بسمه تعالی

School of Computer Engineering

Advanced Computer Networks

Application Layer, Video Streaming, and CDN

Part 3

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Fall 1401

Lecture overview

- Principles of network applications
- Web and HTTP
- E-mail, SMTP, IMAP
- The Domain Name System DNS
- video streaming and content distribution networks

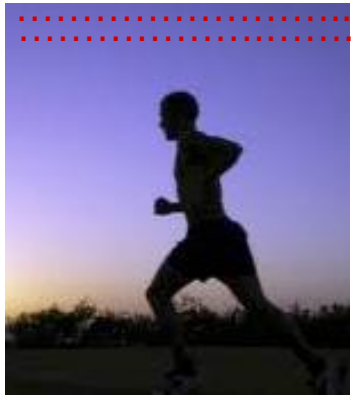
Video Streaming and CDNs: context

- stream video traffic: major consumer of Internet bandwidth
  - Netflix, YouTube, Amazon Prime: 80% of residential ISP traffic (2020)
- *challenge:* scale - how to reach ~1B users?
- *challenge:* heterogeneity
  - different users have different capabilities (e.g., wired versus mobile; bandwidth rich versus bandwidth poor)
- *solution:* distributed, application-level infrastructure

Multimedia: video

- 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)

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

Multimedia: video

- CBR: (constant bit rate): video encoding rate fixed
- VBR: (variable bit rate): video encoding rate changes as amount of spatial, temporal coding changes
- examples:
  - MPEG 1 (CD-ROM) 1.5 Mbps
  - MPEG2 (DVD) 3-6 Mbps
  - MPEG4 (often used in Internet, 64Kbps – 12 Mbps)

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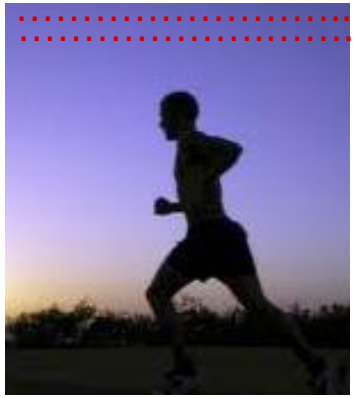


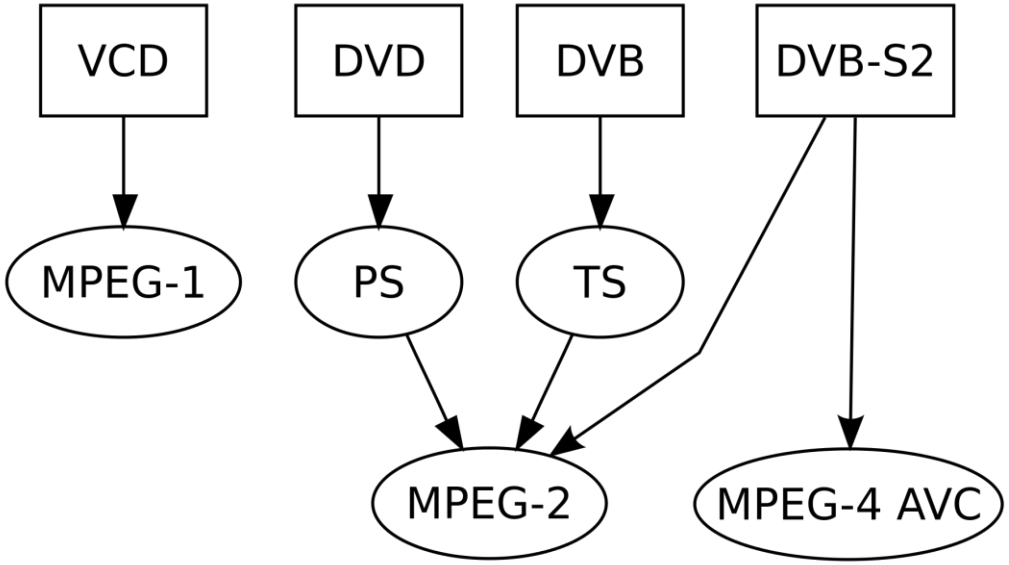
frame *i*

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

frame *i+1*

Multimedia: video

- The **Moving Picture Experts Group (MPEG)** is an alliance of working groups established jointly by ISO and IEC* that sets standards for media coding, including compression coding of audio, video, graphics, and genomic data; and transmission and file formats for various applications.



* International Electrotechnical Commission

Multimedia: video

Recall that:

- A multimedia application can be classified as
  - Streaming stored audio/video,
    - **Related Topics**: client buffering, prefetching, and adapting video quality to available bandwidth
  - Conversational voice/video-over-IP, (Skype, RTP, SIP)
    - **Key features**: highly sensitive to end-to-end delay but can tolerate occasional loss of data
  - Streaming live audio/ video.

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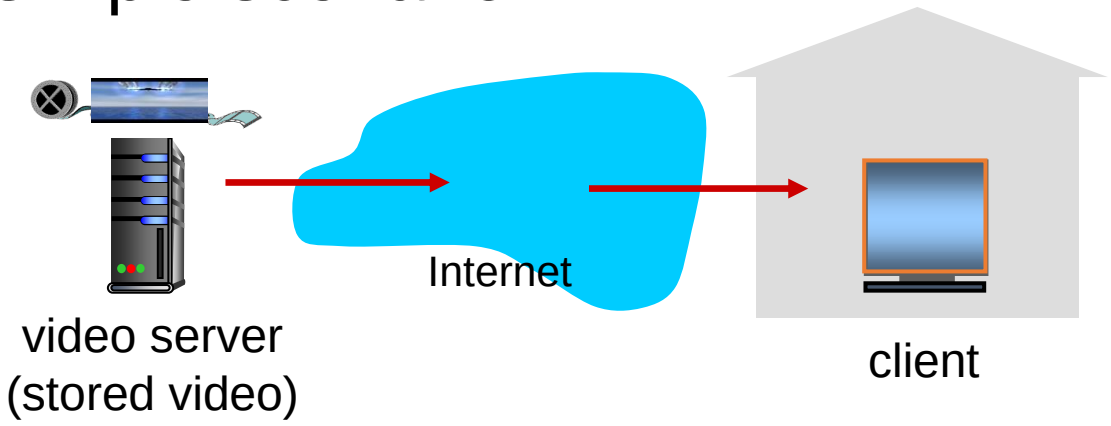
- In this lecture, we consider streaming stored audio/video, and discuss several important related topics.

Streaming stored video

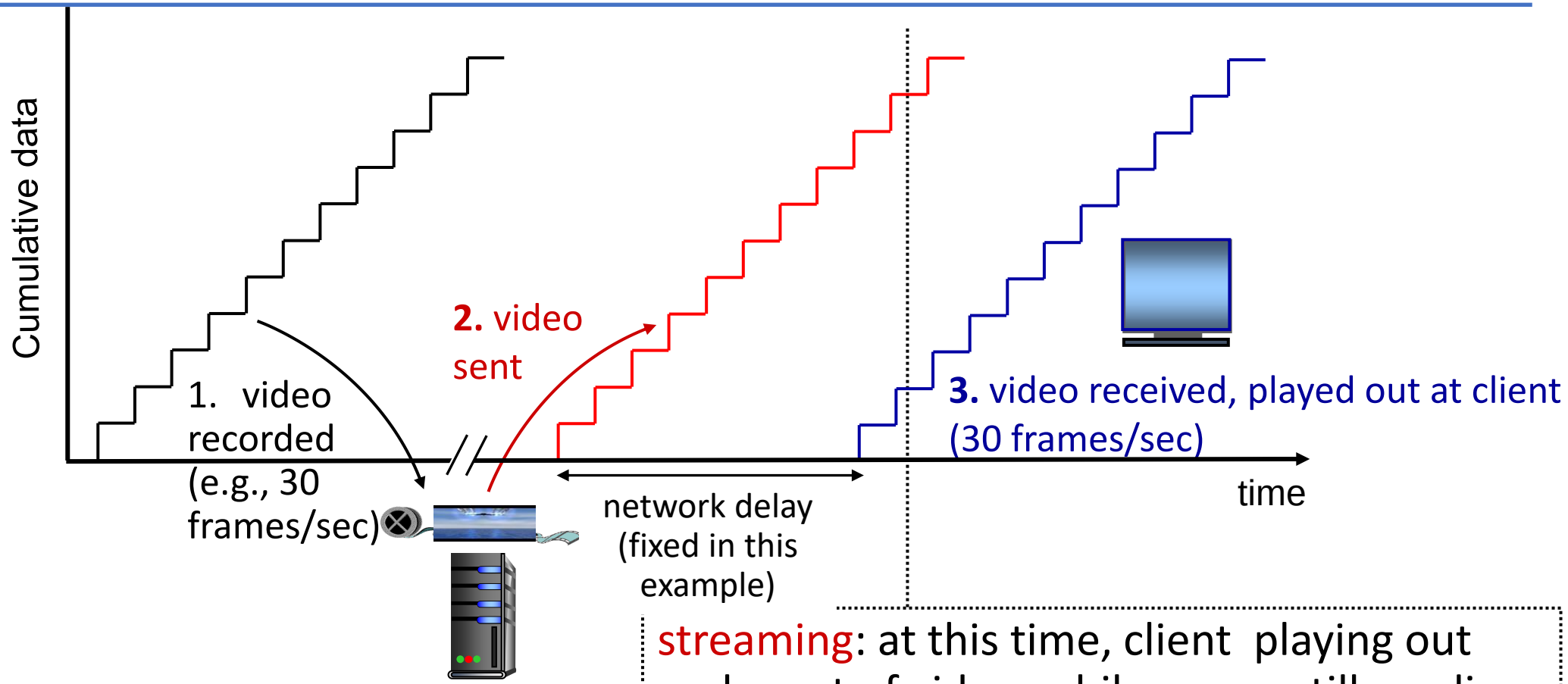
simple scenario:



Main challenges:

- server-to-client bandwidth will *vary* over time, with changing network congestion levels (in house, access network, network core, video server)
- packet loss, delay due to congestion will delay playout, or result in poor video quality

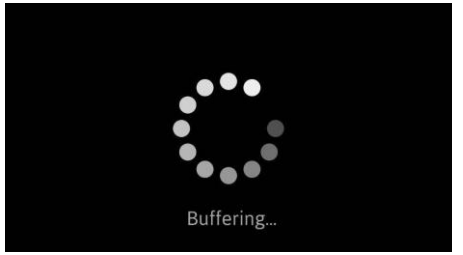
Streaming stored video



streaming: at this time, client playing out early part of video, while server still sending later part of video

Streaming stored video: challenges

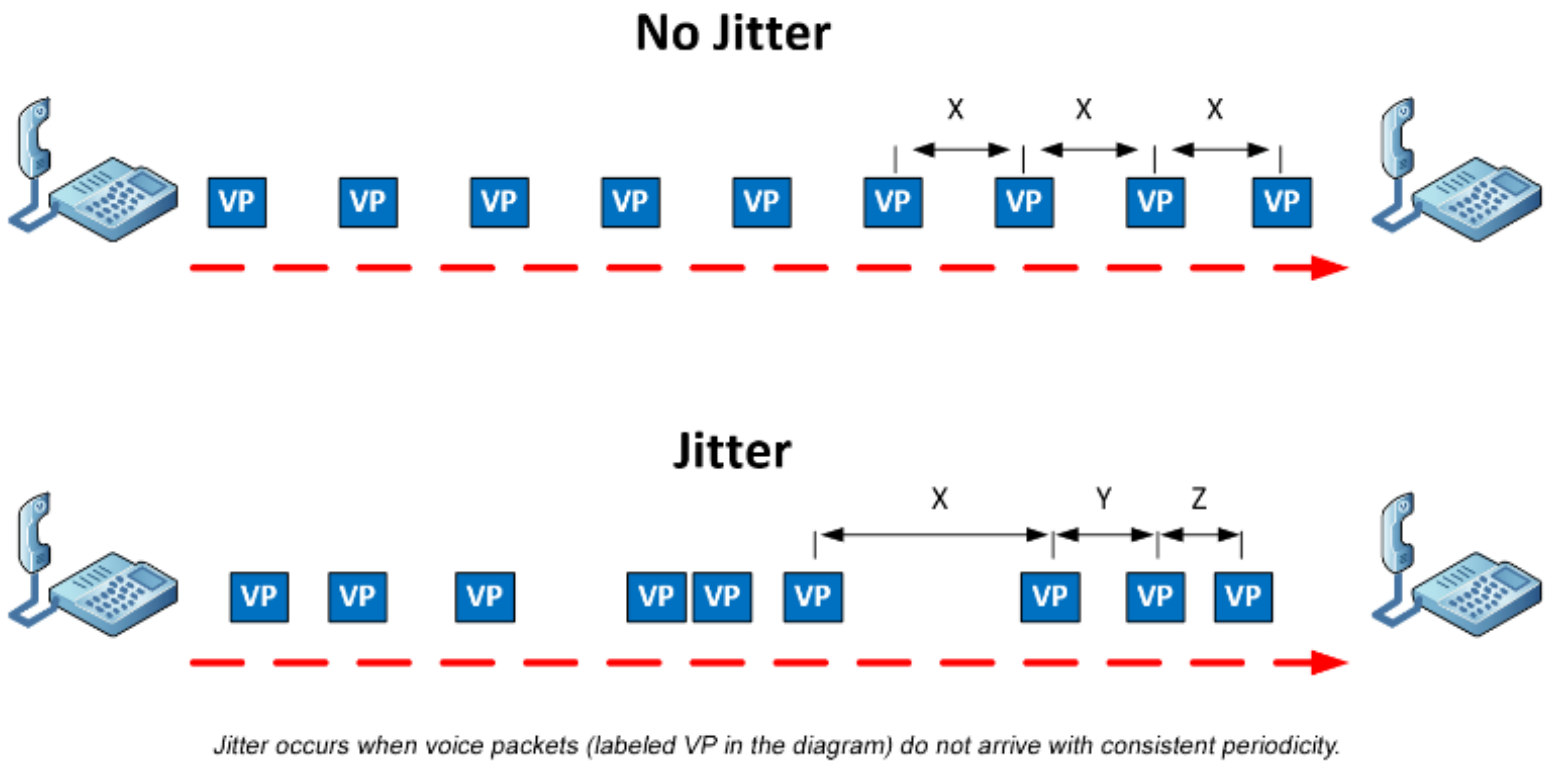
- continuous playout constraint: during client video playout, playout timing must match original timing
  - … but network delays are variable (jitter), so will need client-side buffer to match continuous playout constraint



- other challenges:
  - client interactivity: pause, fast-forward, rewind, jump through video
  - video packets may be lost, retransmitted

Streaming stored video: challenges

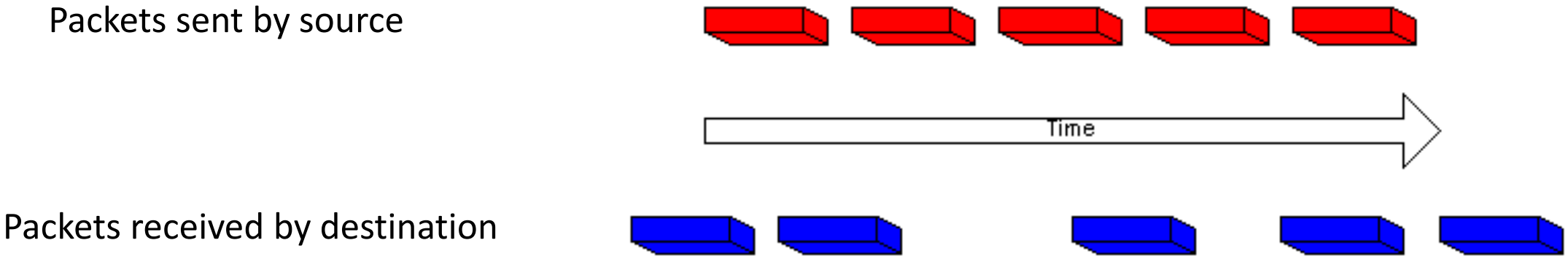
- Jitter in packet networks (example of voice packets in the figure)



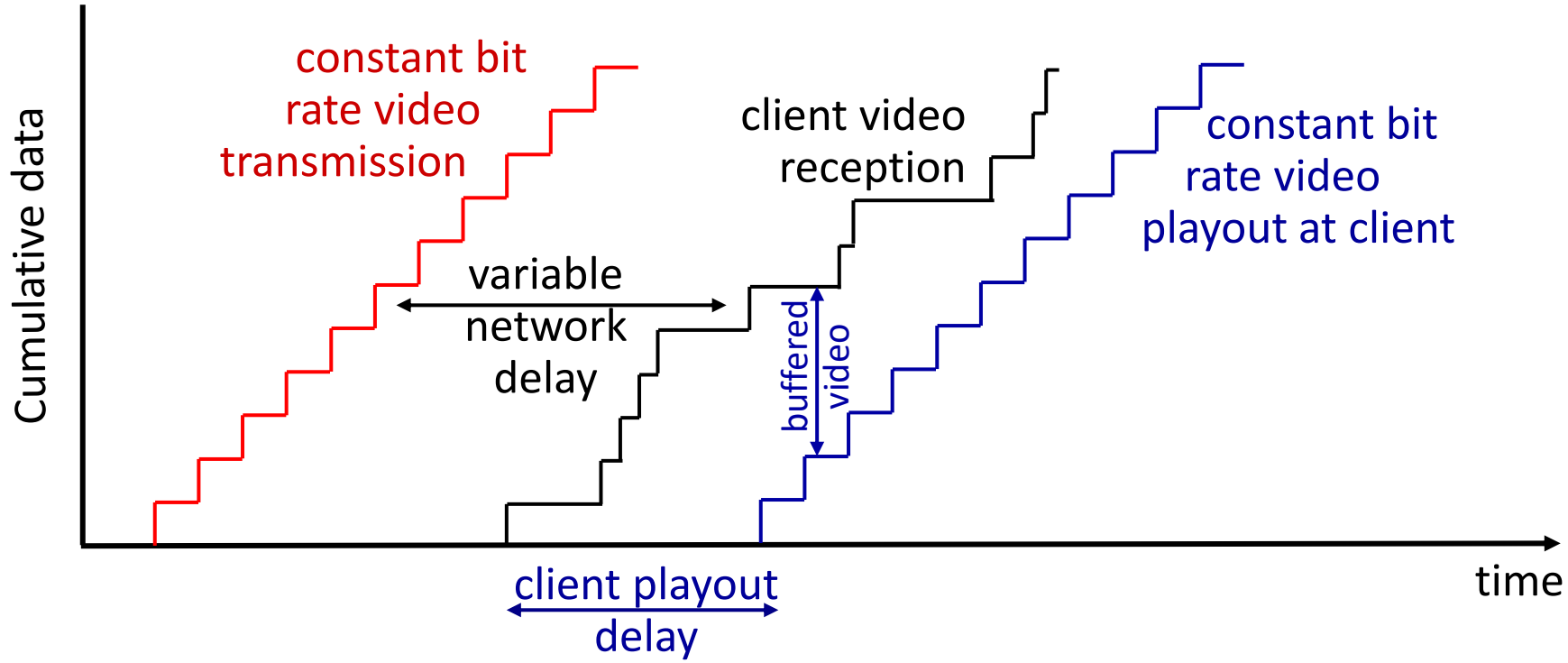
Jitter occurs when voice packets (labeled VP in the diagram) do not arrive with consistent periodicity.

Streaming stored video: challenges

- Jitter in packet networks (In general)



Streaming stored video: playout buffering



- *client-side buffering and playout delay:* compensate for network-added delay, delay jitter