Video

Lecture 9

http://www.cs.rutgers.edu/~sn624/352-F24

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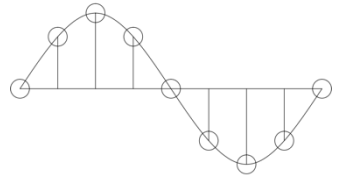
Digital representation of audio and video

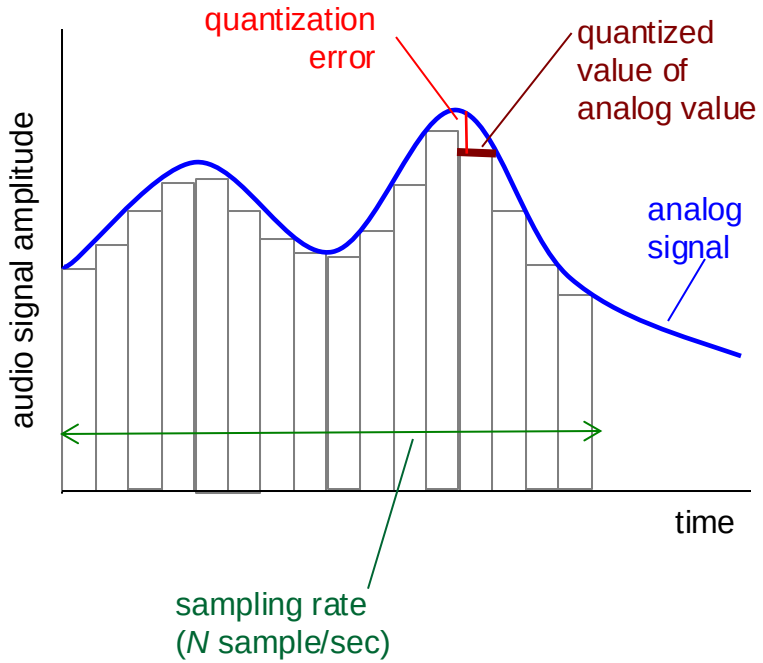
Digital representation of audio



- Must convert analog signal to digital representation
- Sample
  - How many times (twice the max frequency in the signal)
- Quantize
  - How many levels or bits to represent each sample
  - More levels ➔ more accurate representation of signal
  - More levels ➔ more bits to store & need more bandwidth to transmit
- Compress
  - Compact representation of quantized values

Audio representation

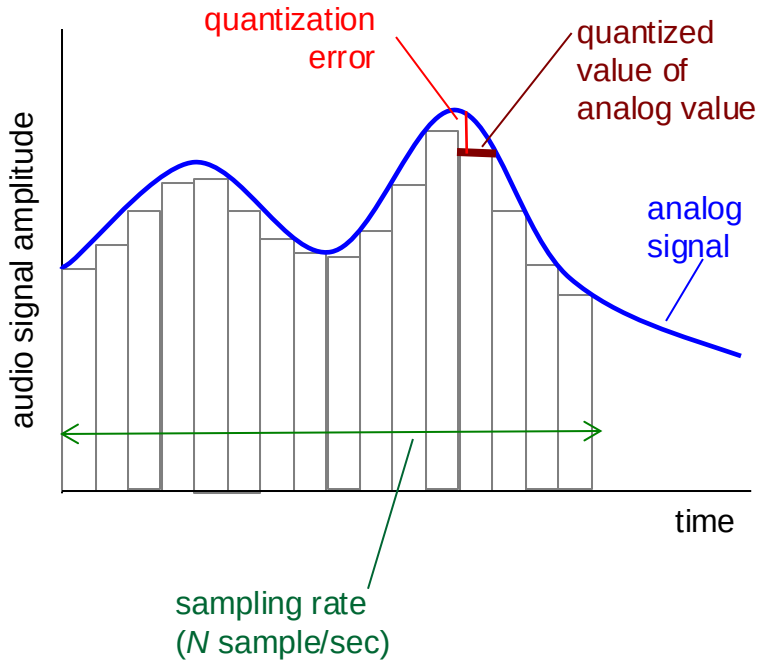
- analog audio signal sampled at constant rate
  - telephone: 8,000 samples/sec
  - CD music: 44,100 samples/sec
- each sample quantized, i.e., rounded
  - e.g., 2^8=256 possible quantized values
  - each quantized value represented by bits, e.g., 8 bits for 256 values



Audio representation

- example: 8,000 samples/sec, 256 quantized values
- Bandwidth needed: 64,000 bps

- receiver converts bits back to analog signal:
  - some quality reduction

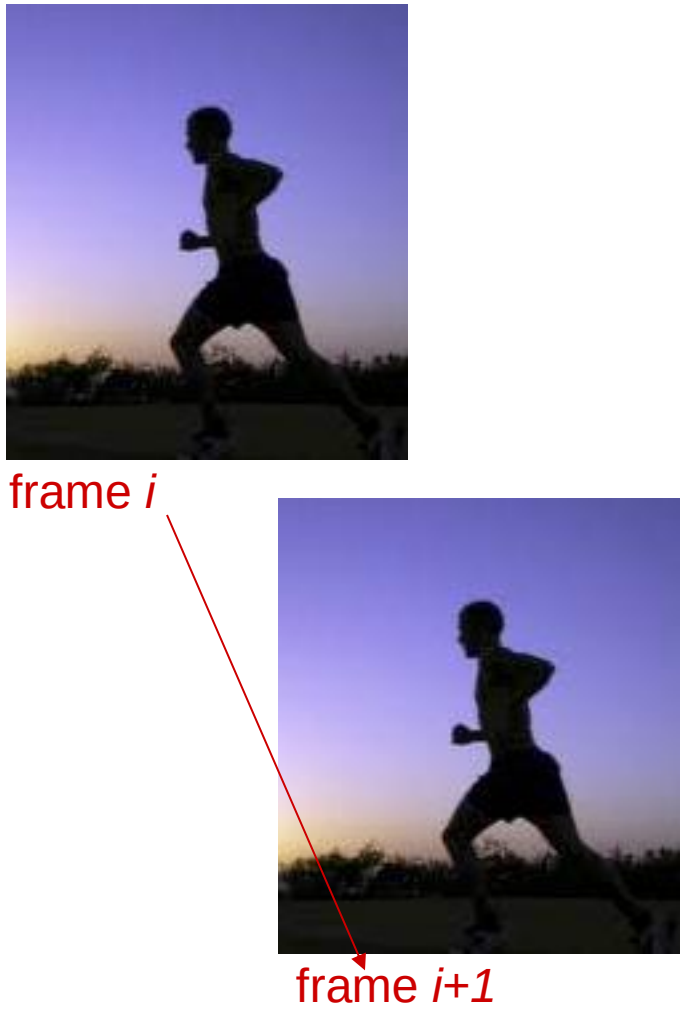


Example rates

- CD: 1.411 Mbps
- MP3: 96, 128, 160 Kbps
- Internet telephony: 5.3 Kbps and up

Video representation

- Video: sequence of images displayed at constant rate
  - e.g., 30 images/sec
  - Appear continuous due to the stroboscopic effect



Video representation

- Digital image: array of pixels
  - each pixel represented by bits
  - Encode luminance and color
  - Number of pixels: resolution
- Coding: use redundancy *within* and *between* images to decrease # bits used to encode image
  - spatial (within image)
  - temporal (from one image to next)
- Encoding/decoding algorithm often called a codec

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)

frame *i*

frame *i+1*

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

Video codecs: terminology

- Video *bit rate*: effective number of bits per second of the video after encoding
- It depends on many factors
  - Resolution of each image: more pixels = more bits
  - Detail per pixel: more luminance & color detail = more bits
  - Amount of movement in the video. More movement = more bits
  - Quality of overall compression in the codec
- Video bit rate is typically correlated with quality of perception
  - Higher bit rate == better to perceive

Bit-rates: terminology

- Bit-rate of a video changes over the duration of the video
- CBR: (constant bit rate): fixed bit-rate video
- VBR: (variable bit rate): different parts of the video have different bit rates, e.g., changes in color, motion, etc.
  - For VBR, we talk about average bit-rate over video's duration
- Examples of average video bit-rates
  - MPEG 1 (CD-ROM) 1.5 Mbps. MPEG2 (DVD) 3-6 Mbps
  - MPEG4 (often used in Internet, < 1 Mbps)
  - In general, one Internet video stream takes up a few Mbit/s (more for HD)

https://blog.video.ibm.com/streaming-video-tips/what-is-video-encoding-codecs-compression-techniques/

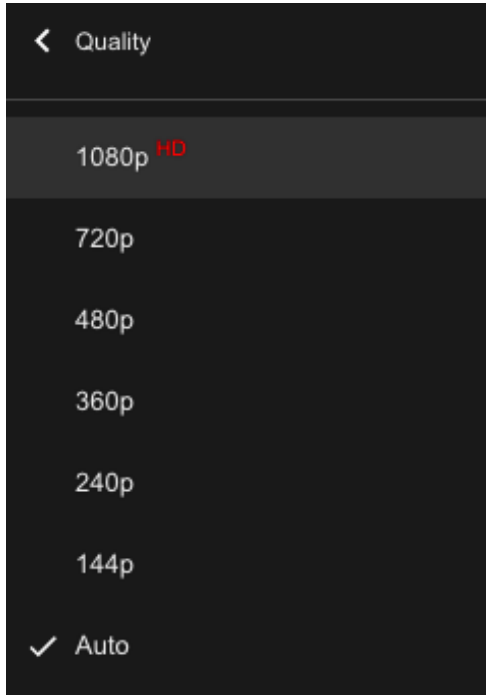
Networking multimedia: 3 types

- On-demand streamed video/audio
  - Can begin playout before downloading the entire file
  - Ful video/audio stored at the server: able to transmit faster than audio/video will be rendered (with storing/buffering at client)
  - e.g., Spotify, YouTube, Netflix
- Conversational voice or video over IP
  - interactive human-to-human communication limits delay tolerance
  - e.g., Zoom
- Live streamed audio, video
  - e.g, sporting event on sky sports
  - Can delay a little, but must be close to the “live edge” of content

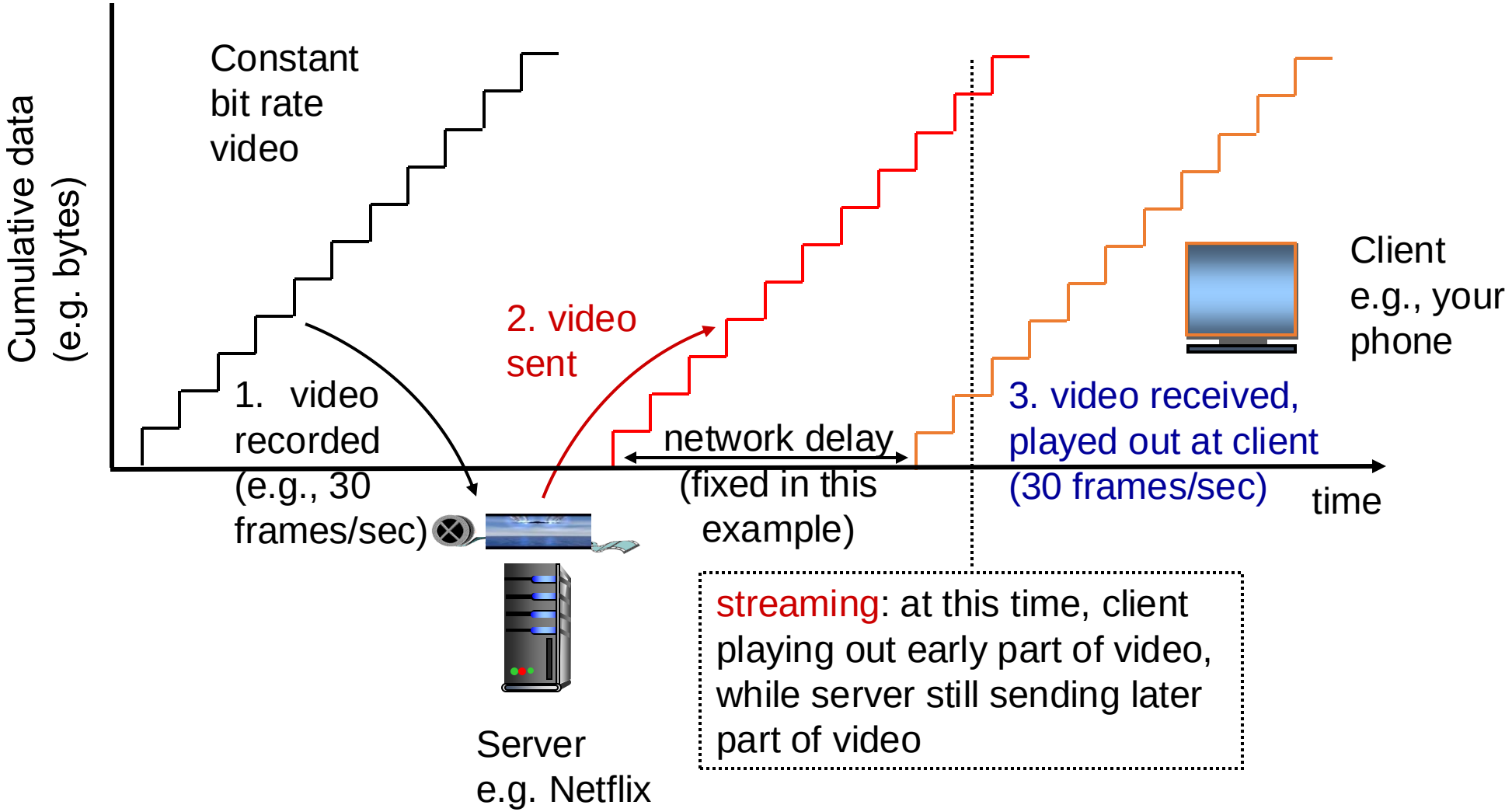
On-demand Video Streaming

Streaming (stored) video

- Media is prerecorded at different qualities
  - Available in storage at the server
- Client downloads an initial portion and starts viewing
  - The rest is downloaded as time progresses
  - No need for user to wait for entire content to be downloaded (streaming)
- Can change the quality of the content and where it’s fetched mid-stream

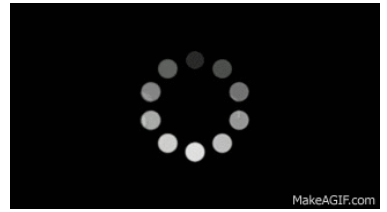


Streaming stored video



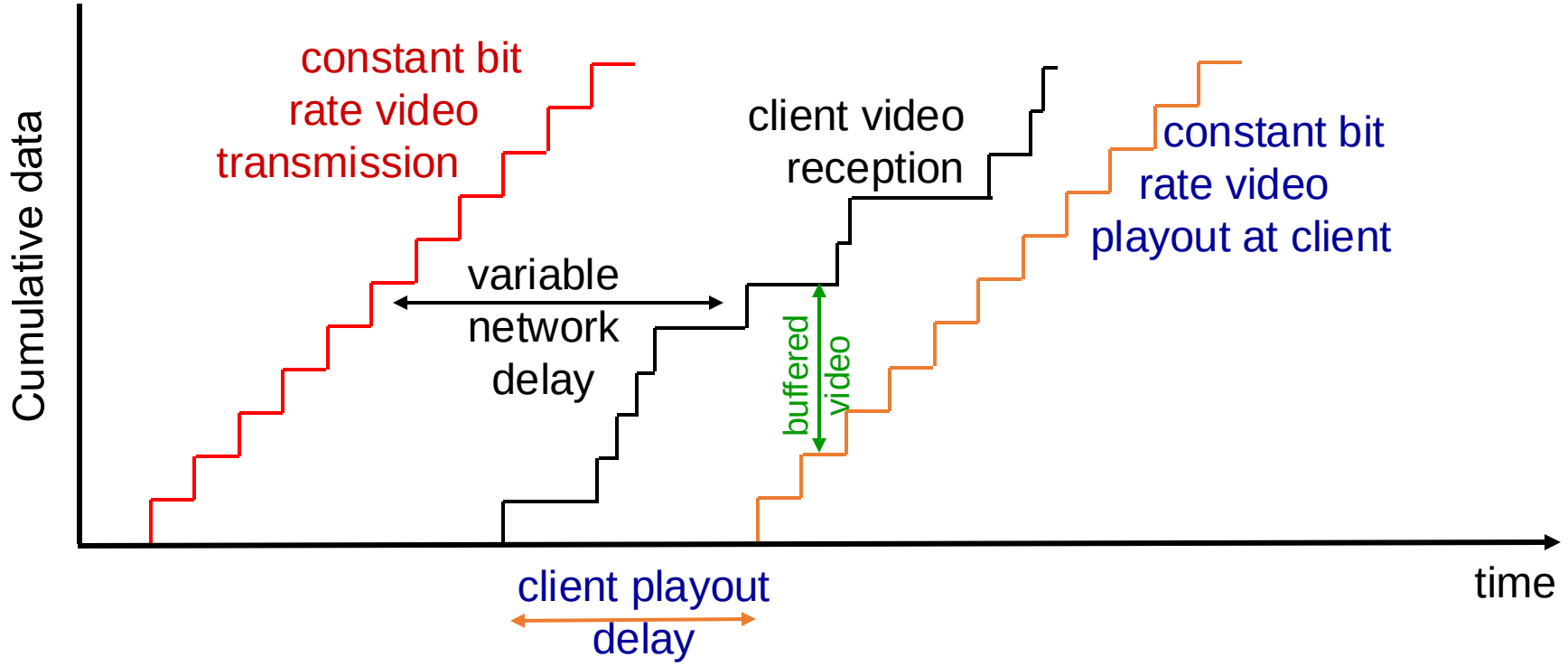
Streaming stored video: challenges

- Continuous playout constraint: once video playout begins at client, time gap between frames must match the original time gap in the video (why?)



- But network delays are variable!
- Clients have a client-side buffer of downloaded video to absorb variation in network delay, available bandwidth
- The video buffer also helps with user interactions: pause, fast-forward, rewind, jump through video

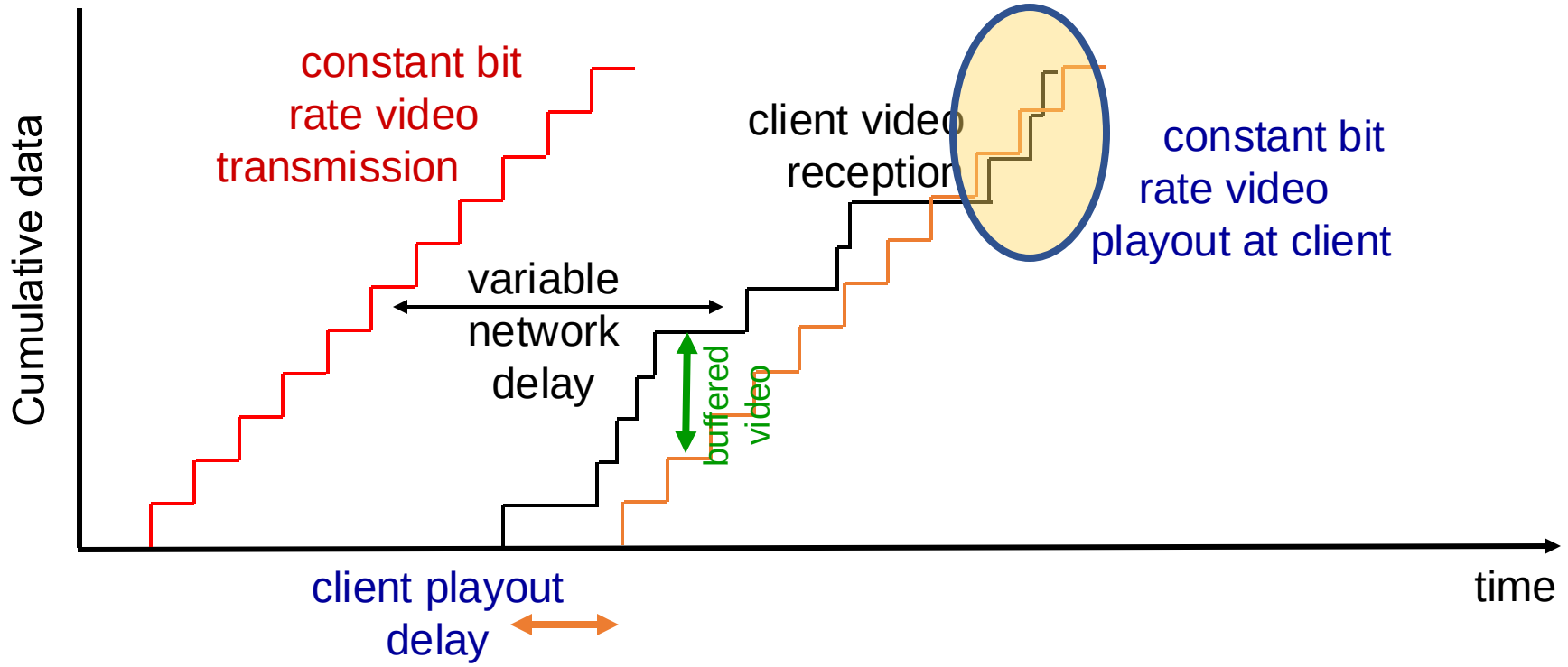
Introduce a delay for smooth playout



Client-side buffering with playout delay:

compensate for variations in the network delay

But not too small a delay



Playout delay that's too small can cause stalls

There's nothing in the buffer to show to the user