15-441/15-641 Computer Networking

Lecture 20 – Internet Video Delivery
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www.cs.cmu.edu/~prs/15-441-F14

Bad Things to Avoid in Streaming Video

1990 – 2004: 1st Generation Commercial PC/Packet Video Technologies

- Simple video playback, no support for rich app
- Not well integrated with Web browser
- No critical mass of compelling content over Internet
- No enough broadband penetration

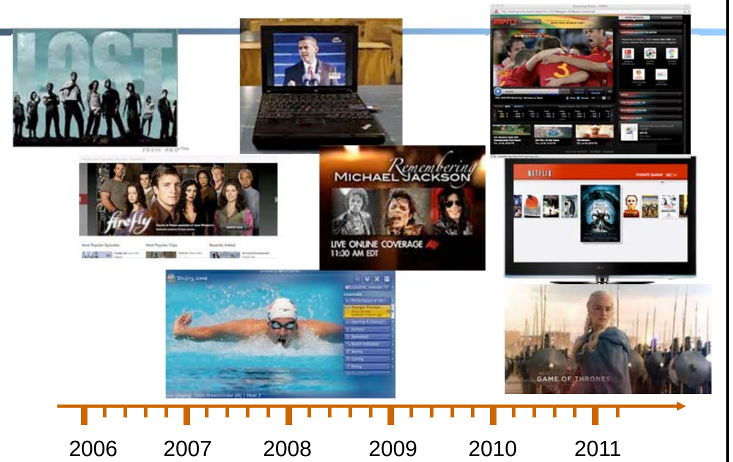
2005: Beginning of Internet Video Era

100M streams first year

BitTorrent

Premium Sports Webcast on Line

2006 – 2013: Internet Video Going Prime Time



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Internet Video on Multiple Devices

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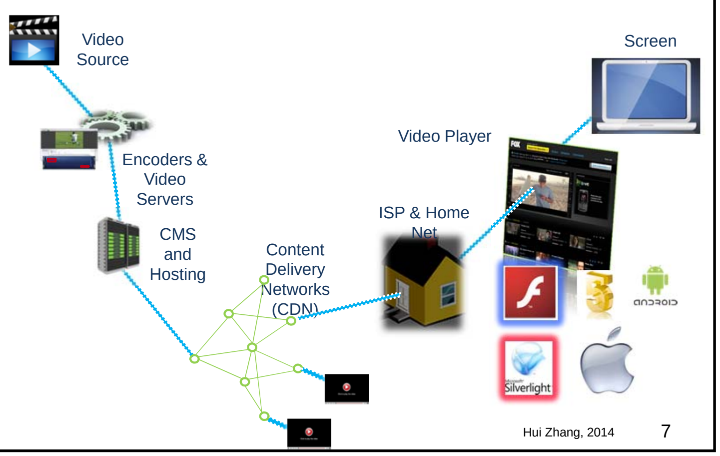
Internet Video Data-plane



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Internet Video Requirements

- Smooth/continuous playback
- Elasticity to startup delay: need to think in terms of RTTs
- Elasticity to throughput
  - Multiple encodings: 200Kbps, 1Mbps, 2 Mbps, 6 Mbps, 30Mbps
- Multiple classes of applications with different requirements

	Delay	Bandwidth	Examples
2, N-way conference	< 200 ms	4 kbps audio only, 200 kbps – 5 Mbps video	Skype, Google hangout, Polycom, Cisco
Short form VoD	< 1-5s	300 kbps – 2 Mbps & higher	Youtube
Long form VoD	< 5-30s	500 kbps – 6 Mbps & higher	Netflix, Hulu, Qiyi, HBOGO
Live Broadcast	< 5-10s	500 kbps – 6 Mbps & higher	WatchESPN, MLB
Linear Channel	< 60s	500 kbps – 6 Mbps & higher	DirectTV Live

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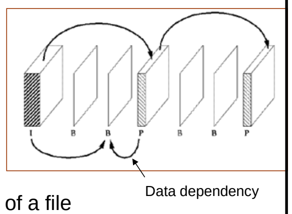
Video Data

- Unlike audio, video compression is essential:
  - Too much data to begin with, but
  - Compression ratios from 50 to 500
- Takes advantage of spatial, temporal, and perceptual redundancy
- Temporal redundancy: Each frame can be used to predict the next -> leads to data dependencies
- To break dependencies, we insert "I frames" or *keyframes* that are independently encoded.
  - Allows us to start playback from middle of a file
- Video data is highly structured



Credit: http://www.icsi.berkeley.edu/PET/GIFS/MPEG_gop.gif

Terminology

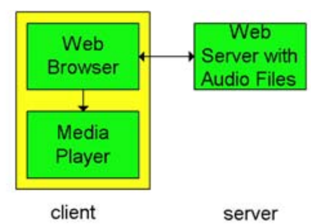
- Bitrate
  - Information stored/transmitted per unit time
  - Usually measured in kbps to mbps
  - Ranges from 200Kbps to 30 Mbps
- Resolution
  - Number of pixels per frame
  - 160x120 to 1920x1080 (1080p) to 4096x2160 (4K)
- FPS (frames per second)
  - 24, 25, 30, or 60

Challenges

- TCP/UDP/IP suite provides best-effort, no guarantees on expectation or variance of packet delay
- Streaming applications delay of 5 to 10 seconds is typical and has been acceptable, but performance deteriorate if links are congested
- Real-Time Interactive requirements on delay and its jitter have been satisfied by over-provisioning (providing plenty of bandwidth), what will happen when the load increases?

First Generation: HTTP Download

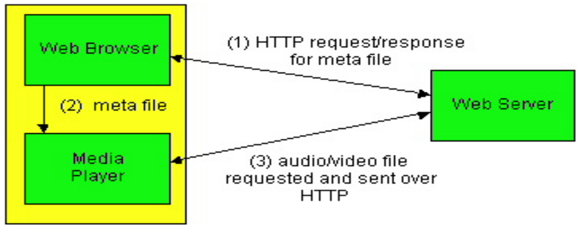
- A simple architecture is to have the Browser request the object(s) and after their reception pass them to the player for display
  - No pipelining



First Gen: HTTP Progressive Download (2)

- Alternative: set up connection between server and player; player takes over
- Web browser requests and receives a **Meta File** (a file describing the object) instead of receiving the file itself;
- Browser launches the appropriate Player and passes it the *Meta File*;
- Player sets up a TCP connection with Web Server and downloads or *streams* the file

Meta file requests

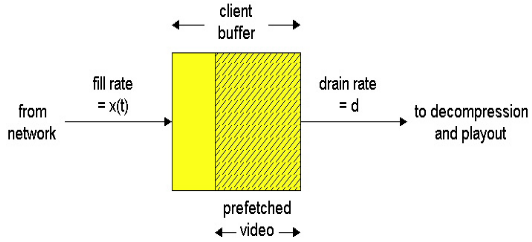


Buffering Continuous Media

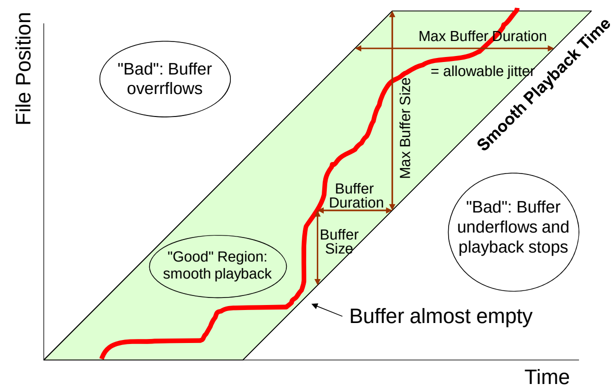
- Jitter = variation from ideal timing
- Media delivery must have very low jitter
  - Video frames every 30ms or so
  - Audio: ultimately samples need <1ns jitter
- But network packets have much more jitter that that!
- Solution: buffers
  - Fill buffer over the network with best effort service
  - Drain buffer via low-latency, local access

HTTP Progressive Download

- With helper application doing the download, playback can start immediately...
- Or after sufficient bytes are buffered
- Sender sends at maximum possible rate under TCP; retransmit when error is encountered; Player uses a much larger buffer to smooth delivery rate of TCP



Streaming, Buffers and Timing

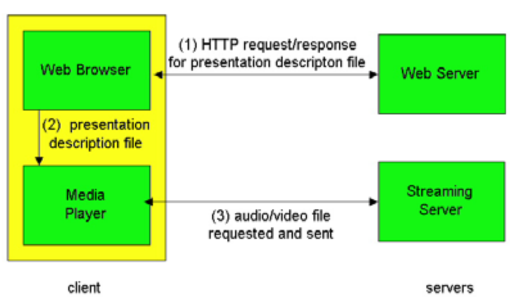


Drawbacks of HTTP Progressive Download

- HTTP connection keeps data flowing as fast as possible to user's local buffer
  - May download lots of extra data if user does not watch the entire video
  - TCP file transfer can use more bandwidth than necessary
- Mismatch between whole file transfer and stop/start/seek playback controls.
  - However: player can use file range requests to seek to video position
- Cannot change video quality (bit rate) to adapt to network congestion

2nd Generation: Real-Time Streaming

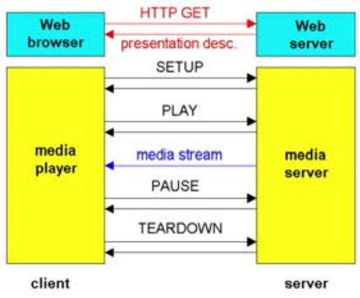
- This gets us around HTTP, allows a choice of UDP vs. TCP and the application layer protocol can be better tailored to Streaming; many enhancements options are possible



Example: Real Time Streaming Protocol (RTSP)

- For user to control display: rewind, fast forward, pause, resume, etc…
- Out-of-band protocol (uses two connections, one for control messages (Port 554) and one for media stream)
- RFC 2326 permits use of either TCP or UDP for the control messages connection, sometimes called the RTSP Channel
- As before, meta file is communicated to web browser which then launches the Player; Player sets up an RTSP connection for control messages in addition to the connection for the streaming media

RTSP Operation



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RTSP Exchange Example

C: SETUP rtsp://audio.example.com/xena/audio RTSP/1.0
Transport: rtp/udp; compression; port=3056; mode=PLAY

S: RTSP/1.0 200 1 OK
Session 4231

C: PLAY rtsp://audio.example.com/xena/audio.en/lofi RTSP/1.0
Session: 4231
Range: npt=0 (npt = normal play time)

C: PAUSE rtsp://audio.example.com/xena/audio.en/lofi RTSP/1.0
Session: 4231
Range: npt=37

C: TEARDOWN rtsp://audio.example.com/xena/audio.en/lofi RTSP/1.0
Session: 4231

S: 200 3 OK

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RTSP Media Stream

- *Stateful* Server keeps track of client's state
- Client issues Play, Pause, ..., Close
- Steady stream of packets
  - UDP - lower latency
  - TCP - may get through more firewalls, reliable

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Example 2: RTMP - Real-Time Messaging Protocol

- Proprietary Adobe protocol
- Runs over TCP
- Manages audio, video, and other
- Multiplex multiple streams over TCP connection

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Drawbacks of RTSP, RTMP

- Web downloads are typically cheaper than streaming services offered by CDNs and hosting providers
- Streaming often blocked by routers
- UDP itself often blocked by firewalls
- HTTP delivery can use ordinary proxies and caches
- Conclusion: rather than adapt Internet to streaming, adapt media delivery to the Internet

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3rd Generation: HTTP Streaming

- Other terms for similar concepts: Adaptive Streaming, Smooth Streaming, HTTP Chunking
- Client-centric architecture with stateful client and stateless server
  - Standard server: Web servers
  - Standard Protocol: HTTP
  - Session state and logic maintained at client
- Video is broken into multiple chunks
- Chunks begin with a keyframe so each chunk is independent of other chunks
- A series of HTTP progressive downloads of chunks
- Playing chunks in sequence gives seamless video

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Adaptive Bit Rate with HTTP Streaming

- Encode video at different levels of quality/bandwidth
- Client can adapt by requesting different sized chunks
- Chunks of different bit rates must be synchronized
  - All encodings have the same chunk boundaries and all chunks start with key frames, so you can make smooth splices to chunks of higher or lower bit rates

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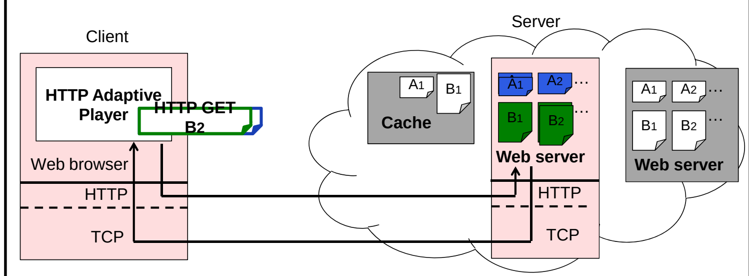
HTTP Chunking Protocol



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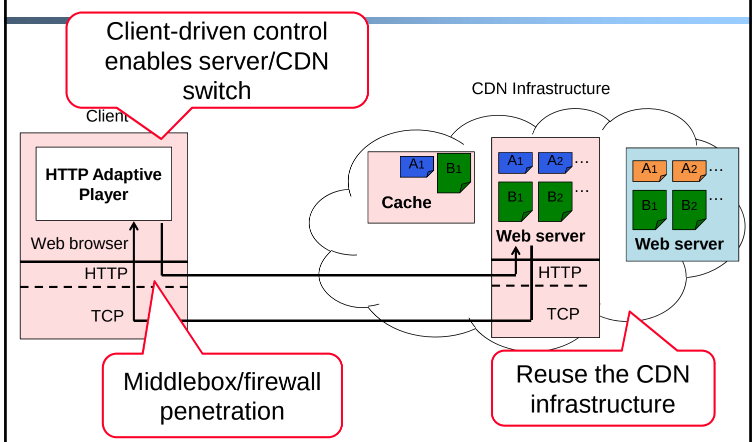
Reasons for Wide Adoption



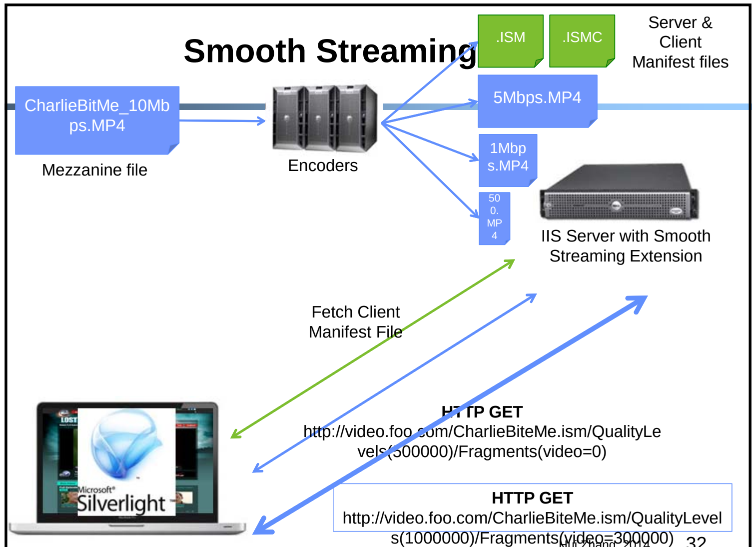
Advantages of HTTP Streaming

- Easy to deploy: it's just HTTP!
  - Work with existing caches/proxies/CDN/Firewall
- Fast startup by downloading lowest quality/smallest chunk
- Bitrate switching is seamless
- Many small files
  - Small with respect to the movie size
  - Large with respect to TCP
    - 5-10 seconds of 1Mbps – 3Mbps → 0.5MB – 4MB per chunk

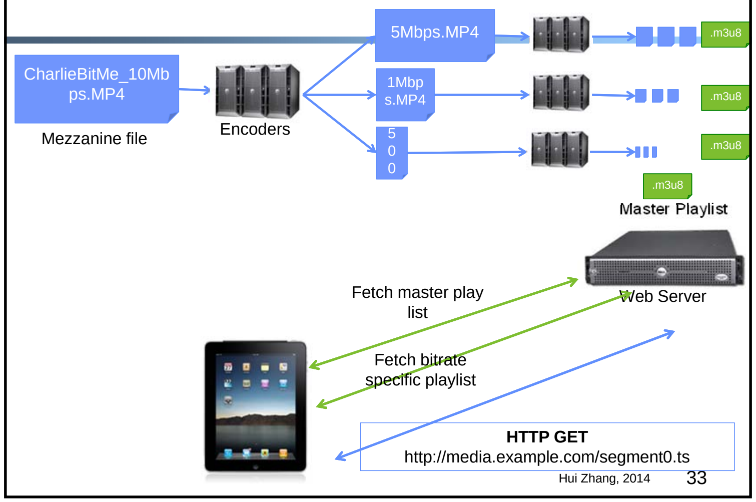
Example of HTTP Streaming Protocols

- Apple HLS: HTTP Live Streaming
- Microsoft IIS Smooth Streaming: part of Silverlight
- Adobe HDS: HTTP Dynamic Streaming
- DASH: Dynamic Adaptive Streaming over HTTP

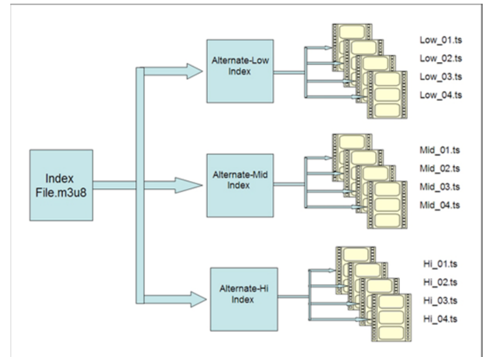
Smooth Streaming



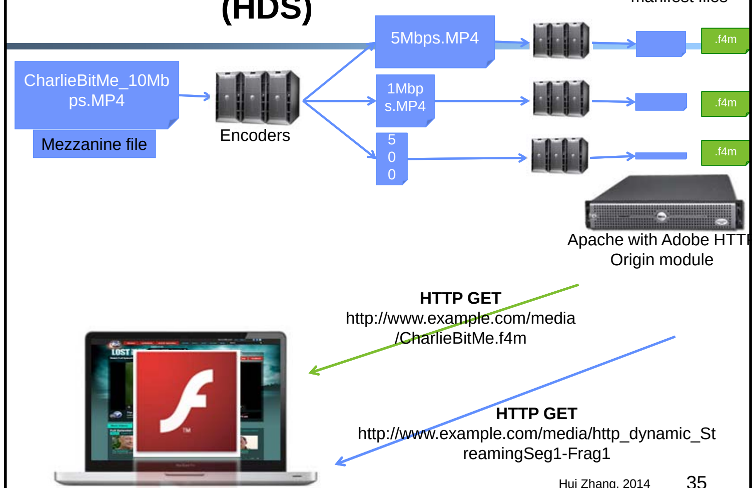
HTTP Live Streaming (HLS)



Example of HLS Meta Data



HTTP Dynamic Streaming (HDS)



Concluding Remarks

- NOT all contents are the same
- Video is fundamentally different from transaction traffic
- We are at the very beginning of Internet video revolution
  - video is more than 60% Internet traffic today,
  - video will be more than 90% Internet traffic in 2-3 years
- What is next?
  - Premium video on big screens → zero tolerance for poor quality: 4K + 3D video
  - Mobile video
- Technical challenges
  - Quality, scalability, mobility, security, usability