Monitoring Video Services in Service Provider Networks

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Presenters Today – Ali C. Begen and Aamer Akhter

- With Cisco since 2007
  - Video and Content Platforms
  - Research & Advanced Development Group
- 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

- With Cisco since 1998
  - NSSTG Medianet Infrastructure Group
  - CCIE # 4543 (R&S and C&S)
- Works in the area of
  - Enterprise medianet systems
  - Lead architect for medianet video monitoring
- Interested in
  - Routing protocols, NBAR, NetFLow
  - Performance routing, WAN optimization
  - Layer-2 MPLS/VPN networks

In This Tutorial

- **We will study**
  - Statistics on video traffic in IP networks
  - Different types of video travelling over service provider networks
  - Requirements video services demand from the network and providers
  - Identification and monitoring techniques
- **We will also touch on several concepts such as**
  - Fault isolation in real time
  - Measuring and assuring QoE in IPTV networks

Slides will be shortly posted at http://ali.begen.net after the tutorial

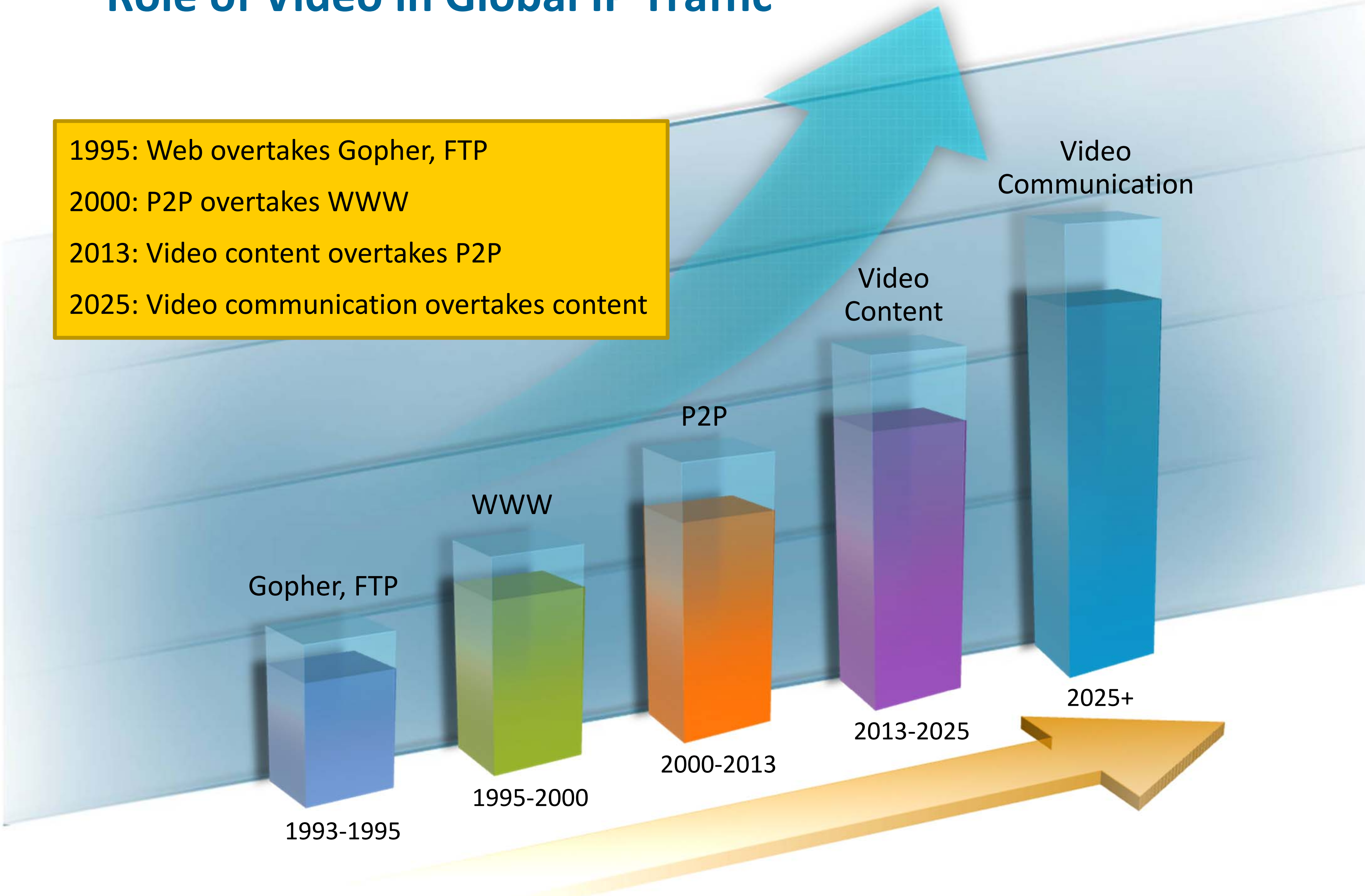
Role of Video in Global IP Traffic

1995: Web overtakes Gopher, FTP

2000: P2P overtakes WWW

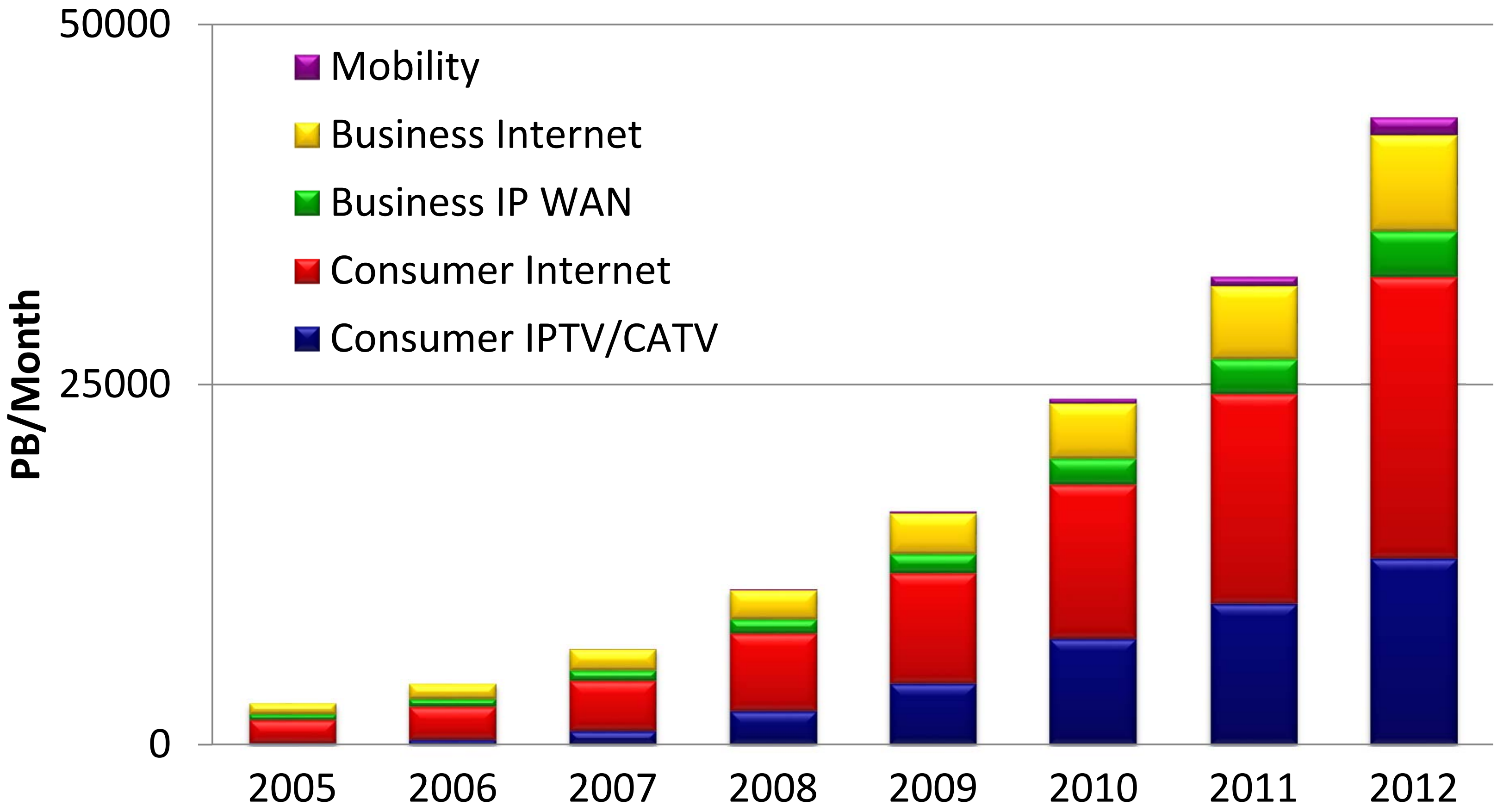
2013: Video content overtakes P2P

2025: Video communication overtakes content



Global IP Traffic Growth

IP Traffic will Increase 6x from 2007 to 2012



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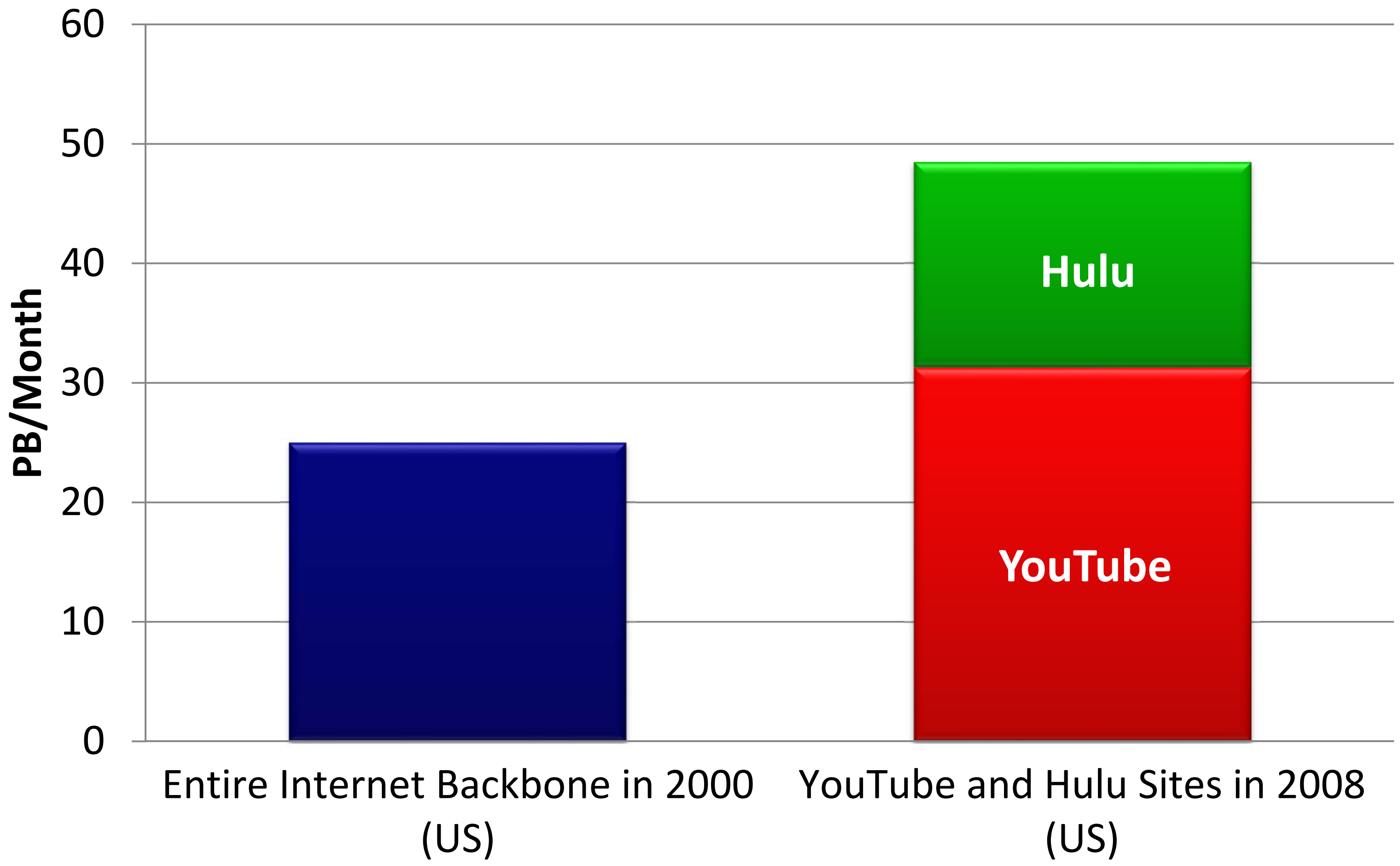
YouTube and Hulu Traffic



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New Non-Traditional Competitors Appearing

Offering Over-the-Top Consumer Video Services

Wireless Video is Emerging

Video Capable Phones to be 397 Million Worldwide by 2013

Consumer Video

Interactivity, Choice and Mobility

Consumer

Service Provider Video

SPs Transforming to Experience Providers

Business Video

Enabling Process Transformation

Collaboration

Accelerated Decision Making

Safety and Security

Protecting People and Assets

Customer Intimacy

New Revenue Streams

Operational Excellence

Manage Complexity and Scale

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Types of Video in Service Provider Networks

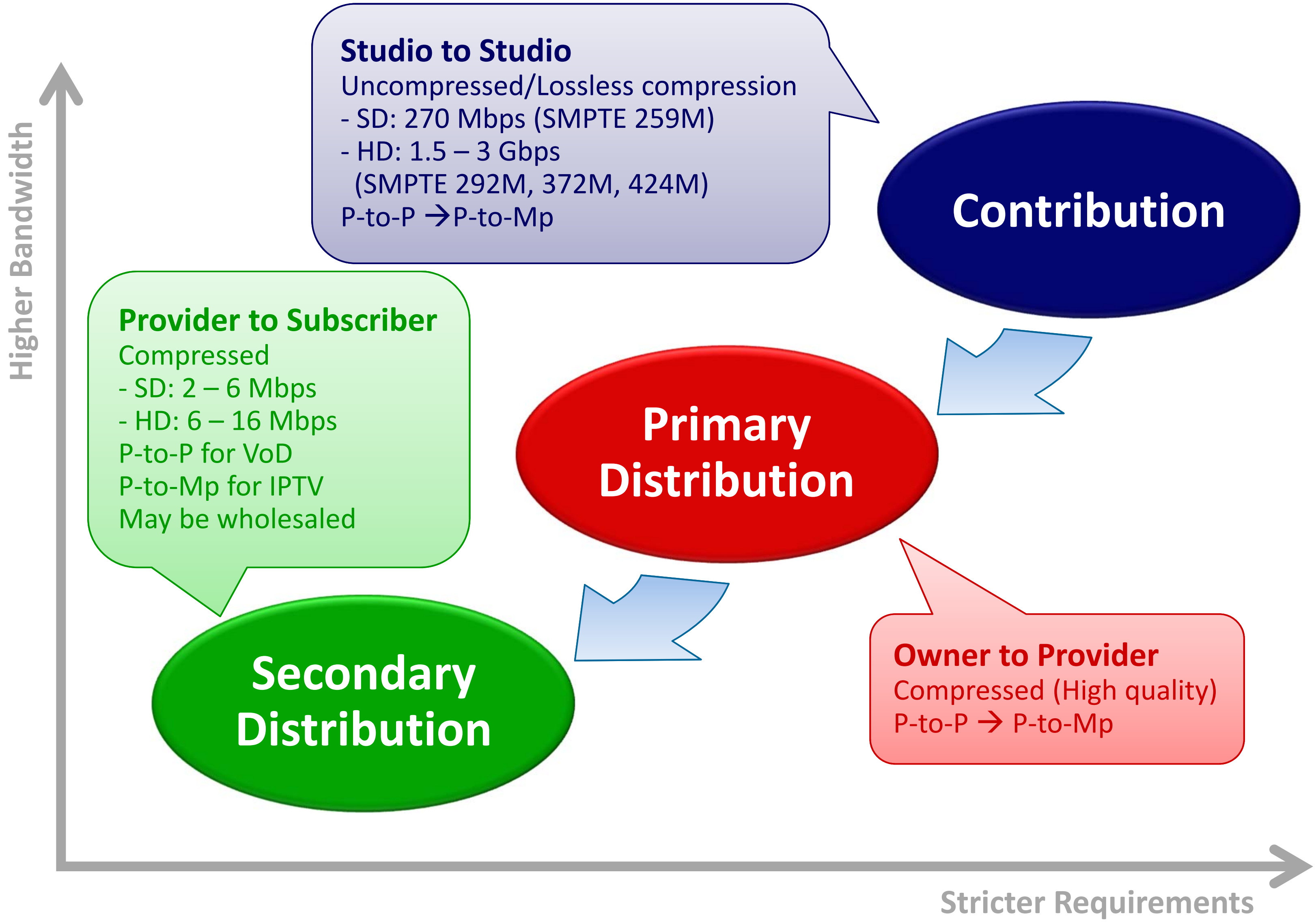
Video Contexts for Service Providers

Context	Examples	Video as Direct Revenue	SLAs
Video Provider	- Time Warner Cable Service - Verizon FIOS	Y	Y (Internally)
Internet Provider	- AT&T DSL Internet Service	N	N
SIP Trunk Provider	- Verizon - Telstra	Y	Y
Enterprise VPN Provider	- AT&T AVPN/EVPN Service Transit for video conferencing, enterprise TV, enterprise VoD Transit for Internet-based video	N	Y
Hosted Enterprise VPN Provider	- AT&T Global Business Solutions Hosted video conferencing Hosted CDN	Y	Y

Types of Video Services

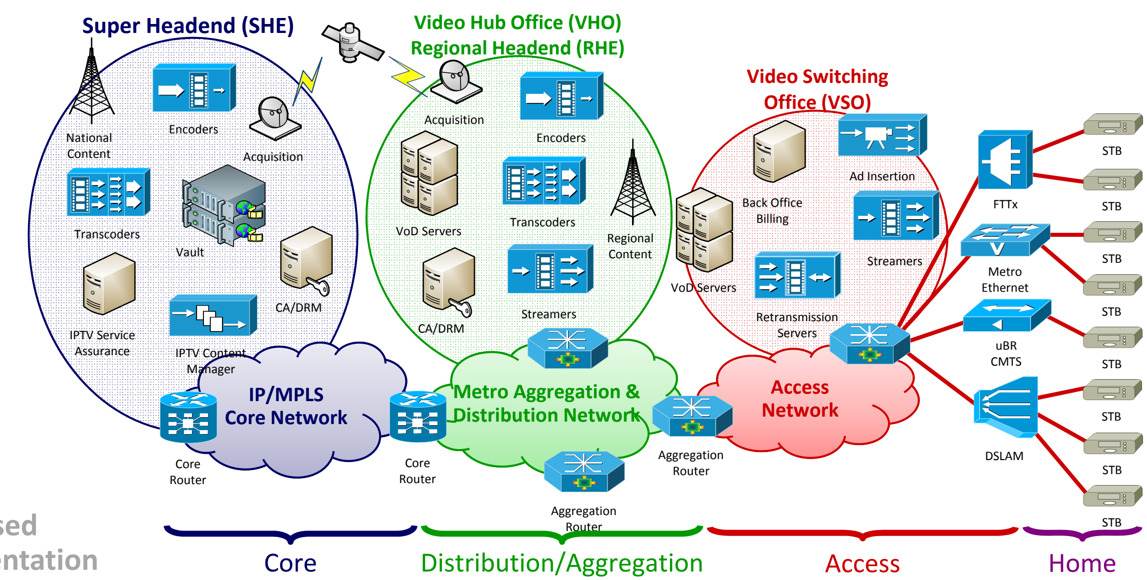
- **Transport (Contribution and Primary Distribution)**
- **IPTV (Secondary Distribution) / CATV**
  - IP multicast distribution from centralized super headends
  - Driving enhanced multicast features and functions
- **VoD (Secondary Distribution)**
  - Distributed architecture for better scalability
  - Non-real-time content distribution to caches
  - More impact on metro and access networks, less impact on the core
- **Enterprise**
  - Video conferencing systems
  - Enterprise TV/VoD (IPTV)
  - Surveillance
- **Over-the-Top (e.g., Hulu, iTV, Google TV, Netflix, TiViBu)**
  - Adaptive streaming methods are quickly becoming ubiquitous

Taxonomy of IPTV Service Providers



Type of Video: IPTV*

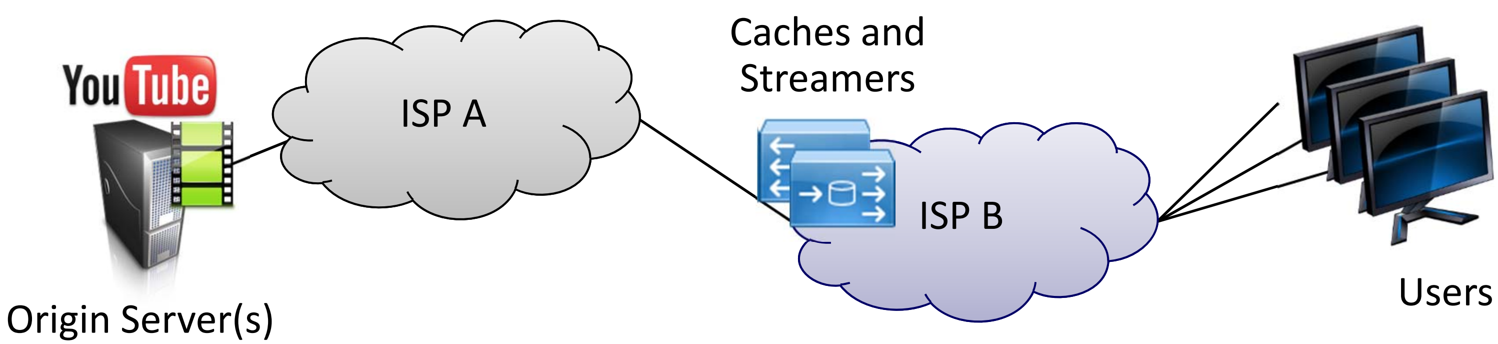
Example	ATT U-verse, Etisalat's E-Vision, Free IPTV (France)
SP Context	• Video provider and sometimes enterprise VPN provider
Format of Video	Multicast IP MPEG2-TS (possibly using RTP via RFC 2250)
Network Designs	Network heavily engineered for high resiliency and redundancy MPLS-TE for path selection, fast-reroute (FRR) technologies



* IPTV is a generic term, used very narrowly in this presentation

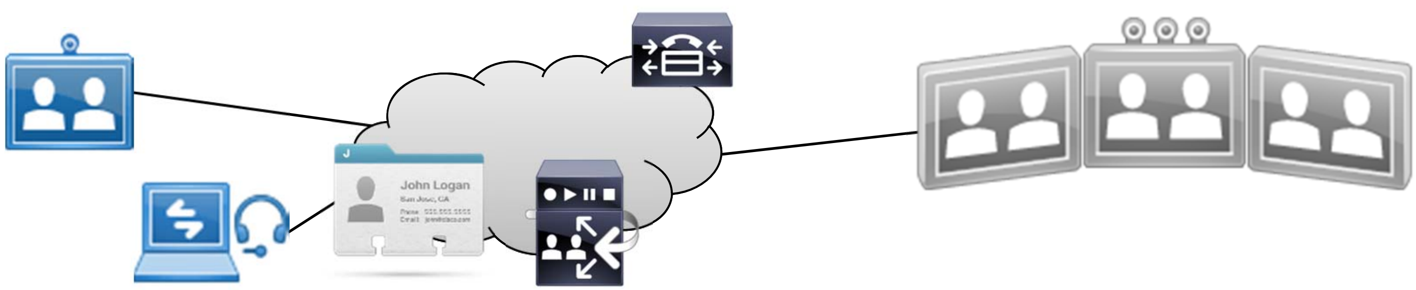
Type of Video: Video-on-Demand and Over-the-Top (OTT)

Example	YouTube, Hulu, TiViBu, enterprise training videos
SP Context	• Applies to all except SIP trunk providers • SP may only be a transit for OTT and VPN providers • SP may offer VoD directly as part of an IPTV package
Format of Video	Unicast IP TCP/HTTP or TCP/proprietary (Flash, Silverlight) UDP/RTP (IPTV/Cable networks)
Network Designs	Distributed caching/hosting of video content Dynamic admission control (Managed networks)



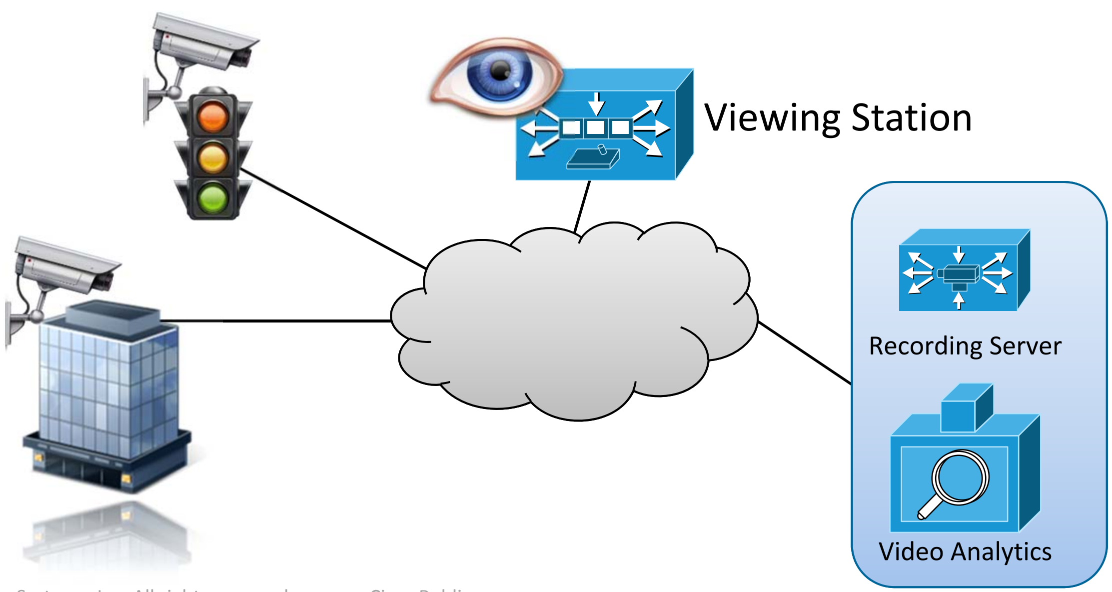
Type of Video: Video Conferencing

Example	Polycom, WebEx, TANDBERG, TelePresence, Skype
SP Context	• All except IPTV providers
Format of Video	Unicast IP UDP/RTP (Managed networks) TCP (Internet networks)
Network Designs	Bandwidth, loss, latency and jitter SLAs SP may offer hosted VC services such as • Recording • Signaling control, directory • Multipoint conferencing • Inter-provider and inter-company exchange



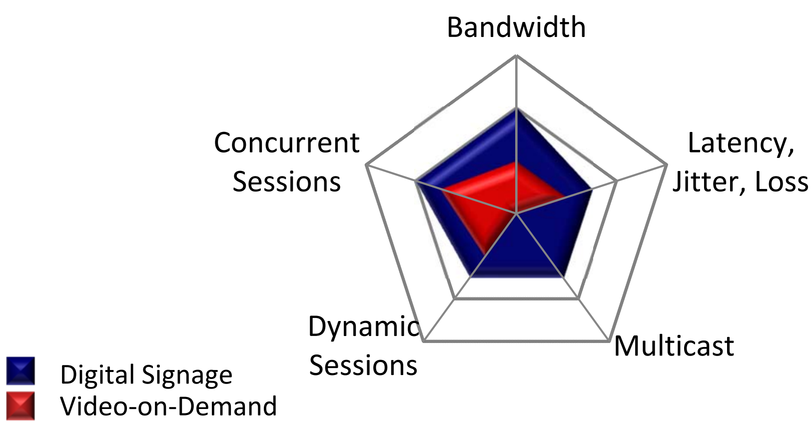
Type of Video: Video Surveillance

Example	Retail outlets, metropolitan areas, airports
SP Context	• Enterprise VPN providers
Format of Video	Unicast IP or multicast UDP/RTP HTTP(s)
Network Designs	Continuous streaming to a recorder Reduction of transport via proximity placement/recorder

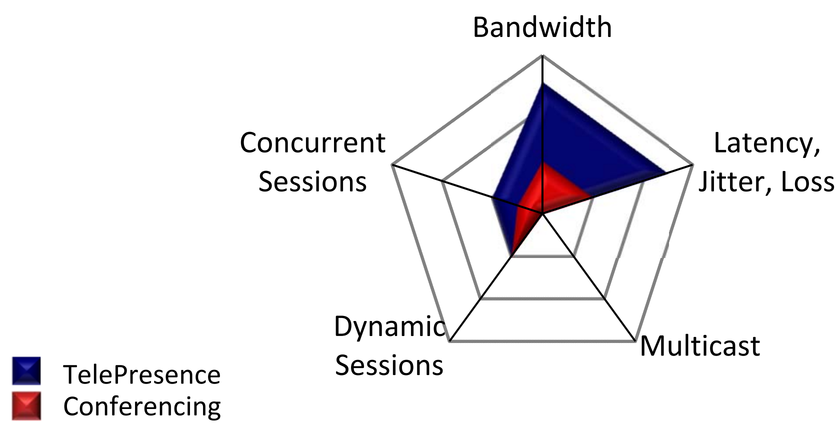


Media Service Requirements

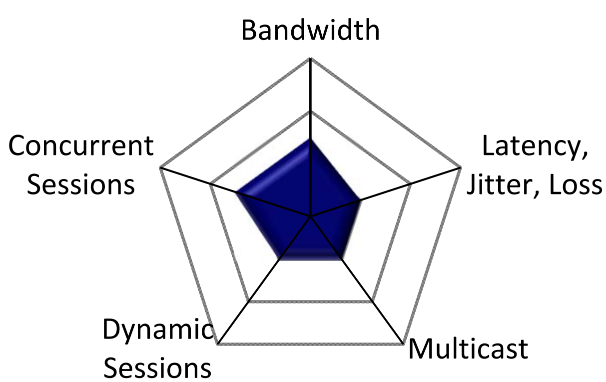
Streaming Media



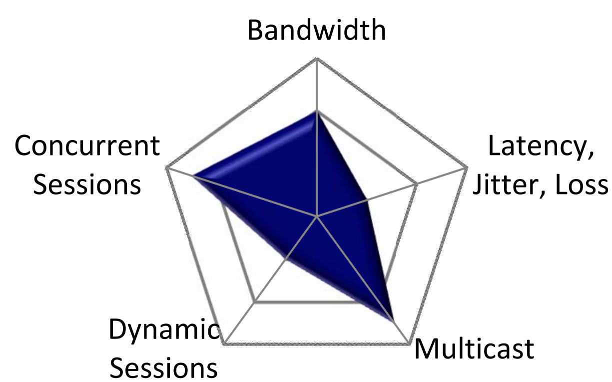
TelePresence / Video Conferencing



Video Surveillance

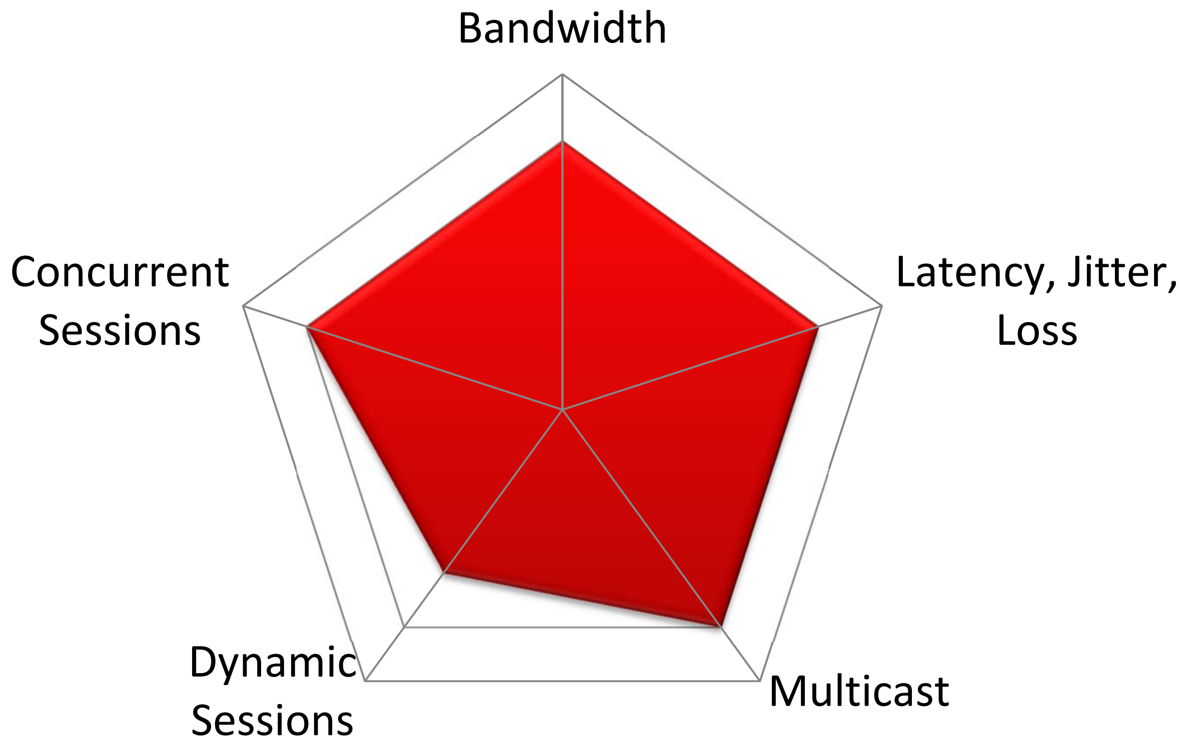


IPTV



Video on Service Provider Networks

Combination of All Video Forms Needs High-Performance Network



Further Reading

- **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

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

- **medianet Technologies**

  http://www.cisco.com/web/solutions/medianet/index.html

  http://www.cisco.com/web/solutions/medianet/sp.html

  "IPTV and video networks in the 2015 timeframe: the evolution to medianets," IEEE Communications Magazine, Dec. 2009

- **Cisco Visual Network Index**

  http://ciscovni.com/

Monitoring Video

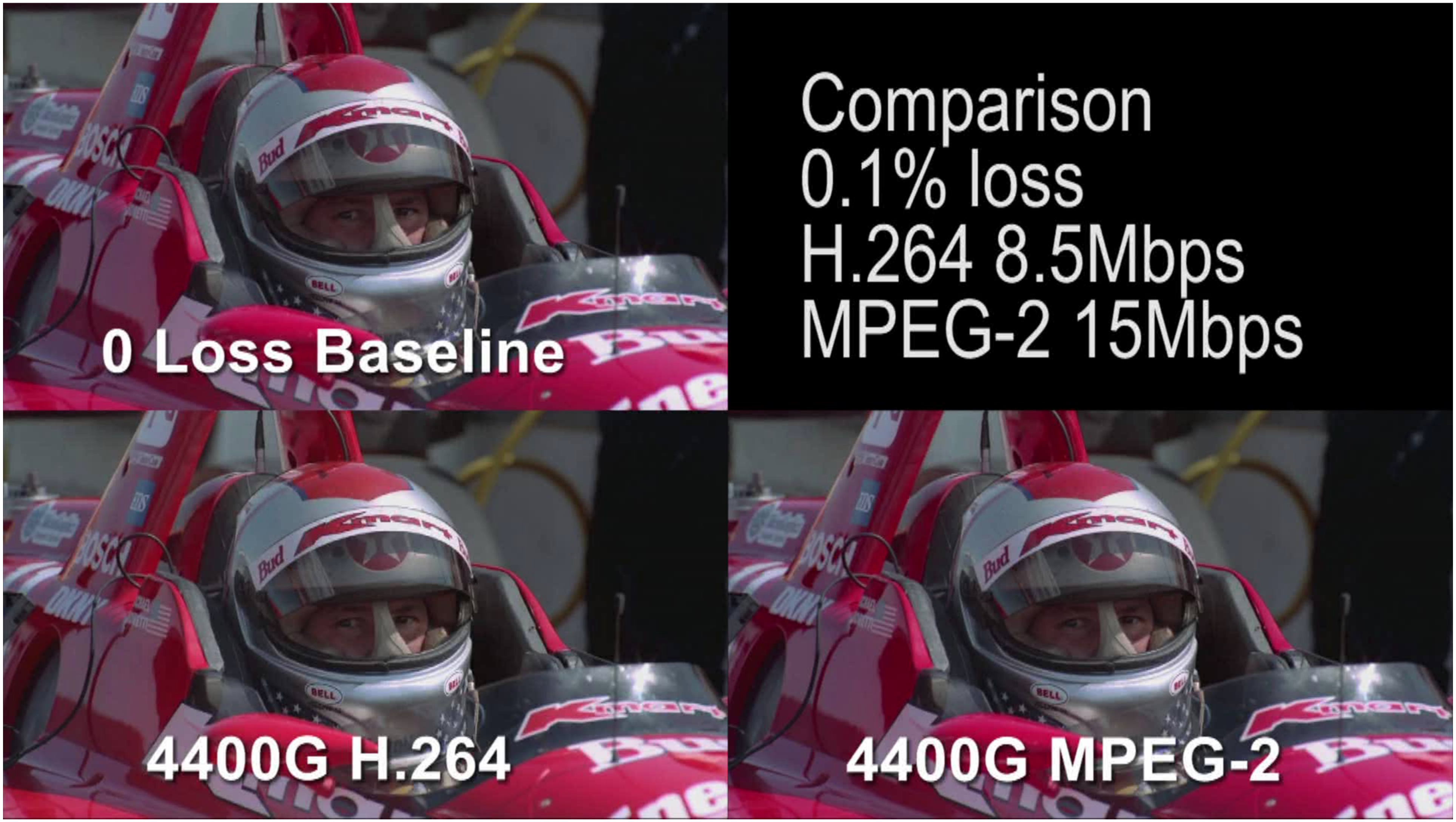
Monitoring Video
Outline

- **Why Monitor Video Services?**
- **Impaired Video**
    - Forms of Impairment
    - Metrics
- **Understanding and Identifying Video in a Network**
    - Deep Packet Inspection (DPI)
    - Classic NetFlow / IPFIX
    - Capacity Planning / Traffic Matrices
- **Analysis of Network Video Quality**
    - Direct and Indirect Metrics, MOS and Synthetic Traffic
    - MPEG2-TS and RTP
    - TCP/HTTP

Why Monitor Video Services?

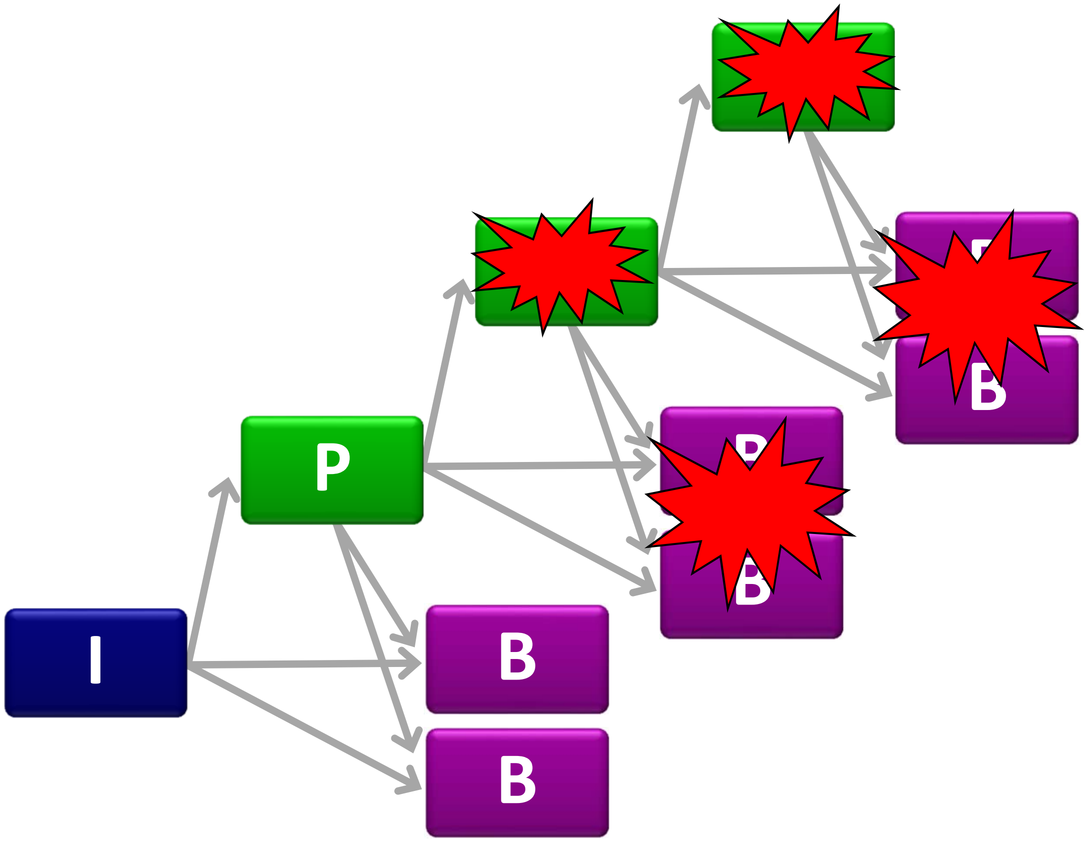
- **IPTV, PPV, etc. generate their own revenues**
- **Customers associate poor video quality with poor network service**
  - Retention is cheaper than acquiring new customers
- **Contractual SLAs need to be validated**
  - Violations may incur punitive costs
- **Early fault detection may point to greater underlying issues**
  - Video is more sensitive than other network traffic
- **Video has a large (and growing) footprint on the network**
  - Understanding video traffic patterns enables to optimize network

Impact of Encoding and Packet Loss on Quality



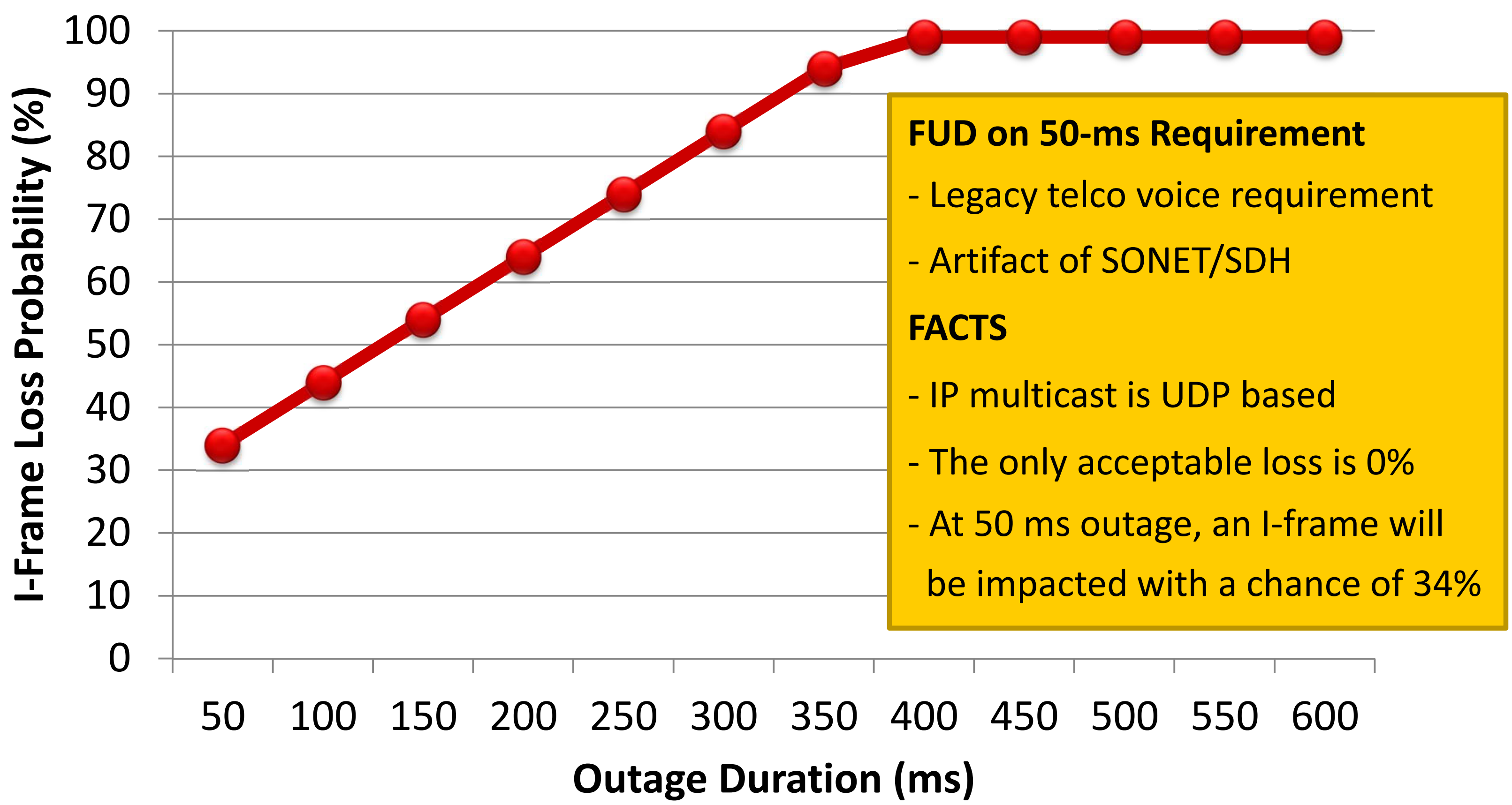
Unequal Importance of Video Packets

IPBBPBBPBB – MPEG GoP



MPEG Frame Impact from Packet Loss

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



Il Buono, il Brutto, il Cattivo

No Loss – Perfect Quality

0.5% Packet Loss

5% Packet Loss

Technologies for Identifying Video Traffic

- **How is Video Defined?**
- **How Much Video does Your Network Carry?**
- **Where in the Network is It?**
- **Technologies**

    Deep Packet Inspection

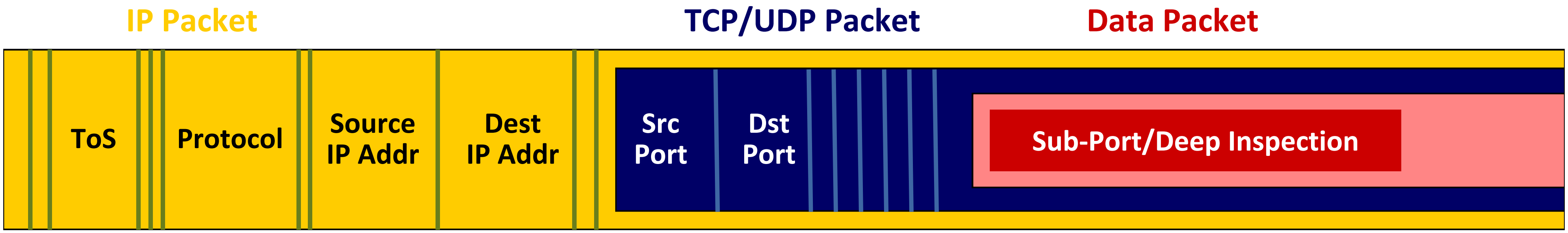
    Traffic Characteristics Analysis

    NetFlow / IPFIX

Identifying Video: Deep Packet Inspection (DPI)

Variety of Heuristics Used to Identify Traffic

- True DPI: Payload analysis of dynamic layer-4 traffic
  - Limited to traffic in clear (non-encrypted)
  - Specialized hardware needed
    - Limitations on performance and scale
    - DPI probe deployment requires port mirroring
  - Lower-end routers may have built-in features
- Traffic Behavior (If X is seen and Y follows, flow may be Z)
  - Geared toward identifying encrypted or stealth flows (e.g., Skype)



Output of DPI

- DPI provides (depending on tool and deployment)
  - Utilization (possibly limited to link) information per traffic type
  - Association of flow identity (IPsrc, IPdst, ports) with traffic type
    - Allows for one-time DPI and reuse of information across network

```
208.65.153.238:80 -> 64.102.35.14:35607 == YouTube
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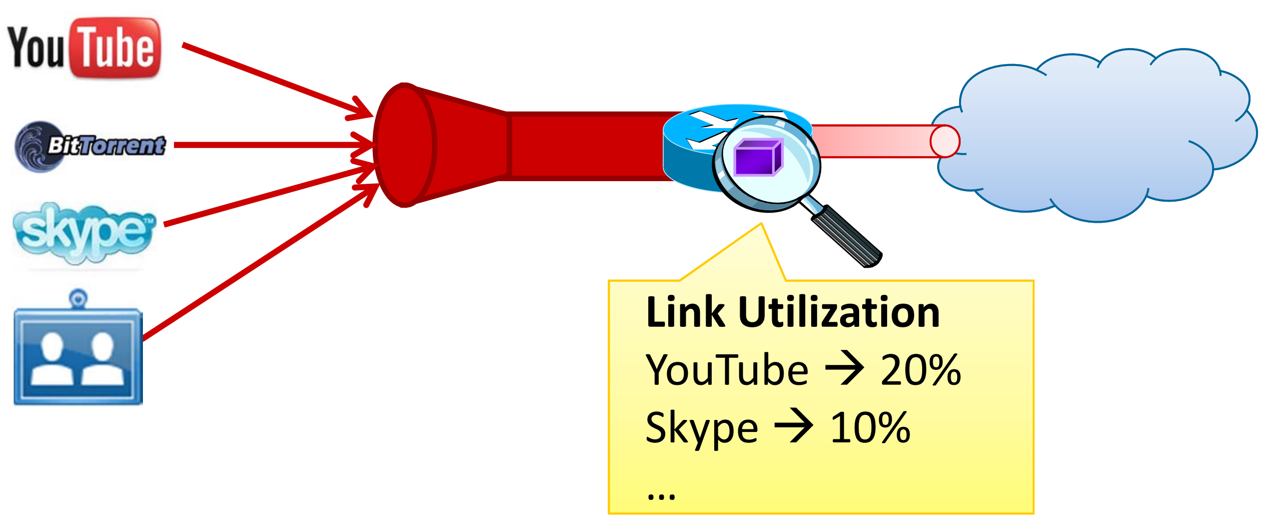
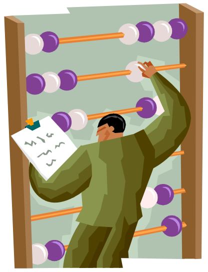


Identifying Video: NetFlow / IPFIX

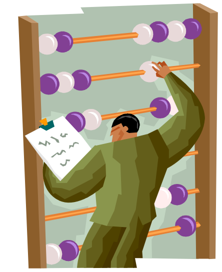
IPFIX is an IETF Standard Based on NetFlow



- Analysis of known addresses, ports, heuristics of byte volume and packet rate can give a rough idea of traffic type
- NetFlow captures packet information (IPsrc/dst, IP protocol, ports, in/out interface) and uses to tabulate counters: bytes, packets, etc.
- Generally available on routers and switches
    - Pervasive in network

SrcIf	SrcIPadd	DstIf	DstIPadd	Protocol	TOS	Flgs	Pkts	Src Port	Src Msk	Src AS	Dst Port	Dst Msk	Dst AS	NextHop	Bytes/ Pkt	Active	Idle
Fa1/0	173.100.21.2	Fa0/0	10.0.227.12	11	80	10	11000	00A2	/24	5	00A2	/24	15	10.0.23.2	1528	1745	4
Fa1/0	173.100.3.2	Fa0/0	10.0.227.12	6	40	0	2491	15	/26	196	15	/24	15	10.0.23.2	740	41.5	1
Fa1/0	173.100.20.2	Fa0/0	10.0.227.12	11	80	10	10000	00A1	/24	180	00A1	/24	15	10.0.23.2	1428	1145.5	3
Fa1/0	173.100.6.2	Fa0/0	10.0.227.12	6	40	0	2210	19	/30	180	19	/24	15	10.0.23.2	1040	24.5	14

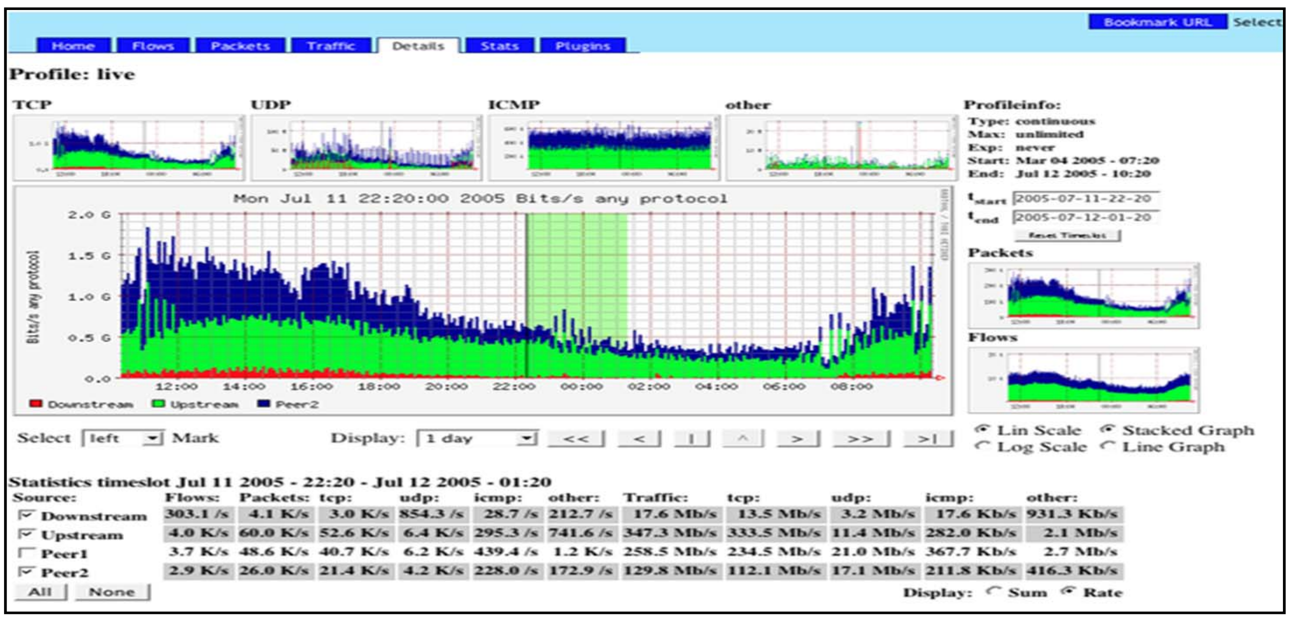
Output of NetFlow Information



- Utilization Information

  If coupled with flow identifiers from DPI (could be from same box), higher confidence in traffic identification

- Location context to build traffic generation and demand matrix



Monitoring for Capacity Planning

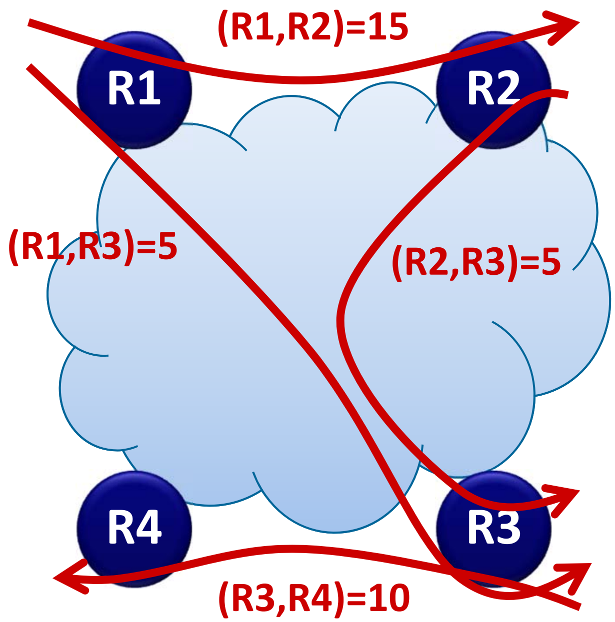
- **Video adoption is increasing at a rapid rate**
- **Adding bandwidth may not be the most economical solution**
  - If adding bandwidth, where to add it?
- **Network operators need to understand**
  - What kind of traffic?
  - Where is it coming from, where is it going to?
  - What is the rate of growth?
- **Next Step: How to optimize traffic (not covered in this talk)**
  - Traffic engineering – Making use of redundant paths
  - Content caching – Relieving upstream pressure
  - Usage caps

Bandwidth Considerations

Approximate Video Bandwidth Requirements per Stream

Desktop Video	
SD VoD and Live	200 Kbps – 1.5 Mbps
Digital Signage / Enterprise TV	
SD/HD VoD and Live	1.5 – 5 / 8 – 25 Mbps
Cisco TelePresence	
CTS-500/CTS-1000 720p/1080p	2.1 – 8.7 / 4.5 – 10.8 Mbps
CTS-3000/CTS-3200 720p/1080p	4.5 – 14.1 / 11.7 – 20.4 Mbps
Desktop Video Collaboration	
CUVA and CUPC (>384 Kbps recommended)	50 Kbps – 1.5 Mbps
Cisco IP 7985G Phone	Up to 768 Kbps
WebEx Conference with Webcam (Max 6 streams)	32 Kbps – 284 Kbps
IP Video Surveillance	
Cisco 4500 HD Cameras (H.264 mode)	~4 Mbps
Cisco 2500 SD Cameras (MPEG4 mode)	~1 Mbps

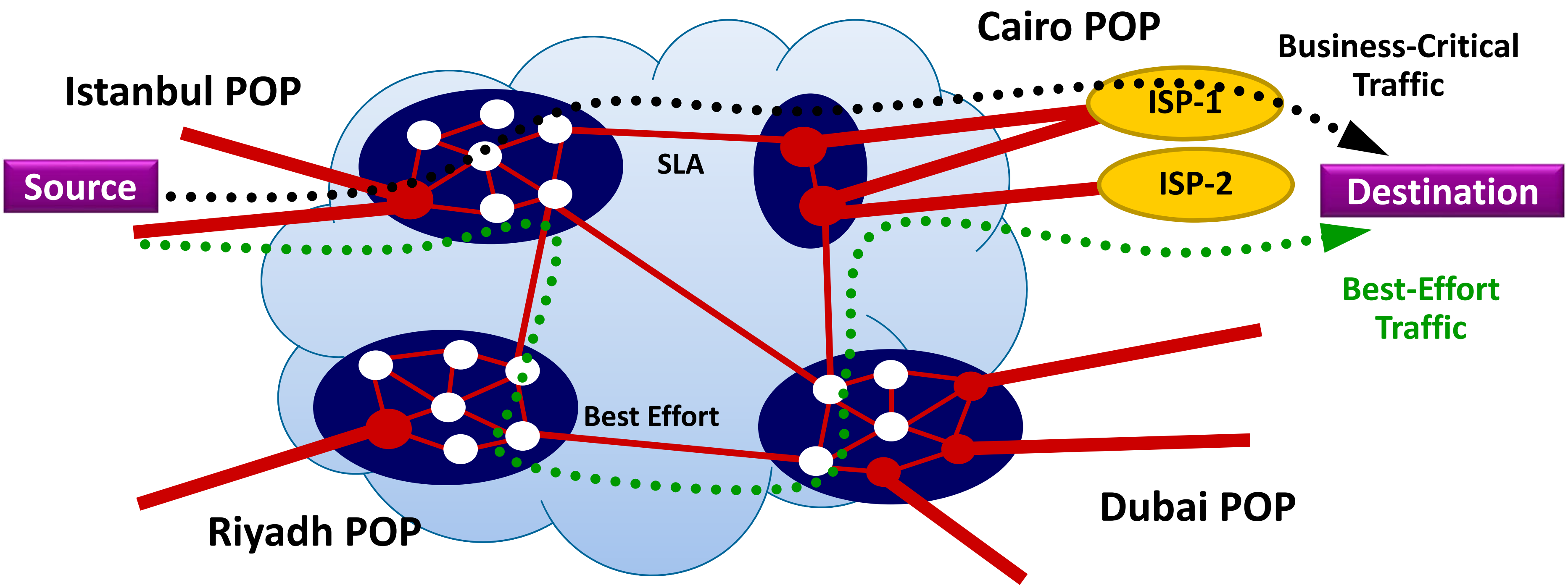
What Is the Traffic Matrix?



From/To	R1	R2	R3	R4
R1	0	15	5	0
R2	0	0	5	0
R3	0	0	0	10
R4	0	0	0	0

Traffic Matrices using NetFlow

Traffic Engineering and Capacity Planning

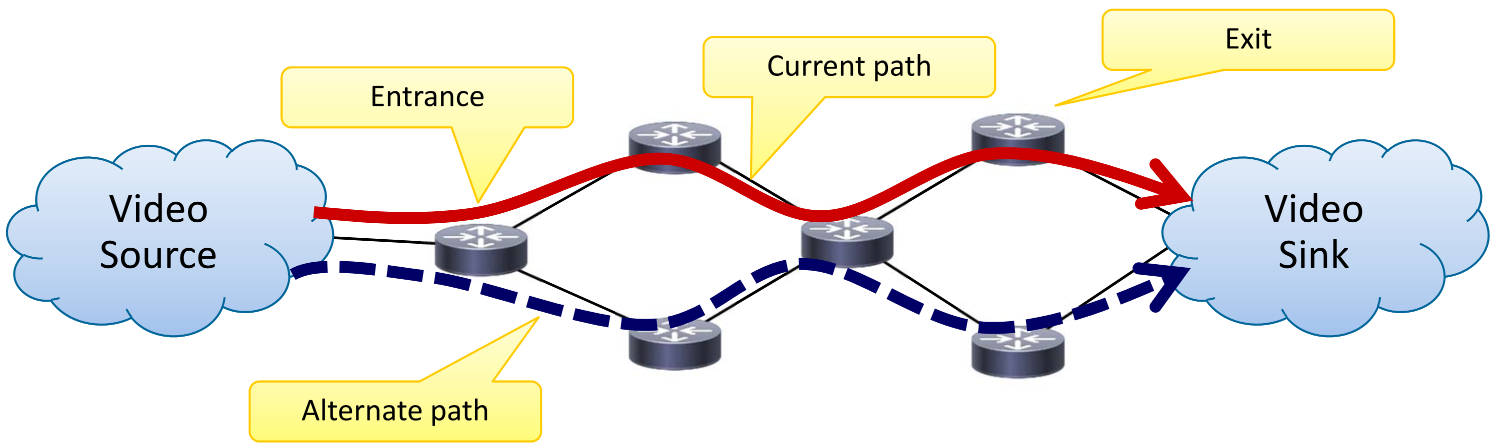


	Istanbul Exit Point	Cairo Exit Point	Riyadh Exit Point	Dubai Exit Point
Istanbul Entry Point	NA (*)	…Mb/s	…Mb/s	…Mb/s
Cairo Entry Point	…Mb/s	NA (*)	…Mb/s	…Mb/s
Riyadh Exit Point	…Mb/s	…Mb/s	NA (*)	…Mb/s
Dubai Exit Point	…Mb/s	…Mb/s	…Mb/s	NA (*)

* Potentially local exchange traffic

How does NetFlow Solve Traffic Matrix?

- NetFlow at entrance/exit points provides location of source and sink
- NetFlow along path provides utilization of current and alternative paths
- Daily, weekly and monthly changes are captured



Network demands can be determined and decisions are made on whether to allocate more/less bandwidth to that site

Direct SLA Metrics for Video

- **Direct metrics involve analysis of the video portion of the stream**
- **Types of Direct Metrics**
  - Video resolution and quality
  - Frozen frames
  - Slice errors
  - Artifacts
  - Smearing
  - Positional issues

Ghosting | Pixelization | Forgetting to plug something in | Slice error

- **Deployment Models**
  - Built into media generators and consumers
  - Dedicated appliances (probes)
  - Specialized service blades hosted inside network hardware

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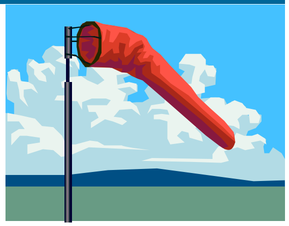
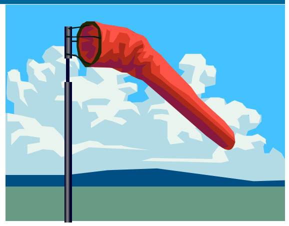
Resolution Comparison

Indirect SLA Metrics for Video



- **Indirect metrics involve analysis of the non-video portion of stream to determine quality of experience**
  - Encapsulation errors, loss, latency and jitter
- **Rely on instrumentation within the packet itself**
  - MPEG2-TS (TR 101 290, RFC 4445 (MDI), etc.): IPTV
  - RTP/RTCP (RFC 3550): IPTV, video conferencing, video surveillance
  - TCP: Video-on-Demand, video conferencing
- **Relatively cheaper to attain than direct metrics**
- **Deployment Models**
  - Probes are still most popular but expensive
  - Network infrastructure augmented with service blades
  - New forwarding hardware that incorporates monitoring features
  - Existing forwarding hardware features enhanced via software

Direct vs. Indirect Metrics and the IP Network



- **Direct metrics try to evaluate what users experience**
  - These metrics process at application layer
  - Relatively more expensive to deploy pervasively
- **Indirect metrics try to estimate user experience based on transport**
  - These metrics may not capture all issues
  - Relatively cheaper to deploy
- **Traditional IP/MPLS forwarding does not modify video payload, rather affects packet loss, latency and jitter**
  - Indirect metrics do measure these
  - Indirect metrics also provide fault isolation

Video Quality Scoring Systems

- **Mean Opinion Score (MOS)**

  Subjective tests performed by human subjects to grade video quality

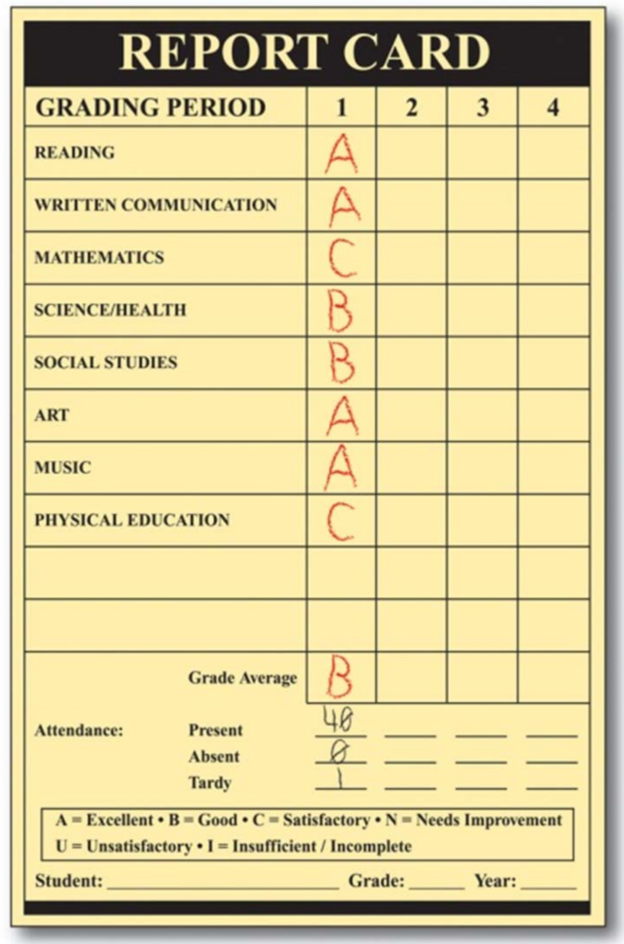
  Very expensive, not practical in real time

- **Automated MOS is quantitative analysis to simulate MOS**

  Generally proprietary systems

  Models available based on direct, indirect as well as hybrid metrics

  Still a big gap from actual MOS but is a lot cheaper



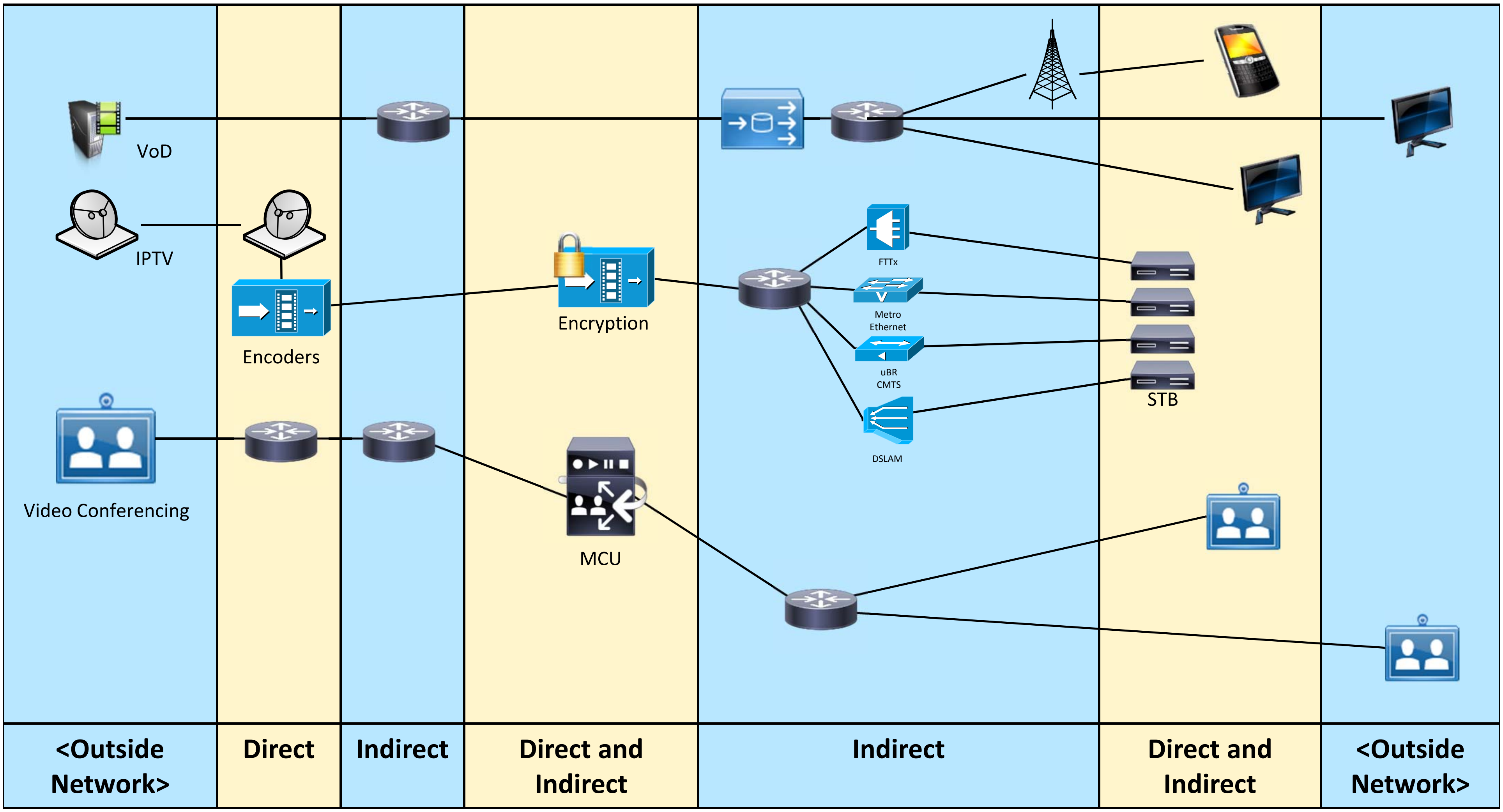
Measurements via Synthetic Traffic

- **In lieu of user traffic, synthetic traffic is instrumented, injected and observed**
- **Solutions of varying complexity are available**
  - Sequence numbers → Loss detection
  - Timestamps → Latency and jitter
  - Trueness to application traffic (Packet sizes, DSCP values, burstiness)
- **Pros**
  - Synthetic traffic can be used even when the user traffic does not exist
  - Designed to allow better measurement than by observing user traffic
- **Cons**
  - Synthetic traffic is fake – at some point the difference is going to matter
  - It puts additional load on network

Experience Metrics
Beyond Visual Aspects

- **Wait Times for Media**
  - Channel change times in linear broadcast
  - Startup and seeking (FF/rewind) latency in VoD
- **Media Synchronization**
  - Audio-video lag (Lip sync)
  - Subtitle synchronization

Placement of Monitoring Systems



Per-Application Latency, Jitter, Loss Targets

General Guidelines

Application	Latency	Jitter	Loss (VoD)	Loss (Live)
Streaming Video	< 1000 ms	< 100 ms	< 0.1%	< 0.05%
Video Conferencing	< 150 ms	< 30 ms	NA	< 0.10%
TelePresence	< 150 ms	< 10 ms	NA	< 0.05%
Digital Signage	< 1000 ms	< 100 ms	< 0.1%	0%
IPTV	< 1000 ms	< 100 ms	< 0.1%	0%
Video Surveillance	< 1000 ms	< 100 ms	< 0.1%	< 0.05%

Delay Targets for Media Synchronization

General Guidelines

Media Synchronization	Delay
Audio + Discrete Info (E.g., slide show)	< 1000 ms
Audio + Pointed objects with narration:	< 200 ms
Audio + Lips or other associated imagery/video	
Audio advance over video	< 30 ms
Audio lag wrt video	< 100 ms

What do Indirect Metrics Measure?

- **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 minimize jitter buffer size to improve responsivity

  → Jitter originating in the core is rather insignificant

- **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

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 (in the Core)**

  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

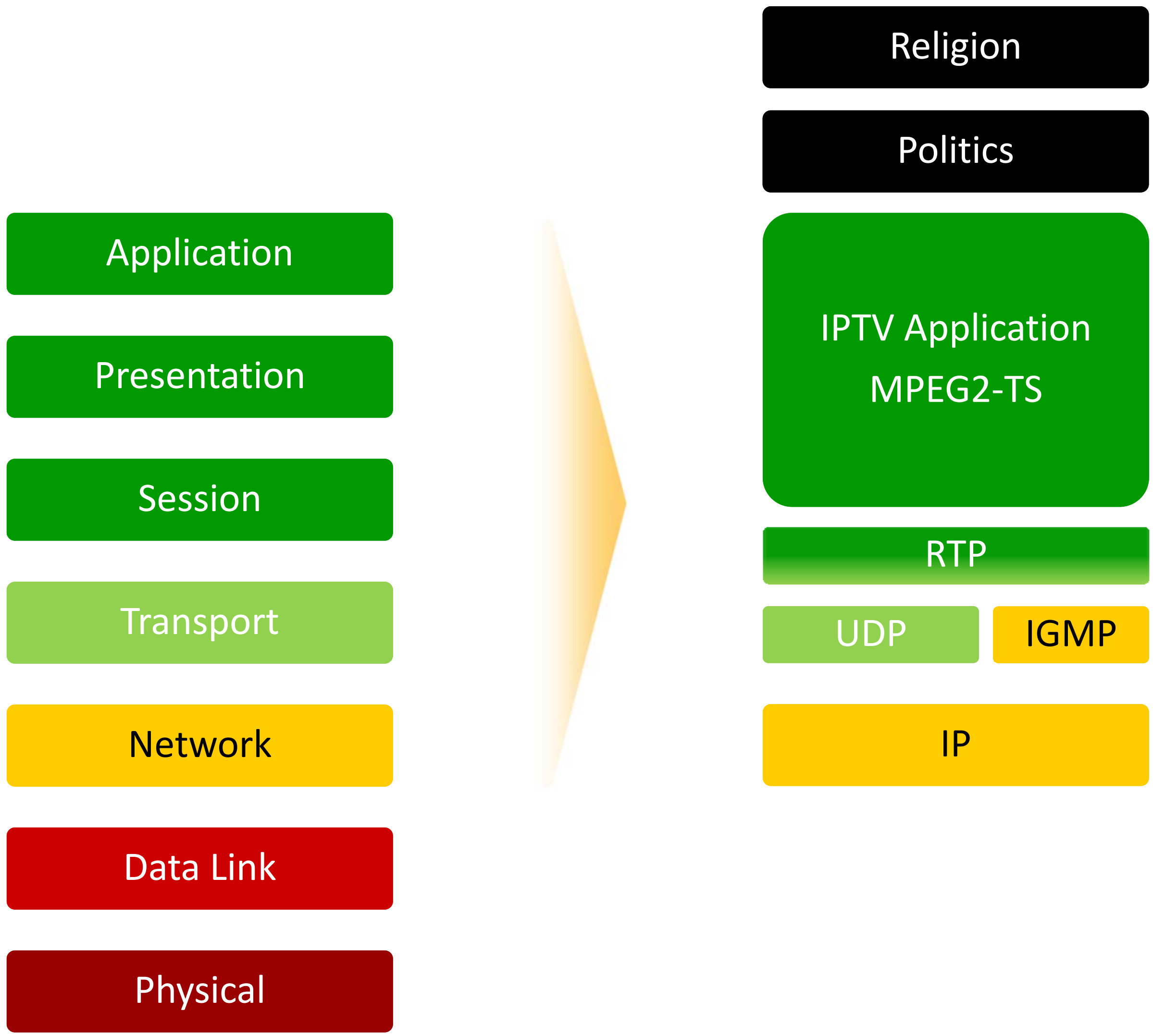
What are the Core Impairment Contributors?

	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
Total	**.0062 /2h**
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

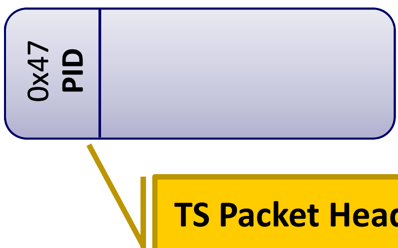
Source: Data from industry standards, customers and assumptions

RTP Transport of MPEG2 Transport Streams



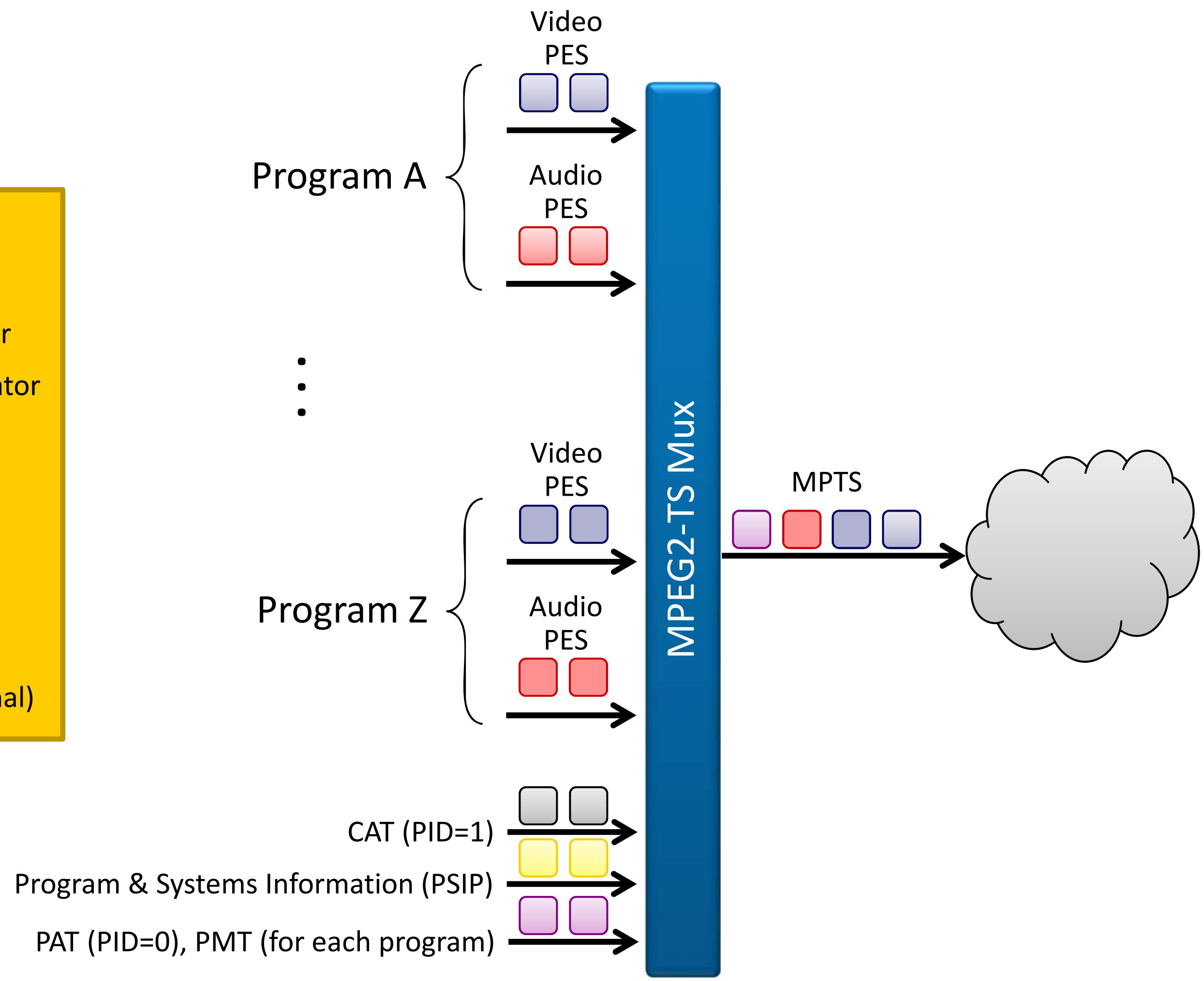
Using MPEG2-TS Encapsulation to Generate Indirect Metrics

188-byte MPEG2-TS Packet



TS Packet Header:

- Sync byte (0x47)
- Transport error indicator
- Payload unit start indicator
- Transport priority
- Packet ID
- Scrambling control
- Adaptation field control
- Continuity counter
- Adaptation field (optional)



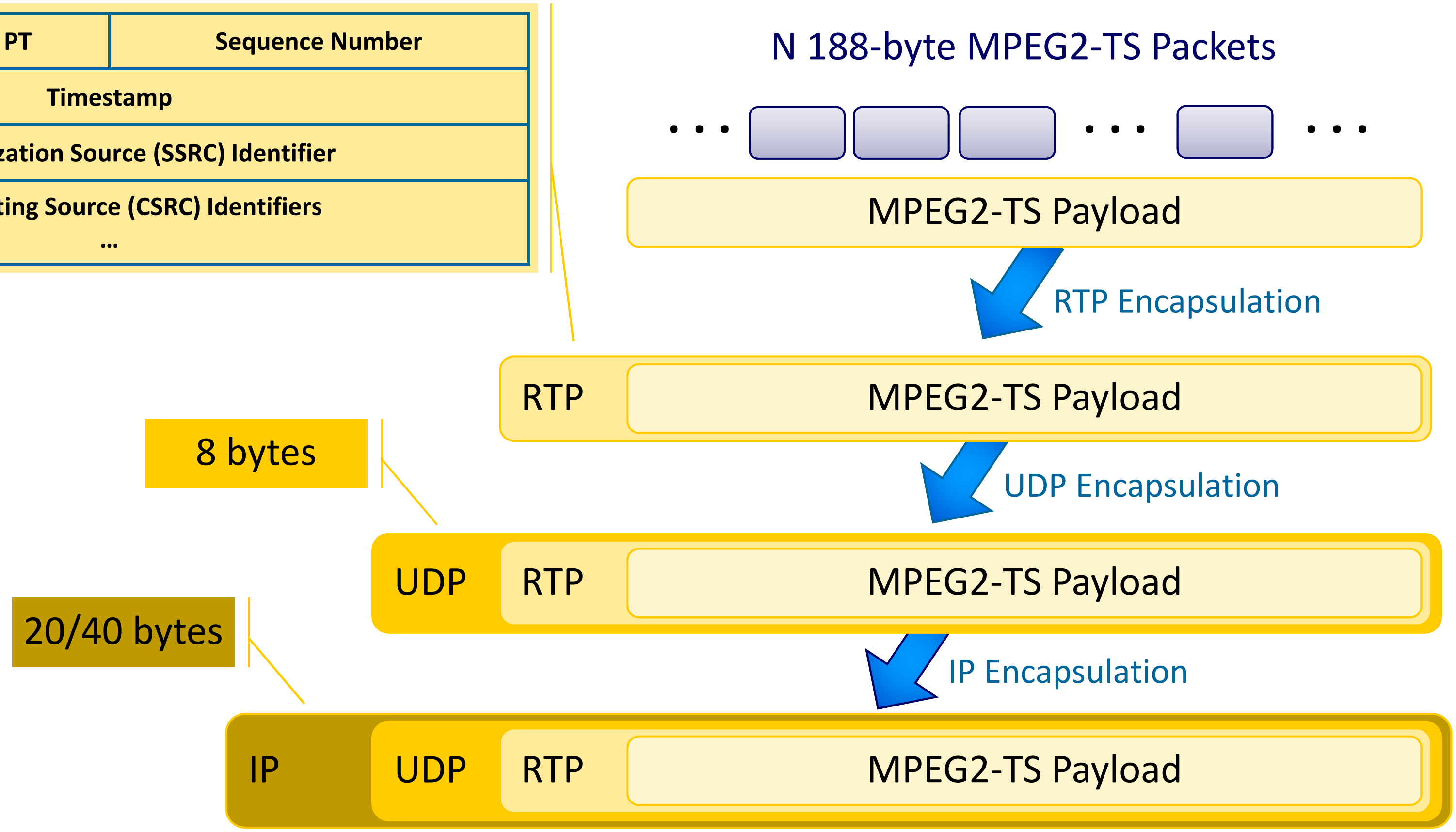
MPEG2-TS Analysis

- MPEG2-TS packet header has 4-bit continuity counter (CC) per PID
  - CC increments by one for every MPEG2-TS packet of PID
  - Non-sequential CC values are indicative of MPEG2-TS packet loss
  - Further analysis to correlate MPEG2-TS packet loss and IP packet loss
- MPEG2-TS payload may include adaptation field which includes program clock reference (PCR)
  - PCR inserted by encoder, represents value of its 27 MHz clock
  - Decoder analysis allows calculation of jitter
- Besides loss and jitter, MPEG2-TS analysis can catch errors with MPEG2-TS mux process, IP packetization, etc.

Scaling Indirect Metrics using RTP Encapsulation

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

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



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

Real-Time Transport Protocol (RTP)
http://tools.ietf.org/html/rfc3550

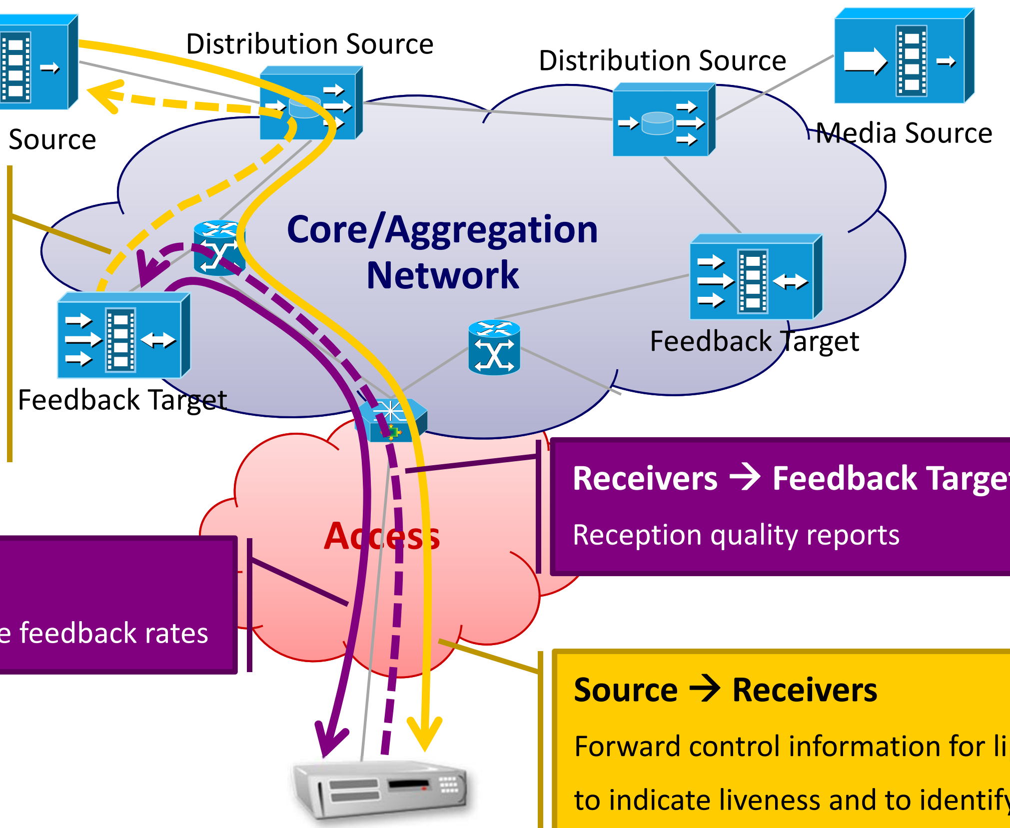
- **Basics**
  - First specified by IETF in 1996, later updated in 2003 (RFC 3550)
  - Runs over any transport-layer protocol (Typically over UDP)
  - Runs over both unicast and multicast
  - No built-in reliability
- **Main Services**
  - Payload type identification
  - Sequence numbering (provides loss metrics)
  - Timestamping (provides jitter metrics)
- **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)
  - RTCP extensions allow for reporting direct metrics

RTCP Sender/Receiver/Extended Reports

- **RTCP Sender Reports provide info on data sent recently**
  - Wallclock time and the corresponding RTP timestamp
  - Total number of packets/bytes sent
- **RTCP Receiver Reports summarize the reception quality**
  - Timestamp of (and delay from) the last received sender report
  - Highest sequence number seen so far
  - Number and fraction of the lost RTP packets
  - Estimate of the interarrival jitter
- **RTCP Extended Reports (XR) provide**
  - Detailed transport-level stats and application-specific information about the RTP transport
  - Several advantages over traditional and proprietary monitoring solutions
- **RTCP XR framework is easily extensible to report on**
  - Packet-level loss events, loss patterns, mean time between losses, loss durations, etc.
    - → Correlation engines identify, characterize and isolate the problems
  - Audiovisual reception quality
  - Effectiveness of the loss-repair methods
    - → Loss-repair methods can be adapted and improved depending on the network conditions
  - Effectiveness of channel change acceleration

Four RTCP Flows, Two RTCP Loops

A Typical IPTV Distribution Network



Feedback Targets → Source

Reception quality reports reporting quality of the path from source to the feedback target and summarizing reception quality for receivers

Receivers → Feedback Target

Reception quality reports

Feedback Target → Receivers

Forward control information to manage feedback rates

Source → Receivers

Forward control information for lip-synchronization, to indicate liveness and to identify the source

RTCP Extended Reports (XR)

http://tools.ietf.org/html/rfc3611

<table>
<tr><td>V=2</td><td>P</td><td>RC</td><td>PT=RR=201</td><td>Length</td></tr>
<tr><td colspan="5">SSRC of Packet Sender</td></tr>
<tr><td colspan="5">SSRC of Distribution Source</td></tr>
<tr><td colspan="3">Fraction Lost</td><td colspan="2">Cumulative Number of Packets Lost</td></tr>
<tr><td colspan="5">Extended Highest Sequence Number Received</td></tr>
<tr><td colspan="5">Interarrival Jitter</td></tr>
<tr><td colspan="5">Last SR (LSR)</td></tr>
<tr><td colspan="5">Delay since Last SR (DLSR)</td></tr>
<tr><td>V=2</td><td>P</td><td>SC</td><td>PT=SDES=202</td><td>Length</td></tr>
<tr><td colspan="5">SSRC/CSRC_1</td></tr>
<tr><td colspan="3">CNAME=1</td><td>Length</td><td>Canonical Name (MAC Address)</td></tr>
<tr><td colspan="5">…</td></tr>
<tr><td>V=2</td><td>P</td><td>Rsvd.</td><td>PT=XR=207</td><td>Length</td></tr>
<tr><td colspan="5">SSRC</td></tr>
<tr><td colspan="3">BT</td><td>Type Specific</td><td>Block Length</td></tr>
<tr><td colspan="5">Type-specific Block Contents
…</td></tr>
</table>

TCP Analysis

- **TCP analysis is useful for**

  OTT/VoD services (encapsulating HTTP which may embed proprietary protocols)

  Certain video conferencing services

- **Analysis of TCP window sizing and throughput can provide hints on video continuity**

  Much of this is obfuscated by the server-client application

- **Greater information is available via hosted HTTP caches or streaming servers**

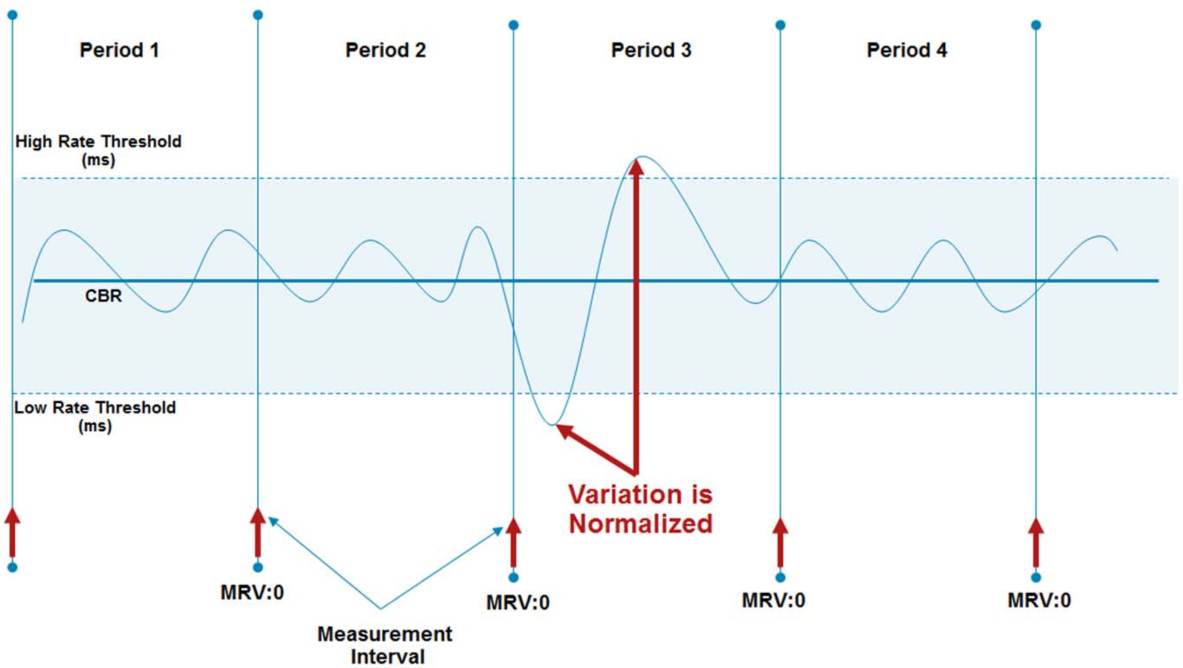
Basic analysis of TCP fields can yield loss and delay information

Rate-Based Analysis

- **Simplest and most widely applicable form of analysis**
- **Basic Assumptions**

  Media is either stopped or flowing; when flowing, bitrate varies within a range

  Network loss leaves detectable change in bitrate



Further Reading

- **Articles and Talks**

  Best Practices for Determining the Traffic Matrix in IP Networks

  http://www.nanog.org/meetings/nanog34/presentations/telkamp.pdf

  Matthew Roughan’s Web site for Traffic Matrices

  http://www.maths.adelaide.edu.au/matthew.roughan/traffic_matrices.html

- **Related Specifications**

  Measurement Guidelines for DVB Systems, ETSI Technical Report ETR 290

  A. Begen, D. Hsu, and M. Lague, “RFC 5725 – Post-Repair Loss RLE Report Block Type for RTCP XR”

  A. Morton and B. Claise, “RFC 5481 – Packet Delay Variation Applicability Statement”

- **Industry Sites**

  How Cisco IT Uses NetFlow to Improve Network Capacity Planning

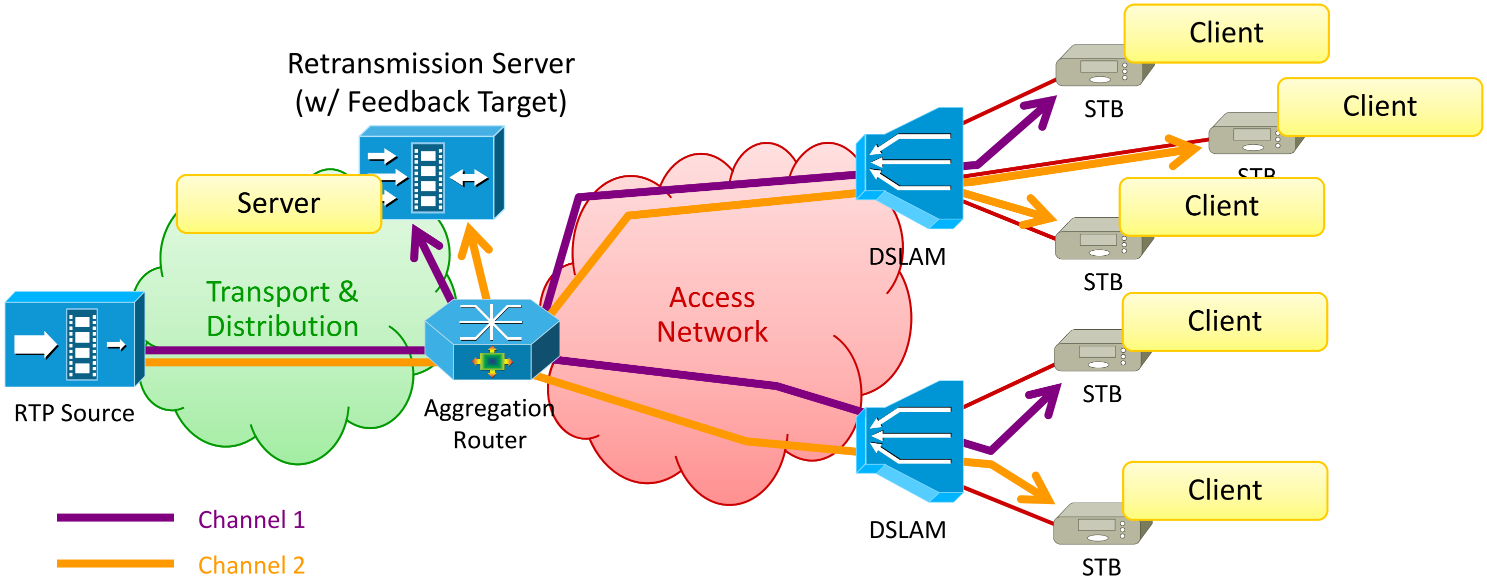
  http://www.cisco.com/web/about/ciscoitatwork/network_systems/network_capacity_planning.html

Case Study: QoE Monitoring for IPTV Distribution

A Unified QoE Solution

- **IPTV viewers have two criteria to judge their service**
  - **Artifact-free audiovisual quality**
    - Packets dropped in access and home networks must be recovered quickly
    - Packet loss may or may not be correlated in spatial and/or temporal domain
    - 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
    - Zapping demand varies 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
- **Our goals are to offer**
  - Glitch-free audiovisual quality, short and consistent zapping
  - Monitoring tools that isolate and pinpoint the problematic locations

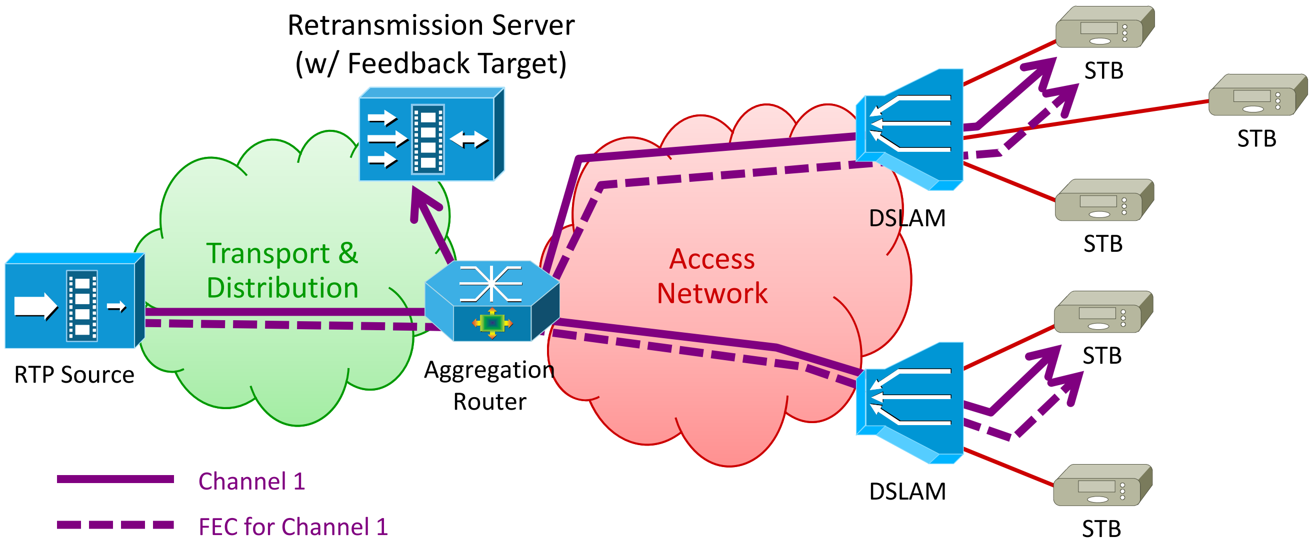
A Simplified Model



- **Each TV channel is served in a unique (SSM) multicast session**
  - IP STBs join the respective multicast session(s) for the desired TV channel
  - Retransmission servers join all the 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

First-Line of Defense in Loss Repair

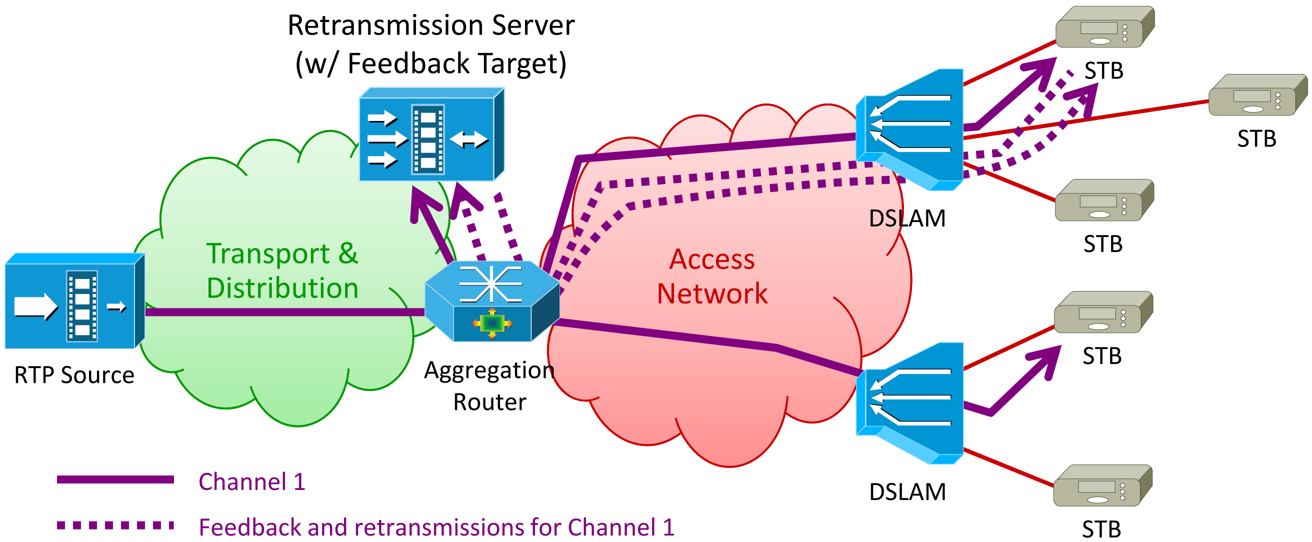
1-D/2-D Parity Forward Error Correction



- **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 Defense 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

  The retransmission is on a separate unicast RTP session

- **General Remarks**

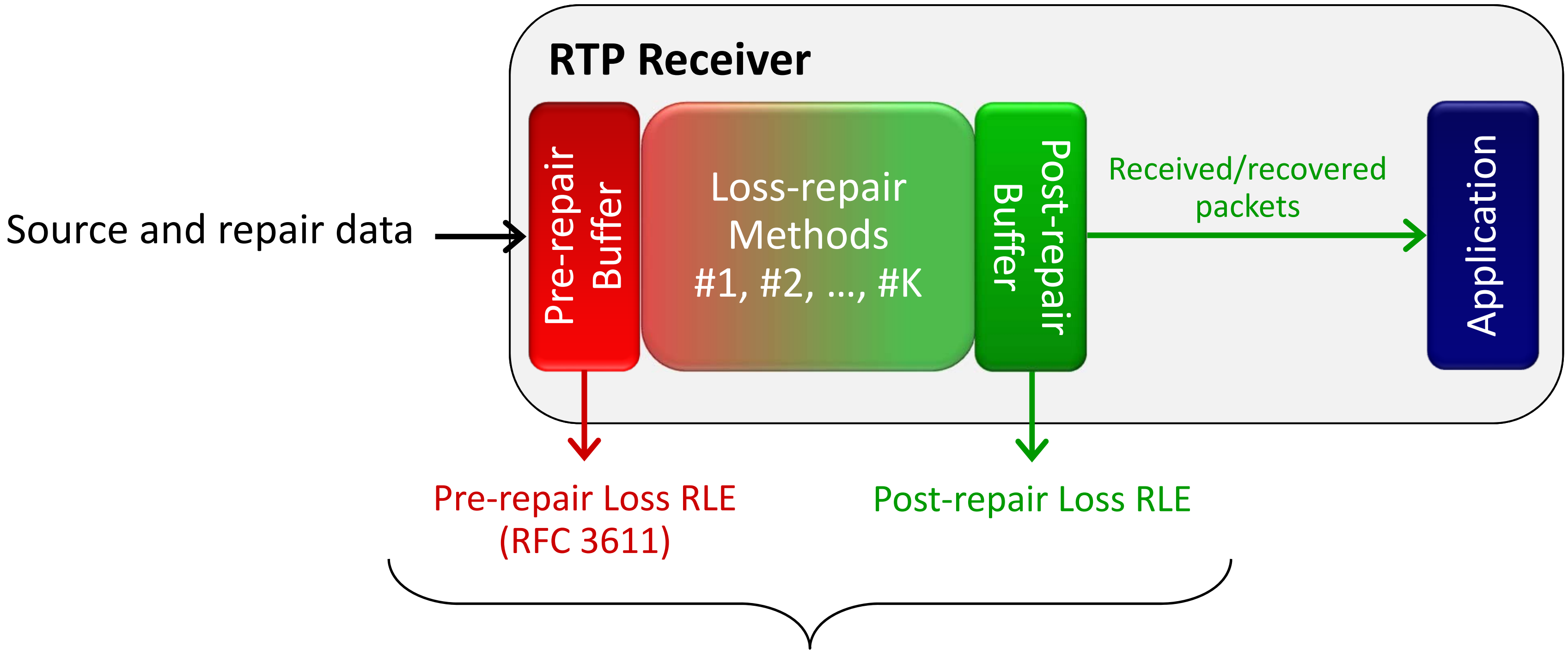
  ✓ Retransmission recovers only the lost packets, so no bandwidth is wasted

  × Retransmission adds a delay of destination-to-source-to-destination

- **Protocol suite comprises RFC 3550, 4585, 4588 and 5760**

RTCP XR Example: How Effective is Loss-Repair Process?

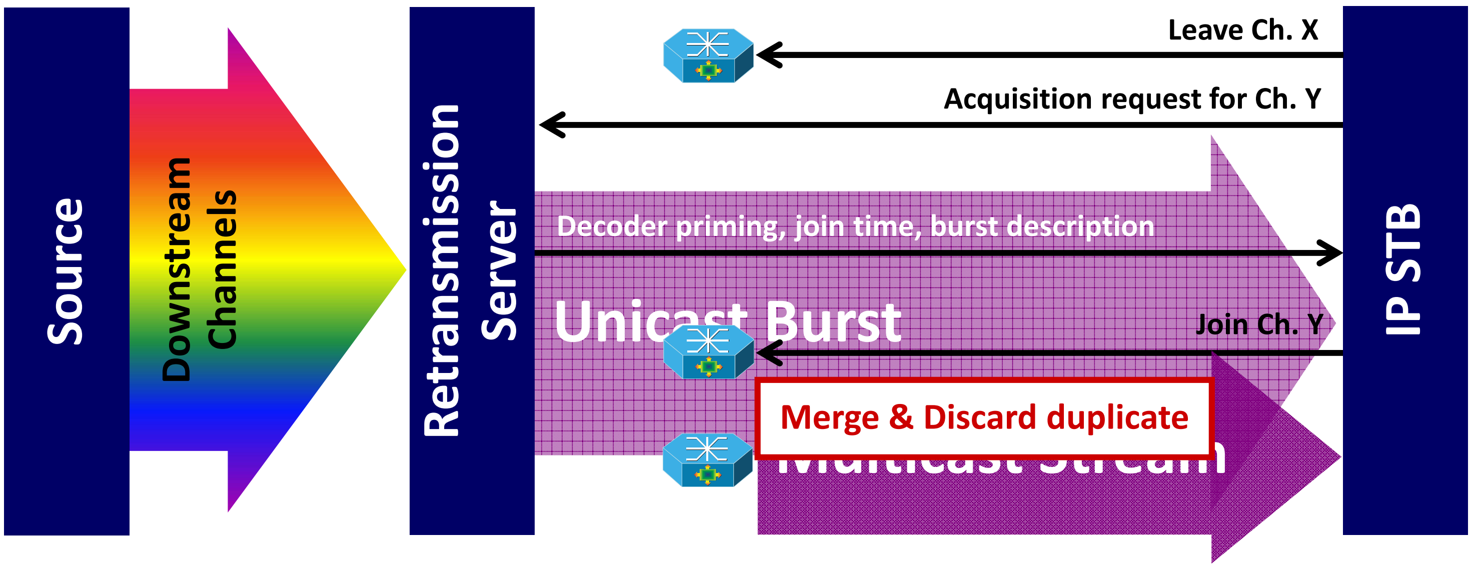
http://tools.ietf.org/html/rfc5725



The difference tells us the aggregated performance of the loss-repair methods

IETF's Solution for Slow Channel Changes in IPTV

http://tools.ietf.org/html/draft-ietf-avt-rapid-acquisition-for-rtp



RTCP XR Example: How Fast are the Channel Changes?

https://datatracker.ietf.org/doc/draft-ietf-avt-multicast-acq-rtcp-xr

- **Multicast-Related Statistics**

  RTP Seqnum of the First Multicast Packet

  SFGMP Join Time

  Application Request-to-Multicast Delta Time

- **Application-Related Statistics**

  Application Request-to-Presentation Delta Time

  Application Request-to-RAMS Request Delta Time

- **Unicast-Related Statistics**

  RAMS Request-to-RAMS Information Delta Time

  RAMS Request-to-Burst Delta Time

  RAMS Request-to-Multicast Delta Time

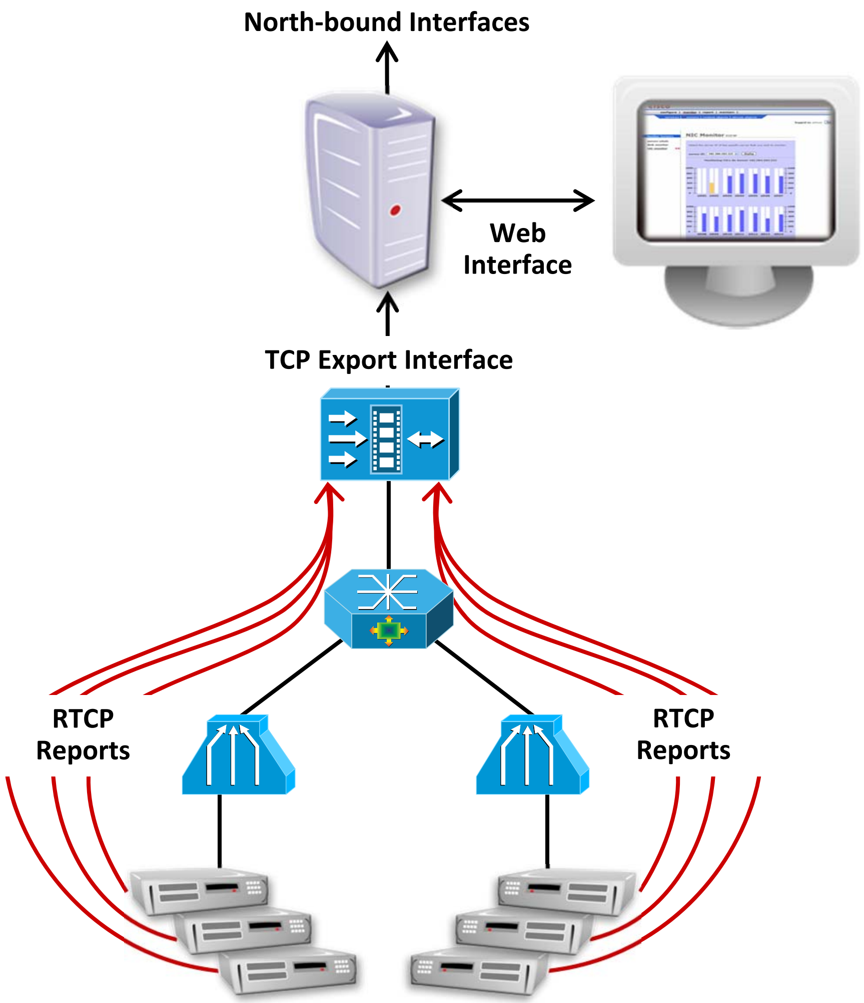
  RAMS Request-to-Burst-Completion Delta Time

  Number of Duplicate Packets

  Size of Burst-to-Multicast Gap

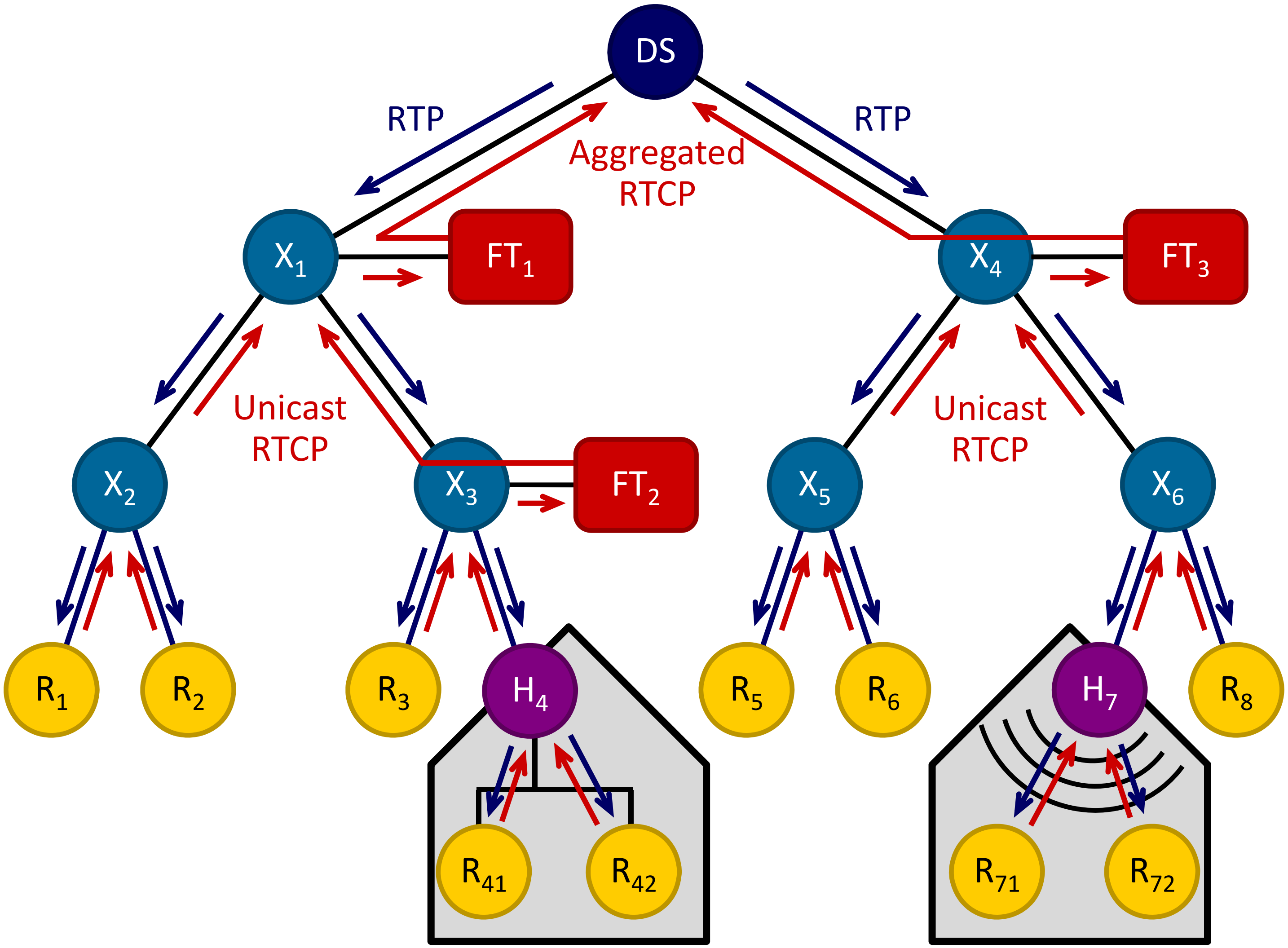
QoS/QoE Monitoring via Reports Collection

- **VQE-S collects RTCP reports and outputs them to the management application**
- **Management application**
  - Collects raw data from exporter
  - Organizes 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



Further Reading

- **Articles**

  "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

- **Related Specifications**

  http://www.ietf.org/dyn/wg/charter/avt-charter.html

  http://www.dvb.org/technology/standards/index.xml#internet

- **Industry Tests**

  Light Reading: IPTV & Digital Video QoE: Test & Measurement Update

  http://www.lightreading.com/insider/details.asp?sku_id=2382&skuitem_itemid=1181