Buffer sizing and Video QoE Measurements at Netflix

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How big should a buffer be?

**Too big:** packets wait for too long

**Too small:** too many packets thrown away
How big should this buffer be?

**BDP:** Villamizar and Song 1994

**BDP/√n:** Appenzeller, McKeown, Keslassy 2004

**O(n):** Dhamdhere, Jiang, Dovrolis 2005

**O(1):** Enachescu, Ganjali, Goel, McKeown, Roughgarden 2006
Which is correct?
It’s complicated
1. TCP New Reno (mostly) behaves as expected
2. Video performance varies
3. Real routers complicate this story
Our Experiment
Catalog servers

Uses spinning disks, cheaply stores entire catalog
Offload servers
Use SSDs to serve top ~30% of content faster
These three racks are called a stack.
Make this buffer small... …and this one large
1. TCP New Reno (mostly) behaves as expected
2. Video performance varies
3. Real routers complicate this story
Large buffer has higher latency during congested hour
Sometimes the large buffer has much higher latency

% Sessions

Uncongested hour

A: 3MB

B: 500MB
Large buffer has lower loss during congested hour
1. TCP New Reno (mostly) behaves as expected
2. Video performance varies
3. Real routers complicate this story
Good buffer size:
+ Fewer rebuffers
+ Better video quality
+ Videos start faster

Bad buffer size:
- More rebuffers
- Worse video quality
- Videos start slower

This happens when buffer is too large or too small.
Site #2: A smaller buffer is better

Reducing the buffer from **500MB** to **25MB**
- **15.6%** decrease in sessions with a rebuffer
- **5.3%** decrease in low quality video
- **13.5%** decrease in play delay
Site #3: A smaller buffer is better

Reducing the buffer from **500MB** to **50MB**
- **22.1%** decrease in sessions with a rebuffer
- **7.0%** decrease in low quality video
- **14.8%** decrease in play delay
Site #1: A smaller buffer is worse

Reducing the buffer from **500MB** to **50MB**

+46.3% increase in sessions with a rebuffer

+5.7% increase in low quality video

-5.9% decrease in play delay
1. TCP New Reno (mostly) behaves as expected
2. Video performance varies
3. Real routers complicate this story
Large buffer has higher latency during congested hour
Remember how the large buffer has much higher latency…
Servers have different very latency distributions
What are we talking about?
Buffer architecture

Server #1

Server #2

Server #3

“Offload” VOQ

“Catalog” VOQ

2/3

100Gbps

ISP

1/3
Traffic is fairly split when load is equal.

- "Offload" VOQ:
  - 40 Gbps
  - 40 Gbps

- "Catalog" VOQ:
  - 40 Gbps

- ISP:
  - 67 Gbps
  - 33 Gbps
  - 100 Gbps
When one VOQ offers less than its fair share, it sees no congestion.
VOQs explain the RTT differences

This VOQ is served faster

This VOQ is served slower

This VOQ is all over the place
Switches prioritize long-tail content

-3
-2
-1
+0
+1
+2
+3
+4

Hours to peak

Same latency during uncongested hours

Long-tail content not congested

Popular content is congested

Min. RTT (ms)
Buffers are served at variable rates
1. TCP New Reno (mostly) behaves as expected
2. Video performance varies
3. Real routers complicate this story
Future steps

1. Working with router manufacturer to explore ways of setting buffer size
2. What buffer size is best?
Thanks!