ENGR E-516: Engineering Cloud Computing

Introduction to Cloud Computing

Week 1

Cloud Computing Origins

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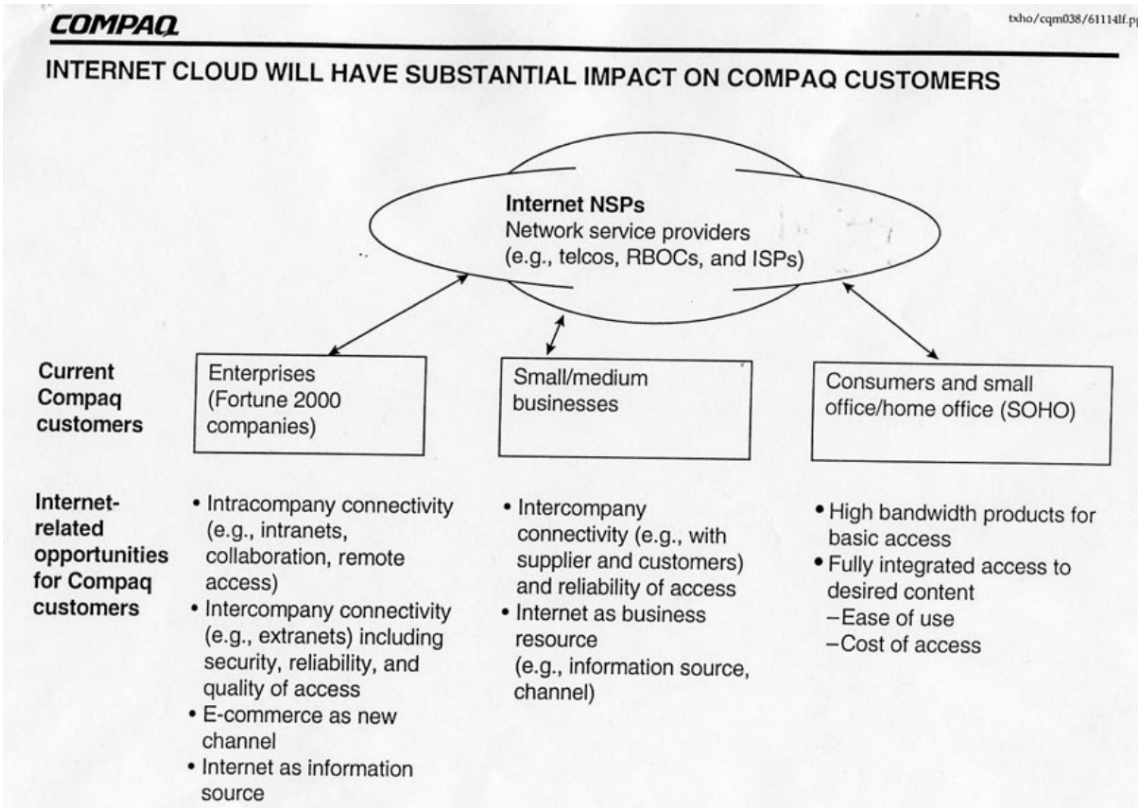
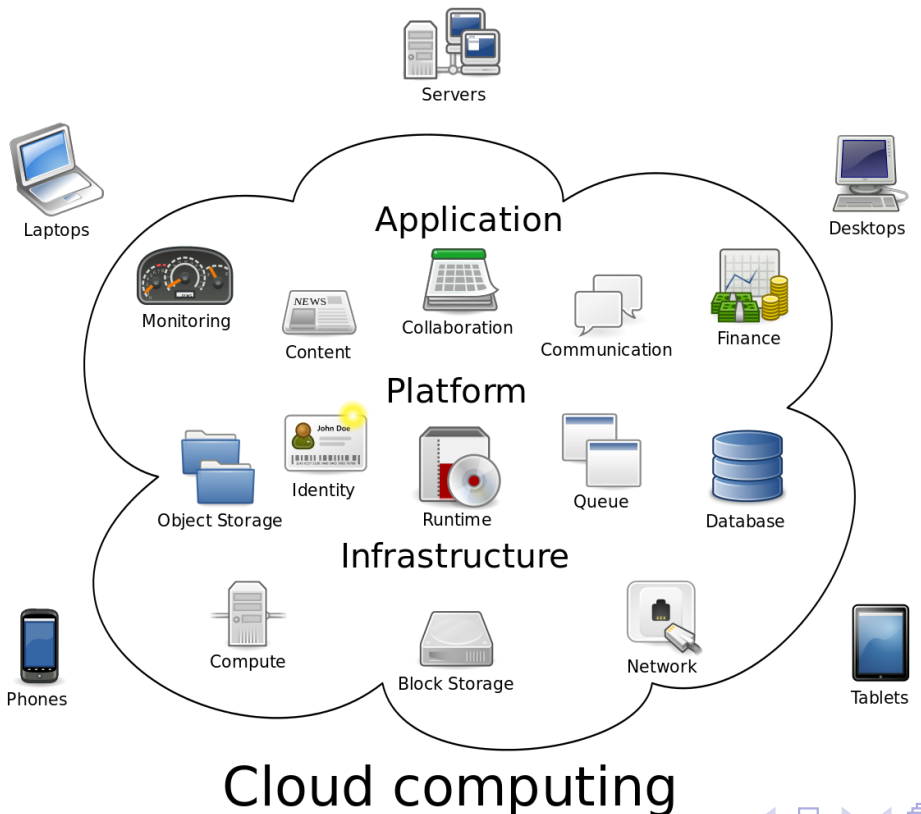
- Etymology: Networks often represented as “clouds” in architecture diagrams
- Compaq 1996 memo: “Internet Solutions Division Strategy For Cloud Computing”



What is Cloud Computing?

1. A way for end-devices to access computational and storage resources over the internet
2. Computing as a utility
3. Cloud $\equiv$ infinite, elastic computer
4. Programming platform for complex applications
   - A way to deploy applications as distributed networked services



Provisioning of resources

"Pre-cloud":

1. Build application
2. Request hardware (servers, disks) to run application
   - Go through enterprise, university purchasing and procurement
   - Can take several days, even months
3. Deploy application
4. Application becomes popular, needs more servers. Goto step 2

Cloud provisioning:

- `server = request_instance(size, number)`
- ...wait 30 seconds
- `ssh(server)` *// deploy application*

Analogy

Building a house vs. staying in a hotel

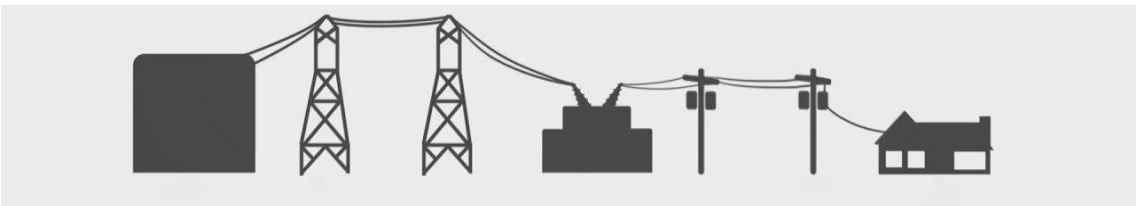
Utility Computing

Can computing be a utility just like electricity, water, etc.?

John McCarthy 1961

"*Computing may someday be organized as a public utility just as the telephone system is a public utility*"

- Where's the electricity coming from?
- What are the sources of generation?
- Can ignore complex interaction between powerplants, grid, and utility companies.
- Can ignore transformers, phases, . . .
- From the consumer perspective, just a flick of the switch.
- Appliances "dont care".



What being a utility entails

- Standardization of client endpoints [plugs]
- Resource provider and consumer agree on resources provided [voltage, frequency, max current draw]

Other issues:

- Utilities must match supply and demand
- Billing
- Time of day pricing [lower during the night]
- Demand-response pricing [higher prices during peak-loads to discourage excess use]
- Users/appliances do not worry about any of these things!

Fungibility of Computing Resources

- Fungible goods can be easily interchanged
- Example: gasoline/petrol
- Energy $\rightarrow$ Computing $\rightarrow$ Applications $\rightarrow$ \$\$\$

Can computing be made fungible?

Spoiler

Yes, mostly, using different abstractions.

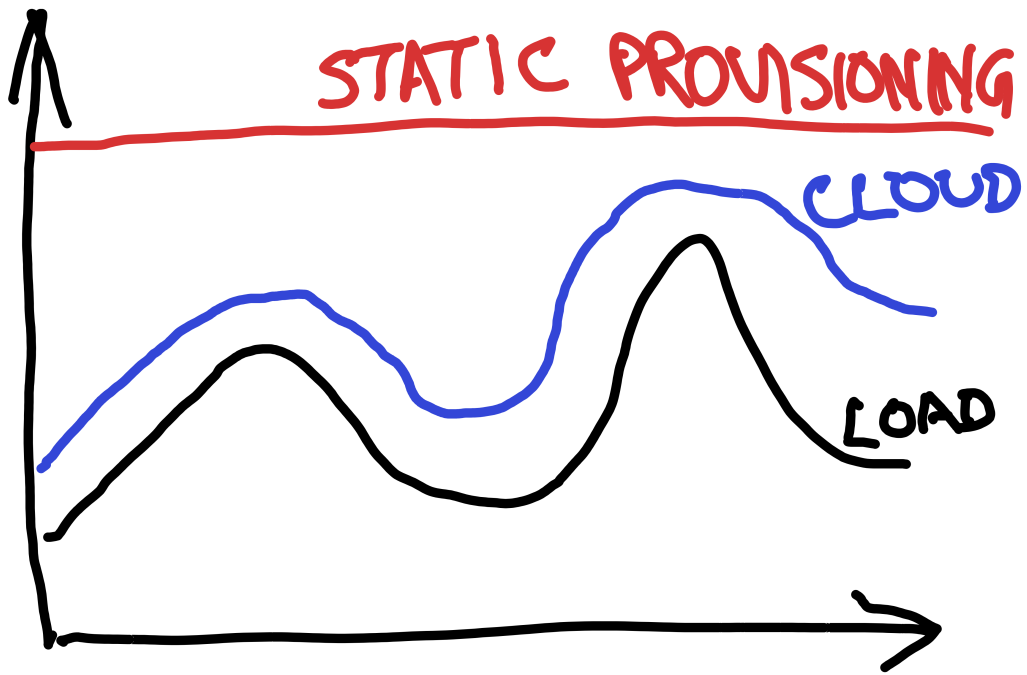
Elastic Computing

- Can view the cloud as “one giant computer”
- That can meet different-sized computing demands
  - Use 1 CPU for 1 year, 10^4 CPUs for 1 hour
- “On-demand”: Near-instantaneous request-use-discard process
- Utility computing $\rightarrow$ Pay for what you use
- Different sized computing resources can be leased at various timescales
  - “Rent” a server for a minute, hour, day, year, . . .

Elastic Provisioning

Elasticity enables many use-cases:

- Popular applications can “scale up” to meet user demands
- Many applications see fluctuating load
  - More people check email during day vs. night
- Cloud computing enables *dynamic* allocation of resources



Shared Cloud-based Applications

- Consider a service with multiple users, such as Canvas
- Multiple software components and tiers:
  - Web-server for serving pages on `iu.canvas.edu`
  - Application-tier (ex: compute grades based on scores)
  - Database to store student data
- Different components run on different servers
- Servers have a limit on the number of operations/users they can support
  - Example: A single web-server may be limited to 10 requests/second

Clouds as application platforms

- We all “use” the cloud through cloud-based applications
- Email [gmail, . . .]
- Data storage [dropbox, box, . . .]
- Various web-services like Slack, Uber,. . .

What does it mean for an application to be “on the cloud”?

Local vs. Cloud Application : Email

Local email client such as Thunderbird:

- Retrieve messages from mail server periodically
- Store messages on local disk
- User interface
- Search, spam-filtering of messages
- Sending emails via smtp

Web-based email client (gmail):

- UI is operated through browser (HTML)
- No local storage of messages [Good and bad thing. 2TB of messages]
- All operations (view, delete, search, etc.) performed remotely
- Can't operate offline: Must be connected to gmail for all operations

Cloud application: Someone else's problem

Advantages:

- Can access from anywhere
- Software updates and security patches
- Spam optimizations can be globally deployed

Down-sides:

- Control over UI: What if UI changes and you don't like it?
- Privacy : full control over code if local.

Network-centric computing

- Use remote computing resources
- Servers located in data centers
- Possible due to advancements in networking
- Access remote services with thin clients (e.g., chromebooks)
- Standardized interfaces for data transfer (WWW, HTTP)

Cloud Advantages Recap

- Utility
- Pay only for what you use [mailbox size]
- Maintenance and security ensured by service providers
- Economy of scale: increases efficiency due to specialization and centralization [spam]
- Resource multiplexing [not everyone uses 2TB] lowers costs
- Redundancy: can store data on multiple locations

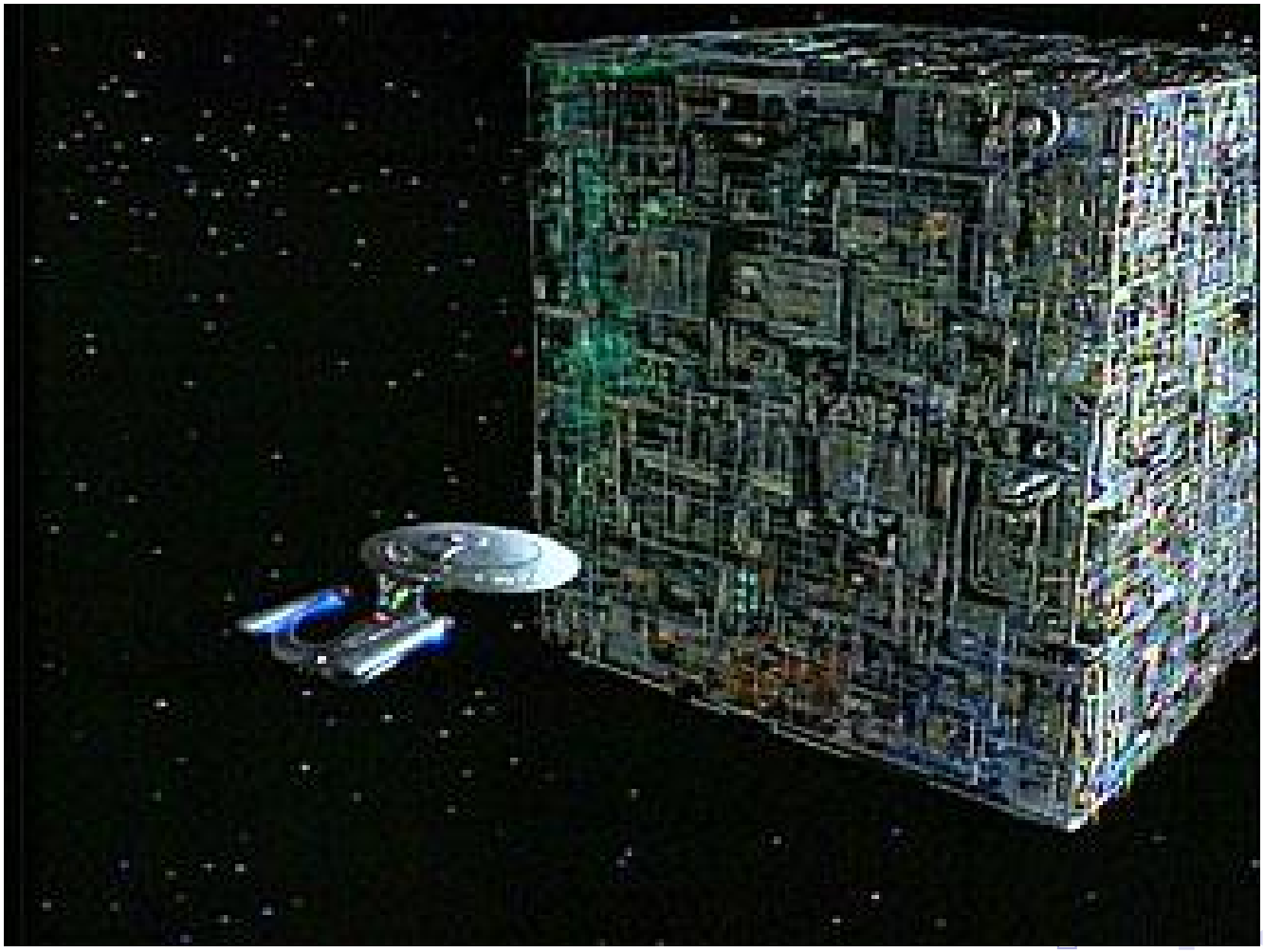
Cloud Platforms

Cloud uses

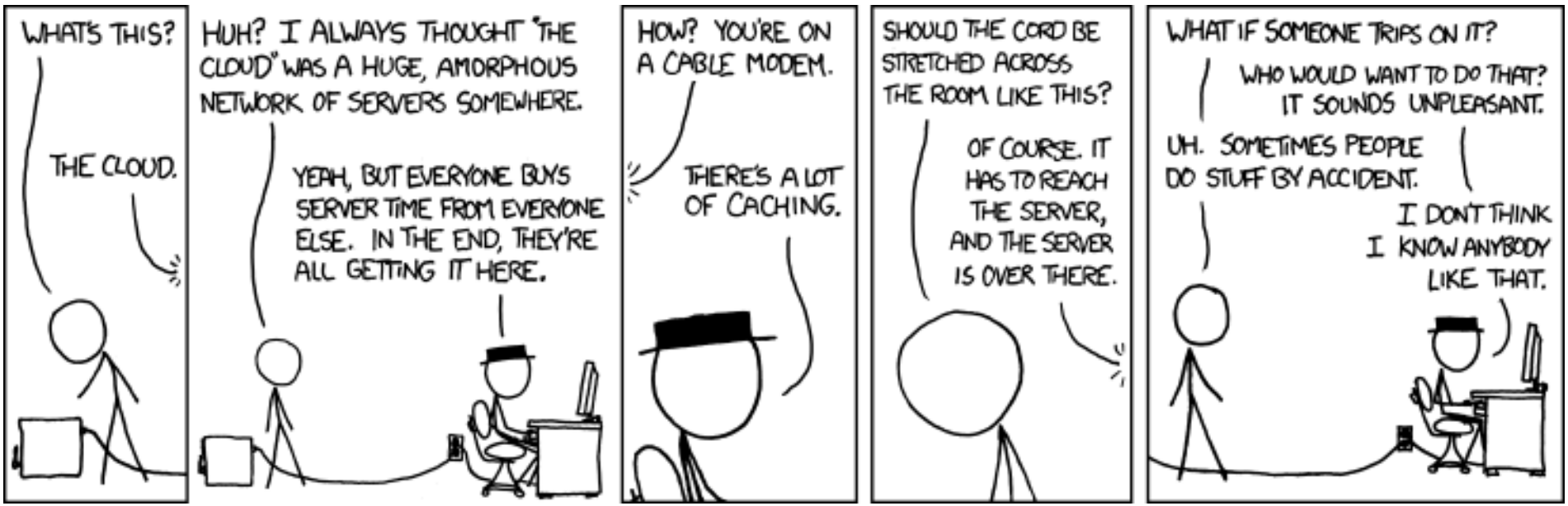
- Large enterprises
- Software startups: easy to deploy and scale.
  - Don’t have to worry about buying and maintaining hardware
  - Uber: $3Billion cloud bill per year
  - Netflix: famous as an early user of Amazon AWS
- Scientific computing: NSF Chameleon Cloud
- Data analytics and machine learning

Resistance Is Futile

- $500B industry
- Key reason for boom in Deep Learning and AI
- The cloud will assimilate all computing applications

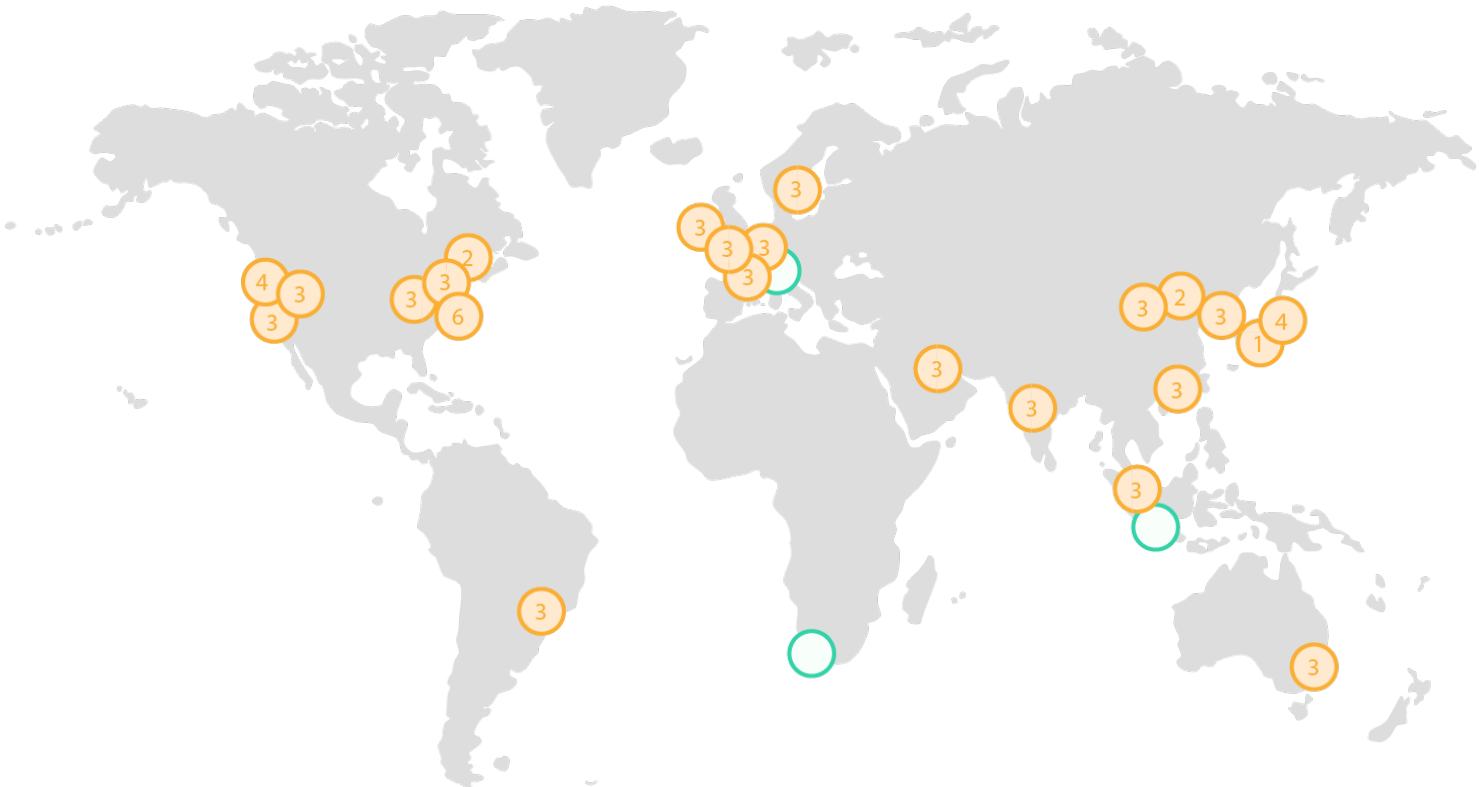


There's an xkcd for that



Providers of Cloud Services

- Large: Amazon AWS, Google Cloud, Microsoft Azure, Alibaba
- Smaller: IBM, Rackspace, Heroku, Joyent (RIP), Oracle
- Dozens of data centers spread worldwide



Modern Cloud Computing (Post 2006)

Folk-lore of how AWS began:

- Excess server capacity during slow shopping periods
- Use supply-side elasticity to offer unused resources as a service
- S3 (Simple Storage Service) and EC2 (Elastic Compute Cloud) in 2006

Eric Schmidt in 2006

"It starts with the premise that the data services and architecture should be on servers. We call it cloud computing—they should be in a "cloud" somewhere."

Cloud Data Centers

- Warehouse sized buildings housing thousands of servers
- $2\times$ more efficient than conventional data centers

Centralization

- Data processing and storage can be done more efficiently centrally in large data centers

Alternative: Decentralized Architectures

- Example: SETI@Home in the 1990's used a vast network of volunteer desktop computers for highly parallel computation

Clouds enable specialization

- Cloud Computing also reduces redundant software and hardware setups
- Running your own computing and storage cluster is *hard*
- Setting up and maintaining complex software is also painful

Why are cloud platforms efficient?

- Resource pooling and multiplexing: multiple agents/tenants can share a large pool of resources, instead of strict division
- Large, optimized data centers that house all the hardware
- Higher hardware utilization (related to power proportionality)
- Virtualization
- “Software-defined” everything: networking, storage, data-centers

Data center Challenges

Hardware challenges:

- Powering, running, and cooling 10^5 servers
- Reliability and redundancy
- Low energy consumption
- Location: must be close enough to end-users

Cluster management software:

- Run multiple apps and services
- Software for multiplexing, elasticity, . . .
- Manage resources across all servers
- Where (which server) to run an application on?

Economies of Scale

- Larger data centers more efficient
- Large scale optimizations at different levels possible
- Better energy efficiency
- Administrative overhead
- Custom hardware [servers] possible. Remove unneeded components. Add more redundancy
- Easier to scale with larger clusters

Cloud service abstractions

Cloud platforms offer computing resources at different levels of abstraction:

- **Infrastructure as a service**. Provide basic computing, storage, networking resources, typically virtualized.
- **Platform as a service**. Limited application deployment and programming API.
- **Software as a service**. Specific application such as email.

Tradeoffs:

- Programmer convenience vs. flexibility
- Higher abstraction services may have restrictions
- More management required with lower abstraction (Iaas)

Cloud services

- 100s of different services for computing, storage, networking, etc.
- Examples: Databases as a service, email-relays, DNS servers, message queues,. . .
- Many services added **each week**
- Autoscaling , Deployment , Analytics , Distributed data processing, machine learning , Stream processing , Databases and data storage , Workflow automation , Network services: smtp, dns, etc.

Infrastructure level:

- Availability zones
- Geographical regions
- Network IP addresses

Cloud Costs

- Due to economies of scale, cloud resources often cheaper
  - Energy efficiency of cloud data centers:90%
  - Energy efficiency of smaller data centers: 50%
- Google cloud: $0.02 per hour per CPU
- Bare-metal cloud (Hetzner) : $0.004 per hour per CPU
- Total cloud costs includes storage and networking costs
- Cost of other services: load-balancers, elastic-mapreduce, . . .

Cloud vs. local deployment

Cost considerations of moving applications to the cloud:

- Investment aka capital expenses: building data center, buying servers, ...
- Operating expenses: energy costs for running servers, cooling, and maintenance.

Potential Pitfalls

- Lock in
- Privacy and security
- Costs