Delivering Triple Play Over Broadband

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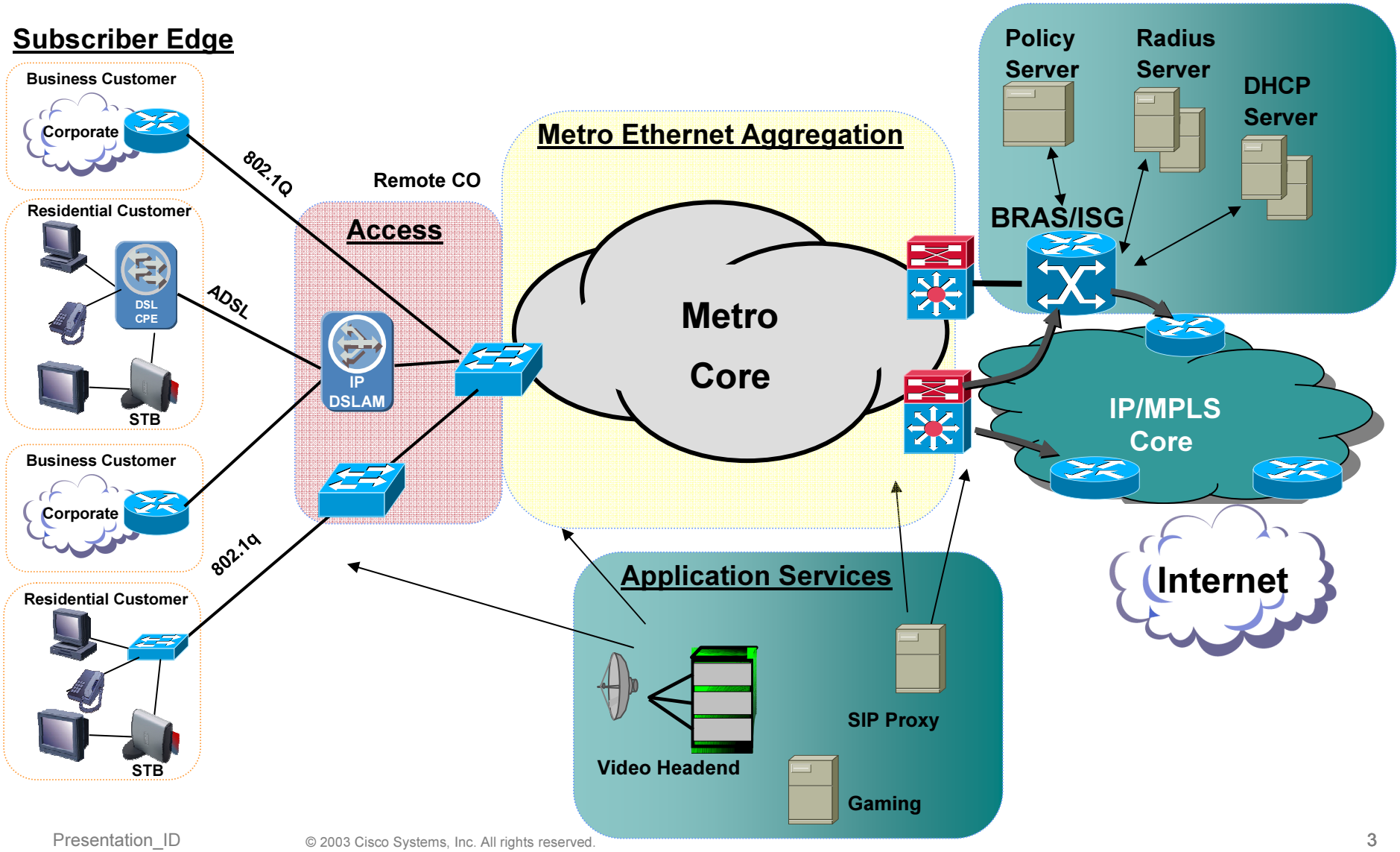
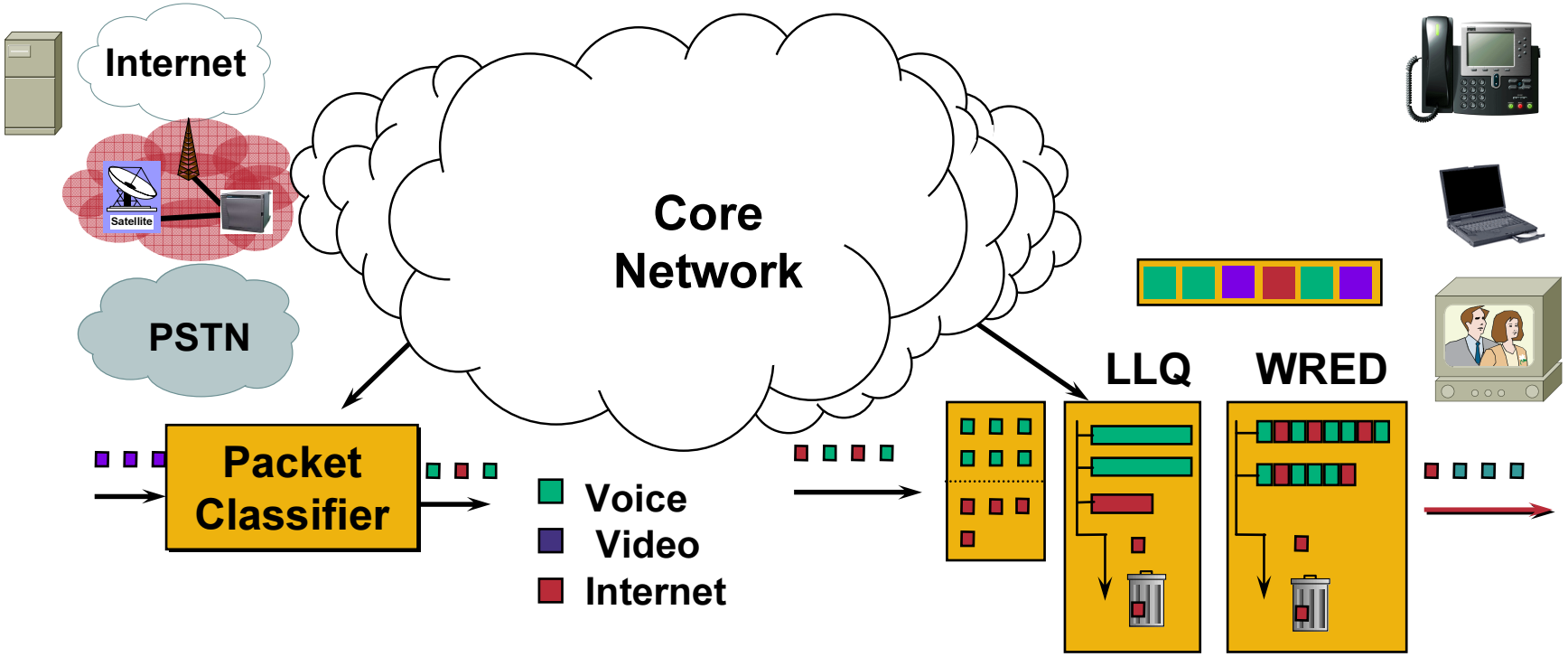
Agenda

- Triple play application requirements
- Triple play transport Architecture
- Home Access Gateway

Why so difficult to deliver new services ?

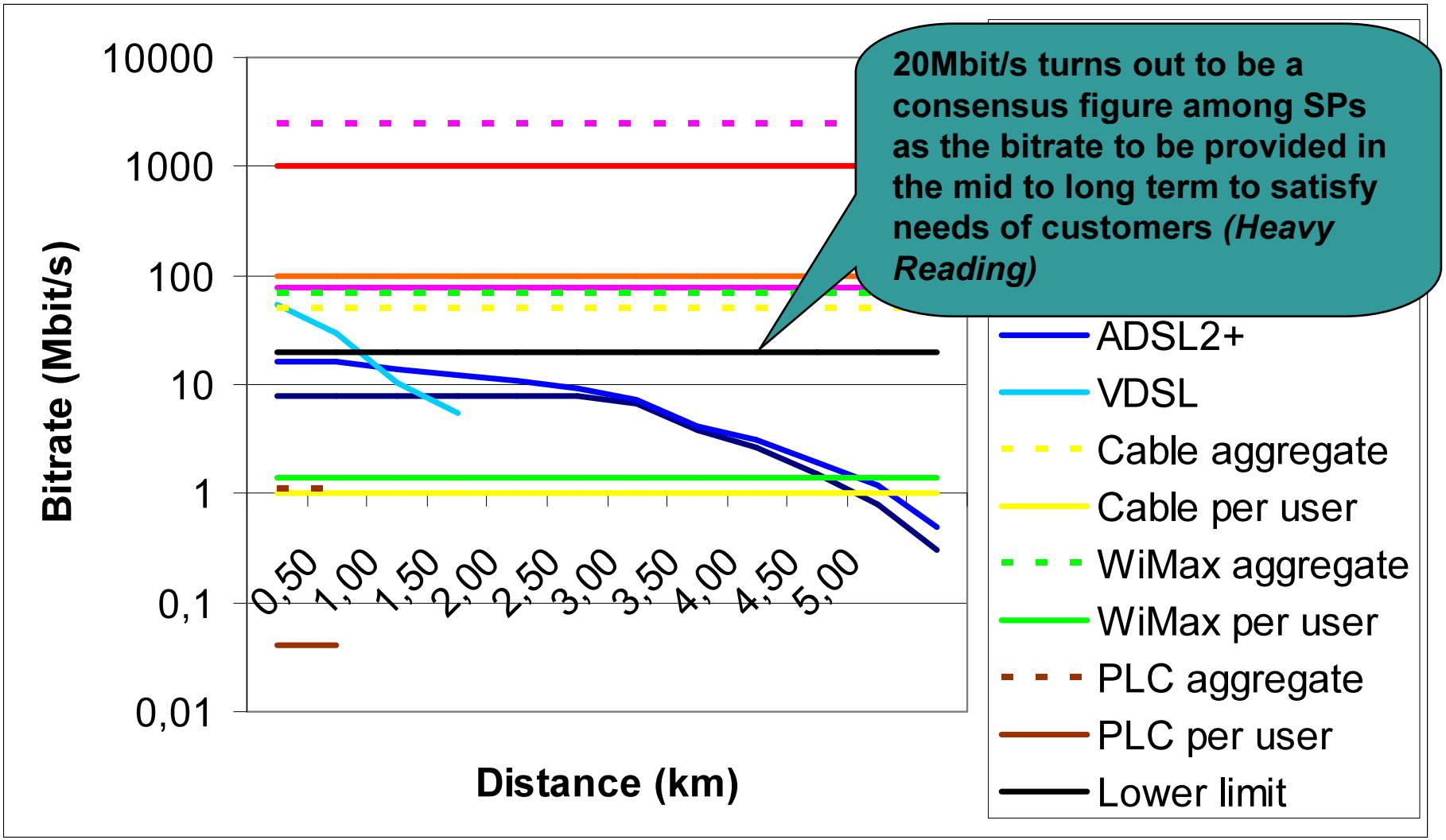


Multi-Service Network

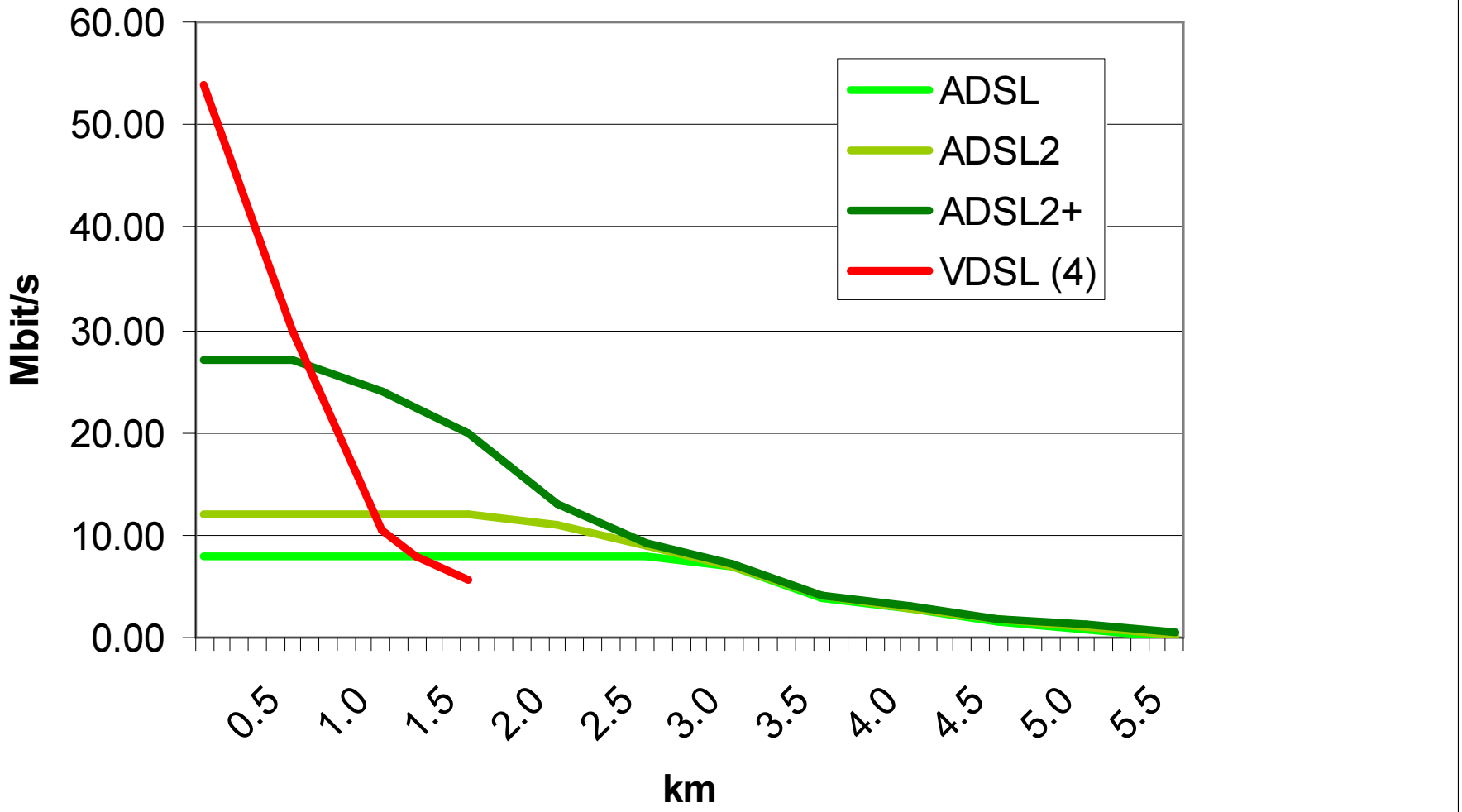


- Bandwidth
- Delay
- Jitter
- Packet Loss
- Out of Sequence Packet

Access Technology - Bandwidth



xDSL subscriber line



Voice Quality vs. Bandwidth

Compression Method	Bit Rate (kbps)	Processing (MIPs)	MOS Score	Compression Delay (msec)
G.711 PCM	64	0.34	4.1	0.75
G.726 ADPCM	32	14	3.85	1
G.728 LD-CELP	16	33	3.61	3-5
G.729 CS-ACELP	8	20	3.92	10
G.729a CS-ACELP	8	10.5	3.7	10
G.723.1 MPMLQ	6.3	16	3.9	30
G.723.1 ACELP	5.3	16	3.65	30

- **Mean Opinion Score (MOS) quantifies the performance of the speech CODEC. 5=excellent=no impairment, 4=good=just perceptable impairment (not annoying), 3=fair=percepable and slightly annoying, 2=poor=annoying but not objectionable,1=bad=annoying and objectionable**

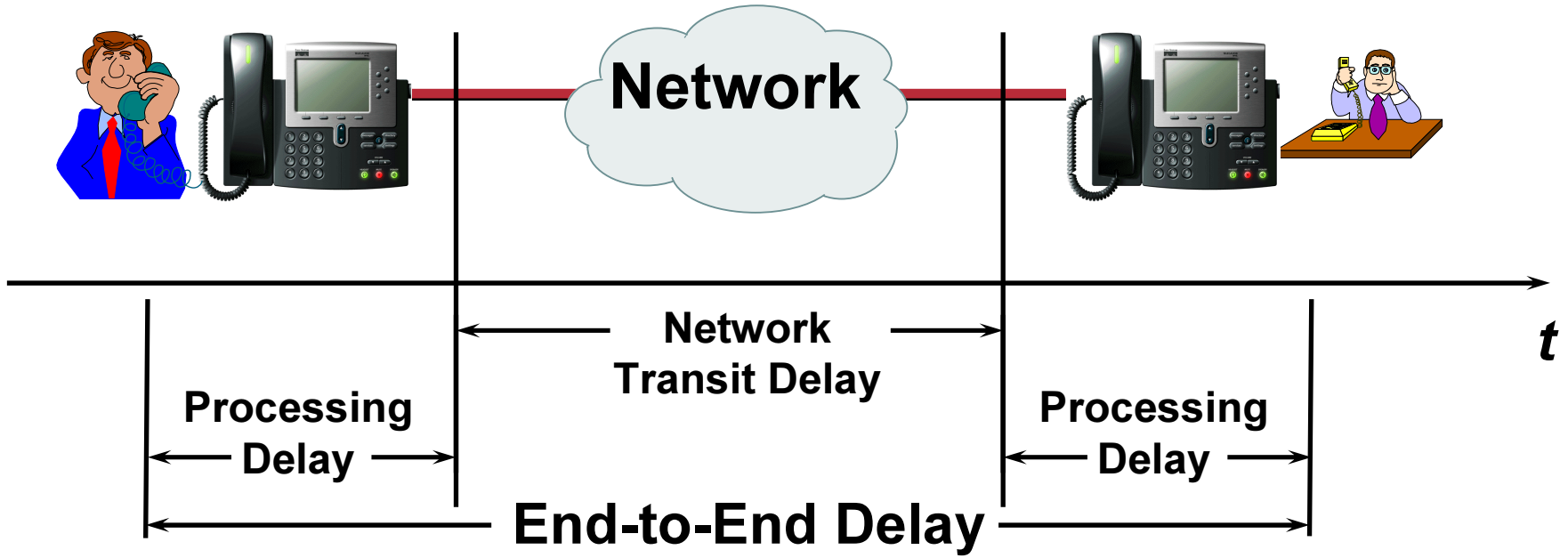
Video Bandwidth Requirement

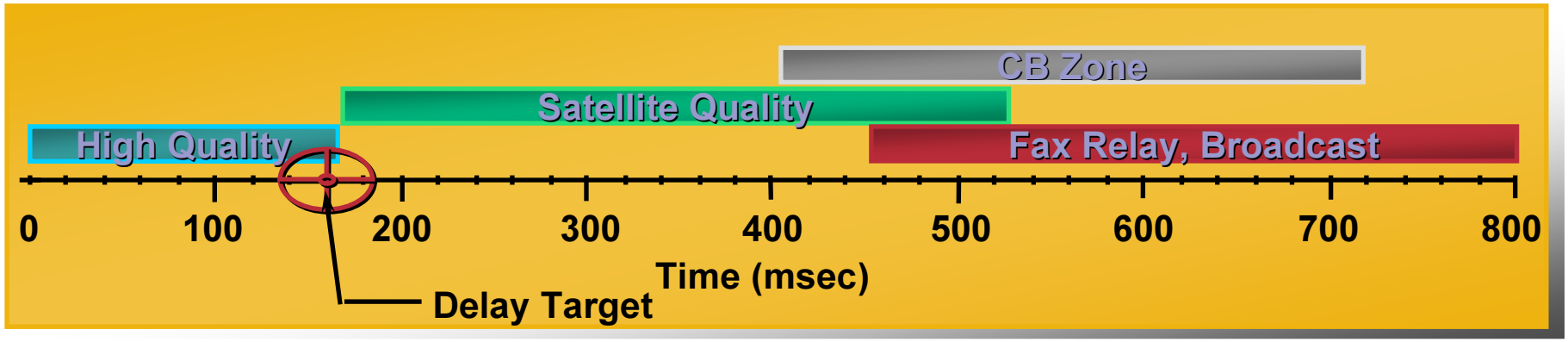
- MPEG-2 – 4 Mbps per channel
- MPEG-4 – 1.5 Mbps per channel
- H.264 – 1 Mbps per channel
- HDTV – 6 Mbps per channel

Video Broadcast vs. On Demand Requirements

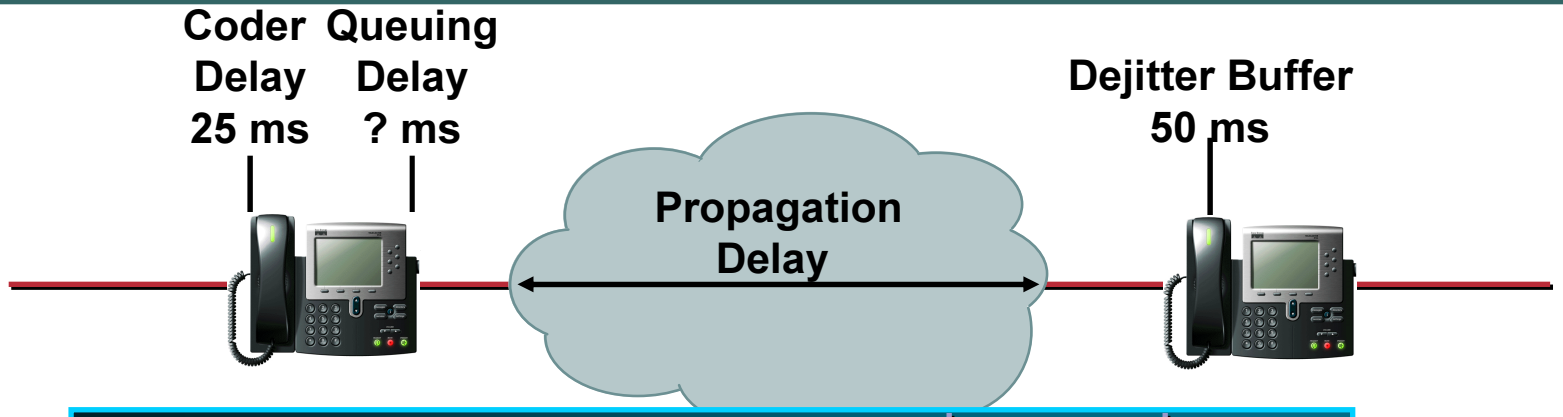
- Broadcast B/W < On Demand in Distribution Network
- Broadcast B/W Based on # Channels
  - 300 MPEG-2 Channels ~= 1 Gigabit
- On Demand B/W Based on # Subscribers
  - 20,000 Video Subscribers * 10% Peak ~= 7.5 Gigabit
- Broadcast Availability > Higher Than On Demand
- Broadcast Must Not Be Affected in Event of Link Failure
  - Engineer Links for > 2X Max Broadcast B/W
- VoD May Be Affected in Event of Link Failure
  - May Engineer Links for < 2X Max VoD B/W
- Drop VoD First in Event of Link Congestion
  - Must Drop Subset of all VoD Flows

Delay – Real-Time Application



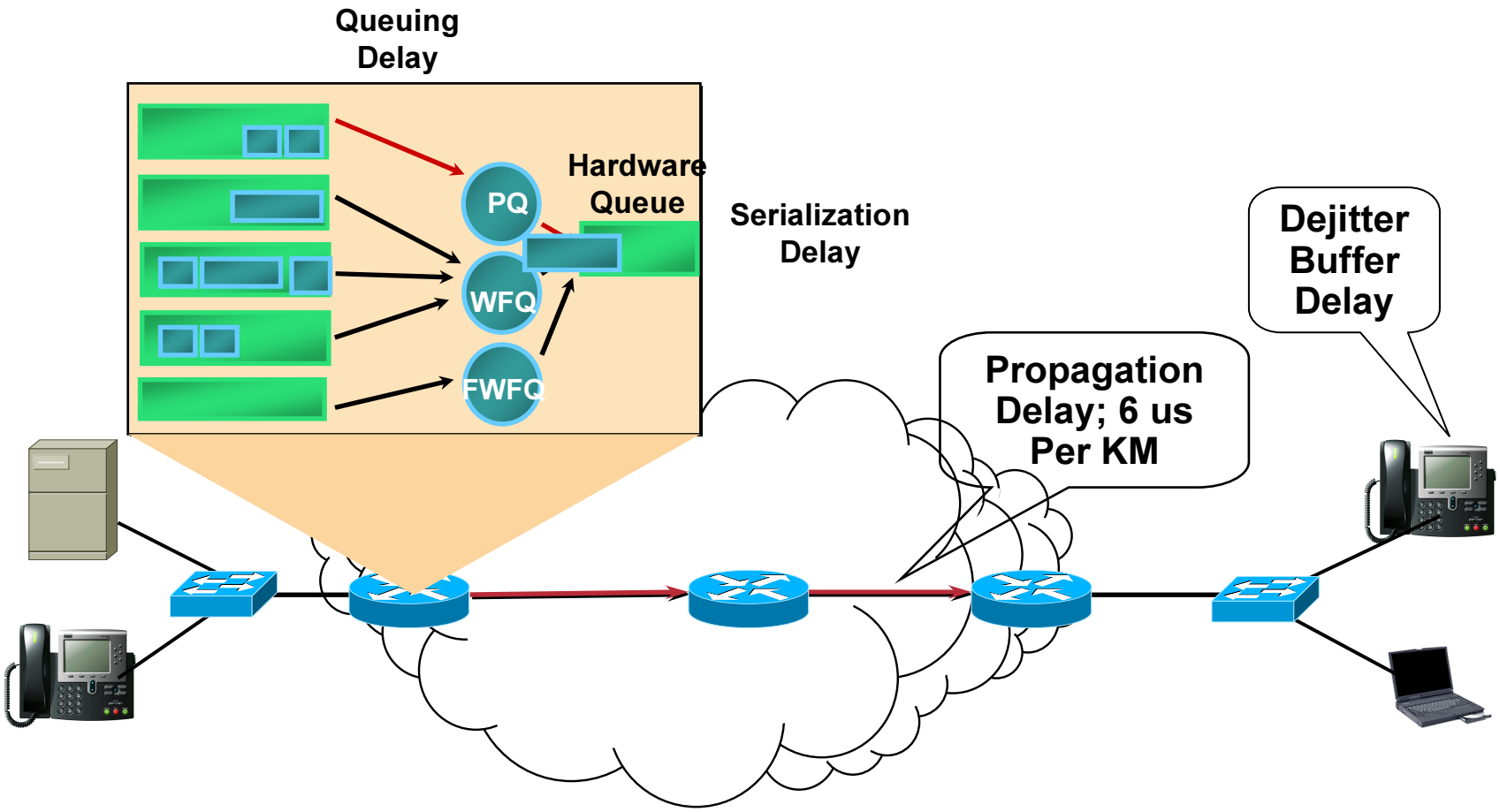


Calculate Delay Budget



	Fixed Delay	Variable Delay
Coder Delay G.729 (5 msec look ahead)	5 msec	
Coder Delay G.729 (10 msec per frame)	20 msec	
Packetization Delay—Included in Coder Delay		
Queuing Delay		? msec
Serialization Delay		
Propagation Delay		
Network Delay	25 msec	
Dejitter Buffer	50 msec	
Total	? msec	

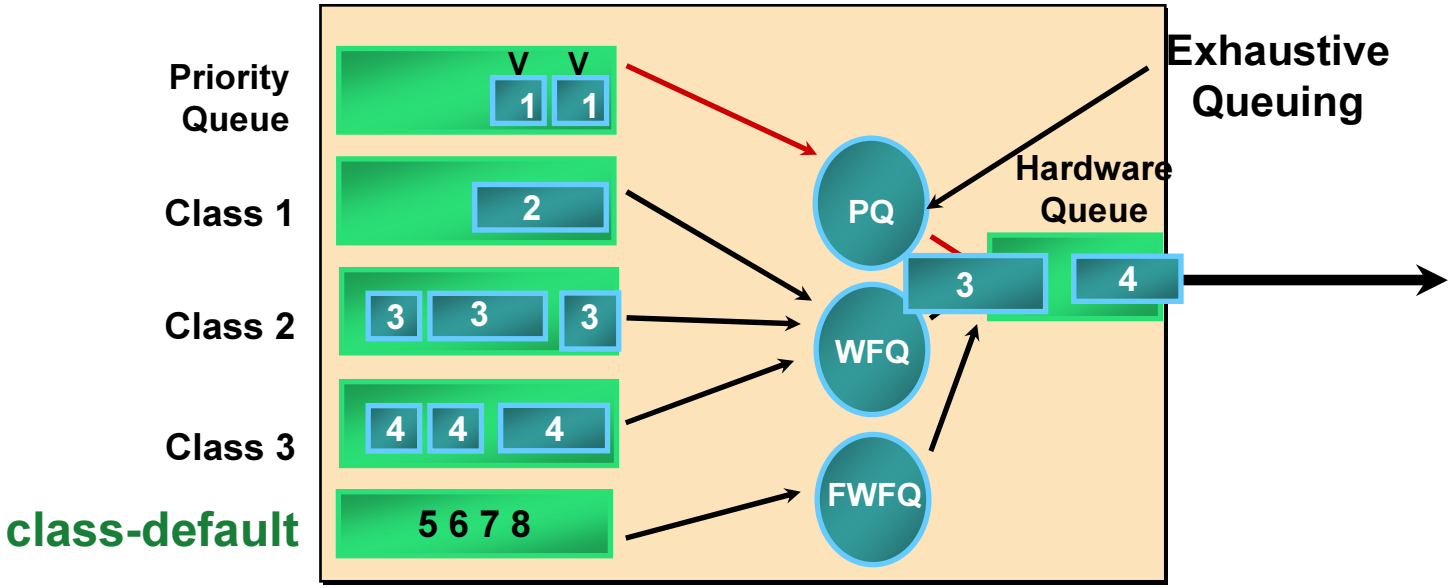
Delay



Fixed Frame Serialization Delay

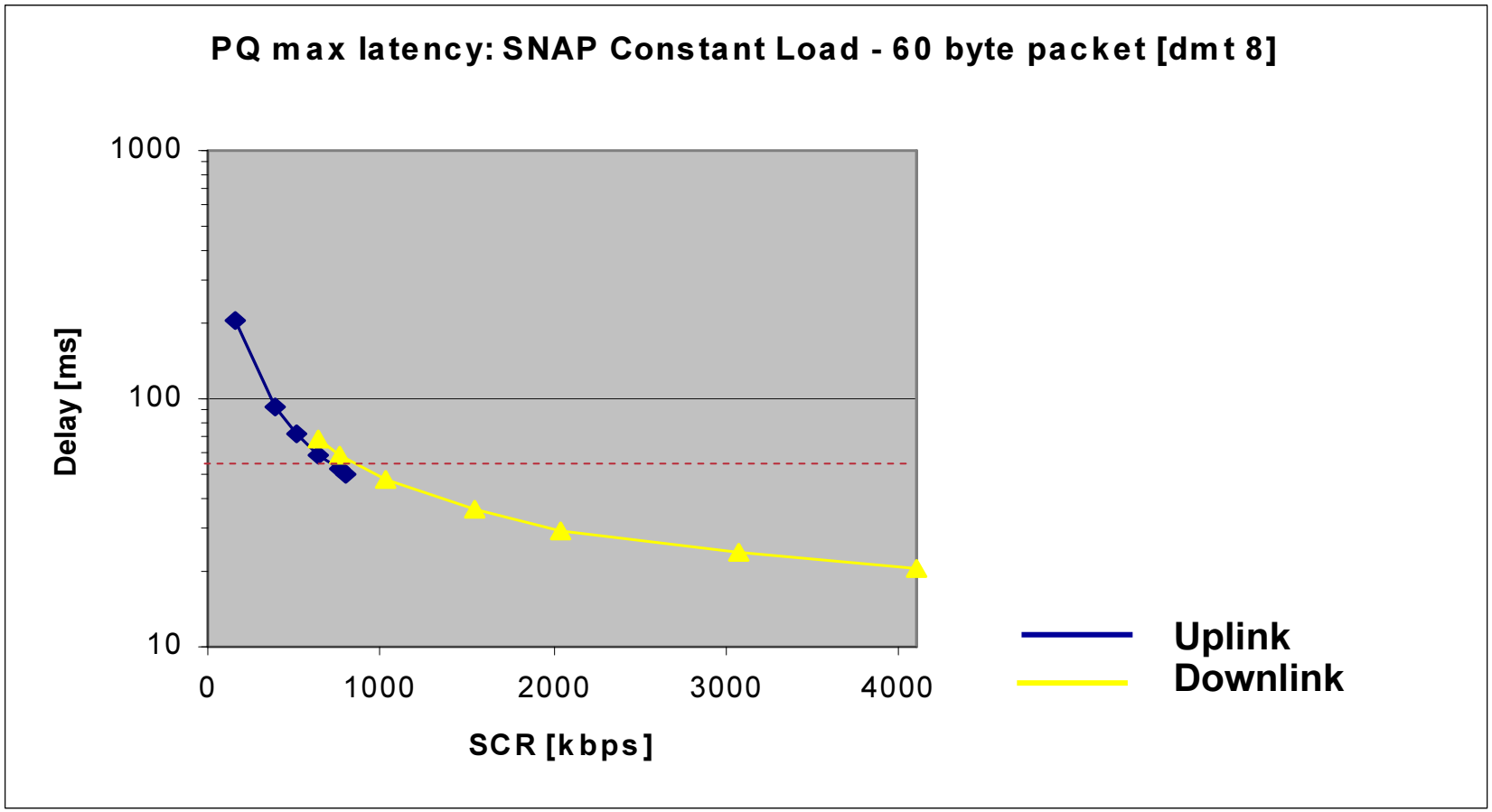
		Frame Size						
		1 byte	64 byte	128 bytes	256 bytes	512 bytes	1024 bytes	1500 bytes
	56 kbps	143 us	9 ms	18 ms	36 ms	72 ms	144 ms	214 ms
	64 kbps	125 us	8 ms	16 ms	32 ms	64 ms	128 ms	187 ms
Link	128 kbps	62.5 us	4 ms	8 ms	16 ms	32 ms	64 ms	93 ms
Speed	256 kbps	31 us	2 ms	4 ms	8 ms	16 ms	32 ms	46 ms
	512 kbps	15.5 us	1 ms	2 ms	4 ms	8 ms	16 ms	23 ms
	768 kbps	10 us	640 us	1.28 ms	2.56 ms	5.12 ms	10.24 ms	15 ms
	1536 kbps	5 us	320 us	640 us	1.28 ms	2.56 ms	5.12 ms	7.5 ms

Low Latency Queuing

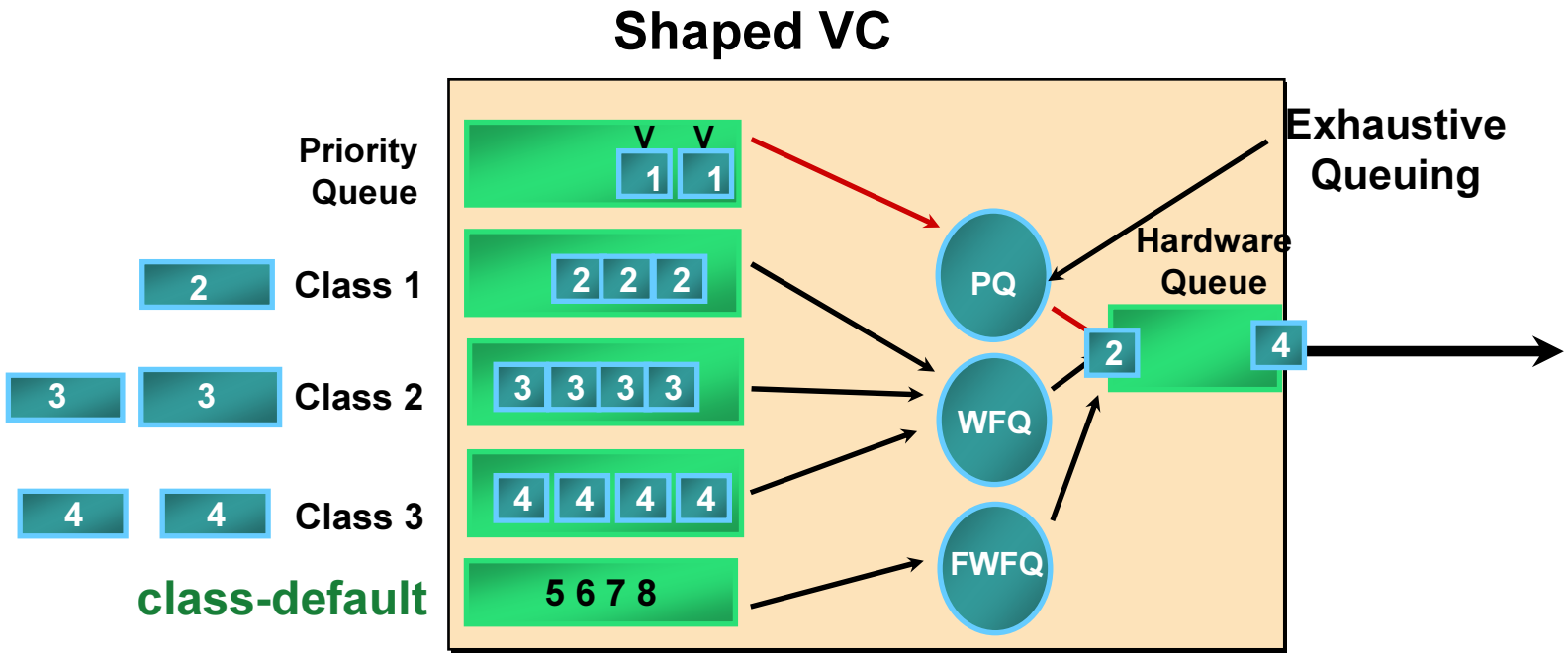


Worst case delay – LLQ

- **Fragmentation scheme is needed to mitigate serialisation delay**

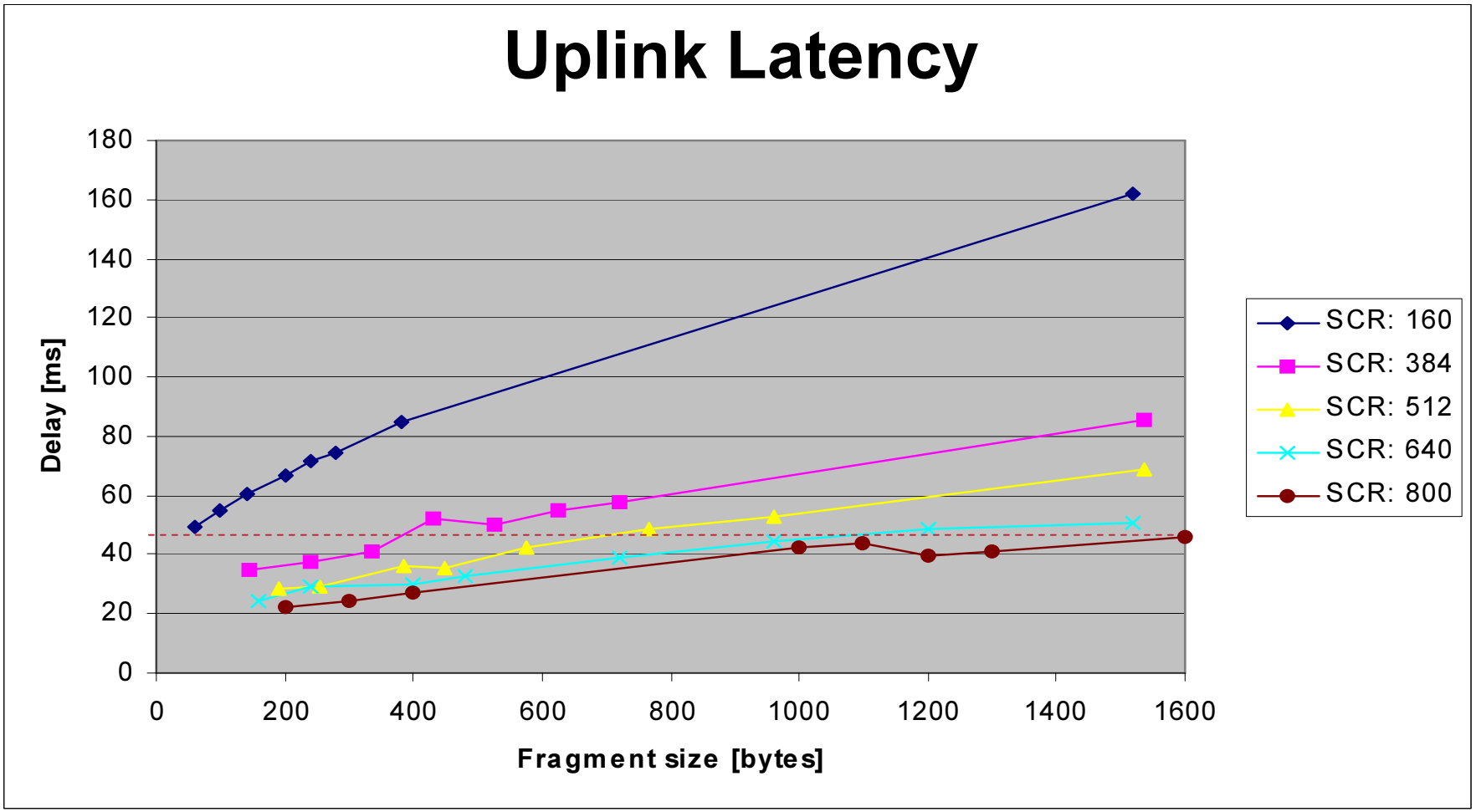


Low Latency Queuing + MLP/LFI



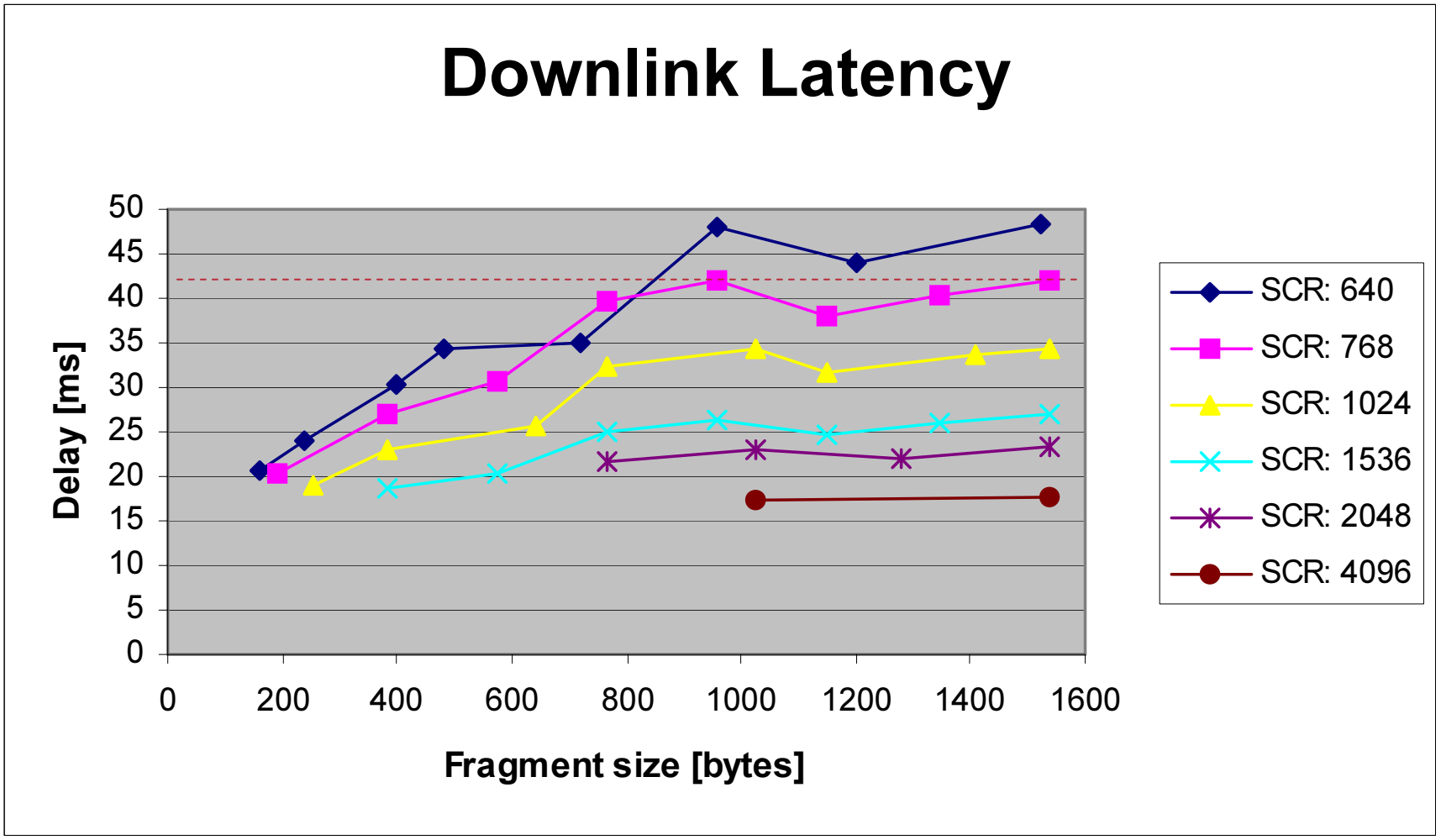
Example : Priority queue 25% of the VC Bandwidth

Worst case delay – LLQ + Fragmentation/Interleaving



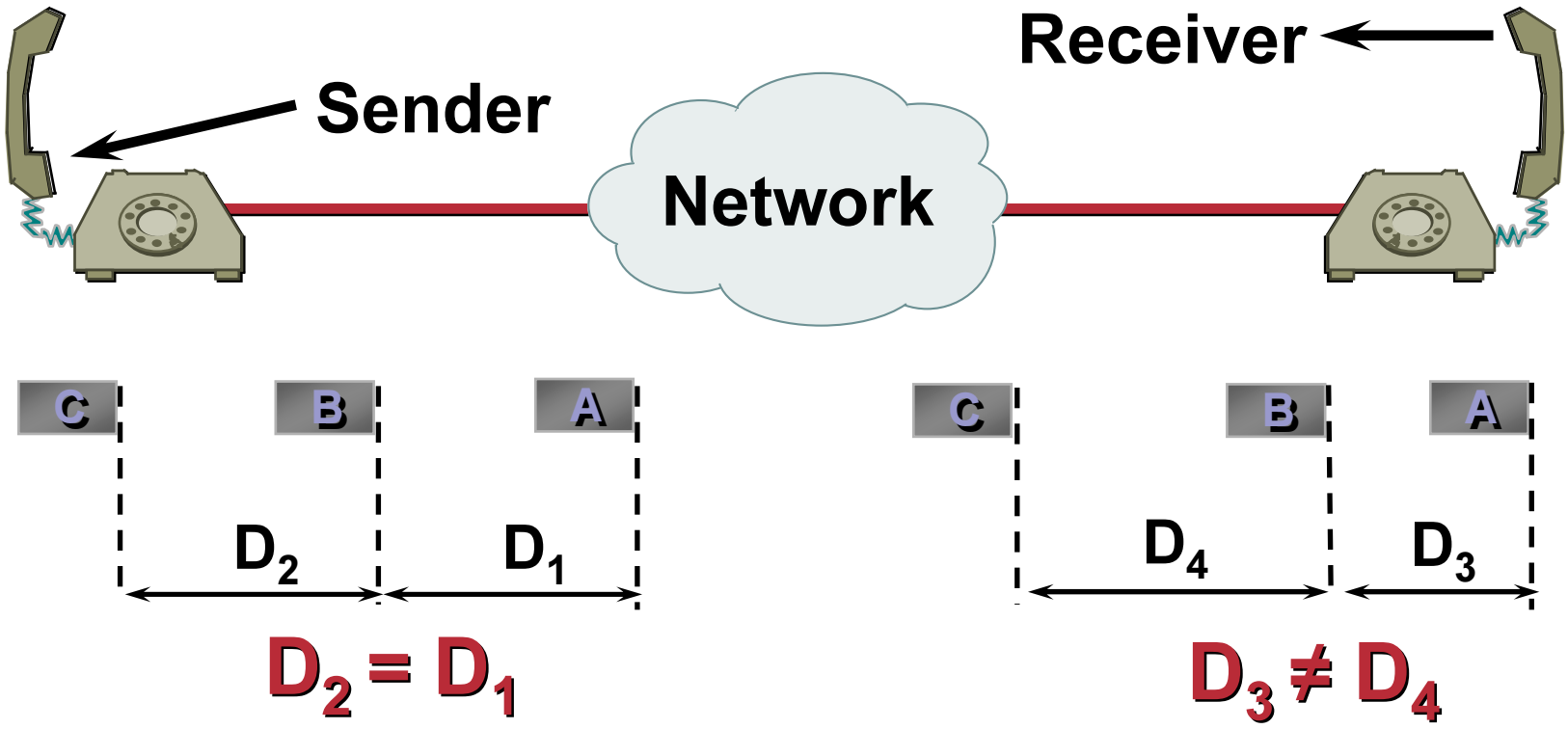
Home Gateway to BRAS

Worst case delay – LLQ + Fragmentation/Interleaving



BRAS to Home Gateway

Jitter – Delay Variation



- **Adaptive jitter buffers (20-50 msec) in end points**

Jitter – Delay Variation cont.

- Video
  - Allowed Jitter ~= 200 Msec
  - Large STB de-jitter buffer
  - Use DiffServ AF PHB
- Voice
  - Allowed Jitter ~= 60 Msec
  - Use DiffServ EF PHB; Priority Queue

Packet Loss – Video

- **Video is compressed**
  - Each Packet Carries Multiple Frames, any loss likely causes visible artifact for a varying amount of time
- **Loss of 1 Packet Causes Various Artifacts**
  - (B-Frame Hit) = Pixelization For 1 frame – min
  - (P-Frame Hit) = A Few Frames Affected (100 msec) – intermediate
  - (I-Frame Hit) = Screen Freezes for Up to 1 Sec – Bad
  - Some Codecs Loose Sync Due to Packet Loss, Screen Freezes for Many Seconds – Very bad
  - Rule of thumb is no more than one artifact per 2 hour movie Allowed Packet Loss Ratio ~= 10**-6

Packet Loss – Bit Errors in DSL

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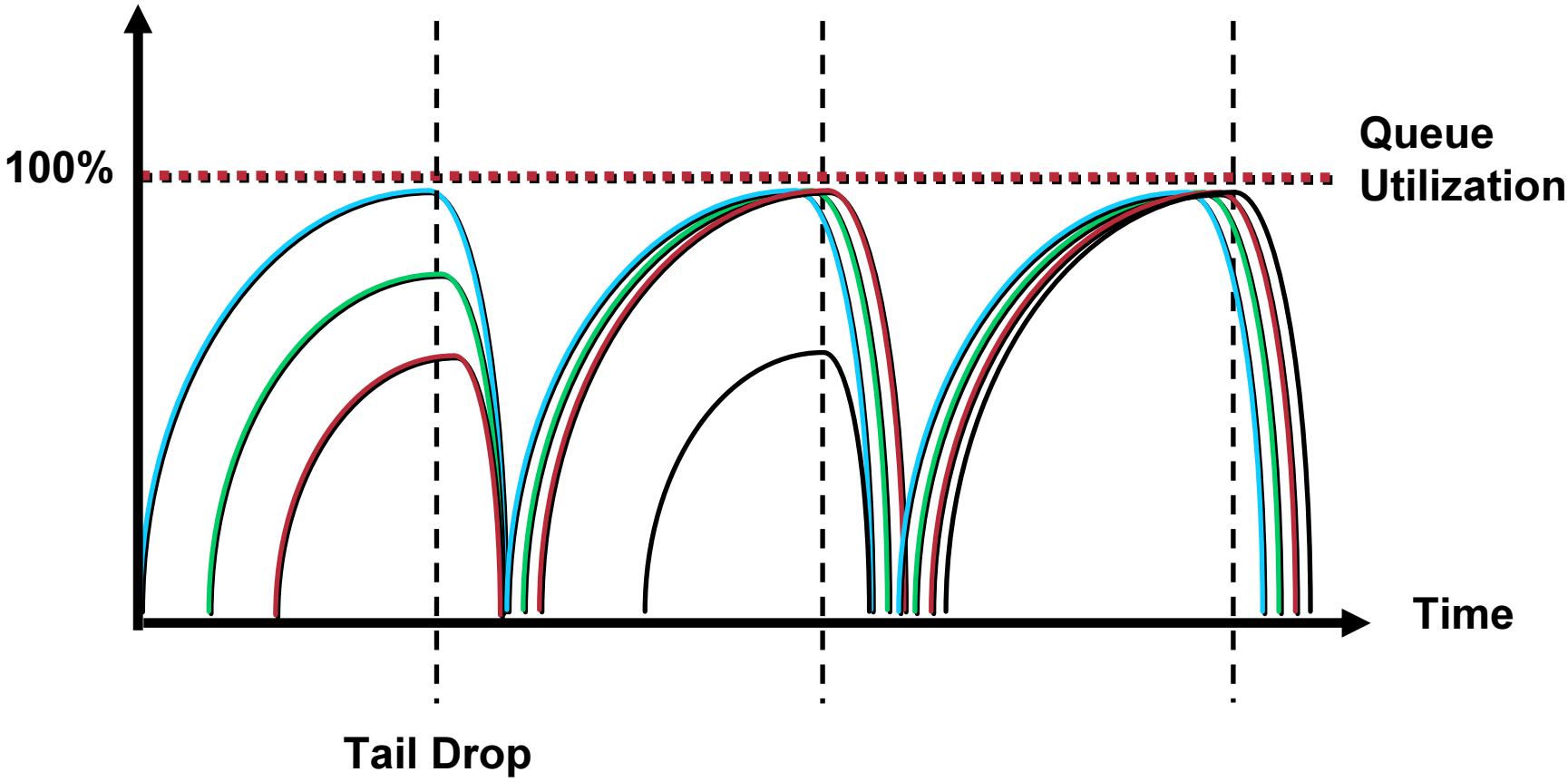
- **Causes for Packet Loss**
  - Set Top Box Jitter Buffer Overflow, Underflow
    - QoS in Routers Prevents This
  - Router Buffer Overflow
    - Admission Control + QoS Prevents This
- **Bit Errors on Physical Links**
  - 10^{-6} Packet Loss Ratio ≈ 10^{-10} Bit Error Rate
- **Optical Links – Engineered to 10^{-14} BER**
  - Insignificant Source of Loss
- **DSL Line – Guarantees 10^{-7} BER >> 10^{-6} PLR**
  - Noise in Copper Loop
  - Modem Retrains if BER > 10^{-7}
  - BER= 10^{-7} – One video Glitch Every 2 Minutes ; not Acceptable for Commercial Video Service

Packet Loss – VoIP

Consecutive Frames Lost:	1	2	3	4	5
M.O.S. :	4.2	3.2	2.4	2.1	1.7

- Allowed Drop Rate ~= 10**-2
- Use Priority Queue

Packet Loss – Data



Video Queue Recommendations

- Use Weighted Queue and Provide Maximum Buffering
- Provide 200 msec of buffer for worst case flow
- Provide 20 msec of buffer for average video flow
- Video Queue Size = Link Speed * 20 msec * Video Link Util

  For 1 GigE and 70% Video Link Util

  Video Queue Size = 1 GigE * 20 msec * .7 = 1.75 Mbytes

QoS Recommendation

- **Queue Recommendations In Aggregation / Distribution**
  - Voice = COS 5 = Priority Queue
  - Video = COS 4, COS 2, COS 1 = Weighted Queue
    - Weight = 80% Link Util
    - Video Util Must be < 70% of Link
    - Queue Size (Bytes) = Link Speed * 20 msec * Video Link Util
    - Thresholds From Previous Slide
  - Voice / Video Signaling = COS3 = Weighted Queue
    - Weight = 5% Link Bandwidth
  - Internet Access = Weighted Queue
    - Weight = 15% Link Bandwidth
- **QoS Recommendations On Access Links using ATM CoS**
  - Voice = CBR
  - Broadcast + On Demand Video = VBR
  - Internet Access = UBR

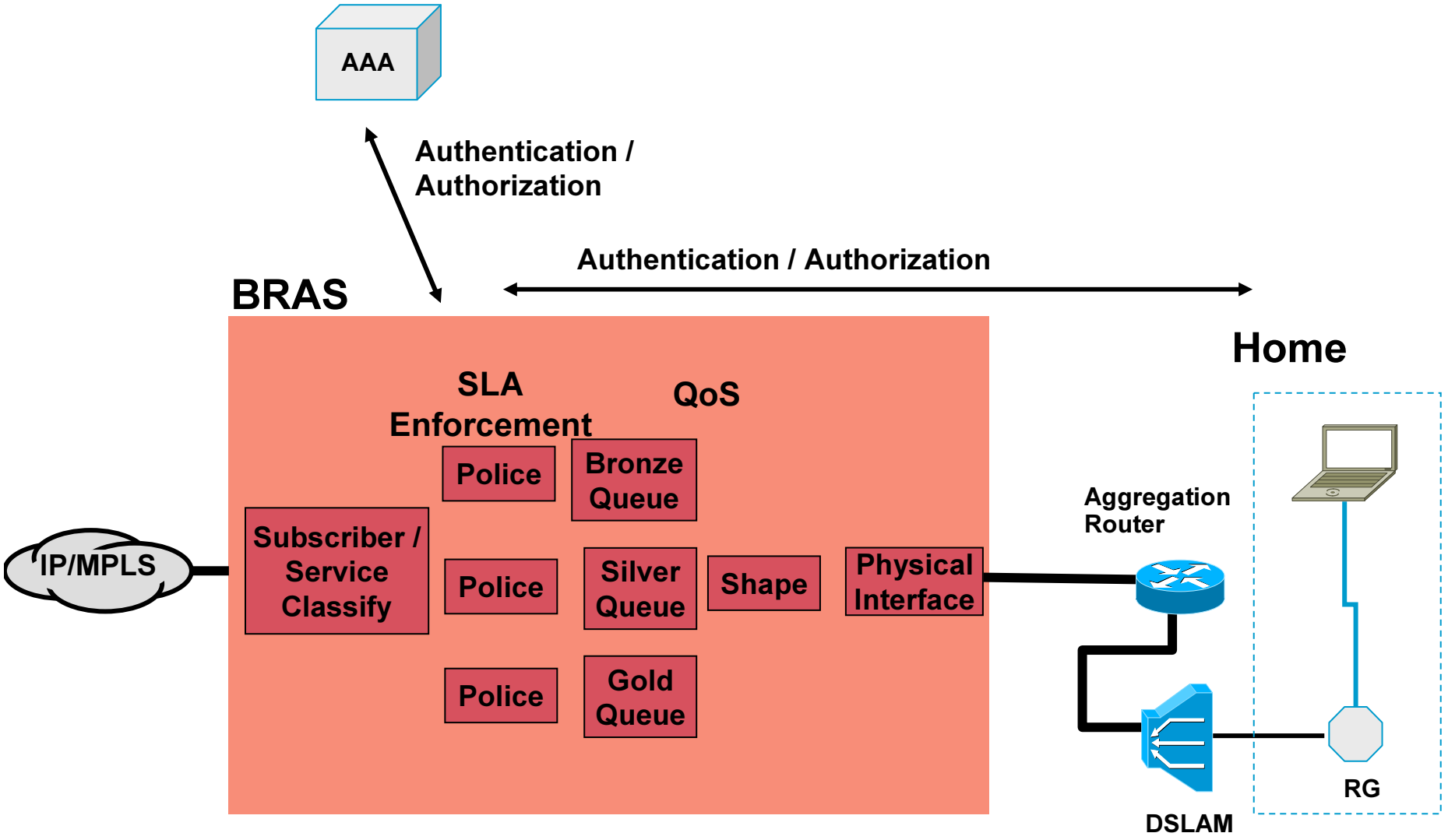
Agenda

- Triple play application requirements
- Triple play transport Architecture
- Home Access Gateway

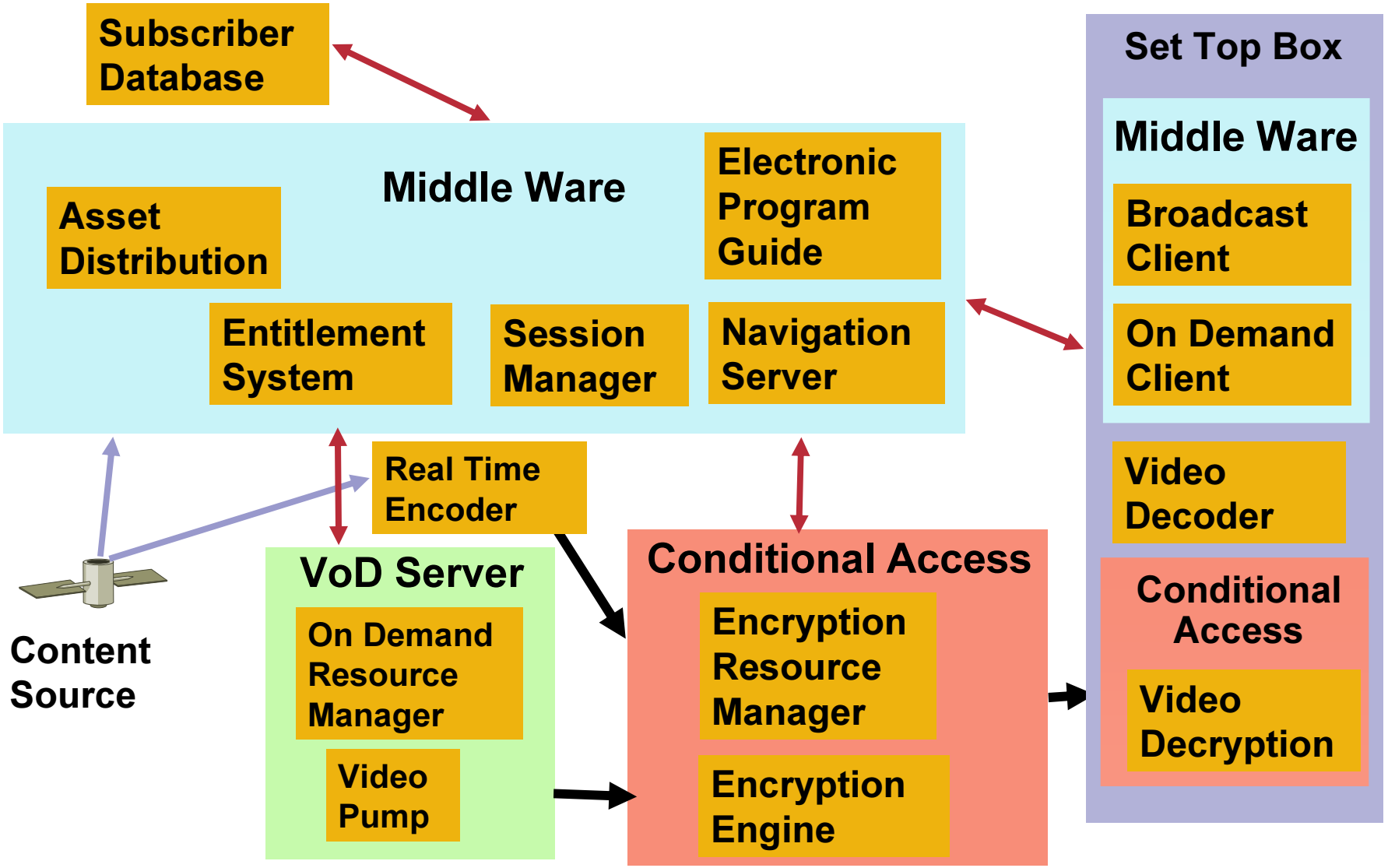
Application vs. Transport Services

- **Internet Access is offered as Transport Service**
  - **Max Bandwidth, Latency, drop etc.**
  - **PPPoE, 802.1x, DHCP option 82, per subscriber VLAN**
  - **Subscriber Device (PC) is Unmanaged**
- **Residential Video Typically Sold as an Application Service**
  - **Max Video Streams, Basic vs. Premium Channels, etc.**
  - **AAA – Video Middleware**
  - **Subscriber Device (Set Top) Managed by Provider**

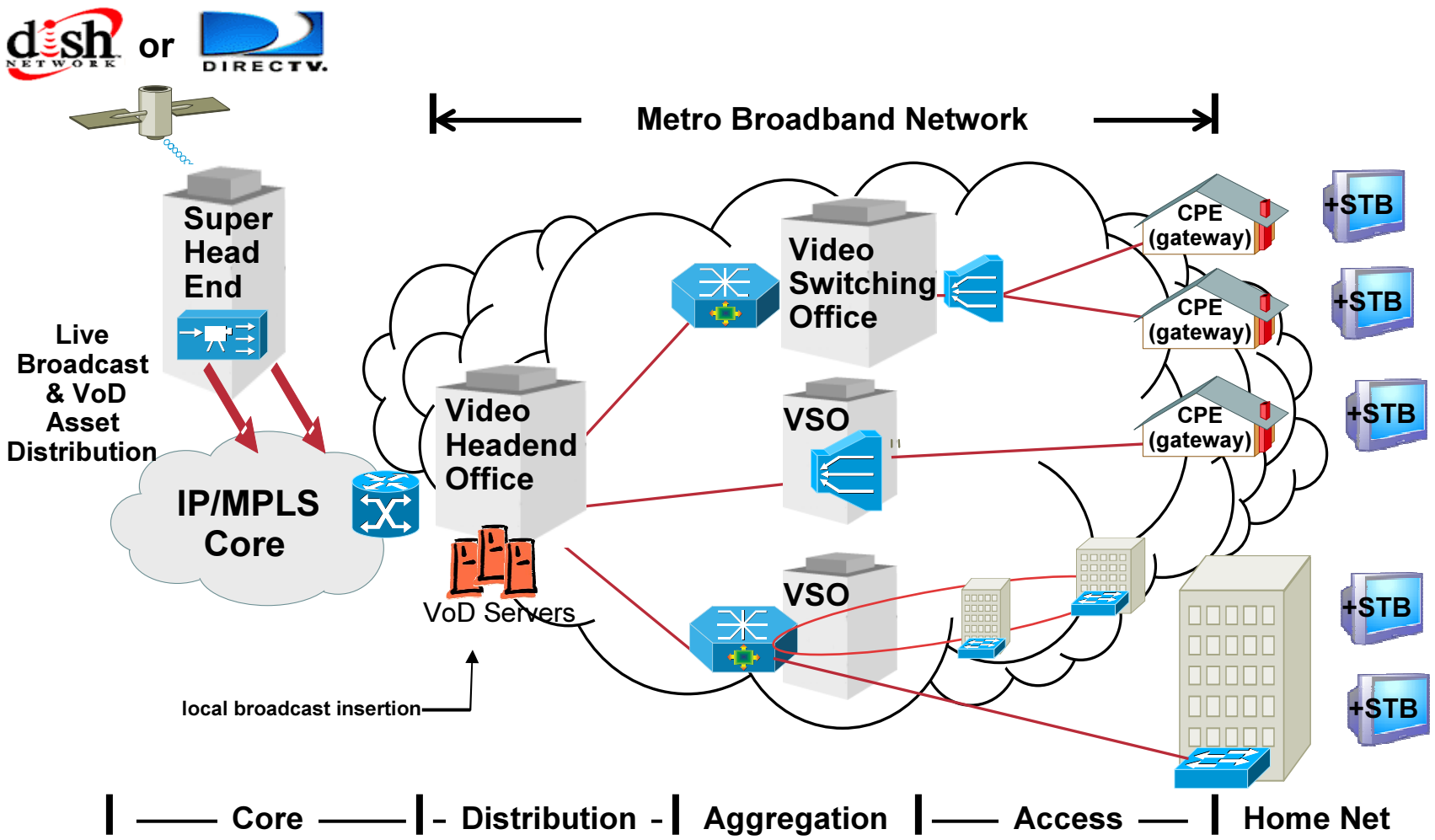
Internet Access Transport



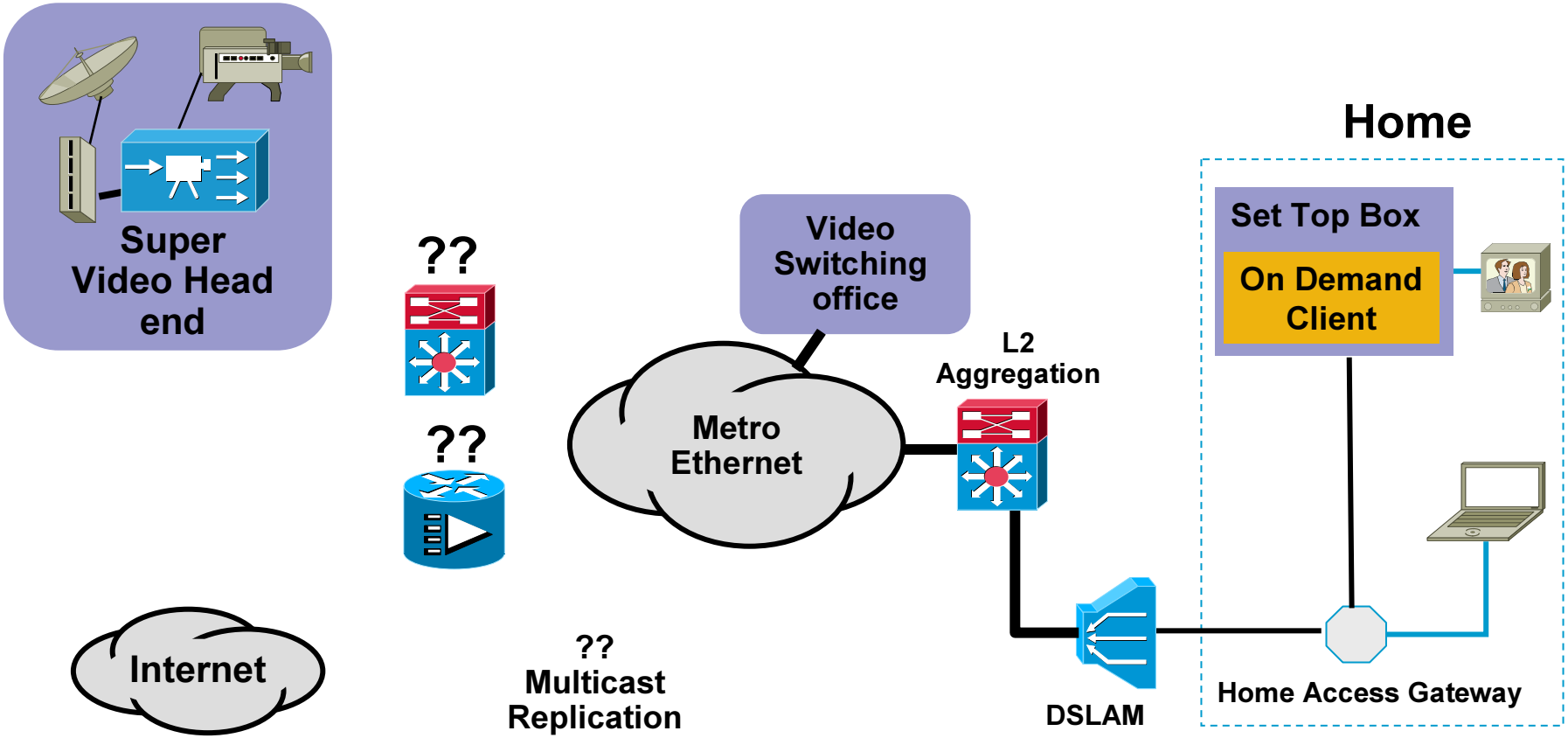
Video over Broadband Components



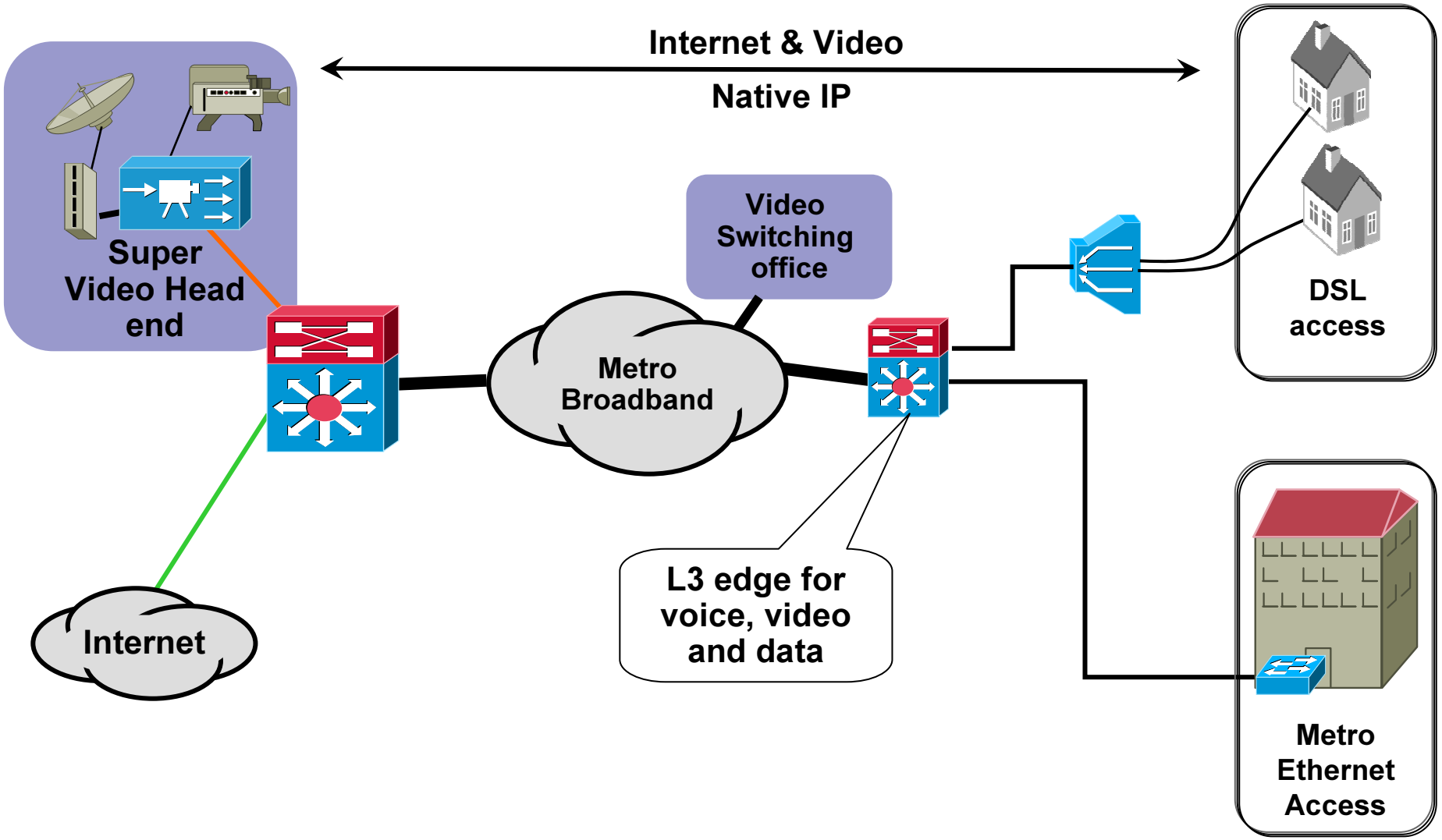
Video over Broadband Transport Architecture



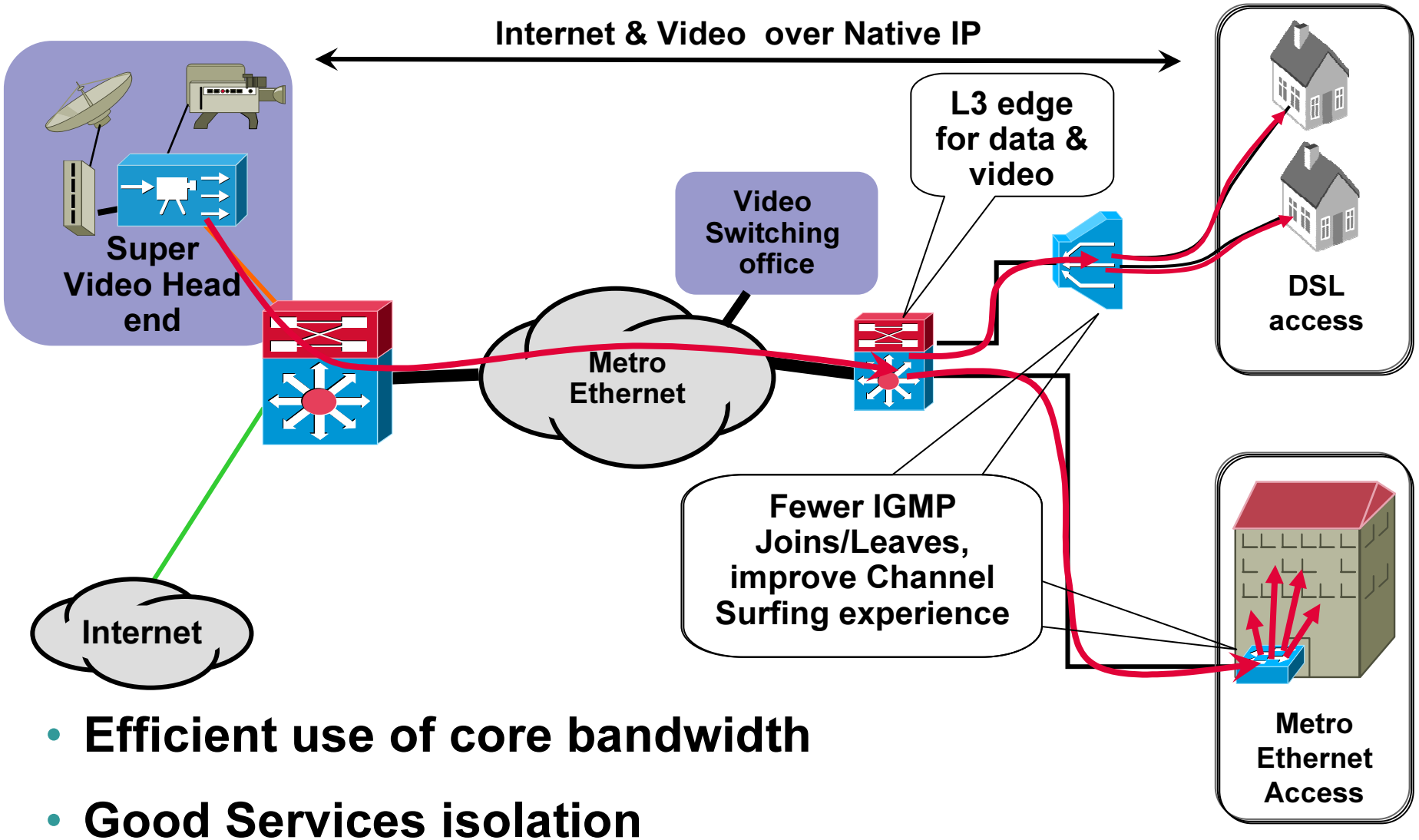
The Combined Architecture ?



Internet Access & Video over Native IP

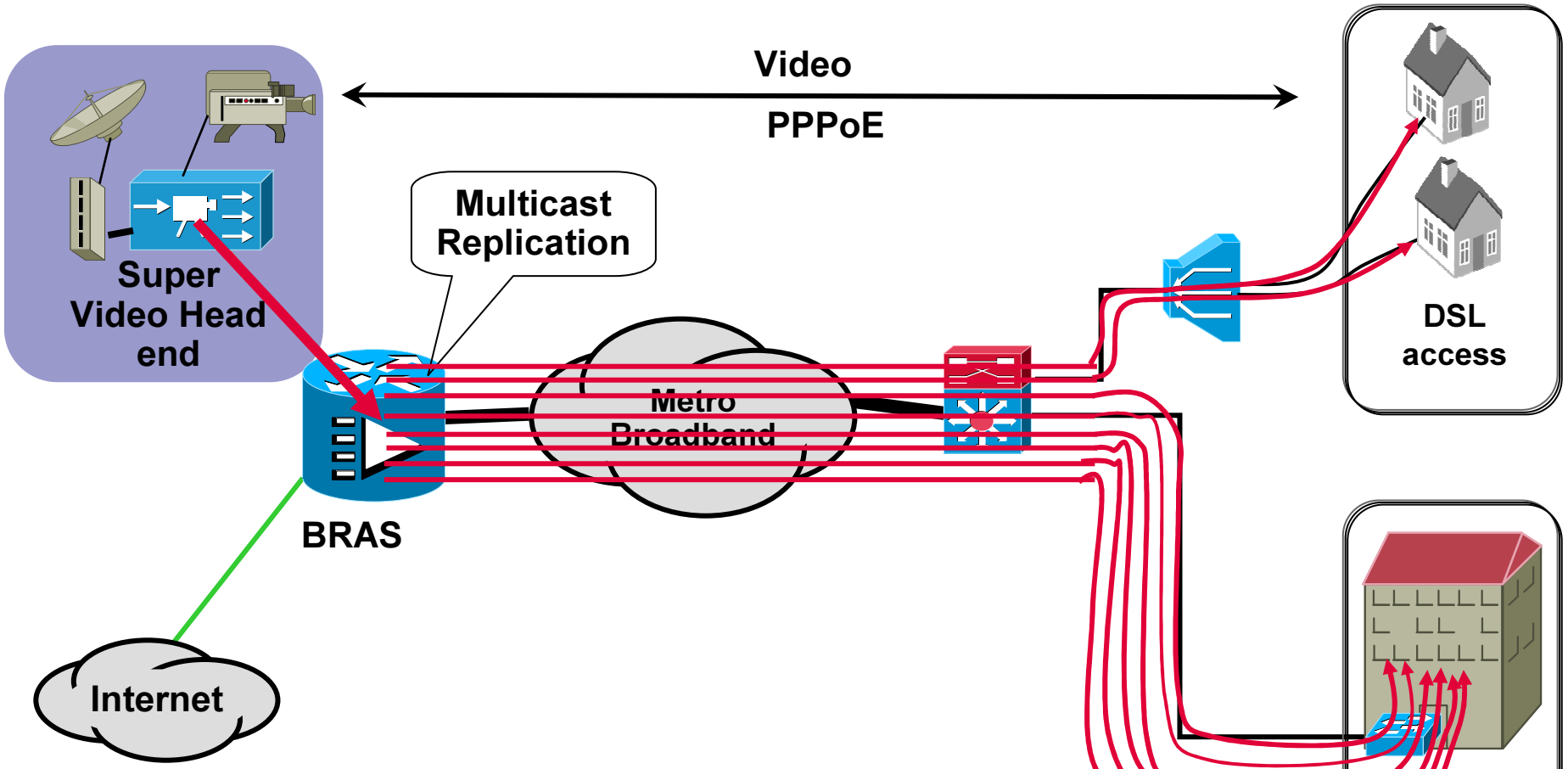


Internet Access & Video over Native IP



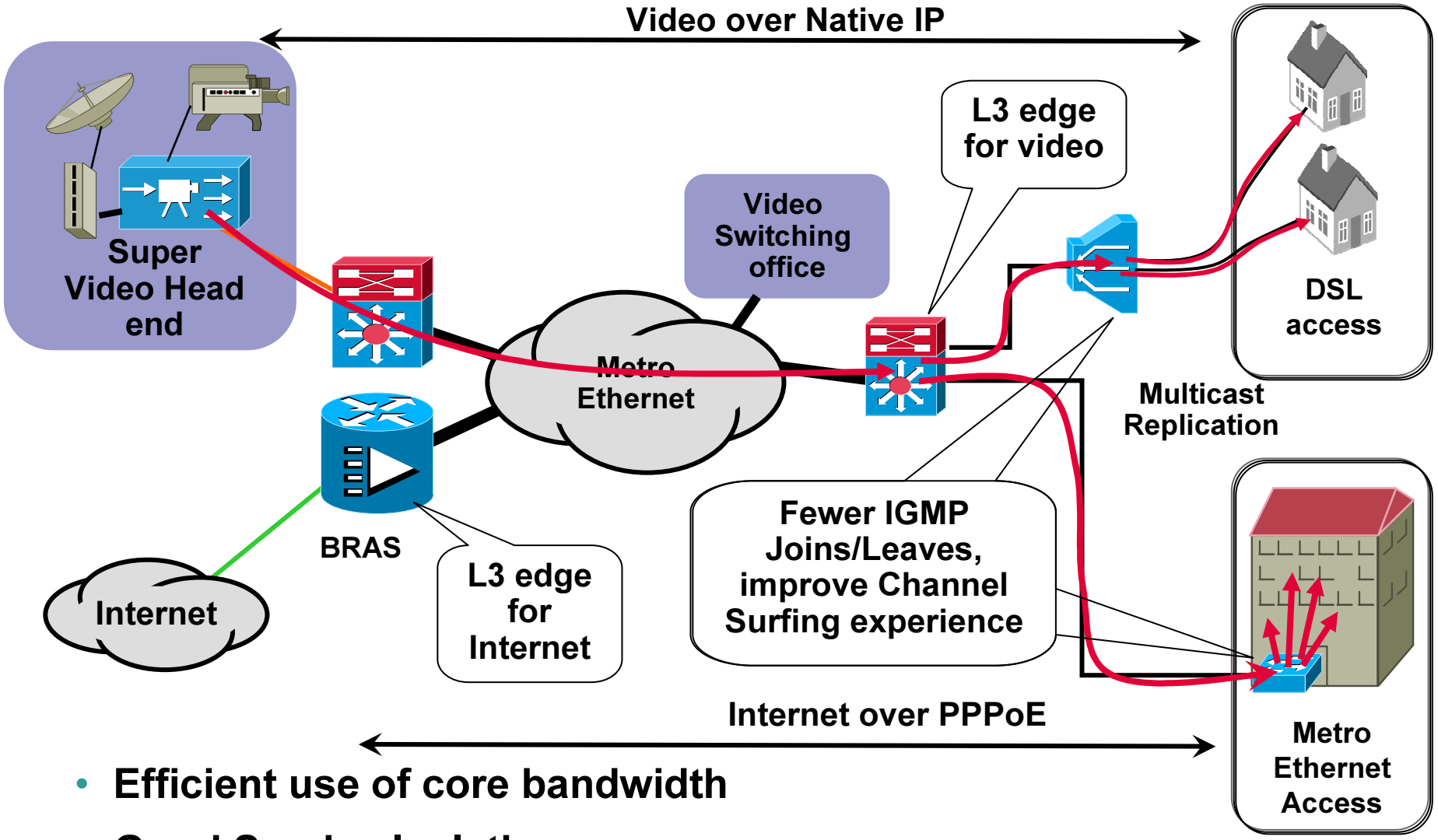
- **Efficient use of core bandwidth**
- **Good Services isolation**

Internet Access & Video over PPPoE



- Inefficient use of core bandwidth
- Substantially increase number of MAC addresses on the network, potential switch MAC table overflow

Internet Access over PPPoE + Video over Native IP

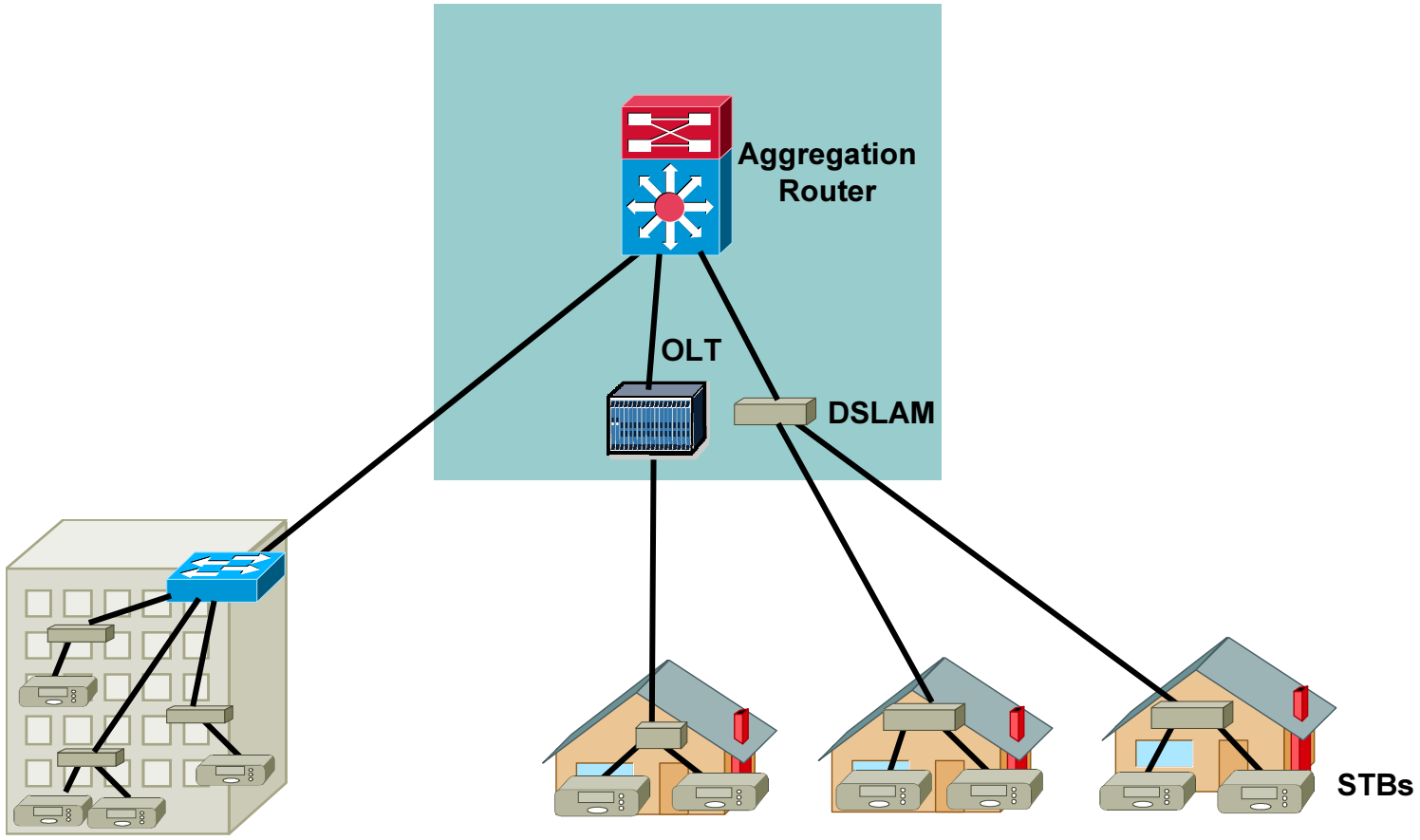


- Efficient use of core bandwidth
- Good Service Isolation

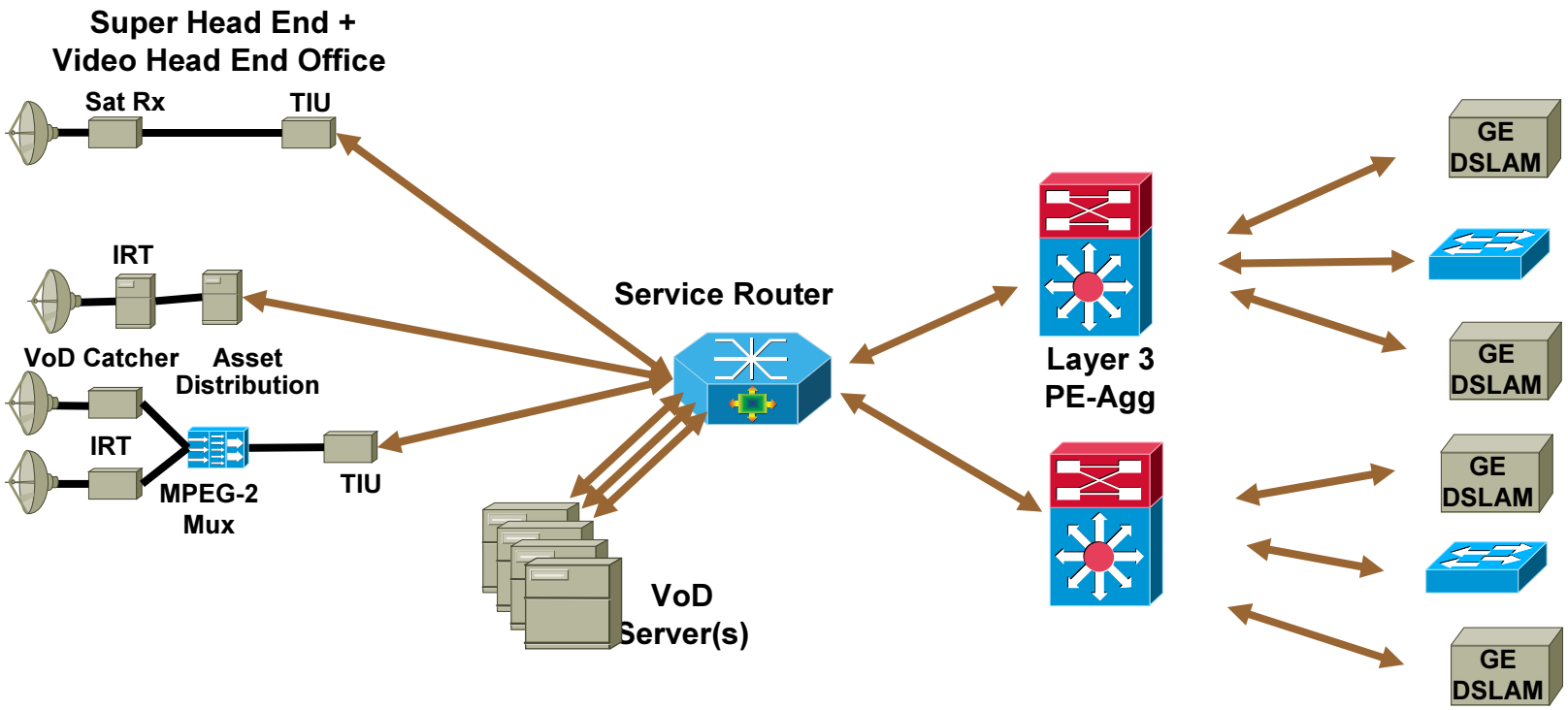
Recommendations

- Separate VLANs for Video / Internet Access
- VLANs Terminated at Different Layer 3 Edge Nodes
  - Internet Access = BRAS
  - Video Broadcast + Video On Demand = Aggregation Router
- Simplifies Set Top Implementation
  - Single Encapsulation (Native IP) for All Video Services
- Simplifies QoS Architecture
  - BRAS Hierarchical QoS Not Used for Bandwidth Guarantees

Edge Transport

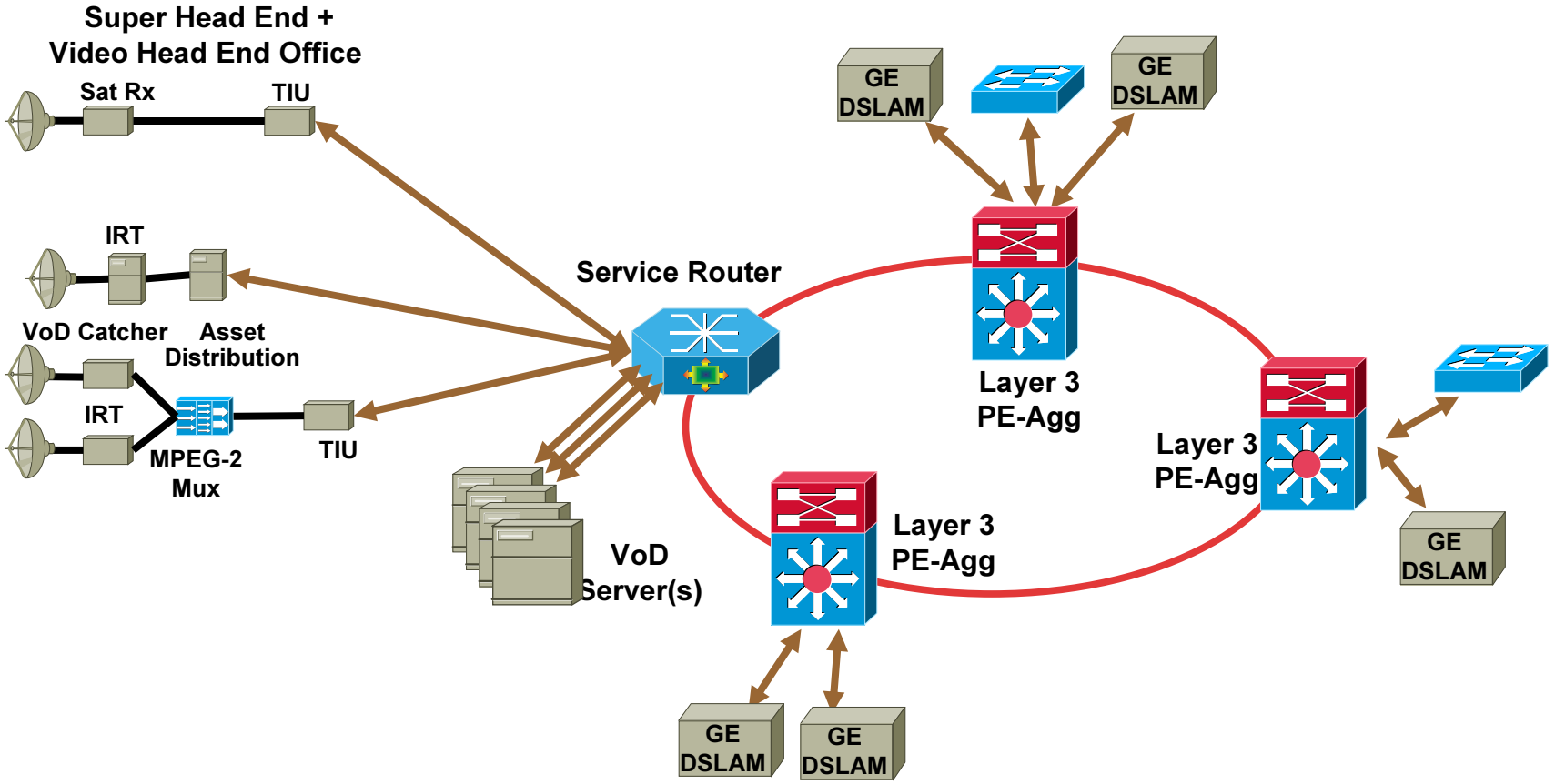


Distribution Architecture – Hub & Spoke

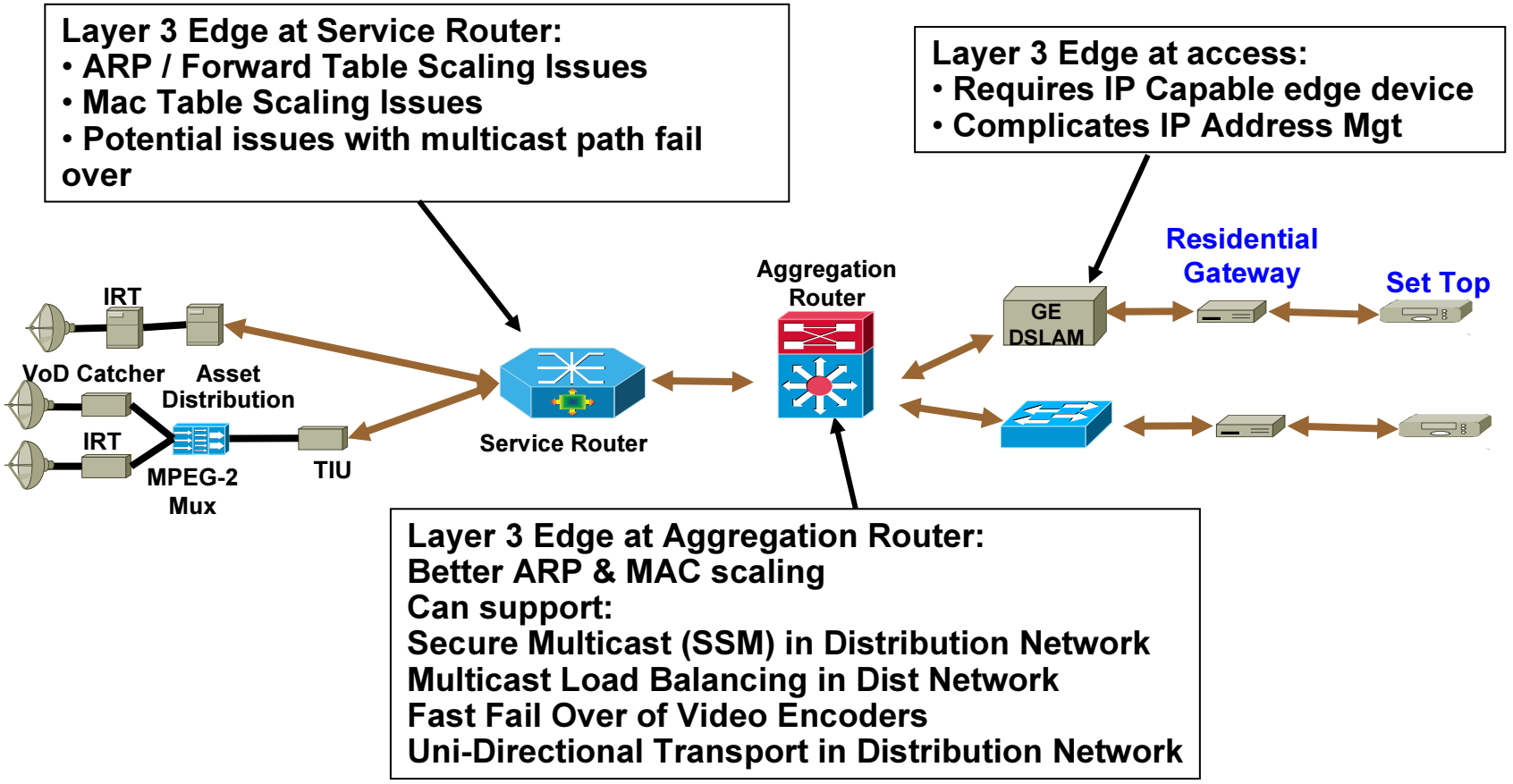


Distribution Architecture – GE Ring

Layer 3 Video Aggregation @PE-Agg
Path Redundancy for All Services



Potential Video Layer 3 Edge Choices

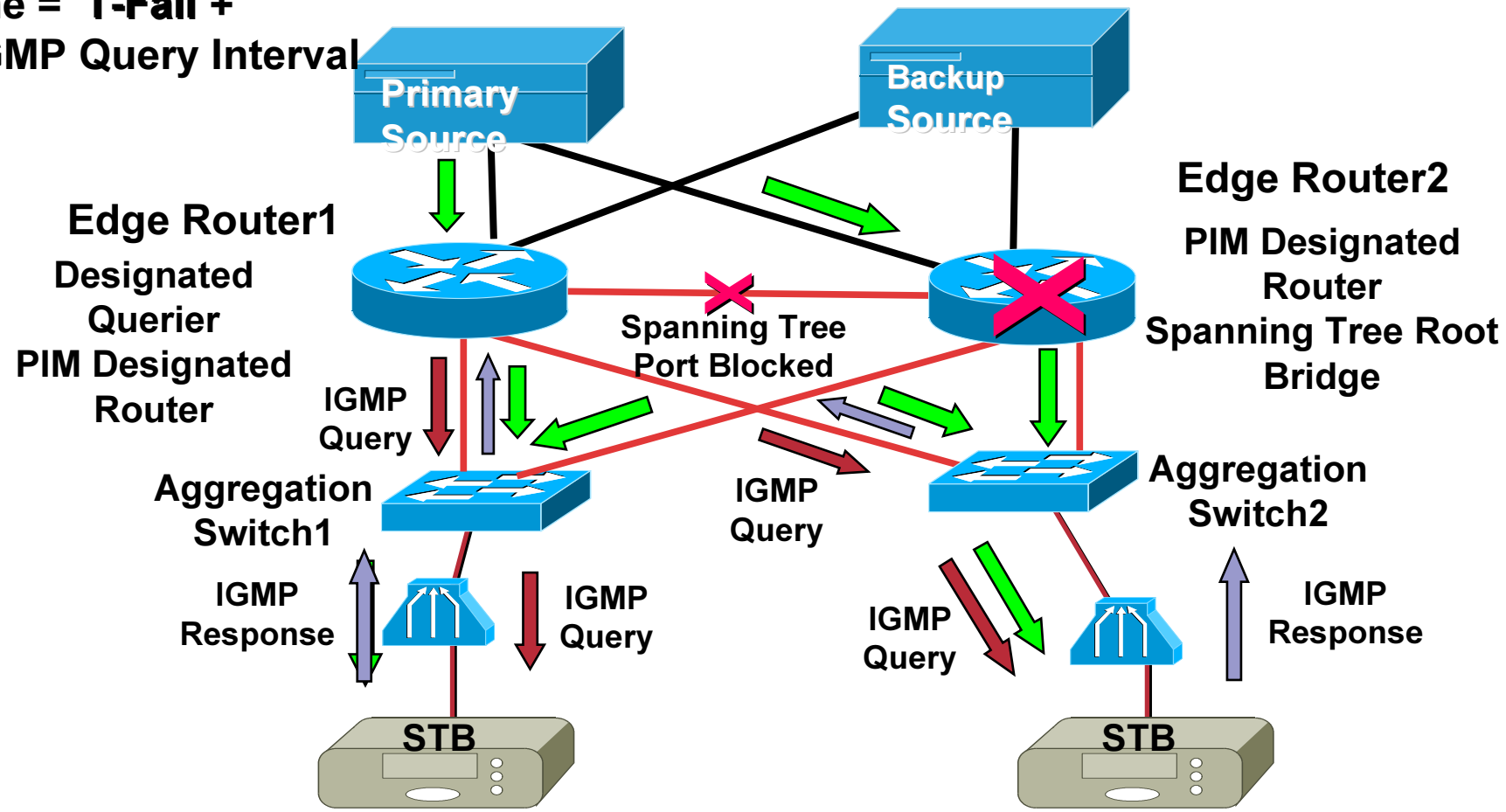


Recommendation = Layer 3 Edge At Aggregation Router

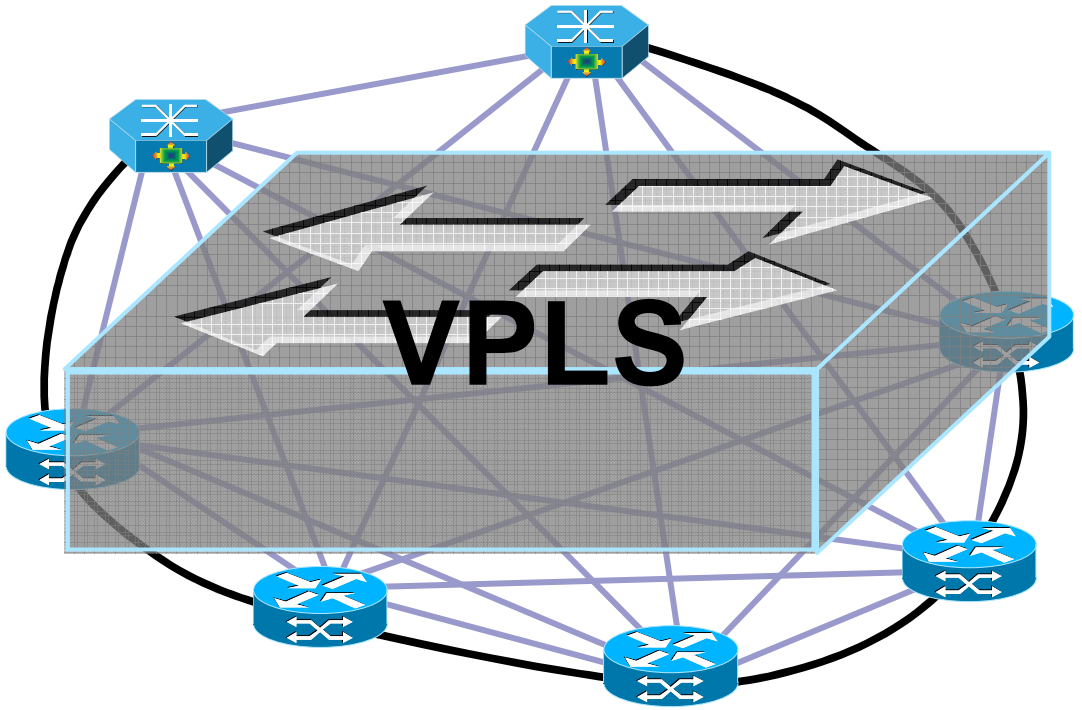
Multicast Traffic Flow with Layer 2 Distribution
Spanning Tree

Recovery After Spanning Tree Root Node Failure = 12 secs >> 120 secs
Service Disruption

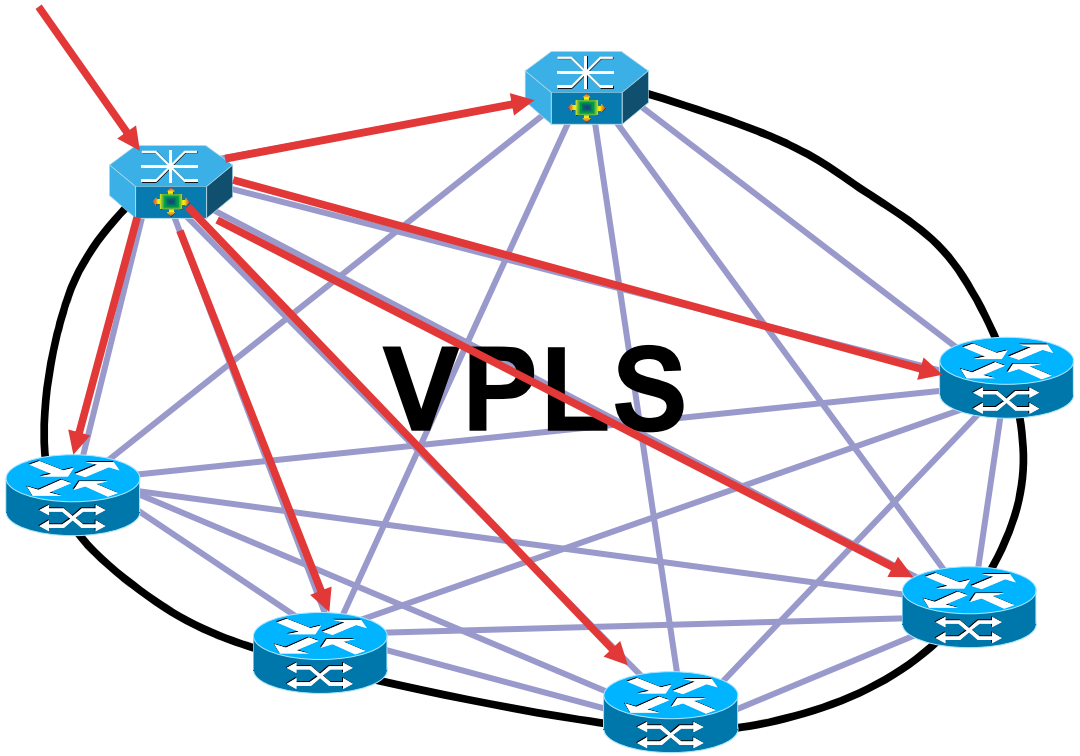
Time = T-Fail + IGMP Query Interval



L2 Ring – Virtual Private LAN Service (VPLS)



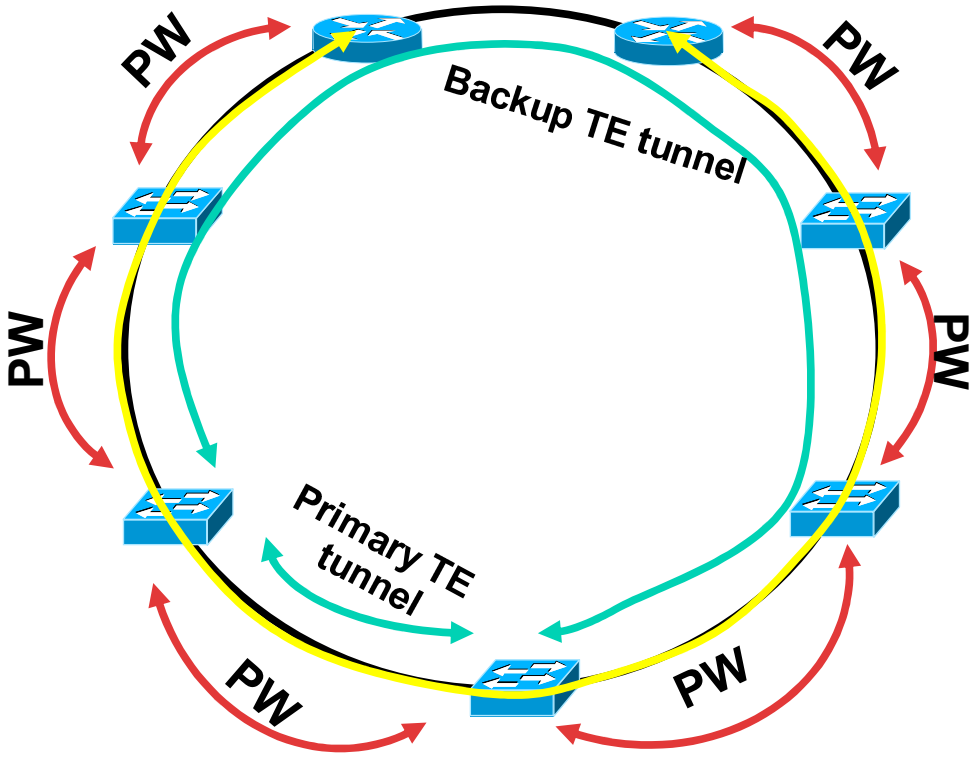
L2 Ring – Virtual Private LAN Service cont.



- **Same channel will transverse the ring multiple times**

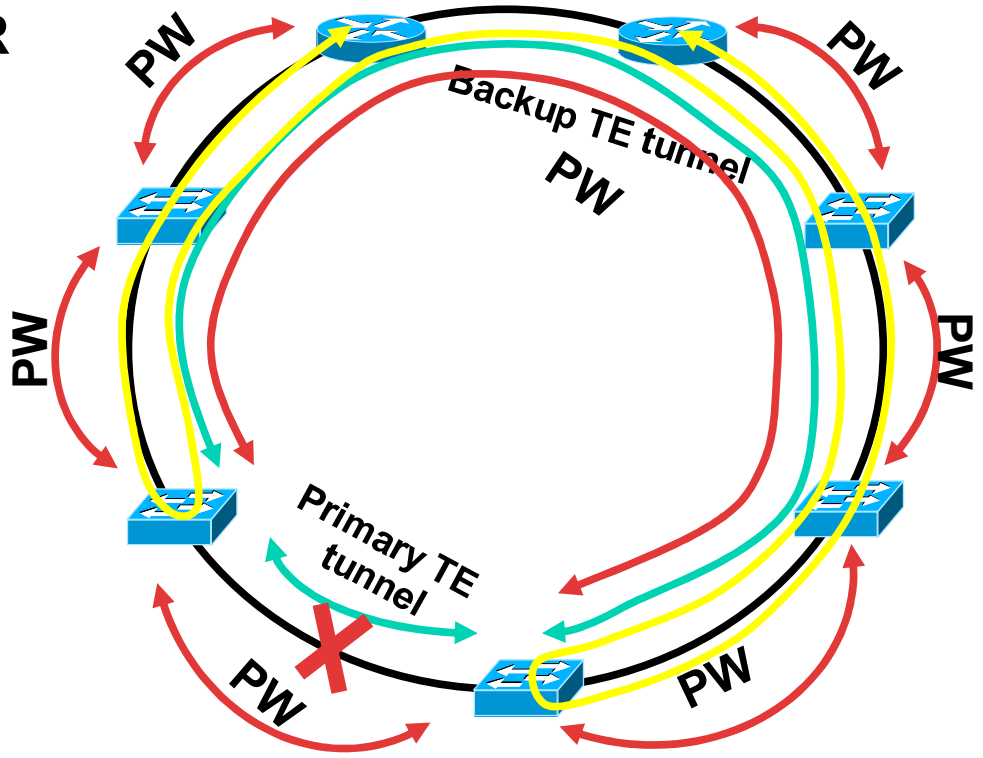
L2 Ring – Daisy Chain Pseudo-wires

- Logical or Physical ring
- Daisy chain pseudo-wires
- MPLS + TE FRR + PW
  - Marketed as VPLS
  - 3 labels – complicated
- TE FRR for link failure protection
- Service Router ARP table/MAC table scaling issues



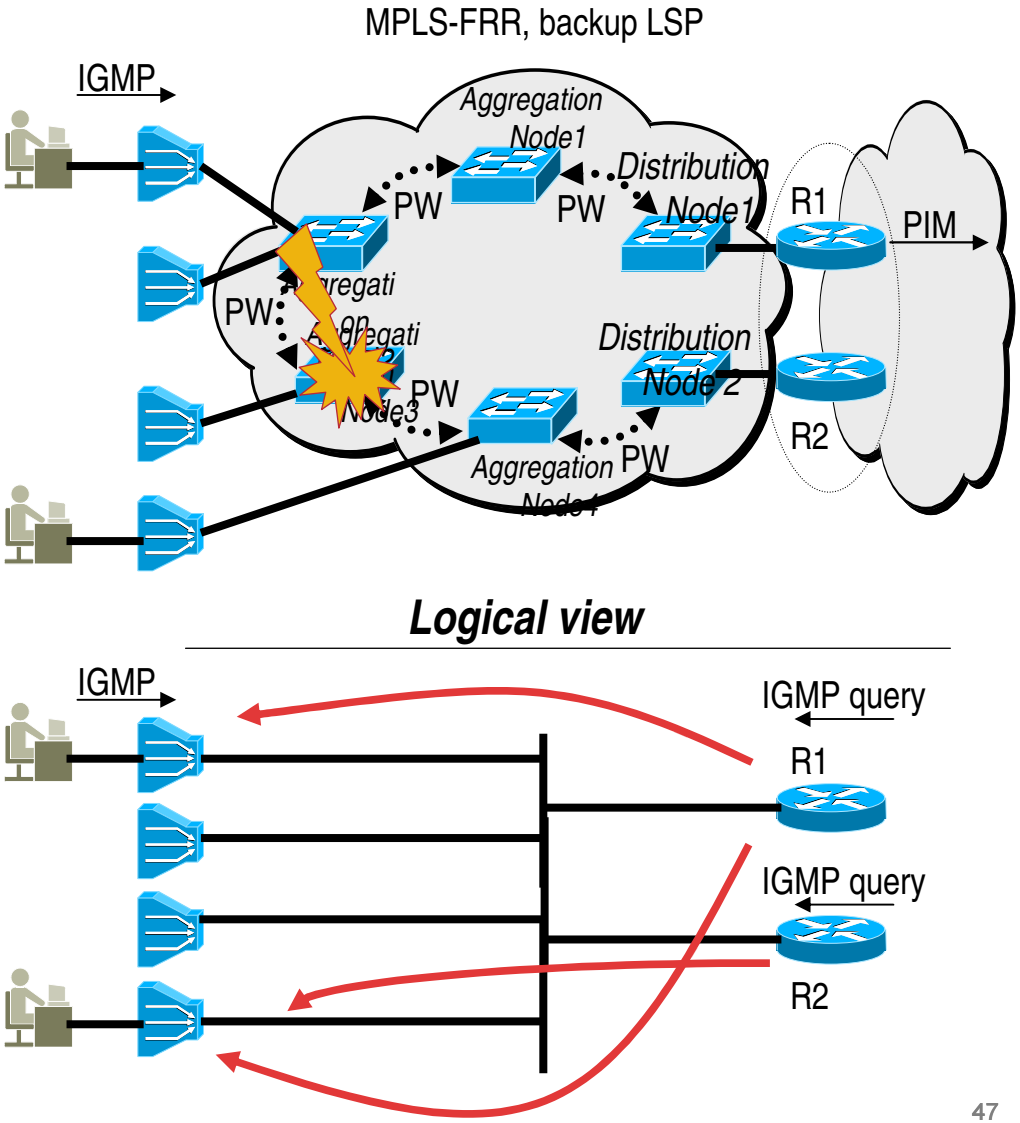
L2 Ring – Daisy Chain Pseudo-wires cont.

- **Link Failure – MPLE TE FRR 50ms re-convergence**
- **Same channel will transverse the ring twice under link failure condition**

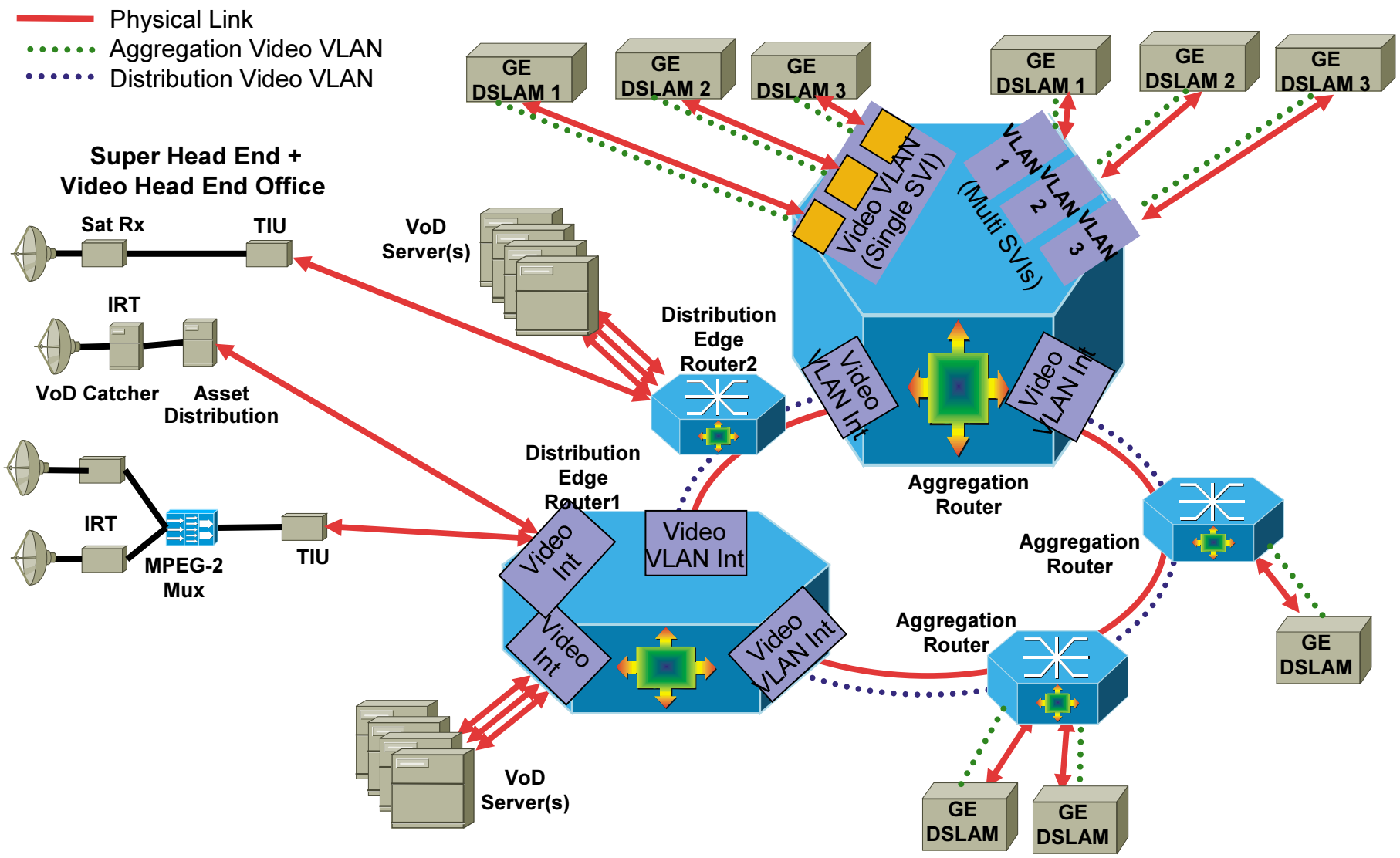


L2 Ring – Box failure

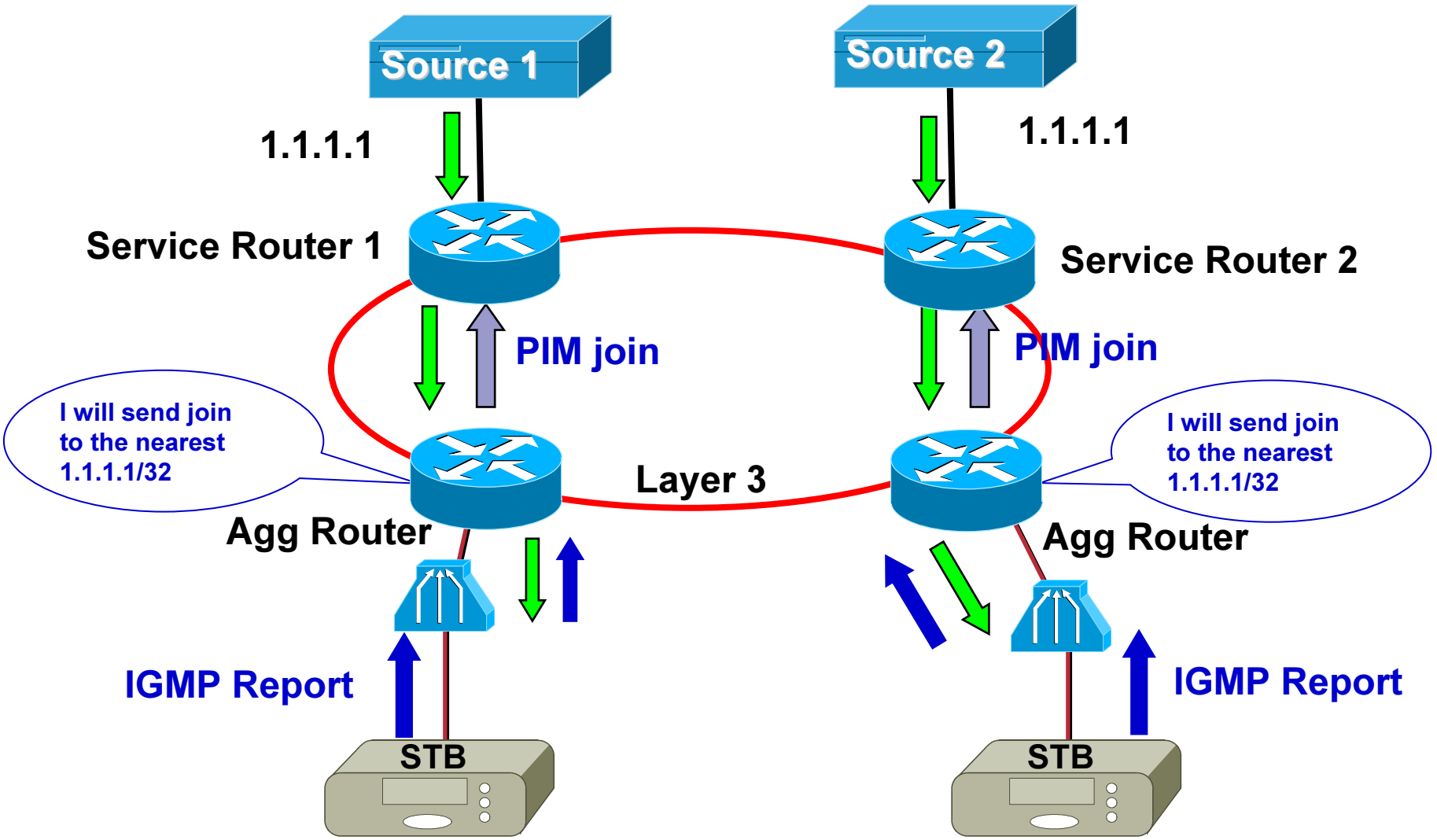
- **Assume: R1 IGMP querier: If R2 does not see IGMP-queries from R1 any more it usually starts being a querier after 2 x query-interval (default 120s)**
- **Reducing Query Interval Increases IGMP Traffic in Aggregation (Network Becomes Less Scalable)**



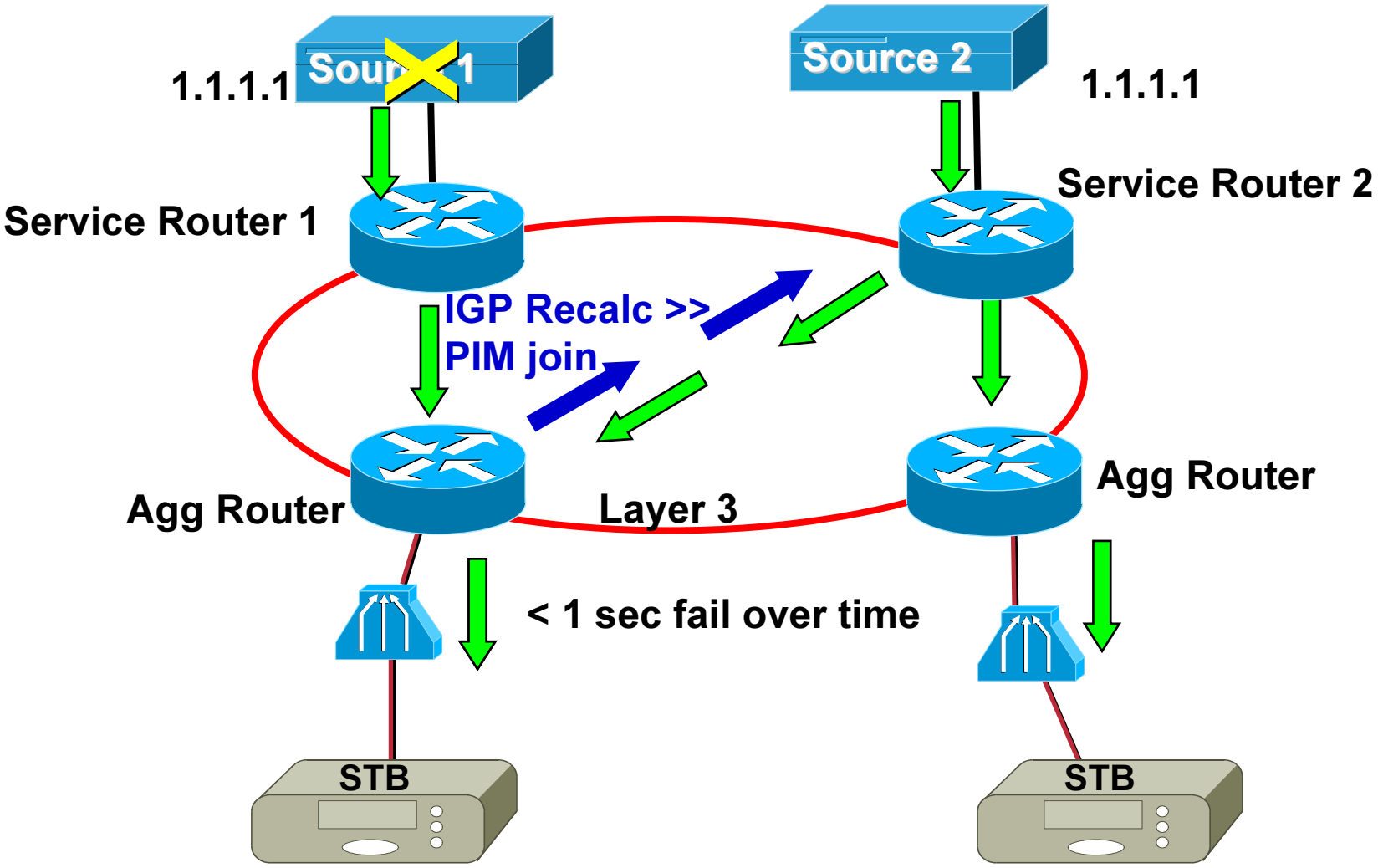
Forwarding Architecture
Video VLAN Config



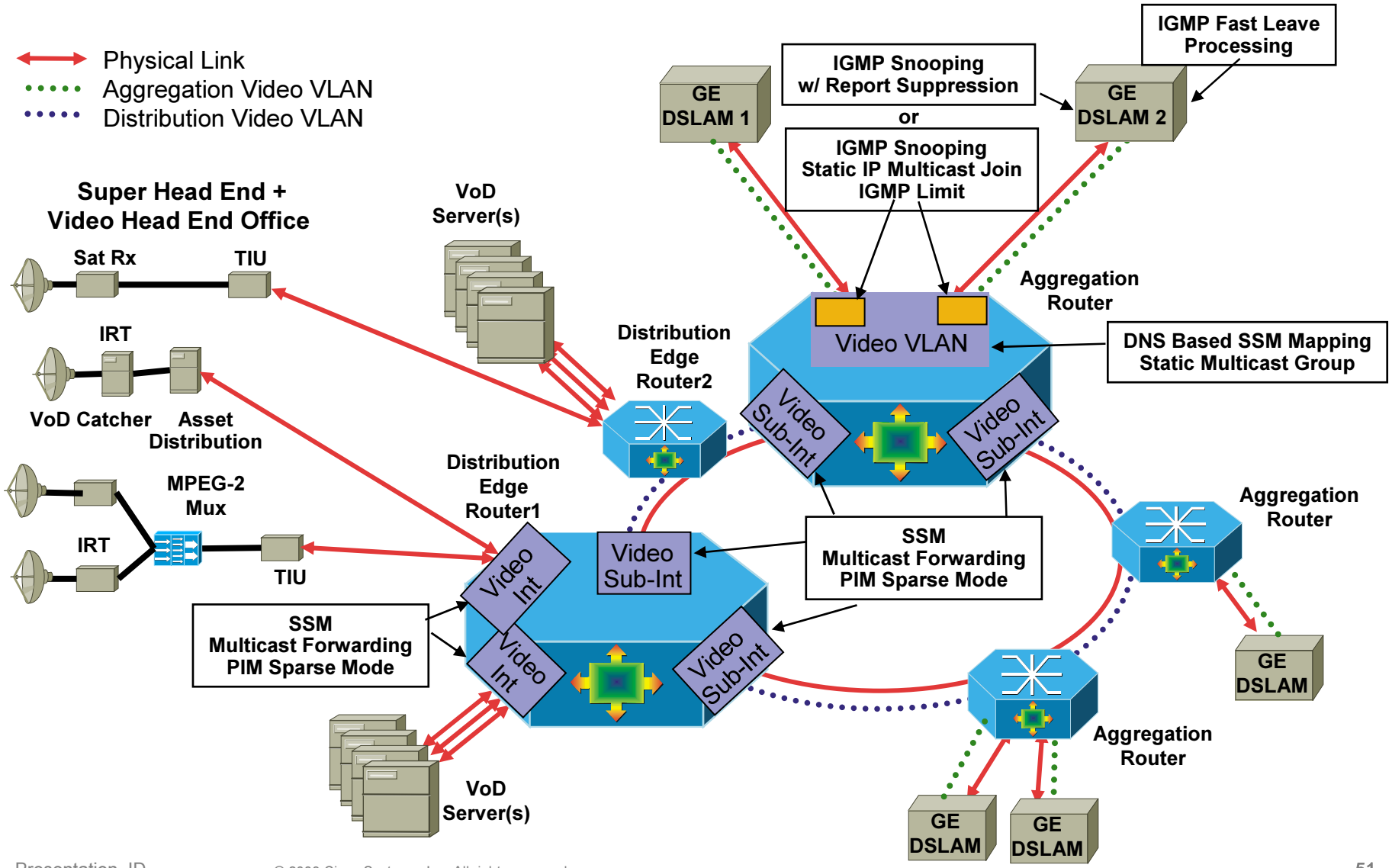
Anycast Based Load Sharing



Encoder Fail Over Using Anycast



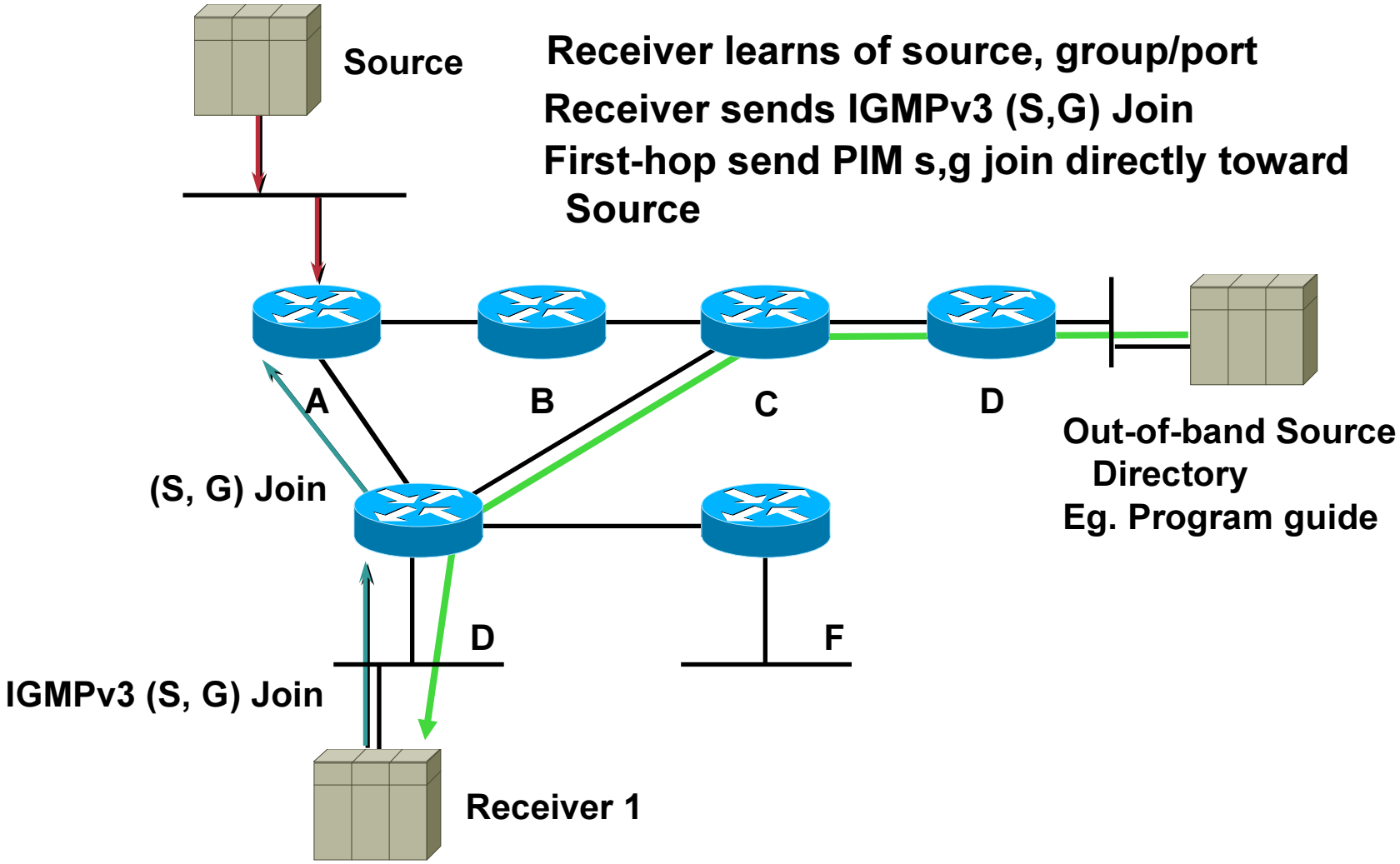
Multicast Forwarding



Source Specific Multicast

- **Ideal for one source to many receivers applications**
  - **Broadcast Video, audio and stock market data**
- **Content identified by both source and group address instead of group address alone.**
  - **Eliminates shared tree**
- **Solves address allocation problem**
  - **Since each (S,G) flow is unique, content providers can use the same group ranges**
- **Multicast from a well-know Source**
  - **Helps prevent DoS attacks from “Bogus” sources**

PIM Source Specific Mode



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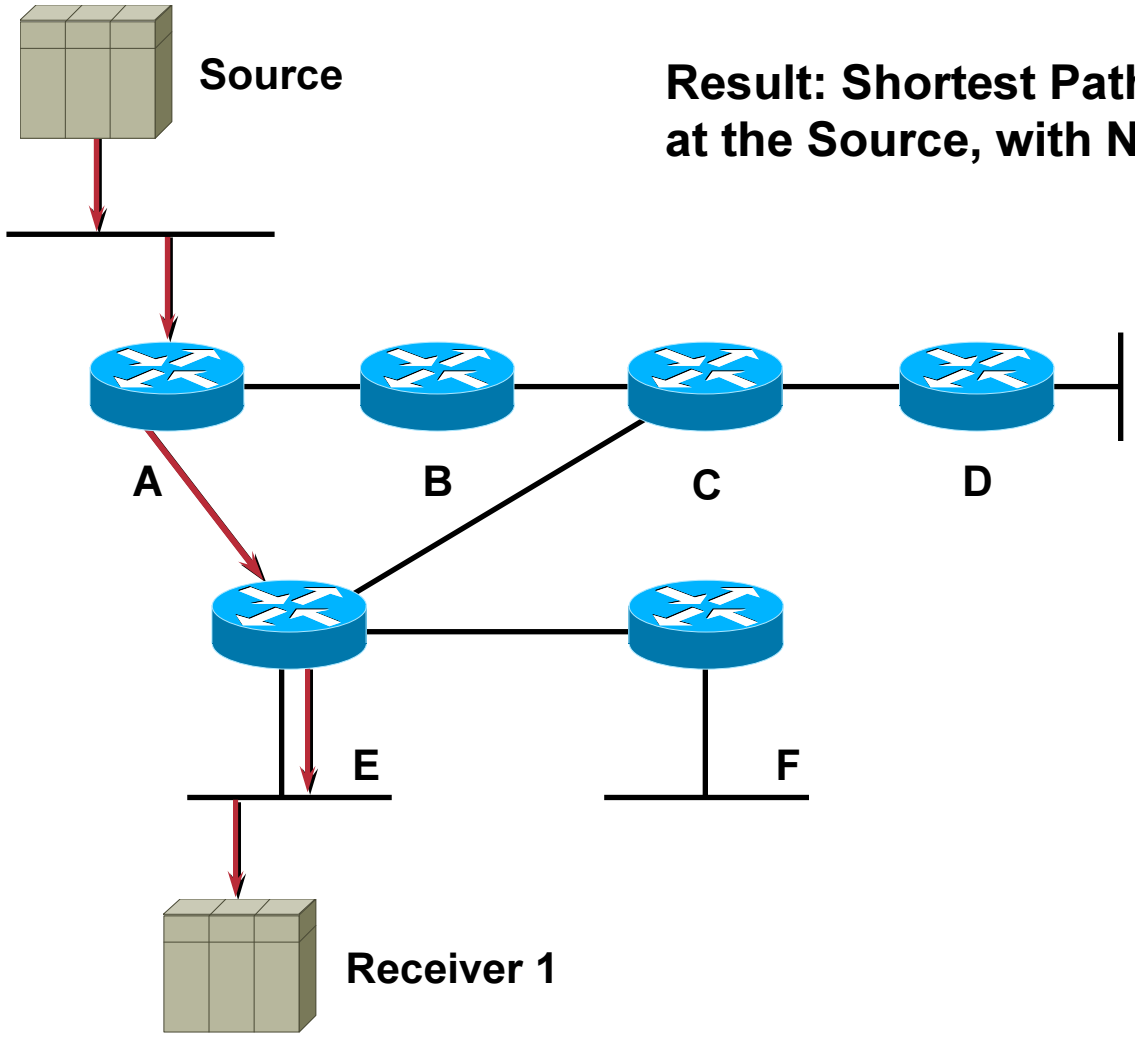


Result: Shortest Path Tree rooted at the Source, with NO Shared Tree.

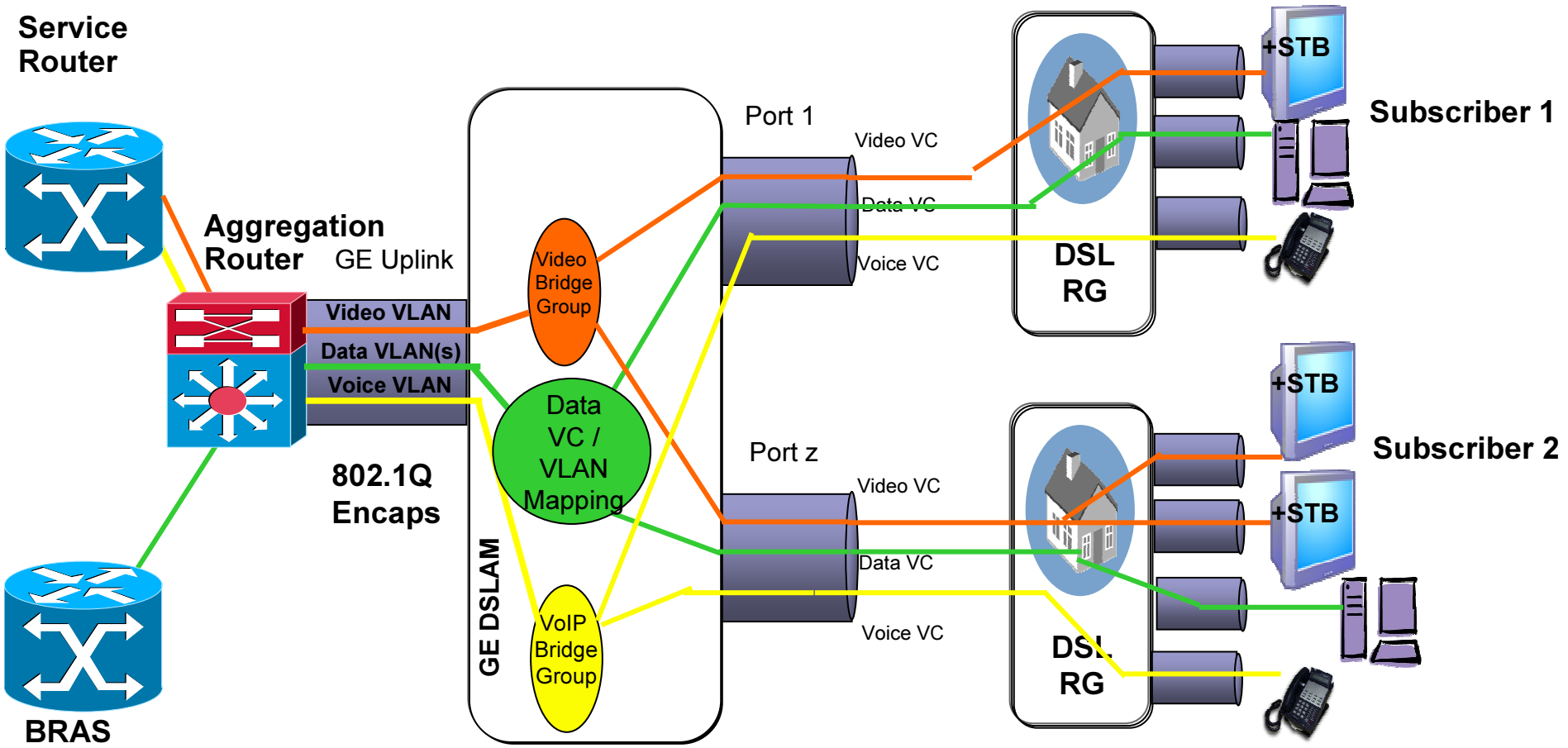
Channel Change Delay – STB

- Multicast Leave for old Channel (50 msec)
- Delay for Multicast Stream to Stop (150 msec w/ Fast Leave)
  - Delays Due to IGMP Queries / Timeouts on Access Link
  - Fast Leave Processing on DSLAM Removes This Delay
- Multicast Join for New Channel (50 msec – 200 msec)
- Jitter Buffer Fill (200 msec)
- Encrypted frame – Time for the CAC keys to arrive
- I-Frame Delay (500 msec – 1 sec)

Agenda

- Triple play application requirements
- Triple play transport Architecture
- Home Access Gateway

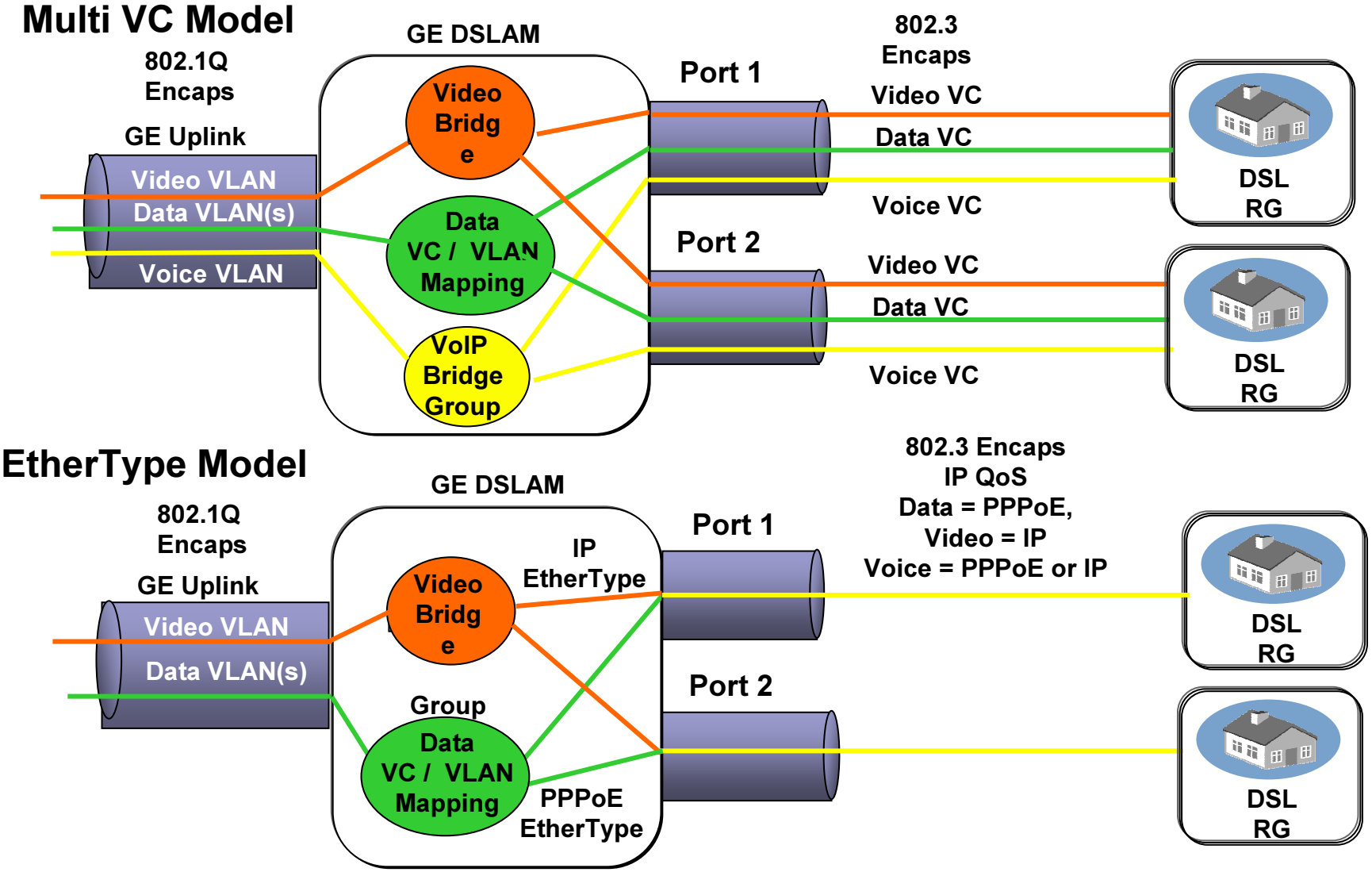
Triple Play Architectural Model



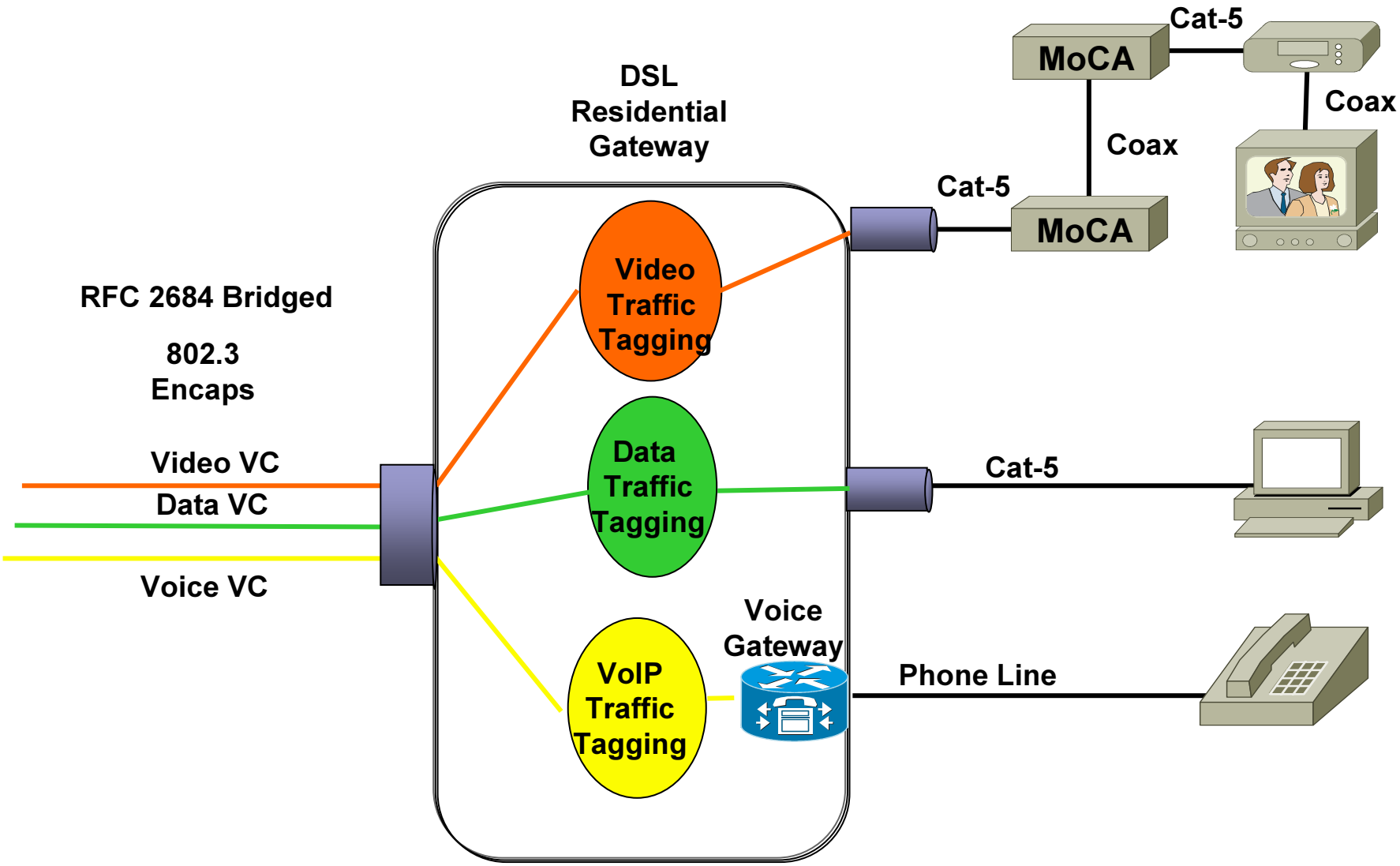
Recommendations Based on WT-101

- Distributed Multicast Replication
- Multi VC or Single VC Model
- VLAN Architecture
  - 1:1 or N:1 VLANs for Internet Access (N:1 Model Preferred)
  - N:1 VLANs for Video
    - Required for Distributed Multicast Replication
  - DSLAM Performs All VLAN Tagging
    - L2 Aggregation Provides S-Tag For Non WT-101 Compliant DSLAMs
- Encapsulation
  - PPPoE or IP for Internet Access
  - IP for Video - Simpler Distributed Multicast Replication

Home Device Based Service Mapping



Layer 2 RG Physical Port Based Service Mapping



Layer 3 / NAT Functionality in the RG