

画像情報特論 (1)

Advanced Image Information (1)

Introduction and Streaming Background

情報理工・情報通信専攻 甲藤二郎

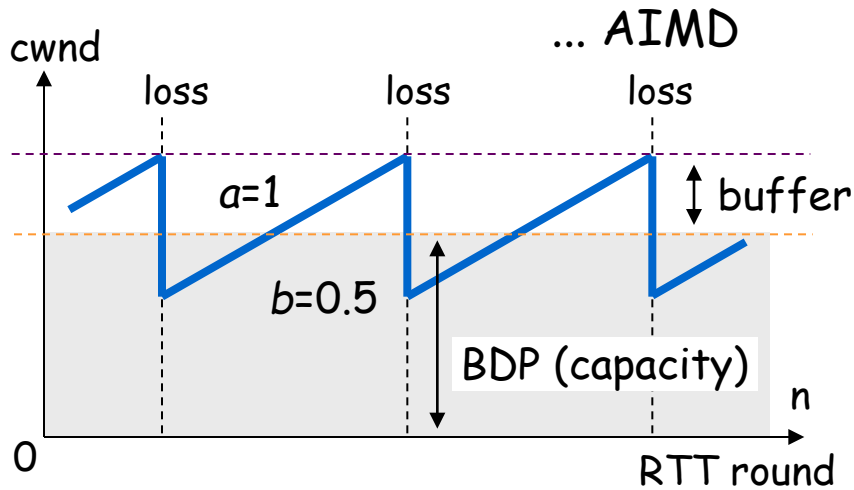
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Introduction

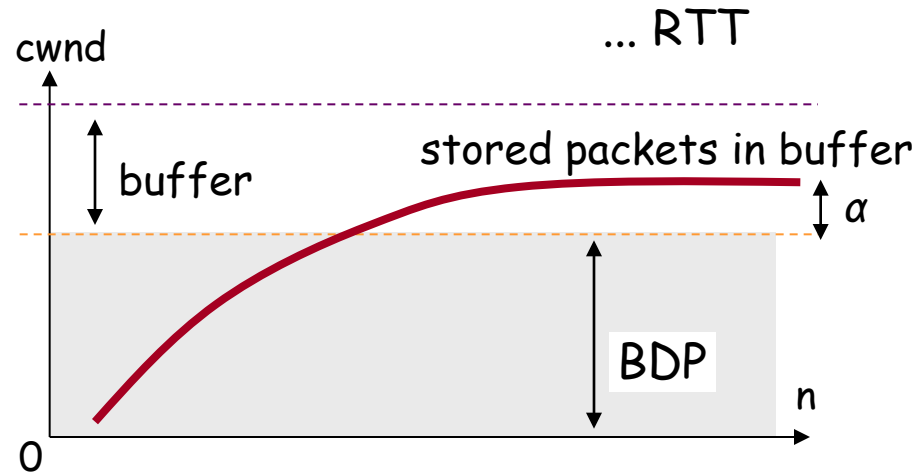
TCP Variants

■ Loss-based



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

■ Delay-based



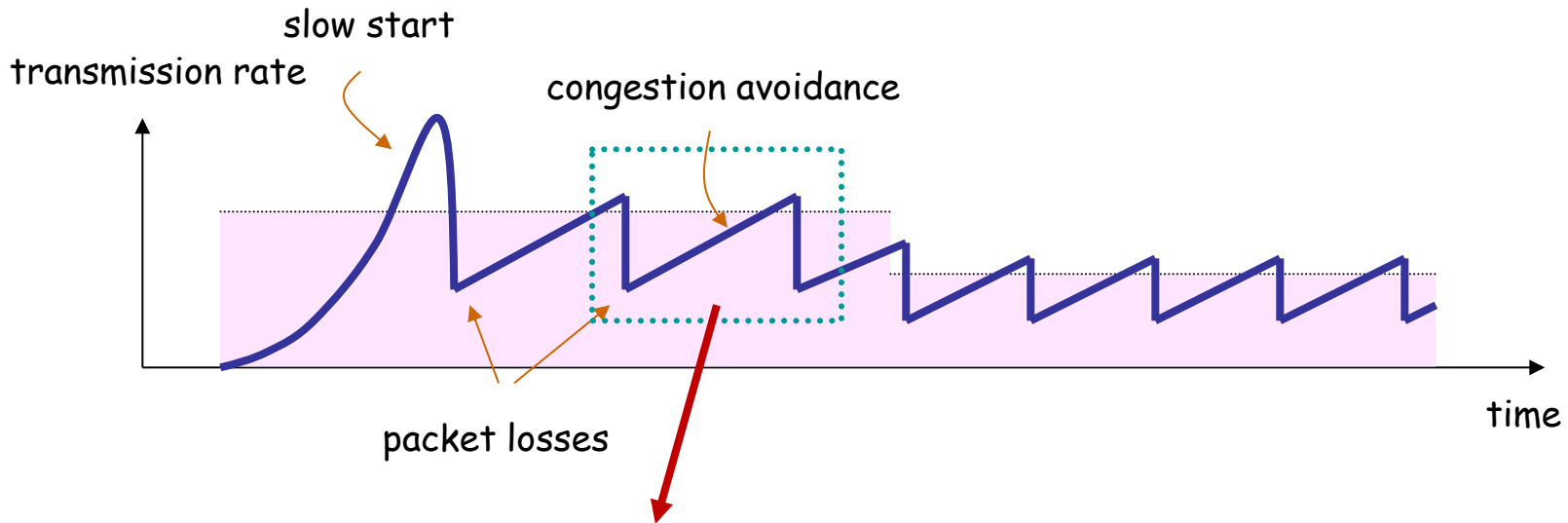
TCP-Vegas, FAST-TCP

■ Hybrid Compound TCP

■ TCP-BBR

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

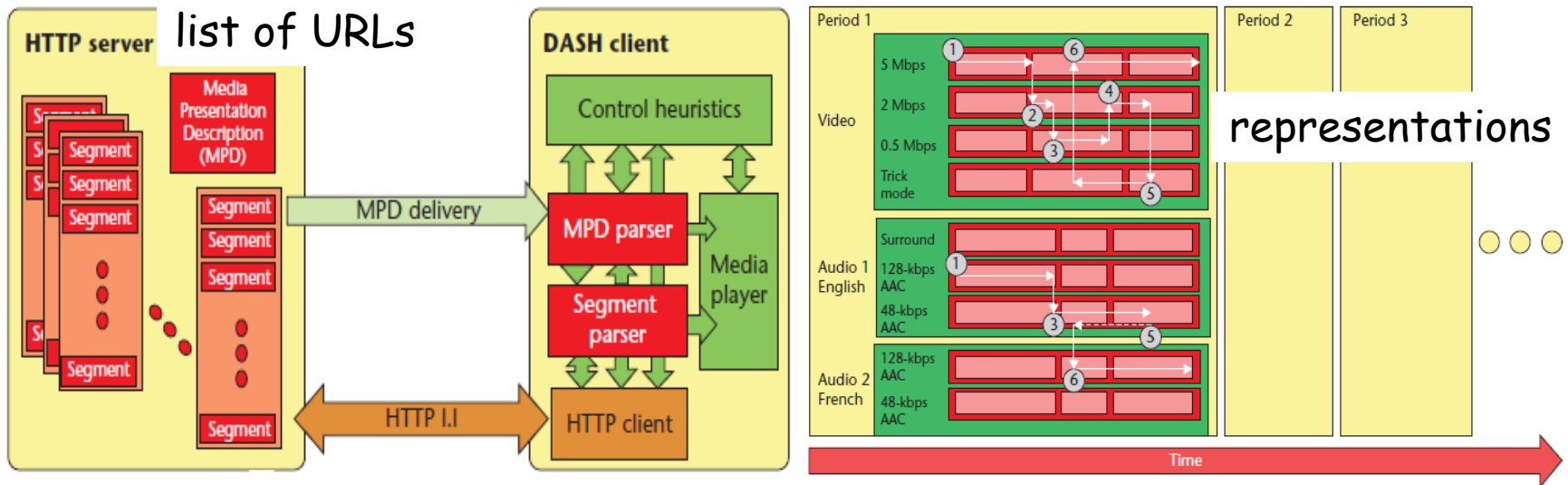
BDP/Buffer relationship

small buffer → × efficiency
large buffer → × delay



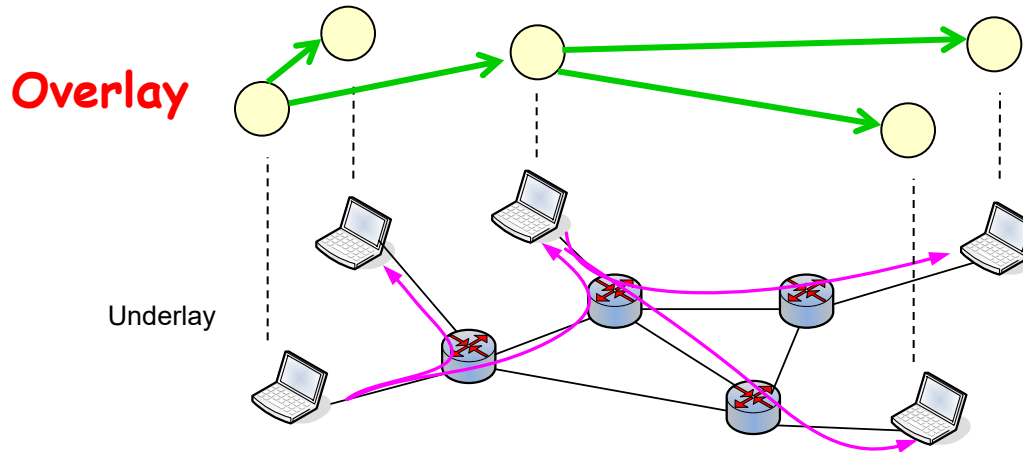
HTTP and MPEG-DASH

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

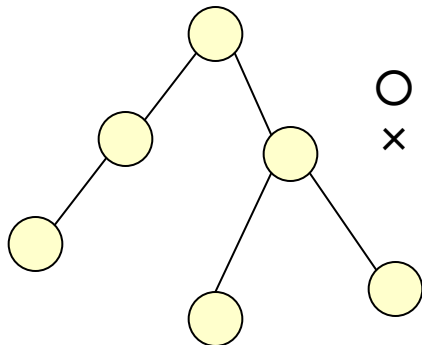


CDN, P2P & Cloud

■ Overlay networks

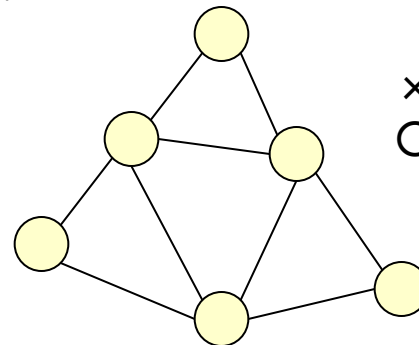


■ tree



○ complexity
× robustness

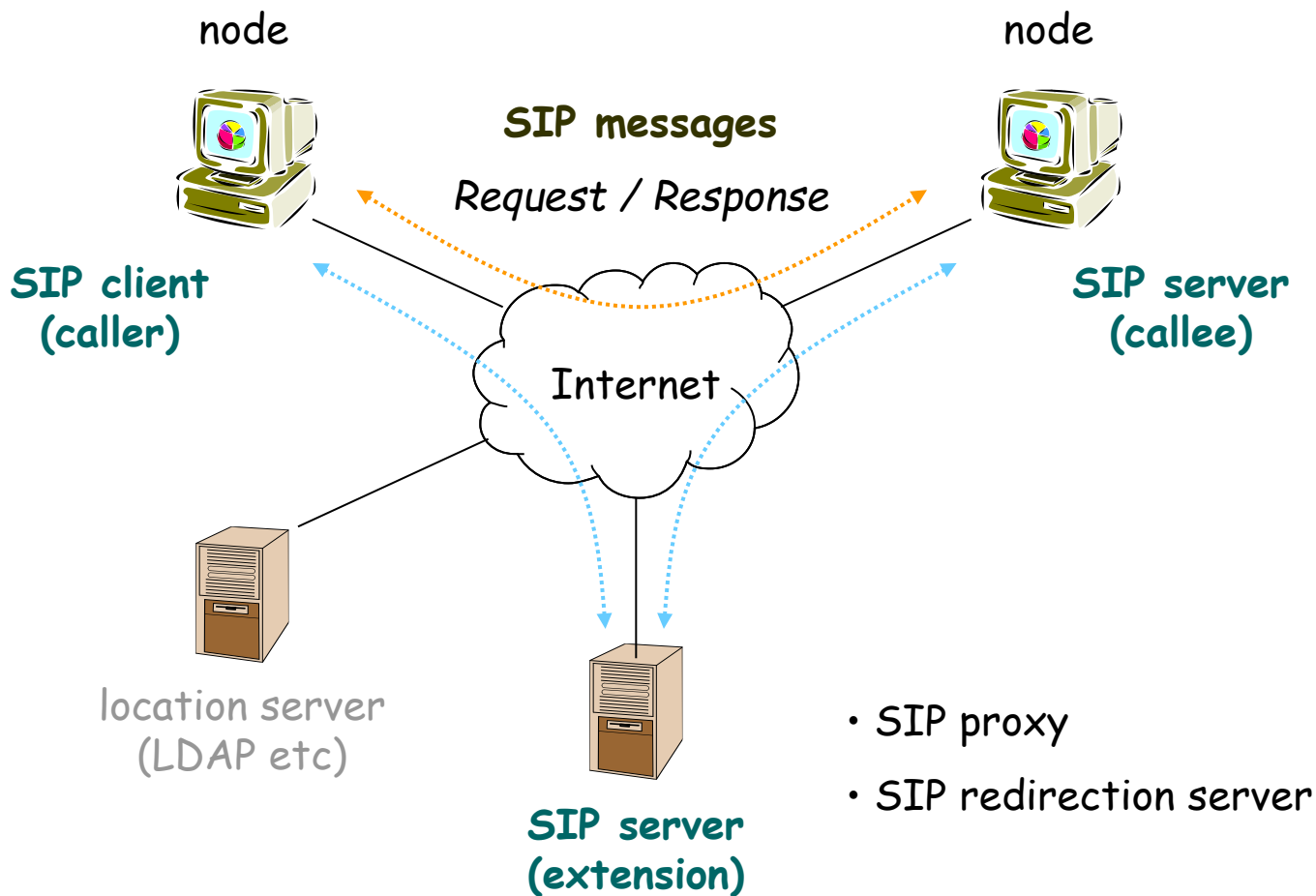
■ mesh



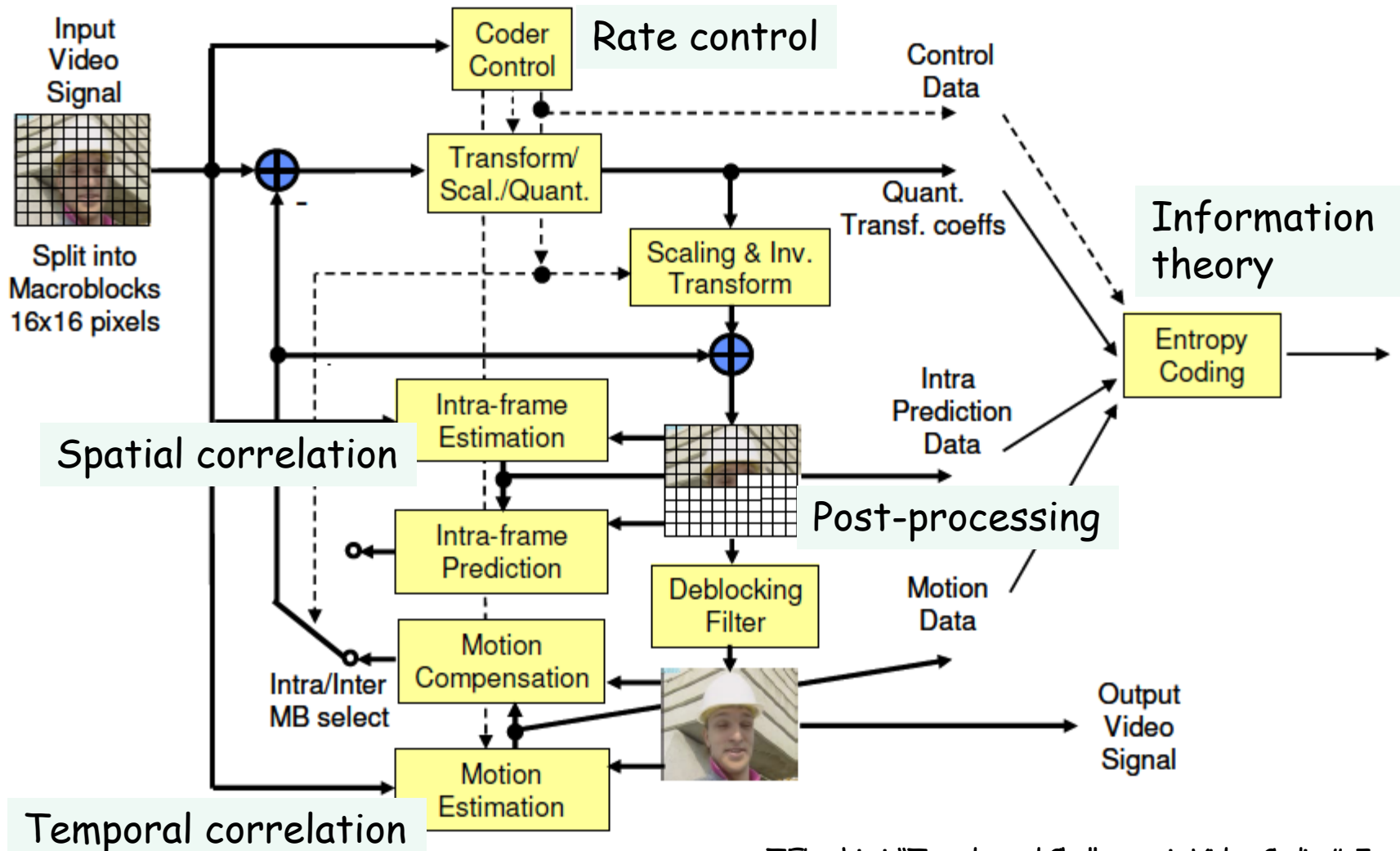
× complexity
○ robustness

SIP and WebRTC

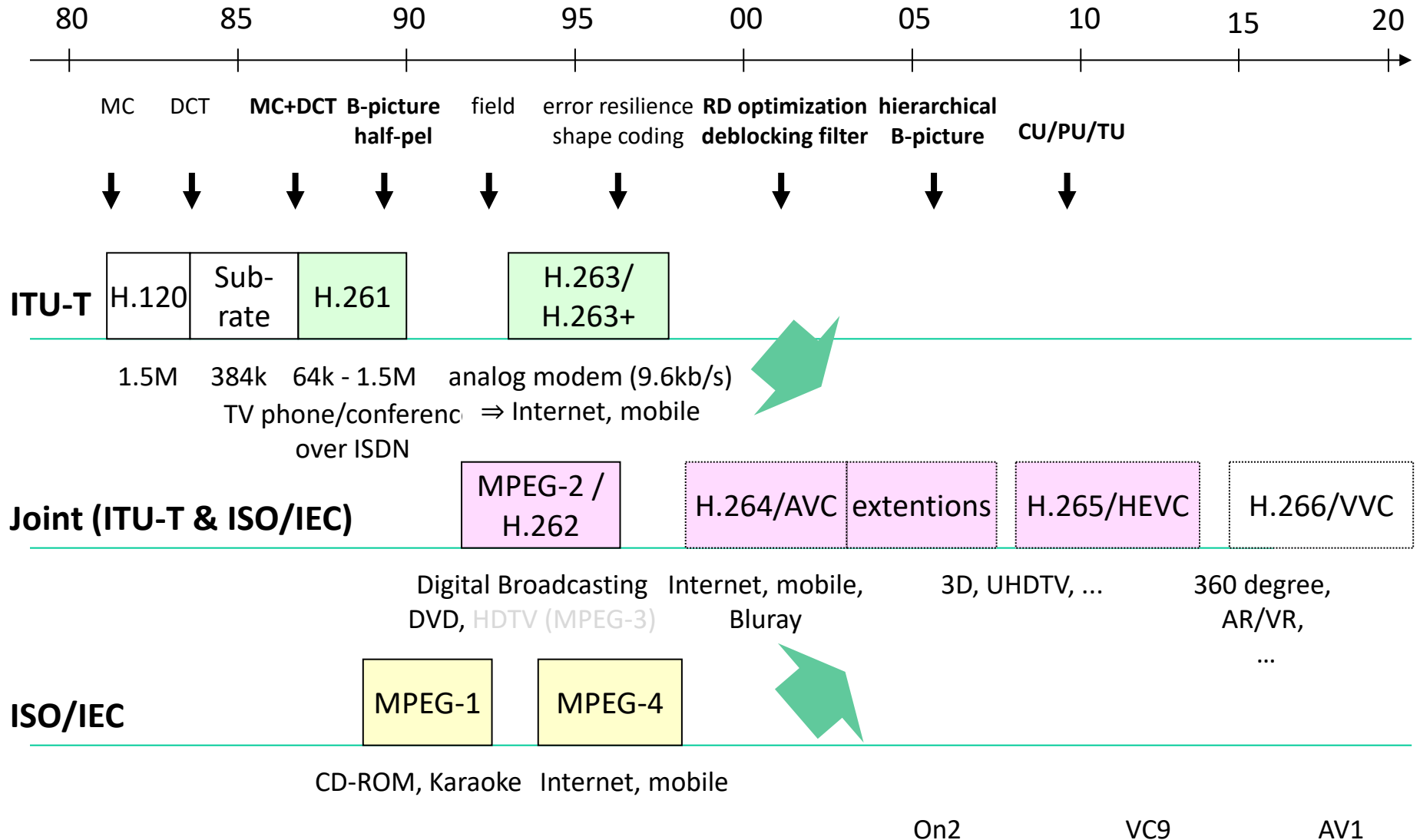
■ SIP: Session Initiation Protocol



Video Compression Basics

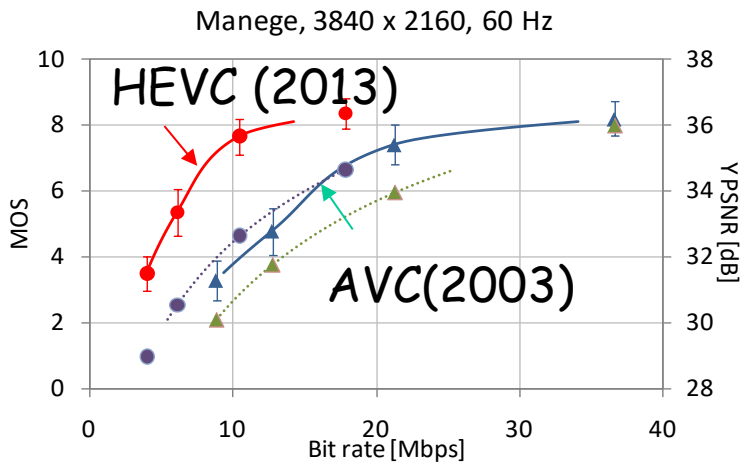


Video Compression History



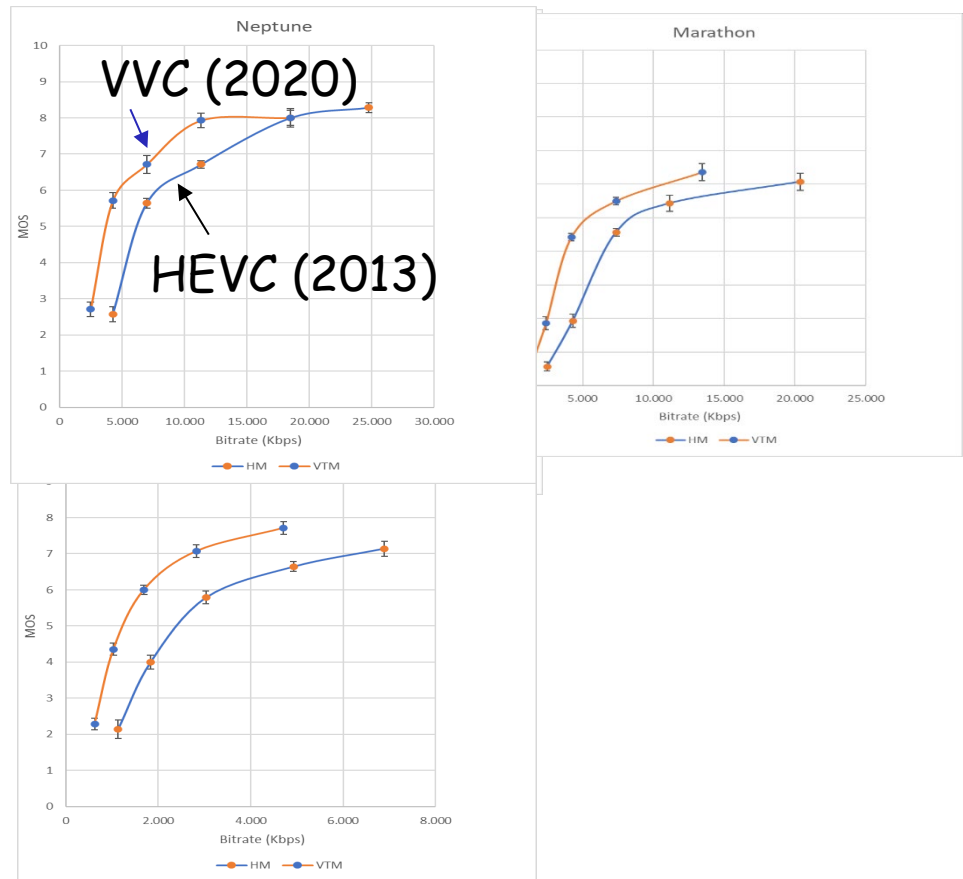
AVC, HEVC and VVC

- HEVC (2013)



- HEVC MOS
- ▲ AVC MOS
- HEVC MOS BD-rate range
- AVC MOS BD-rate range
- HEVC PSNR
- ▲ AVC PSNR
- ⋯ HEVC PSNR BD-rate range
- ⋯ AVC PSNR BD-rate range

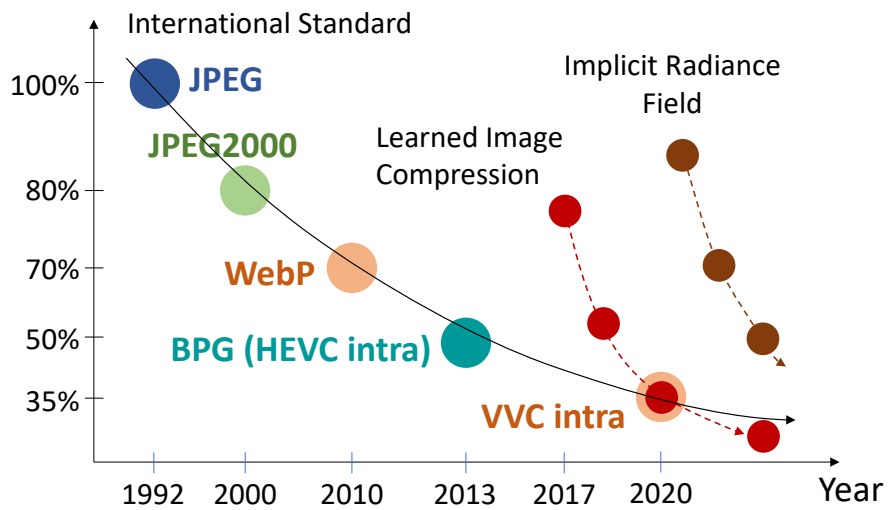
- VVC (2020)



Learned Image/Video Compression

- Active topics in these years

Still Image Compression



JPEG-AI (2025)

Video Compression

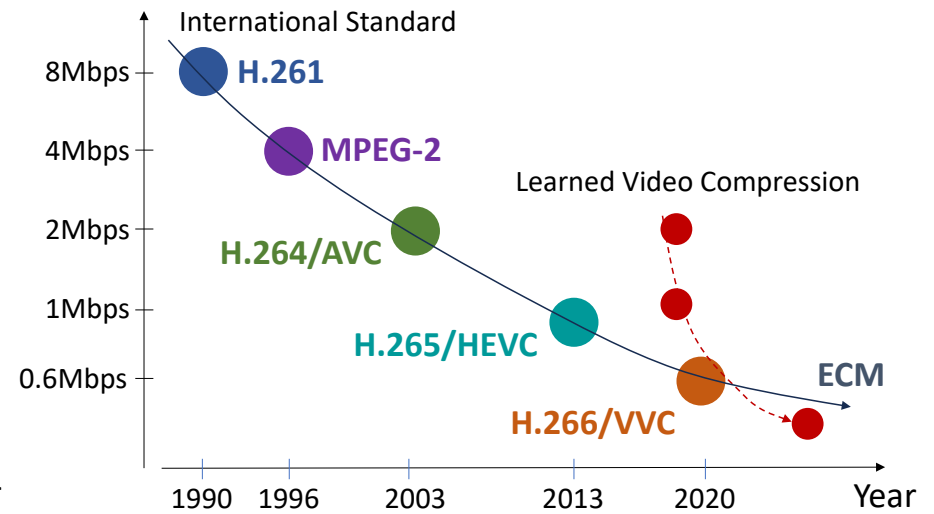
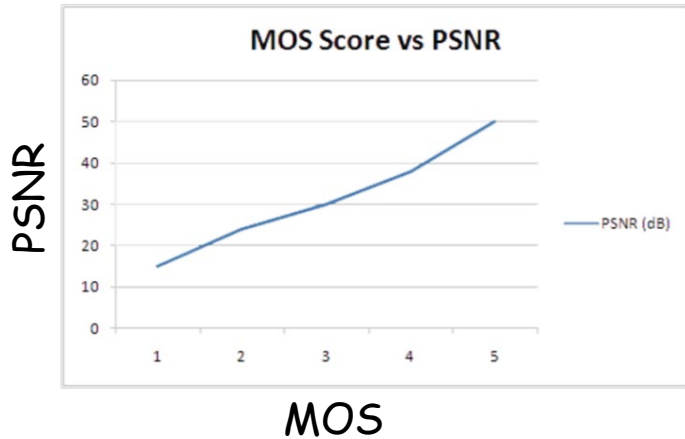


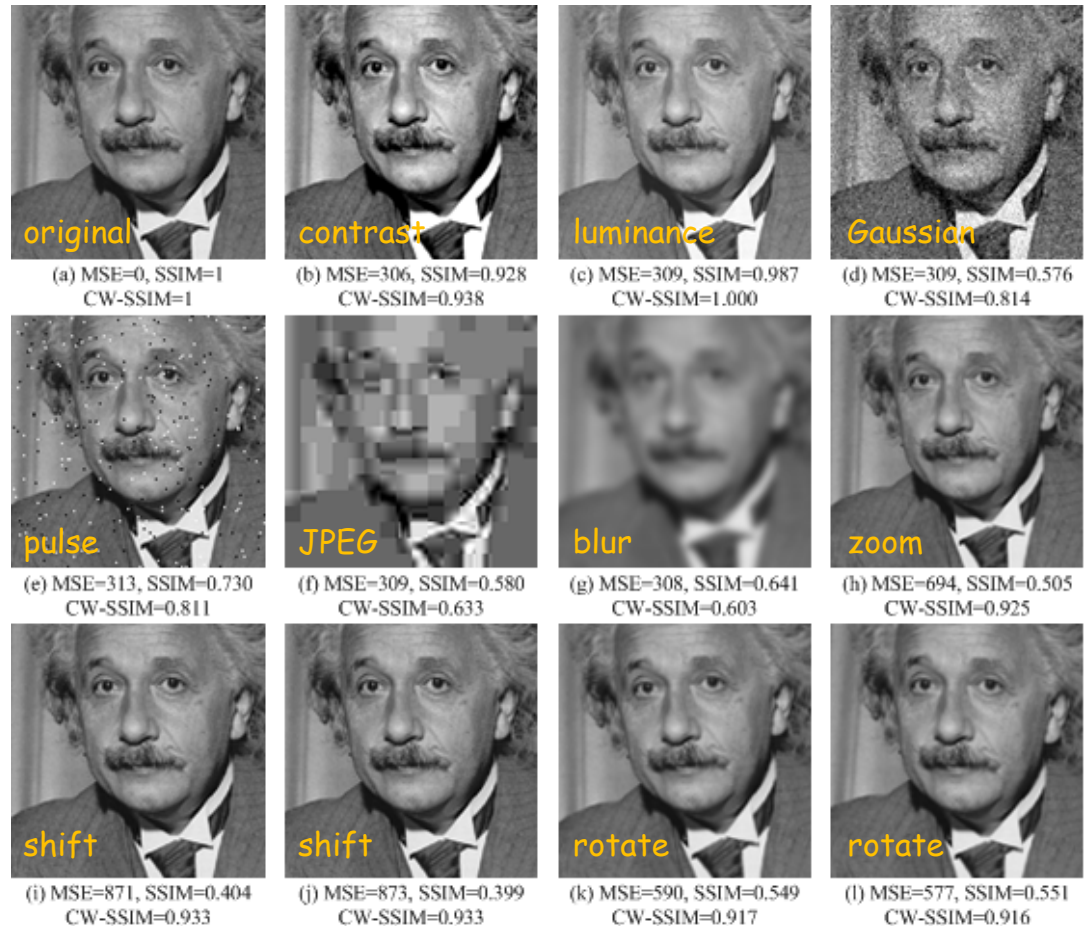
Image Quality Assessment



There exists strong correlation between MOS and MSE but not enough

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

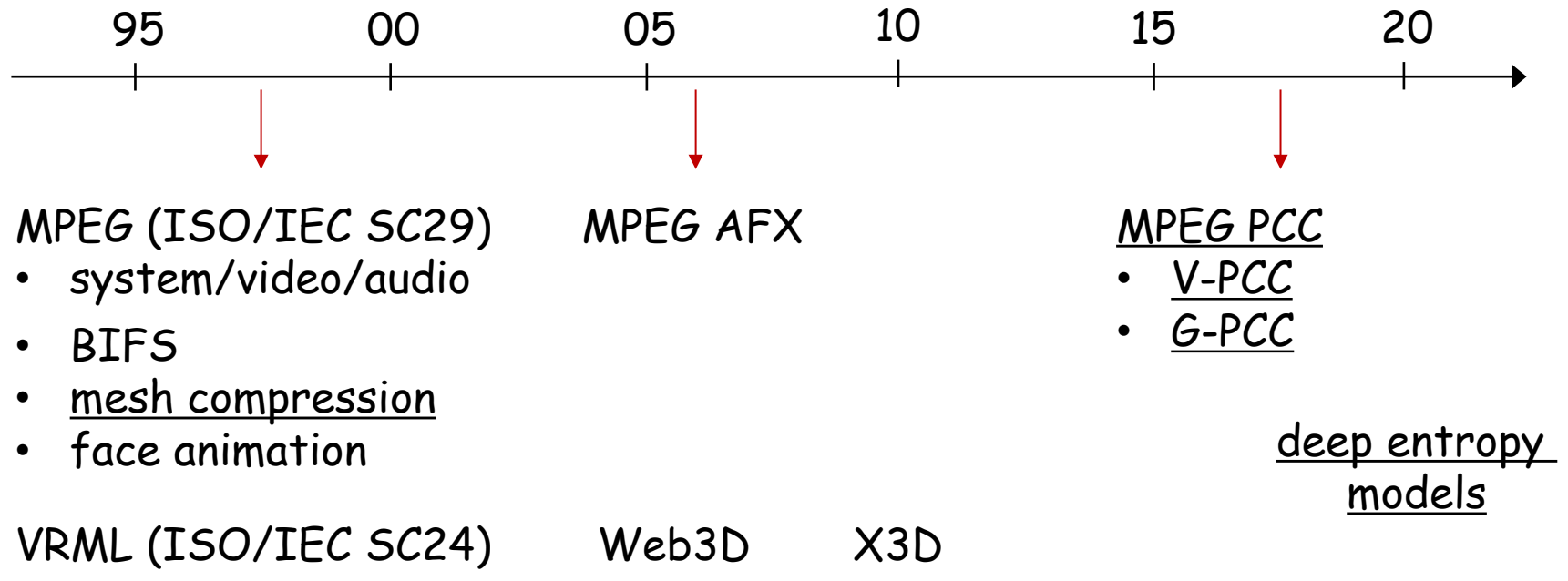
(h)-(l) images are scaled, shifted or rotated, and have different MSEs



[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).

PSNR, SSIM, VMAF, LPIPS, ...

Point Cloud Compression



BIFS: BInary Format for Scene description

VRML: Virtual Reality Modeling Language

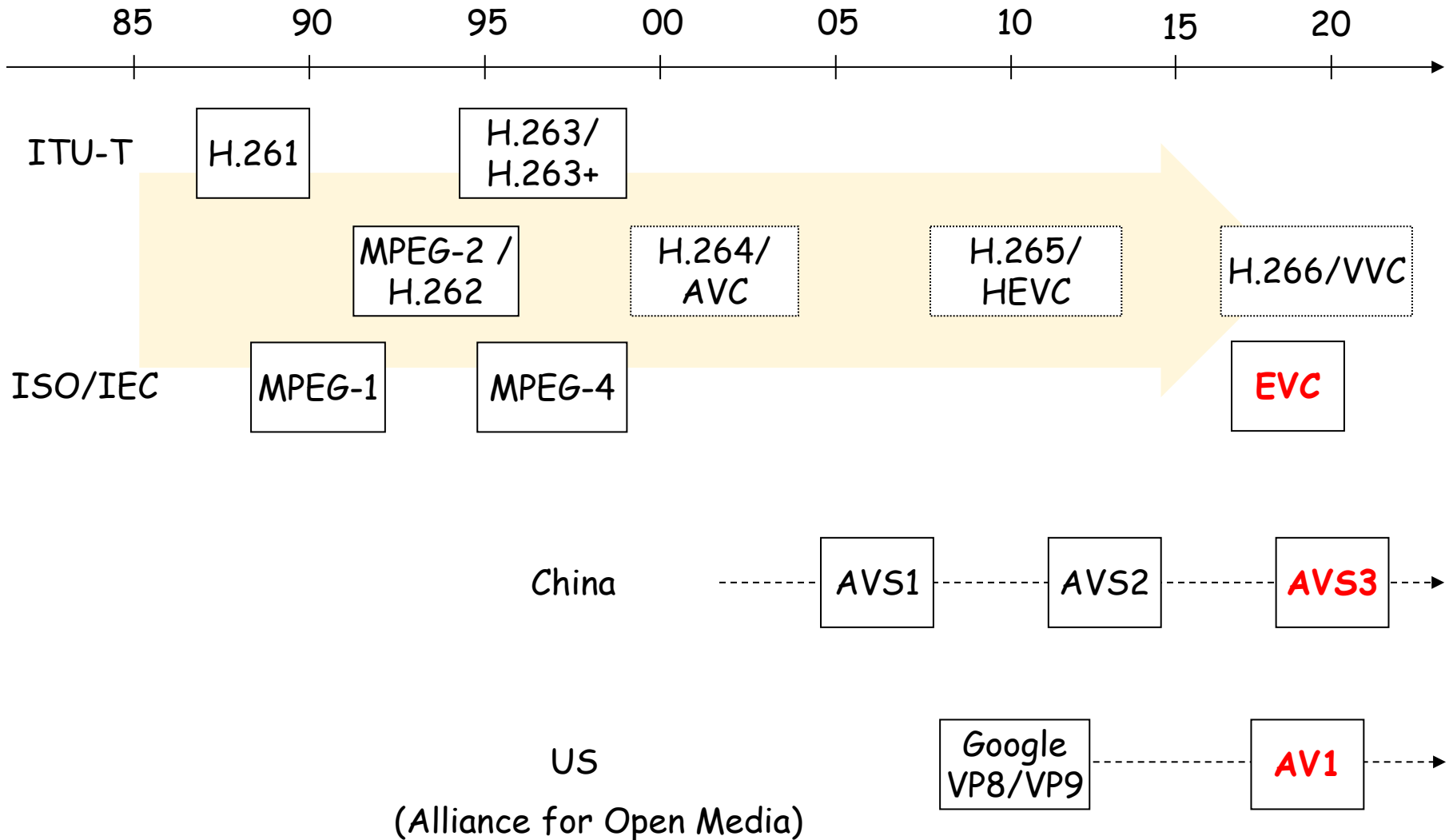
AFX: Animation Framework eXtension

PCC: Point Cloud Compression

V-PCC: Video-based PCC

G-PCC: Geometry-based PCC

EVC, AVS, and AV1

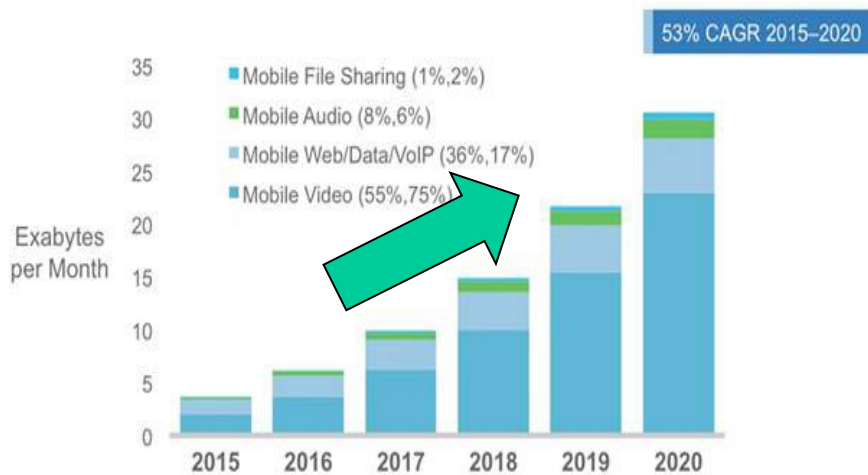


Streaming Background

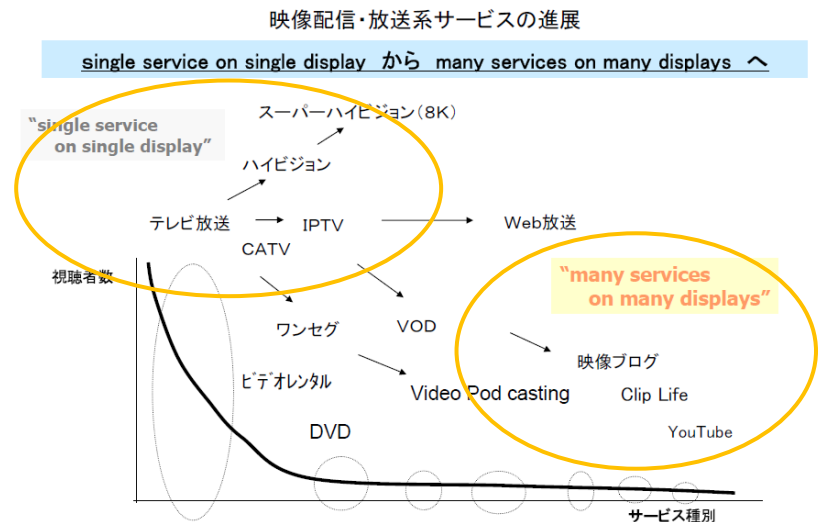
Recent Trends

- Drastic Increase of Video Traffic on Internet
 - more than 70%

- Evolution of Various Video Services
 - higher resolution and personalization

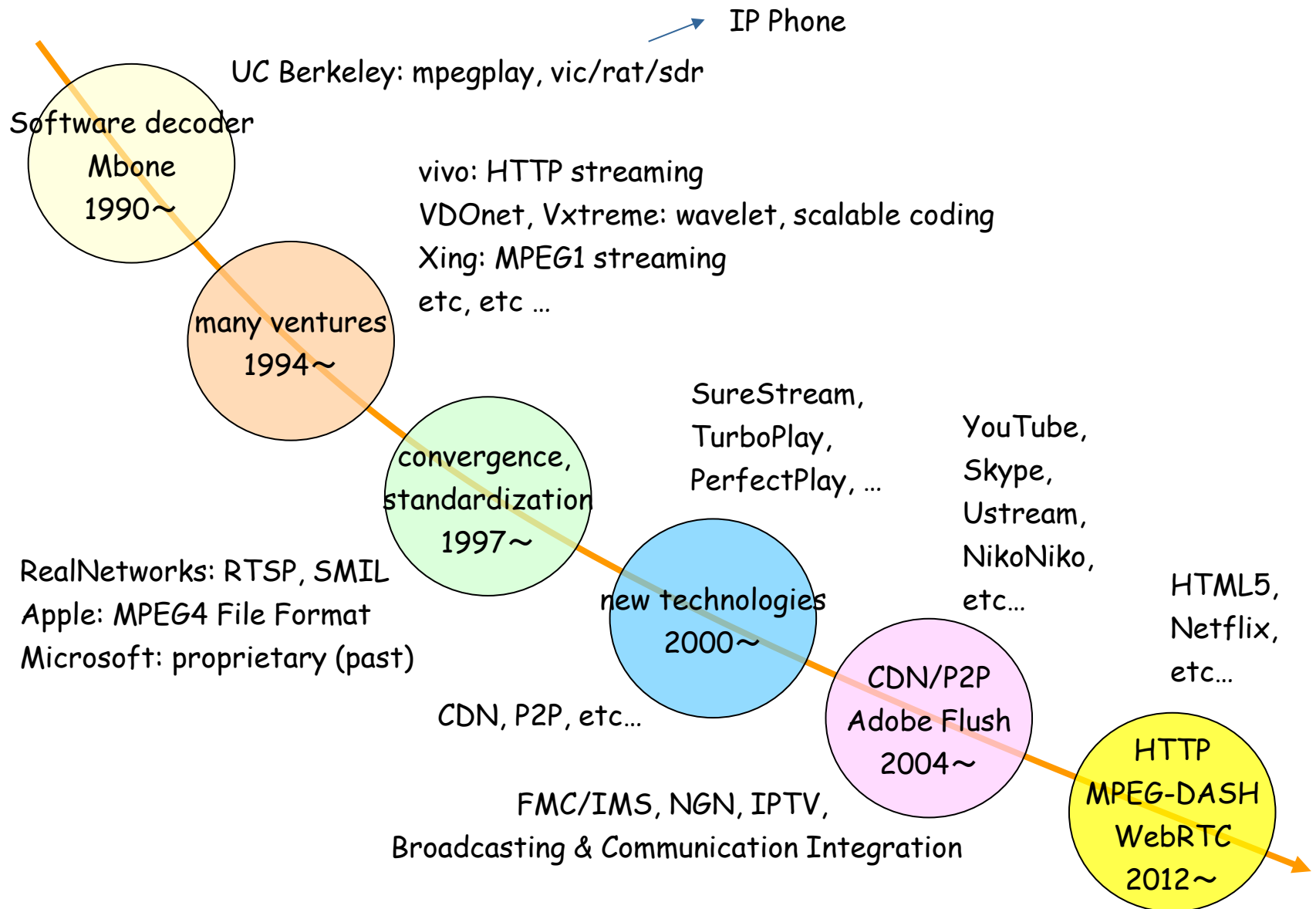


(Cisco VNI, 2016)



(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)

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

* SAP: delivered by IP-multicast for program advertisement

Protocol Stack of HTTP Video Streaming

protocol stack for one-way video streaming

| | | | | |
|--|--|-------|--------------------|------------------|
| application (L7) | video (H.264 etc...) | audio | MPD (MPEG-DASH) | layout (HTML) |
| adaptation | HTTP | | | |
| transport (L4) | TCP | | | |
| network (L3) | IP (IPv4, IPv6) | | | |
| datalink & physical (L2 & L1) | actual networks (802.3 (ethernet), 802.11 (WiFi), etc) | | | |

Protocol Stack of WebRTC

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

NAT traversal

media

data

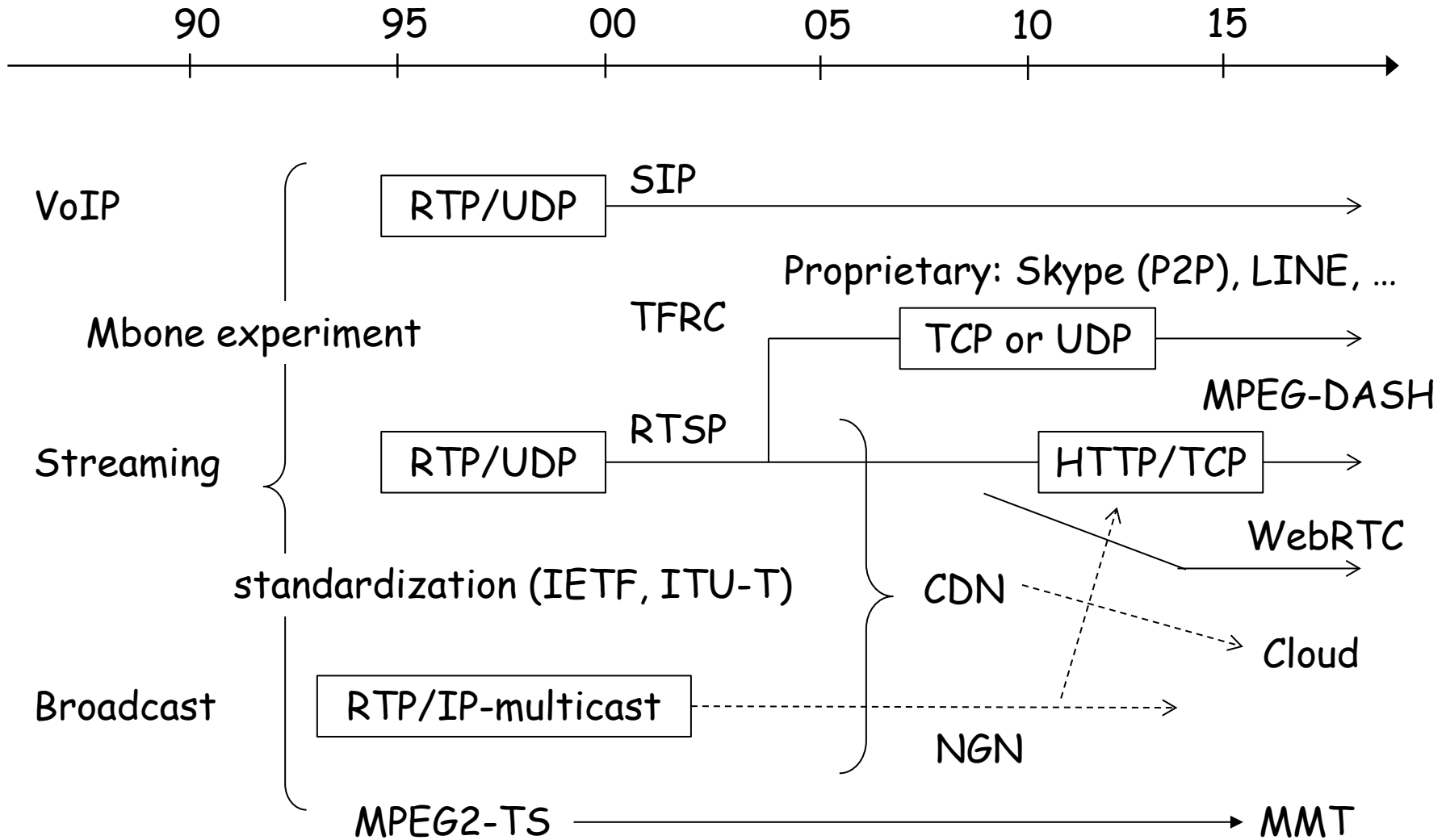
signaling

| | | | | |
|------------|-------|-------|-----------|------------------------|
| | video | audio | data | SIP, SDP |
| STUN, TURN | SRTP | | SCTP/DTLS | HTTP/TLS, WebSocket |
| UDP | | | | TCP |
| IP | | | | |
| MAC / PHY | | | | |

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

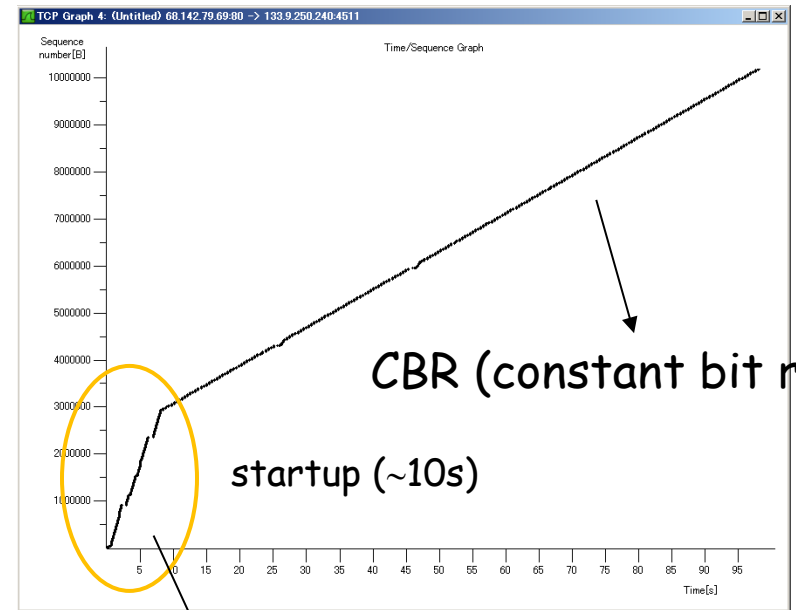
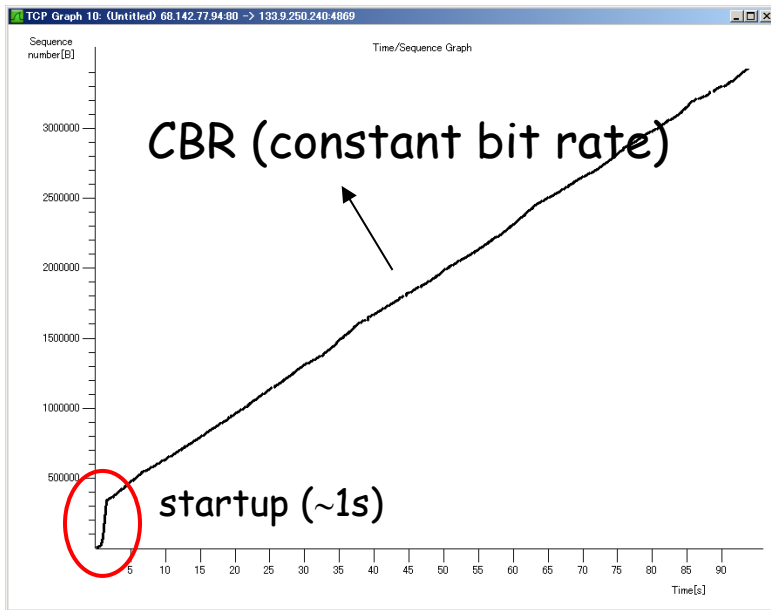
(prefetch, then CBR)

sequence
number



Live

On-Demand



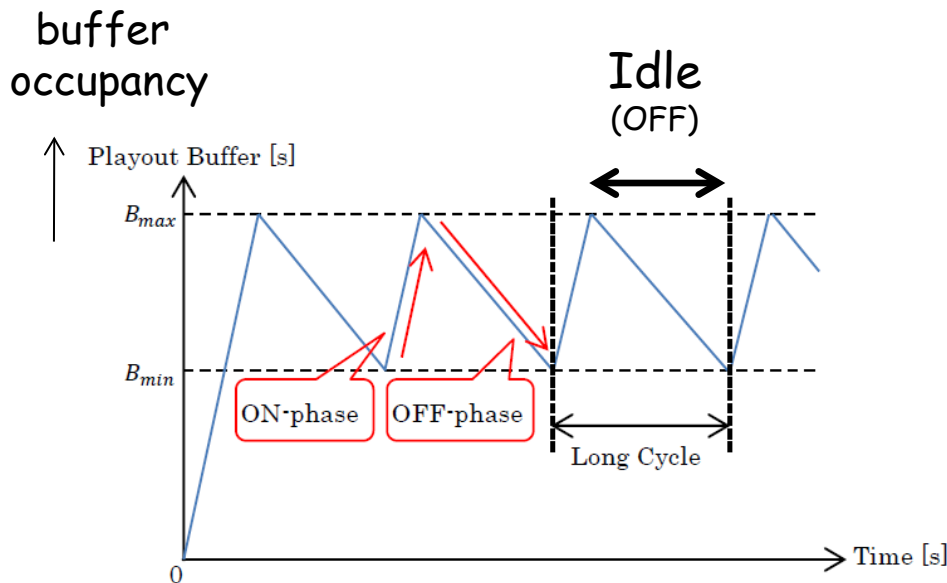
time

prefetching

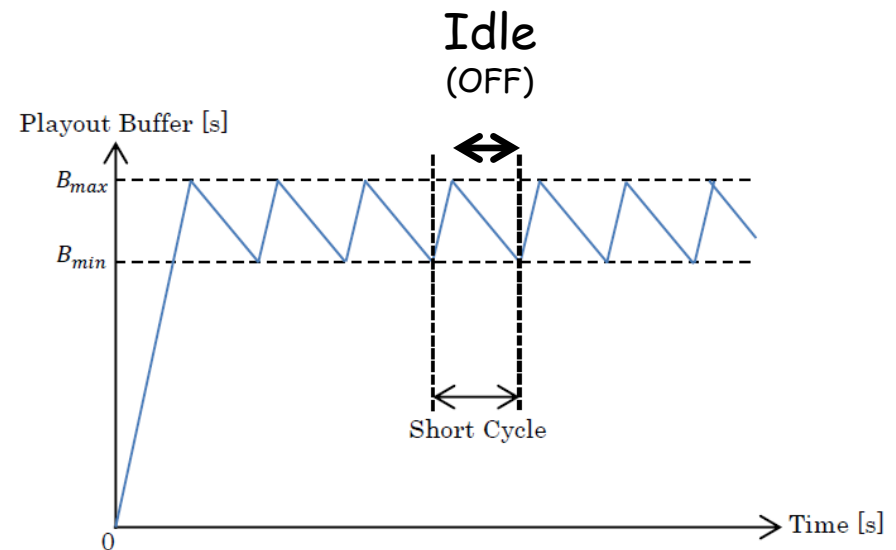
ON/OFF cycles

(prefetch & idle cycles)

- receiver buffer behaviors



(a) long ON-OFF Cycle (sawtooth)



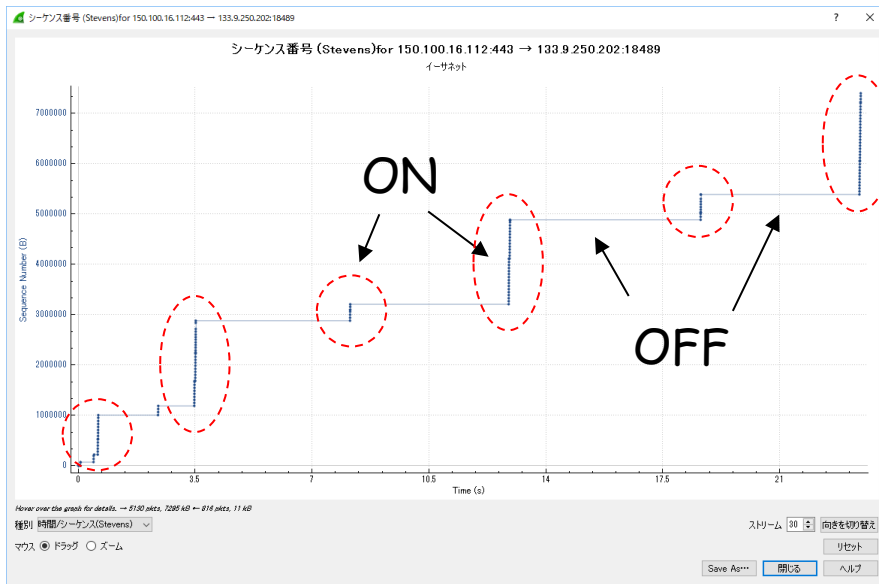
(b) short ON-OFF Cycle (zippy pacing)

one-way streaming nowadays

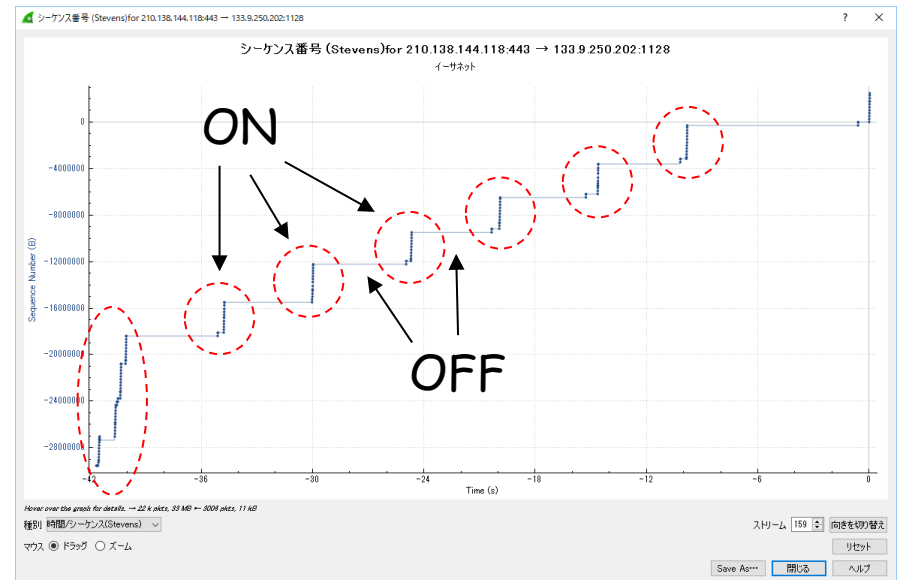
ON/OFF cycles

- sequence number behaviors

sequence
number



example 1 (YouTube)



example 2 (TVer)

This year's schedule
(tentative)

This Year's Schedule

tentative

| | |
|-----------|---|
| (Apr 18) | Class overview and backgrounds of video streaming |
| (Apr 25) | TCP variants |
| (May 02) | RTP and TFRC over UDP |
| (May 09) | HTTP and MPEG-DASH |
| (May 16) | CDN, P2P and Cloud |
| (May 23) | SIP and WebRTC |
| (May 30) | Other topics and <u>test</u> |
| (June 06) | Video compression basics |
| (June 13) | H.264/AVC |
| (June 20) | HEVC/H.265 and VVC/H.266 |
| (June 27) | Learned image/video compression |
| (July 04) | Image quality assessment |
| (July 11) | Point cloud compression |
| (July 18) | Class summary and <u>test</u> |
| on Moodle | Final report |