NETFLIX

The Networking Channel: Netflix adaptive streaming and more

Renata Teixeira / Te-Yuan (TY) Huang
rteixeira@netflix.com / thuang@netflix.com

The Networking Channel
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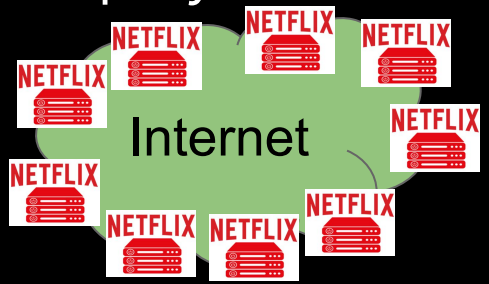
NETFLIX
I WOULD LIKE TO EXTEND A HEARTFELT
WELCOME TO YOU ALL

Challenge: Delivering high-quality video to hundreds of millions

Two phases of Netflix video delivery

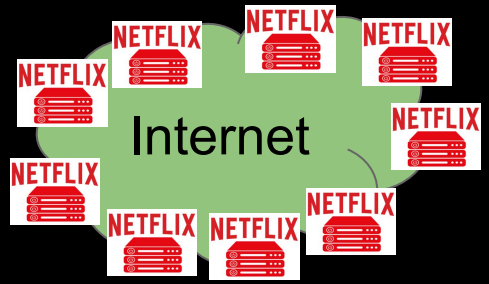
From content creation to deployment

Production



Deployment

From content servers to users



Streaming

From content creation to deployment

Production

Encoding

Deployment

Achieve the same high quality with the fewest bits

Before 2015

One encoding for all

Standard Definition (SD) at 1,000 kbps

Fewer bits ⟷ **More bits**

2015

Per-title encoding

640 kbps

710 kbps

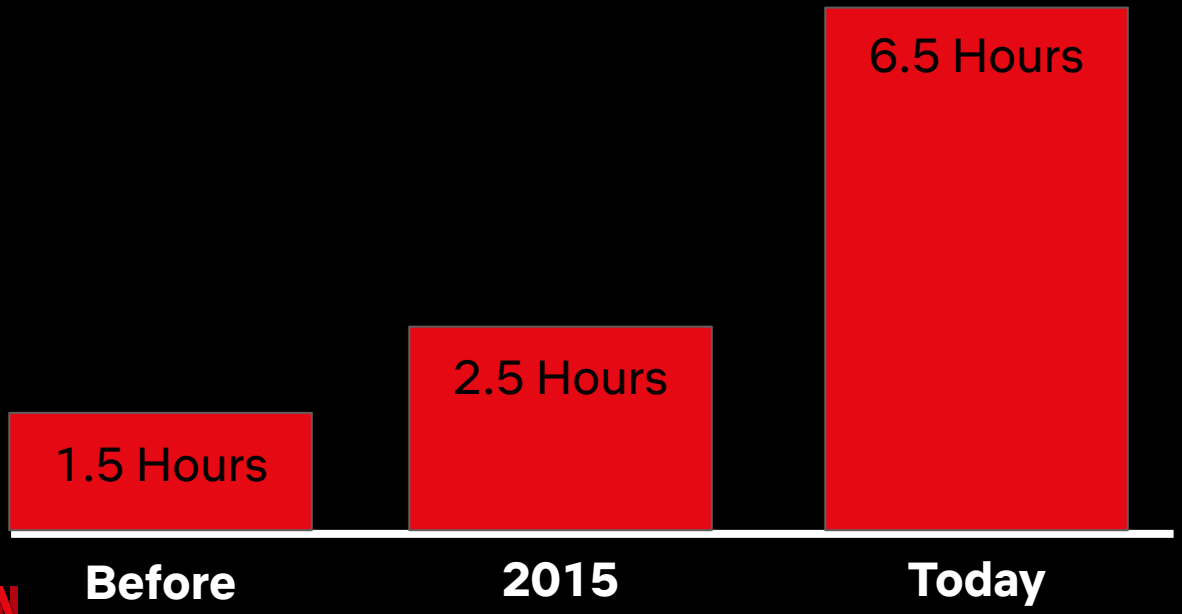
910 kbps

Today

Per-shot encoding

As low as 250 kbps

Hours of Netflix on 1GB of data



~7 episodes

VMAF: a measure of human-perceived video quality in the presence of encoding artifacts

- Conduct subjective tests to build a model of how encoding artifacts affect perceived quality
- Apply model to get VMAF for every encoded file in the catalog

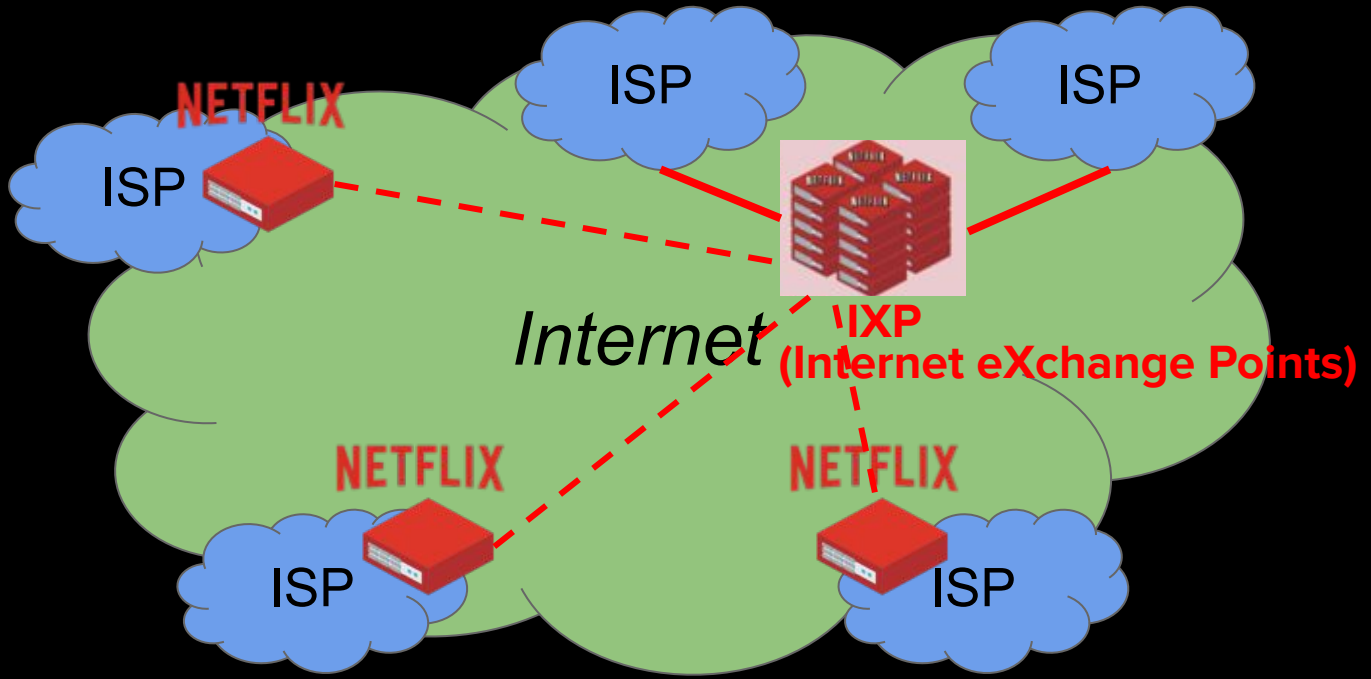
https://github.com/Netflix/vmaf

Every title has many files

- Video Tracks
  - VP9
  - HDR
  - H264
    - 5800 kbps
    - 560 kbps
    - 175 kbps
  - VC1
- Audio Tracks
  - AAC 5.1
  - 2.0
    - 64kbps
    - 96kbps
  - 5.1
- Subtitle Tracks
  - Korean
  - English
  - Arabic

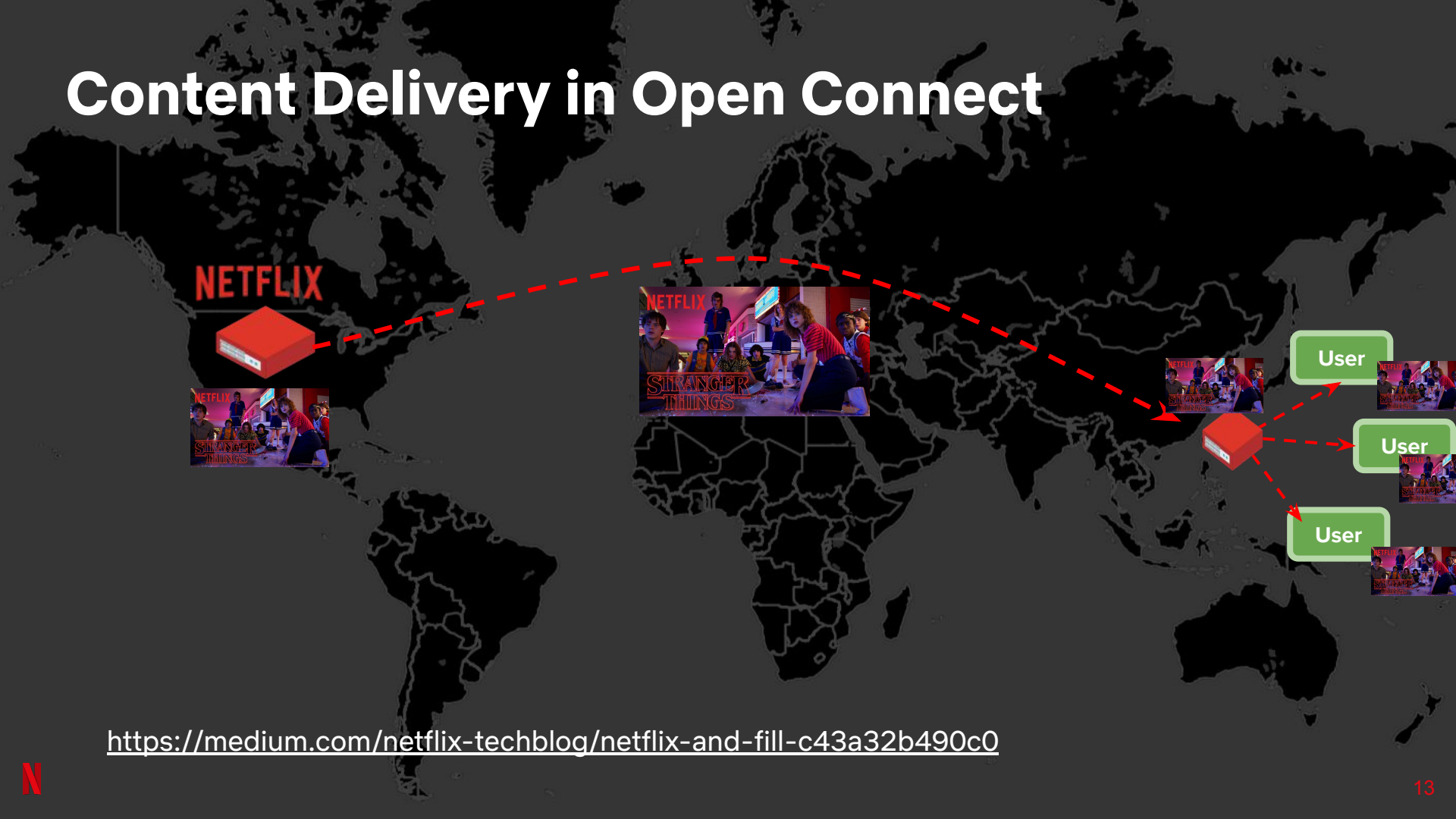
Thai
Turkish
Japanese
French

Open Connect: Content Delivery Network



As close as possible to the users!

Content Delivery in Open Connect



https://medium.com/netflix-techblog/netflix-and-fill-c43a32b490c0

Win-Win Solution

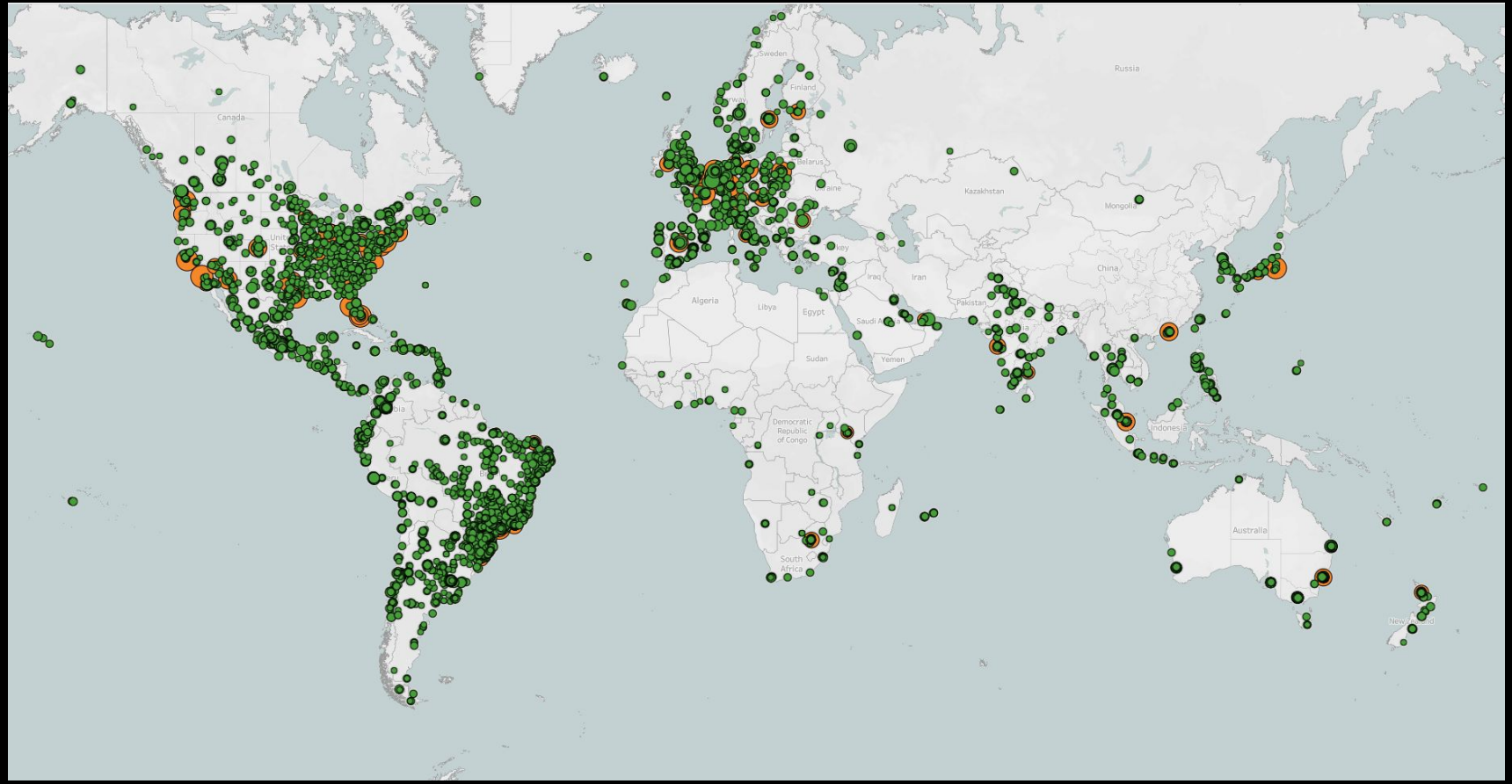
For Netflix

- Best possible user experience
  - Less transmission delay
  - Less congestion

For ISPs

- Receive videos at no cost
  - Netflix pushes videos to ISPs
  - Netflix pays for the transmission

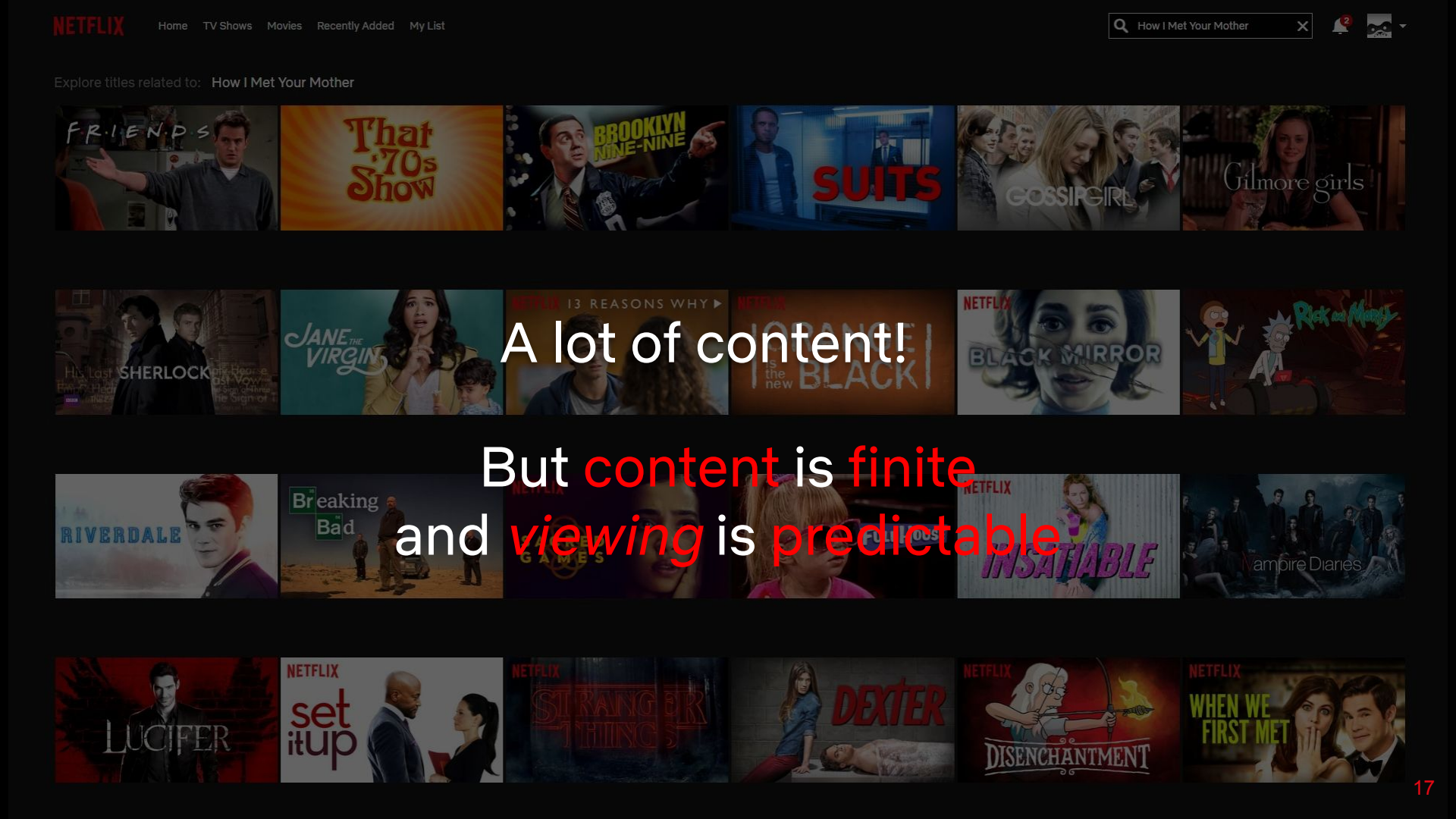
Netflix content server deployment map



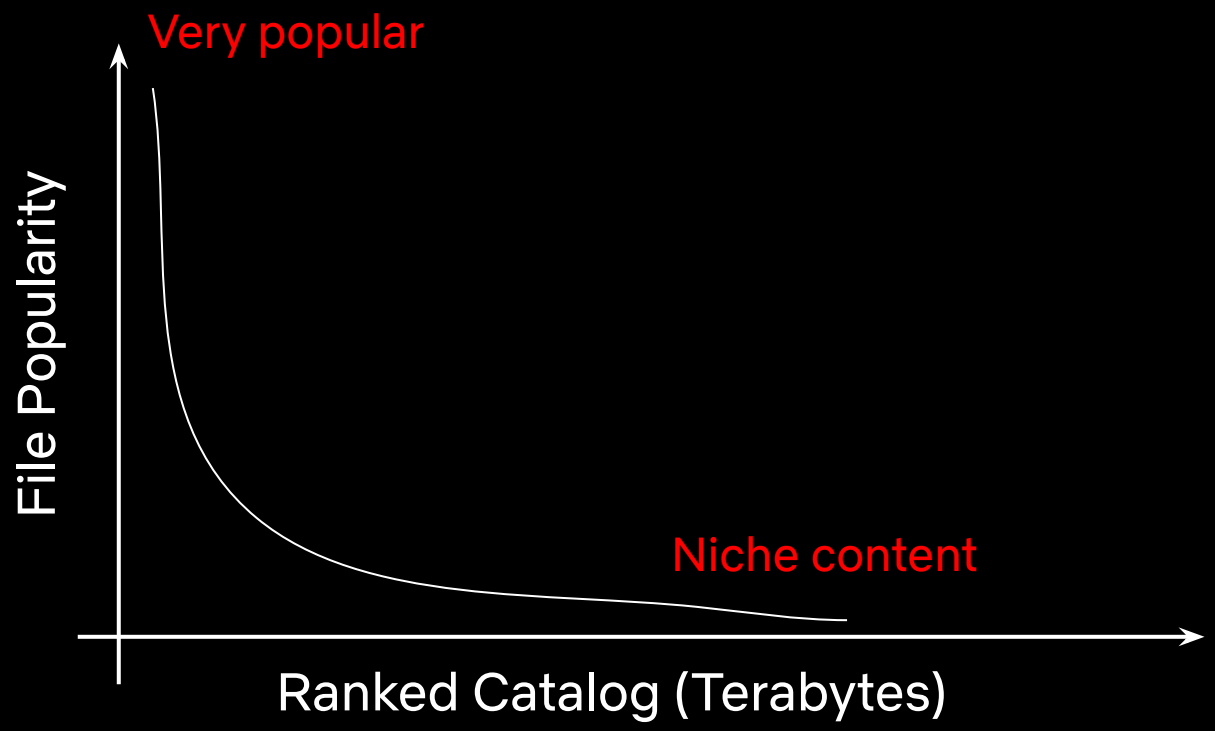
NETFLIX Home TV Shows Movies Recently Added My List

How I Met Your Mother

Explore titles related to: How I Met Your Mother


NETFLIX
Home
TV Shows
Movies
Recently Added
My List
How I Met Your Mother
Explore titles related to: How I Met Your Mother
FRIENDS
That '70s Show
BROOKLYN NINE-NINE
SUITS
GOSSIP GIRL
Gilmore girls
SHERLOCK
JANE THE VIRGIN
13 REASONS WHY
BLACK MIRROR
Rick and Morty
RIVERDALE
Breaking Bad
INSATIABLE
Vampire Diaries
LUCIFER
set it up
STRANGER THINGS
DEXTER
DISENCHANTMENT
WHEN WE FIRST MET
A lot of content!
But content is finite
and viewing is predictable

Popularity


Very popular
File Popularity
Niche content
Ranked Catalog (Terabytes)

Predictable popularity dimensions to rank our files

Video Tracks
- VP9
- HDR
- H264
  - 5800 kbps
  - 560 kbps
  - 175 kbps
- VC1

Audio Tracks
- AAC 5.1
- 2.0
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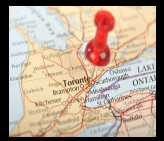


Title

Encoding Profile

Bitrate

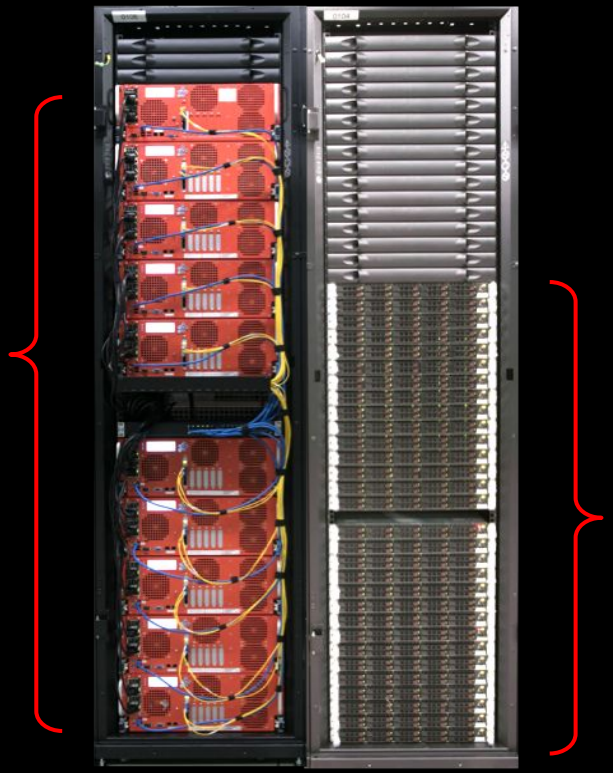
あ Language

Using two types of servers to meet the demand

Storage servers

- I/O limited
- Lots of storage

hold a large portion of catalog

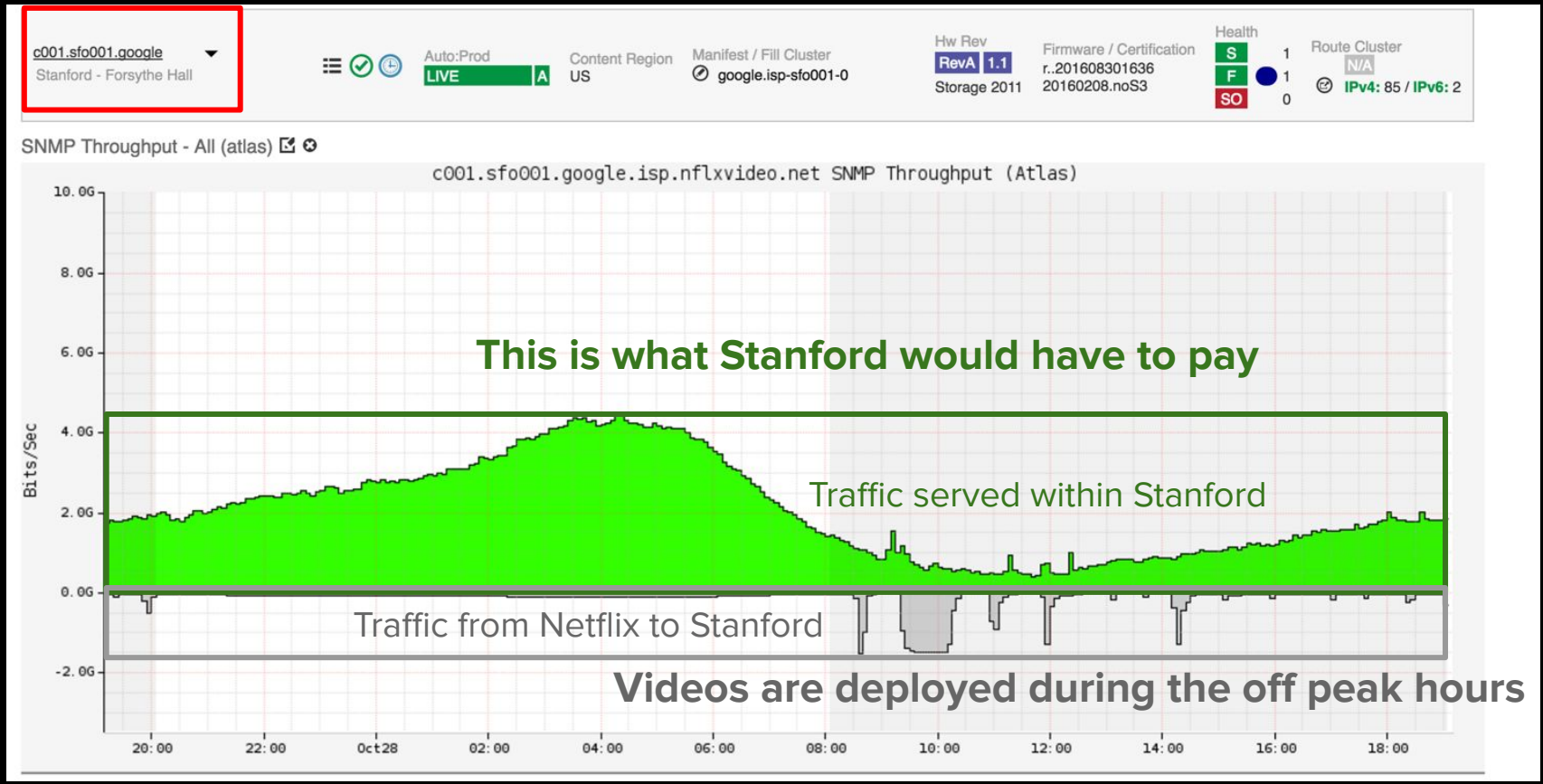


Flash servers

- I/O optimized
- Limited storage

hold popular content

Proactive content placement



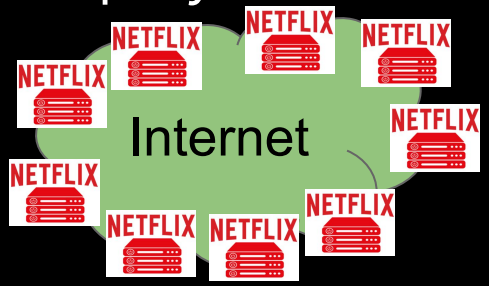
From content production to deployment: Summary

- More efficient, per-shot encoding reduces network and storage demands
- Deployment of content close to users leads to shorter delay and better quality

Two phases of Netflix video delivery

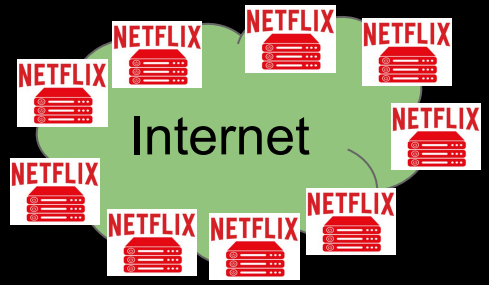
From content creation to deployment

Production



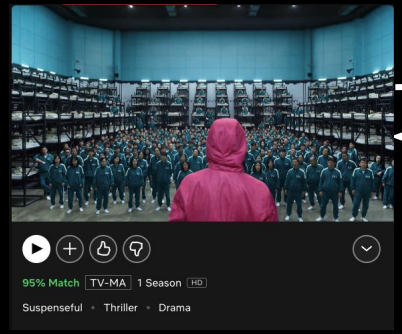
Deployment

From content servers to users



Streaming

What happens when we click play?



Netflix Client

Optimize quality through adaptive streaming

Where can I get squid game?

c001.bos + list of quality levels

First segment of squid game at 8Mbps, please?

c001.bos

AWS

Netflix Control Plane

NETFLIX

Netflix Data Plane

What would be optimal quality?

Start quickly with high video quality and no rebuffers

often not possible ...

- Network conditions keep changing

- Devices have constrained resources

Adapting to the changing network conditions

Congestion control algorithm

You know more about this than I do!

Adaptive Streaming Algorithm

Adapt video quality based on changing conditions

Adapt video quality based on changing conditions

High quality

Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | ...

Mid quality

Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | ...

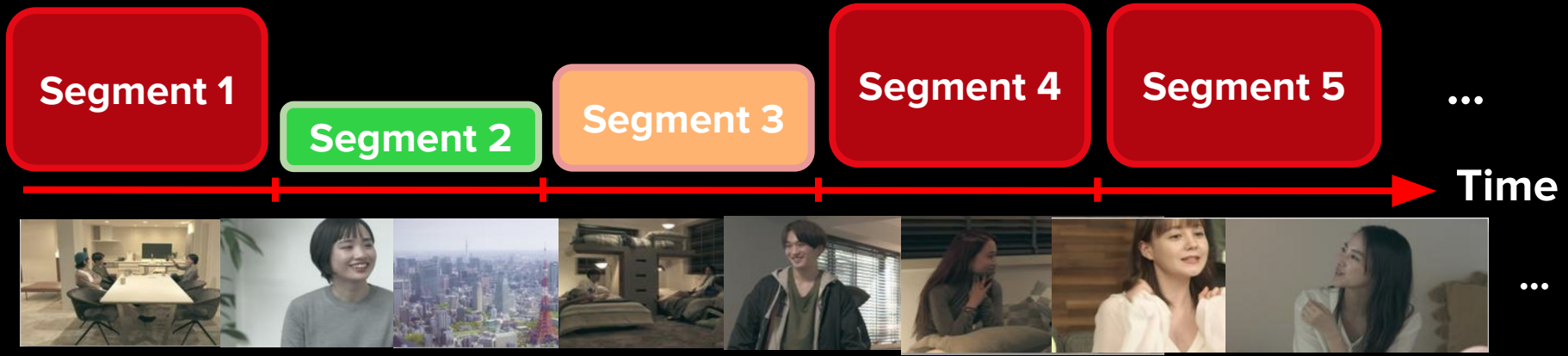
Low quality

Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | ...

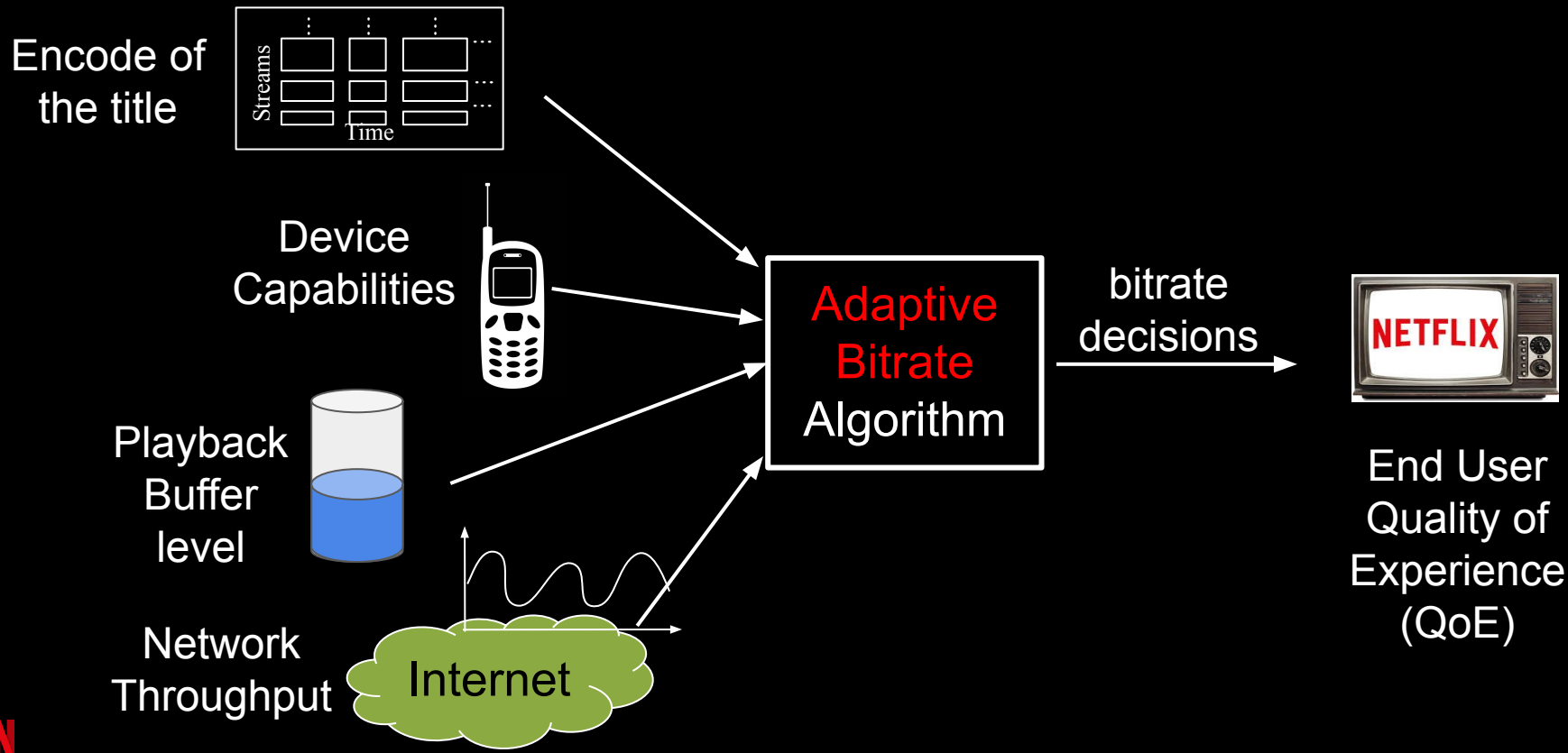
Time

Adapt video quality based on changing conditions

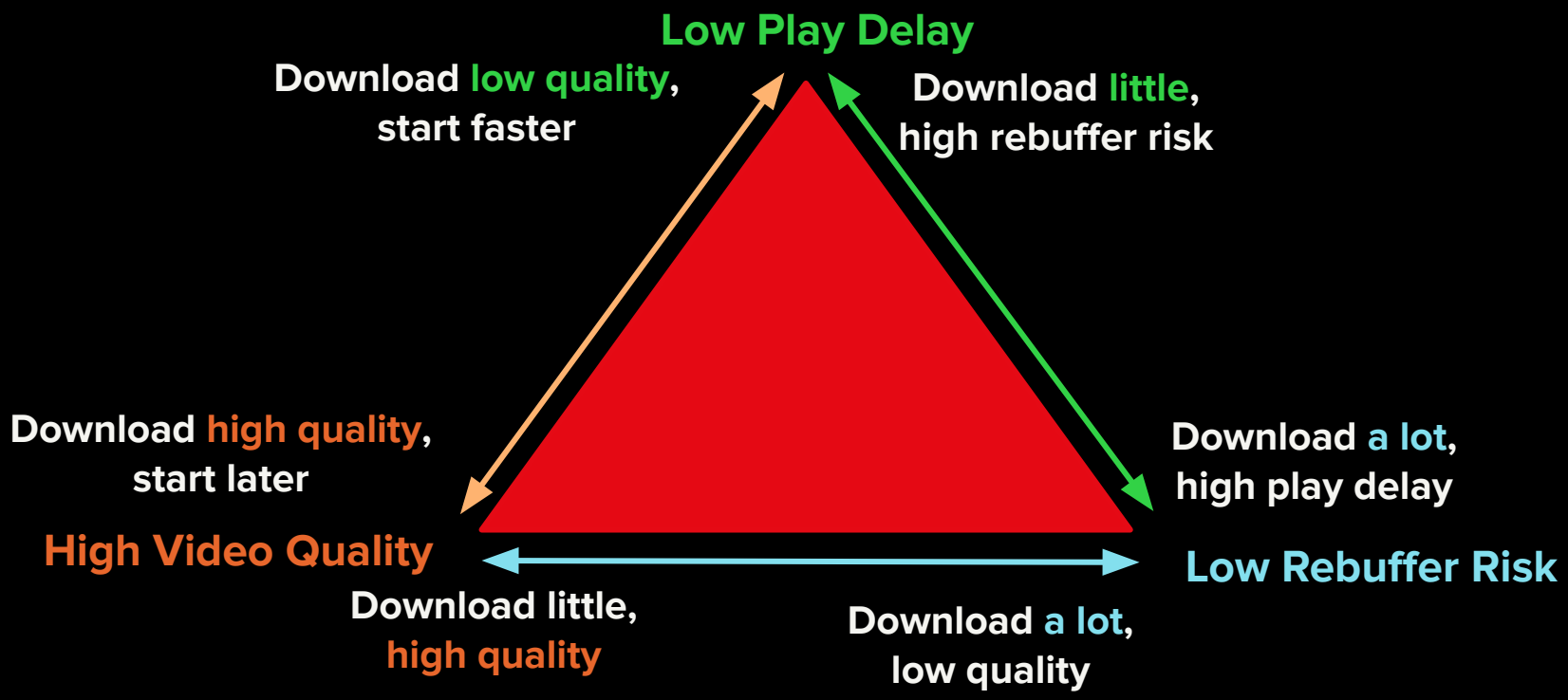
Resulting experience



How to pick the bitrate of the next segment?



Challenge:
Simultaneously optimize all QoE metrics



How to tune parameters to achieve best QoE tradeoffs?

use **A/B tests** to explore QoE effects in a large and diverse user base

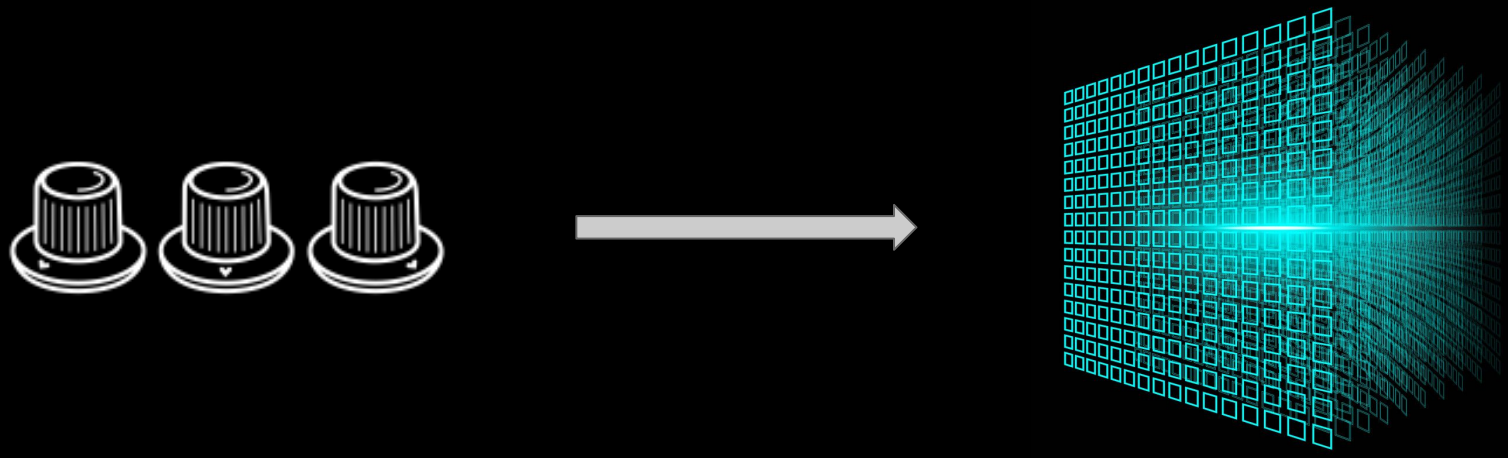
Example A/B test report

ABlaze

METRICS as of Sep 3, 2019		1 - Control	2 - Encode 1	3 - Encode 2
Play Delay (Fabricated Data)				
Descriptive Stats	# of accounts	10,000	10,000	10,000
	Δ Mean	—	+24.99	-16.97
	Δ Median	—	-11.03	-25.38
Mann-Whitney	p-value	—	**0.000**	**0.000**

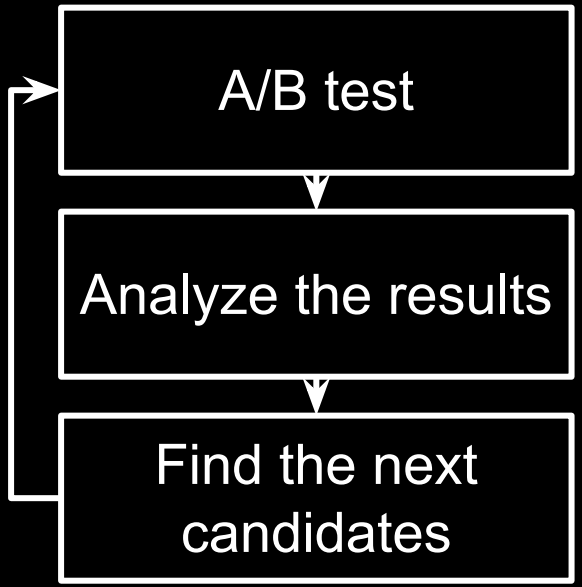
Huge high-dimensional search space!

No way to “A/B test” them all!



millions of (potentially bad) combinations to try!

We need a methodology to systematically explore the space



Apply some magic from Bayesian Optimization

From content servers to users: Summary

- Adaptive Bitrate algorithm adapts to throughput, buffer level, and device capabilities in real time
- Continuous re-evaluation and fine tuning based on A/B testing

A lot of work remains to be done!

Production

Encoding

Next generation encoding recipe (ex: AV1)

Deployment

Better prediction of content popularity

Congestion control

Streaming

Adaptive bitrate algorithms

Joint Optimization

Internship @ Netflix

Jobs @ Netflix

Reach out to thuang@netflix.com and

rteixeira@netflix.com for more info.

Te-Yuan (TY) Huang
thuang@netflix.com
Renata Teixeira
rteixeira@netflix.com
NETFLIX