画像情報特論 (1)
Advanced Image Information (1)

Introduction and Streaming Background

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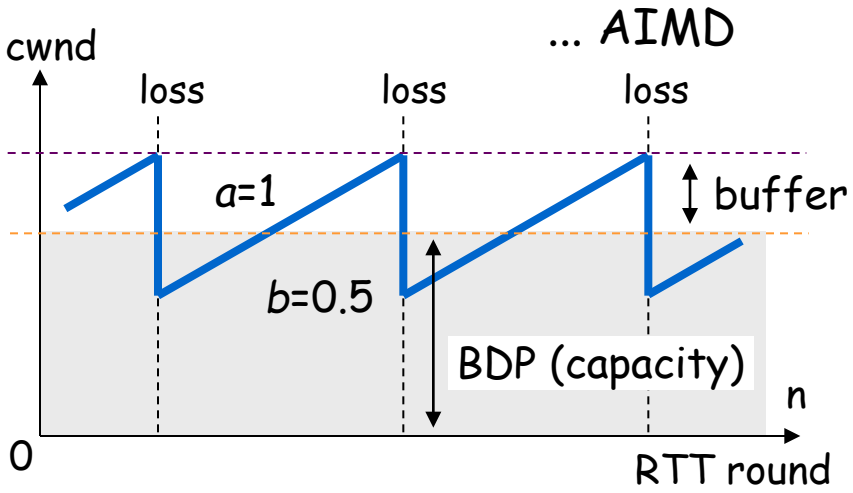
Introduction

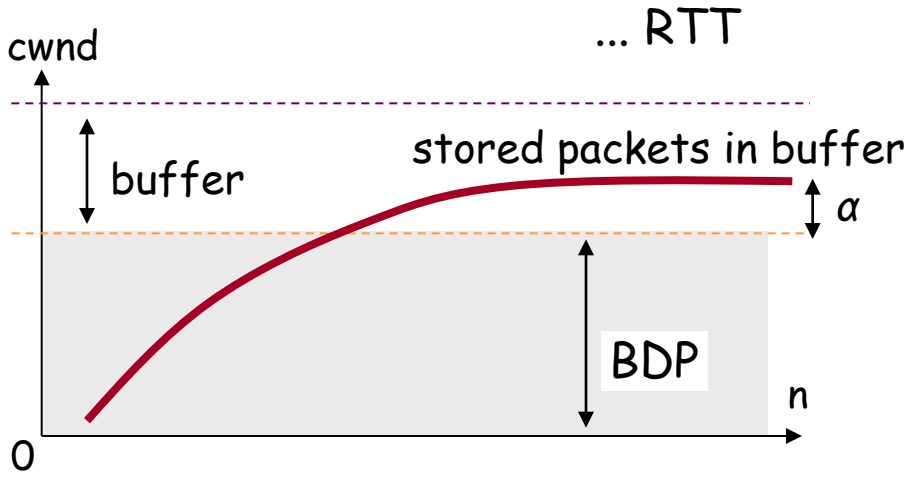
TCP Variants

- Loss-based



TCP-Reno, High-Speed TCP,
TCP-Westwood, CUBIC-TCP, ...

- Delay-based



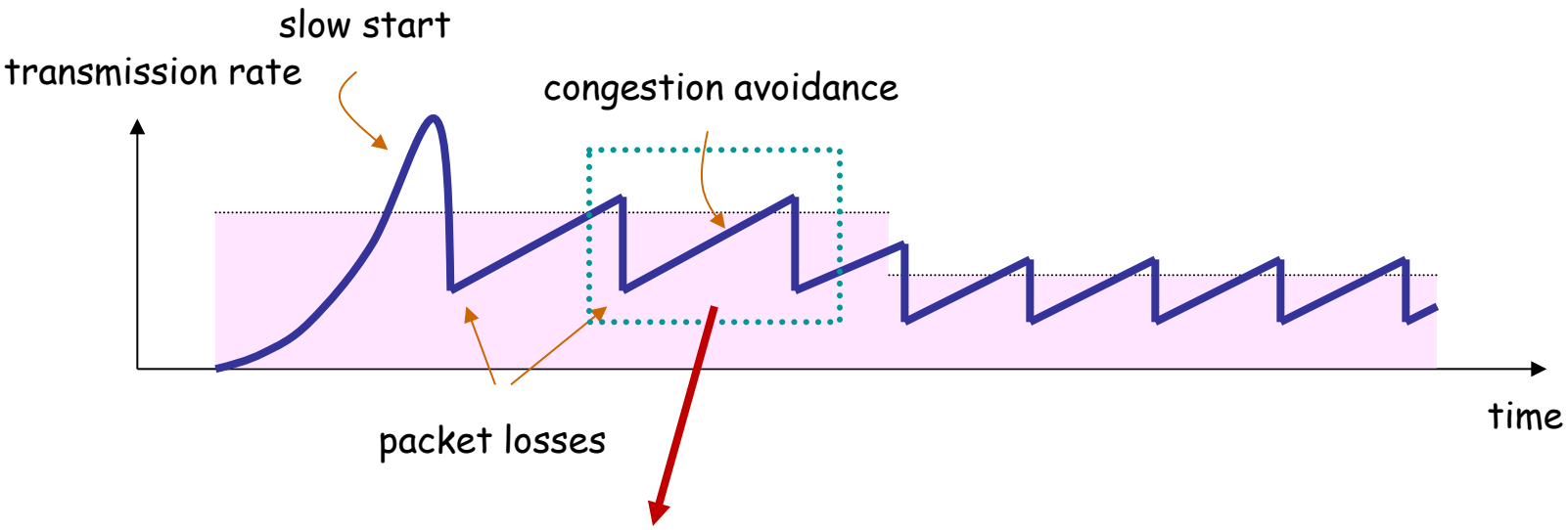
TCP-Vegas, FAST-TCP

- Hybrid — Compound TCP
- TCP-BBR

BDP: Bandwidth-Delay Product

RTP and TFRC

- TFRC (over RTP/UDP)



Modeling of steady-state TCP behaviors

$$R = \frac{1}{RTT}\sqrt{\frac{3}{2p}}$$

p: packet loss rate

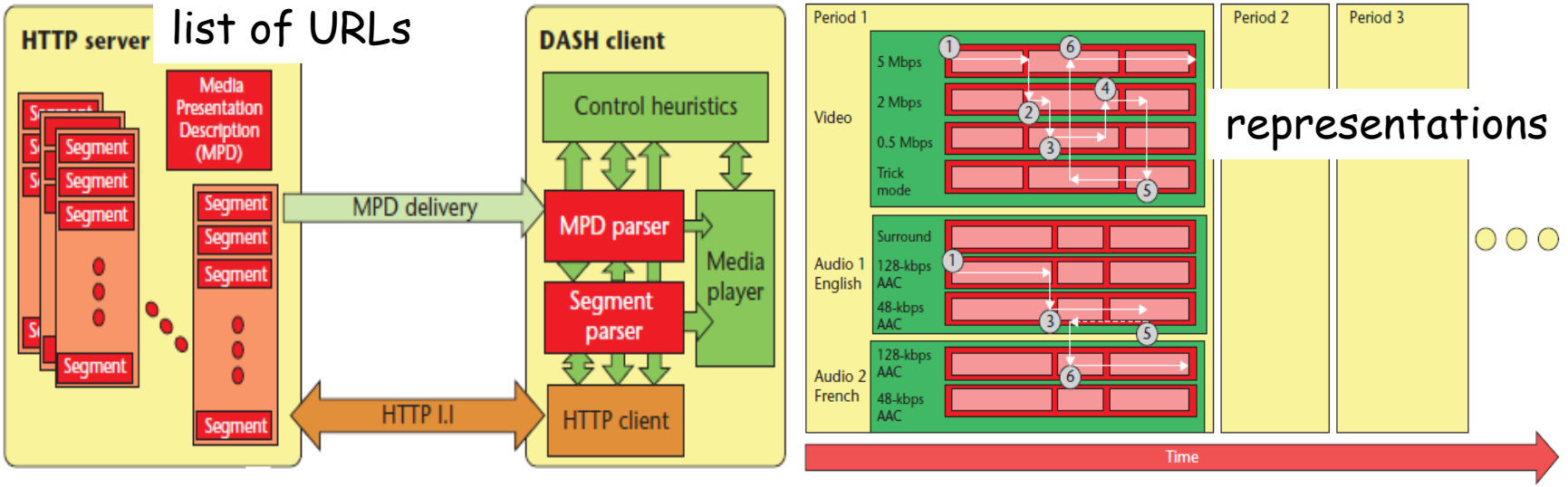
BDP/Buffer relationship

small buffer → ×efficiency
large buffer → ×delay

TFRC: TCP Friendly Rate Control

HTTP and MPEG-DASH

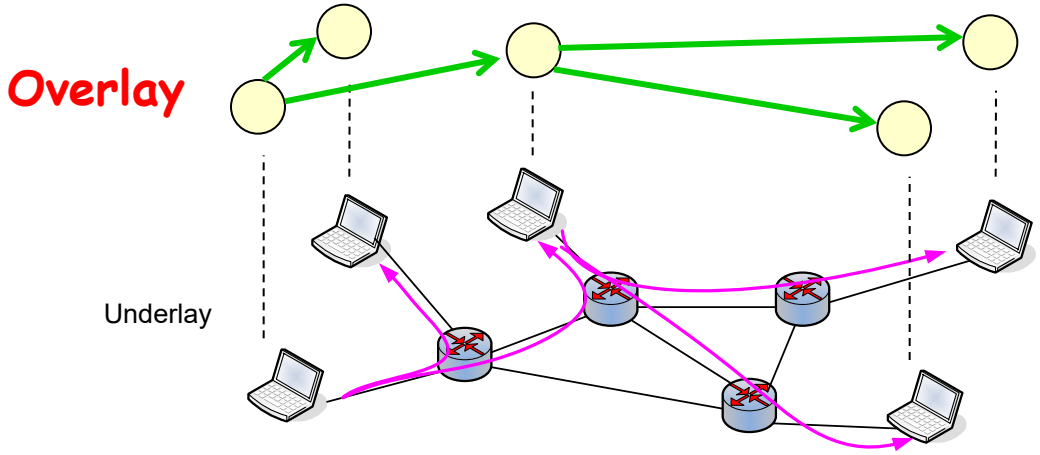
- MPEG-DASH: Dynamic Adaptive Streaming over HTTP
  - Multiple (bitrate, resolution) pairs … representation
  - Adaptive selection of representations



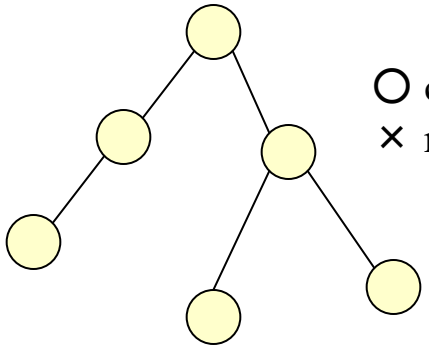
I. Sodagar, et al. : The MPEG-DASH Standard for Multimedia Streaming Over the Internet, IEEE Multimedia, Apr.2011.

CDN, P2P & Cloud

- Overlay networks

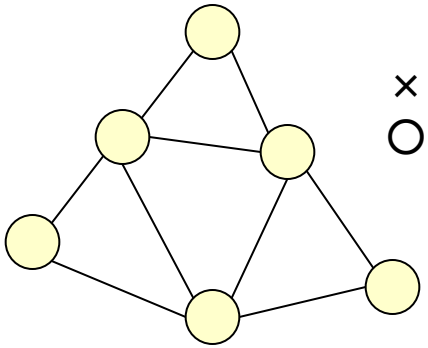


- tree



○ complexity
× robustness

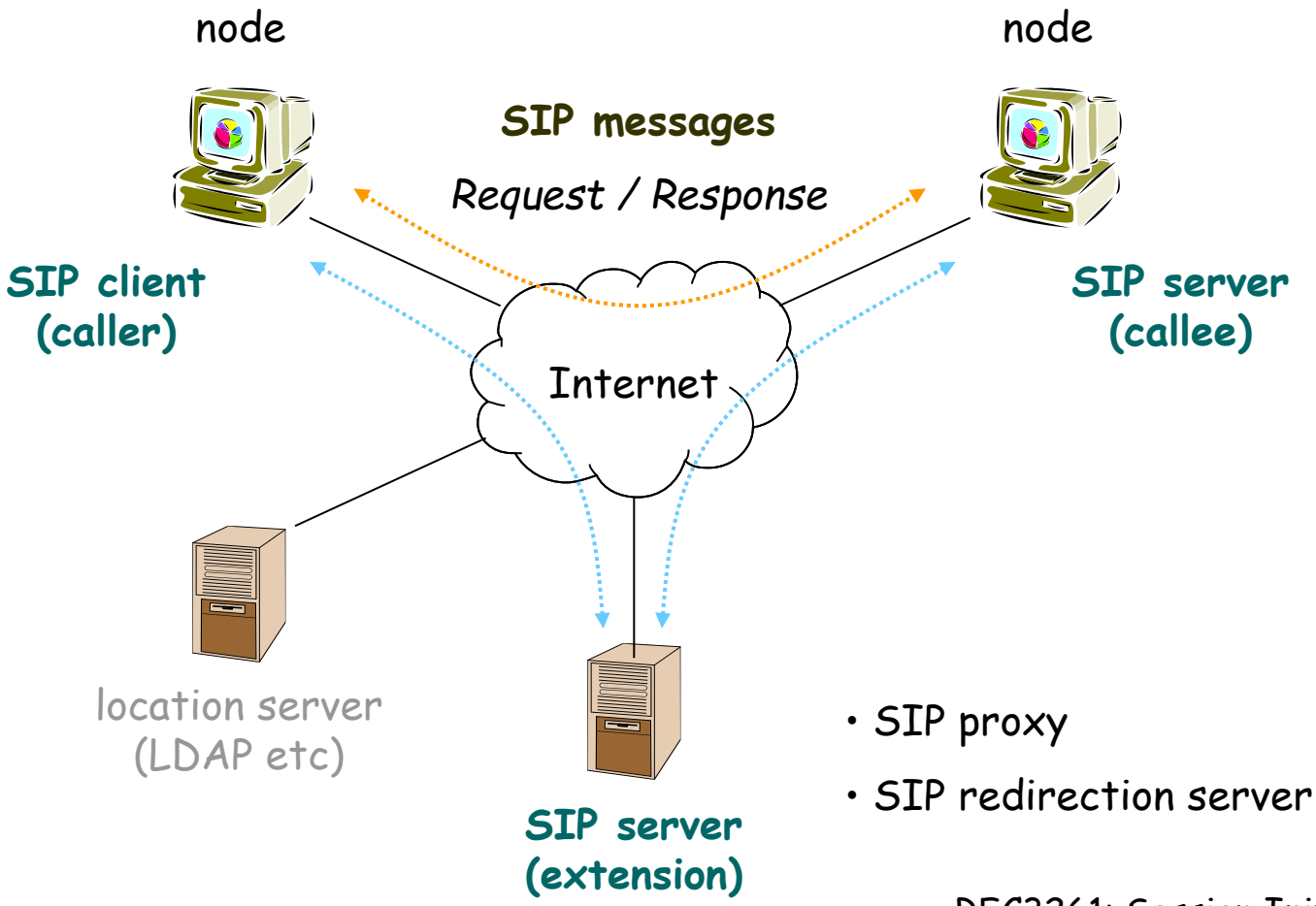
- mesh



× complexity
○ robustness

SIP and WebRTC

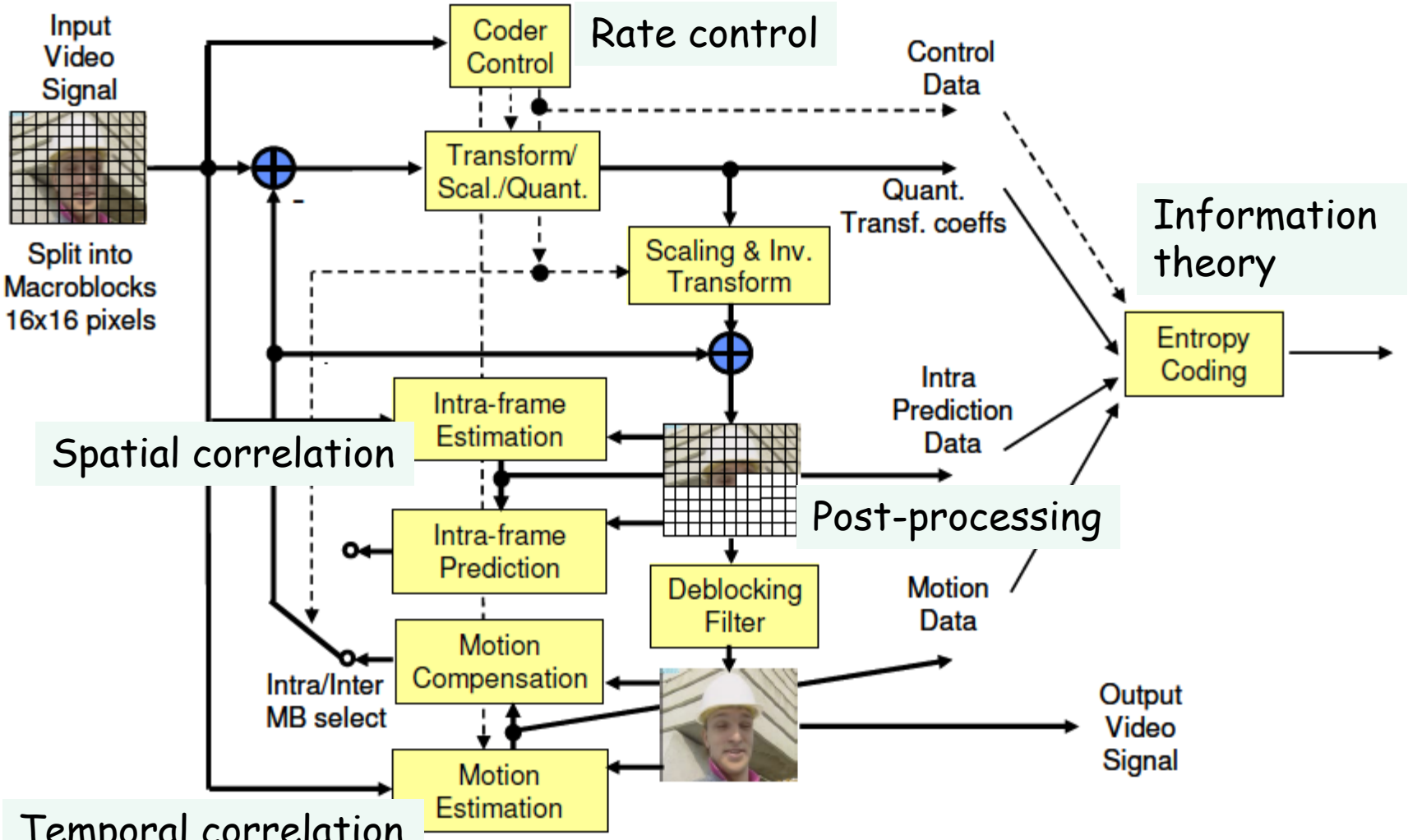
- SIP: Session Initiation Protocol



- SIP proxy
- SIP redirection server

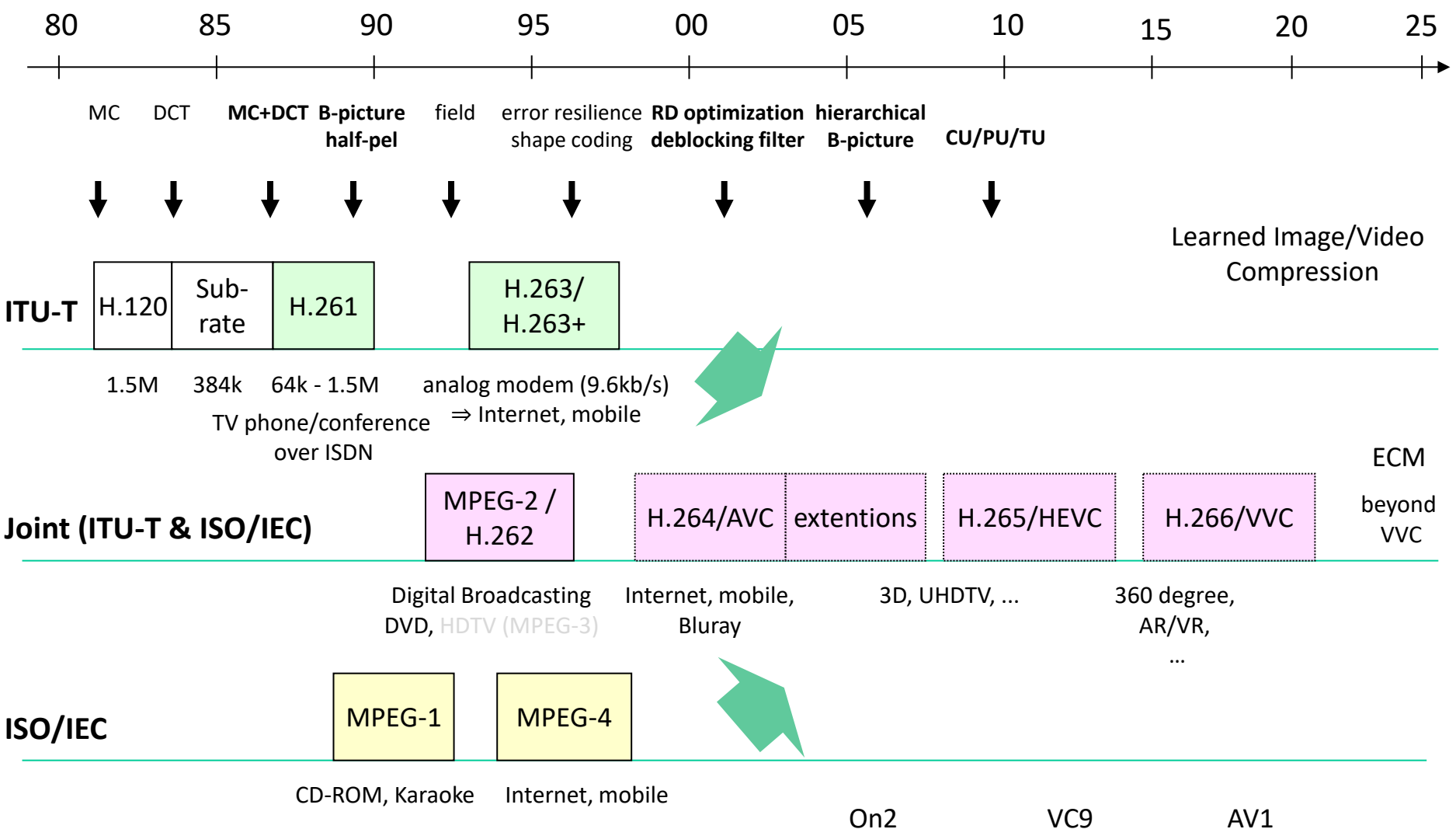
RFC3261: Session Initiation Protocol

Video Compression Basics



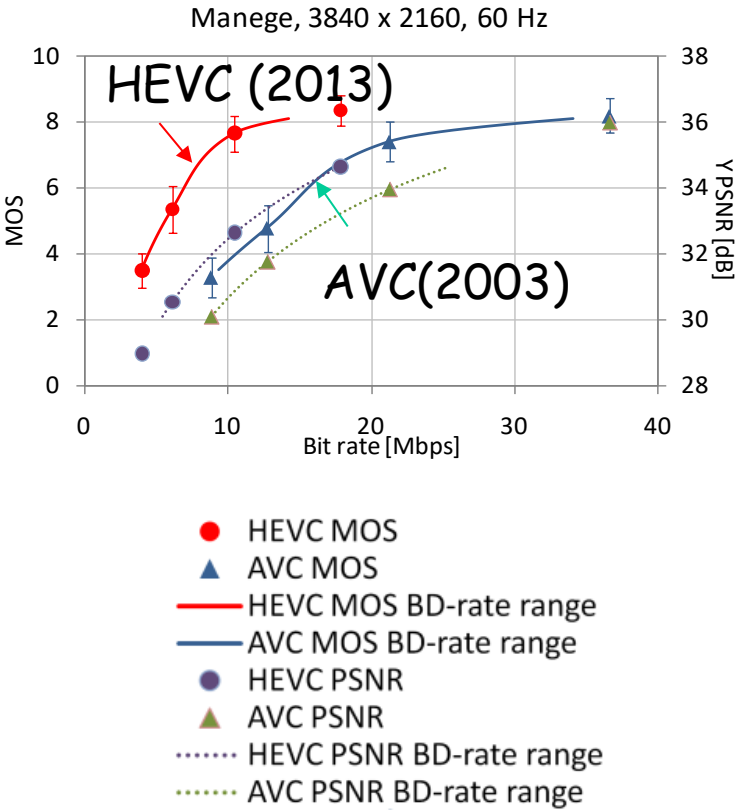
T.Ebrahimi: "Trends and Challenges in Video Coding", June.2009.

Video Compression History

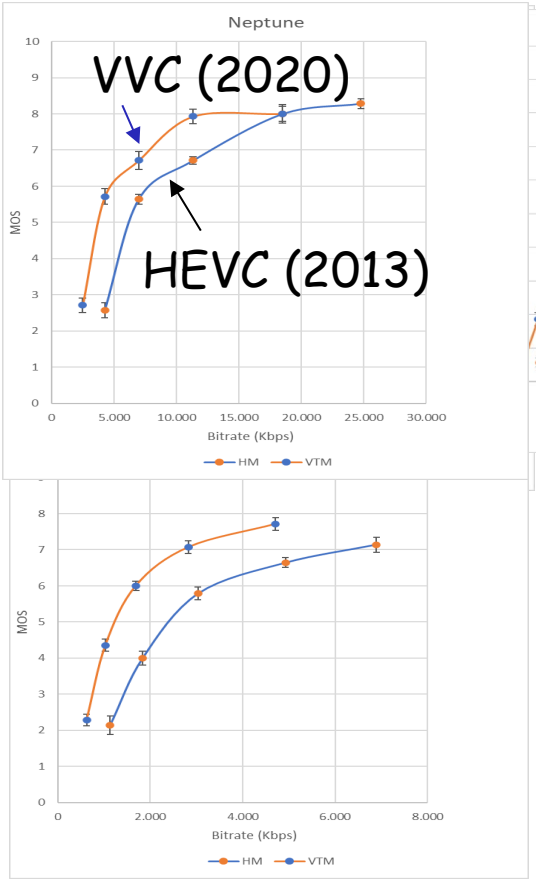


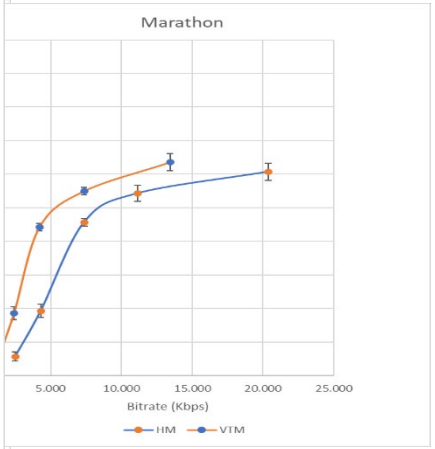
AVC, HEVC and VVC

- HEVC (2013)



- VVC (2020)

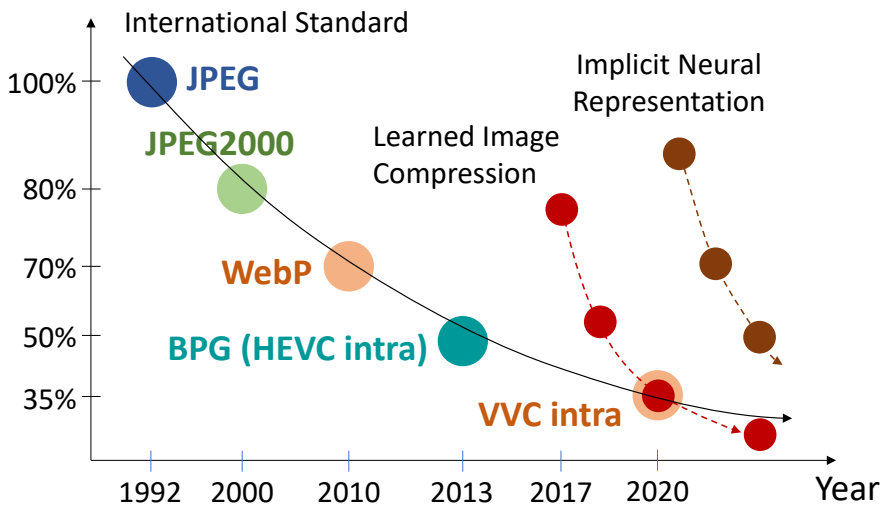




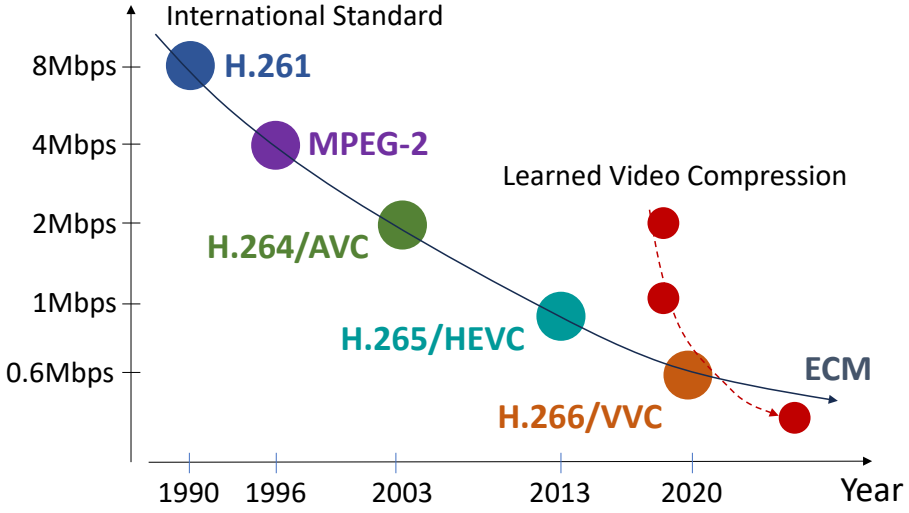
Learned Image/Video Compression

- Active topics in these years

Still Image Compression

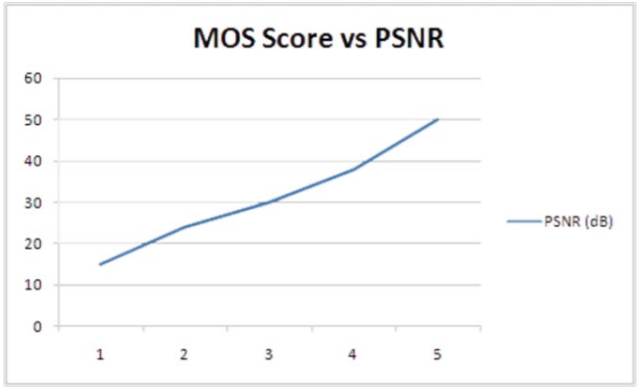


Video Compression



JPEG-AI (2025)

Image Quality Assessment



There exists strong correlation between MOS and MSE but not enough

(b)-(g) images have the same MSEs, but subjective impressions are different

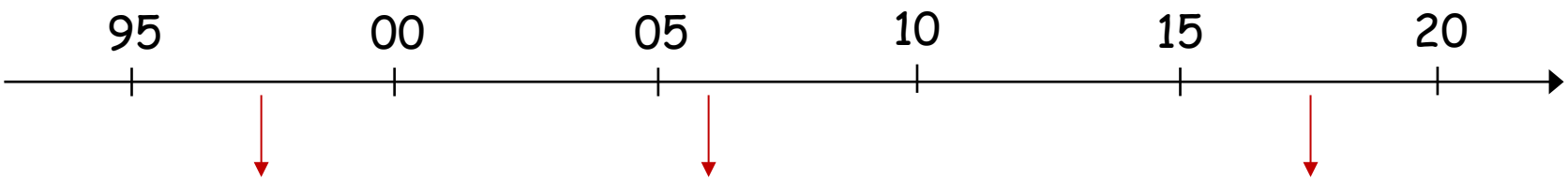
(h)-(l) images are scaled, shifted or rotated, and have different MSEs

PSNR, SSIM, VMAF, LPIPS, …

[FIG2] Comparison of image fidelity measures for "Einstein" image altered with different types of distortions. (a) Reference image. (b) Mean contrast stretch. (c) Luminance shift. (d) Gaussian noise contamination. (e) Impulsive noise contamination. (f) JPEG compression. (g) Blurring. (h) Spatial scaling (zooming out). (i) Spatial shift (to the right). (j) Spatial shift (to the left). (k) Rotation (counter-clockwise). (l) Rotation (clockwise).

Z.Wang and A.Bovik: "Mean Squared Error: Love It or Leave It", IEEE Sig. Mag., Jan2009.

Point Cloud Compression



MPEG (ISO/IEC SC29)
- system/video/audio
- BIFS
- mesh compression
- face animation

VRML (ISO/IEC SC24)

MPEG AFX

Web3D

X3D

MPEG PCC
- V-PCC
- G-PCC

deep entropy models

BIFS: BInary Format for Scene description

VRML: Virtual Reality Modeling Language

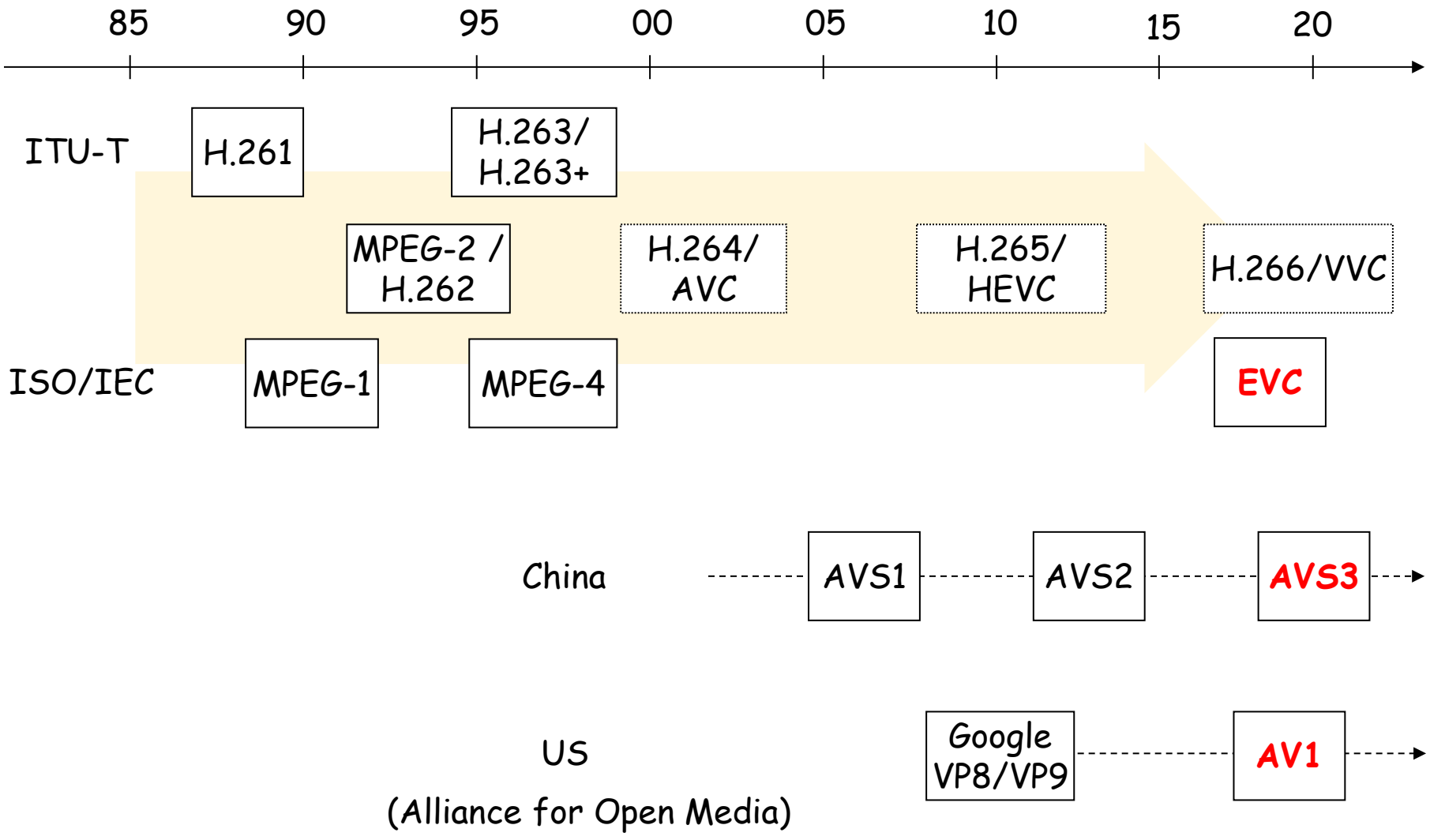
AFX: Animation Framework eXtension

PCC: Point Cloud Compression

V-PCC: Video-based PCC

G-PCC: Geometry-based PCC

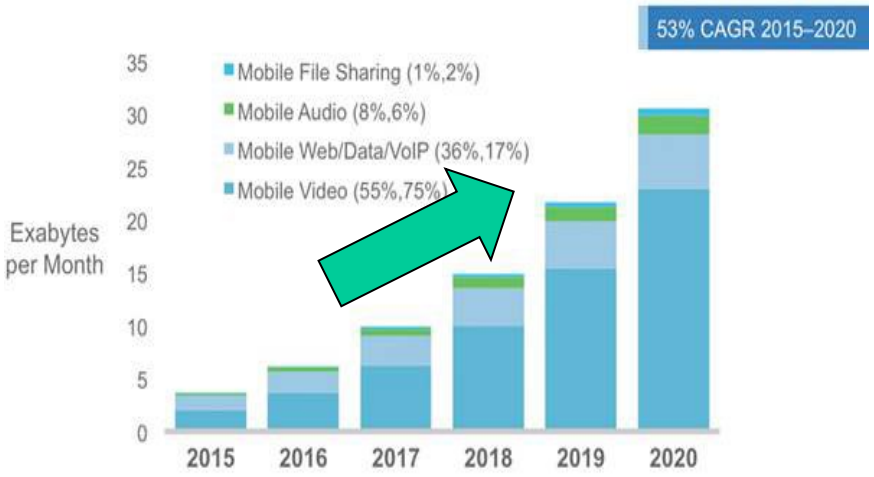
EVC, AVS, and AV1



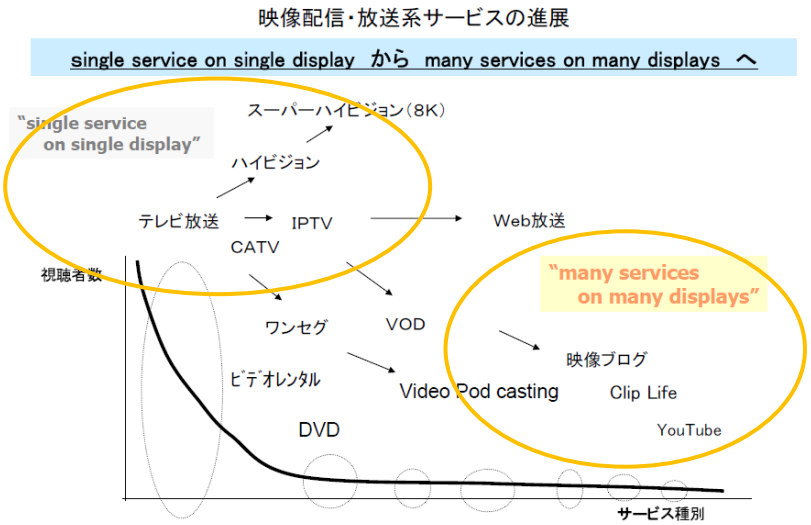
Streaming Background

Recent Trends

- Drastic Increase of Video Traffic on Internet
  - more than 70%
- Evolution of Various Video Services
  - higher resolution and personalization

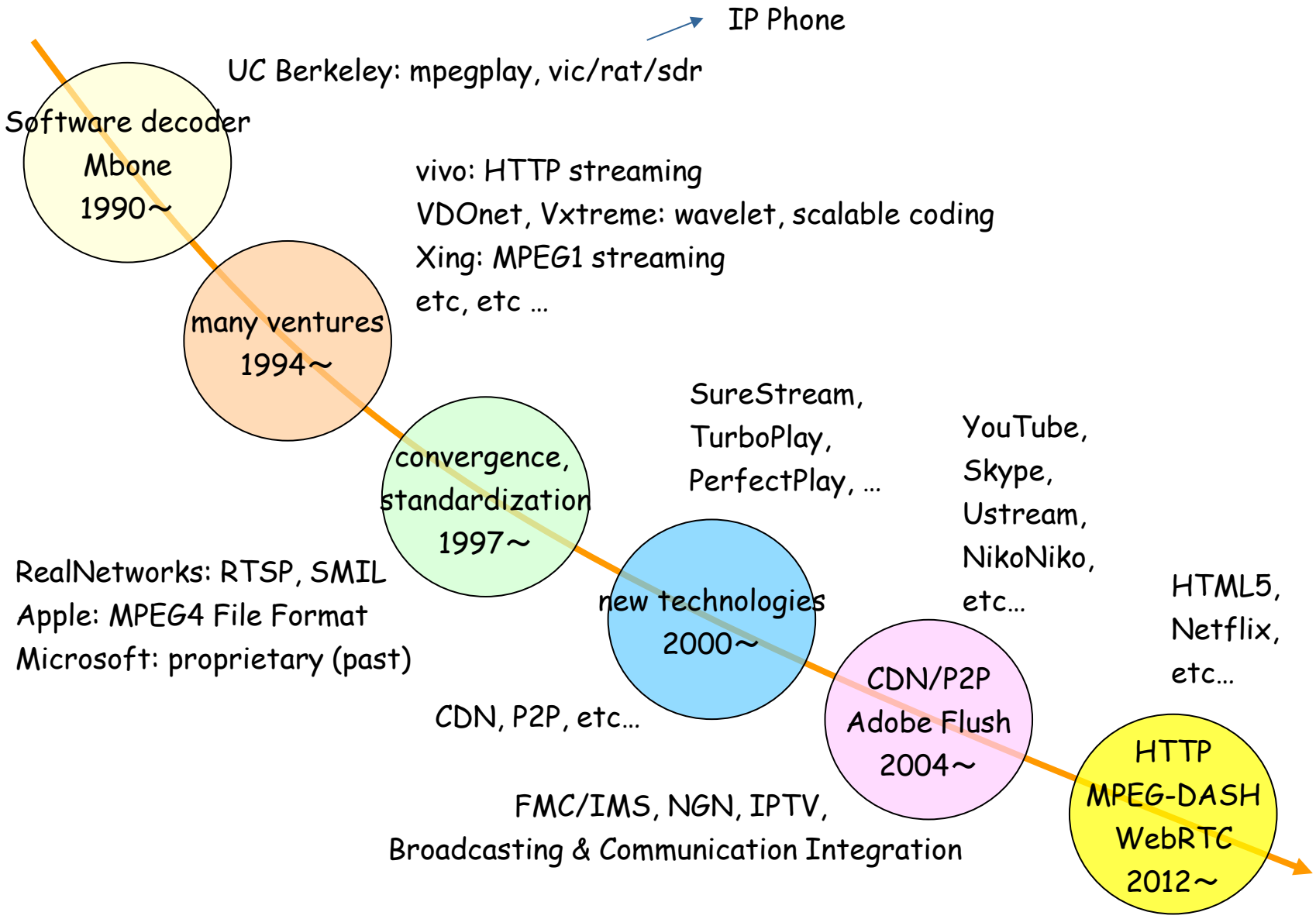


(Cisco VNI, 2016)



(MIC Report, 2008)

History of Video Streaming



Protocol Stack of RTP/UDP Video Streaming (and IP phone)

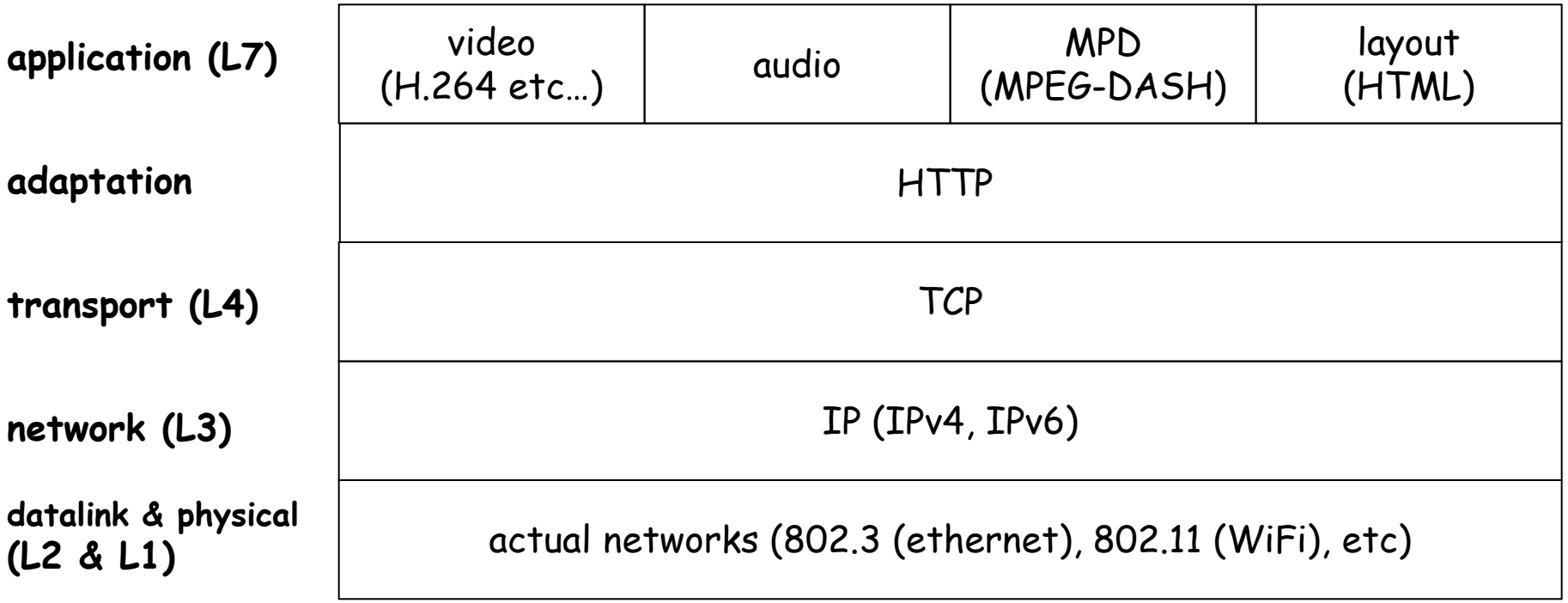
protocol stack for low-delay & interactive video streaming (e.g. conference)

<table>
<tr><td>application (L7)</td><td>video
(H.264 etc…)</td><td>audio</td><td>SDP</td><td>layout
(HTML. SMIL)</td></tr>
<tr><td>adaptation</td><td colspan="2">RTP / RTCP</td><td>RTSP, SIP, SAP*</td><td>HTTP</td></tr>
<tr><td>transport (L4)</td><td colspan="2">UDP / TCP / DCCP</td><td colspan="2">TCP / UDP / SCTP</td></tr>
<tr><td>network (L3)</td><td colspan="4">IP (IPv4, IPv6, IP-multicast)</td></tr>
<tr><td>datalink & physical (L2 & L1)</td><td colspan="4">actual networks (802.3 (ethernet), 802.11 (WiFi), etc)</td></tr>
</table>

* SAP: delivered by IP-multicast for program advertisement

Protocol Stack of HTTP Video Streaming

protocol stack for one-way video streaming



Protocol Stack of WebRTC

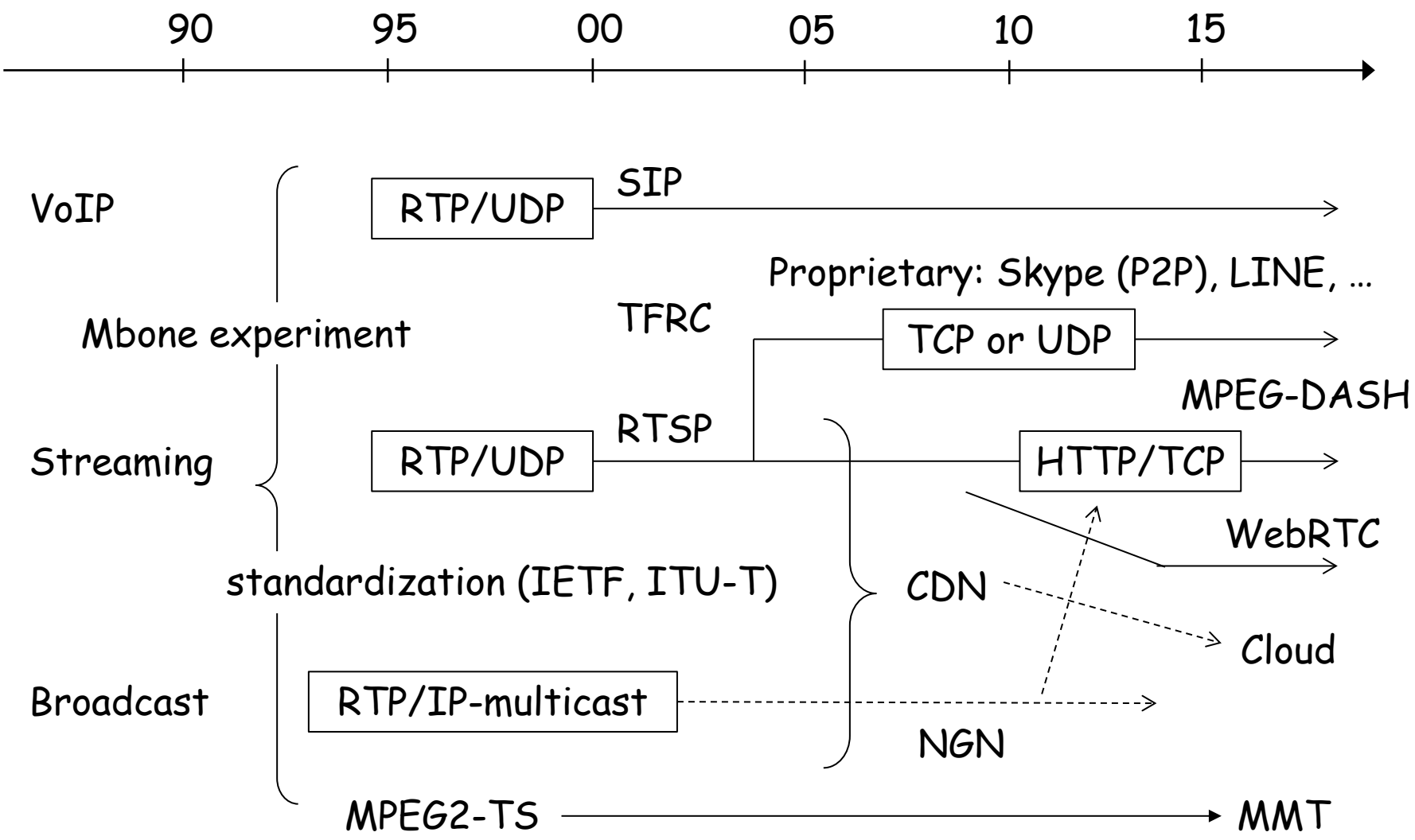
protocol stack for low-delay & interactive video streaming (e.g. conference)

<table>
<tr><td>NAT traversal</td><td colspan="2">media</td><td>data</td><td>signaling</td></tr>
<tr><td></td><td>video</td><td>audio</td><td>data</td><td>SIP, SDP</td></tr>
<tr><td>STUN, TURN</td><td colspan="2">SRTP</td><td>SCTP/DTLS</td><td>HTTP/TLS,
WebSocket</td></tr>
<tr><td colspan="3">UDP</td><td colspan="2">TCP</td></tr>
<tr><td colspan="5">IP</td></tr>
<tr><td colspan="5">MAC / PHY</td></tr>
</table>

IP Video Services

Services	Examples
IP phone & conference (interactive)	Telecommunication (SIP, H.323)
IPTV (one-way)	CATV, Telecommunication (MPEG-2 TS)
Web conferencing (interactive)	Zoom, Cisco WebEx, Skype, Google Hangout, etc …
Video streaming (one-way)	YouTube, Amazon Prime Video, Facebook, etc …

Protocol Transition



TCP vs. UDP

	Reliability	Low Delay	Congestion Control	Typical Application
TCP	◎ (ACK and lost packet retransmission)	× → ○ (thanks to CDN & broadband network)	○ → ◎ (TCP versions)	One way (on-demand) streaming
UDP	× (no ACK nor sequence number)	◎ (no ACK nor packet retransmission)	× → △ (RTP/RTCP and TFRC)	Interactive (bi-directional) phone & conference

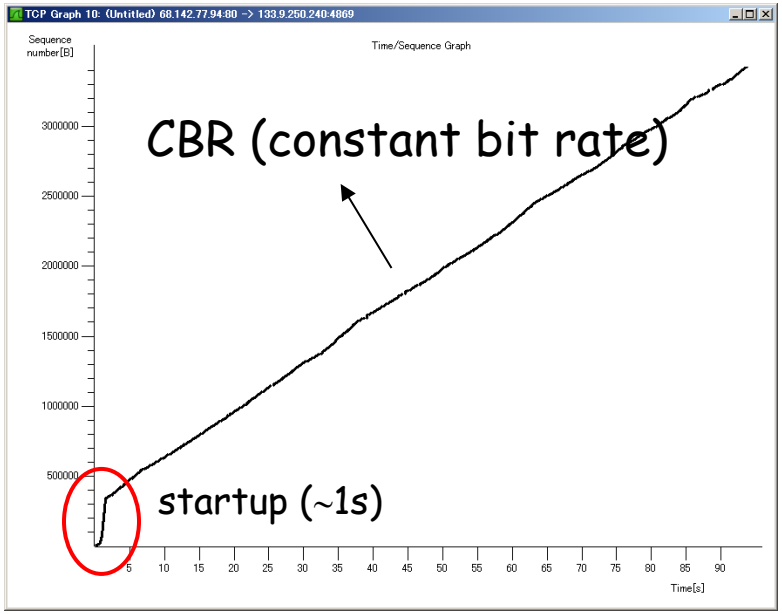
one-way streaming in 20 years ago

prefetching & CBR

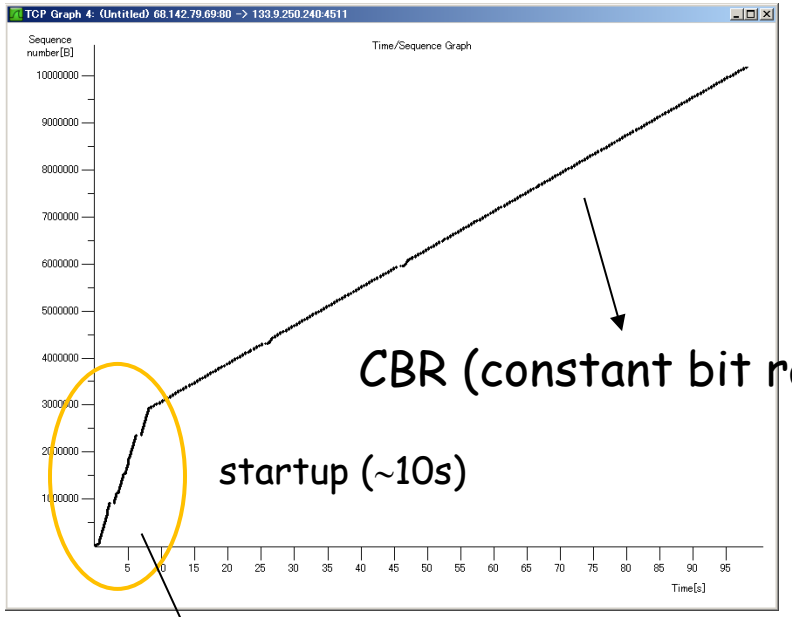
(prefetch, then CBR)

sequence number

Live



On-Demand



time

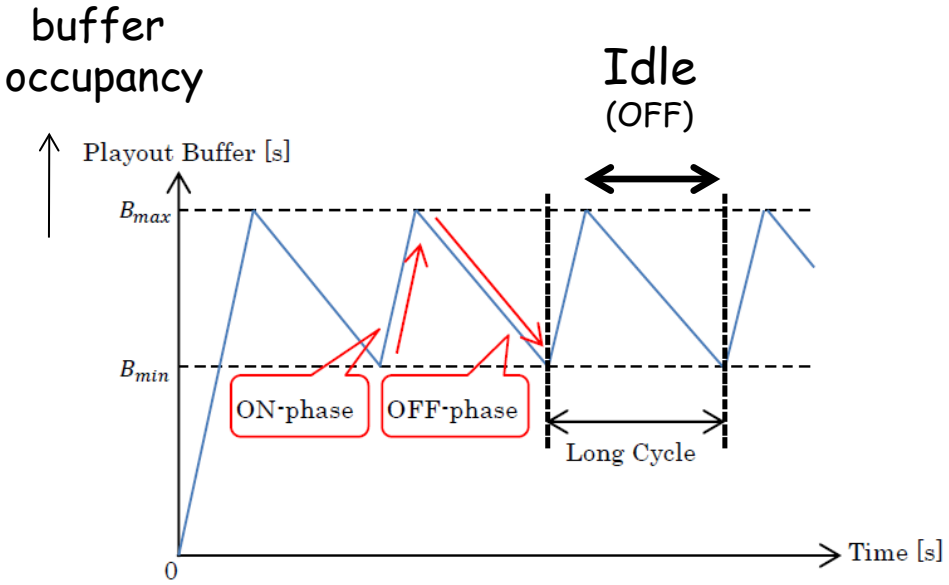
prefetching

one-way streaming nowadays

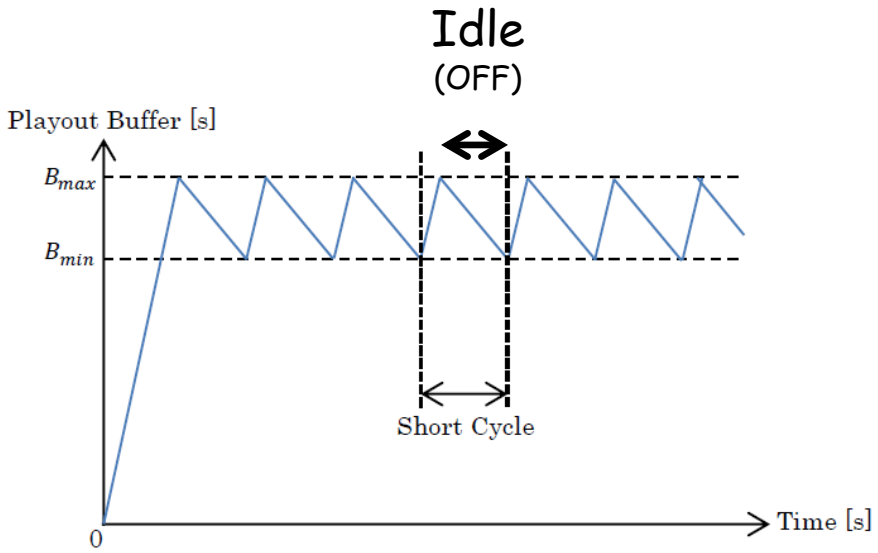
ON/OFF cycles

(prefetch & idle cycles)

- receiver buffer behaviors



(a) long ON-OFF Cycle (sawtooth)



(b) short ON-OFF Cycle (zippy pacing)

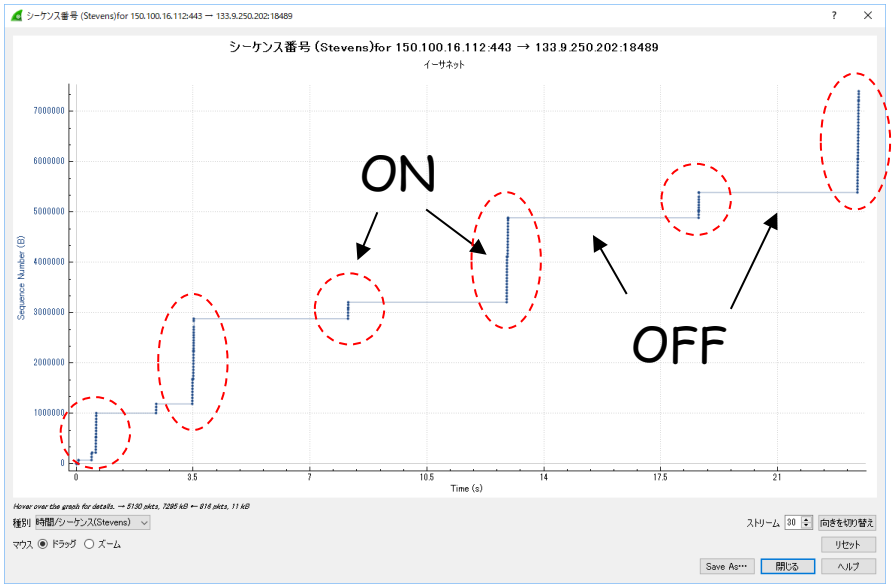
A. Rao, et al. ACM CoNEXT 2011

one-way streaming nowadays

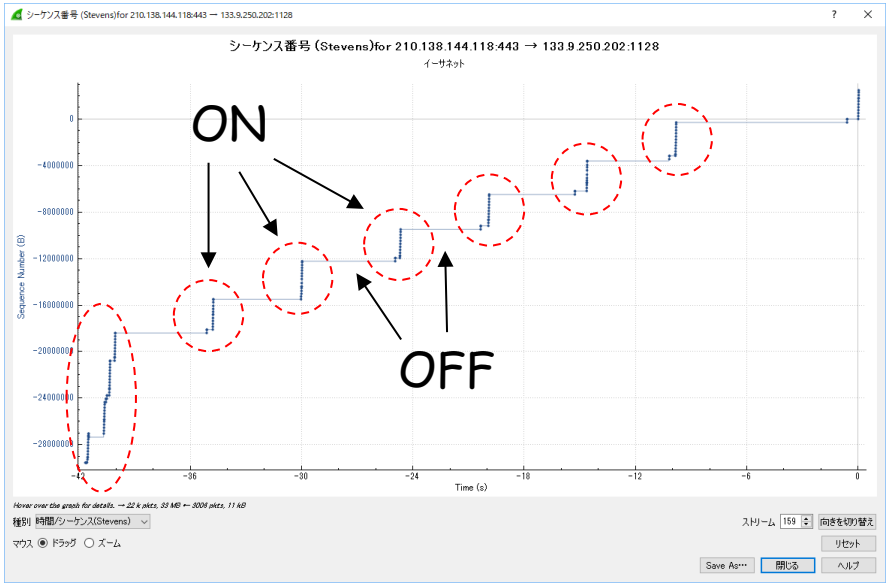
ON/OFF cycles

- sequence number behaviors

sequence number



example 1 (YouTube)



example 2 (TVer)

This year's schedule (tentative)

This Year's Schedule

tentative

(Apr 17)	Class overview and backgrounds of video streaming
(Apr 24)	TCP variants
(May 01)	RTP and TFRC over UDP
(May 08)	HTTP and MPEG-DASH
(May 15)	CDN, P2P and Cloud
(May 22)	SIP and WebRTC
(May 29)	Other topics and test
(June 05)	Video compression basics
(June 12)	H.264/AVC
(June 19)	HEVC/H.265 and VVC/H.266
(June 26)	Learned image/video compression
(July 03)	Image quality assessment
(July 10)	Point cloud compression
(July 17)	Class summary and test
on Moodle	Final report (tbd)