10 lessons in running the largest, bestest WAN
Or, how I learned to stop worrying and love the chaos.

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B2 - Google’s global WAN

- **35** regions
- **106** zones
- **173** network edge locations
- **22** subsea cables
- **200+** countries
What Googlers see…

Third-party “Colos”
Large (YAWN) Datacenters
Miniclusters
Core clusters
B4 Routers
B2 Routers
...under the ground...
...and under the ocean.
2x Internet Scale!

Externally visible 12% of internet
Necessity is the mother of invention

... so don’t let the impossible stand in the way of the necessary
This Googler drew a picture of a data center network on a napkin in 2003 as a blueprint for a 10,000 port data center network he wanted to build.

All networking vendors came back with blank bids, asking us to check if we had an “extra zero” in the port count.
A simple goal

Deliver unlimited, free, high quality video to anyone, anytime, anywhere in the world*

* and try not to go out of business while doing it
... with a lot of middlemen to get through

Ref: https://www.opte.org/the-internet

Internet: 2007
Flattening the Internet

Ref: Cloud Provider Connectivity in the Flat Internet, IMC ’20: Proceedings of the ACM Internet Measurement Conference October 2020
Gold plated peering...

- This is our (circa 2013) peering edge router, Juniper MX960
- Cost for 100 Tb/s of ports in 2013: $60 million
- ... plus, you have to build a backbone network with that capacity.
- We needed to figure out a way to reduce this cost by 10x
$60 million for 100Tb/s of peering capacity

Espresso [Sigcomm ‘17]

$7 million per 100Tb/s of peering capacity
In the end, it’s all just software

- Cheaper hardware, with some packet forwarding features
- Disaggregated design with device controlled by Google software
- Peers directly connect to our SW

Cost for 100 Tb/s of ports: $7 million
Sometimes, it’s not just the tech that needs changing
Our (truly) Global Edge
Public ... enemy?

Use the public as your ally, by publishing a Video Quality Report ...

... but support your ISP partners, by giving them the tools they need to identify and fix performance issues.
Video streaming quality results for Huntsville, AL

There are many factors that influence your video streaming quality, including your choice of Internet Service Provider (ISP). Learn how your ISP performs and understand your options.

Standard Definition

Users on networks rated as Standard Definition should expect smooth playback on standard-definition YouTube videos (720p) and may experience occasional interruptions on high-definition YouTube videos (1080p and above).

If you’re experiencing issues playing your video, try these troubleshooting tips.
Any manual process done on a large network is guaranteed to fail...

... and so are automated processes, for that matter.
Human error rates range from 1% for routine tasks, to >10% for complicated non-routine tasks [Smith DJ et al].

Adding more humans to build a bigger network only works to a point, after which errors and delays choke the system.

As the scale of the network grows, and the rate of growth accelerates, automation is a must.
Correlated failures

What would cause multiple parallel devices to “fail” at the same time?

~2%

65%

28%

Meteorites...
or fires, explosions, sharks in tornadoes eating network operators

Management
You must touch all redundant devices to make a change

Messaging
Routing / signalling protocols spreading contagion in the network

Management operations are a dominant trigger of correlated-failure network outages
[Evolve-or-die Sigcomm ’16, Facebook ’15, Microsoft ’12]

Automation can make this better, but can often make it worse
Drive defensively

Scripts are unsafe network automation.

Network management software should be written and operated like the production service it is.
When you’re done, you’re just getting started

and you don’t know where this journey will take you
No design survives contact with 10x growth

When you grow 10-15% a year, your designs will last 8 years.

When you grow 40-50% a year, you get 5 years.

When you grow 2-3x a year (pandemic serving), you have no time.

Growth can be non-uniform, so stress cracks can appear earlier in different parts.
From Espresso, we expanded our network automation to every router in the network.

Our egress traffic engineering system can serve 15-20% more video for the same cost, while improving user experience by 2x fewer rebuffers and 2x higher video bitrate.

Our globally connected network is now a key differentiating factor to allow Google Cloud customers to reach their users as well.

What will we get out of today’s projects?
Watch what breaks, but also what works

... just because it ain’t broke doesn’t mean you don’t need to fix it
Inspect the entire airplane

Don’t just focus on the outages. Sometimes, systems that are working are slipping, but just not enough to cause trouble.

This can be an early warning sign.

Every system should have metrics it’s measured against, and these metrics should be monitored.
Thank you.