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

Introduction and Streaming Background

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Introduction

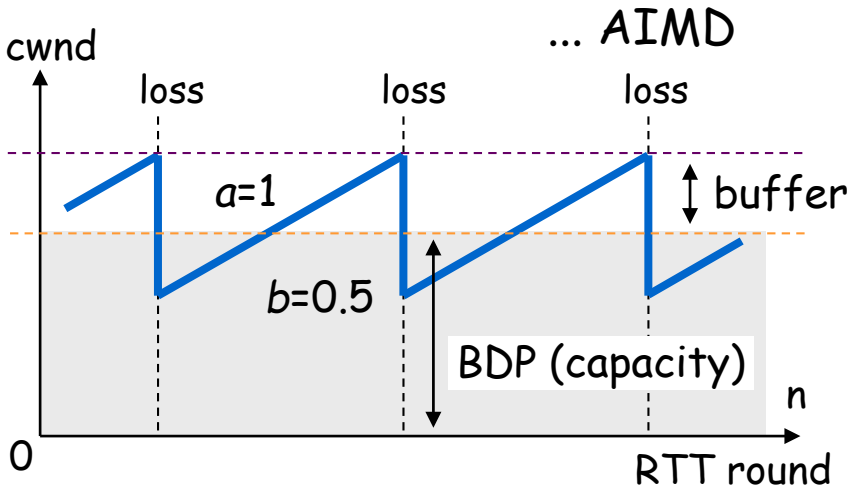
This Year's Schedule

tentative

(May 15)	Class overview and backgrounds of video streaming
(May 22)	TCP variants
(May 29)	RTP and TFRC over UDP
(June 5)	HTTP and MPEG-DASH
(June 12)	CDN, P2P and Cloud
(June 19)	SIP and WebRTC
(June 26)	Other topics and online test
(July 3)	Video compression basics
(July 10)	H.264/AVC
(July 17)	HEVC/H.265 and VVC/H.266
(July 24)	Learned image compression
(July 31)	Class summary and online test
----------	Final report

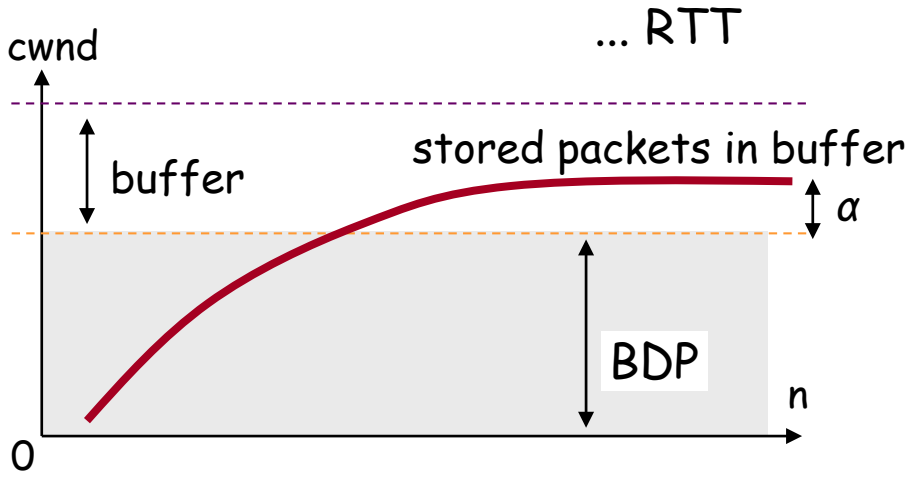
TCP Variants

- Loss-based



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

- Delay-based



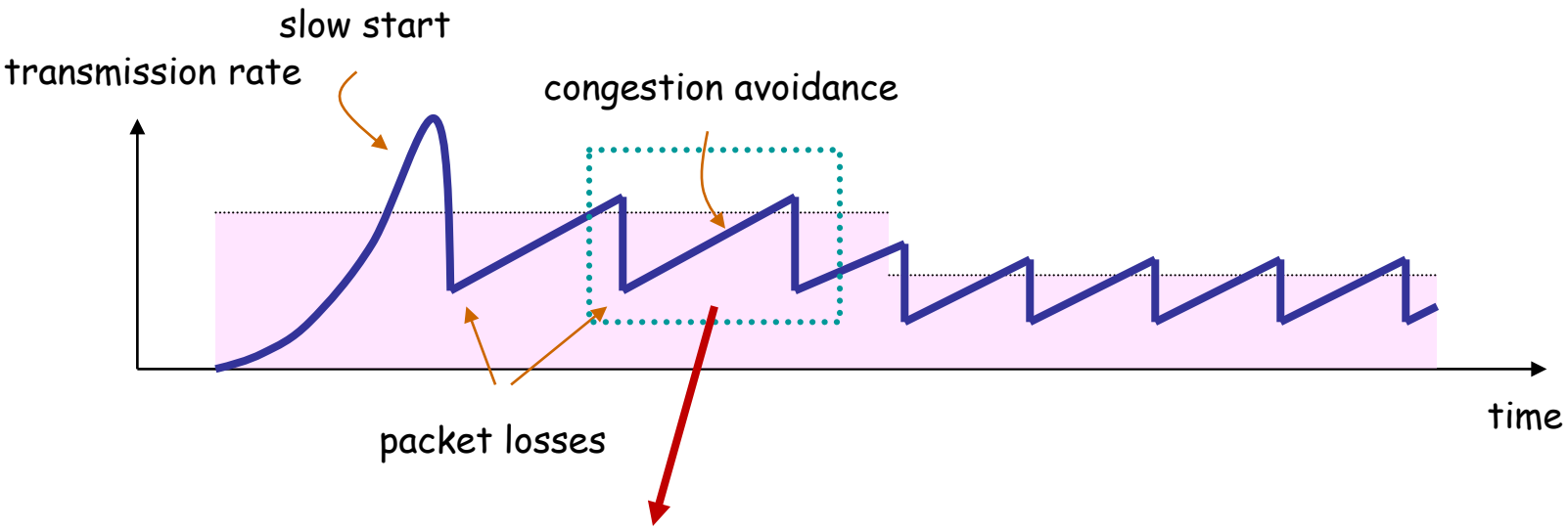
TCP-Vegas, FAST-TCP

- 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

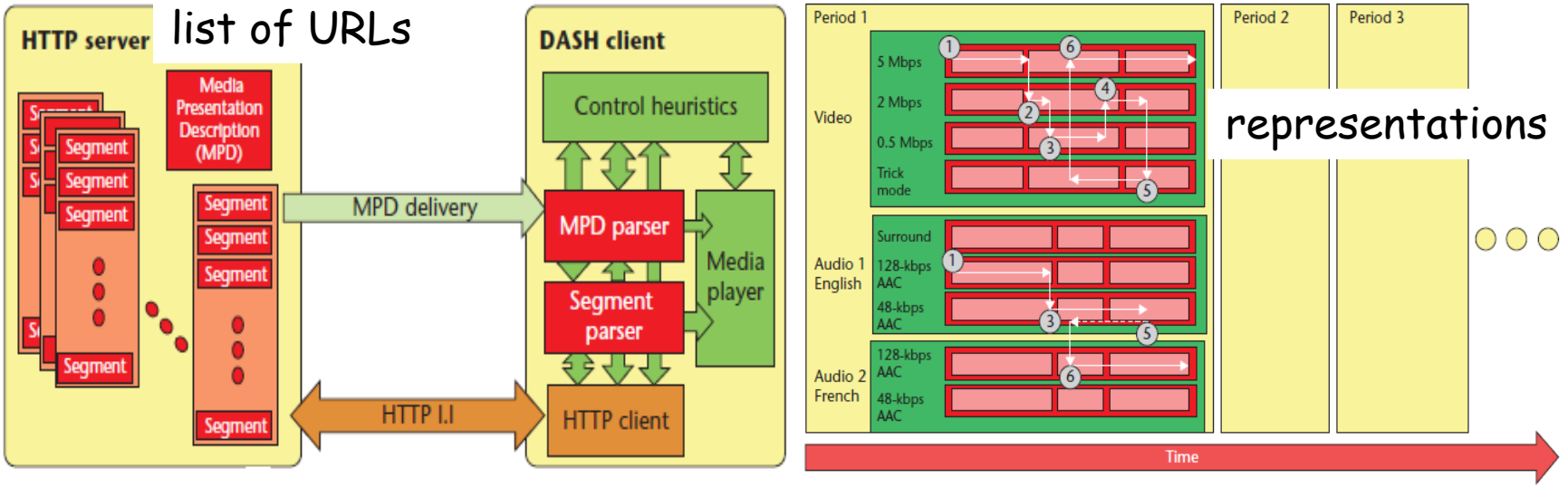
BDP/Buffer relationship

small buffer → × efficiency
large buffer → × delay

TFRC: TCP Friendly Rate Control

HTTP and MPEG-DASH

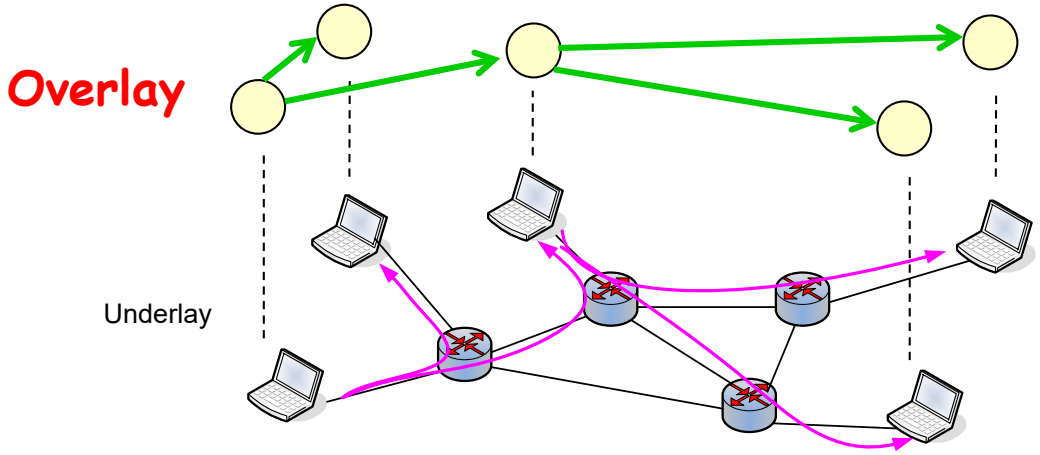
- MPEG-DASH: Dynamic Adaptive Streaming over HTTP
  - Multiple (bitrate, resolution) pairs … representation
  - Adaptive selection of representations



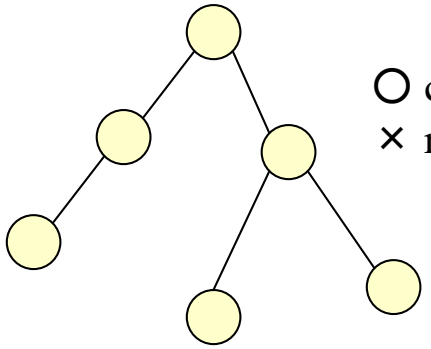
I. Sodagar, et al. : The MPEG-DASH Standard for Multimedia Streaming Over the Internet, IEEE Multimedia, Apr.2011.

CDN, P2P & Cloud

- Overlay networks

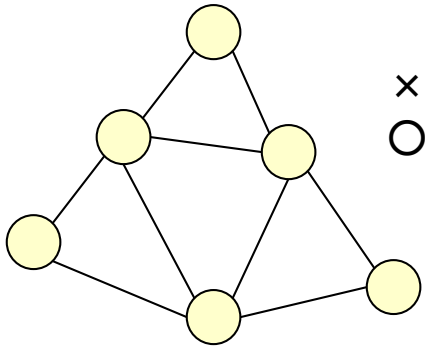


- tree



○ complexity
× robustness

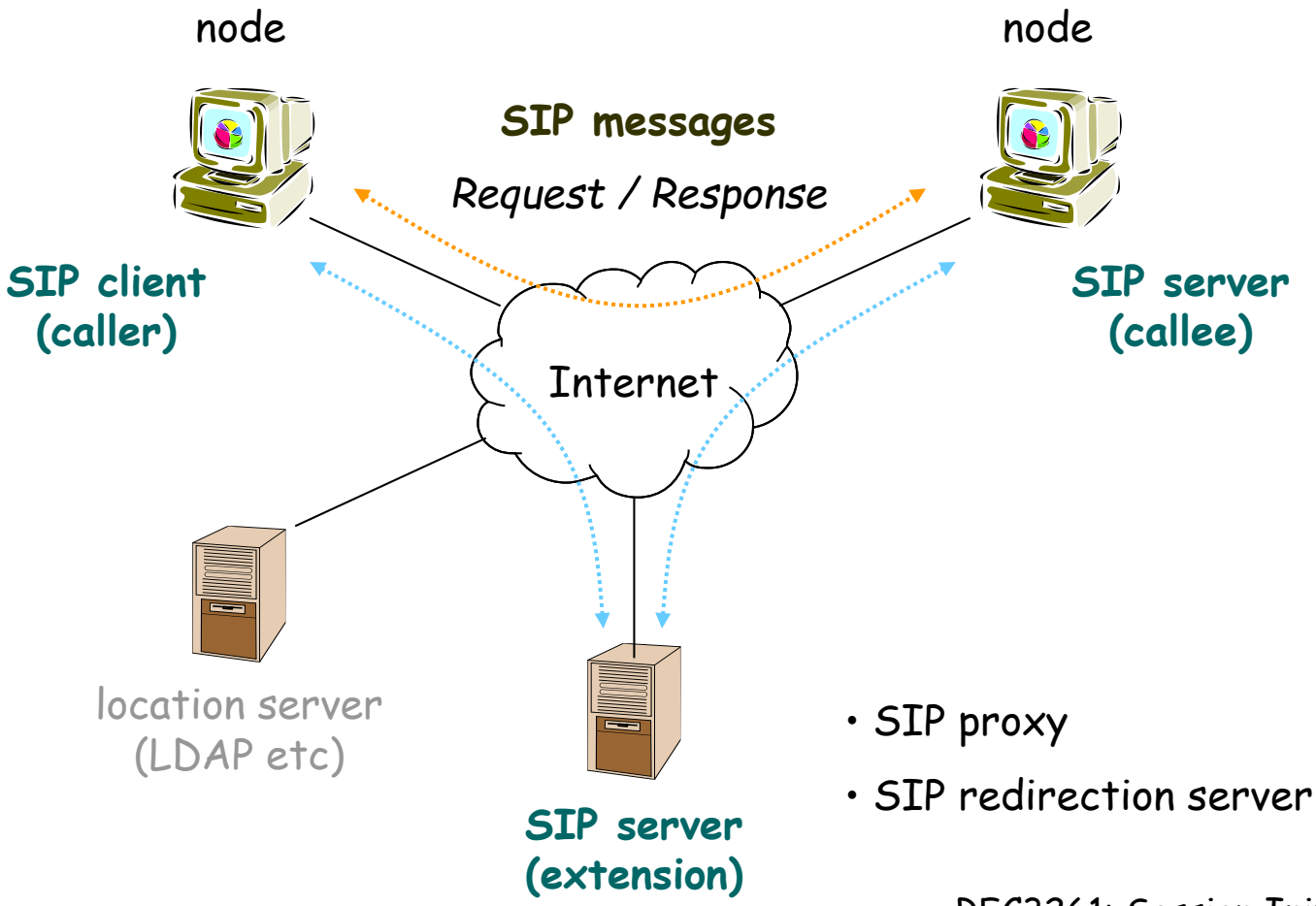
- mesh



× complexity
○ robustness

SIP and WebRTC

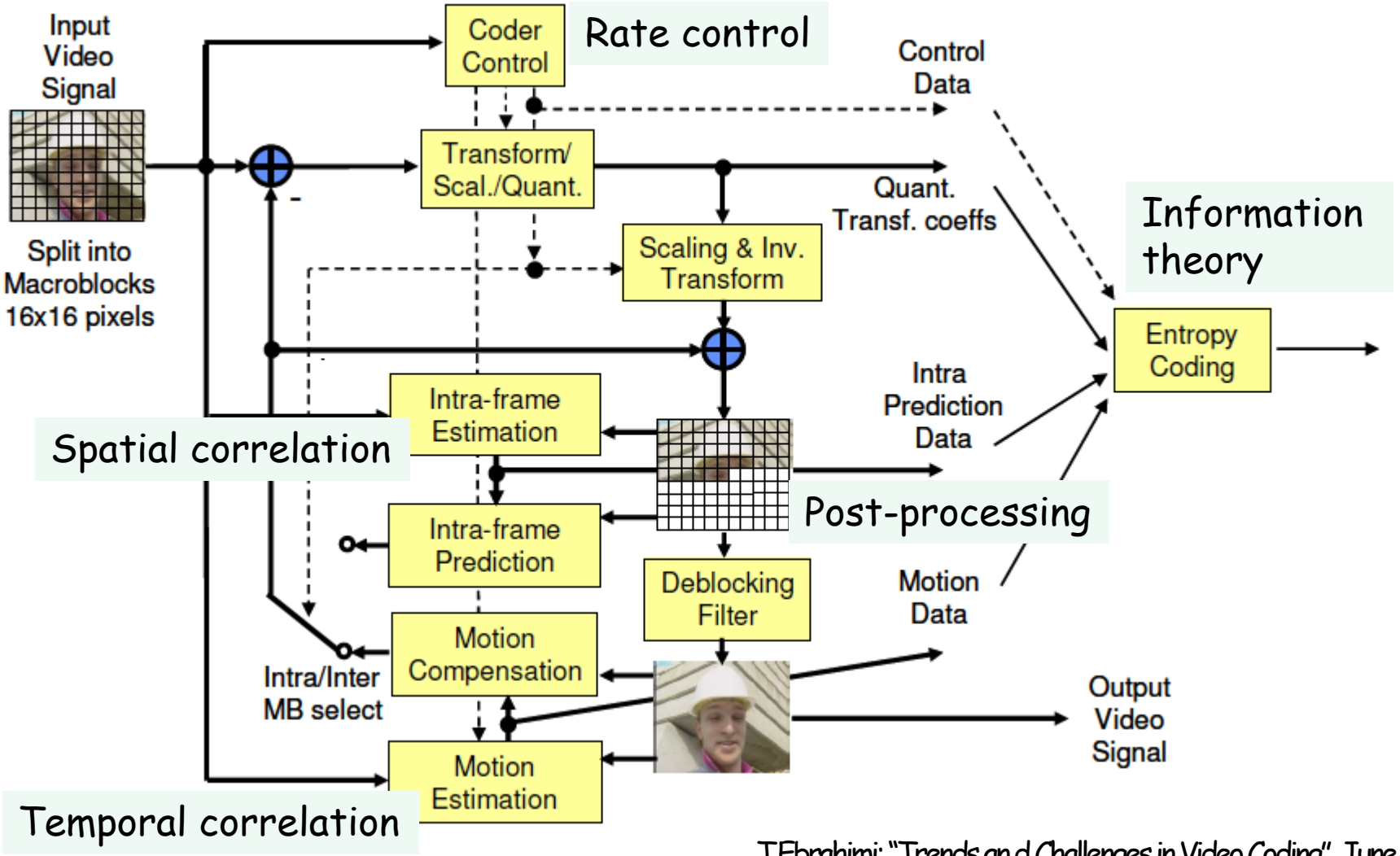
- SIP: Session Initiation Protocol



- SIP proxy
- SIP redirection server

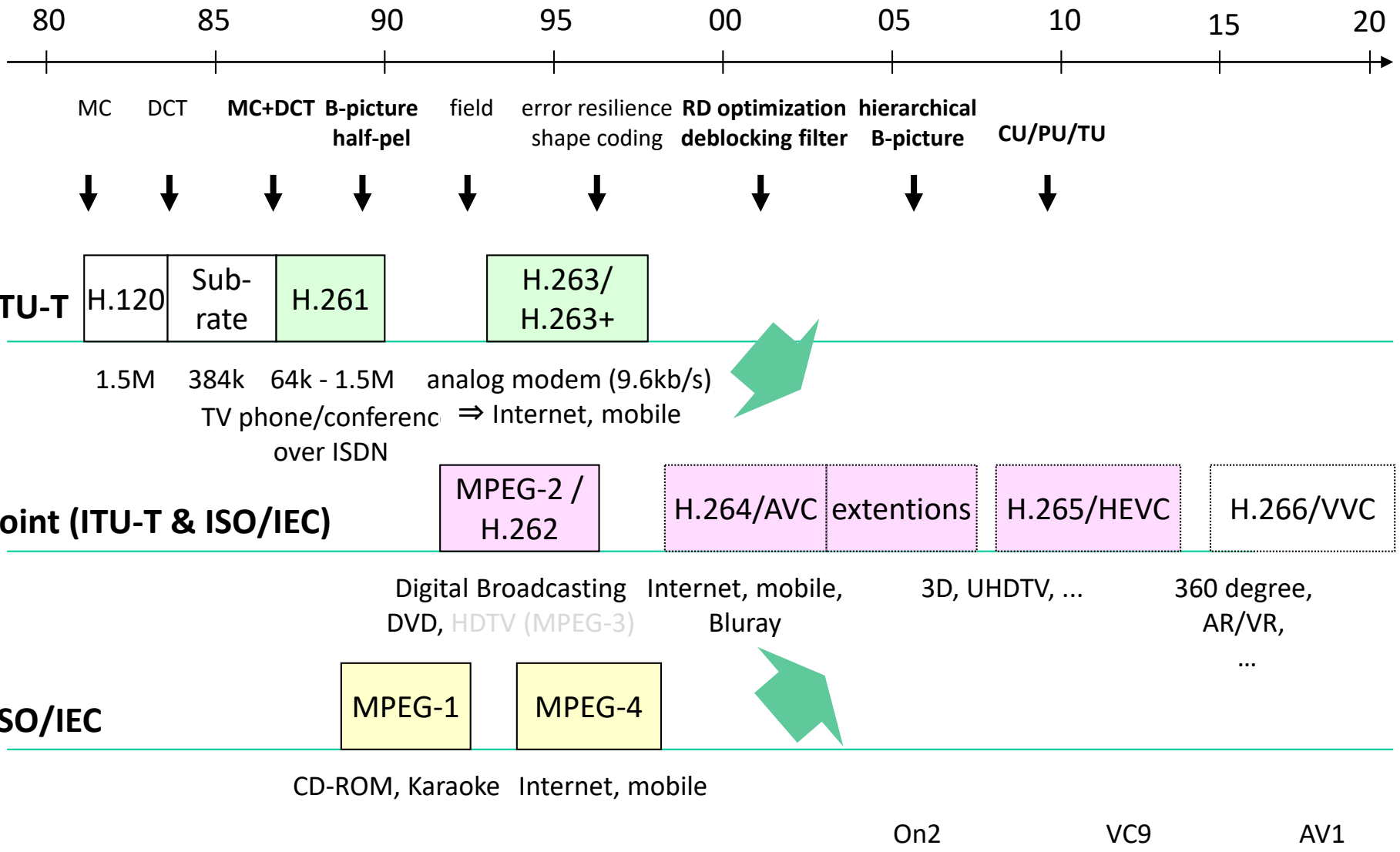
RFC3261: Session Initiation Protocol

Video Compression Basics



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

Video Compression History

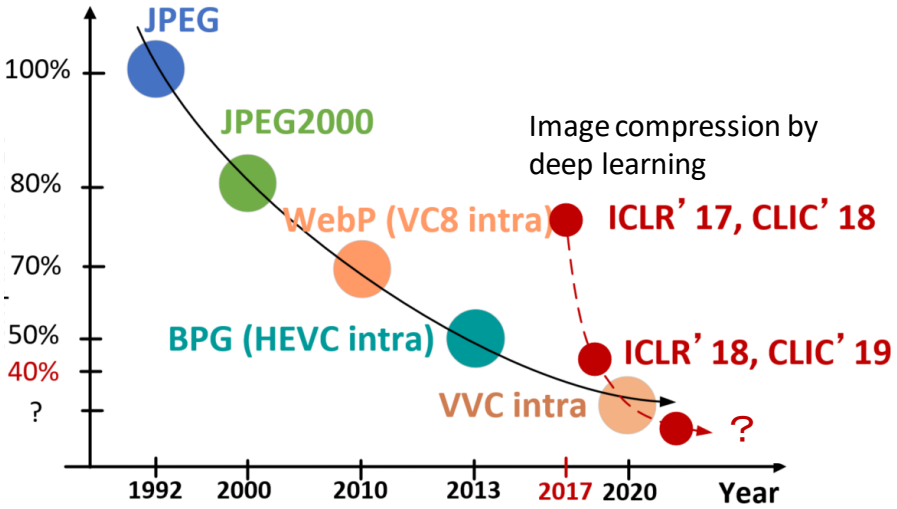


Learned Image Compression

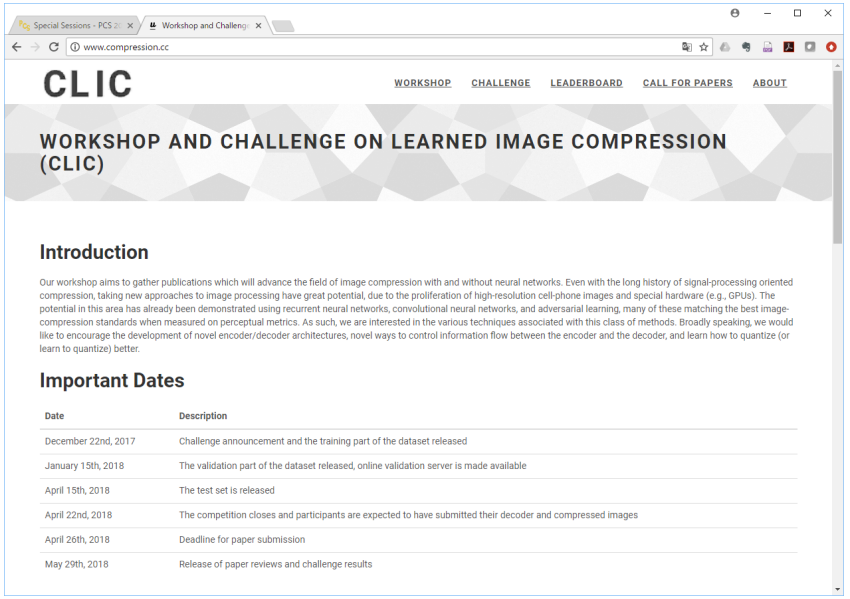
- Active topics in these three years

Compression performance

International standard for image compression



CLIC in CVPR 2020 in June



http://www.compression.cc/

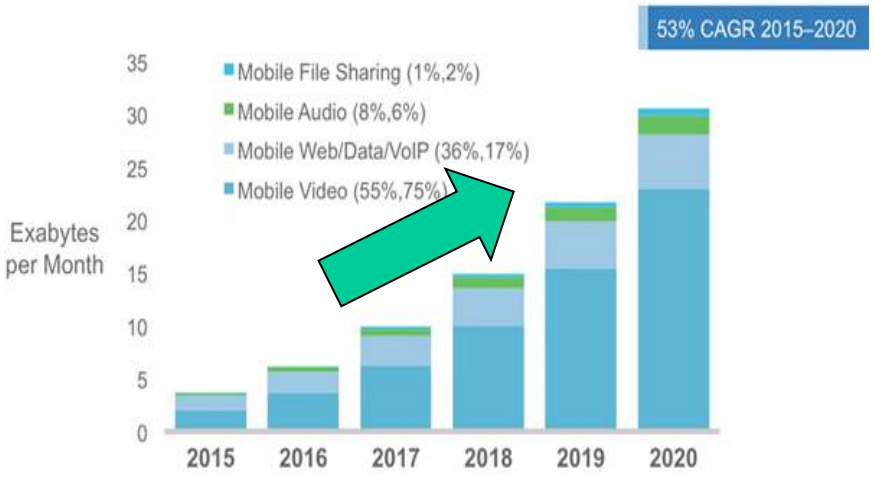
Handouts

- Check handouts on Waseda Moodle

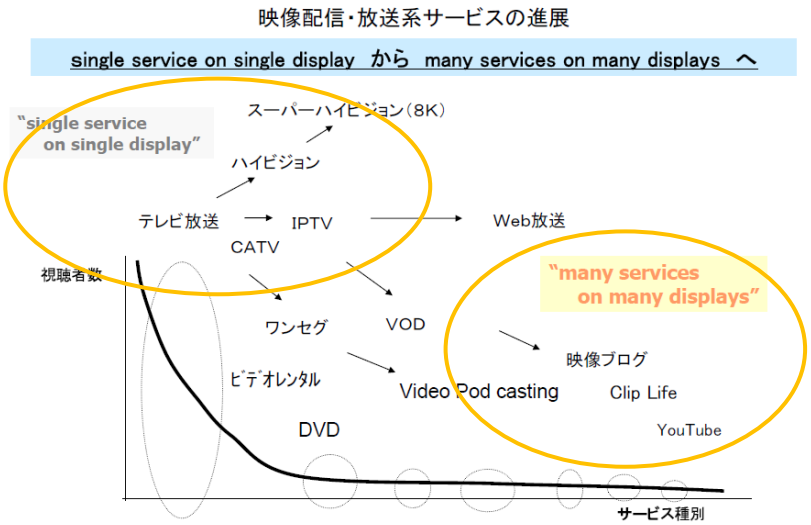
Streaming Background

Recent Trends

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

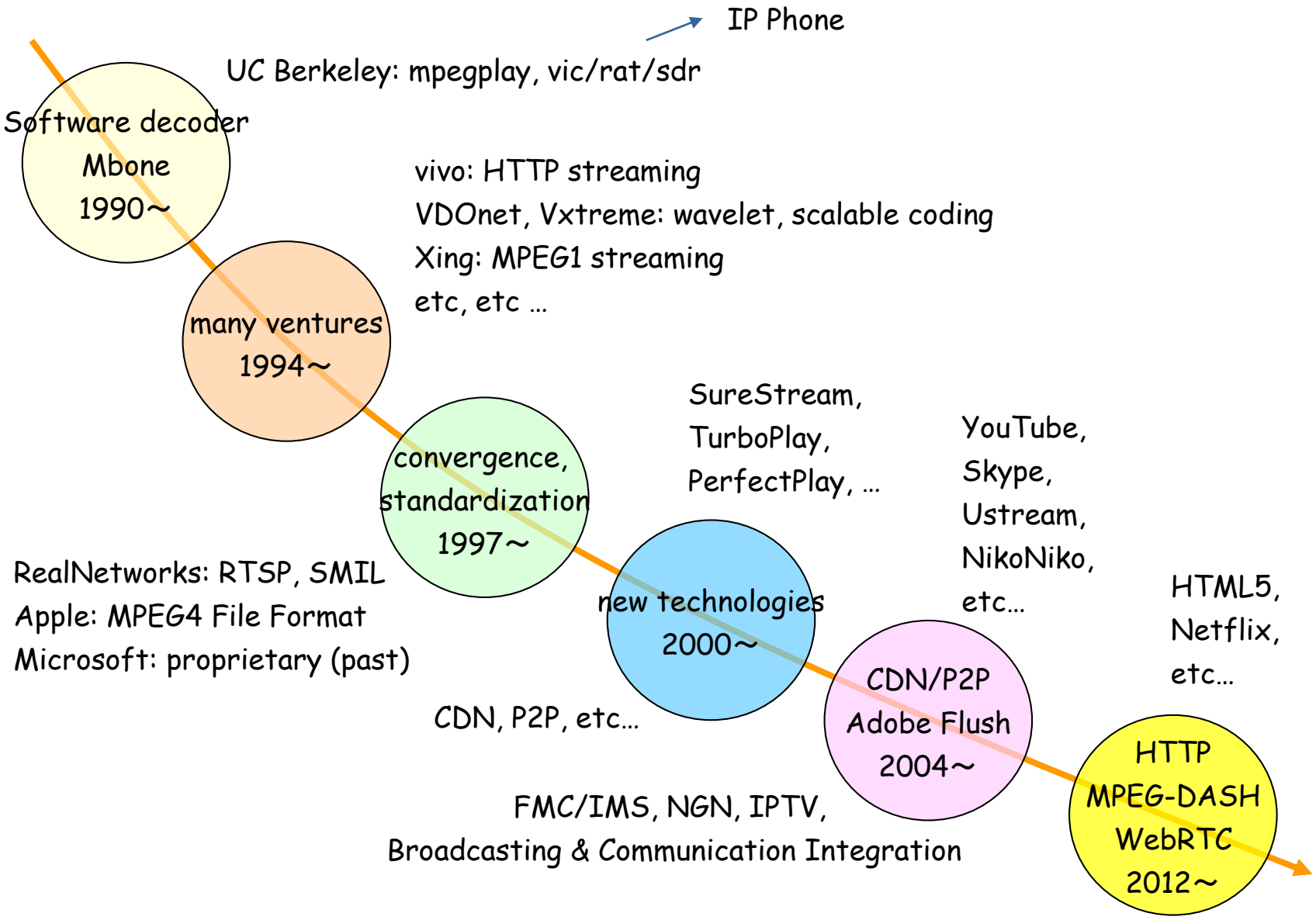


(Cisco VNI, 2016)



(MIC Report, 2008)

History of Video Streaming



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

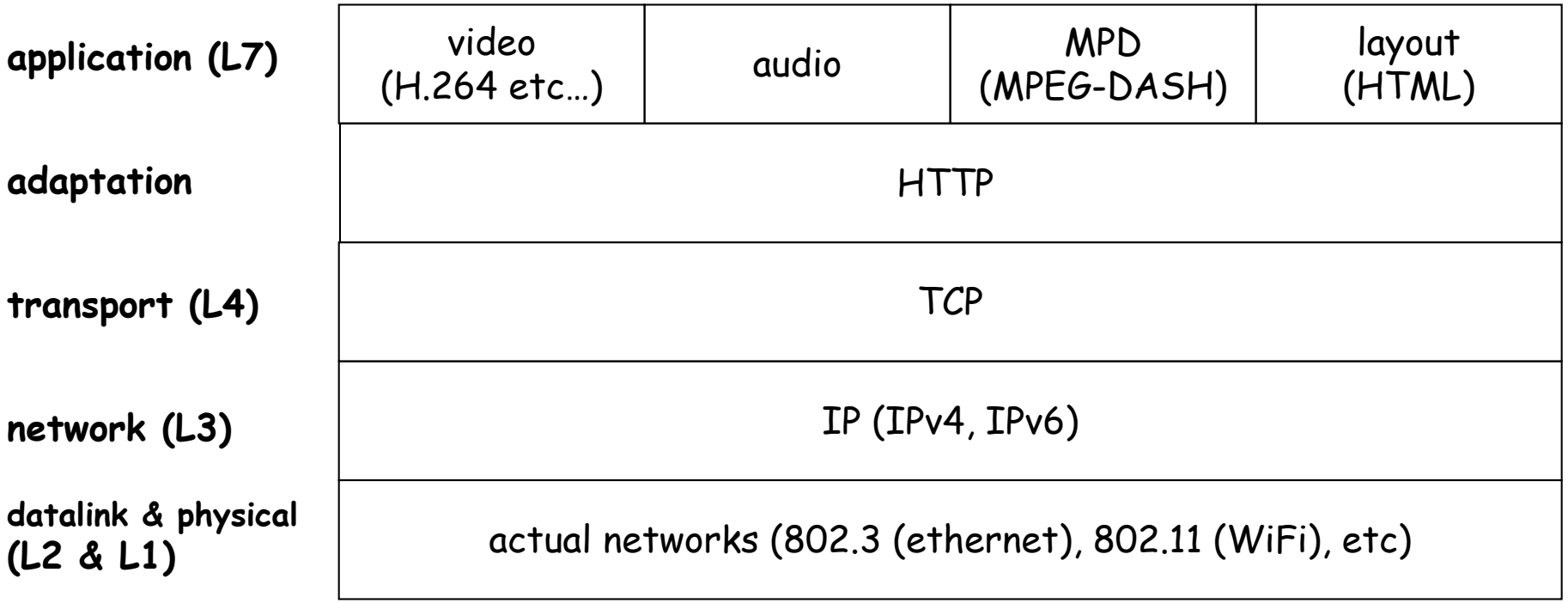
protocol stack for low-delay & interactive video streaming (e.g. conference)

<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



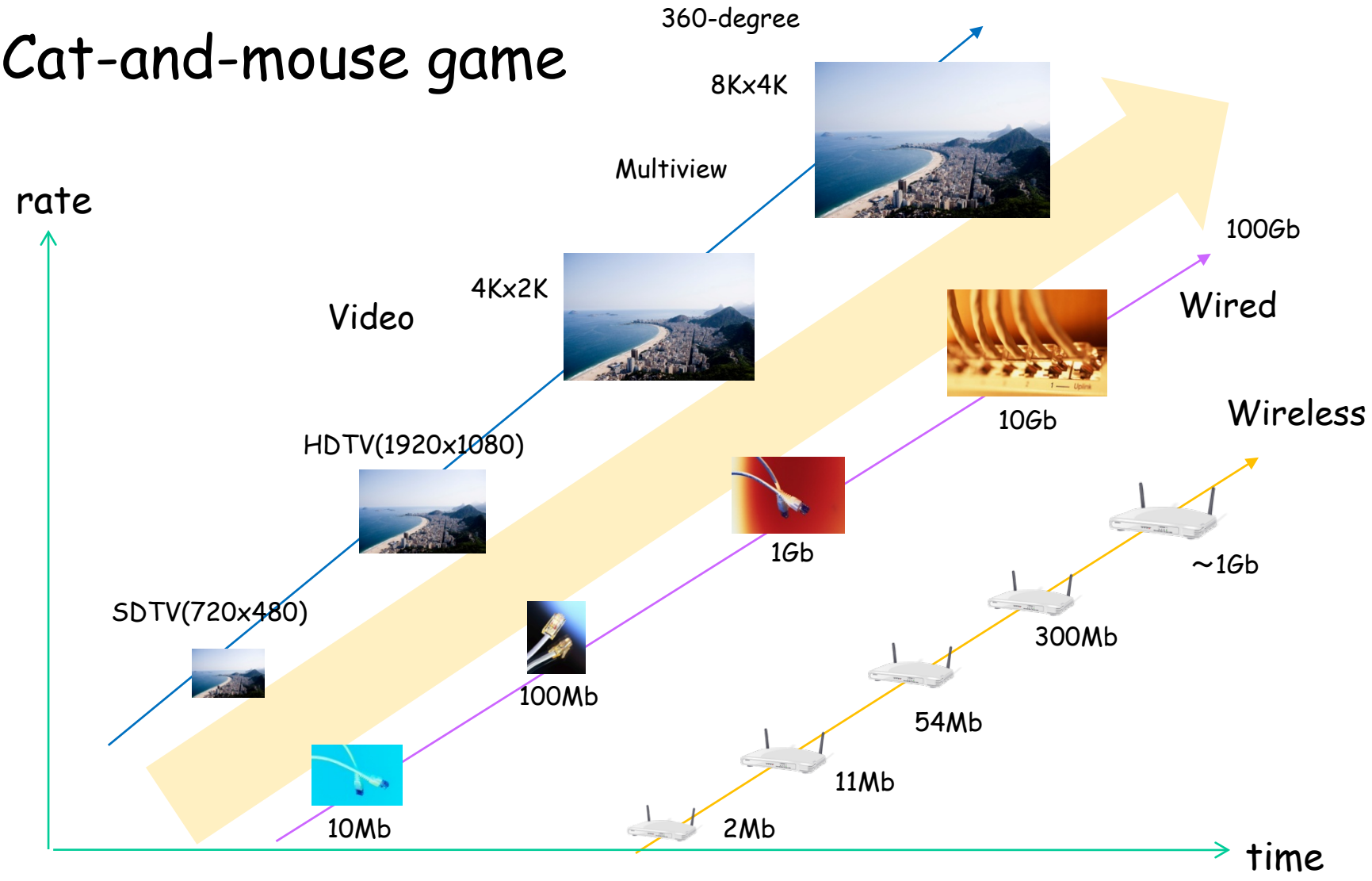
Protocol Stack of WebRTC

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

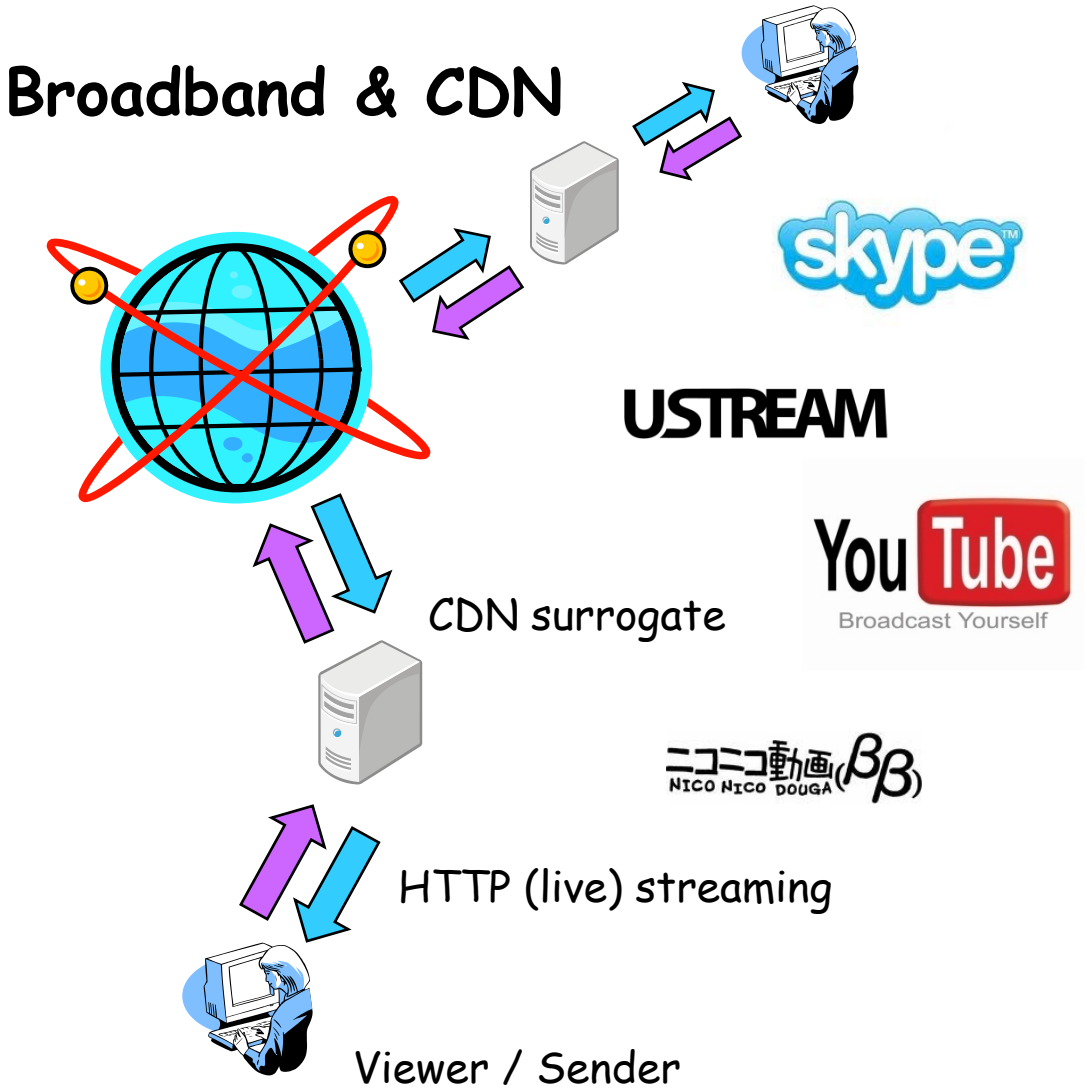
<table>
<tr><td>NAT traversal</td><td colspan="2">media</td><td>data</td><td>signaling</td></tr>
<tr><td></td><td>video</td><td>audio</td><td>data</td><td>SIP, SDP</td></tr>
<tr><td>STUN, TURN</td><td colspan="2">SRTP</td><td>SCTP/DTLS</td><td>HTTP/TLS,
WebSocket</td></tr>
<tr><td colspan="3">UDP</td>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

Networks and Multimedia

- Cat-and-mouse game



Broadband and CDN



RTP/UDP & RTSP & TFRC

→ HTTP/TCP streaming

- Broadband
- CDN (Akamai, Lime Networks)
- Firewall (port 80)
- …

One-way (on-demand / live)

- large buffer

Bi-directional (interactive)

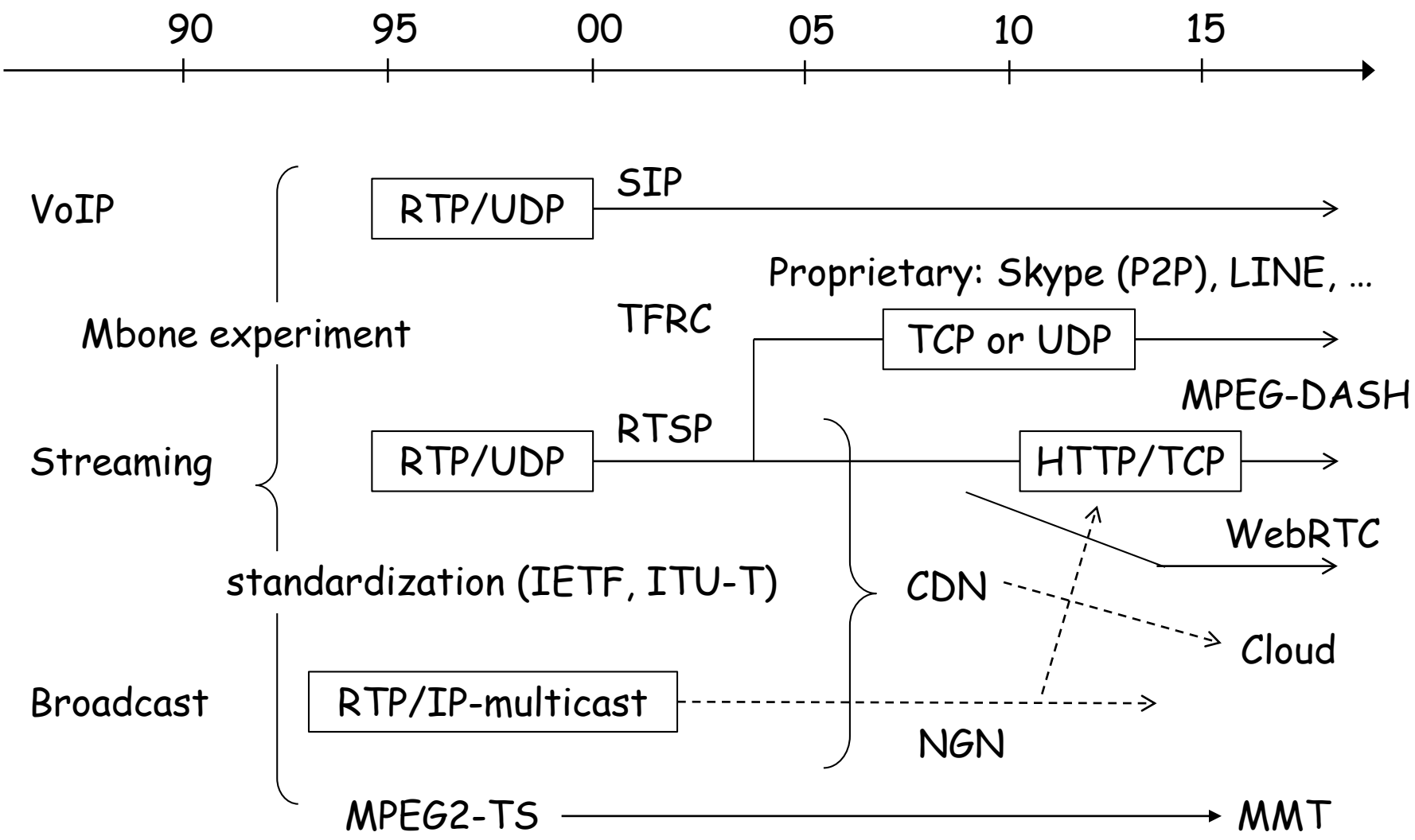
- small buffer

CDN: Content Delivery Network ⇒ Cloud

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

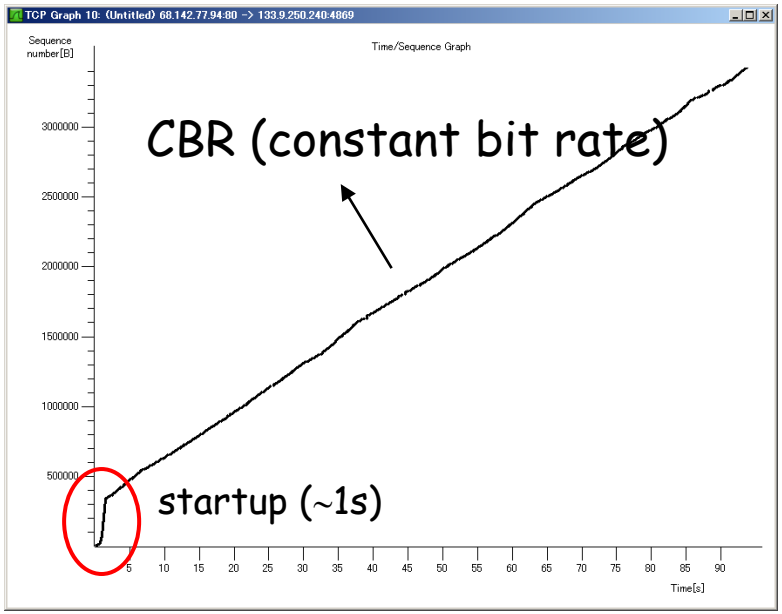
one-way streaming in 20 years ago

prefetching & CBR

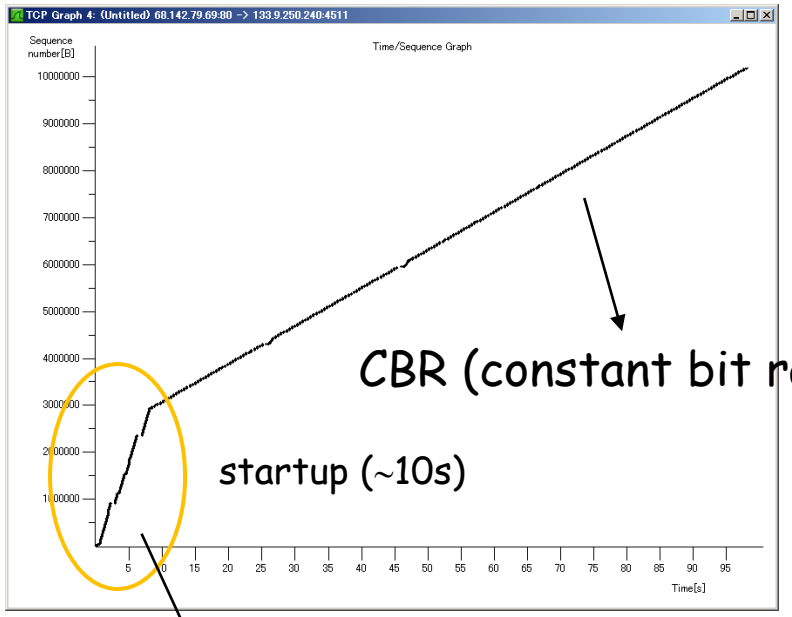
(prefetch, then CBR)

sequence number

Live



On-Demand



time

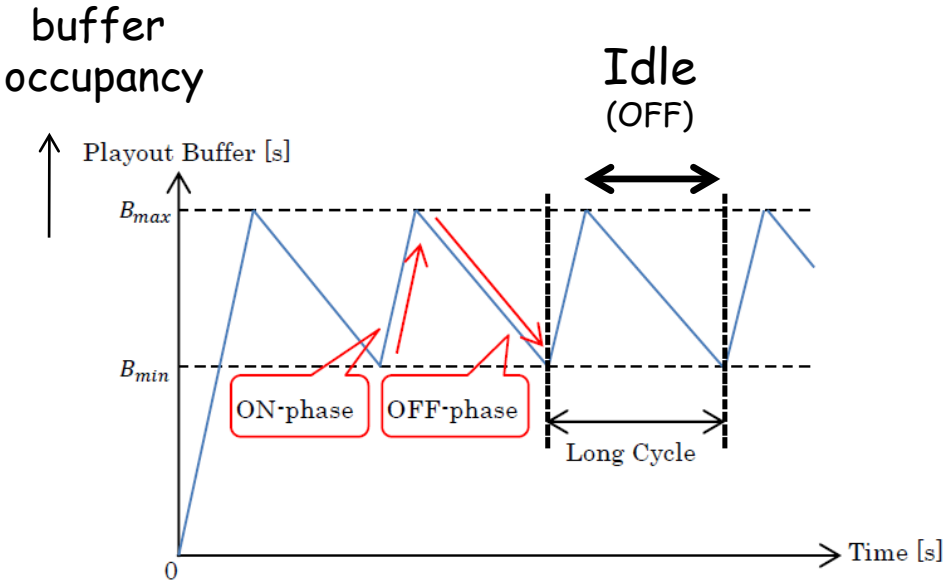
prefetching

one-way streaming nowadays

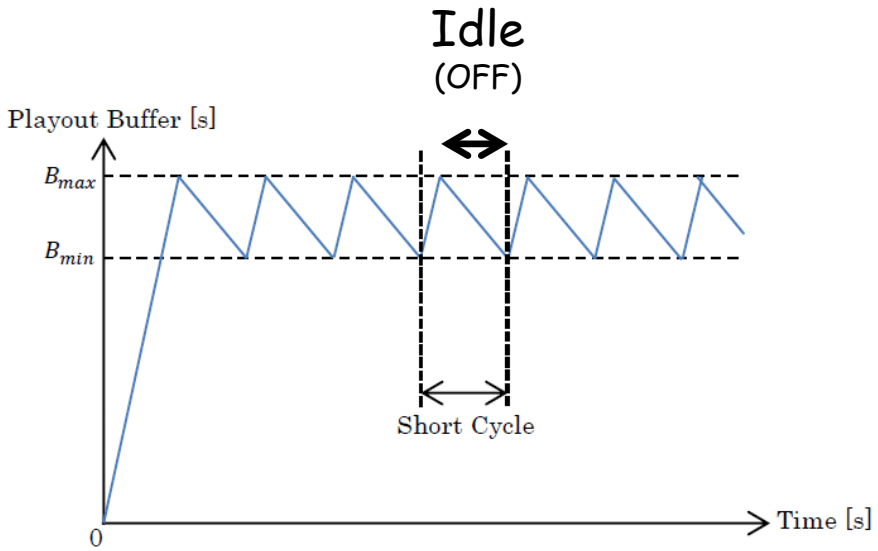
ON/OFF cycles

(prefetch & idle cycles)

- receiver buffer behaviors



(a) long ON-OFF Cycle (sawtooth)



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

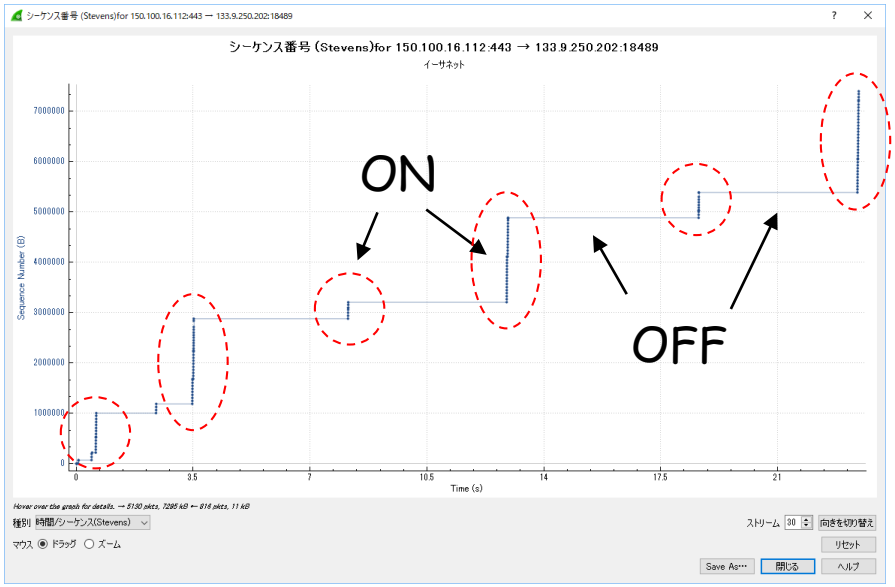
A. Rao, et al. ACM CoNEXT 2011

one-way streaming nowadays

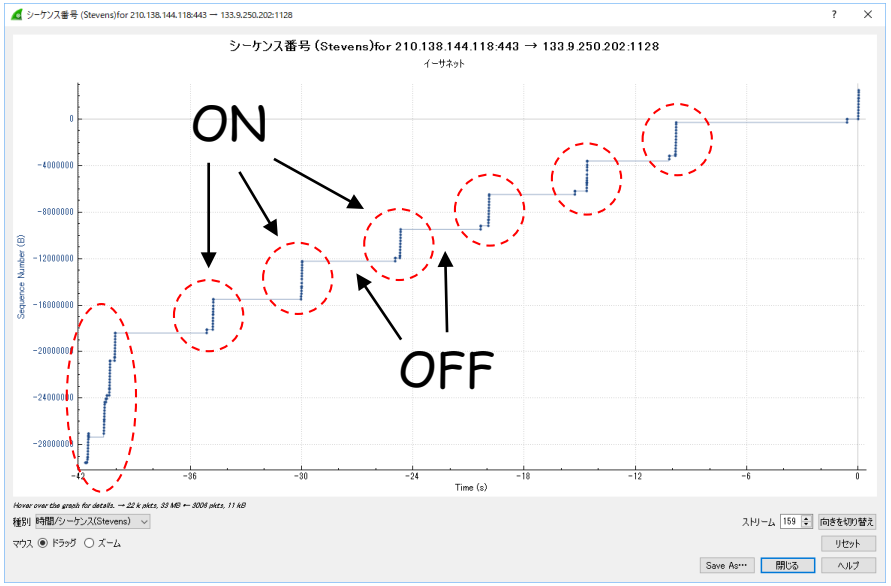
ON/OFF cycles

- sequence number behaviors

sequence number



example 1 (YouTube)



example 2 (TVer)

Supplement

- Keynotes and tutorials on video streaming
  - "Internet Video: The 2011 Perspective," IWQoS 2011.

    http://www.ieee-iwqos.org/2011/keynote.html
  - "Internet Video: Past, Present, and Future," SIGCOMM 2013 Tutorial.

    http://conferences.sigcomm.org/sigcomm/2013/ttliv.php
  - "Optimizing QoE in Large-Scale Video Networks," Packet Video 2013 (YouTube).
  - "Double, Double, Toil and Trouble, Bandwidth Grows and Congestion Bubbles," Packet Video 2013 (Akamai).

    http://pv2013.itec.aau.at/workshop-program/