Communication Networks

Prof. Laurent Vanbever

Online/COVID-19 Edition

Communication Networks

Spring 2020

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nsg.ee.ethz.ch

ETH Zürich (D-ITET)
May 11 2020

Materials inspired from Scott Shenker, Jennifer Rexford, and Ankit Singla

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Last week on

Communication Networks

DNS

Web

google.ch ⟷ 172.217.16.131

http://www.google.ch

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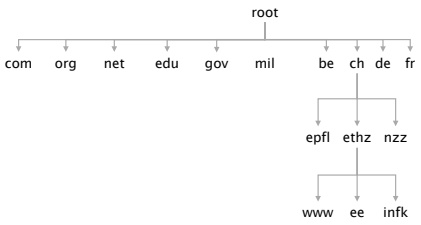
infrastructure

hierarchy of DNS servers

The DNS infrastructure is hierarchically organized



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13 root servers (managed professionally) serve as root (*)

a.	root-servers.net	VeriSign, Inc.
b.	root-servers.net	University of Southern California
c.	root-servers.net	Cogent Communications
d.	root-servers.net	University of Maryland
e.	root-servers.net	NASA
f.	root-servers.net	Internet Systems Consortium
g.	root-servers.net	US Department of Defense
h.	root-servers.net	US Army
i.	root-servers.net	Netnod
j.	root-servers.net	VeriSign, Inc.
k.	root-servers.net	RIPE NCC
l.	root-servers.net	ICANN
m.	root-servers.net	WIDE Project

To scale root servers, operators rely on BGP anycast

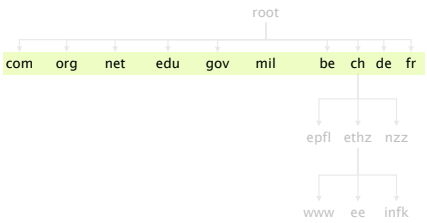
Intuition

Routing finds shortest-paths

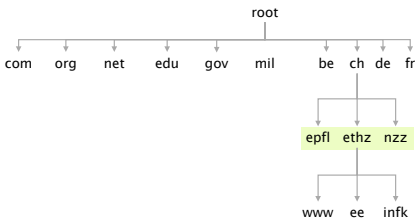
If several locations announce the same prefix, then routing will deliver the packets to the "closest" location

This enables seamless replications of resources

TLDs server are also managed professionally
by private or non-profit organization



The bottom (and bulk) of the hierarchy is
managed by Internet Service Provider or locally



A DNS server stores Resource Records
composed of a (name, value, type, TTL)

Records	Name	Value
A	hostname	IP address
NS	domain	DNS server name
MX	domain	Mail server name
CNAME	alias	canonical name
PTR	IP address	corresponding hostname

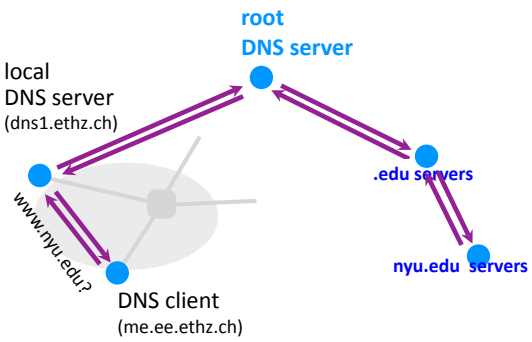
Using DNS relies on two components

trigger resolution process
send request to local DNS server

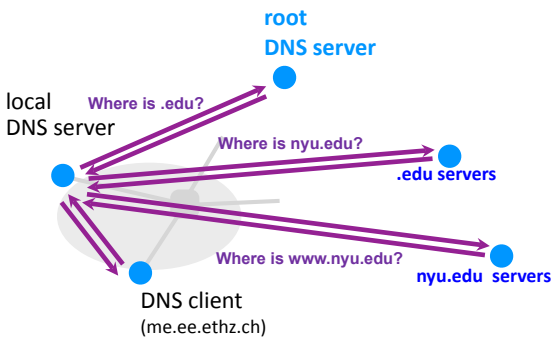
usually, near the endhosts
configured statically (resolv.conf)
or dynamically (DHCP)

DNS resolution can either be
recursive or iterative

When performing a recursive query,
the client offload the task of resolving to the server



When performing a iterative query,
the server only returns the address of the "next server"



DNS

Web

http://www.google.ch

The WWW is made of three key components

Infrastructure	Content	Implementation
Clients/Browser	Objects	URL: name content
Servers	files, pictures, videos, …	HTTP: transport content
Proxies	*organized* in	
	Web sites	
	a collection of objects	

We'll focus on its implementation

Infrastructure	Content	Implementation
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Infrastructure	Content	Implementation
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	Web sites	
	a collection of objects	

A Uniform Resource Locator (URL) refers to an Internet ressource

protocol://hostname[:port]/directory_path/resource

Infrastructure	Content	Implementation
Clients/Browser	Objects	URL: name content
Servers	files, pictures, videos, …	**HTTP: transport content**
Proxies	*organized* in	
	Web sites	
	a collection of objects	

HTTP is a rather simple synchronous request/reply protocol

HTTP is layered over a bidirectional byte stream
typically TCP, but QUIC is ramping up

HTTP is text-based (ASCII)
human readable, easy to reason about

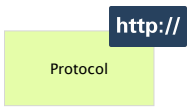
HTTP is stateless
it maintains *no info* about past client requests

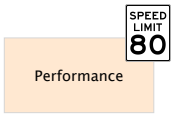
http://

Protocol

SPEED LIMIT 80

Performance





HTTP clients make request to the server

HTTP request

method <sp> URL <sp> version	<cr><lf>
header field name: value	<cr><lf>
...	
header field name: value	<cr><lf>
<cr><lf>	
body	

method	GET	return resource
	HEAD	return headers only
	POST	send data to server (forms)
URL		relative to server *(e.g., /index.html)*
version		1.0, 1.1, 2.0

HTTP servers answers to clients' requests

HTTP response

version <sp> status <sp> phrase	<cr><lf>
header field name: value	<cr><lf>
...	
header field name: value	<cr><lf>
<cr><lf>	
body	

	3 digit response code		reason phrase
Status	1XX	informational	
	2XX	success	200 OK
	3XX	redirection	301 Moved Permanently
			303 Moved Temporarily
			304 Not Modified
	4XX	client error	404 Not Found
	5XX	server error	505 Not Supported

HTTP makes the client maintain the state.
This is what the so-called cookies are for!

client stores small state
on behalf of the server *X*

client sends state
in all future requests to *X*

can provide authentication

This week on
Communication Networks

Web

http://www.google.ch

Video Streaming

HTTP-based

(the end, from slide 70/97)

Web

Video Streaming

http://www.google.ch

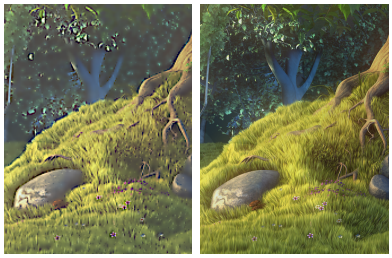
(the end, from slide 70/97)

Web

Video Streaming

HTTP-based

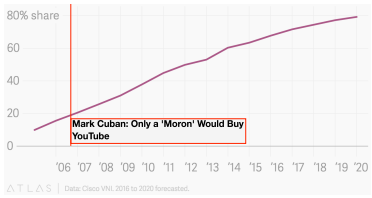
We want the highest video quality



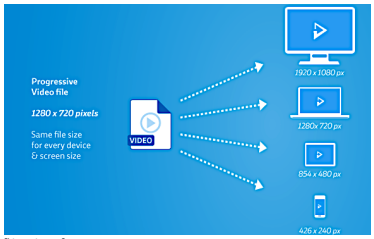
(c) copyright 2008, Blender Foundation / www.bigbuckbunny.org, CC-BY-3.0

Without seeing this ...

Why should you care? Just look at this: video's share of global internet traffic

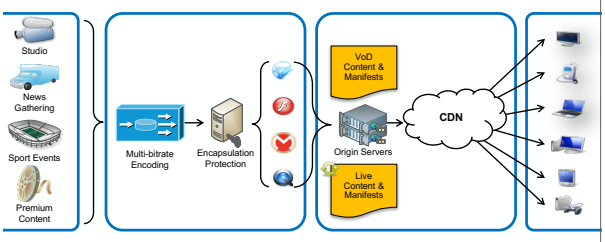


A naive approach: one-size-fits-all



[bitmovin.com]

In practice, things are complex



[Adapted from: Adaptive Streaming of Traditional and Omnidirectional Media, Begen & Timmerer, ACM SIGCOMM Tutorial, 2017]

The three steps behind most contemporary solutions

- Encode video in multiple bitrates
- Replicate using a content delivery network
- Video player picks bitrate adaptively
  - Estimate connection's available bandwidth
  - Pick a bitrate ≤ available bandwidth

Encoding

Replication

Adaptation

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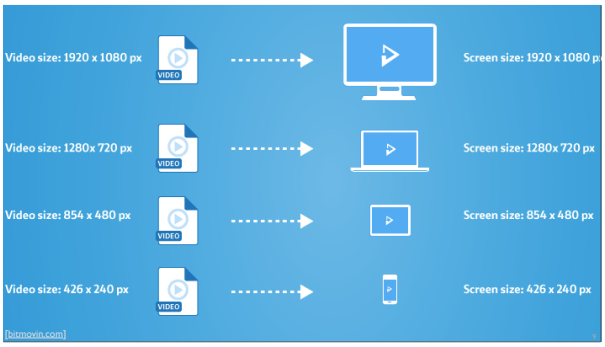
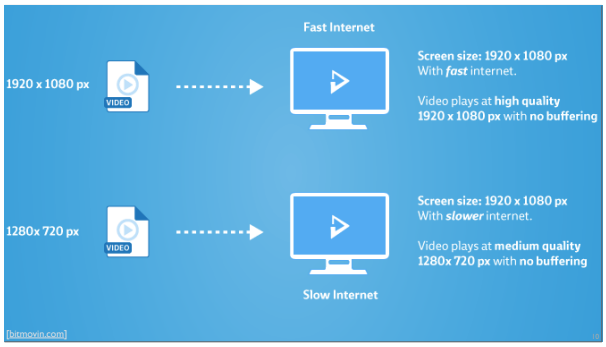
Encoding

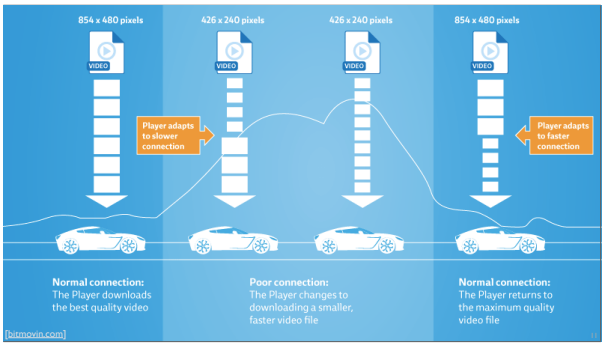
Replication

Adaptation

8







Simple solution for encoding: use a "bitrate ladders"

Bitrate (kbps)	Resolution
235	320x240
375	384x288
560	512x384
750	512x384
1050	640x480
1750	720x480
2350	1280x720
3000	1280x720
4300	1920x1080
5800	1920x1080

[netflix.com]

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Problem: this doesn't take into account the variability in the video content (slow moving vs. fast moving)

Bitrate (kbps)	Resolution
235	320x240
375	384x288
560	512x384
750	512x384
1050	640x480
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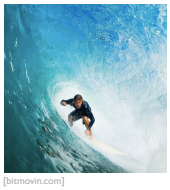
[netflix.com]

[netflix.com]



[bitmovin.com]

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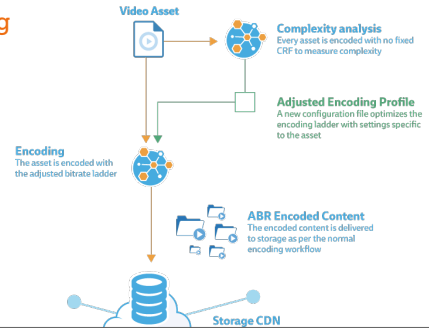
Encoding



bitmovin.com

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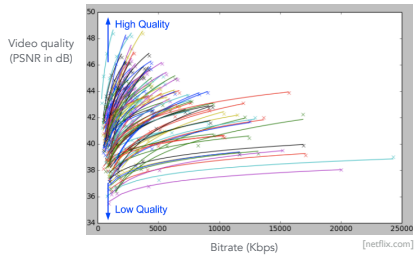
Encoding



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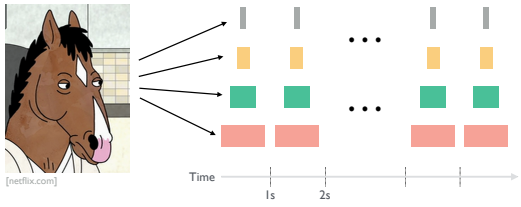
Your player download "chunks" of video at different bitrates



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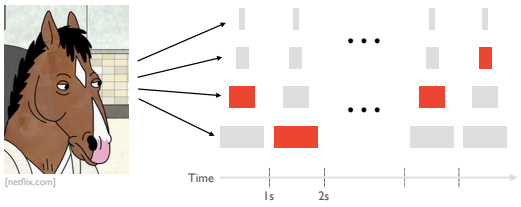
Depending on your network connectivity, your player fetches chunks of different qualities



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Your player gets metadata about chunks via "Manifest"

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns="urn:mpeg:DASH:schema:MPD:2011"
    xsi:schemaLocation="urn:mpeg:DASH:schema:MPD:2011"
    profiles="urn:mpeg:dash:profile:isoff-main:2011"
    type="static"
    mediaPresentationDuration="PT0H9M56.46S"
    minBufferTime="PT1S.0S">
  <BaseURL>http://witestlab.poly.edu/~ffund/video/2s_480p_only/</BaseURL>
  <Period start="PT0S">
      <AdaptationSet bitstreamSwitching="true">
    <Representation id="0" codecs="avc1" mimeType="video/mp4"
       width="480" height="360" startWithSAP="1" bandwidth="101492">
      <SegmentBase>
        <Initialization sourceURL="bunny_2s_100kbit/bunny_100kbit.mp4"/>
      </SegmentBase>
      <SegmentList duration="2">
        <SegmentURL media="bunny_2s_100kbit/bunny_2s1.m4s"/>
        <SegmentURL media="bunny_2s_100kbit/bunny_2s2.m4s"/>
        <SegmentURL media="bunny_2s_100kbit/bunny_2s3.m4s"/>
        <SegmentURL media="bunny_2s_100kbit/bunny_2s4.m4s"/>
        <SegmentURL media="bunny_2s_100kbit/bunny_2s5.m4s"/>
        <SegmentURL media="bunny_2s_100kbit/bunny_2s6.m4s"/>
```

[witestlab.poly.edu]

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Encoding

Replication

Adaptation

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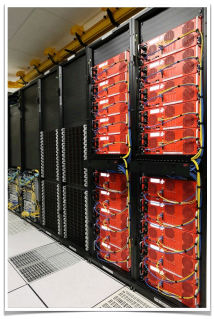
NETFLIX

Open Connect: Starting from a Greenfield (a mostly Layer 0 talk)

Dave Temkin
06/01/2015



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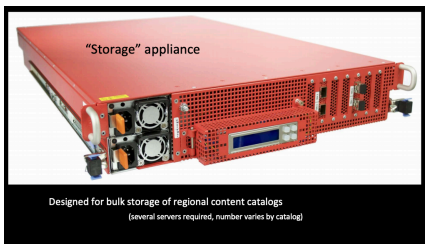

[more-ip-event.net]

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Storage Appliances

Storage appliances are 2U servers that are focused on reliable dense storage and cost effective throughput. This appliance is used to hold the Netflix catalog in many IX locations around the world and embedded at our larger ISP partner locations.

Storage appliance focus areas

- Large storage capacity
- 2U for rack efficiency (no deeper than 29 inches)
- Enough low cost NAND to reach 10GB/s of throughput (~0.3 DWPD)
- Network flexibility to connect at 6x10GE LAG or 1x100GE
- 2 and 4 post racking
- AC or DC power
- Single processor

Storage appliance high-level specifications

Option	Vendors
Chassis	Sanmina
Motherboard	Supermicro
Processor	Intel
Memory	Micron
Hard Drive	HGST
Solid State Drive	Micron, Toshiba
Network Controller	Chelsio
Power draw operational (peak)	~500W
Power Supply Unit	Redundant Hot Swap AC/DC
Operational throughput	~360Gbps
Raw storage capacity	~288 TB

[openconnect.netflix.com]

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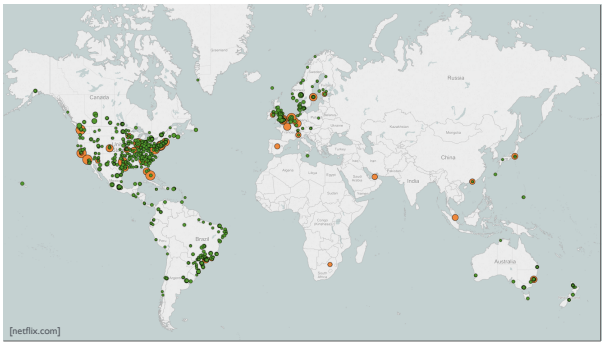
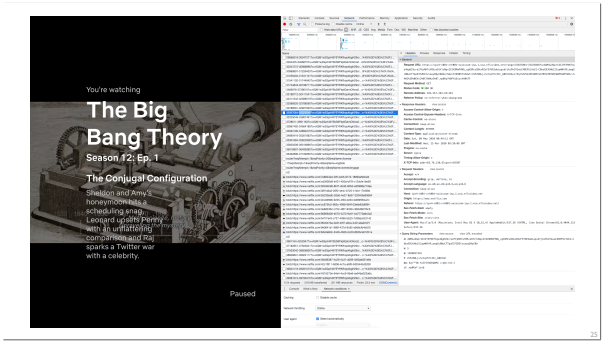
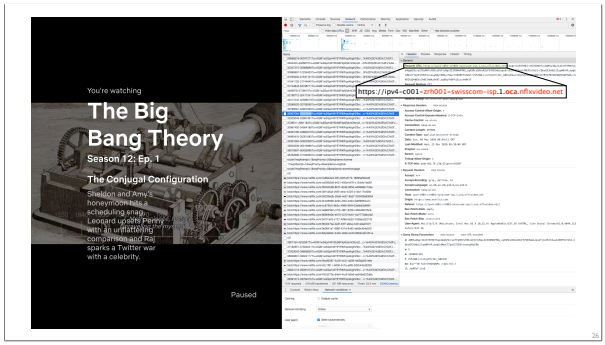
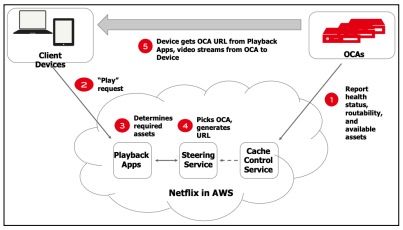






Complete Playback Workflow @Netflix



[more-ip-event.net]

How many OCA appliances in Swisscom?
I found at least 35 of them

ipv4-c001-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.34	ipv4-c001-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.2
ipv4-c002-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.35	ipv4-c002-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.3
ipv4-c003-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.36	ipv4-c003-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.4
ipv4-c004-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.37	ipv4-c004-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.5
ipv4-c005-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.38	ipv4-c005-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.6
ipv4-c006-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.39	ipv4-c006-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.7
ipv4-c007-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.40	ipv4-c007-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.8
ipv4-c008-zrh001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.41	ipv4-c009-gva001-swisscom-isp.1.oca.nflxvideo.net	193.247.193.9
ipv4-c001-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.98	ipv4-c001-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.72
ipv4-c002-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.99	ipv4-c002-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.73
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ipv4-c004-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.101	ipv4-c005-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.67
ipv4-c005-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.102	ipv4-c006-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.68
ipv4-c006-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.103	ipv4-c007-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.69
ipv4-c007-zrh002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.104	ipv4-c008-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.70
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ipv4-c001-zrh003-swisscom-isp.1.oca.nflxvideo.net	193.247.193.242	ipv4-c010-gva002-swisscom-isp.1.oca.nflxvideo.net	193.247.193.66
ipv4-c002-zrh003-swisscom-isp.1.oca.nflxvideo.net	193.247.193.243		

Assuming all of them are fully loaded → **10 080 TB** of storage!! (288 TB x 35)
>2 million 1080p movies, assuming 100 min encoded at 5 Mbps

Besides OCAs within ISPs, Netflix also hosts caches at various IXPs and datacenters

ipv4-c001-zrh001-ix.1.oca.nflxvideo.net	45.57.18.130	ipv4-c013-zrh001-ix.1.oca.nflxvideo.net	45.57.19.135
ipv4-c002-zrh001-ix.1.oca.nflxvideo.net	45.57.18.131	ipv4-c014-zrh001-ix.1.oca.nflxvideo.net	45.57.19.136
ipv4-c003-zrh001-ix.1.oca.nflxvideo.net	45.57.18.132	ipv4-c015-zrh001-ix.1.oca.nflxvideo.net	45.57.18.137
ipv4-c004-zrh001-ix.1.oca.nflxvideo.net	45.57.19.130	ipv4-c016-zrh001-ix.1.oca.nflxvideo.net	45.57.18.138
ipv4-c005-zrh001-ix.1.oca.nflxvideo.net	45.57.19.131	ipv4-c017-zrh001-ix.1.oca.nflxvideo.net	45.57.19.137
ipv4-c006-zrh001-ix.1.oca.nflxvideo.net	45.57.19.132	ipv4-c018-zrh001-ix.1.oca.nflxvideo.net	45.57.19.138
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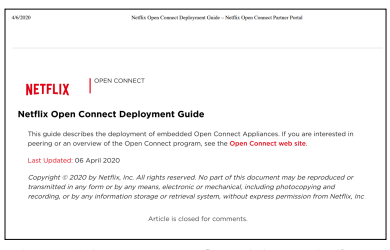
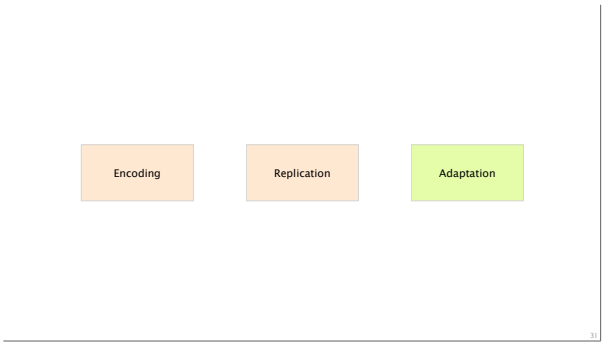
ipv4-c008-zrh001-ix.1.oca.nflxvideo.net	45.57.18.134	ipv4-c020-zrh001-ix.1.oca.nflxvideo.net	45.57.18.140
ipv4-c009-zrh001-ix.1.oca.nflxvideo.net	45.57.18.135	ipv4-c021-zrh001-ix.1.oca.nflxvideo.net	45.57.18.141
ipv4-c010-zrh001-ix.1.oca.nflxvideo.net	45.57.18.136	ipv4-c022-zrh001-ix.1.oca.nflxvideo.net	45.57.19.139
ipv4-c011-zrh001-ix.1.oca.nflxvideo.net	45.57.19.133	ipv4-c023-zrh001-ix.1.oca.nflxvideo.net	45.57.19.140
ipv4-c012-zrh001-ix.1.oca.nflxvideo.net	45.57.19.134	ipv4-c024-zrh001-ix.1.oca.nflxvideo.net	45.57.19.141

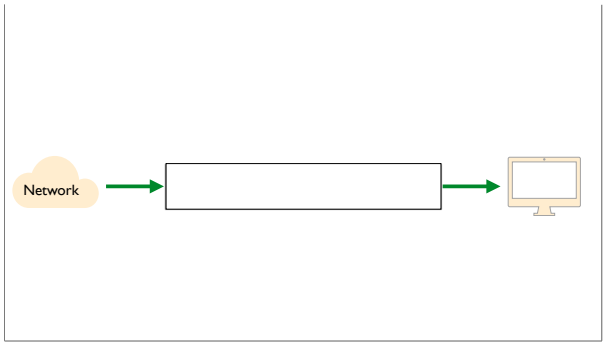
At least 24 instances in Zurich Equinix, see https://openconnect.netflix.com/en/peering/#locations

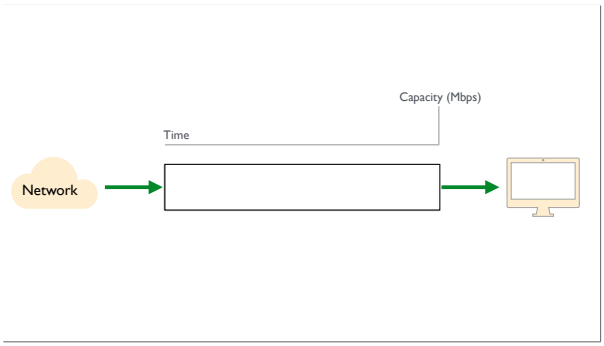
If you are interested in finding out more: check out https://openconnect.netflix.com

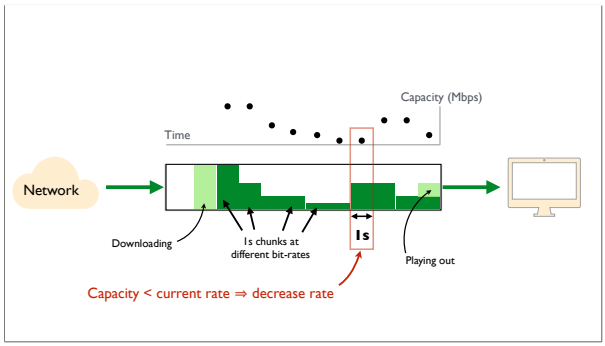


Deployment guide: https://openconnect.netflix.com/deploymentguide.pdf









Common solution approach

- Encode video in multiple bitrates
- Replicate using a content delivery network
- Video player picks bitrate adaptively
  - Estimate connection's available bandwidth
  - Pick a bitrate ≤ available bandwidth

Estimating available capacity

ACM SIGCOMM

A Buffer-Based Approach to Rate Adaptation: Evidence from a Large Video Streaming Service

Te-Yuan Huang, Ramesh Johari, Nick McKeown, Matthew Trunnell*, Mark Watson*
Stanford University, Netflix*

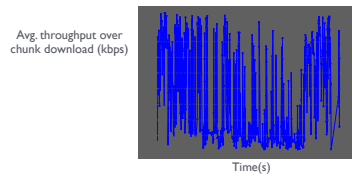
Avg. throu
chunk dow

"A random sample of 300,000 Netflix sessions shows that roughly 10% of sessions experience a median throughput less than half of the 95th percentile throughput."

"20–30% of rebuffers are unnecessary"

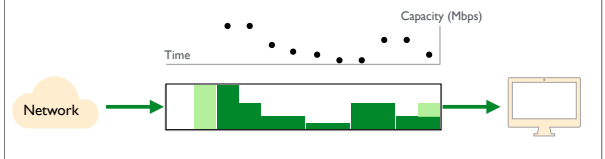
Time(s)

Estimating available capacity



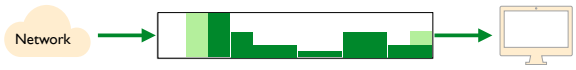
[A Buffer-Based Approach to Rate Adaptation: Evidence from a Large Video Streaming Service, Huang et al., ACM SIGCOMM 2014]

Capacity estimation



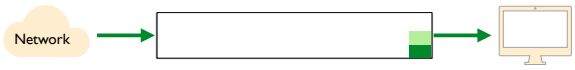
Decide based on the buffer alone?

Buffer-based adaptation



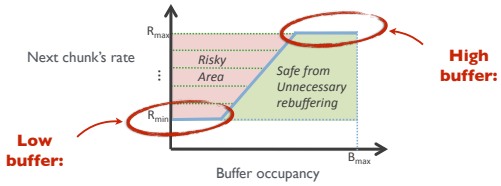
Nearly full buffer ⇒ large rate

Buffer-based adaptation



Nearly empty buffer ⇒ small rate

Buffer-based adaptation



[A Buffer-Based Approach to Rate Adaptation: Evidence from a Large Video Streaming Service, Huang et al., ACM SIGCOMM 2014]

Problem: startup phase?

Pick a rate based on immediate past throughput

Communication Networks

Spring 2020

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May 11 2020