Data Centers

Mendel Rosenblum
Evolution of data centers

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

- **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:
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
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

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

- 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°F
  - 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