Advanced Computer Architecture:
A Google Search Engine

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Produced with prosper and LaTeX

Properties of a search engine

- Different time zones $\Rightarrow$ 24h availability
- Response time < 0.5s per query (including network latency)
- Multiple interconnected sites
- Multiple redundant high bandwidth connections to internet

Potential Query Load

- Handle 1000s of queries per second
  - 1994: WWWW receives 1 per minute
  - 1997: Altavista handles 200 per second
  - 2000: Google handles 1000 per second
  - 2003: Google handles 1700 per second?
- Keep up-to-date picture of web sites
- Need to do a web crawl at least every 4 weeks

Extra services

- Acts as an archive service caching heterogeneous document types
- Provides a translation engine to provide on-the-fly translation of multilingual documents
- Second guess user input errors e.g. spelling mistakes (reduce future queries)

Bandwidth issue

- 2000 queries per second (average 20K per results page)
  - 312Mbit s^{-1} downlink
- Web crawl: 3,308,000,000 documents every 4 weeks (average 50K per page)
  - = 154 terabytes (1×10^{12} bytes)
  - Requires 533Mbit s^{-1} uplink

Bandwidth issue II

- Assume 7Tbyte index ($\sim$2k index material per page)
  - Index duplication to 3 sites once per week
  - Requires 291Mbit s^{-1}
- Total 1136Mbit s^{-1}
- Compare with total of 211Mbit s^{-1} in 2000 (Hennessy 2003)

Snapshot from Dec. 2000

Information/diagram in pp. 857–860, [Hennessy]:

- 6000 processors
- 12000 hard disks = 1 petabyte storage (1×10^{15} bytes)
- 4 independent sites
  - 2 on West coast of US
  - 2 in West Virginia

Snapshot II

- Search index (of order terabytes) is replicated across all sites
- Search index and local version of internet cache stored at each site
- Each site connected to internet with OC48 connection (2488Mbit s^{-1} link)
- OC12 link (622Mbit s^{-1}) connects pairs of local sites

Google Cluster Architecture

Each cluster location has:

- 2 BigIron 8000 switches both connect
  - OC48 and OC12 external lines to...
  - 128 1Gbit s^{-1} possible ethernet interfaces
- Each rack is connected twice to each BigIron switch i.e. 4 interface cards
  - Max of 64 racks per location

A single rack...

- Has room for 80 PCs and 2 modular HP switch
- HP switch has:
  - 5 *blades* each with 8 100Mbit s^{-1} ports = 40 possible connections
  - 2 *blades* each with 2 1Gbit s^{-1} ports to the BigIron switches
- 3 inch gap between each column of 40 PCs to provide a chimney for exhaust heat

The heat/power issue

- 55W output heat per PC
- 70W per switch

$\Rightarrow$ 4.5kW per rack i.e. 2 boiling kettles

$\Rightarrow$ 288kW for 64 racks

$\Rightarrow$ 0.3MW per site

Each PC has...

- 2 40-80Gb ATA/IDE hard disks
- 256Mb RAM
- 533MHz Celeron - 800MHz Pentium III processor
- Runs Redhat Linux OS
- Is upgraded for disk capacity/processor/DRAM every 2-3 months

The Cost Issue

- 80 PCs across 64 racks = 5120 machines

$\Rightarrow$ every \$100 of extra cost at the PC level gives \$512,000 per site

$\Rightarrow$ \$2,000,000 extra cost across 4 sites

- In March 2000:
  - 800MHz PIIIs were \$800
  - 533MHz Celerons were \$200
- i.e. 50% faster for 4 times the cost
- ...or \$3,000,000 per site of upgrade cost
- By November 2000, 800MHz PIIIs were \$200

The Site Cost

- $1500 per PC (x 5120)
- $1500 per HP switch (x 128)
- $1600 per rack (x 64)
- $100,000 per BigIron switch (x 2)

= $8.17 million per site

+ $5.12 million of upgrades per year to keep site effective (assume 2×$500 per PC per year)