The Economics of Cloud Computing

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How did we get here?

- 1969: Apranet, first packet switching network

- 1969: Unix developed

- 1971:Email invented by Ray Tomlinson

- 1974: The beginning of TCP/IP

- 1977: First PC modem

- 1978: First Spam sent

- 1984: Domain Name System (DNS)

- 1989: AOL is launched

- 1991: AOL email for DOS environment

How did we get here?

1991: First web page created

1991: MP3 becomes a standard

1992: Dephi is the first national email and internet
  provider

1993: AOL email for Windows 3.1

1993: Mosaic First Browser devloped at UIUC

1994: Netscape Navigator

1995: Amazon, Ebay go live

1996: Hotmail is the first webmail service

1998: Google founded

How did we get here?

- 1999: Salesforce.com enterprise application software in the cloud

- 1999: SETI@home Grid computing project

- 2000: Internet bubble bursts

- 2001: Wikipedia launched

- 2002: Amazon EC2 Cloud service launched

- 2003: Skype released to public

- 2004: Flickr launched

- 2004 World of Warcraft launched
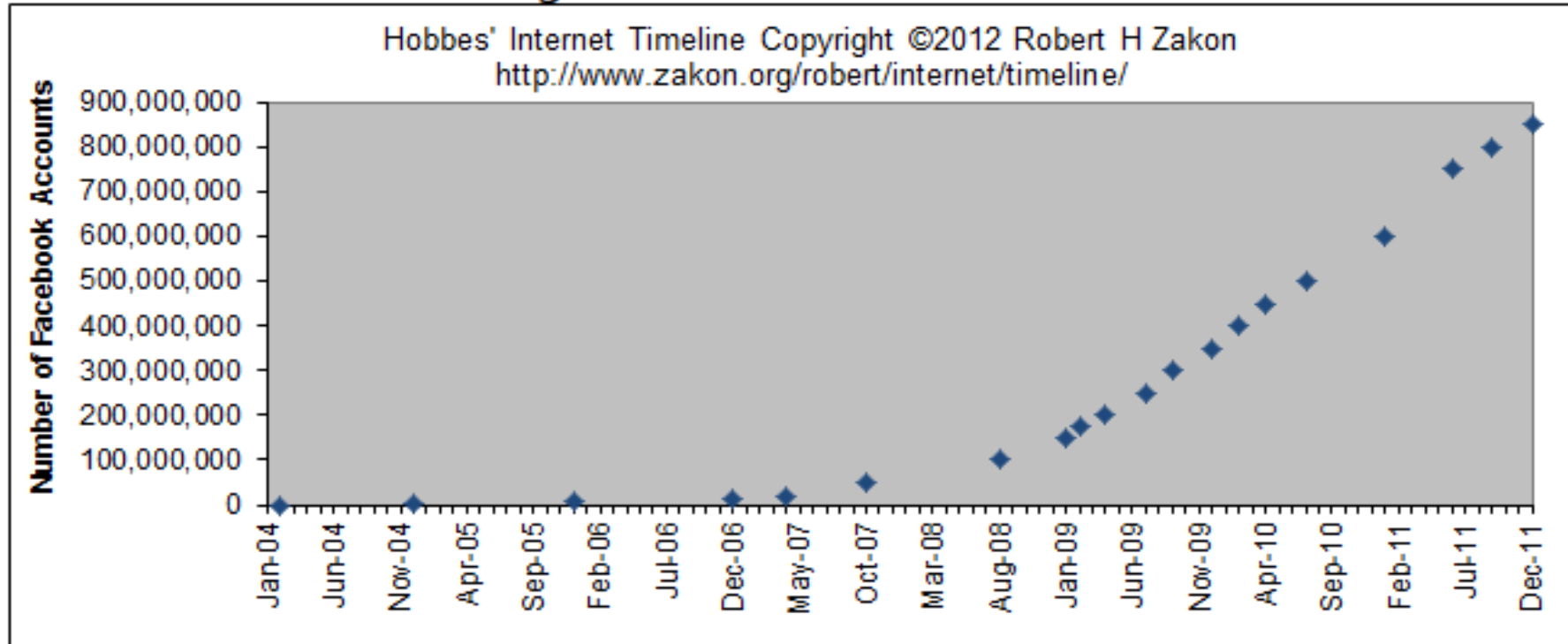
How did we get here?

- 2004: Facebook lauched (600 million users today)
- 2005 YouTube launched
- 2006: Twitter lauched
- 2006: Amazon S3 (simple storage solutions) lauched
- 2007: iPhone released (mobile web)
- 2008: Google App Engine cloud service launched

How did we get here?

- 2009: Windows Azure cloud service lauched

- 2010: Ipad launched

- 2010: First internet addresses in non-Latin chacters

- 2010: Instagram founded

- 2011: 4.3 billion IP addresses exist

How did we get here?

Figure: Facebook Accounts

Hobbes' Internet Timeline Copyright ©2012 Robert H Zakon
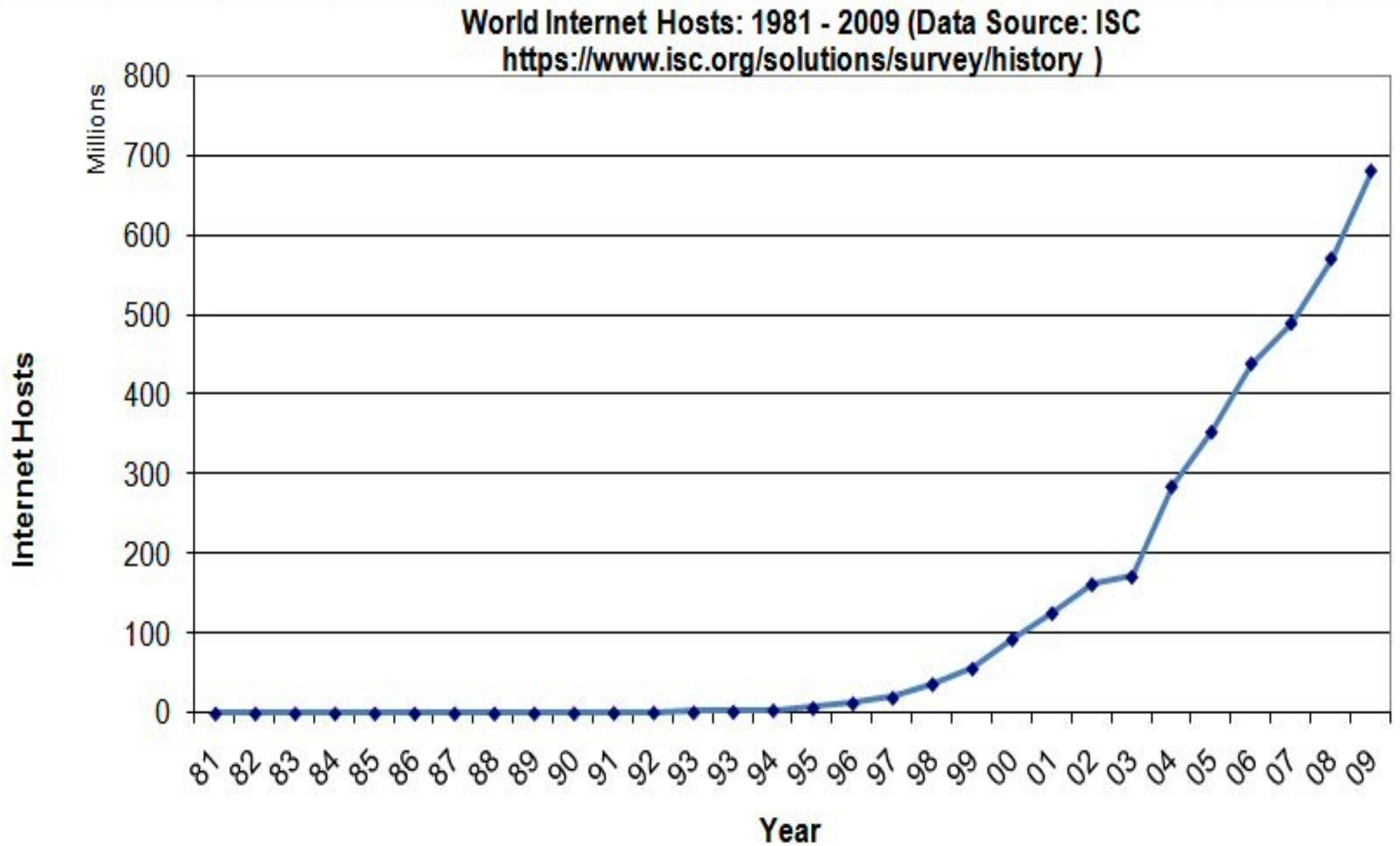http://www.zakon.org/robert/internet/timeline/

Facebook's growth in the fall of 2007 was staggering. Over 1 million new users signed up every week
How can a company deploy the computing infrastructure to handle that?

How did we get here?

World Internet Hosts: 1981 - 2009 (Data Source: ISC https://www.isc.org/solutions/survey/history)

What is 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.

(United States National Institute of Standards and Technology (NIST) 15th revision)

What is Cloud Computing?

Infrastructure as a Service (IaaS) Consumers directly lease processing, storage, bandwidth, and other fundamental computing resources as bundles (e.g. virtual machines, dedicated servers) or separately (communication (CaaS), data storage (DaaS)).

- Amazon's Elastic Computing Cloud (EC2)

- Simple Storage Service (S3)

- Microsoft's Connected Service Framework (CSF)

What is Cloud Computing?

<u>Platform as a Service</u> (PaaS) Consumers lease a development or runtime environment with set programming languages and application programming interfaces (APIs) to design and deploy consumer-created applications onto the cloud. Servers, software stacks, networking, etc. is hidden from the end-user.

- Google App Engine
- Microsoft Azure

What is Cloud Computing?

Software as a Service (SaaS) Consumers use the cloud provider's applications running on a cloud infrastructure. Applications are accessible from various client devices through thin client interfaces such as web browsers.

- Gmail
- Google Docs
- YouTube
- Salesforce.com
- Oracle

How Big is Cloud Computing?

- Cloud services Industry was $68.3 billion in 2010 and should reach around $150 billion by 2014.

- The US Recorded Music, Movie, and Electronic Gaming industries are each around $10 Billion

- By the way, the US Snow Removal industry is about $12 Billion.

What are the Social Impacts of Cloud Computing?

It is useful to think of Retail and Wholesale sides of the market

Wholesale is mostly business directed and centered on PaaS and IaaS. Firms lease computing power instead of buying their own server farms to provide both internal and client facing services.

Retail is mostly consumer directed and centered on SaaS. Consumers outsource their storage, communication, content, and software application needs to the cloud

The Economics Literature on Cloud Computing

- Conley et. al. (2013): Survey
- Etro (2009) +one more recent: Macro estimates

- Friedman et. al.(2011): Social choice

- Ghodsi et.al. (2010): Social choice

- Langford et.al. (2009): Experiment in packet pricing

Wholesale Cloud Computing

Democratizing Entrepreneurship

- Turns fixed costs into variable costs.

- Lowers barriers to entry since the Cloud provider can be the IT/security expert

- Less skin in the game

- However, the importance of search engine optimization creates a tendency to concentration and a first mover advantage

- Death of the Venture Capitalist?

Wholesale Cloud Computing

Flexibility

- Virtualization allow companies to scale rapidly in storage, bandwidth, and CPU power without investing in and deploying physical machines.

- Hypervisors can optimize this automatically.

- Thus, companies are never caught flatfooted when demand grows or spikes, and are not left with unneeded capacity if things don't meet expectations.

Wholesale Cloud Computing

Environmental

- Private Servers used at 20% capacity, the cloud at 80%.

- Place cloud where land/electricity/backbone cheap.

- Economies of scale.

- Use natural cooling (50% of electricity is cooling).

- Recycling is more practical (economies of scale).

Wholesale Cloud Computing

<u>Security</u>

- Cloud computing providers are experts.

- You don't know where the data is or what laws apply.

- No servers in China.

- Patriot act-violates EU Privacy laws.

- HIPAA: Health Insurance Portability and Accountability Act.

- FERPA: Family Educational Rights and Privacy Act.

Wholesale Cloud Computing
Business Intelligence/Integration Failure

- Large scale data integration: Using combinations of XaaS to integrate payroll, inventory, sales, manufacturing, shipping, customer support etc. data into one inoperable system.

- Business intelligence: Using data mining,prestructured reports, automatic triggers, and work flow management to give managers finer control and to exploit economies and new potential sales and markets

- However this is expensive, takes two years on average, and has a 60% failure rate.

- Legacy systems?

Wholesale Cloud Computing

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Wholesale Cloud Computing

Business Intelligence/Integration Failure

First mover advantage? (since lower costs if successful allow for scalability and gaining critical mass)

Second mover advantage? (Learning from others failures, and waiting for better technologies.)

Advantage of new over old companies (integration harder than building from the ground up)

Principle agent problems (Managers want to avoid responsibility)

Signaling, hail Mary?

Wholesale Cloud Computing

Lock-in

- For PaaS you write your code on top of an existing software stack (LAMP/WAMP) and even propietry API's. Costly to move to a new provider, which makes you exploitable.

- For SaaS, your data lives on someone else's server in their format. Also hard to move. What if your provider stops supporting certain features you use, or updates break the way you interact with the data?

Wholesale Cloud Computing

New models of the workplace

Cloud technologies allow work at home of variable schedules.

- empirically study whether we see greater work force participation, especially by women and the disabled in certain industries as the cloud gets more ubiquitous.

- From a theory standpoint, one could explore what kinds of jobs lend themselves to this sort of decentralized system of labor, what kind of incentive and monitoring schemes will be efficient, and what types of workers and businesses will be attracted to these new models.

Wholesale Cloud Computing

Portfolio questions

- One can think of cloud coustomers as being similar to stocks in a portfolio.
- They have means, variace and covariance in their usage of services.
- This affects the costs and loads they impose on the system.
- Porfolio analyis could provide insight into how to choose and charge customers.

Wholesale Cloud Computing

Data Runs?

Bankruptcy, reorganizations or even changes in business focus on the part of cloud service provides pose significant risks for users.

In the worst case, users may lose data stored in the cloud. (Megaupload failure 2012) At a less catastrophic level, features and functionality may be dropped or no longer supported, service levels of companies distracted by internal problems may decline.

Seeing this, users who can may withdraw their data and find new providers of services.

This further weakens the company, and induces more customers to leave. The dynamics are very much like a bank-run.

Impact of Retail Cloud Computing

Ubiquitous Access to Documents/Files/Content/Communication

- Since your documents and content is stored elsewhere, you can access your stuff anywhere. Computers become a gateway, not tool in itself.

- We can now access almost any song, movie, show, book, and the full content of the web anywhere. Why have a library or a record collection?

- Hulu/Netflix replaces cable.

- Skype/Vonage replace landlines.

Retail Cloud Computing

Mobile Computing/Ubiquitous Contact

- We also can text, email, Facebook, read, watch shows and sports, work, buy and sell, and of course talk via mobile devices.

- We never have to be (or can be) out of touch.

- We are always in a crowd.

Impact of Retail Cloud Computing

Networking/Splintering

- We can now share our personal content on Facebook, Flickr,Twitter, blogs, reviews, personal webpages, etc. We can join TWoP, WOW and find like minded people

- This networking allows people to hone their interests and find a coalition they like

- It also means that we are less reliant on our neighbors for support, status or interaction.

- The Cloud both brings us together and splinters us.

Impact of Retail Cloud Computing

Privacy

- Privacy has become a kind of currency. You give it up to Facebook when you post, to Google when you search, to Amazon, Ebay and Expedia when you buy. In exchange, you get content and web services.

- We used to gain a degree of privacy from the transactions cost of spreading rumors, the limits of human memory, and the shear volume of information that was humanly impossible to sort and absorb.

- Once something is in the cloud it is likely to be mirrored, indexed, archived, and cached. It is there forever.

Impact of Retail Cloud Computing

<u>Pirates vs. Gangsters</u>

- We can store things on the cloud, use P2P networks to share content, find content that others have posted. In other words, the cloud makes it easy to pirate content.

- The RIAA is essentially bribing congress to twist copyright protection far beyond any original (and I think reasonable) intent.

- The idea was create an incentive to create new works for people to enjoy but also so that others could build on the knowledge and art and so the culture advance. IP holders use bribery, threats, blackmail and extortion. They are copyright gangsters.

Impact of Retail Cloud Computing

Network Externalities/Lock-in

- We want to be on Facebook Because that is where everyone else is. We have to tolerate their privacy policies.

- Google has the best search engine, but if we don't like the way they treat us, what can we do?

- Will Apple always support DRM? Will Kindel books always be available? (e.g. MSN Music store stopped supporting keys in 2008).

- Why can't we lend books or sell them on Kindel?

Conclusions

- Cheaper, more efficient and environmentally friendly computing services

- Democratizing entrepreneurship.

- Cheap distribution of content both legal and illegal.

- Democratization of Content production/no publishers.

- Ubiquitous contact with whatever group, whatever content you want, whenever you want.

- Lose of control over data and privacy.

- Network externalities tend to generate monopolies.