University of Glasgow | School of Computing Science

Networked Multimedia and Internet Video

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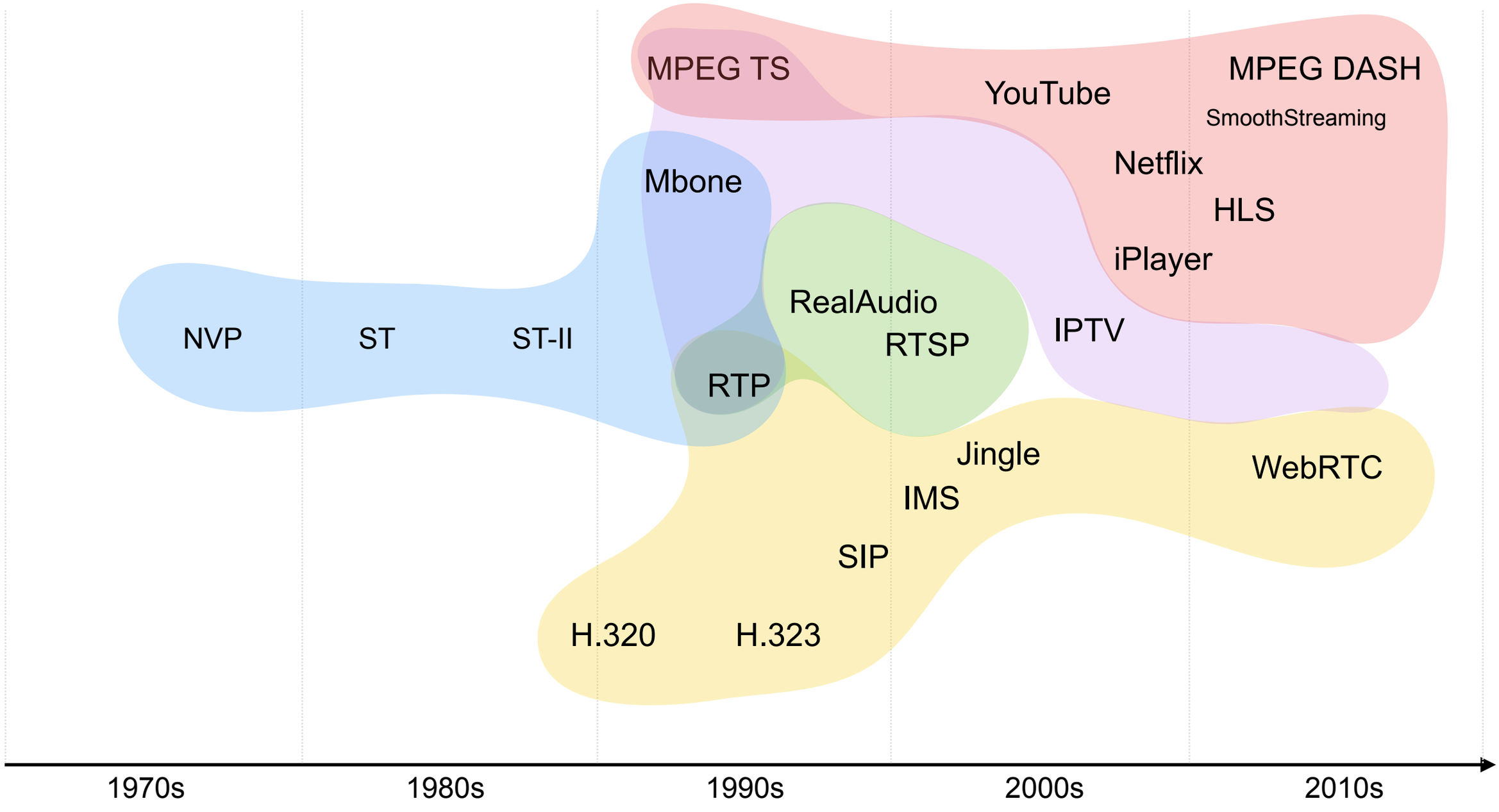
“IP video will represent 80% of all traffic by 2019, up from 67% in 2014”

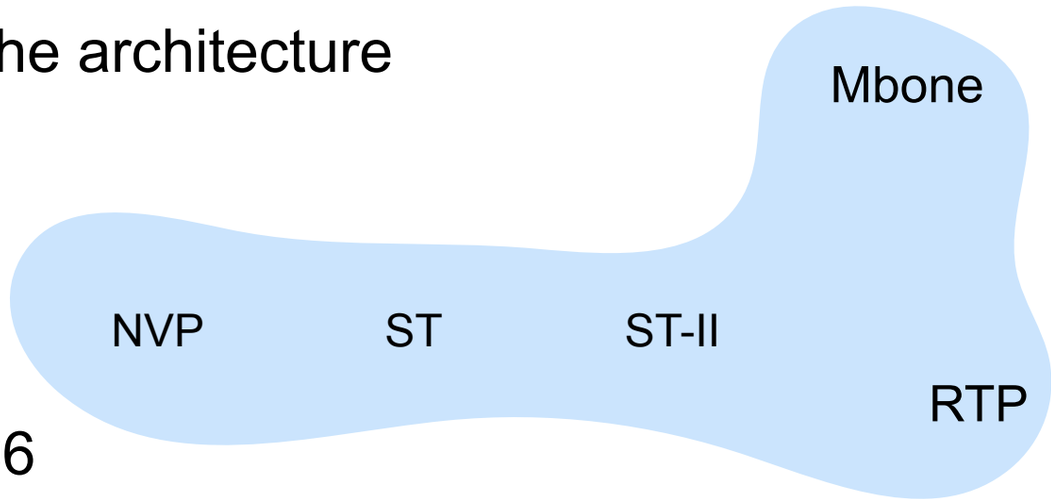
Source: Cisco Visual Networking Index, 2015

History


MPEG TS
YouTube
MPEG DASH
SmoothStreaming
Netflix
Mbone
HLS
iPlayer
RealAudio
NVP
ST
ST-II
RTSP
IPTV
RTP
Jingle
WebRTC
IMS
SIP
H.320
H.323
1970s
1980s
1990s
2000s
2010s

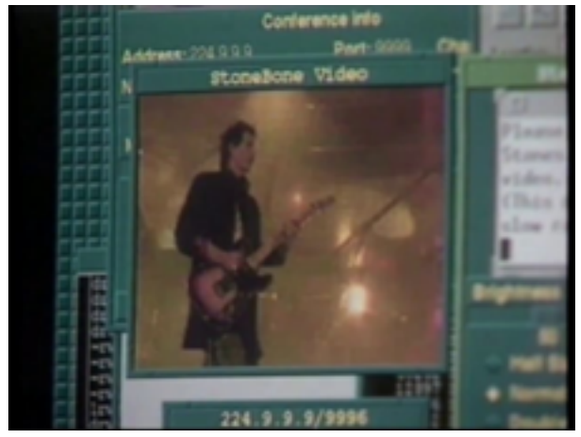
Phase 1: Experimental

- Initial experimentation – understanding the architecture



- Network voice protocol (NVP), 1977
- Internet Streaming Protocol (ST, ST-II)
- Real-time Transport Protocol (RTP), 1996

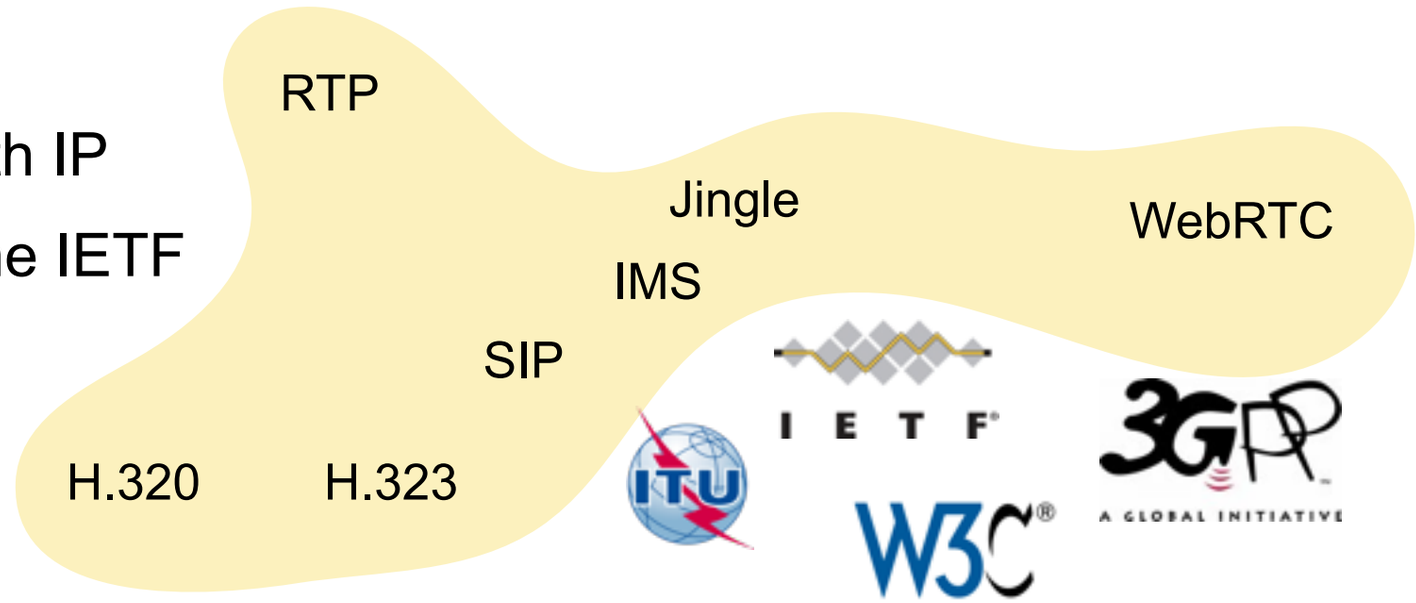
- Is packet-based networked multimedia feasible?
  - Scepticism from traditional telephony, TV, and video communities
  - Media packetisation, fragmentation, and reassembly – use of application level framing for robustness
  - Re-sequencing and timing recovery
  - Is sufficient quality-of-service possible without network support?
  - Self-identifying vs signalled media formats; signalling needed to negotiate media formats and parameters
  - Scalable media transport protocols – Mbone
  - Custom protocols → application-layer transport over UDP as IP matured



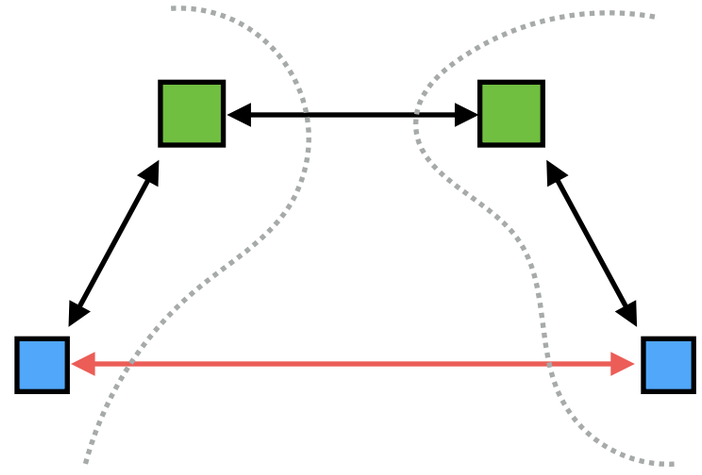
Rolling Stones, Mbone, Nov. 1994

Phase 2a: Telephony and Conferencing

- Telephony convergence with IP
- SIP: the protocol that ate the IETF

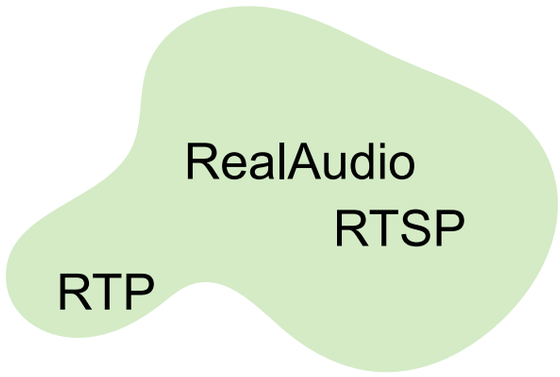


- Standardisation on RTP-based media over UDP
  - Peer-to-peer media channel
  - Server-assisted NAT traversal as IP addressing crunch hit
- Innovation in signalling vs legacy systems
  - Separate signalling channel and media path
  - Session and media description formats
  - Multi-stage negotiation vs offer-answer model
  - Signalling protocols vs APIs for defining signalling protocols
- Complexity – is a standard signalling protocol needed?



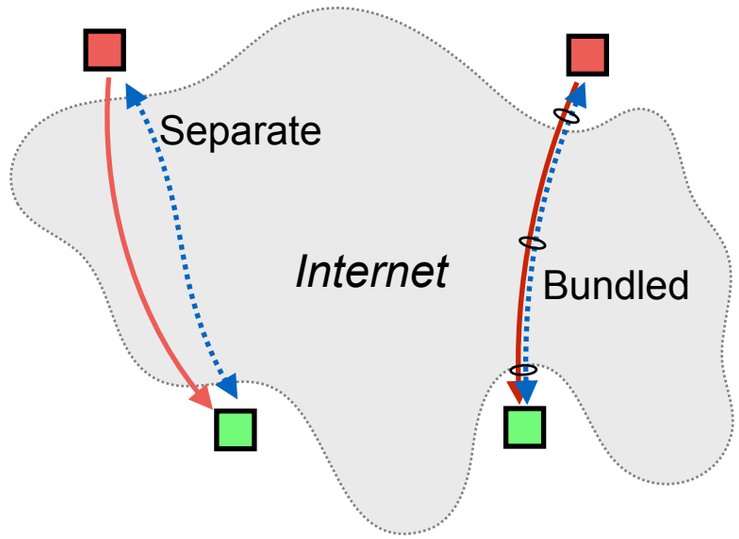
Phase 2b: Video on Demand

- Proprietary streaming protocols and applications
  - RealAudio, QuickTime, Flash
  - Standardisation: RealAudio → RTSP



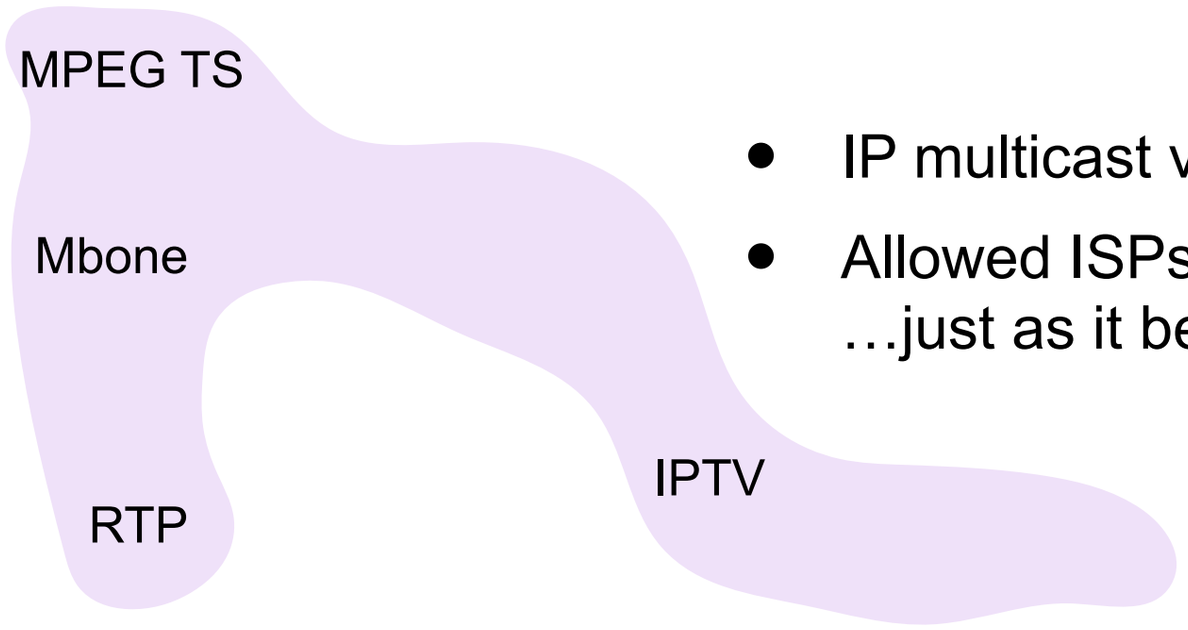
- Resource constraints suggested media flows needed special treatment
  - Dedicated media server – packetisation complexity, custom protocols
  - Dedicated client applications – complex codec, error resilience

- Signalling over TCP, RTP-over-UDP for media
- Media and signalling multiplexed in single flow
- Custom, but increasingly HTTP-influenced, protocols



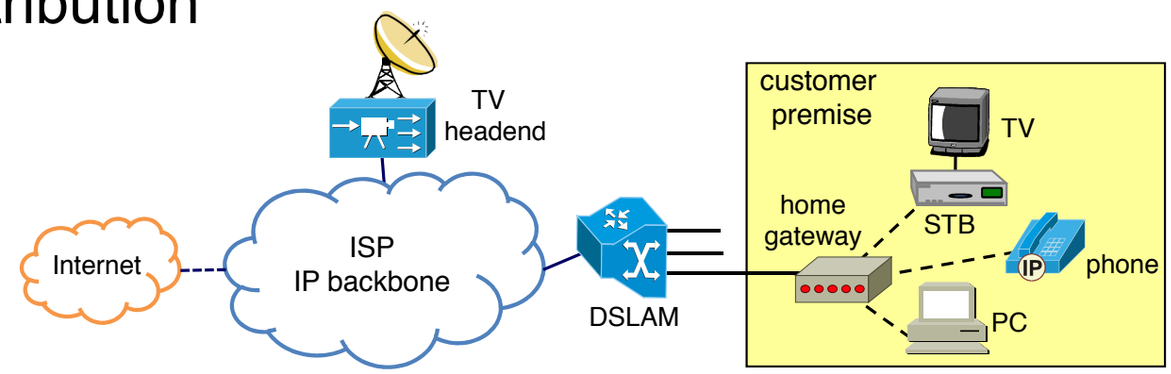
- Business model disrupted by growth of web CDNs

Phase 3: IPTV



- IP multicast video vs broadcast TV industry
- Allowed ISPs to replicate a cable TV service …just as it became obsolete?

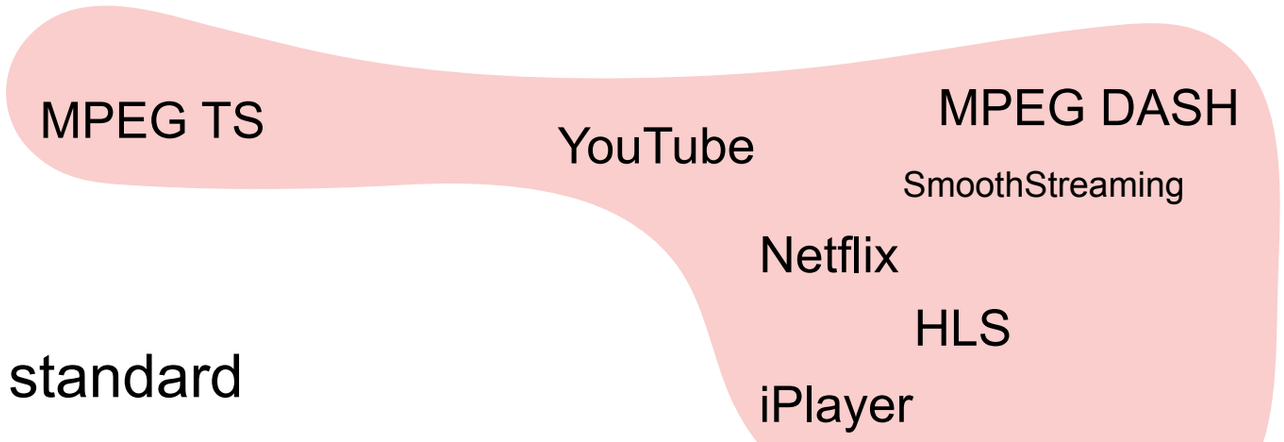
- IP multicast provides scalable distribution channel for traditional TV content
- Combine protocol mechanisms prototyped in Mbone tools with broadcast TV
- A multicast group per TV channel



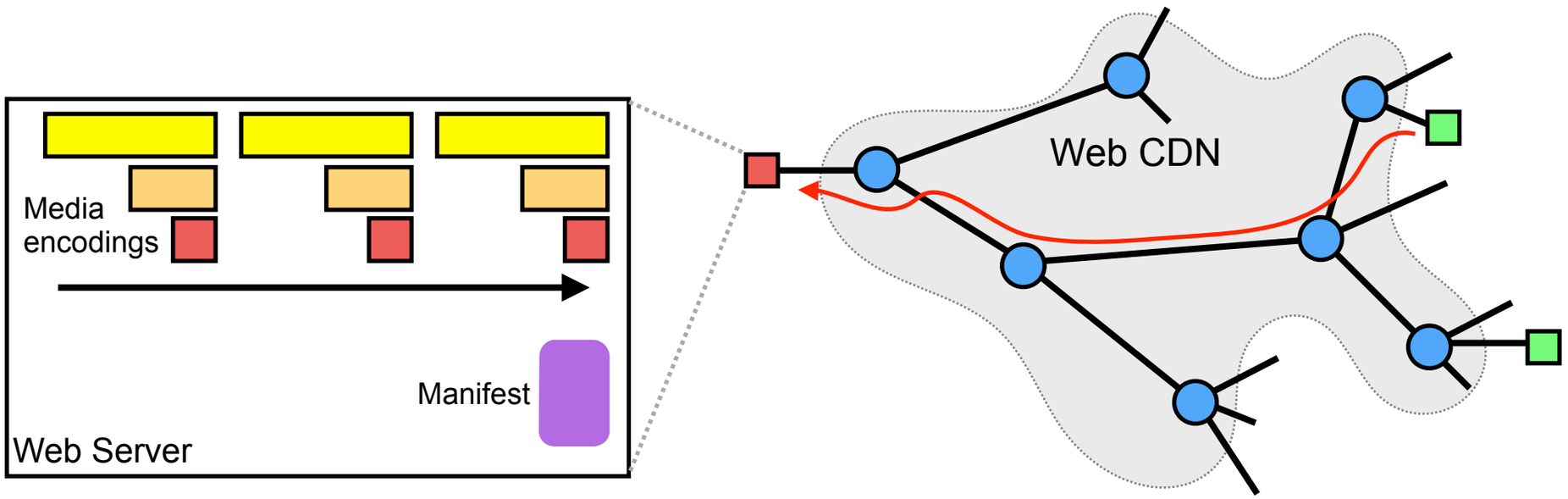
Source: Cha *et al*., "Watching Television Over Nationwide IP Multicast", 2007

Phase 4: Web Video

- HTTP-based adaptive streaming – web infrastructure now performant enough
  - Apple HTTP live streaming (HLS)
  - Microsoft SmoothStreaming
  - Adobe HTTP dynamic streaming



- Converging on MPEG DASH standard
  - Web CDNs, cloud computing, and cheap storage
  - Multiple representations of the content
  - Adaptation decisions at the client; real-time HTTP GET requests

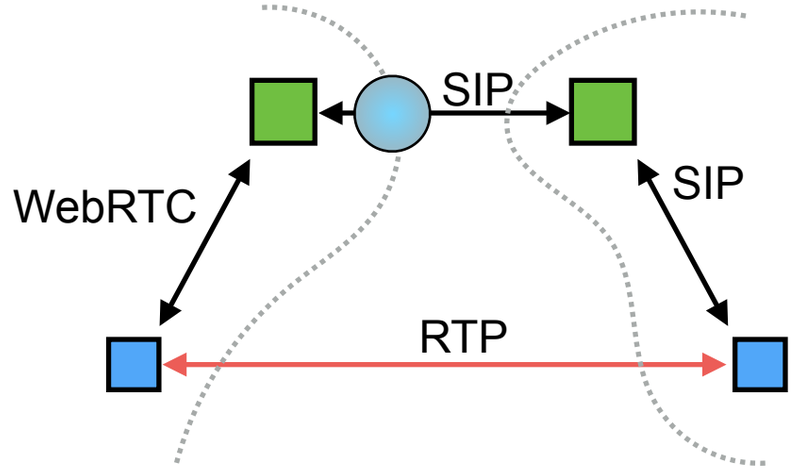


Reflection

- Benefit of common media transport
- Impact of legacy systems
- Impact of Moore’s law on protocols and codecs

Benefits of Common Media Transport

- RTP media transport widely favoured:
  - Conferencing and telephony
  - Streaming using RTSP
  - Many IPTV deployments
- In principle, can gateway between protocols without touching media packets



- Will MPEG DASH play the same role for streaming?

- Common signalling standards elusive
  - Complexity of the problem space, non-invented-here, or…?

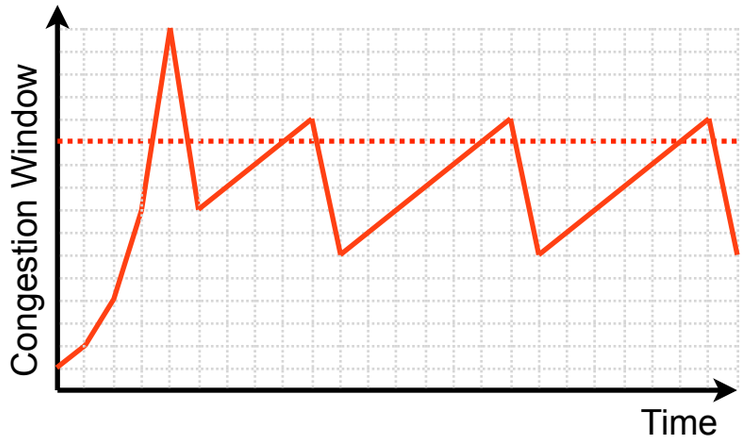
Impact of Legacy

- SIP failed because it cared about the PSTN
  - IP telephony standards aimed for parity with legacy standards
  - Feature and bug compatibility with the PSTN → overwhelming complexity
    - Early media (e.g., ring tones, 1-800-go-FedEx), DTMF and fax-over-VoIP, …
  - Security, identity, and PSTN gateways
    - Wiretapping regulations
    - Interworking with other systems
    - SDP security descriptions → no end-to-end security, no authentication, trusted middleboxes
- Legacy issues recurring with WebRTC

Impact of Moore's Law (1)

- Custom protocols → web protocols
  - Early systems required highly optimised protocols running over UDP
  - Increasingly superseded by generic web protocols
  - Hard problems become easy over time

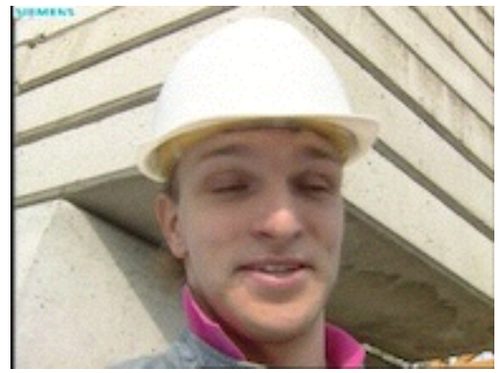
- TCP is ~~not~~ suitable for real-time?
  - TCP congestion response fills in-network queues; induces latency but ensures consistent throughput to receiver
  - Increasing network capacity allows sustained rate sufficient for TV streaming



- Latency vs sustained bandwidth vs expected media rate variation: increasing range where trade-off allows TCP

Impact of Moore's Law (2)

- Why are we still arguing about codecs?
  - H.264 vs VP8 → H.265 vs VP9
  - Patents and licensing fees



- Performance differences negligible between codecs of same generation
  - 2x performance changes across generations → 10 years
  - Dwarfed by increase in network, storage, and processing capacity

- Excessive codec support is harmful
  - Implementations are complex: signalling, parsing, and decoding
  - Low-level programming for performance → security issues
  - Surely we can build a type safe byte code for downloadable codecs?

Current Challenges

- Political and engineering issues:
  - Congestion control
  - Network neutrality
  - Media quality and codecs

- Hard problems, but in the long term will likely be resolved by Moore’s law

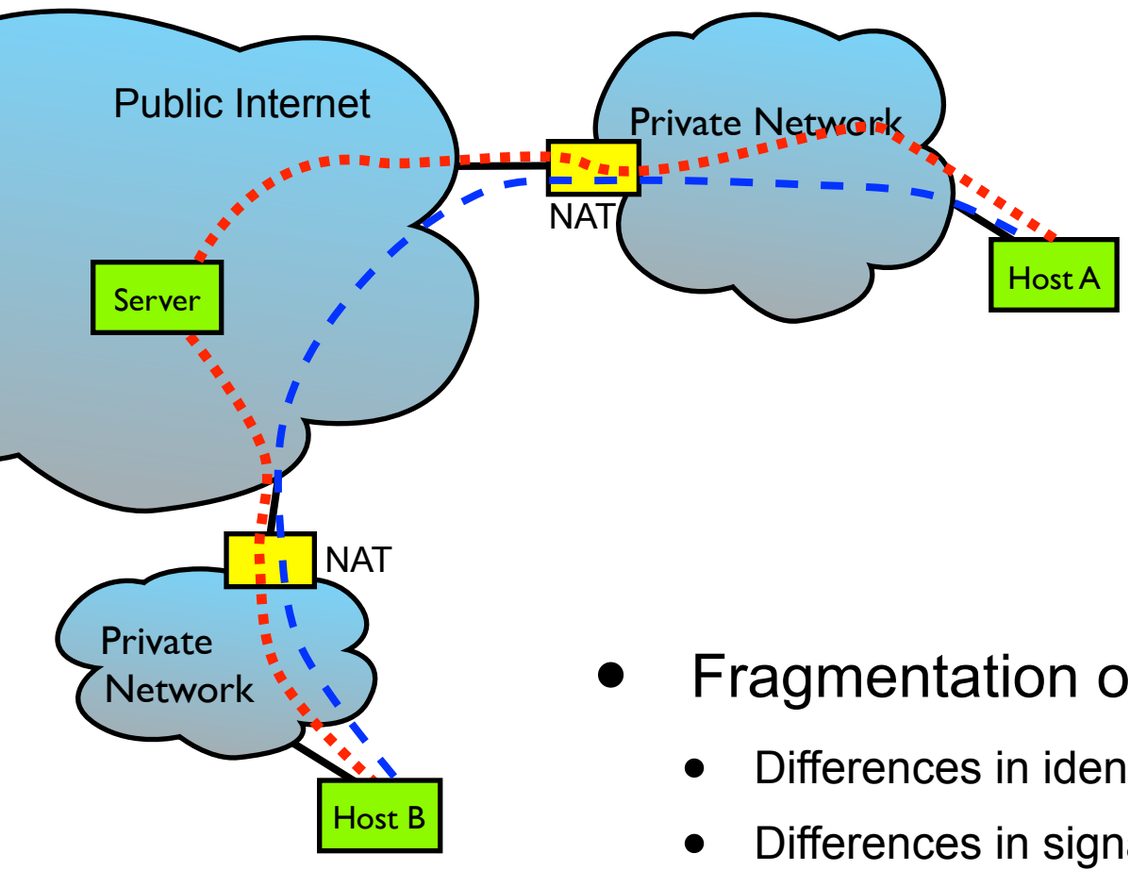
Security

- Current systems not end-to-end secure
  - Signalling metadata, including media keys, exposed to servers, gateways, and media processing middleboxes
  - Required by wiretapping regulations



- Open issues for enabling strong security
  - Legal issues
  - Media path security via DTLS-SRTP, but relies on certificate authority
  - Identity provision – who are you calling?
  - Gateways to legacy systems with weaker security models
  - Use of in-network processing for conference servers

Balkanisation



- Fragmentation of the network – NAT hurts interactive video
  - ICE helps ensure happy eyeballs
  - But, latency penalty for call setup

- Fragmentation of conferencing and telephony application space
  - Differences in identity provision – is federated identity management feasible?
  - Differences in signalling protocols and/or use of WebRTC signalling building blocks – how to translate protocols?
  - Can we maintain media path compatibility?

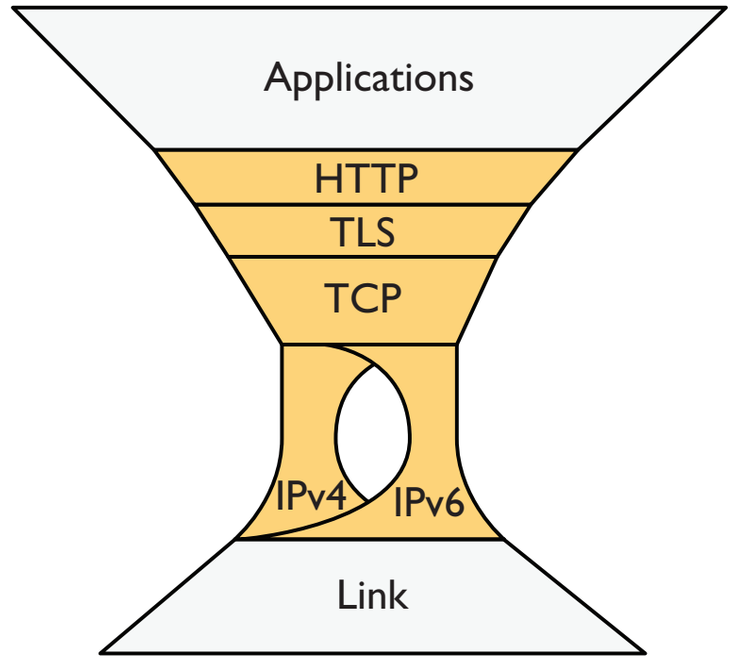
- How to maintain uniform TV viewing experience across content providers with smart TVs?
  - Infrastructure quality and support issues – security and longevity

Ossification

- Lower-layer innovation increasingly difficult
  - NATs, firewalls, proxies, caches, and other middleboxes galore
  - Each understands (a subset of) current protocols
- Network assumes HTTPS over TCP/IP

- Such ossification is essential – implies backwards compatibility – but hinders the deployment of new features

- Promising future directions for video – content centric networking – require changes to these lower layers for full effect



Source: Trammell & Hildebrand “Evolving Transport in the Internet”, IEEE Internet Computing, Sep/Oct 2014.

Futures

- Increasing video quality and ubiquity, telepresence, virtual reality, immersive environments
  - Bigger, better, faster, more… fits within the existing architecture
  - Expect interesting congestion control/network neutrality/bandwidth crunch for the next 5-10 years, especially in mobile
- Architecture evolves to support a content-centric model with pervasive caching but zero visibility
  - Hints with MPEG DASH and CDNs today, but doesn't go far enough for a world of ubiquitous multimedia content – have router venders internalised Moore's law for storage?
- Privacy concerns will push processing to the edges
  - Cannot trust servers to mediate