Lecture 5

Next-up

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Multimedia: video

spatial coding example: instead of sending *N* values of same color (all purple), send only two values: color value (*purple*) *and number of repeated values* (N)

- video: sequence of images displayed at constant rate
  - e.g., 24 images/sec
- digital image: array of pixels
  - each pixel represented by bits
- coding: use redundancy *within* and *between* images to decrease # bits used to encode image
  - spatial (within image)
  - temporal (from one image to next)

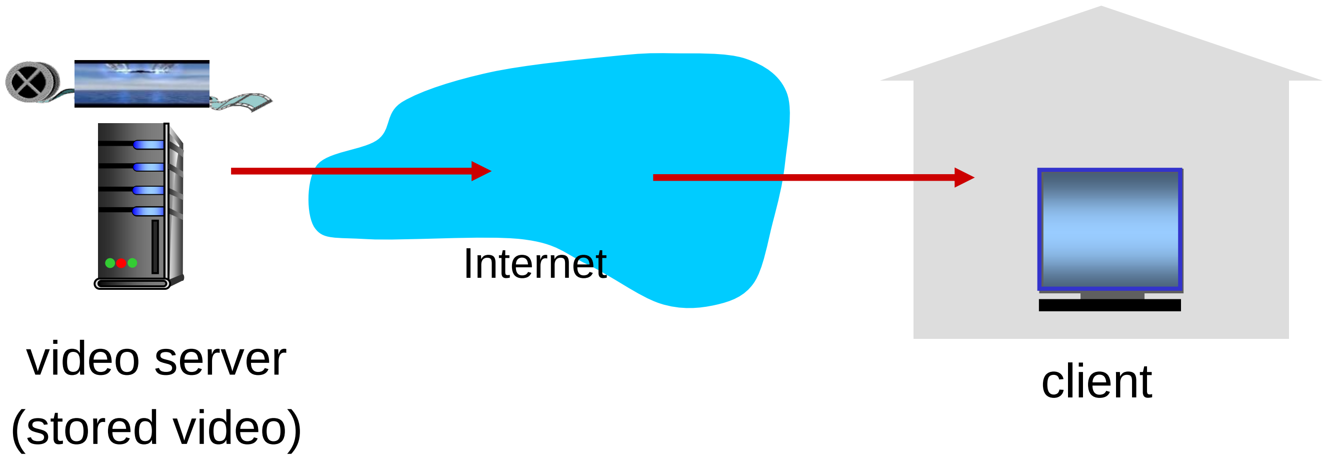
frame *i*

frame *i+1*

temporal coding example: instead of sending complete frame at i+1, send only differences from frame i

Streaming stored video:

- simple scenario:

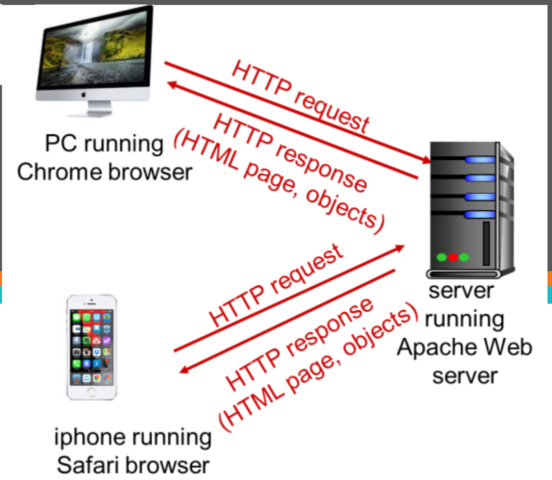


❖ *streaming stored* audio, video

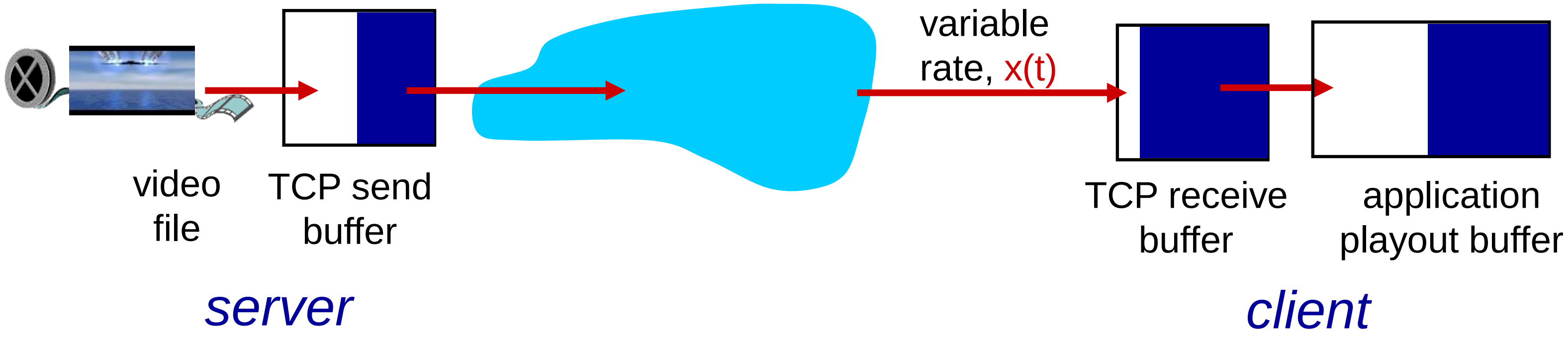
- *streaming:* can begin playout before downloading entire file
- *stored (at server):* can transmit faster than audio/video will be rendered (implies storing/buffering at client)
- e.g., YouTube, NetFlix, Vimeo, …

Streaming multimedia: HTTP

HTTP: hypertext transfer protocol uses TCP:



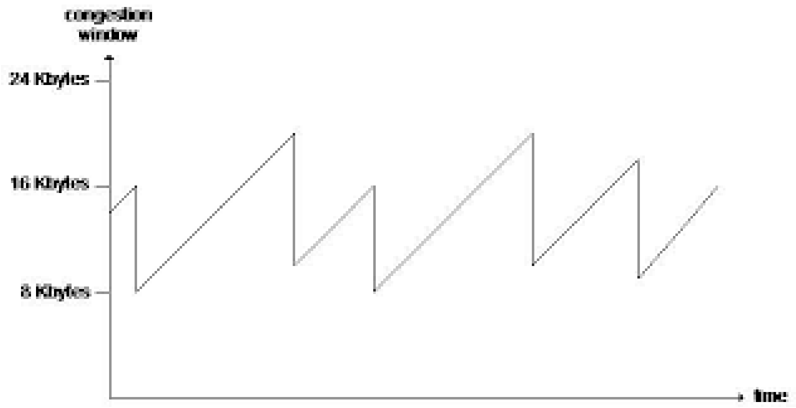
- multimedia file retrieved via HTTP GET (Same as Web!)
- send at maximum possible rate under TCP



- Buffer fill rate fluctuates due to TCP congestion control, retransmissions (in-order delivery)
- Use application playout buffer: larger playout delay - smooth application playout
- Examples: Youtube, Netflix, and most streaming applications…

Why HTTP (TCP)?

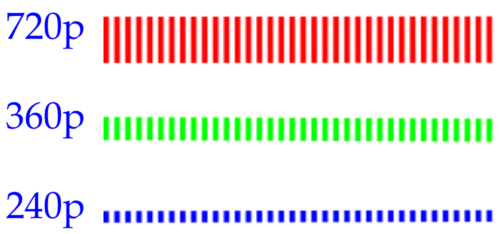
- UDP vs. TCP
  - UDP: unreliable (no acks), lightweight (faster), smooth
  - TCP: reliable (use acks), heavyweight (slower), sawtooth pattern (congestion control)



- UDP was used mainly for multimedia streaming
  - But UDP traffic is blocked at firewalls – security issue
  - Need separate servers for Video streaming
- Why HTTP (TCP)?
  - HTTP/TCP passes more easily through firewalls (UDP cannot)
  - Can utilize existing Web servers (can be used for both Web and Video streaming)
  - TCP sawtooth pattern can be smoothened by application buffer

DASH: Dynamic, Adaptive Streaming over HTTP

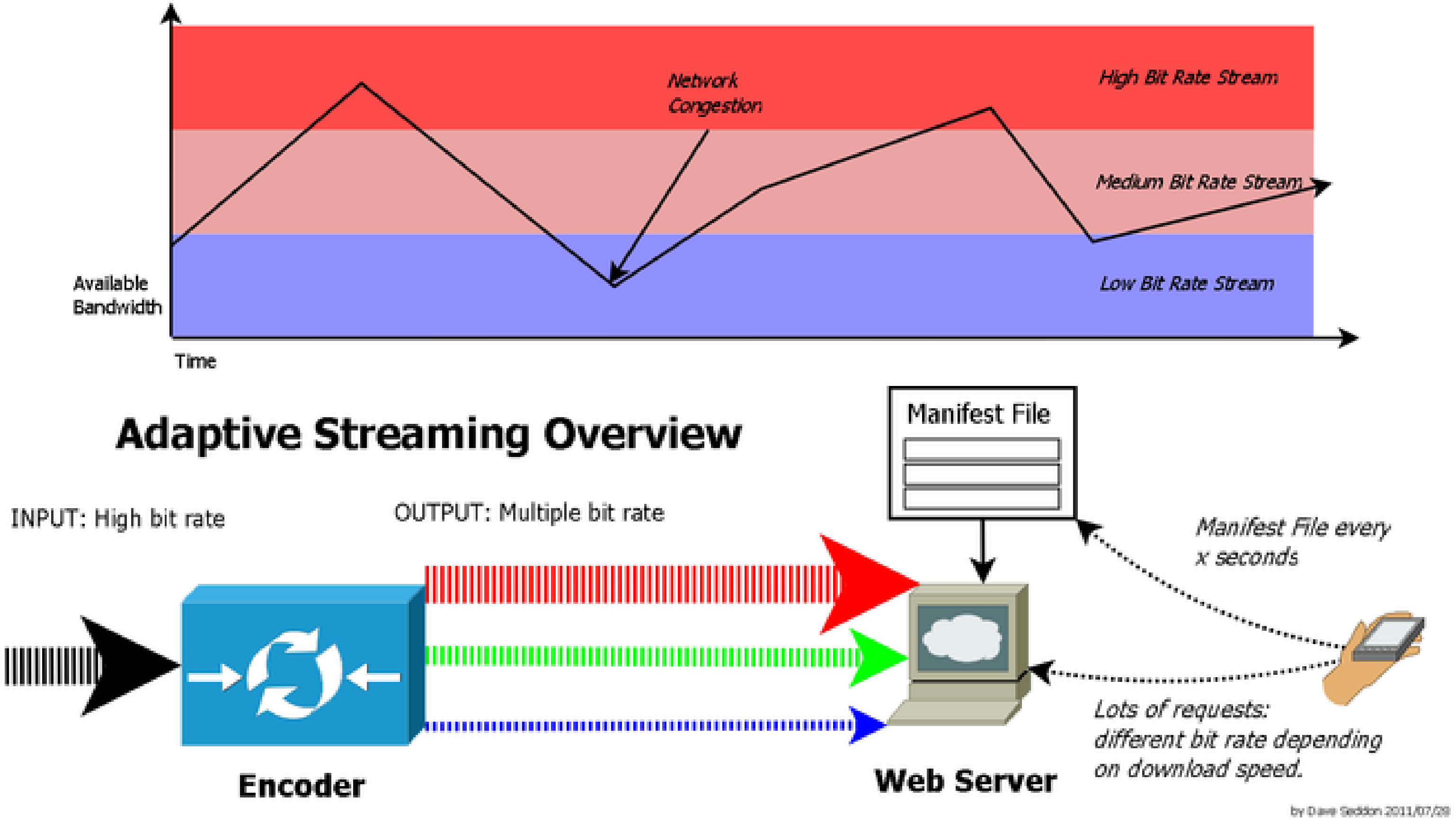
- server:
  - divides video file into multiple chunks
    - each chunk is 1~15 seconds of video data
  - each chunk stored, encoded at different rates



- client:
  - periodically measures server-to-client bandwidth
  - chooses maximum coding rate sustainable given current bandwidth
  - can choose different coding rates at different points in time (depending on available bandwidth at time)
- Examples: MPEG-DASH, Adobe, Apple, MS, …

mpeg-DASH

DASH: Dynamic, Adaptive Streaming over HTTP



http://en.wikipedia.org/wiki/Adaptive_bitrate_streaming

Next-up

- MP-DASH: Adaptive Video Streaming Over Preference-Aware Multipath, CoNEXT'16
  - Multipath TCP + DASH = MP-DASH
  - Main Goal: Enhance MPTCP to support adaptive video streaming (DASH)
  - Example: Use less cellular data (=less money) with negligible degradation of QoE

Motivations

- Multipath TCP
  - Path selection in MPTCP is defined by MPTCP scheduler: select the smallest RTT path
- Measurement Study in the Wild
  - Can Wi-Fi alone support 1080p video? → 3 scenarios:
    1) Wi-Fi only is never able to support 1080p (64%)
    2) Wi-Fi can sometimes play 1080p, but not always (15%)
    3) Wi-Fi can almost always stably support 1080p (21%)
  - 79% of the time Wi-Fi is poor: Wi-Fi alone cannot always support 1080p
    - MPTCP can be helpful... increases throughput – better QoE!
  - 21% of time Wi-Fi alone is enough (next slide)

Motivations

- 21% of time Wi-Fi alone is enough (continued)
  - MPTCP can use unnecessary use LTE bandwidth
  - Example: 1080p needs 4Mbps, current Wi-Fi 12.1Mbps, LTE 14.6Mbps – MPTCP still uses LTE!

Controlled Experiments

- Observation 1: LTE link is almost always used even though we need only 0.2Mbps LTE for 1080p
- Observation 2: After finishing downloading a chunk, networks will be idle. This means enough video chunks in receiver buffer.
  - QoE will not be affected if chunks arrive a bit late, as long as playback deadline is met

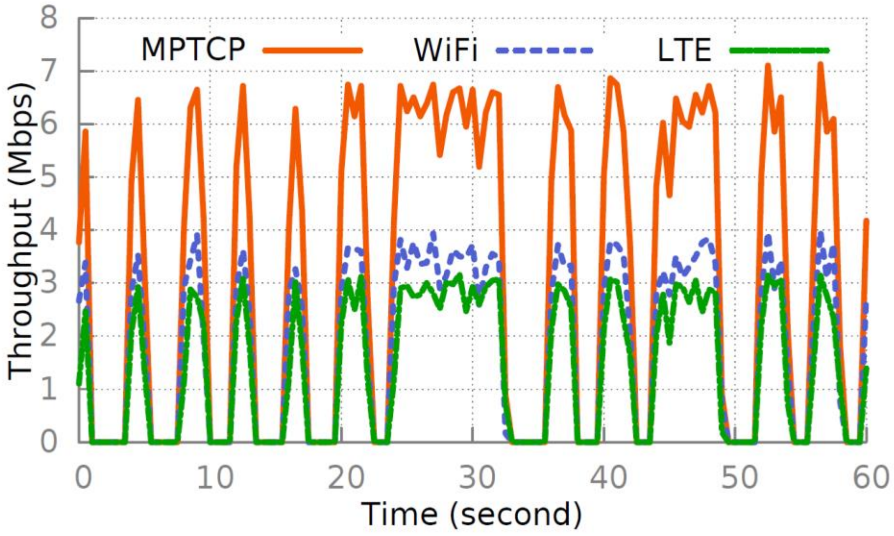


Figure 1: WiFi/LTE throughput when playing a DASH video over MPTCP.