Data Centers

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Evolution of data centers

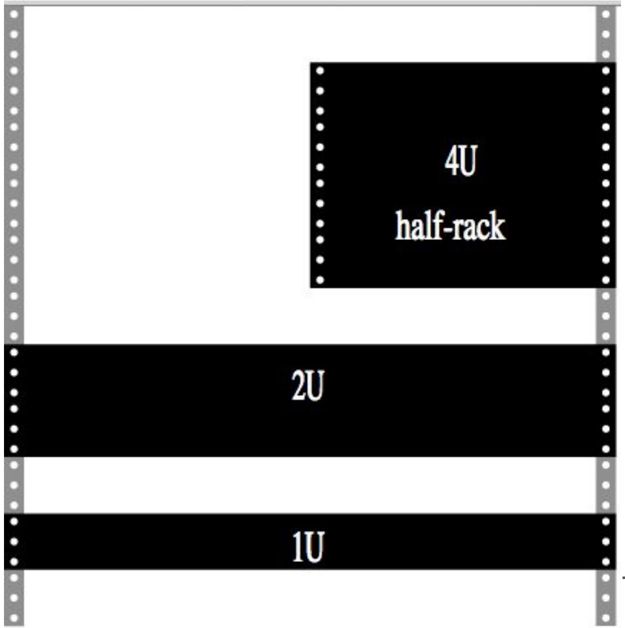
- 1960's, 1970's: a few very large time-shared computers
- 1980's, 1990's: heterogeneous collection of lots of smaller machines.
- Today and into the future:
  - Data centers contain large numbers of nearly identical machines
  - Geographically spread around the world
  - Individual applications can 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

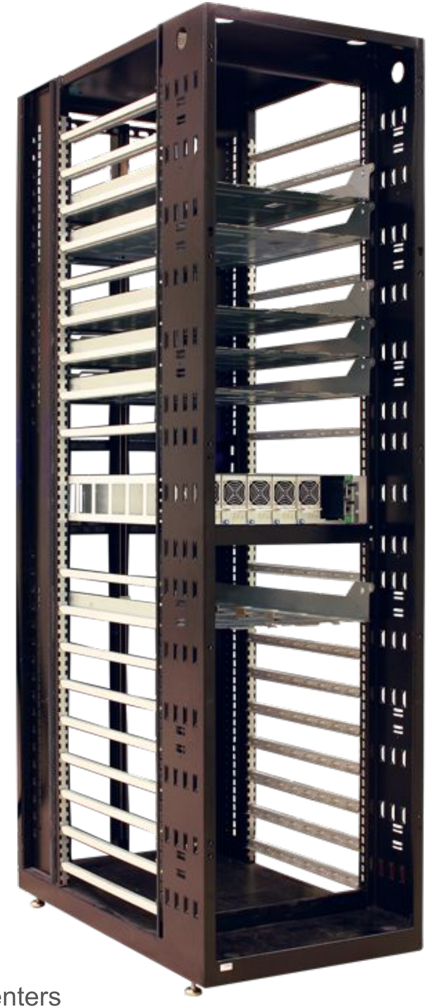
- 15-40 megawatts power (Limiting factor)
- 50,000-200,000 servers
- $1B construction cost
- Onsite staff (security, administration): 15

Rack

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



- 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

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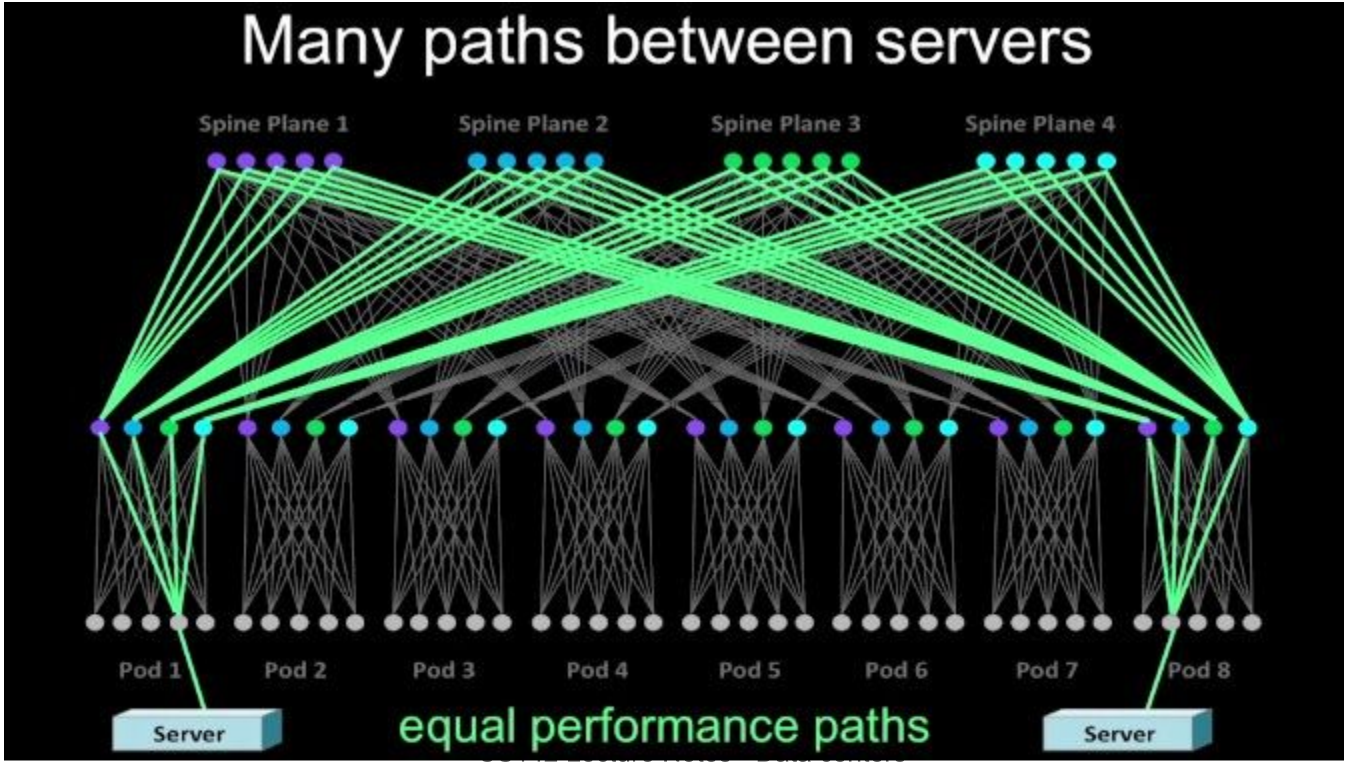
Row/Cluster

- 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)

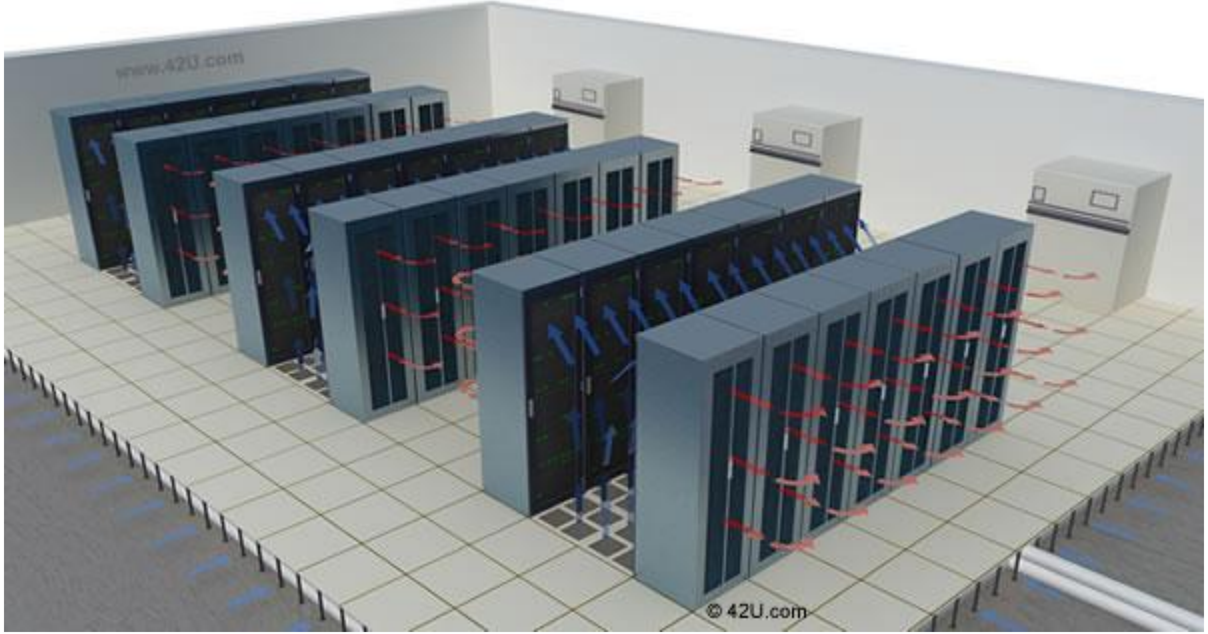
- Early data centers built with off-the-shelf components
  - Standard servers
  - HVAC unit designs from malls
- Inefficient: Early data centers had PUE of 1.7-2.0

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

- 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



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

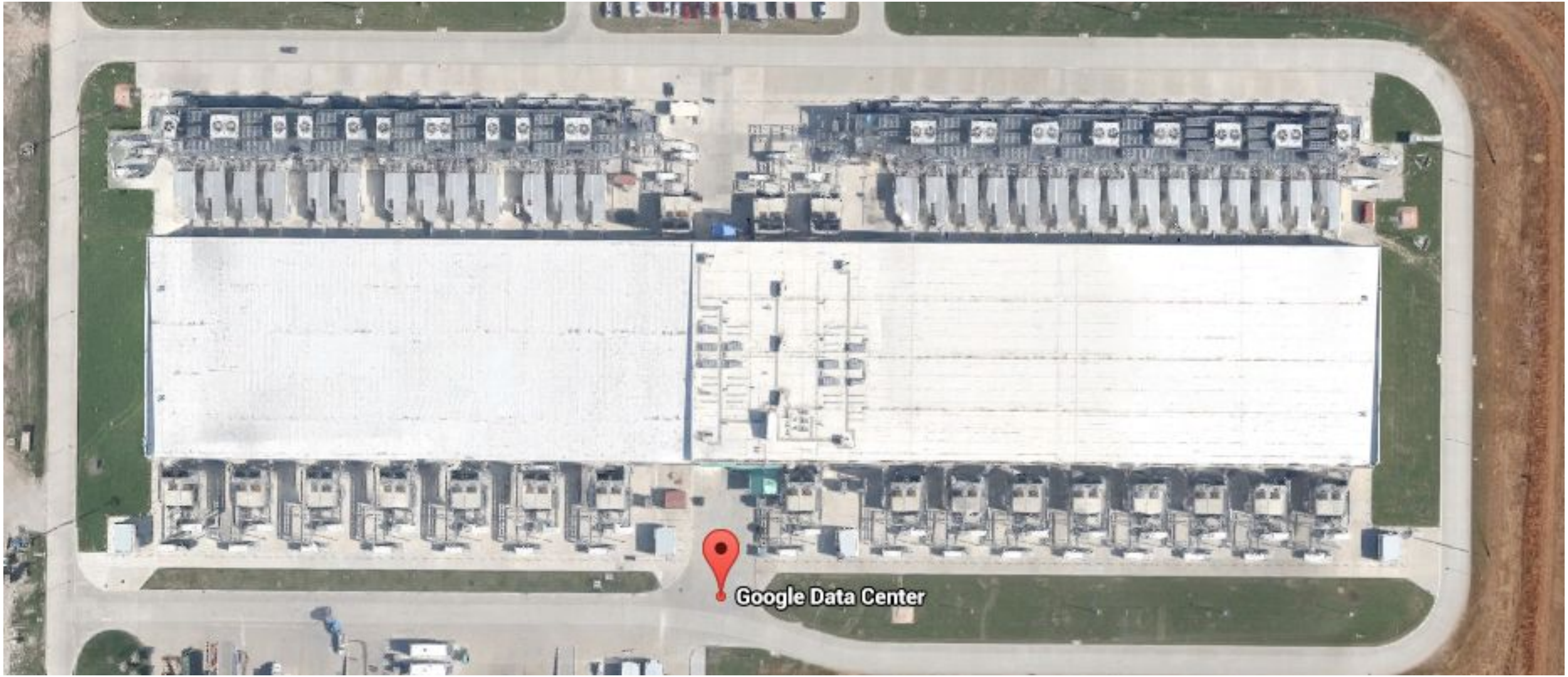
Asia

Changhua County, Taiwan
Singapore

Europe

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

Google Data Center - Council Bluffs, Iowa, USA



Google data center pictures: Council Bluffs