# Data Centers

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# Evolution of data centers

- 1960's, 1970's: a few very large time-shared computers

- 1980's, 1990's: heterogeneous collection of lots of smaller machines.

- Today and into the future:
  - Data centers contain large numbers of nearly identical machines
  - Geographically spread around the world
  - Individual applications can use thousands of machines simultaneously

- Companies consider data center technology a trade-secret
  - Limited public discussion of the state of the art from industry leaders
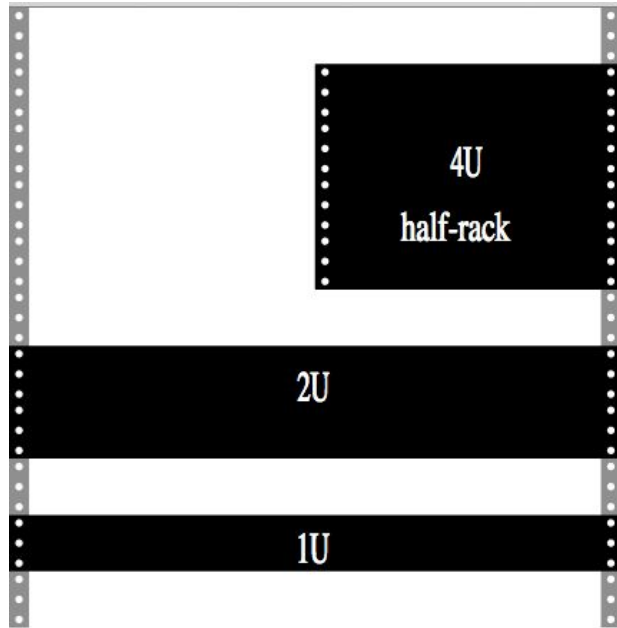
# Typical specs for a data center today

- 15-40 megawatts power  (Limiting factor)

- 50,000-200,000 servers

- $1B construction cost

- Onsite staff (security, administration): 15

# Rack

- Typically is 19 or 23 inches wide
- Typically 42 U
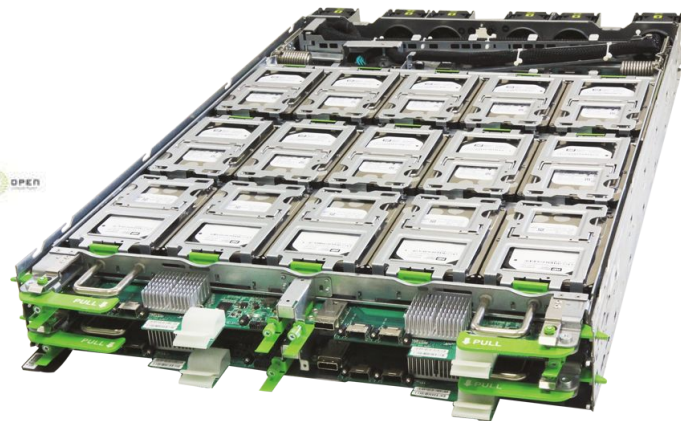  - U is a Rack Unit - 1.75 inches

- Slots:

4U
half-rack

2U

1U

- Data centers

# Rock Slots

- Slots hold power distribution, servers, storage, networking equipment

- Typical server: 2U
  - 8-128 cores
  - DRAM: 32-512 GB

- Typical storage: 2U
  - 30 drives

- Typical Network: 1U
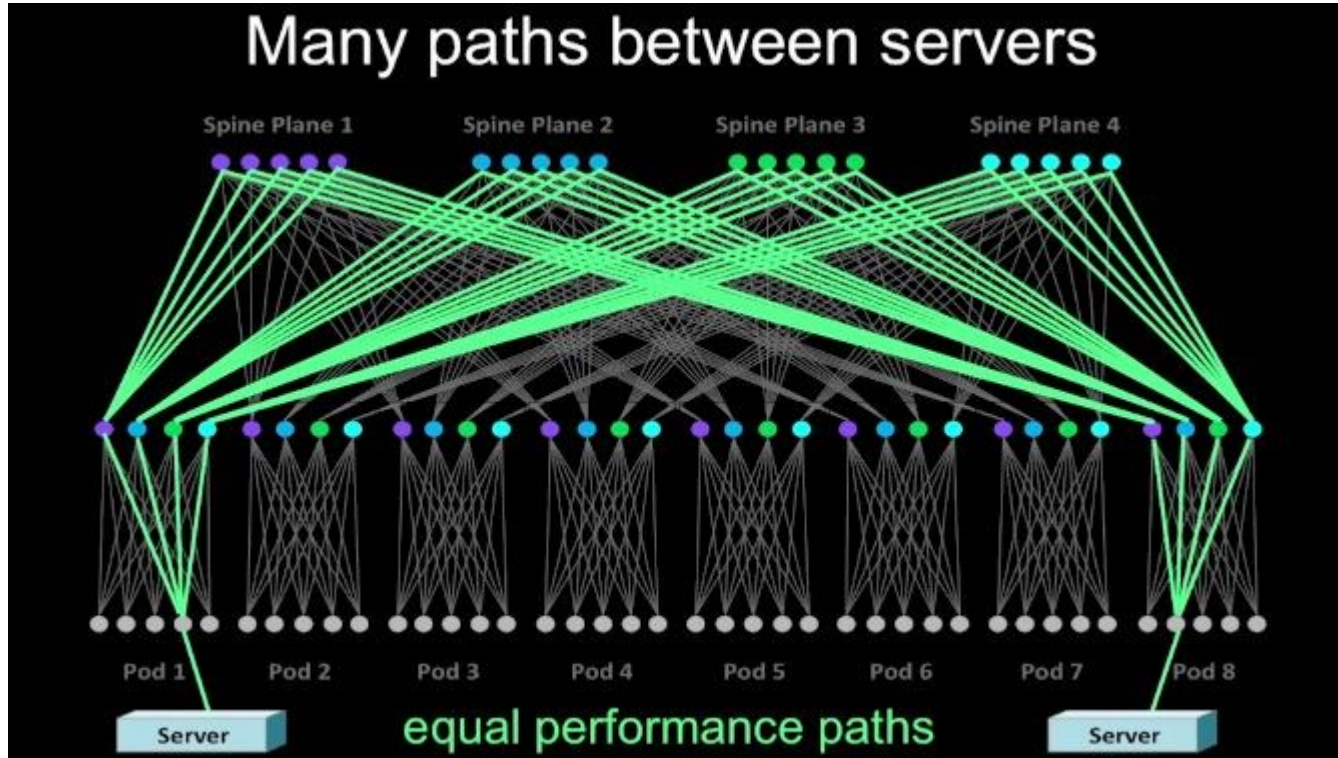  - 72 10GB

s

# Row/Cluster

- 30+ racks

# Networking - Switch locations

- Top-of-rack switch
  - Effectively a cross-bar connecting machines in rack
  - Multiple links going to end-of-row routers
- End-of-row router
  - Aggregate row of machines
  - Multiple links going to core routers
- Core router
  - Multiple core routers

# Multipath routing

# Ideal: "full bisection bandwidth"

- Would like network like cross-bar

  - Everyone has a private channel to everyone else

- In practice today: some oversubscription (can be as high as 100x)
  - Assumes applications have locality to rack or row but this is hard to achieve in practice.
  - Some problem fundamental: Two machines transferring to the same machine

- Consider where to place:
  - Web Servers
  - Memcache server
  - Database servers - Near storage slots

- Current approach: Spread things out

# Power Usage Effectiveness (PUE)

- Early data centers built with off-the-shelf components
  - Standard servers
  - HVAC unit designs from malls

- Inefficient: Early data centers had PUE of 1.7-2.0

  PUE ratio =    $\underline{\text{Total Facility Power}}$
                      Server/Network Power

- Best-published number (Facebook): 1.07 (no air-conditioning!)

- Power is about 25% of monthly operating cost

# Energy Efficient Data Centers

- Better power distribution - Fewer transformers

- Better cooling - use environment (air/water) rather than air conditioning
  - Bring in outside air
  - Evaporate some water

- Hot/Cold Aisles:

- IT Equipment range
  - OK to +115℉
  - Need containment



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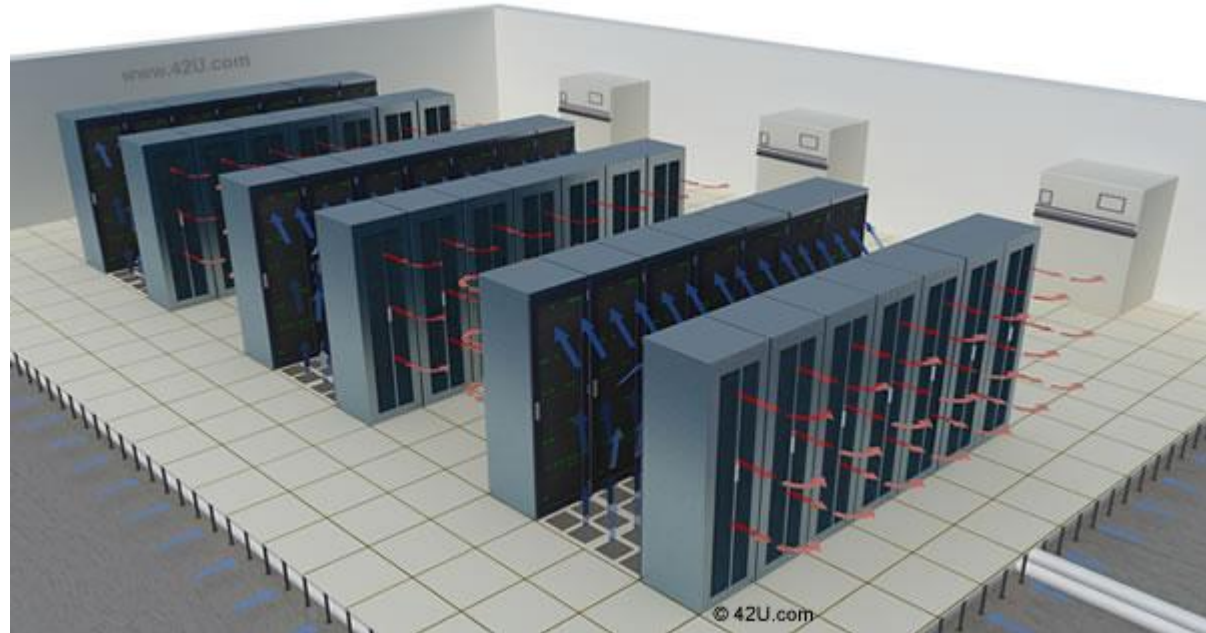
# Backup Power

- Massive amount of batteries to tolerate short glitches in power
  - Just need long enough for backup generators to startup

- Massive collections of backup generators

- Huge fuel tanks to provide fuel for the generators

- Fuel replenishment transportation network (e.g. fuel trucks)

# Fault Tolerance

- At the scale of new data centers, things are breaking constantly

- Every aspect of the data center must be able to tolerate failures

- Solution: Redundancy
  - Multiple independent copies of all data
  - Multiple independent network connections
  - Multiple copies of every services

# Failures in first year for a new data center (Jeff Dean)

~thousands of hard drive failures

~1000 individual machine failures

~dozens of minor 30-second blips for DNS

~3 router failures (have to immediately pull traffic for an hour)

~12 router reloads (takes out DNS and external VIPs for a couple minutes)

~8 network maintenances (4 might cause ~30-minute random connectivity losses)

~5 racks go wonky (40-80 machines see 50% packet loss)

~20 rack failures (40-80 machines instantly disappear, 1-6 hours to get back)

~1 network rewiring (rolling ~5% of machines down over 2-day span)

~1 rack-move (plenty of warning, ~500-1000 machines powered down, ~6 hours)

~1 PDU failure (~500-1000 machines suddenly disappear, ~6 hours to come back)

~0.5 overheating (power down most machines in <5 mins, ~1-2 days to recover)

# Choose data center location drivers

- Plentiful, inexpensive electricity
  - Examples - Oregon: Hydroelectric;   Iowa: Wind

- Good network connections
  - Access to the Internet backbone

- Inexpensive land

- Geographically near users
  - Speed of light latency
  - Country laws (e.g. Our citizen's data must be kept in our county.)

- Available labor pool

# Google Data Centers

**Americas**

Berkeley County, South Carolina
Council Bluffs, Iowa
Douglas County, Georgia
Quilicura, Chile
Jackson County, Alabama
Mayes County, Oklahoma
Lenoir, North Carolina
The Dalles, Oregon

**Asia**

Changhua County, Taiwan
Singapore

**Europe**

Hamina, Finland
St Ghislain, Belgium
Dublin, Ireland
Eemshaven, Netherlands

# Google Data Center - Council Bluffs, Iowa, USA



Google Data Center

# Google data center pictures: Council Bluffs