Cloud Computing

Current Trends

- Massive amounts of data
  - Petabyte is common for many business
- Thousands to millions of cores
  - Consolidated data centers
  - Shift from clock rate battle to multicore, to many core…
- Cheap, COTS hardware
- <u>Failures are common, but not common to users</u>
- Virtualization based systems
- Making accessible (Easy to use)
  - More people requiring large scale data processing

Current Trends

- Computing Clouds
  - Cloud Infrastructure Services
  - Cloud infrastructure Software
- Distributed File Systems
- Data intensive parallel application frameworks
  - MapReduce
  - High level languages
- Science in the clouds
  - High Performance Computing (HPC)

Information Services Infrastructure
Some numbers (USA)

- 38 million physical servers
  - +700% growth in next 15 years
- $140b unused capacity
- 30%-50% server cost is related to power
- Average costs for a datacenter
  - $5K-$15K / sq meter
  - $2.5K to $20K / server
  - $80K to $700K / rack
- 20-30 : 1 – Server / Administrator ratio
  - … but can reach >1000:1
  - 1 server can have >200 VMs

Information Services Infrastructure

- Datacenters are not green!
  - 1 server = ~150W at average load
  - 1 rack, 32-42 servers = up to ~6.3KW (<4.8KW typical)
  - 1 DC, 50K servers = 7.5MW (for servers only!)

The result is HEAT, which must be removed out of the premises

- Power Usage Effectiveness
  - PUE = Total Energy / IT Energy
  - Currently: 1.2-3
  - 30% to 100% more in other devices (cooling, network, etc…)
  - >15% is simply lost

Power Estimates[1]

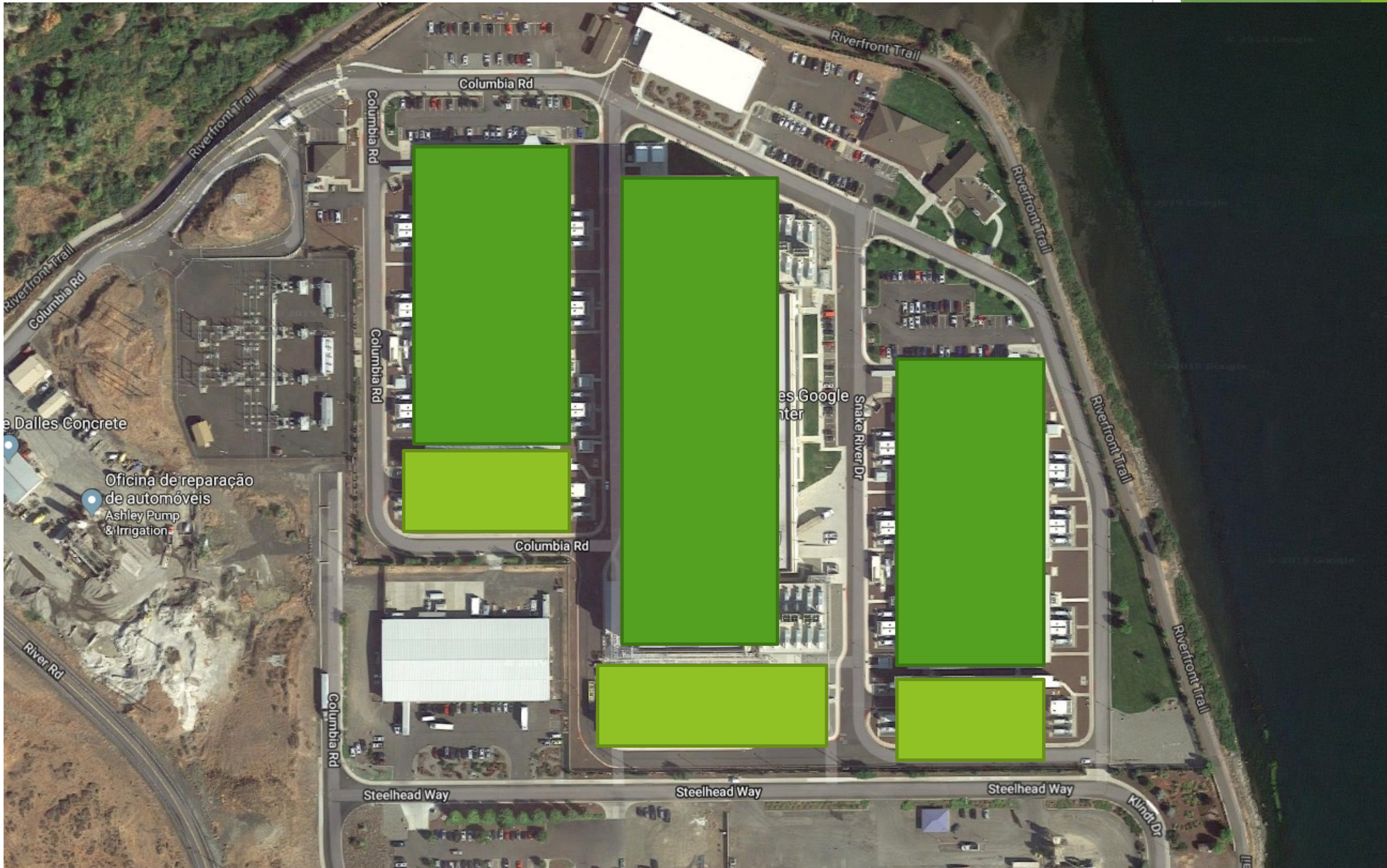
- Google: >1M servers, >400MW power
- Facebook: >240MW
- Amazon: >160MW
- Microsoft: >1M servers, >160MW
- Equinix: >740MW (in >175DCs)
- Total estimated : >400TW/h = 0.03% world power

(1) Ali Ghiasi, Overview of Largest Data Centers, IEEE,

The Dalles

https://goo.gl/maps/B6ea8N8ySYk

The Dalles



https://goo.gl/maps/B6ea8N8ySYk

Scalability

- Vertical Scaling: Add more power to a server
  - More RAM, more storage, more CPUs
- Horizontal Scaling: Add more servers
  - Homogeneous or not
  - Usually not homogeneous as servers are replaced in chunks
- Datacenters are designed to scale horizontally
  - Adding more sections, with more servers

Scalability

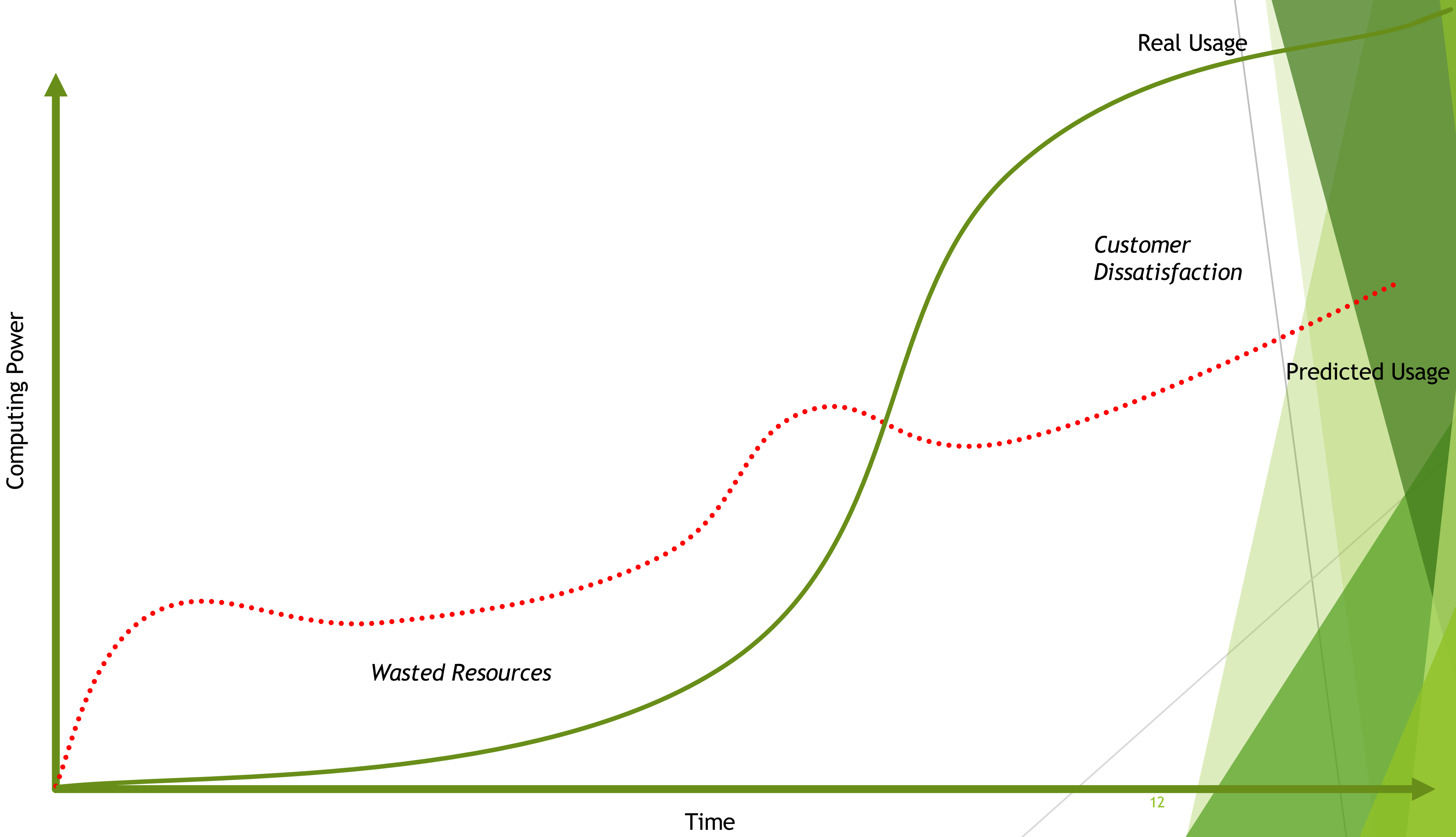
- Systems are designed to scale <u>locally</u> and <u>globally</u>
  - Increase reliability
  - Increase performance
  - Reduce Cost

- <u>Local Scaling:</u> Distribute resource usage in same DC
- <u>Global Scaling</u>: Distribute resource usage across world

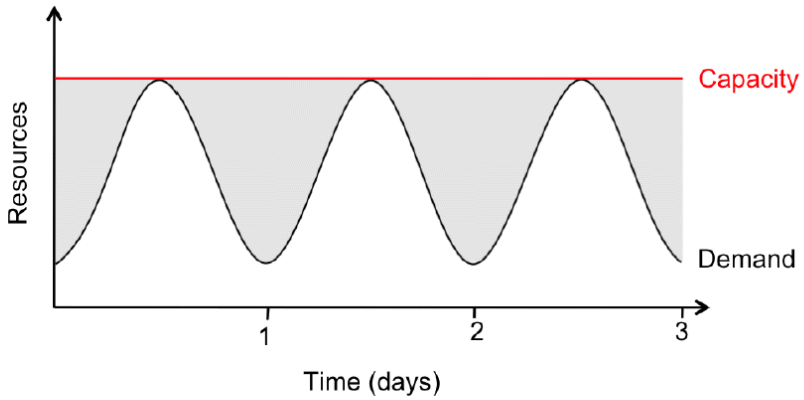
Dimensioning

- Current landscape is too dynamic and unpredictable
- Provisioning for average user load will fail at peak time
  - Weekends, Holidays, Black Friday
- Provisioning for peak time results in a huge waste
  - Peak should reach 80% capacity at most
- What about flash peaks?
  - Viral content, Promotions, Popular content on Twitter, Reddit, FB

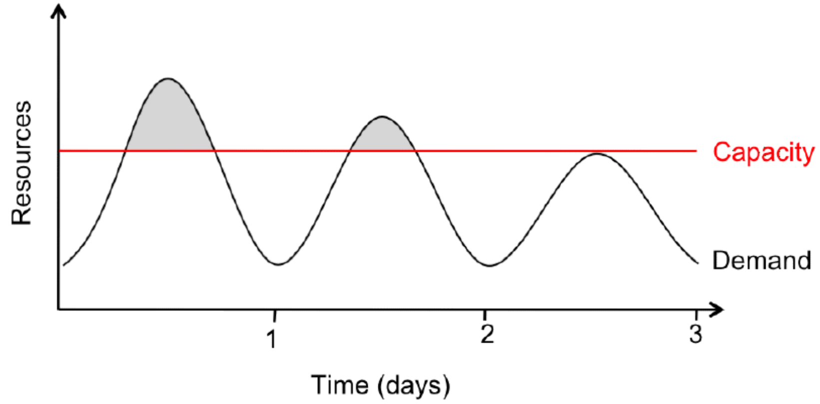
Dimensioning



Problem #1: Difficult to dimension



Provisioning for the peak load



Provisioning below the peak

- **Problem: Load can vary considerably**
  - Peak load can exceed average load by factor 2x-10x [Why?]
  - But: Few users deliberately provision for less than the peak
  - Result: Server utilization in existing data centers ~5%-20%!!
  - Dilemma: Waste resources or lose customers!

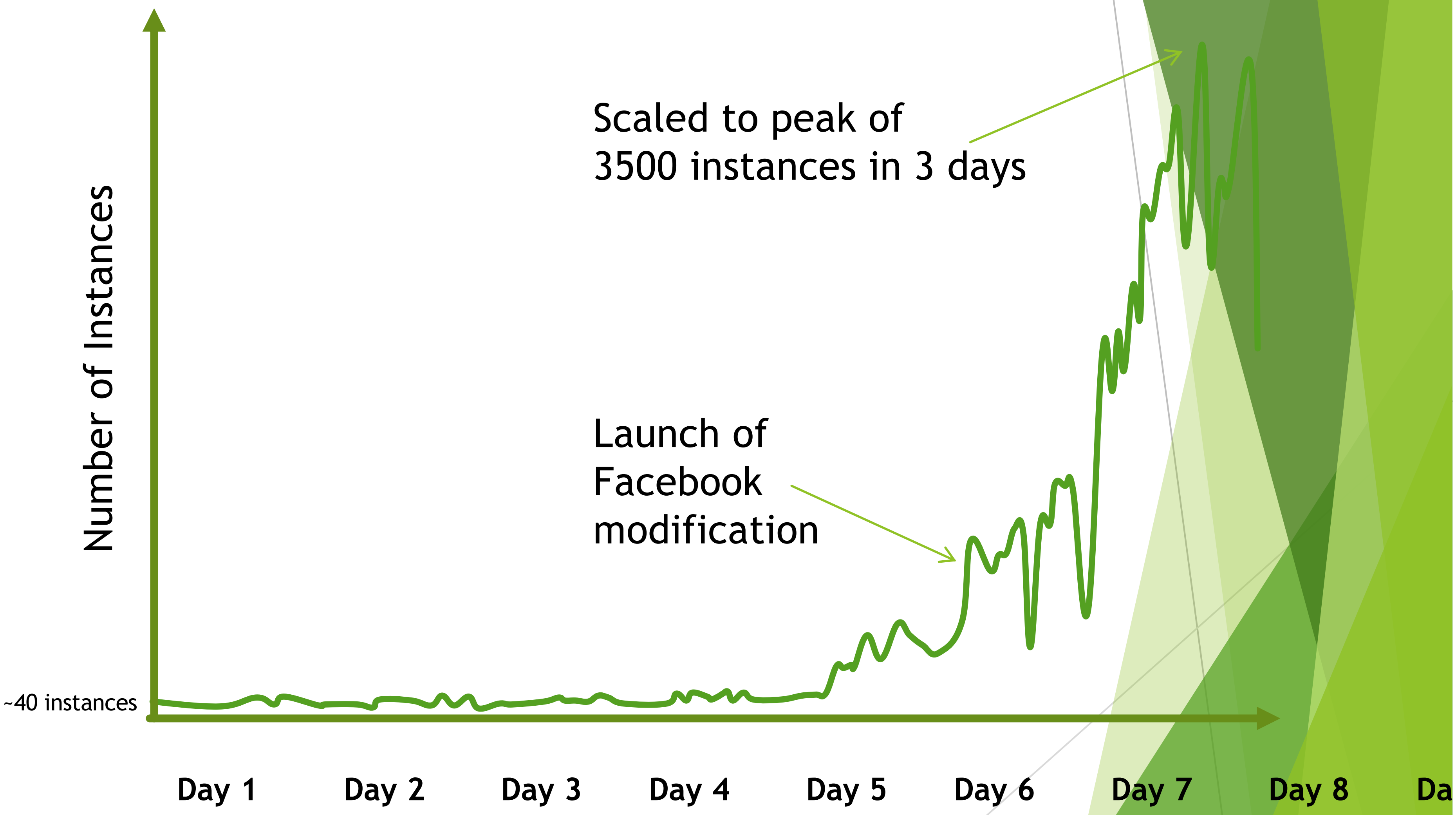
Problem #2: Expensive

- **Need to invest many $$$ in hardware**
  - Even a small cluster can easily cost $100,000
  - Google The Dalles: 1.8B$
- **Need expertise**
  - Planning and setting up a large cluster is highly nontrivial
  - Cluster may require special software, etc.
- **Need maintenance**
  - Someone needs to replace faulty hardware, install software upgrades, maintain user accounts, ...

Problems #3: Difficult to Scale

- **Scaling up is difficult**
  - Need to order new machines, install them, integrate with existing cluster - can take months!
  - Large scaling factors may require major redesign, e.g., new storage system, new interconnect, new building (!)
- **Scaling down is difficult**
  - What to do with superfluous hardware?
  - Server idle power is about 60% of peak $\rightarrow$ Energy is consumed even when no work is being done
  - Many fixed costs, such as construction

Use Case: Animoto



https://aws.amazon.com/solutions/case-studies/animoto/

Case Studies: Medical Research

- Novartis Institutes for Biomedical Research
  - focused on the drug discovery phase of the ~10 year / $1 billion drug development process
- 2013: ran a project to screen 10 M compounds against a common cancer target
- Compute requirements >> internal capacity / $
- Project ran across 10,500 EC2 Spot instances (~87,000 cores) for $4,232 in 9 hours (peanuts)
- **Equiv. of 39 years** of computational chemistry

Problem #4: Availability is hard

- No single computer can handle today's workloads
  - The Growth of Ebay: https://bit.ly/2BG8FBB
- No single computer can provide high availability
  - Hard disk replacements, upgrades, hardware failure?
- Typical availability
  - 99.999% uptime=5.26 minutes downtime per year
  - 99.9999% uptime = 31.8 seconds downtime per year
- Availability is highly demanded
  - Google failed? What?

Summary

- Modern applications require **huge amounts of processing and data**
  - Measured in petabytes, millions of users, billions of objects
  - Need special hardware, algorithms, tools to work at this scale
- **Clusters and data centers can provide the resources we need**
  - Main difference: Scale (room-sized vs. building-sized)
  - Special hardware; power and cooling are big concerns
- **Clusters and data centers are not perfect**
  - Difficult to dimension; expensive; difficult to scale

Cloud Computing

- Web and Internet based on **on demand** computational services
- Infrastructure complexity **transparent** to end user
- **Horizontal scaling** with no additional delay
  - Increased throughput
- Public Clouds
  - Amazon Web Services, Windows Azure, Google AppEngine, …
- Private Cloud Infrastructure Software
  - Eucalyptus, Nimbus, OpenNebula, OpenStack, Kubernetes,

Cloud Computing

- Running a DataCenter is **expensive**.
  - Costs too much to built (CapEx)
  - Costs too much to run (OpEx)

"Need milk? Don't buy the cow… buy the milk"

- Rent what you need instead of buying and running everything!
- Cloud Computing advantages:
  - Pay per use
  - Instant Scalability
  - Security
  - Reliability
  - APIs

Cloud Computing

“Cloud computing is a model for enabling **convenient**, **on-demand** network access to a **shared** pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be **rapidly provisioned** and released with **minimal** management effort or service provider interaction. “

Everything As a Service

SaaS

- Salesforce, Google Apps, MS Office 360

PaaS

- MS Azure, Google App Engine, Heroku

IaaS

- Amazon, Google Cloud Platform, IBM Bluemix

IaaS: Infrastructure As A Service

- Grids of virtualized servers, storage & networks
  - E.g. Amazon (EC2, S3, EBS), IBM Bluemix, Google Cloud Platform
- Access to infrastructure stack:
  - Full OS access
  - Firewalls
  - Routers
  - Load balancing
- Advantages
  - Pay per use
  - Instant Scalability
  - Security
  - Reliability
  - APIs

Platform as a Service

- **The abstraction of applications from traditional limits of hardware**
  - allowing developers to focus on application development
  - and not worry about operating systems, infrastructure scaling, load balancing and so on.
  - Examples include Google App Engine (Java, Python), MS Azure (.net), Heroku (RoR)
- **Platform delivery model**
  - Platforms are built upon Infrastructure, which is expensive
  - Estimating demand is not a science!
  - Platform management is not fun!
- **Advantages**
  - Pay per use
  - Instant Scalability
  - No sysadmin tasks
  - Better Security

Software as a Service

- **Applications with a Web-based interface accessed via Web Services and Web 2.0.**
  - E.g. Google Apps, SalesForce.com and social network applications such as FaceBook
- **Software delivery model**
  - Increasingly popular with SMEs
  - No hardware or software to manage
  - Service delivered through a browser
- **Advantages**
  - No Installation Required
  - Not platform specific
  - Automatic Upgrades
  - Access your data anywhere

Other

- Cloud as a Service
- Network as a Service
- Storage as a Service
- AI as a Service
- Energy Storage as a Service
- Security as a Service
- ...https://en.wikipedia.org/wiki/As_a_service

Cloud Types

- **Cloud is presented with different flavors**
- **Public cloud:** Commercial service; open to (almost) anyone
  - Example: Amazon AWS, Microsoft Azure, Google App Engine
- **Community cloud:** Shared by several similar organizations.
  - Example: Google's "Gov Cloud"
- **Private cloud:** Shared within a single organization.
  - Example: Internal datacenter of a large company.