
- **General Remarks**
  - ✓ Retransmission recovers only the lost packets, so no bandwidth is wasted
  - × Retransmission adds a delay of destination-to-source-to-destination
- **Protocol suite comprises RFCs 3550, 4585, 4588 and 5760**




Improving Viewer Quality of Experience

TV Viewers Love Zapping

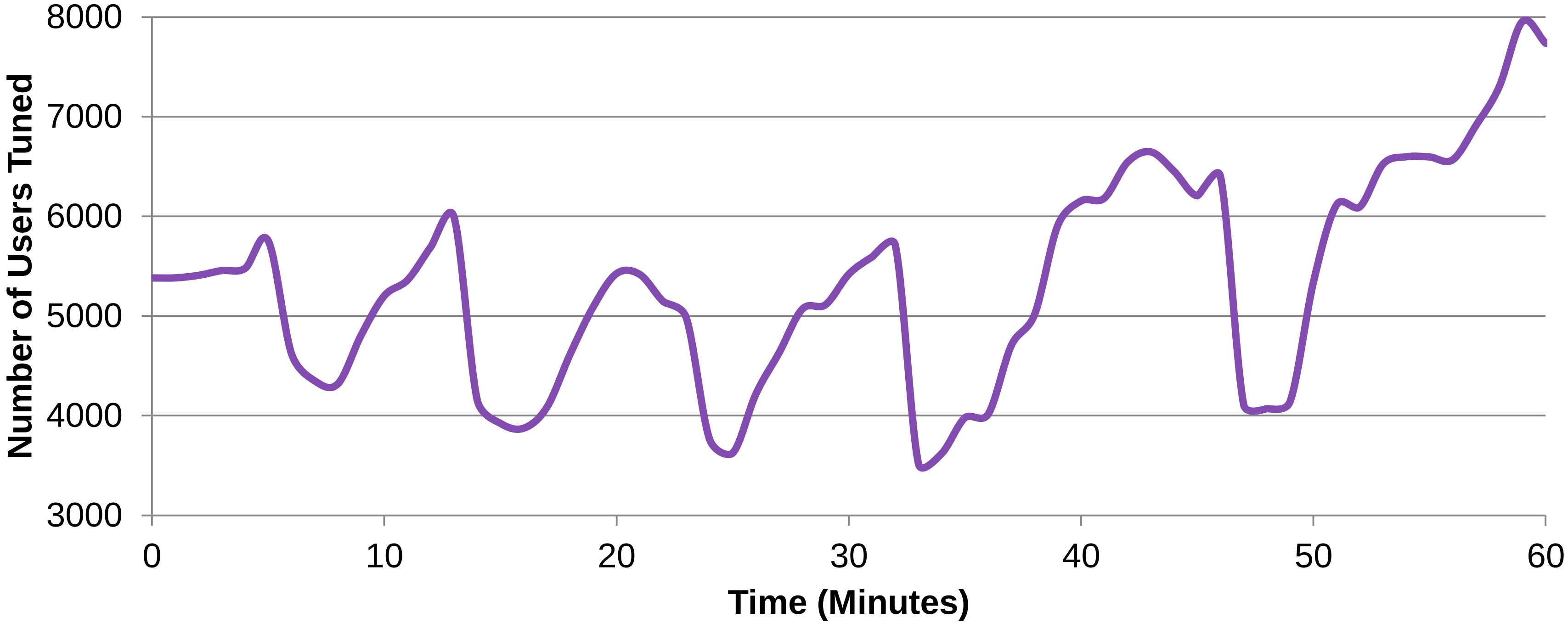
Results are Based on 227K+ Users in NA



Min	1
Mean	726
Std	814
90th Percentile	1672
95th Percentile	2250
99th Percentile	3798
Max	24186

Zappings are Correlated in Temporal Domain

On a Sunday between 8:00 – 9:00 PM



Delay Elements in Multicast MPEG2-TS Video

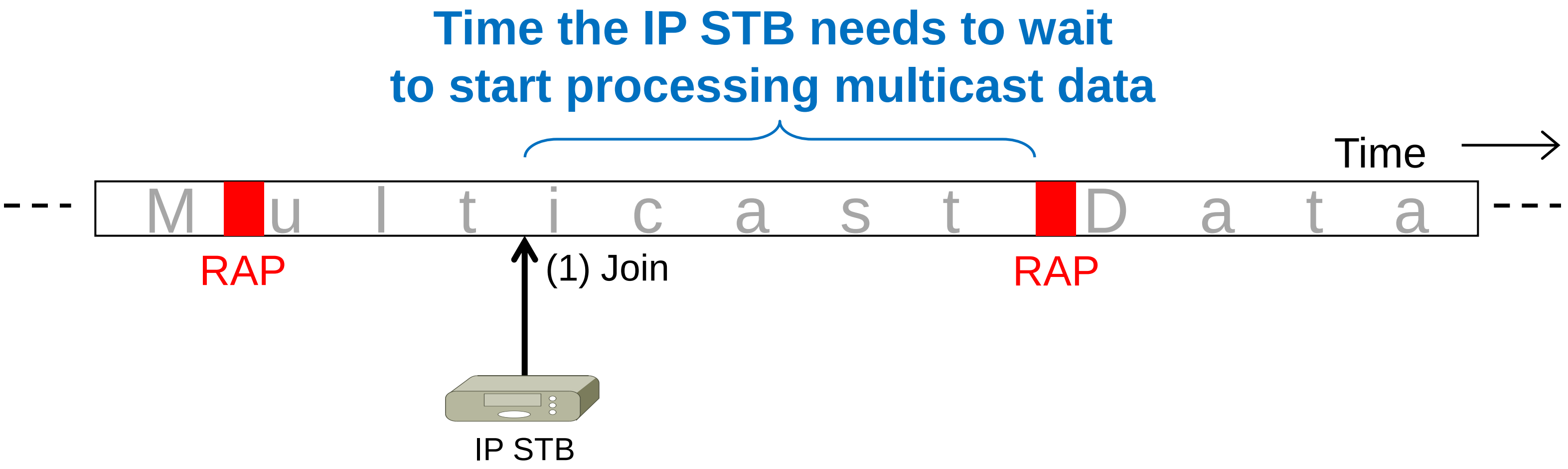
- **Multicast Switching Delay**
  - IGMP joins and leaves
  - Route establishment (Generally well-bounded)
- **Reference Information Latency**
  - PSI (PAT/CAT/PMT) acquisition delay
  - CAS (ECM) delay
  - RAP acquisition delay
- **Buffering Delays**
  - Loss-repair, de-jittering, application buffering
  - MPEG decoder buffering

Reference information latency and buffering delays are more critical in MPEG-based AV applications

Typical Zapping Times on DSL IPTV

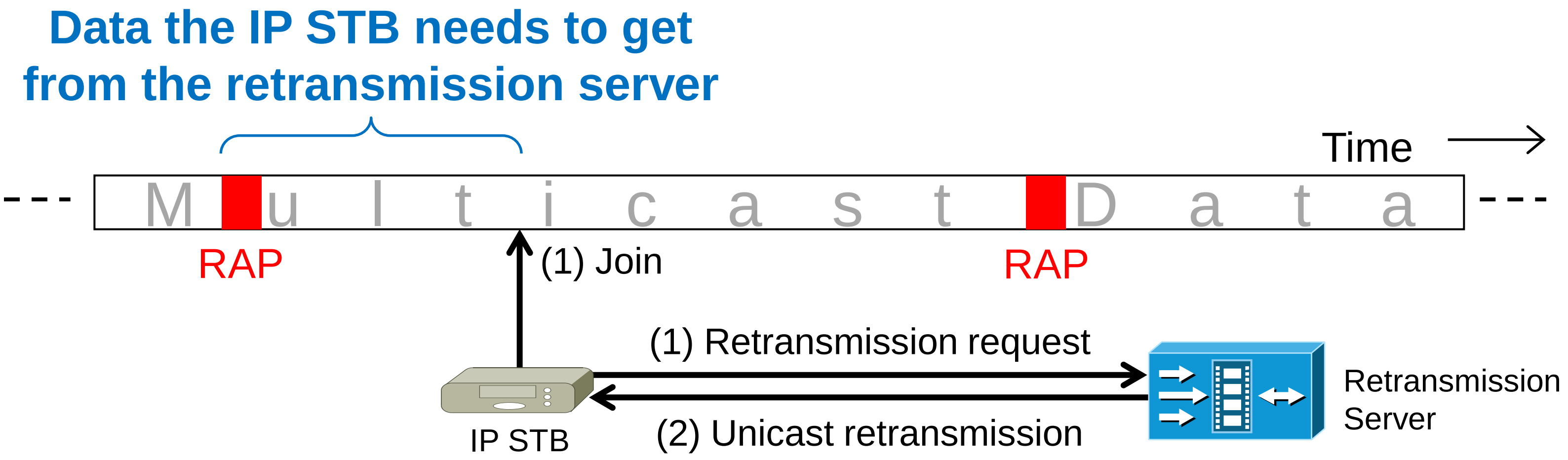
	Unit Time	Total Time
IP STB sends IGMP Leave	< 100 ms	
IP STB sends IGMP Join	< 100 ms	
DSLAM gets IGMP Leave	< 100 ms	
DSLAM gets IGMP Join	< 100 ms	~ 200 ms
DSLAM switches streams	50 ms	~ 250 ms
Latency on DSL line	~ 10 ms	~ 260 ms
IP STB receives PAT/PMT	~ 150 ms	~ 400 ms
Buffering		
De-jittering buffer	~ 150 ms	~ 550 ms
Wait for CA	< 50 ms	~ 600 ms
Wait for I-frame	0 – 3 s	0.5 – 3.5 s
MPEG decoding buffer	1 – 2 s	1.5 – 5.5 s
Decoding	**< 50 ms**	**1.5 – 5.5 s**

A Typical Multicast Join



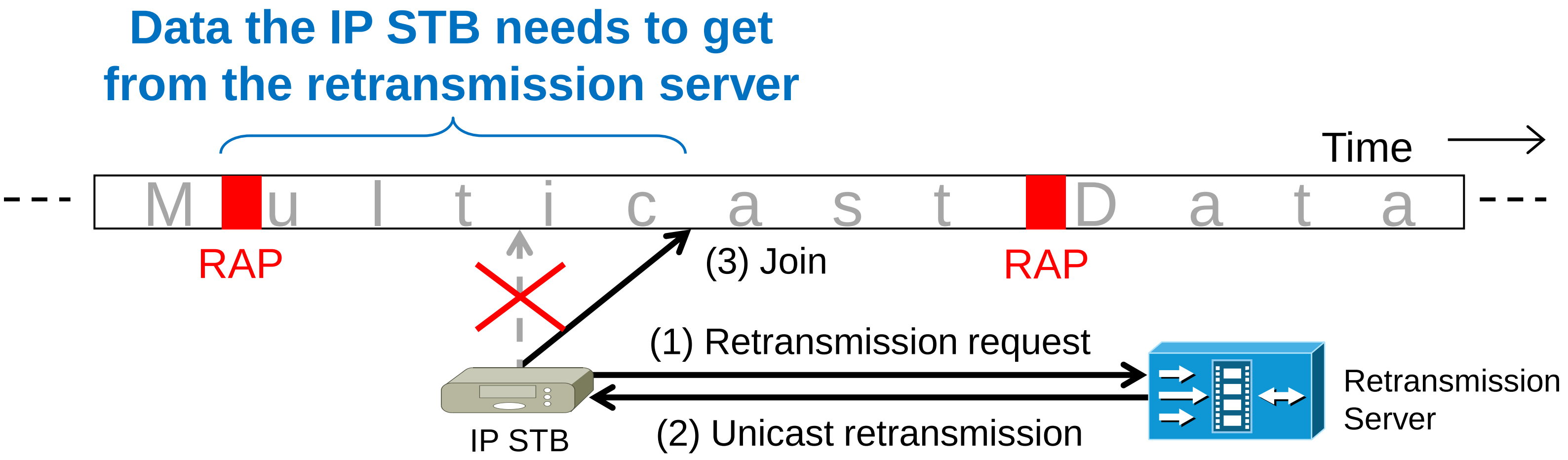
RAPs might be far away from each other
RAP data might be large in size and non-contiguous

Concurrent Multicast Join and Retransmission



If the residual bandwidth remaining from the multicast stream is small, retransmission may not be able to provide any acceleration

Retransmission Followed by Multicast Join



More data are retransmitted due to deferred multicast join
However, IP STB ultimately achieves a faster acquisition

Proposed Solution

Unicast-Based Rapid Acquisition

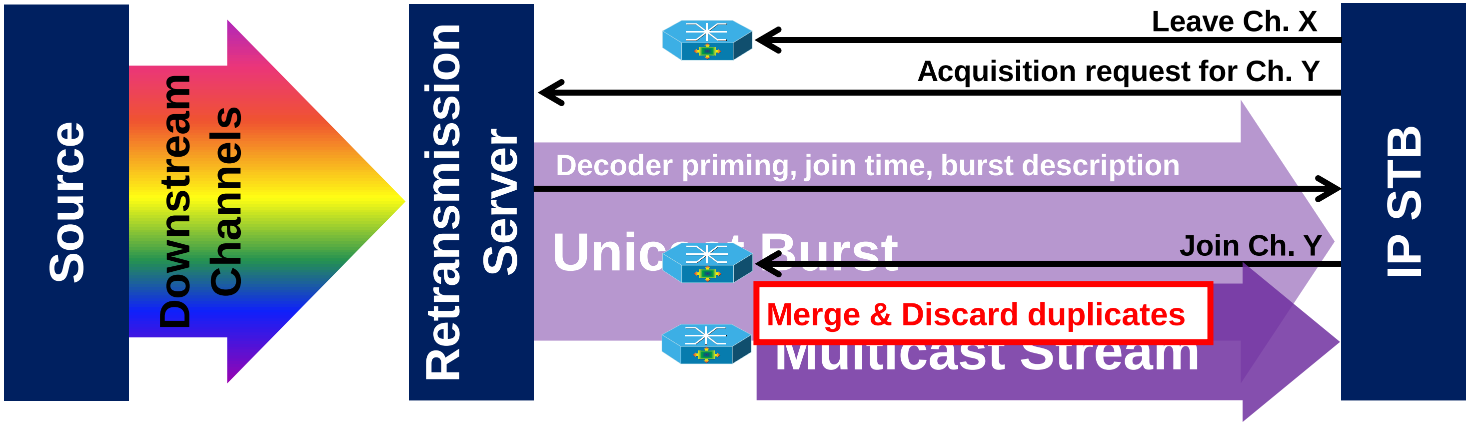
- **IP STB says to the retransmission server:**

"I have no synch with the stream. Send me a repair burst that will get me back on the track with the multicast session"

- **Retransmission server**
  - Parses data from earlier in the stream and bursts faster than real time
  - Coordinates the time for multicast join and ending the burst
- **This solution uses the existing toolkit for repairing packet losses**
  - RFC 3550 (RTP/RTCP)
  - RFC 4585 (RTP AVPF)
  - RFC 4588 (RTP Retransmissions)
  - RFC 5760 (RTCP Extensions for SSM)

Unicast-Based Rapid Acquisition (RAMS)

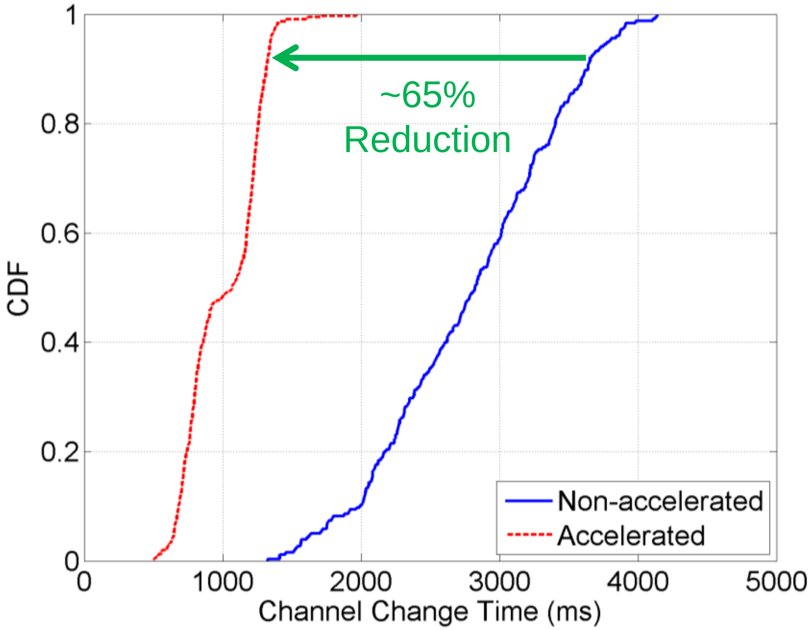
http://tools.ietf.org/html/rfc6285



Experimental Setup

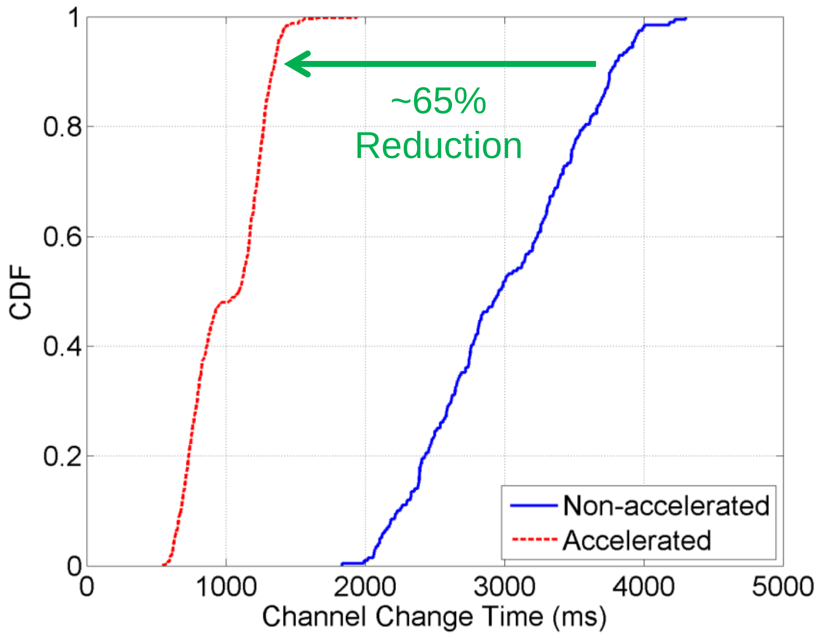
- **Comparison**
  - One IP STB with non-accelerated channel changes
  - One IP STB with accelerated channel changes
- **Video Streams**
  - Encoded with AVC at 2 Mbps and 30 fps
    - One stream with 15 frames per GoP (Short-GoP)
    - One stream with 60 frames per GoP (Long-GoP)
- **Transport**
  - 1356-byte RTP packets (7 TS packets plus RTP/UDP/IPv4 headers)
  - 20% additional bandwidth consumption for bursting
  - 500 ms loss-repair buffer in each IP STB

Short-GoP Results



	Min	Mean	Std	95th	99th	Max
Non-accelerated	1323	2785	645	3788	4101	4140
Accelerated	501	1009	260	1345	1457	1965

Long-GoP Results



	Min	Mean	Std	95th	99th	Max
Non-accelerated	1831	3005	575	3920	4201	4300
Accelerated	536	1013	265	1377	1521	1937

Unicast-Based Rapid Acquisition

Reading

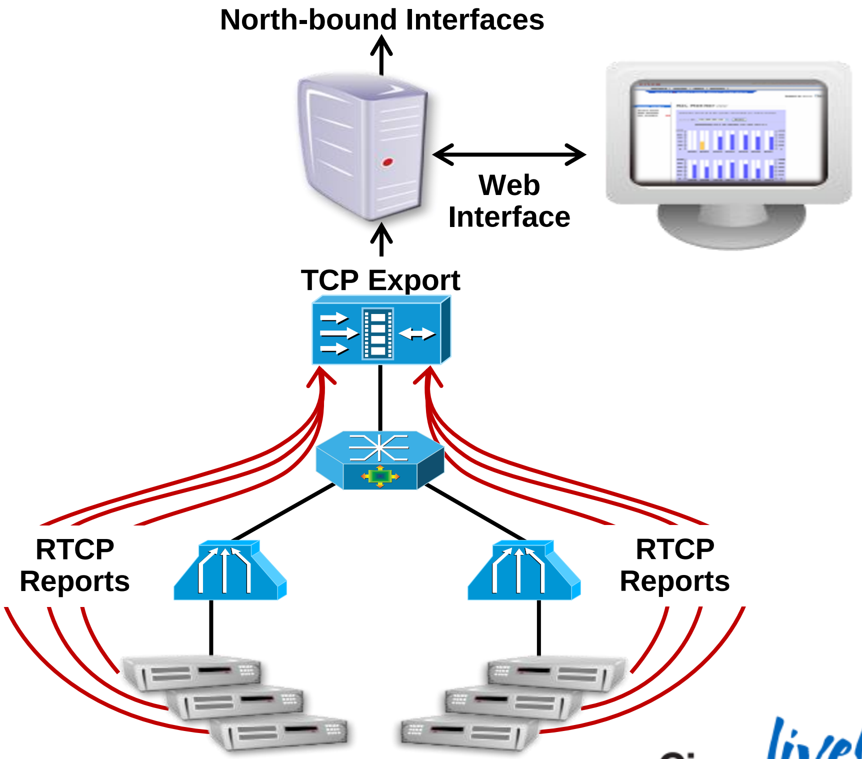
“Scaling server-based channel-change acceleration to millions of IPTV subscribers,” Packet Video Wksp. 2012

“Reducing channel-change times with the real-time transport protocol,” IEEE Internet Computing, May/June 2009

VQE QoS/QoE Monitoring

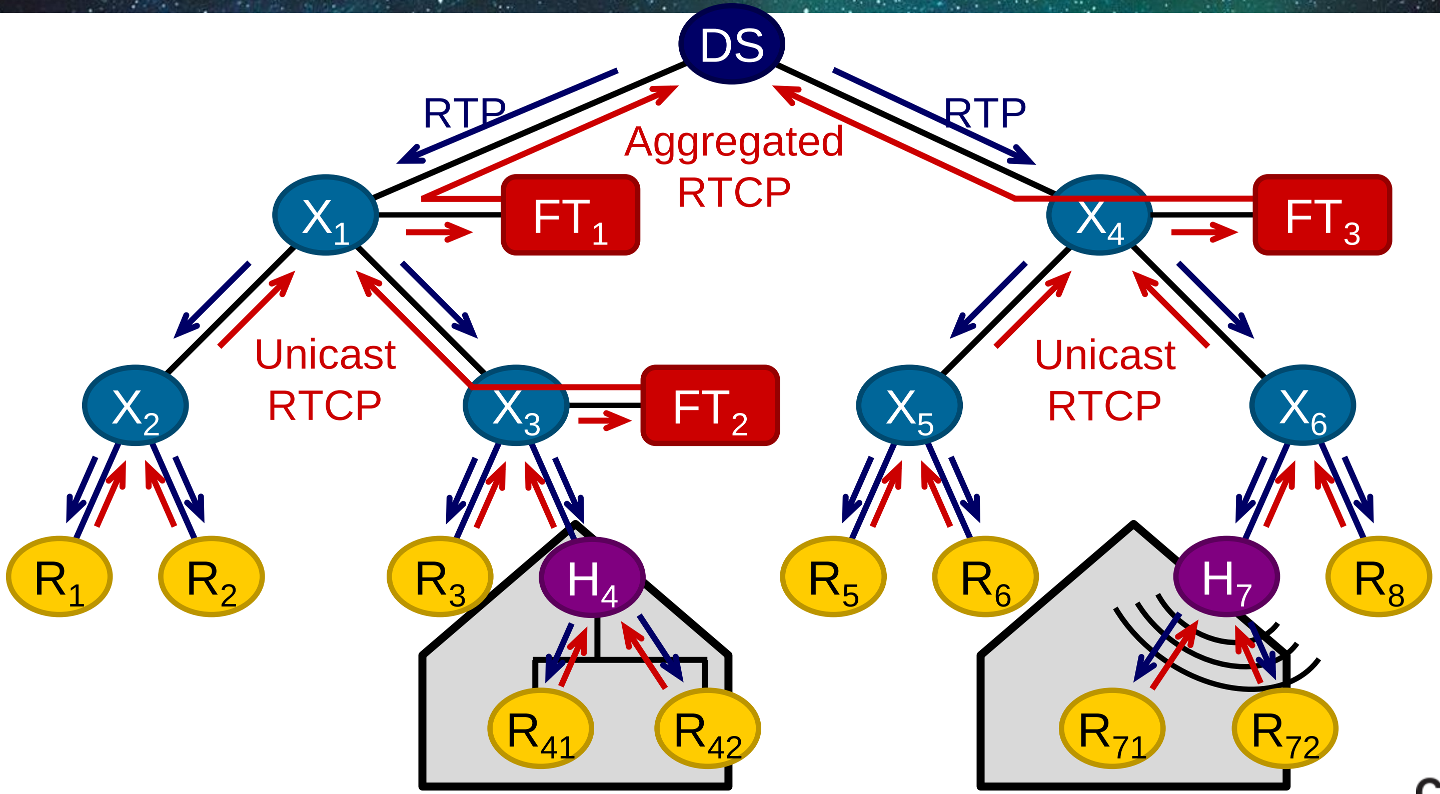
Tools to Isolate and Pinpoint the Problematic Locations

- VQE-S collects RTCP reports and outputs them to the management application
- Management application
  - Collects raw data from exporter
  - Organises database
  - Conducts data analysis, trends
  - Create alerts
- Management application supports standards-based north-bound interfaces
- Reports and analysis can be granular to
  - Regions, edge routers
  - DSLAMs, access lines
  - Home gateways
  - Set-tops
- Set-tops can support RTCP reporting and TR-069 (or TR-135) concurrently



Fault Isolation through Network Tomography

Monitoring Viewer QoE with No Human Assistance



Fault Isolation through Network Tomography

Reading

"On the scalability of RTCP-based network tomography for IPTV services," IEEE CCNC 2010

"On the use of RTP for monitoring and fault isolation in IPTV," IEEE Network, Mar./Apr. 2010




Part II: Internet Video and Adaptive Streaming

Internet Video Essentials

Reach	• Reach all connected devices
Scale	• Enable live and on-demand delivery to the mass market
Quality of Experience	• Provide TV-like consistent rich viewer experience
Business	• Enable revenue generation thru paid content, subscriptions, targeted advertising, etc.
Regulatory	• Satisfy regulations such as captioning, ratings and parental control

Creating Revenue – Attracting Eye Balls

- High-End Content
  - Hollywood movies, TV shows
  - Sports
- Excellent Quality
  - HD/3D/UHD audiovisual presentation w/o artefacts such as pixelisation and rebuffering
  - Fast startup, fast zapping and low glass-to-glass delay
- Usability
  - Navigation, content discovery, battery consumption, trick modes
- Service Flexibility
  - Linear TV
  - Time-shifted and on-demand services
- Reach
  - Any device, any time
- Auxiliary Services
  - Targeted advertising, social network integration

Internet TV vs. Traditional TV

- Areas most important to overall TV experience are:
  - Content
  - Timing control
  - Quality
  - Ease of use
- While traditional TV surpasses Internet TV **only in quality**, it delivers better "overall experience"

When comparing traditional and Internet TV, which option is better?

	Traditional	Internet
Content	7%	➢ 79%
Timing / Control	7%	➢ 83%
Quality	➢ **80%**	16%
Ease of Use	23%	➢ 52%
Control (FF, etc.)	9%	➢ 77%
Portability	4%	➢ 92%
Interactivity	31%	➢ 52%
Sharing	33%	➢ 56%
Overall Experience	➢ 53%	33%

Source: Cisco IBSG Youth Survey, Cisco IBSG Youth Focus Group Sessions, 2010




Example Over-the-Top (OTT) Services

The Lines are *Blurring* Between TV and the Web

AT&T U-verse – US

Verizon FlexView – US

ABC TV – Australia

TiViBu – Turkey

Amazon – US

Onet – Poland

Netflix

Content

Over 100K titles (DVD)

Shipped 1 billionth DVD in 02/07

Shipped 2 billionth DVD in 04/09

Today: SuperHD and 3D. Plans for UltraHD

Revenue

$1.1B in Q3 2013

$3.6B (2012), $3.2B (2011), $2.1B (2010)

Streaming Subscribers

31M in the US by Q3 2013 (9.2M 40 countries)

[7.1M DVD subscribers in the US by Oct. 2013]

Competitors

Hulu Plus, Amazon Prime, TV Everywhere

Difficulties

ISP data caps (Most notably in Canada)

ISP/CDN throughput limitations

Big Data at Netflix

Library: 3PB

Ratings: 4M/day, searches: 3M/day, plays: 30M/day

5B hours streamed in Q3 2013 (2B in Q4 2011, 3B in Q3 2012)

Plans

Unlimited streaming (only) for $7.99 (US and Canada)

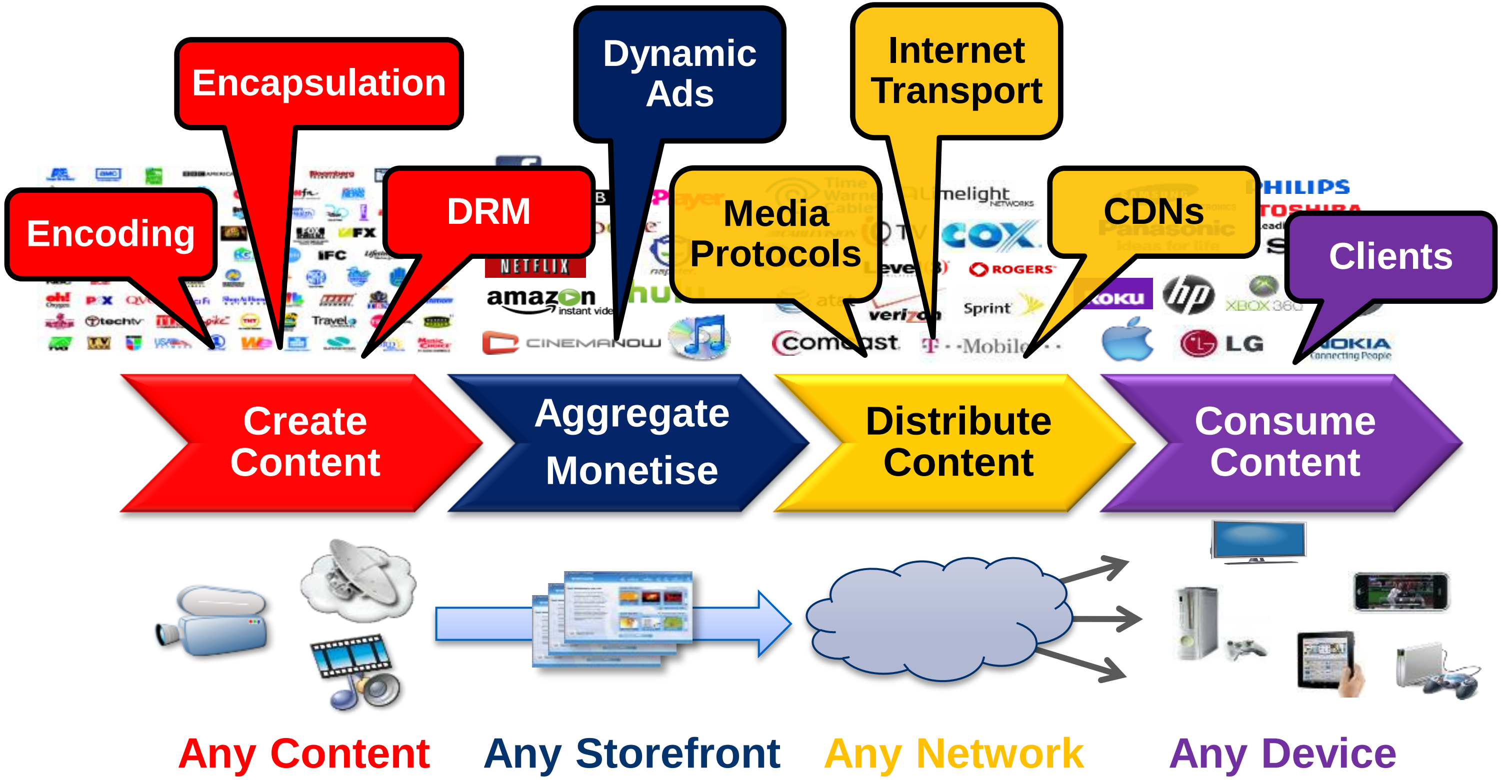
(4-stream plan at $11.99)

[Supported by over 450 devices]

1 DVD out at-a-time for $7.99 (US)

Blu-rays for an additional $2 per month (US)

Open Digital Media Value Chain






Media Delivery over the Internet

Push and Pull-Based Video Delivery

	Push-Based Delivery	Pull-Based Delivery
Source	Broadcasters/servers like Windows Media Apple QuickTime, RealNetworks Helix Cisco VDS/DCM	Web/FTP servers such as LAMP Microsoft IIS Adobe Flash RealNetworks Helix Cisco VDS
Protocols	RTSP, RTP, UDP	HTTP, RTMPx, FTP
Video Monitoring and User Tracking	RTCP for RTP transport	(Currently) Proprietary
Multicast Support	Yes	No
Caching Support	No	Yes for HTTP

Pull-Based Video Delivery over HTTP

Progressive Download vs. Pseudo and Full Streaming

Progressive Download

- Server sends a file as fast as possible
- Client starts playout after a certain initial buffering

Pseudo Streaming

- Server paces file transmission
- Client can seek
- Some metadata is required

Full Streaming

- Client requests small chunks enabling adaptation
- Live streaming and dynamic ads are supported

What is Streaming?

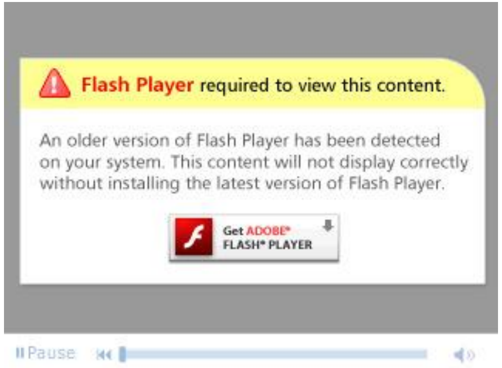
Streaming is transmission of a continuous content from a server to a client and its simultaneous consumption by the client

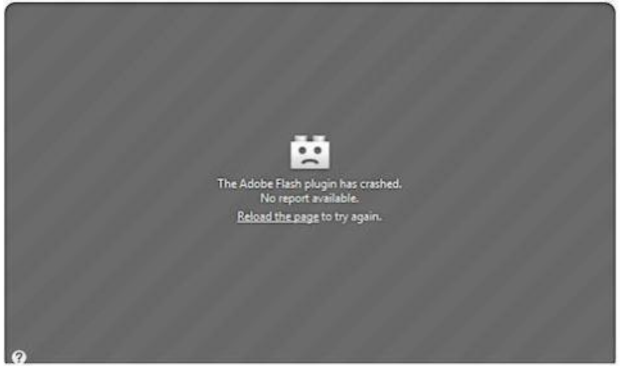
Two Main Characteristics

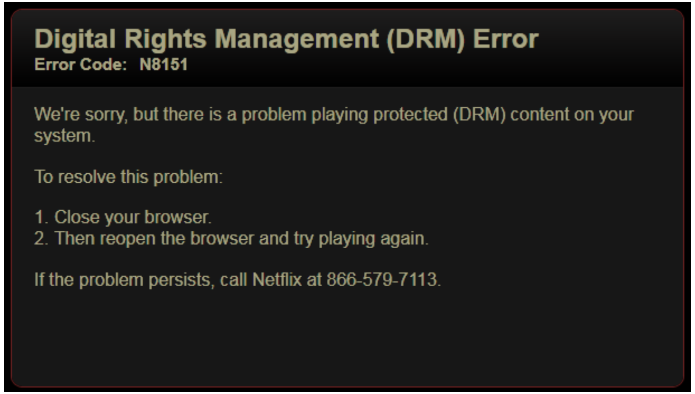
1. Client consumption rate may be limited by real-time constraints as opposed to just bandwidth availability
2. Server transmission rate (loosely or tightly) matches to client consumption rate

Common Annoyances in Streaming

Stalls, Slow Start-Up, Plug-In and DRM Issues









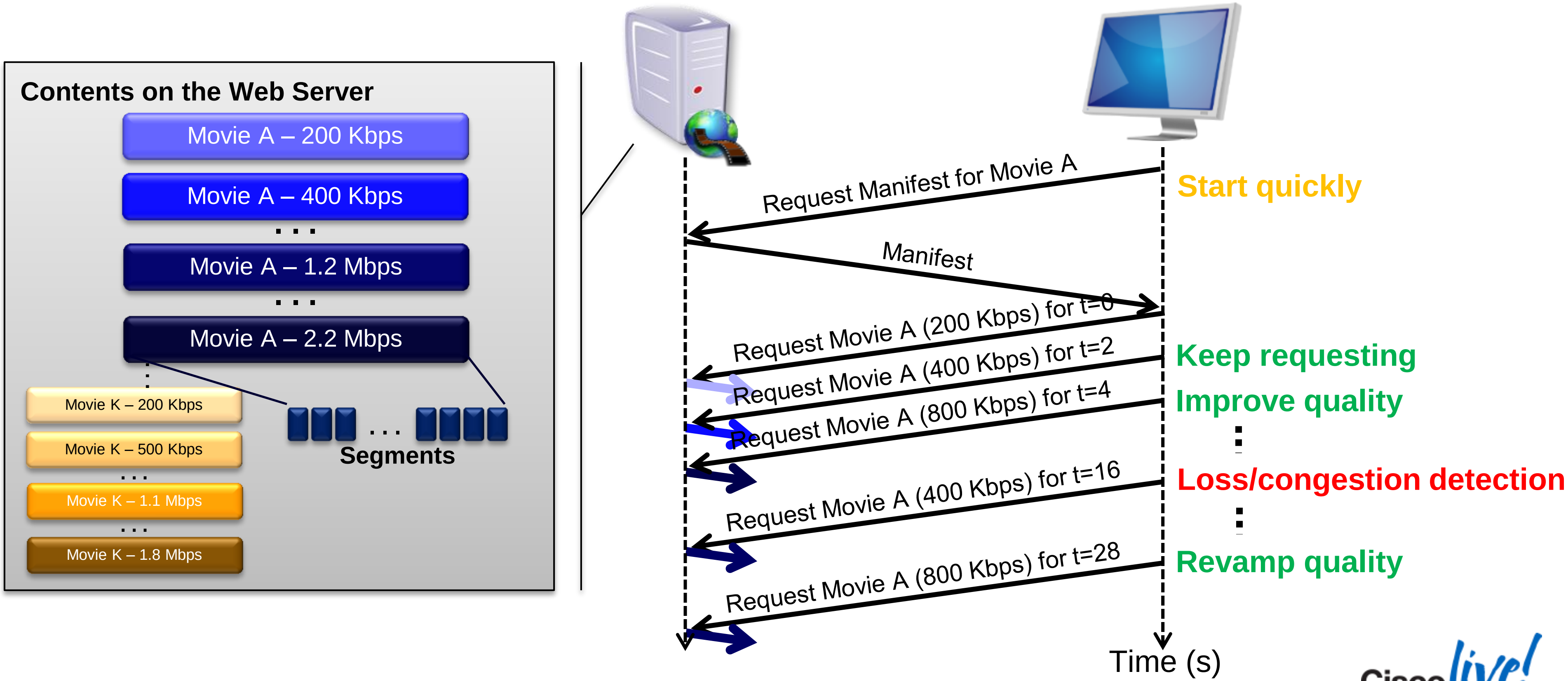

Adaptive Streaming over HTTP

Adaptive Streaming over HTTP

Adapt Video to Web Rather than Changing the Web

- **Imitation of Streaming via Short Downloads**
  - Downloads desired portion in small chunks to minimise bandwidth waste
  - Enables monitoring consumption and tracking clients
- **Adaptation to Dynamic Conditions and Device Capabilities**
  - Adapts to dynamic conditions anywhere on the path through the Internet and/or home network
  - Adapts to display resolution, CPU and memory resources of the client
  - Facilitates “any device, anywhere, anytime” paradigm
- **Improved Quality of Experience**
  - Enables faster start-up and seeking (compared to progressive download), and quicker buffer fills
  - Reduces skips, freezes and stutters
- **Use of HTTP**
  - Well-understood naming/addressing approach, and authentication/authorisation infrastructure
  - Provides easy traversal for all kinds of middleboxes (e.g., NATs, firewalls)
  - Enables cloud access, leverages existing HTTP caching infrastructure (Cheaper CDN costs)

Multi-Bitrate Encoding and Representation Shifting



Example Representations

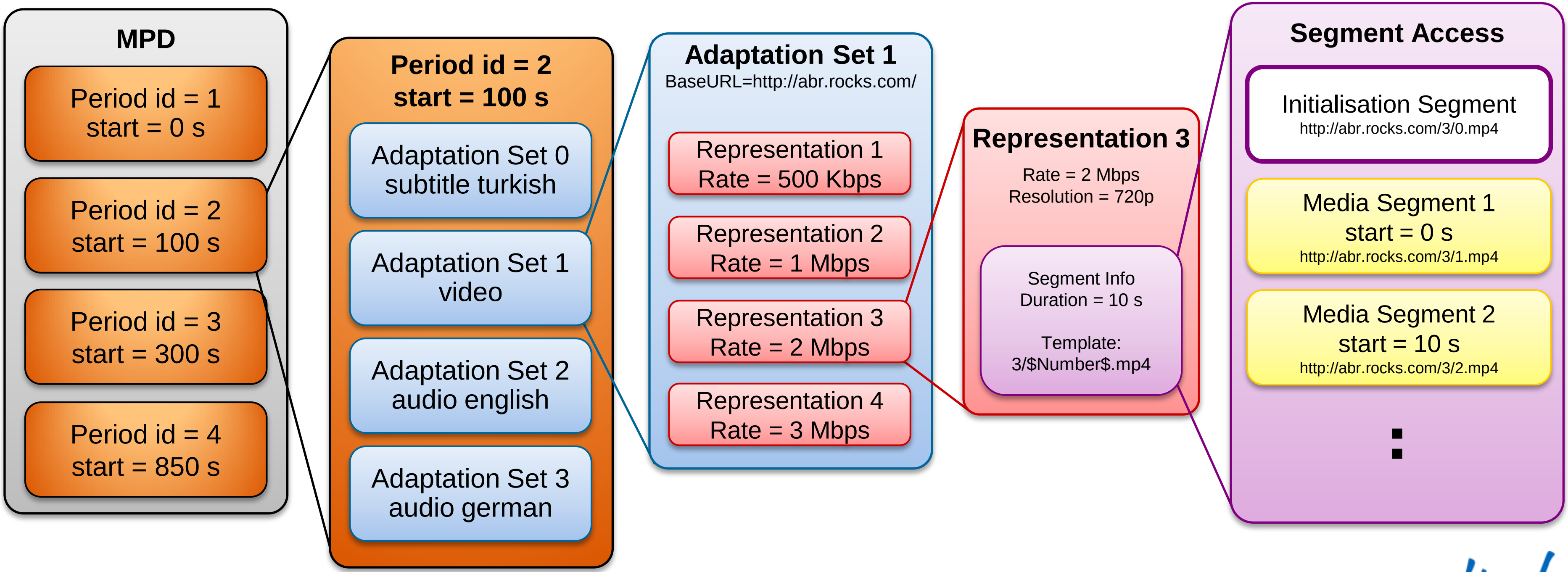
From Vancouver 2010 Winter Olympics

	Target Encoding Bitrate	Resolution	Frame Rate
Representation #1	3.45 Mbps	1280 x 720	30 fps
Representation #2	1.95 Mbps	848 x 480	30 fps
Representation #3	1.25 Mbps	640 x 360	30 fps
Representation #4	900 Kbps	512 x 288	30 fps
Representation #5	600 Kbps	400 x 224	30 fps
Representation #6	400 Kbps	312 x 176	30 fps

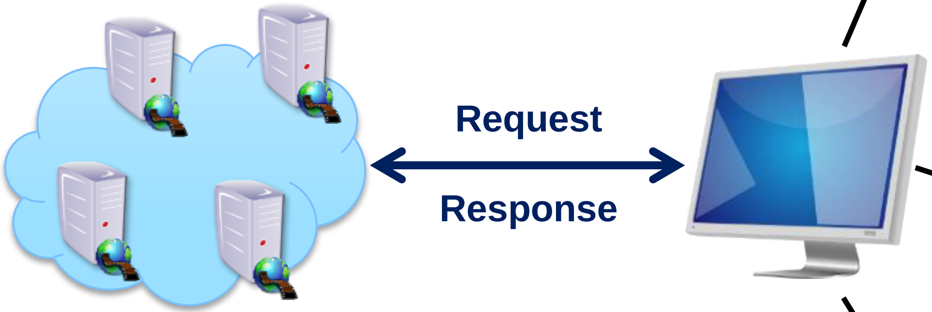
Source: Vertigo MIX10

An Example Manifest Format

List of Accessible Segments and Their Timings



Smart Clients



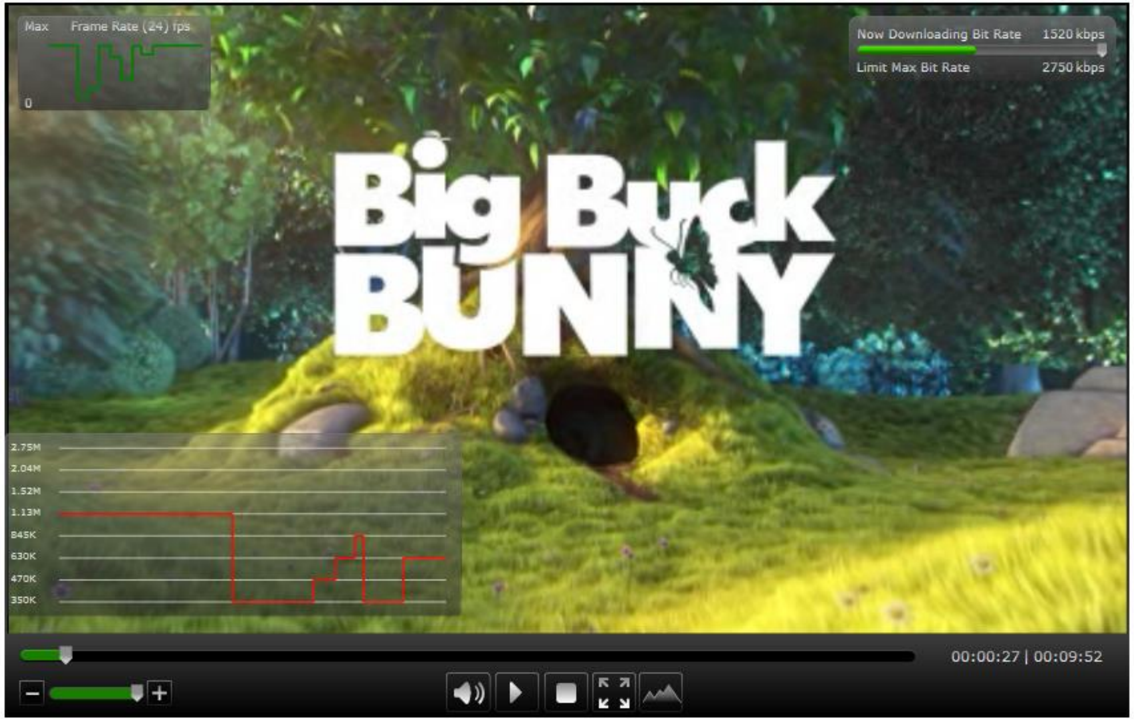
Client manages
- Manifest(s)
- HTTP transport
- TCP connection(s)

Client monitors/measures
- Playout buffer
- Download times and throughput
- Local resources (CPU, memory, screen, etc.)
- Dropped frames

Client performs adaptation

Microsoft Smooth Player Showing Adaptation

http://www.iis.net/media/experiencesmoothstreaming



Major Players in the Market

- **Microsoft Smooth Streaming**
  - http://www.iis.net/expand/SmoothStreaming
- **Apple HTTP Live Streaming**
  - http://tools.ietf.org/html/draft-pantos-http-live-streaming
  - http://developer.apple.com/library/ios/#documentation/networkinginternet/conceptual/streamingmediaguide/
- **Netflix**
  - http://www.netflix.com
- **Adobe HTTP Dynamic Streaming**
  - http://www.adobe.com/products/httpdynamicstreaming/
- **Move Adaptive Stream (Now Echostar)**
  - http://www.movenetworks.com
- **Others**
  - Widevine Adaptive Streaming (Now Google)
  - Vidiator Dynamic Bitrate Adaptation

Where does the Market Stand Today? Fragmented!

Codecs
- H.264 (Standard)
- HEVC (Coming soon)
- VC-1 (Almost Dead)
- WebM (Probably hype)

DRM
Microsoft PlayReady -
Adobe Flash Access -
Marlin -
NDS VGC -

Clients
- iOS/Android devices
- HTML5 browsers
- Connected TVs
- Game consoles

Protocols
Apple HLS -
Microsoft Smooth -
Adobe HDS -

What does This Mean?

- Fragmented architectures
  - Advertising, DRM, metadata, blackouts, etc.
- Investing in more hardware and software
  - Increased CapEx and OpEx
- Lack of consistent analytics

- Preparing and delivering each asset in several incompatible formats
  - Higher storage and transport costs
- Confusion due to the lack of skills to troubleshoot problems
- Lack of common experience across devices for the same service
  - Tricks, captions, subtitles, ads, etc.

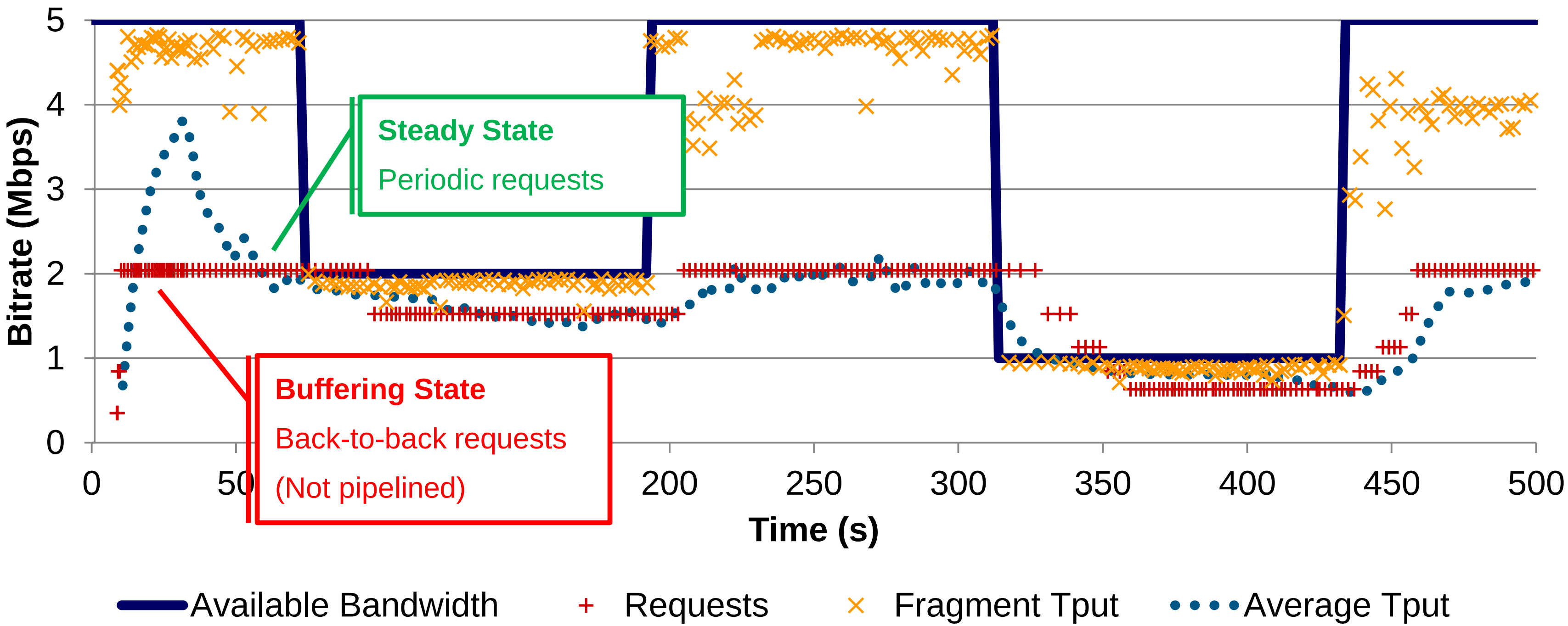
More Details Later…

DASH intends to be to the Internet world …

what MPEG2-TS has been to the broadcast world

Adaptive Streaming is not w/o Its Problems

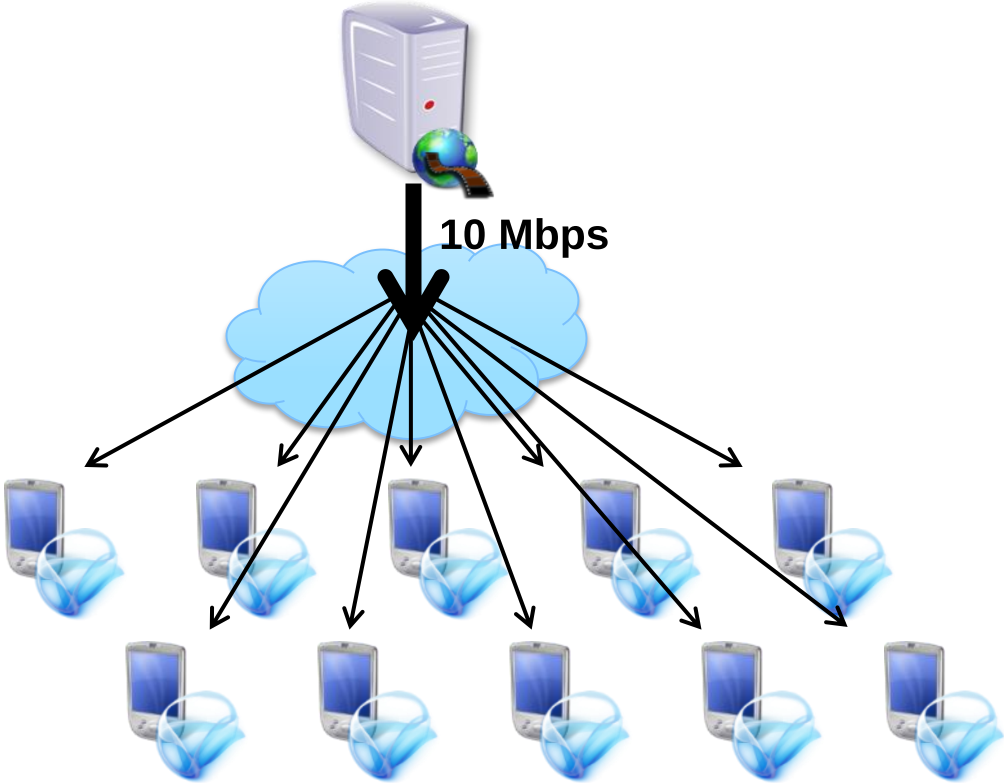
Microsoft Smooth Streaming Experiments



Reading: "An experimental evaluation of rate-adaptation algorithms in adaptive streaming over HTTP," ACM MMSys 2011

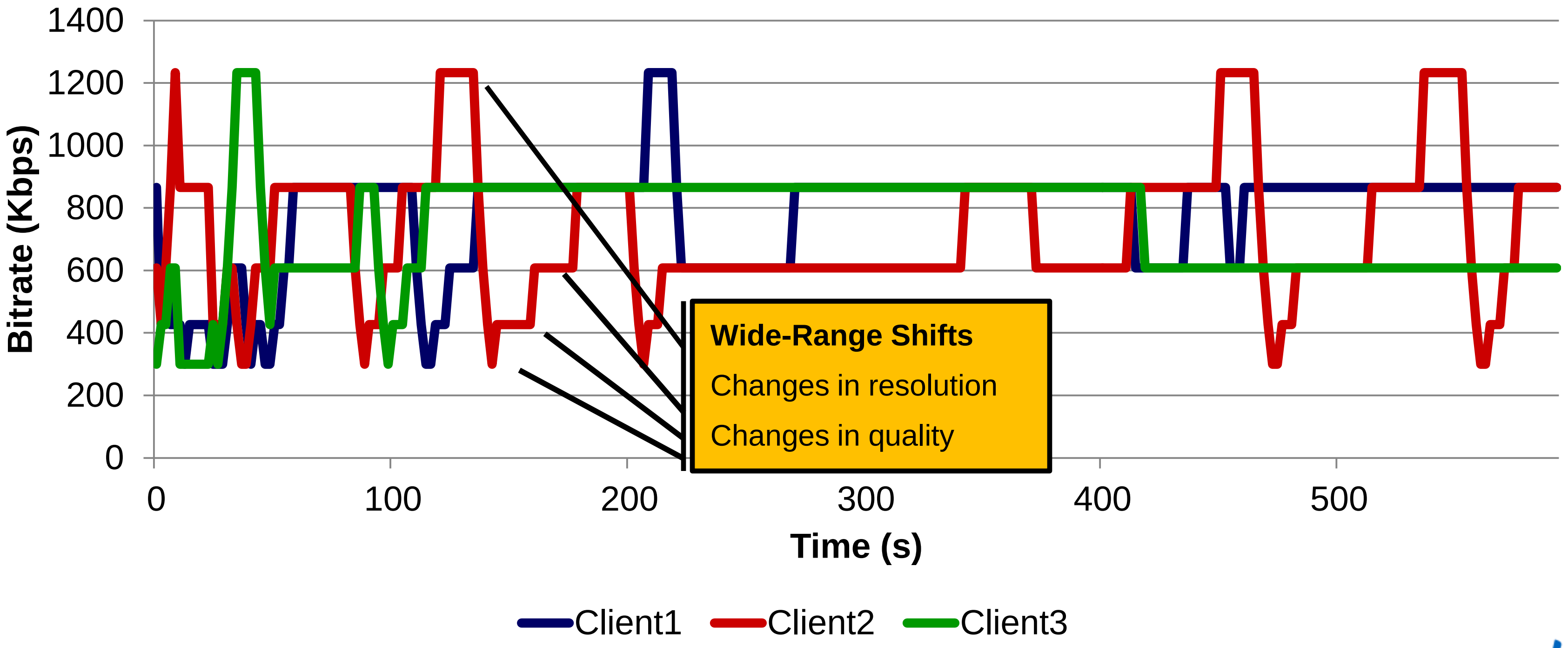
Simple Competition Experiment

10 Microsoft Smooth Clients Sharing 10 Mbps Link



10 Microsoft Smooth Clients Sharing 10 Mbps Link

Streaming "Big Buck Bunny" (Three Clients are Shown)



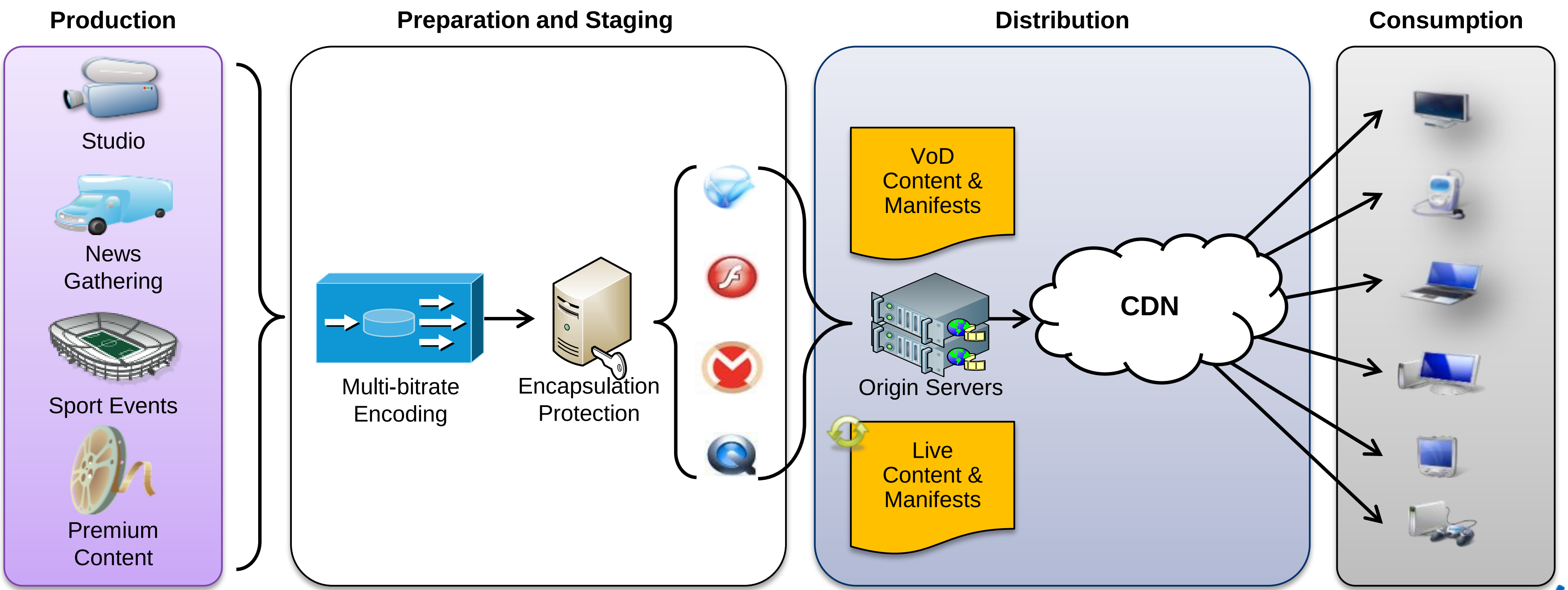
Available Representations: 300, 427, 608, 866, 1233, 1636, and 2436 Kbps

Some Interesting Stats from Conviva

Based on Analysis of 22B Streams for Netflix, ESPN, HBO, Viacom, VEVO, MLB, USA, NBC, etc.

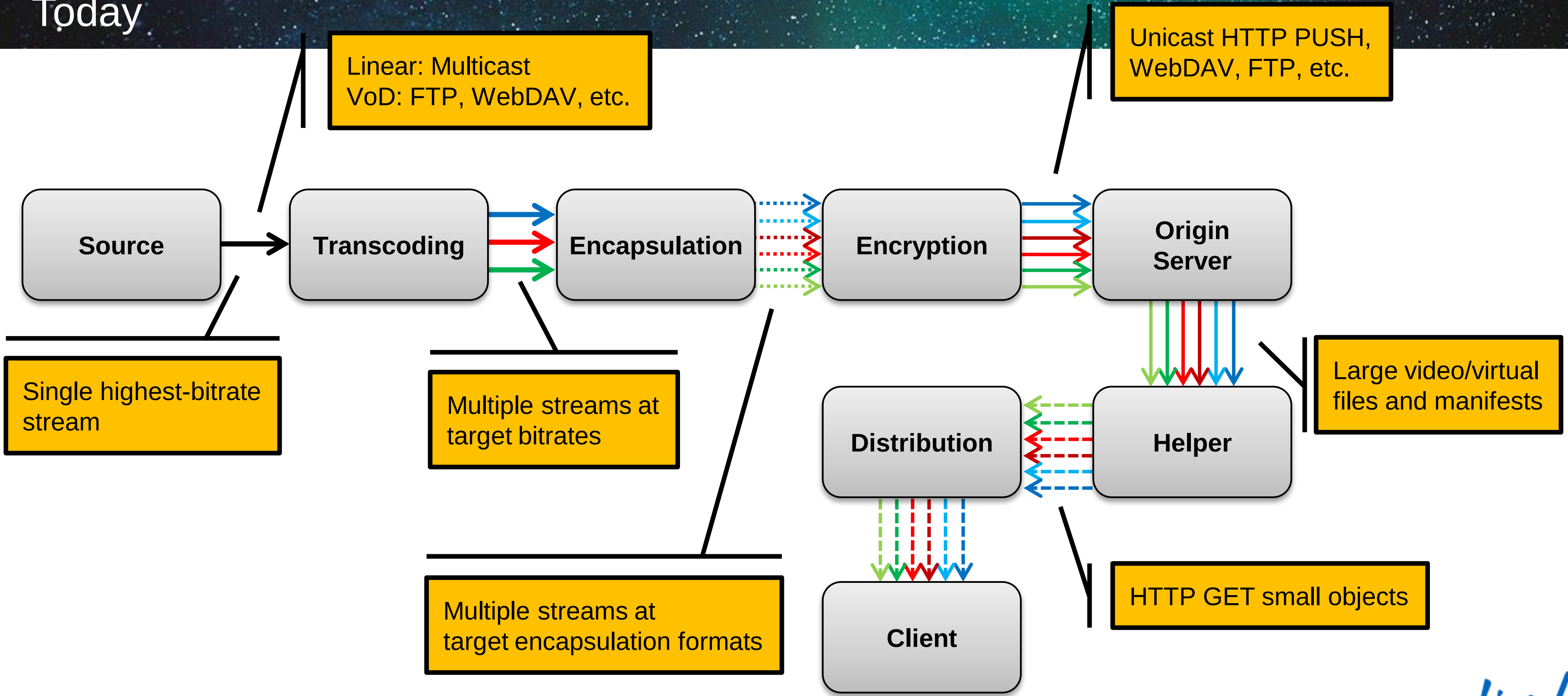
- **Poor quality is pervasive:**
  - Viewer interruption from re-buffering affected 20.6% of streams
    - For live video streams, viewers not impacted by buffering watch 10 times longer
  - 19.5% were impacted by slow video startup
  - 40% were plagued by grainy or low-resolution picture quality caused by low bitrates
- **Viewers are less tolerant:**
  - In 2011, a 1% increase in buffering resulted in 3 minutes less of VoD viewing time per view
  - In 2012, a 1% increase led to 8 minutes lost in viewing time per view for similar content
- **Startup time is critical:**
  - If startup time exceeds 2 seconds, the number of people that abandon viewing dramatically increases
- Access the full report at http://www.conviva.com/vxr/

End-to-End Over-the-Top Adaptive Streaming Delivery



Adaptive Streaming Content Workflow

Today



Source Representation

	Container	Manifest	Packaging Tools
Move	2-s chunks (.qss)	Binary (.qmx)	Proprietary
Apple HLS	Fixed-duration MPEG2-TS segments (.ts)	Text (.m3u8)	Several vendors
Adobe Zeri	Aggregated MP4 fragments (.f4f – a/v interleaved)	Client: XML + Binary (.fmf) Server: Binary (.f4x)	Adobe Packager
Microsoft Smooth	Aggregated MP4 fragments (.isma, .ismv – a/v non-interleaved)	Client: XML (.ismc) Server: SMIL (.ism)	Several vendors MS Expression
MPEG DASH	MPEG2-TS and MP4 segments	Client/Server: XML	Several vendors

- **Source containers and manifest files are output as part of the packaging process**
  - These files are staged on to origin servers
  - Some origin server implementations could have integrated packagers
- **Adobe/Microsoft allow to convert aggregated containers into individual fragments on the fly**
  - In Adobe Zeri , this function is called a Helper
  - In Microsoft Smooth, this function is tightly integrated as part of the IIS
- **Server manifest is used by Helper modules to convert the large file into individual fragments**

Staging and Distribution

	Origin Server	Packager → OS Interface	Distribution
Move	Any HTTP server	DFTP, HTTP, FTP	Plain Web caches
Apple HLS	Any HTTP server	HTTP, FTP, CIFS	Plain Web caches
Adobe Zeri	HTTP server with Helper	Integrated packager for live and JIT VoD Offline packager for VoD (HTTP, FTP, CIFS, etc.)	Plain Web caches → Helper running in OS Intelligent caches → Helper running in the delivery edge
Microsoft Smooth	IIS	WebDAV	Plain Web caches Intelligent IIS servers configured in cache mode
MPEG DASH	Any HTTP server	HTTP, FTP, CIFS	Plain Web caches

Delivery

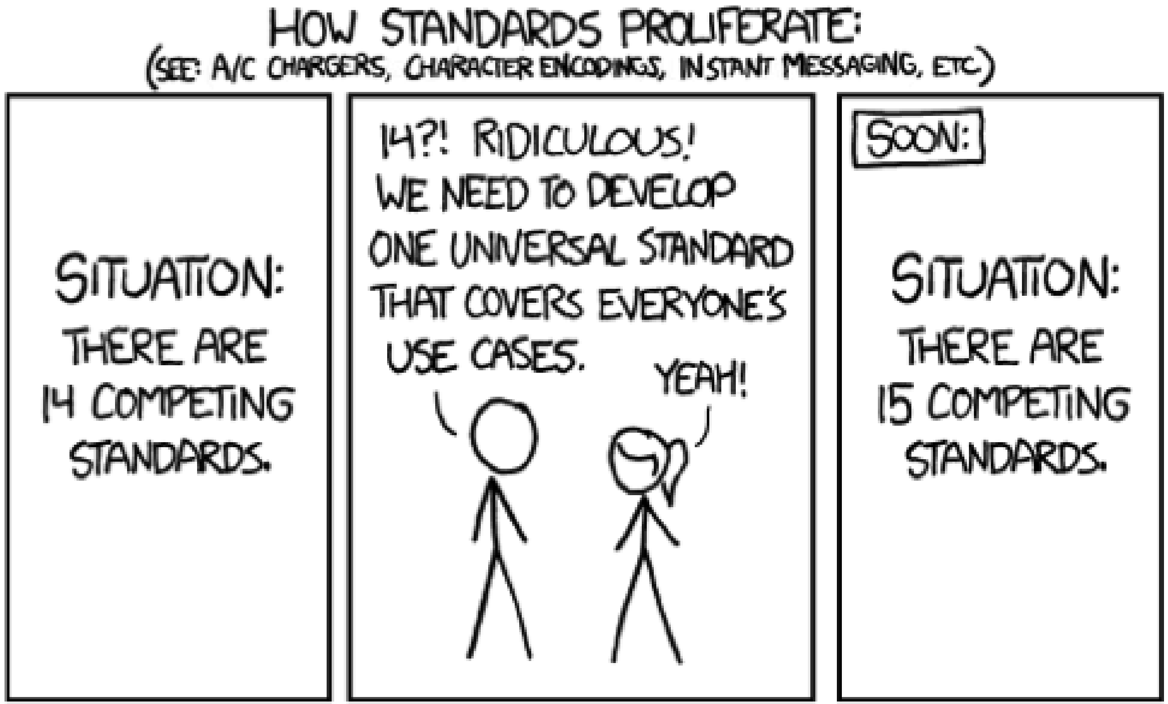
	Client	# of TCP Connections	Transaction Type
Move	Proprietary Move player	3-5	Byte-range requests
Apple HLS	QuickTime X	1 (interleaved)	Whole-segment requests Byte-range requests (iOS5)
Adobe Zeri	OSMF client on top Flash player	Implementation dependent	Whole-fragment access Byte-range access
Microsoft Smooth	Built on top of Silverlight	2 (One for audio and video)	Whole-fragment requests
MPEG DASH	DASH client	Implementation dependent	Whole-segment requests Byte-range requests

- **In Smooth, fragments are augmented to contain timestamps of future fragments in linear delivery**
  - Thus, clients fetch the manifest only once
- **In HLS, manifest is continuously updated**
  - Thus, clients constantly request the manifest




MPEG DASH Standard

Where We Were



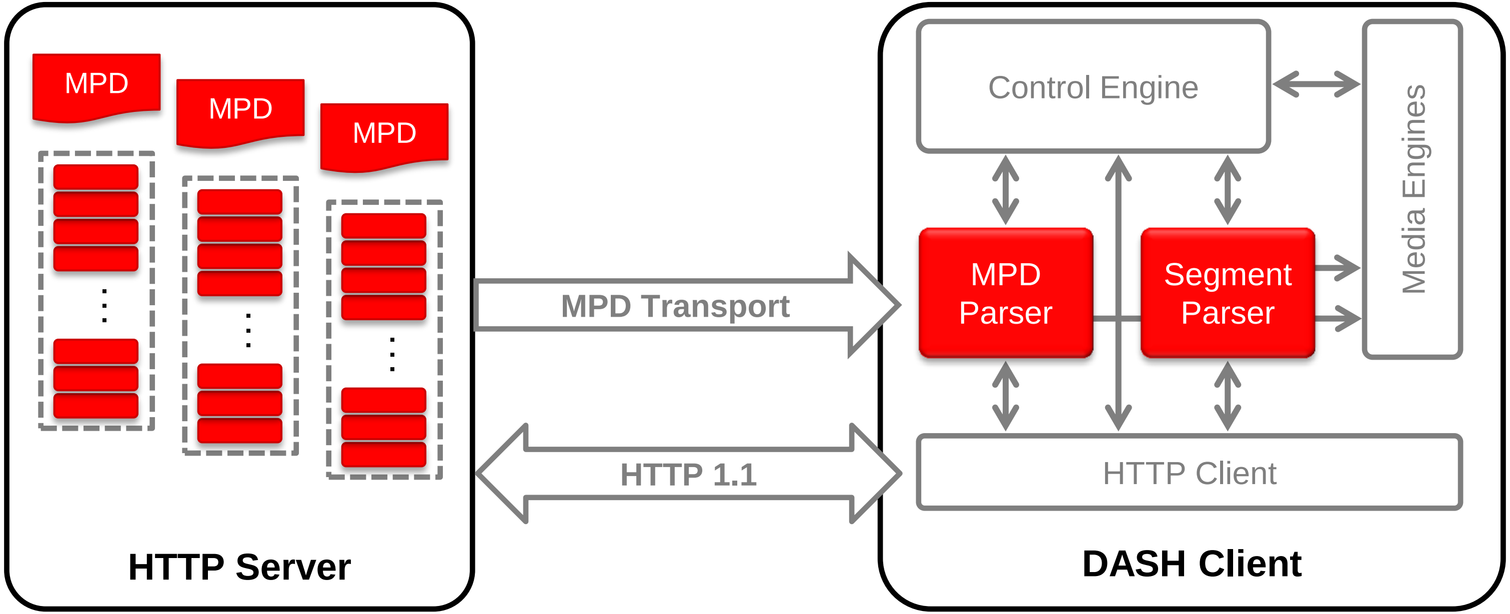
MPEG – Dynamic Adaptive Streaming over HTTP

A New Standard: ISO/IEC 23009-1

- **Goal**
  - Develop an international, standardised, efficient solution for HTTP-based streaming of MPEG media
- **Some Objectives**
  - Do the necessary, avoid the unnecessary
  - Be lazy: reuse what exists in terms of codecs, formats, content protection, protocols and signalling
  - Be backward-compatible (as much as possible) to enable deployments aligned with existing proprietary technologies
  - Be forward-looking to provide ability to include new codecs, media types, content protection, deployment models (ad insertion, trick modes, etc.) and other relevant (or essential) metadata
  - Enable efficient deployments for different use cases (live, VoD, time-shifted, etc.)
  - Focus on formats describing functional properties for adaptive streaming, not on protocols or end-to-end systems or implementations
  - Enable application standards and proprietary systems to create end-to-end systems based on DASH formats
  - Support deployments by conformance and reference software, implementation guidelines, etc.

Scope of MPEG DASH

Shown in Red



Major Functional Components – Data Model

- Provide information to a client, where and when to find the data that composes A/V → **MPD**
- Provide the ability to offer a service on the cloud and HTTP-CDNs → **HTTP-URLs and MIME Types**
- Provide service provider the ability to combine/splice content with different properties into a single media presentation → **Periods**
- Provide service provider to enable the client/user selection of media content components based on user preferences, user interaction device profiles and capabilities, using conditions or other metadata → **Adaptation Sets**
- Provide ability to provide the same content with different encodings (bitrate, resolution, codecs) → **Representations**
- Provide extensible syntax and semantics for describing representation/adaptation set properties → **Descriptors**
- Provide ability to access content in small pieces and do proper scheduling of access → **Segments and Subsegments**
- Provide ability for efficient signalling and deployment optimised addressing → **Playlist, Templates, Segment Index**
- Provide ability to enable reuse of existing encapsulation and parsing tools → **MPEG2-TS and ISO-BMFF**

Major Functional Components – Timing

- **Common Media Presentation Time**
  - Provide ability to present content from different adaptation sets synchronously
  - Provide ability to support seamless switching across different representations
- **Switching Support Features**
  - Signalling of Stream Access Points
  - Segment Alignment to avoid overlap downloading and decoding
- **Playout Times per Segment and Track Fragment Decode Times**
  - Provide ability to randomly access and seek in the content
- **Segment Availability Time**
  - Mapped to wall-clock time
  - Expresses when a segment becomes available on the server and when ceases it to be available
  - Provide ability to support live and time-shift buffer services with content generated/removed on the fly

Major Functional Components – Operations

- Provide ability for personalised access to media presentation, e.g. targeted advertisement → **MPD Assembly with xlink**
- Provide ability to provide redundant content offering → **Multiple Base URLs**
- Provide ability to announce unforeseen/unpredictable events in live services → **MPD Updates**
- Provide ability to send events associated with media times → **In-band and MPD-based Event Messages**
- Provide the ability to log and report client actions → **DASH Metrics**
- Provide ability to efficiently support trick modes → **Dedicated IDR-frame Representations and Sub-representations**
- Provide ability to signal collection of a subset/extension of tools → **Profiles and Interoperability Points**

Ongoing Work in MPEG DASH

- **ISO/IEC 23009 Parts**
  - Part 1: Media Presentation Description and Segment Formats
    - 1st edition was published in 2012, 2nd edition will be published in early 2014
  - Part 2: Conformance and Reference Software
    - 1st edition will be published in early 2014, WD for 2nd edition is in progress
  - Part 3: Implementation Guidelines
    - 1st amendment is in progress
  - Part 4: Segment Encryption and Authentication
    - 1st edition will be published in early 2014
- **Currently Running Core Experiments (as of MPEG 106)**
  - Server and Network Assisted DASH Operation
  - DASH Authentication for Content URL Validation
  - Spatial Relationship Description
  - Signalling Intended Source and Display Characteristics
  - Controlling DASH-Client Behaviour

Organisations Working on DASH, etc.

- **MPEG DASH**
  - http://standards.iso.org/ittf/PubliclyAvailableStandards/index.html
  - Mailing List: http://lists.uni-klu.ac.at/mailman/listinfo/dash
- **DASH Industry Forum**
  - http://dashif.org
- **3GPP PSS and DASH**
  - http://ftp.3gpp.org/specs/html-info/26234.htm
  - http://ftp.3gpp.org/specs/html-info/26247.htm
- **DECE – UltraViolet**
  - http://www.uvvu.com/
- **HbbTV (Hybrid Broadcast Broadband TV)**
  - http://www.hbbtv.org/pages/about_hbbtv/specification.php
- **Digital TV Group (DTG)**
  - http://www.dtg.org.uk/publications/books.html
- **Digital Video Broadcasting (DVB)**
  - http://www.dvb.org

Summary

- Part I: IPTV
  - IPTV – Architecture, Protocols and SLAs
  - Video Transport in the Core Networks
  - Video Distribution in the Access Networks
  - Improving Viewer Quality of Experience
- Part II: Internet Video and Adaptive Streaming
  - Example Over-the-Top (OTT) Services
  - Media Delivery over the Internet
  - Adaptive Streaming over HTTP
  - MPEG DASH Standard




Further Reading and References

Further Reading and References

IPTV Basics – Architecture, Protocols and SLAs

- **Articles**
  - "Not all packets are equal, part I: streaming video coding and SLA requirements," IEEE Internet Computing, Jan./Feb. 2009
  - "Not all packets are equal, part II: the impact of network packet loss on video quality," IEEE Internet Computing, Mar./Apr. 2009
  - "Deploying diffserv in backbone networks for tight SLA control," IEEE Internet Computing, Jan./Feb., 2005
- **Special Issues**
  - EURASIP Signal Processing: Image Communication (August 2011)
  - IEEE Network (March 2010)
  - IEEE Transactions on Broadcasting (June 2009)
  - IEEE Internet Computing (May/June 2009)
  - IEEE Communications Magazine (Multiple issues in 2008)

Further Reading and References

Video Transport in the Core Networks

- **Articles**
  - "Toward lossless video transport," IEEE Internet Computing, Nov./Dec. 2011
  - "Designing a reliable IPTV network," IEEE Internet Computing, May/June 2009
- **Standards**
  - http://tools.ietf.org/html/rfc2475
  - http://tools.ietf.org/html/rfc2205
  - http://tools.ietf.org/html/rfc3209
  - http://tools.ietf.org/html/rfc4090

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Video Distribution in the Access Networks

- **Articles**
  - "Error control for IPTV over xDSL networks," IEEE CCNC 2008
  - "IPTV service assurance," IEEE Communications Magazine, Sept. 2006
  - "DSL spectrum management standard," IEEE Communications Magazine, Nov. 2002
- **Standards and Specifications**
  - "Asymmetric digital subscriber line (ADSL) transceivers," ITU-T Rec. G.992.1, 1999
  - http://www.dvb.org/technology/standards/index.xml#internet
  - http://tools.ietf.org/html/rfc5760
  - http://tools.ietf.org/html/rfc5740
  - http://tools.ietf.org/html/rfc4588
  - http://tools.ietf.org/html/rfc4585
  - http://tools.ietf.org/html/rfc3550

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Improving Viewer Quality of Experience

- **Articles**
  - “Scaling server-based channel-change acceleration to millions of IPTV subscribers,” Packet Video Wksp. 2012
  - “Reducing channel-change times with the real-time transport protocol,” IEEE Internet Computing, May/June 2009
  - “On the scalability of RTCP-based network tomography for IPTV services,” IEEE CCNC 2010
  - “On the use of RTP for monitoring and fault isolation in IPTV,” IEEE Network, Mar./Apr. 2010
- **Standards and Specifications**
  - http://www.broadband-forum.org/technical/download/TR-126.pdf
  - https://www.atis.org/docstore/product.aspx?id=22659
- **Open Source Implementation for VQE Clients**
  - Documentation
    - http://www.cisco.com/en/US/docs/video/cds/cda/vqe/3_6/user_guide/VQE_3_6.html
  - FTP Access
    - ftp://ftpeng.cisco.com/ftp/vqec/

Further Reading and References

Targeted Advertising

- **SCTE Standards**
  - SCTE 30: Digital Program Insertion Splicing API
  - SCTE 35: Digital Program Insertion Cueing Message for Cable
  - SCTE 130: Digital Program Insertion – Advertising Systems Interfaces
  - URL: http://www.scte.org/standards/Standards_Available.aspx

Further Reading and References

Industry Tests

- **Light Reading: Cisco Put to the Video Test**
  - http://www.lightreading.com/document.asp?doc_id=177692&site=cdn
- **EANTC Experience Provider Mega Test**
  - http://www.cisco.com/en/US/solutions/ns341/eantc_megatest_results.html
- **IPTV & Digital Video QoE: Test & Measurement Update**
  - http://www.heavyreading.com/insider/details.asp?sku_id=2382&skuitem_itemid=1181

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- **Articles**
  - "Watching video over the Web, part 2: applications, standardisation, and open issues," IEEE Internet Computing, May/June 2011
  - "Watching video over the Web, part 1: streaming protocols," IEEE Internet Computing, Mar./Apr. 2011
- **Special Session in Packet Video Workshop 2013**
  - Technical program and slides: http://pv2013.itec.aau.at/
- **Special Sessions in ACM MMSys 2011**
  - Technical program and slides: at http://www.mmsys.org/?q=node/43
  - VoDs of the sessions are available in ACM Digital Library
    - http://tinyurl.com/mmsys11-proc (Requires ACM membership)
- **W3C Web and TV Workshops**
  - http://www.w3.org/2013/10/tv-workshop/
  - http://www.w3.org/2011/09/webtv
  - http://www.w3.org/2010/11/web-and-tv/

IEEE JSAC Special Issue – Spring 2014

on Adaptive Media Streaming

Received about 50 submissions by the deadline, review process was completed in December.

Guest Editors:

- Christian Timmerer (Alpen-Adria-Universität)
- Ali C. Begen (CISCO)
- Thomas Stockhammer (QUALCOMM)
- Carsten Griwodz (Simula Research Laboratory)
- Bernd Girod (Stanford University)

Further Reading and References

Source Code for Adaptive Streaming Implementations

- **DASH Industry Forum**
  - http://dashif.org/software/
- **Microsoft Media Platform: Player Framework**
  - http://playerframework.codeplex.com/
- **Adobe OSMF**
  - http://sourceforge.net/adobe/osmf/home/Home/
- **OVP**
  - http://openvideoplayer.sourceforge.net
- **LongTail Video JW Player**
  - http://www.longtailvideo.com/jw-player/about/

Further Reading and References

Adaptive Streaming Demos

- **DASH**
  - http://dash-mse-test.appspot.com/dash-player.html
  - http://dashif.org/reference/players/javascript/index.html
- **Akamai HD Network**
  - http://wwwns.akamai.com/hdnetwork/demo/flash/default.html
  - http://wwwns.akamai.com/hdnetwork/demo/flash/hds/index.html
  - http://wwwns.akamai.com/hdnetwork/demo/flash/hdclient/index.html
  - http://bit.ly/testzeri
- **Microsoft Smooth Streaming**
  - http://www.iis.net/media/experiencesmoothstreaming
  - http://www.smoothhd.com/
- **Adobe OSMF**
  - http://www.osmf.org/configurator/fmp/
  - http://osmf.org/dev/2.0gm/debug.html
- **Apple HTTP Live Streaming (Requires QuickTime X or iOS)**
  - http://devimages.apple.com/iphone/samples/bipbopall.html
- **OVP**
  - http://openvideoplayer.sourceforge.net/samples




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