

QoE in Large-Scale Video Networks

Jason Gaedtke

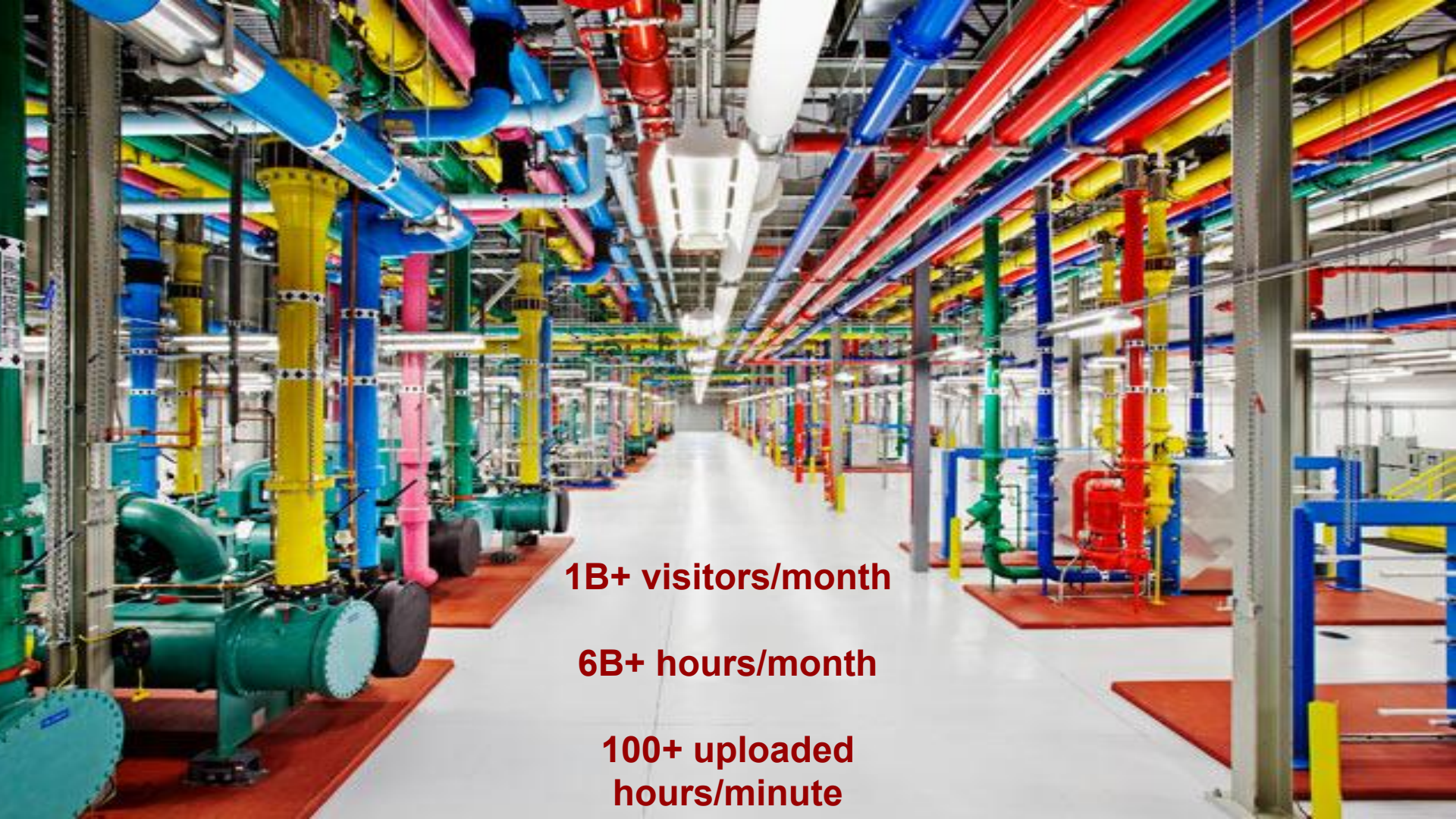
Engineering Director, YouTube

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What I'll talk about today

- **YouTube after 8-years:** Enabling a thriving ecosystem of creators, viewers, advertisers... *and networks*.
- A look inside **Google's media pipeline** - feeding a multi-terabit platform.
- Current video delivery trends and drivers for **future network growth**.
- Meeting growing demand for **fast, reliable HD-quality streams**.



1B+ visitors/month

6B+ hours/month

**100+ uploaded
hours/minute**

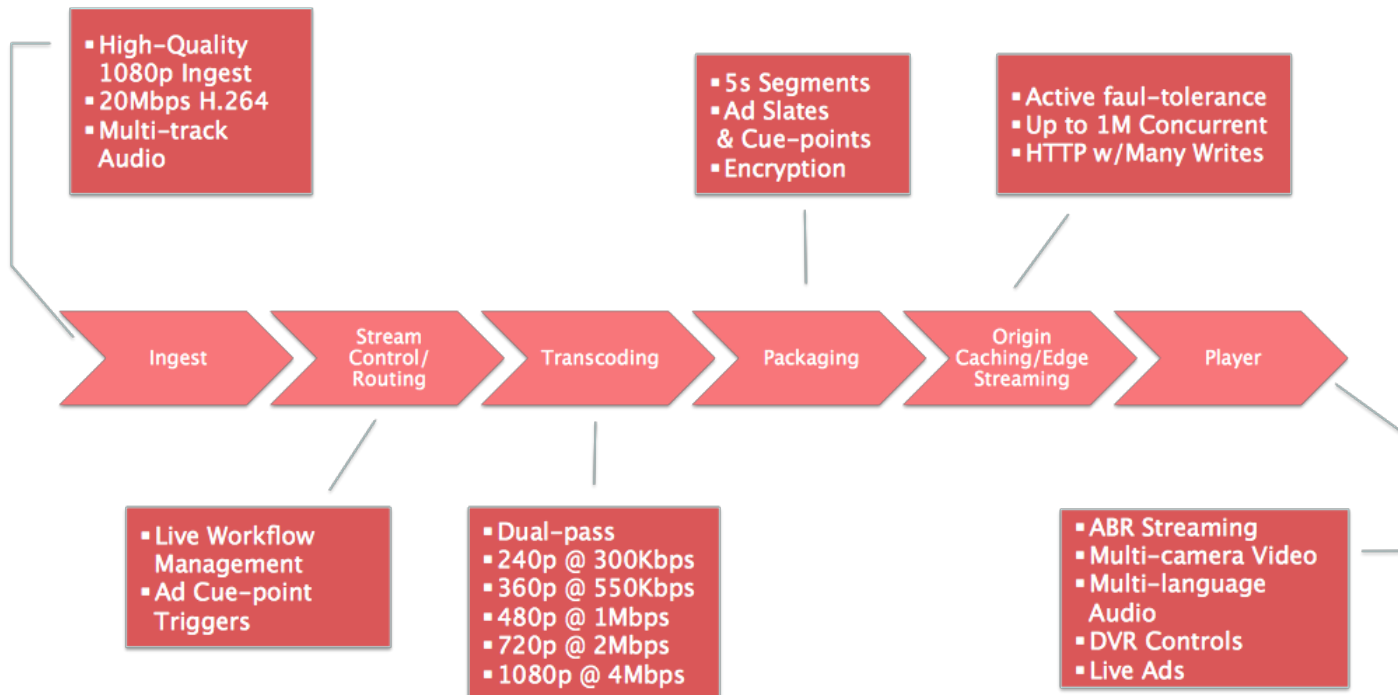
YouTube's Goals

- **Channels:** Offer a platform for the next generation of content creators
- **Make YouTube Fast:** Continually looking for opportunities to optimize delivery
 - **Scale** - Ensure sufficient network capacity to meet growing demand
 - **Performance** - Provide high QoE as measured by low-latency startup, stream reliability and quality
 - **Cost** - Align incentives and establish ISP partnerships to ensure QoE
- **Tune-in to YouTube:** Support moments that change how & what we watch: *Olympics, Red Bull Stratos, Elections, Concerts, Breaking News*

Google's Media Pipeline

1Tbps, 10Tbps, 100Tbps opportunities

The Terabit video pipeline



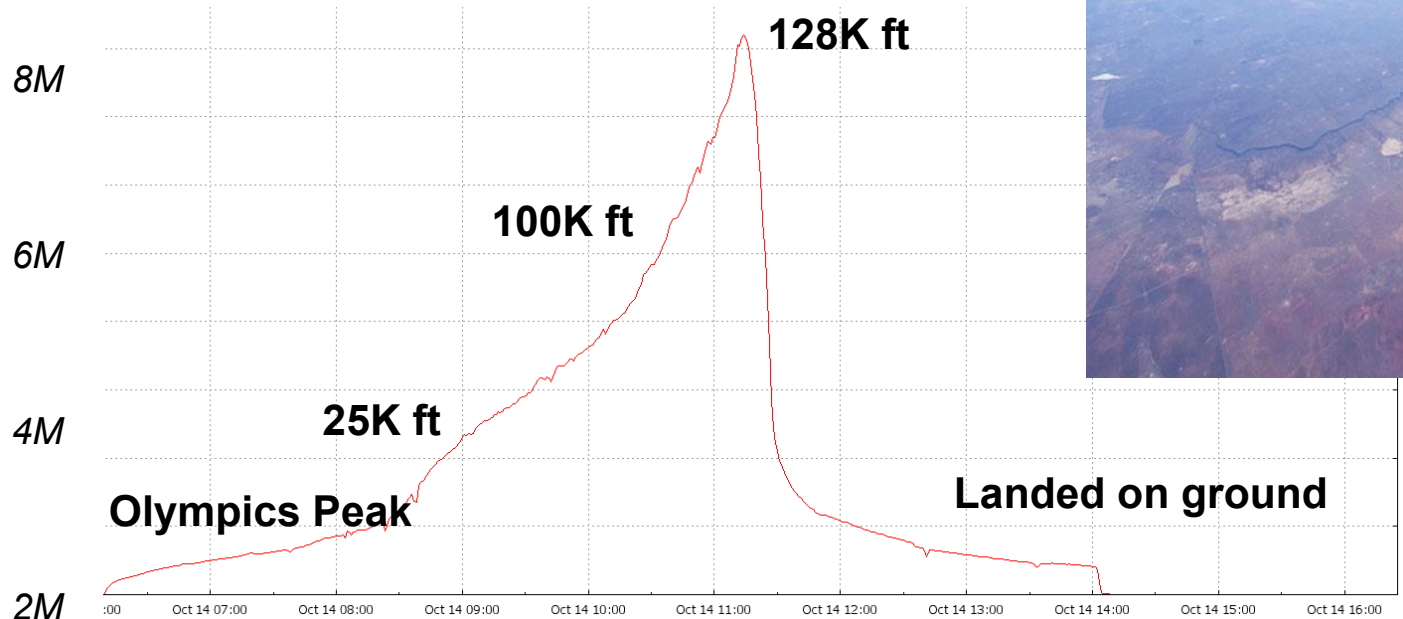
1T-Scale: 2012 Summer Olympics

- Partnership with NBC and IOC
 - US distribution hosted @ NBCOlympics.com
 - ABR streaming w/DVR and Live-to-VOD
 - Real-time ad-insertion
- Delivery highlights:
 - 1.25k live events over 19 days
 - ~60 simultaneous live HD feeds
 - **500k+ concurrents**
 - 225M+ streams



10T-Scale: Red Bull Stratos

Viewers



Connecting a Global Community



Emmy Award-winning Infrastructure

- **Olympics** - *OUTSTANDING NEW APPROACHES SPORTS PROGRAMMING, THE GEORGE WENSEL TECHNICAL ACHIEVEMENT AWARD*
- **Stratos** - *OUTSTANDING NEW APPROACHES SPORTS EVENT COVERAGE*
- **Bandaid/Viper/ContentID** - *PRIMETIME ENGINEERING AWARD*



100T-Scale: When?

2013 Nielsen TV Ratings (Week of Nov 18)

RANK	PROGRAM	NETWORK	VIEWERS (M)
1	NBC SUNDAY NIGHT FOOTBALL	NBC	26.5
2	NCIS	CBS	19.7
3	SUNDAY NIGHT NFL PRE-KICK	NBC	19.6
4	THE BIG BANG THEORY	CBS	18.9
5	The OT	FOX	16.0

- 100Tbps = 100M+ concurrents @ 1Mbps
 - 2010 FIFA World Cup: **620M TV viewers** (Worldwide)
 - 2012 NFL Superbowl: 111M TV viewers (US record)

Growth Drivers: Implications for the Network

- **HD Content**

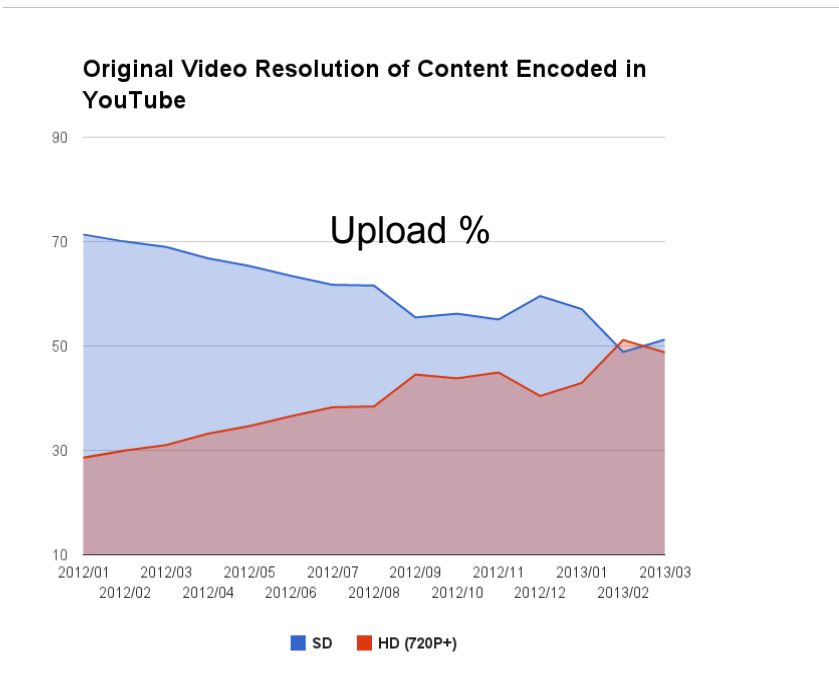
- HD uploads > SD uploads
- 2x growth in bit-rate
- Web (full-screen)
- Tablets (hi-res)
- TV Devices (HD-default)

- **Live Events**

- Simultaneous demand
- Self-service broadcasting

- **Long-form Content**

- Longer sessions
- New business models



Scaling Strategies

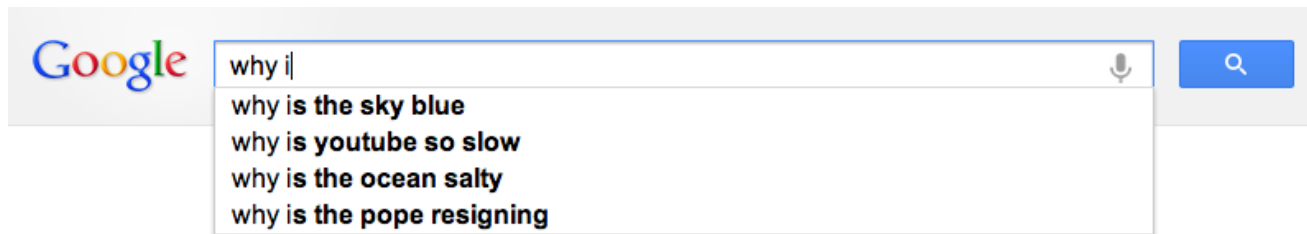
- **Provisioning** - more access/backbone/interconnect
 - +1Tbps = space/power/cooling for 100 x 10G ports
- **Caching** - increased density near edge; predictive loading
 - Live streams require real-time cache-fill
- **Adaptation** - trade-off resolution/bit-rate for fewer rebuffers
 - Beyond a baseline quality threshold, availability trumps quality
- **Compression** - WebM VP9 delivers equivalent quality at 40-50% of H.264 bitrate - plus an open innovation model
 - Live now on YouTube's WebMVP9 channel with Chrome

Scaling and Quality

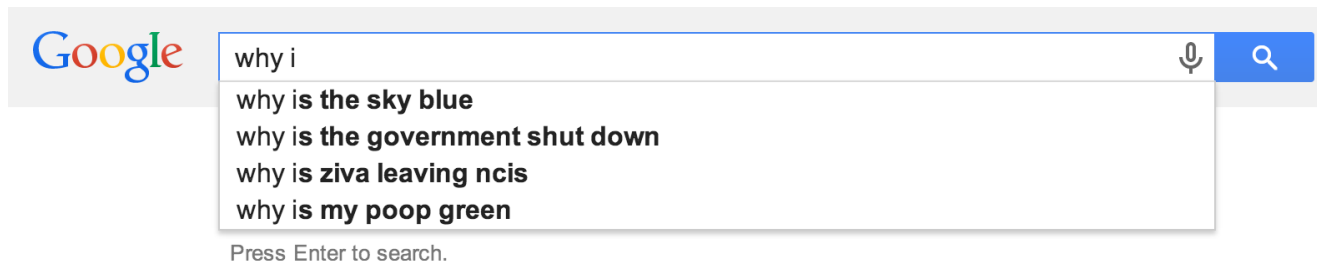
Focus on Quality of Experience

- **Latency** - reduce time to first-frame
- **Rebuffers** - more time watching, less waiting
- **Optimality** - deliver ideal resolution for device + content source
- **Goodput** - stream reliability as a function of application-level throughput

In Q2:

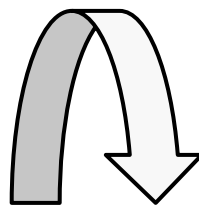
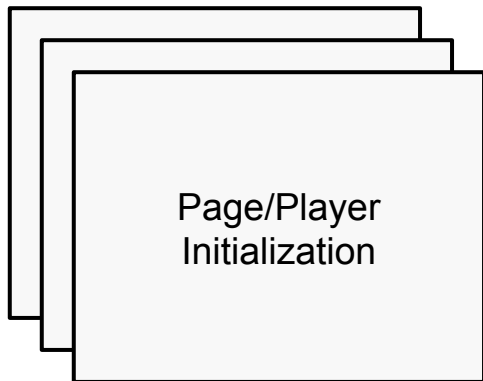


Today:



Latency

- Time spent is largely client side, in three main areas:



Get Video



Decode/Render

- CDN server responses are fast (<30ms) but we delay the 'get video' request
- Restructuring Watch page into reusable, cached modules (AJAX)
- Persist Video Player across views
- Major refactoring and optimization (pre-loading, parallel calls) in the Video Ads stack
- Video Processing optimizations yield 20-50% fewer bits at equivalent quality

Factors influencing QoE

Network

- Content proximity (caching)
- Client mapping
- Network peering
- Backbone capacity
- Access network performance
- Users in-home network setup

Video Production

- Source quality
- Encoding complexity
- Transcoder profiles
- Target bit-rates

Client

- Platform capability (codecs, transports)
- Device constraints (resolution, acceleration)
- Resource contention (player vs page/app)
- Adaptive Bit-Rate algorithm

Demand

- Content popularity
- Seasonality
- Weather
- Events
- Holidays

What is "Goodput"

- In short, **sustainable application-level bandwidth**
 - *"Why can't my 20Mbps connection sustain a 2Mbps HD stream?"*
- For video, this is the ability to stream at a particular quality-level without re-buffering
 - An end-to-end measure of the quality of a network path - versus peak throughput on the access network (*Speedtest.net*)
 - Varies as a function of *{content popularity, time-of-day, ISP network, CDN performance}*
- ***We have work to do on both CDN and Network layers to ensure high QoE***

Resolution	Bit-rate
360p	500 Kbps
480p	1 Mbps
720p	2 Mbps
1080p	4 Mbps

Recap

- YouTube = **global video platform**
- Viewer demand growing at **+Terabit scale**
- Focus on **fast, reliable HD streams**
- Enabling a **thriving ecosystem** of viewers, creators, advertisers and networks
- **Continual focus on Quality and Scale**

Thank you