CS5412: THE CLOUD VALUE PROPOSITION

Lecture XXII

Ken Birman

Cloud Hype

- The cloud is cheaper

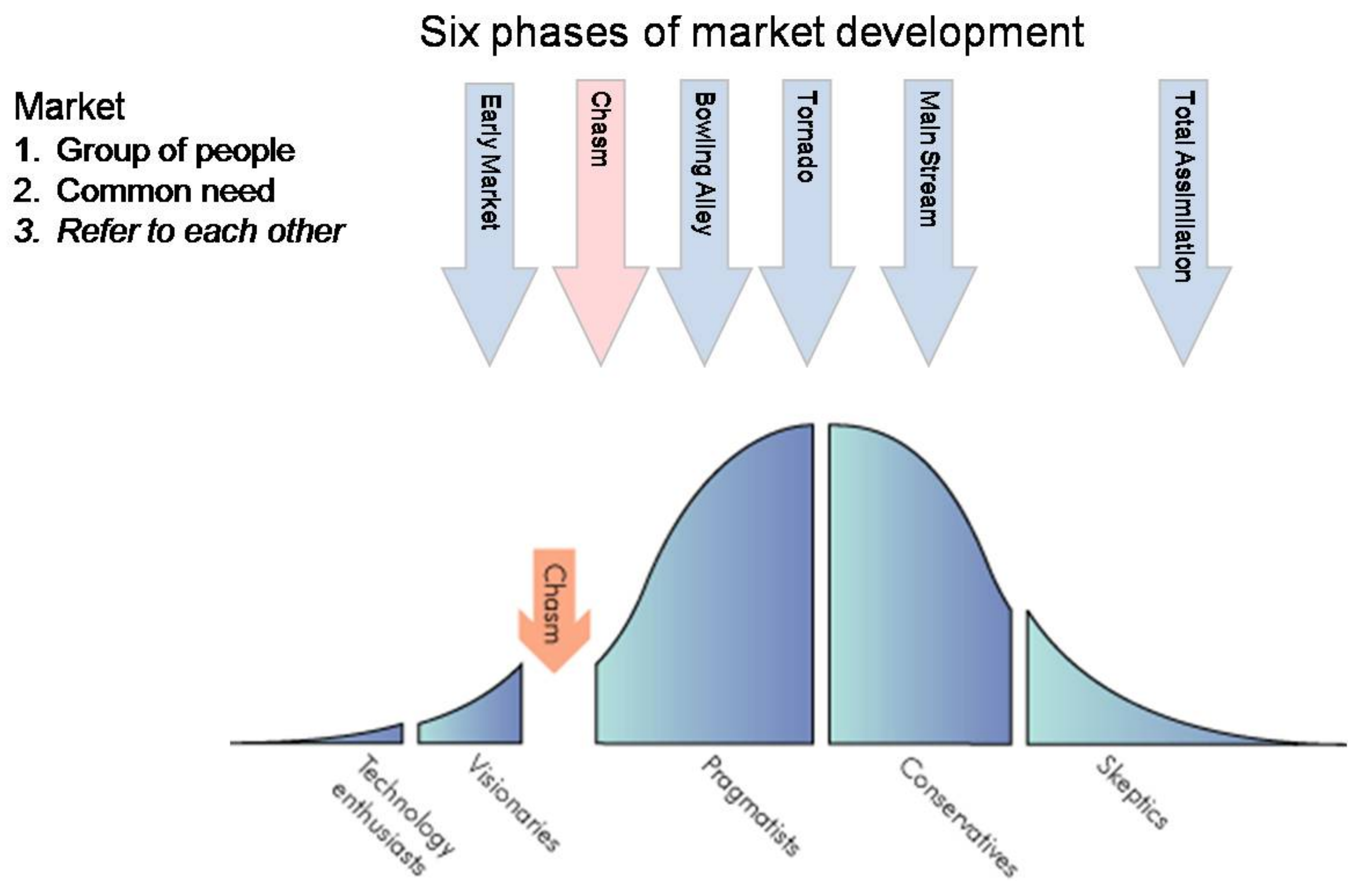
- The cloud business model is growing at an unparalleled pace without any limit in sight

- In the future everything will be on the cloud

… can we find evidence to support, or refute, such claims?

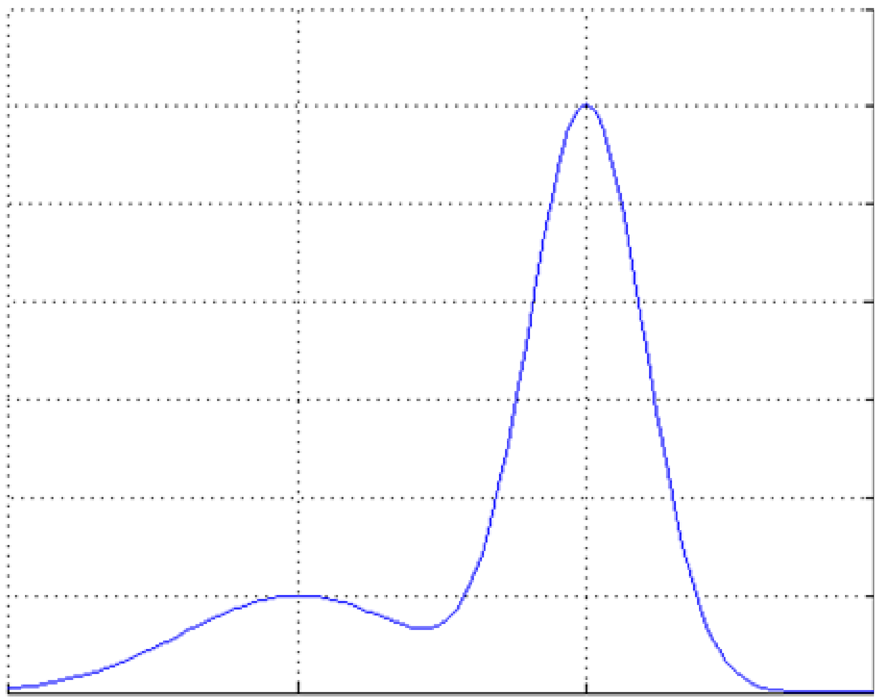
Crossing the Chasm

- Insight from Geoff Moore



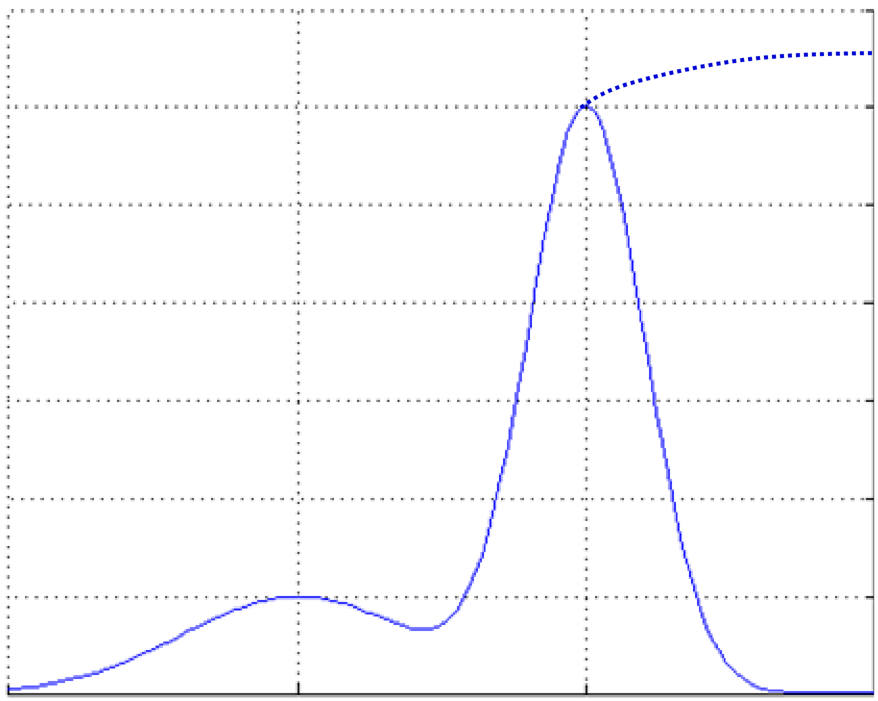
How does the revenue picture look?

- One-time purchases



How does the revenue picture look?

- “Recurring” revenue



A thought question

- Who pays for a "free" app?
  - Some games have advertising but many apps don't
  - So what's the interest in having the app?

- Even more extreme: Who pays for LinkedIn?
  - Huge number of users so it must cost a lot to run
  - Yet no advertising and the site is free

.... and the answer is?

- LinkedIn exists to either be acquired, or to eventually change its revenue model using ads
  - In the eventual profit case, the company would be sustained by venture capital in the interim period
  - Then an IPO lets the company cash in on its “value”

- But what does “value” ultimately mean if the company sells a product that doesn’t really create revenue at all?

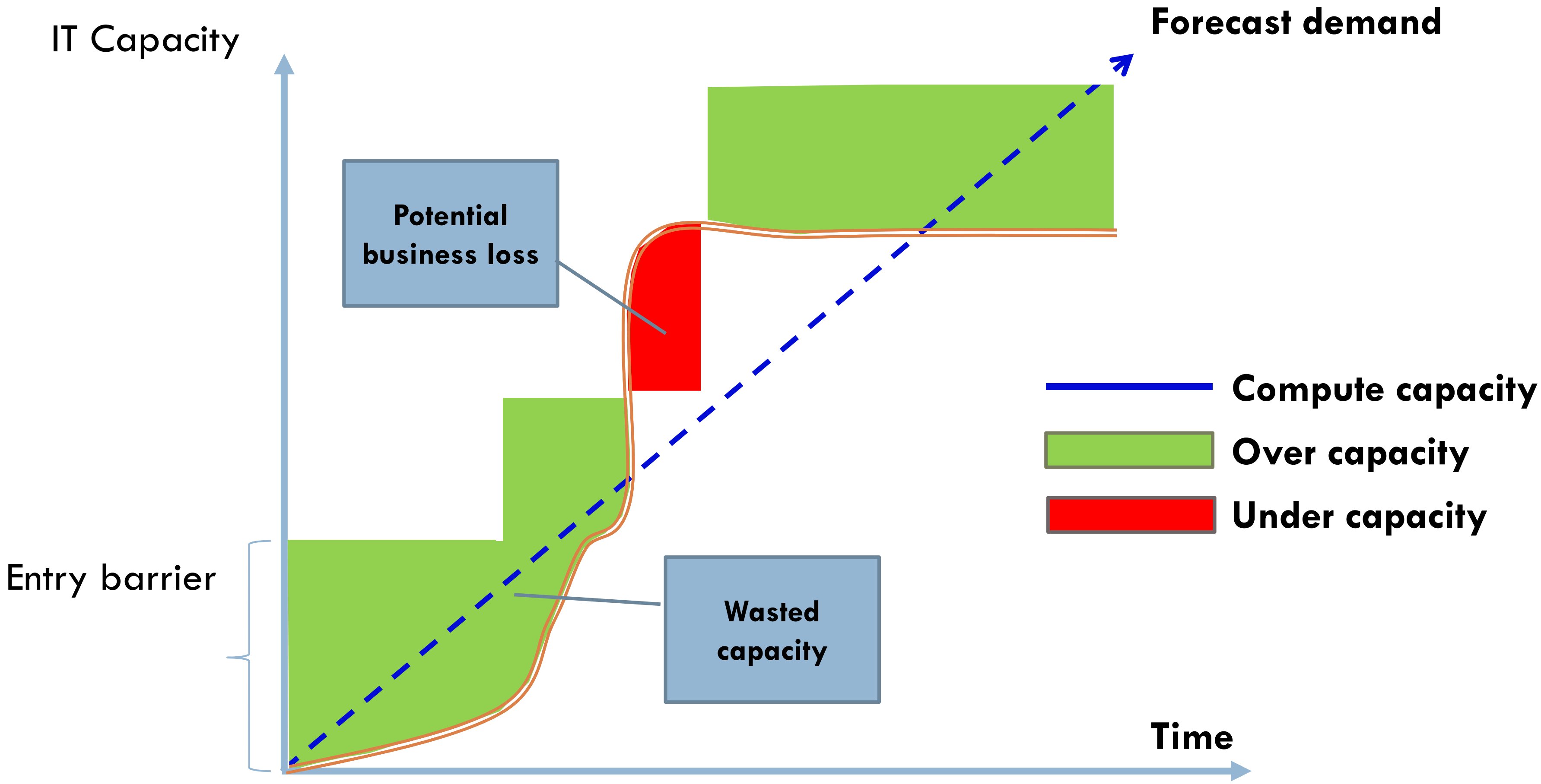
These aren't the only models

- What about a revenue-generating application
  - Why might it ever live on the cloud?

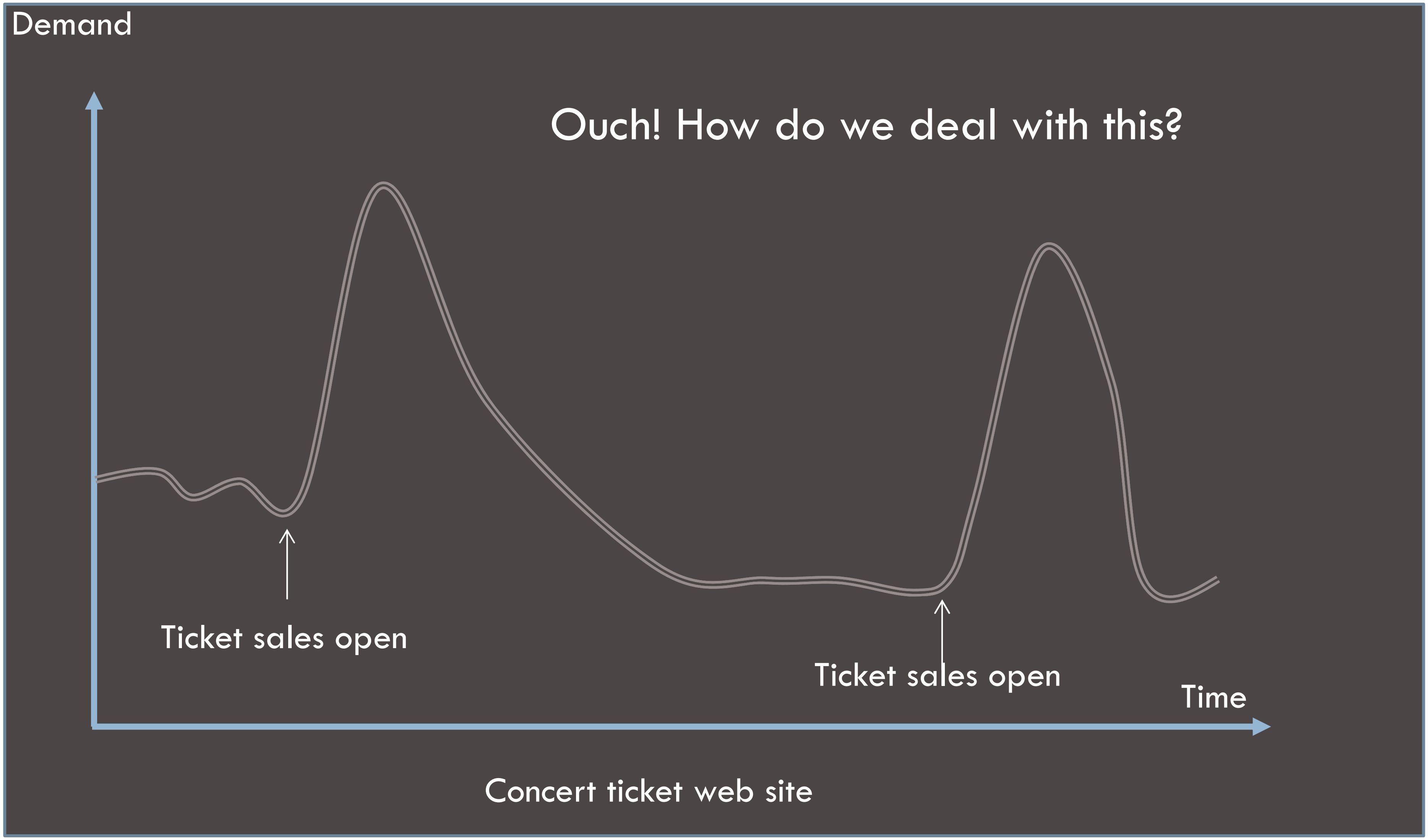
- Imagine that doctors pay "MedRecords4Us" a subscription fee

- Would it make sense for the company to migrate their application to a cloud?

Managing Demand



Coping with Demand Bursts



IT Agility

- How quickly can you
  - Scale up the infrastructure and applications?
  - Upgrade to the latest OS?
  - Respond to a company merger with new requirements for business process and IT capacity?
  - Respond to a divestiture

Cloud Computing

- Shared, multi-tenant environment
- Pools of computing resources
- Resources can be requested as required
- Available via the Internet
  - Private clouds can be available via private WAN
- Pay as you go

Technologies and monetization

- Fundamentally, a technology *must be profitable to survive.*
  - Better technologies often fail
  - The technology everyone buys wins. Then eventually it might acquire features from the losing solutions

- Moreover, the income story needs to "scale"

Two more examples. Who wins?

- Company A has an amazing technology but you need to be an expert to use it.
  - So they hire and train experts of their own
  - When you buy their package they do the work for you

- Company B has a less amazing technology but it just installs itself and works
  - No need to hire experts
  - Just buy as many user accounts as you need

Theil (Stanford)

- In addition to incorrectly assuming that better technology wins over inferior technology, people often confuse competition with competitive success
  - Aggressive competition often *drives pricing down*
  - Much better to be the owner of a unique niche: sole provider of such-and-such a must-have application
    - You can charge higher prices (although not *too* high or competitors move in aggressively). So profit margins will be sharply higher
    - You become a must-be-there platform for advertising aimed at your class of clients, bringing you revenue
- In effect: the best position to be in is to create your own niche and operate it as a mini-monopoly!

Key insight

- Company A will eventually be limited by the number of experts it can actually hire & train
  - So after a period of growth it will stall
  - The revenue stream peaks and this chokes investment in the evolution of the product
  - Ultimately, company A will either fail or at least reach some sort of saturation point
- Company B sees no end in sight and the money pours in
  - This allows B to invest to improve its technology
  - Eventually it will catch up with A on features

Applied to cloud computing?

- We need to ask which stage of the cloud we've reached!
  - But one complication: it isn't just "one" cloud
  - The cloud is a "sum" of multiple business stories/models

- Early business of the cloud was the initial Internet boom (it gave us pets.com and similar web sites)
  - Only a few survived, like Amazon.com, Expedia
  - Winning wasn't easy for them or much fun!

Waves of the cloud revolution

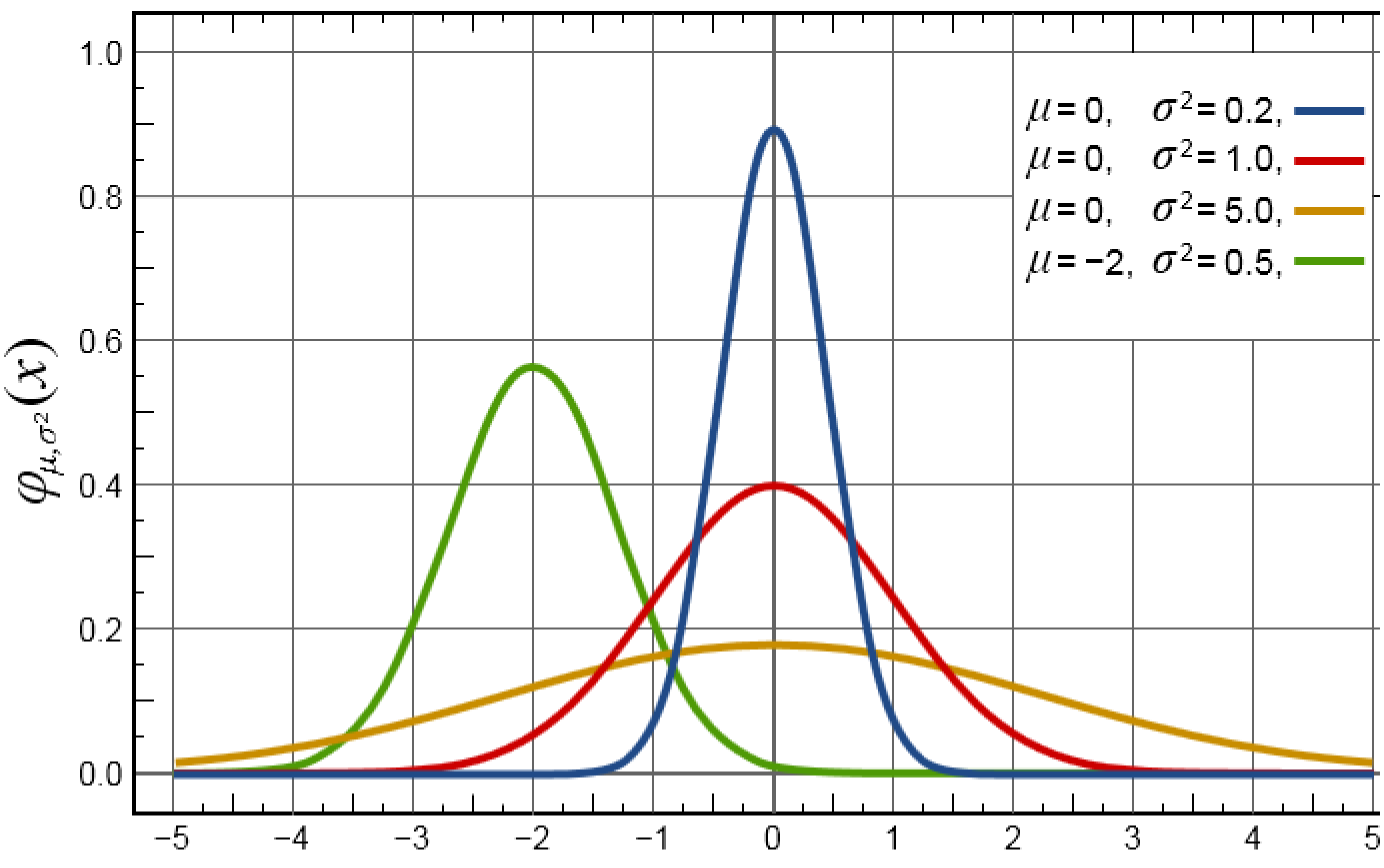
- Early web browser stage
  - Search and advertising (Google)
  - Social Networking (Facebook, Twitter)
  - Cloud as your "home": AOL, Yahoo!, MSN, Google
- Emergence of true web services model
  - Infrastructure as a service ("rent a VM") Apps (Apple)
  - Frames, full cross-site federation
  - Full-featured scripting languages (Javascript, Caja, Silverlight, Adobe Flash…)
- What next?

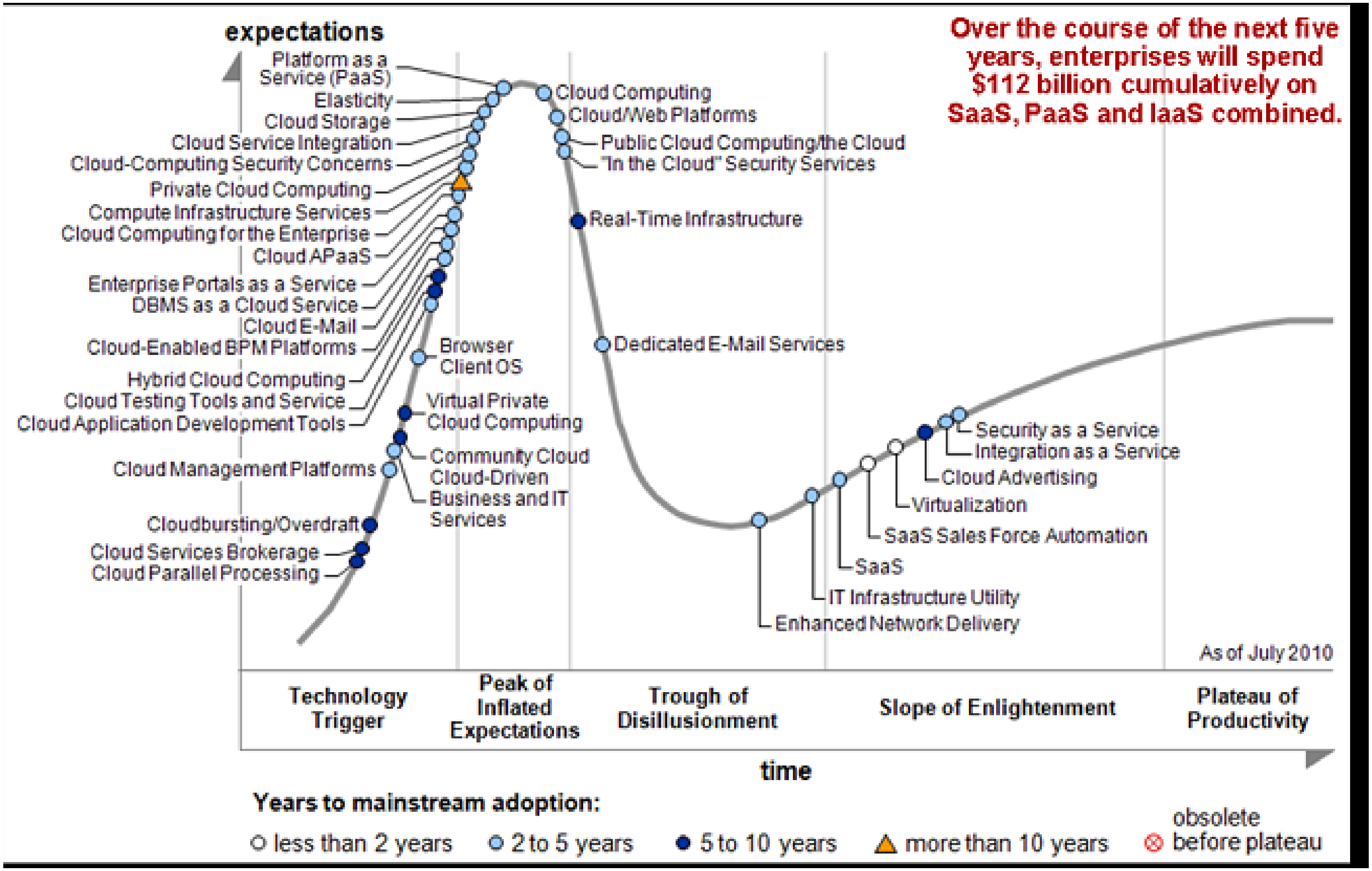
Each has its own revenue model!

- For each style of web solution need to ask what monetizes that model!
  - Google and Facebook make their money on advertising
  - Microsoft combines technology license revenue with advertising, but earns much more on technology
  - Apple earns money on every App
  - Amazon sells stuff but also runs massive data centers really well, and rents space on those
  - Infosys does rote tasks incredibly well and incredibly cheaply (because most of their employees earn $6,500/yr)
- Following the money is the key to understanding what directions each will follow

So the cloud is a sum of stories

- Many of these revenue stories “superimposed”




expectations
Over the course of the next five years, enterprises will spend $112 billion cumulatively on SaaS, PaaS and IaaS combined.
Platform as a Service (PaaS)
Elasticity
Cloud Storage
Cloud Service Integration
Cloud-Computing Security Concerns
Private Cloud Computing
Compute Infrastructure Services
Cloud Computing for the Enterprise
Cloud APaaS
Enterprise Portals as a Service
DBMS as a Cloud Service
Cloud E-Mail
Cloud-Enabled BPM Platforms
Hybrid Cloud Computing
Cloud Testing Tools and Service
Cloud Application Development Tools
Cloud Management Platforms
Cloudbursting/Overdraft
Cloud Services Brokerage
Cloud Parallel Processing
Browser Client OS
Virtual Private Cloud Computing
Community Cloud
Cloud-Driven Business and IT Services
Cloud Computing
Cloud/Web Platforms
Public Cloud Computing/the Cloud
"In the Cloud" Security Services
Real-Time Infrastructure
Dedicated E-Mail Services
Security as a Service
Integration as a Service
Cloud Advertising
Virtualization
SaaS Sales Force Automation
SaaS
IT Infrastructure Utility
Enhanced Network Delivery
As of July 2010
Technology Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Years to mainstream adoption:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau

Inescapable Conclusion?

- **Some of today's cloud computing stories will probably fail as business models**

- **Wallstreet may not realize this, yet!**

The terms have many meanings!

- Everyone talks about cloud computing but there is very little consensus on what cloud computing means
  - We've studied it all semester now
  - But the cloud brings together a lot of technologies that each do very different things
- Best definition so far is basically:
  - *A style of computing that makes extensive use of network access to remote data and remote data centers, presented through web standards.*
  - But this is so general it says almost nothing!

What is a Cloud Platform? Some defining characteristics

- It lets developers create and run apps, store data, and more
- It provides self-service access to a pool of computing resources
- It allows granular, elastic allocation of resources
- It allows charging only for the resources an application uses

Public Clouds and Private Clouds

Typical definitions

- Public cloud: A cloud platform run by a service provider made available to many end-user organizations
- Private cloud: A cloud platform run solely for a single end-user organization, such as a bank or retailer
  - The technology can be much like public clouds, but the economics are different
- Most organizations will probably use some hybrid of both

Cloud Platform Technologies

- The most important today:
  - Computing
    - Infrastructure as a Service (IaaS)
    - Platform as a Service (PaaS)
  - Storage
    - Relational storage
    - Scale-out storage
    - Blobs
- There are many more
  - Messaging, identity, caching, …

Computing

Infrastructure as a Service (IaaS)

- Developers create virtual machines (VMs) on demand
  - They have full access to these VMs
- Strengths:
  - Can control and configure environment
  - Familiar technologies
  - Limited code lock-in
- Weaknesses:
  - Must control and configure environment
  - Requires administrative skills to use

Computing
Platform as a Service (PaaS)

- Developers provide an application, which the platform runs
  - They don’t work directly with VMs
- Strengths:
  - Provides higher-level services than IaaS
  - Requires essentially no administrative skills
- Weaknesses:
  - Allows less control of the environment
  - Can be harder to move existing software

Computing

What's the most popular approach?

- IaaS is more widely used today than PaaS
  - Gartner estimates that public IaaS revenues are significantly greater than public PaaS revenues today
- Perspective:
  - IaaS is easier to adopt than PaaS
    - IaaS emulates your existing world in the cloud
  - Over time, PaaS is likely to dominate
    - PaaS should have an overall lower cost than IaaS
    - It's typically a better choice for new applications

Storage
Relational

- Traditional relational storage in the cloud
  - With support for SQL
- Strengths:
  - Familiar technologies
  - Many available tools, e.g., for reporting
  - Limited data lock-in
  - Can be cheaper than on-premises relational storage
- Weaknesses:
  - Scaling to handle very large data is challenging

Storage
Scale-out

- Massively scalable storage in the cloud
  - No support for SQL
- Strengths:
  - Scaling to handle very large data is straightforward
  - Can be cheaper than relational storage
- Weaknesses:
  - Unfamiliar technologies
  - Few available tools
  - Significant data lock-in

Storage

Blobs

- Storage for *B*inary *L*arge *OB*jects in the cloud
  - Such as video, back-ups, etc.
- Strengths:
  - Globally accessible way to store and access large data
  - Can be cheaper than on-premises storage
- Weaknesses:
  - Provides only simple unstructured storage

CLOUD PLATFORMS: BUILDING A FRAMEWORK

Cloud Platforms

Representative technologies and vendors

	Computing			Storage		
	IaaS	*IaaS*	*PaaS*	*Relational*	*Scale-Out*	*Blobs*
Amazo						
Google						
Salesfor						

Key

Cloud Platform Service

Cloud Platform Software

Cloud Service or Cloud Software?

Understanding the alternatives

- Cloud platform service
  - A hardware/software combination
  - Typically provided by organizations that run Internet-scale services, e.g., Microsoft, Amazon, and Google
    - They write their own software

- *Cloud platform software*
  - Provided by software vendors and open source projects
    - Hosters can use this software to offer a public cloud service
  - The same software can also be used in private clouds

Applying Public Cloud Platforms (1)

Some characteristics of typical applications

- Apps that need high reliability
  - Example: A SaaS application
- Apps that need massive scale
  - Example: A Web 2.0 application
- Apps with variable load
  - Example: An on-line ticketing application
- Apps that do parallel processing
  - Example: A financial modeling application

Applying Public Cloud Platforms (2)

Some characteristics of typical applications

- Apps with a short or unpredictable lifetime
  - Example: An app created for a marketing campaign
- Apps that must fail fast or scale fast
  - Example: Start-ups
- Apps that don’t fit well in an organization’s data center
  - Example: A business unit that wishes to avoid its IT department
- Apps that can benefit from external storage
  - Example: An application that archives data

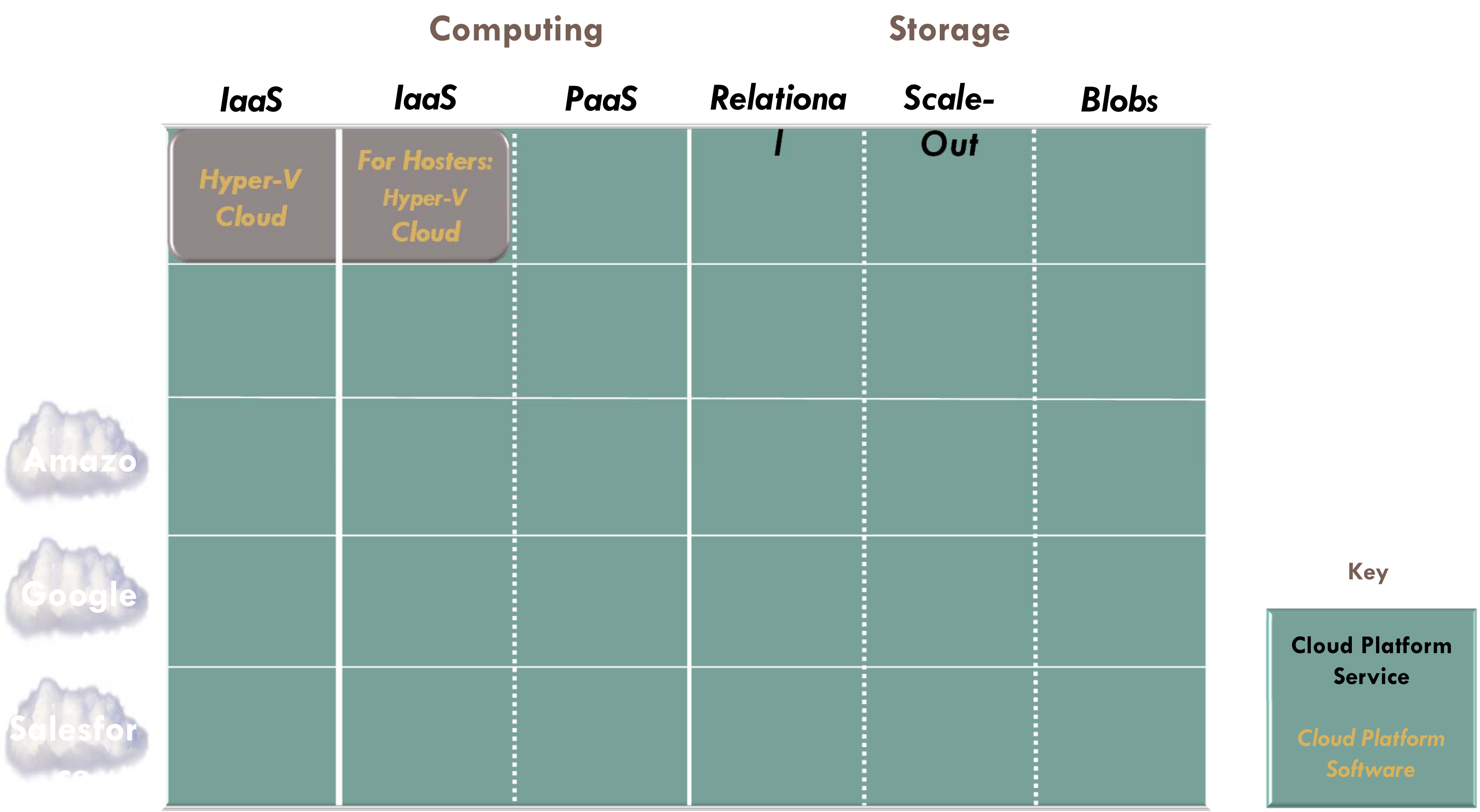
CLOUD PLATFORMS: APPLYING THE FRAMEWORK

From Server Virtualization to Private Clouds

- IaaS allows allocating, managing, and charging for VMs in a more effective way
- This idea first appeared in a public cloud platform
  - If it makes sense there, why not use it in your own data center?
- Private clouds provide IaaS in your data center
  - Although they can also offer more application-oriented services

Microsoft

Private and public cloud platform software



VMware

Private and public cloud platform software

	Computing			Storage		
	IaaS	IaaS	PaaS	Relational	Scale-Out	Blobs
	Hyper-V Cloud	For Hosters: Hyper-V Cloud				
	vCloud	For Hosters: vCloud				
Amazo						
Google						
Salesfor ce						

Key

Cloud Platform Service

Cloud Platform Software

Windows Azure Platform

Public cloud platform

	Computing			Storage		
	IaaS	***IaaS***	***PaaS***	***Relational***	***Scale-Out***	***Blobs***
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
	vCloud	*For Hosters: vCloud*				
Amazo						
Google						
Salesfor						

Key

Cloud Platform Service

Cloud Platform Software

Windows Azure Platform

Pricing examples (in US dollars)

- Compute: $0.05/hour to $0.96/hour for each instance (depending on instance size)
- Storage:
  - Blobs and tables:
    - Data: $0.15/GB per month
    - Access: $0.01/10,000 operations
  - Relational:
    - $9.99/GB per month
- Bandwidth:
  - Inbound: Free
  - Outbound: $0.15/GB

VMware Cloud Foundry

Public cloud platform software

	Computing			Storage		
	IaaS	*IaaS*	*PaaS*	*Relational*	*Scale-Out*	*Blobs*
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
	vCloud	*For Hosters: vCloud*	*Cloud Foundry Frameworks*	*Cloud Foundry Storage*		
Amazo						
Google						
Salesfor ce						

Key

Cloud Platform Service

Cloud Platform Software

VMware Cloud Foundry

Essentials

- Cloud Foundry is an open source PaaS platform
  - Led by VMware
- Designed to support diverse technologies:
  - Frameworks: Spring, Rails, etc.
  - Storage: MySQL, MongoDB, etc.
- Not yet available as a service
  - VMware provides a public dev/test service
  - Partners will provide commercial public platforms

Amazon Web Services

Public cloud platform

	Computing			**Storage**		
	IaaS	***IaaS***	***PaaS***	***Relational***	***Scale-Out***	***Blobs***
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
	vCloud	*For Hosters: vCloud*	*Cloud Foundry Frameworks*	*Cloud Foundry Storage*		
Amazo		Elastic Compute Cloud (EC2)	Elastic Beanstalk	Relational Database Service (RDS)	SimpleDB	Simple Storage Service (S3)
Google						
Salesfor ce						

Key

Cloud Platform Service

Cloud Platform Software

A Broader View of IaaS/Paas

An aside

- More than cloud compute can be viewed through the IaaS/PaaS lens

- Example: Cloud options for relational storage
  - Run a database server in an AWS EC2 VM
    - An IaaS storage service
  - Use a managed database server with AWS RDS
  - Use a managed database service with SQL Azure
    - A PaaS storage service

Amazon Web Services

Pricing examples

- Compute: \$0.02/hour to \$3.68/hour for each VM (depending on size and OS)
- Storage (blobs):
  - Data: \$0.14/GB per month to \$0.037/GB per month (depending on data size and redundancy)
  - Access: \$0.01/1,000 PUT, COPY, POST, LIST operations, \$0.01/10,000 GET operations
- Bandwidth: Free inbound, \$0.12/GB to \$0.05/GB out (depending on volume)

Eucalyptus
Private cloud software

	Computing			Storage		
	IaaS	*IaaS*	*PaaS*	*Relational*	*Scale-Out*	*Blobs*
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
	vCloud	*For Hosters: vCloud*	*Cloud Foundry Frameworks*	*Cloud Foundry Storage*		
Amazon	*Eucalyptus*	Elastic Compute Cloud (EC2)	Elastic Beanstalk	Relational Database Service (RDS)	SimpleDB	Simple Storage Service (S3)
Google						
Salesforce						

Key

Cloud Platform Service

Cloud Platform Software

The Commoditization of IaaS

An aside

- Public IaaS compute service is widely available today

- Providers include:
  - GoGrid Cloud Hosting
  - Terremark vCloud Express
  - IBM SmartCloud Enterprise
  - Rackspace Cloud Servers
    - A leader in creating *OpenStack*, open source IaaS private/public cloud platform software

Google App Engine

Public cloud platform

	Computing			Storage		
	IaaS	*IaaS*	*PaaS*	*Relational*	*Scale-Out*	*Blobs*
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
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Amazo	*Eucalyptus*	Elastic Compute Cloud (EC2)	Elastic Beanstalk	Relational Database Service (RDS)	SimpleDB	Simple Storage Service (S3)
Google			App Engine		Datastore	Blobstore
Salesfor						

Key

Cloud Platform Service

Cloud Platform Software

Google App Engine
Pricing examples (today)

- Compute: $0.10/CPU hour
- Storage:
  - Datastore: $0.15/GB per month
  - Blobstore: $0.15/GB per month
- Bandwidth: $0.10/GB in, $0.12/GB out

- App Engine also allows some free usage every day
  - Other platforms have a free tier as well

Salesforce.com Force.com

Public cloud platform

	Computing			Storage		
	IaaS	*IaaS*	*PaaS*	*Relational*	*Scale-Out*	*Blobs*
	Hyper-V Cloud	*For Hosters: Hyper-V Cloud*	Windows Azure	SQL Azure	Windows Azure Tables	Windows Azure Blobs
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Google			App Engine		Datastore	Blobstore
Salesfor			AppForce VMForce	Database .com		

Key

Cloud Platform Service

Cloud Platform Software

Salesforce.com Force.com

Pricing examples

- One (small) application is free
- Enterprise Edition: $50/user per month
  - Compute: up to 10 applications
  - Storage: up to 200 database objects
  - Bandwidth: No extra charge
- Unlimited Edition: $75/user per month
  - Compute: unlimited applications
  - Storage: up to 2,000 database objects
  - Bandwidth: No extra charge

Challenges to Adoption

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FEATURES

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Cloud Computing Brings New Legal Challenges

By Shari Claire Lewis
July 08, 2009

In the early days of personal computing, users depended on "local" drives and stored their data on floppy disks kept in containers on desktops or in drawers. Applications from software manufacturers permitted users to create, manage and manipulate their business and personal information.

But in short order, software became more and more sophisticated and floppy disks were replaced by hard drives. Operating systems became faster, hard drives were developed with even more capacity and programs grew in size and scope.

Eventually the advent of networks allowed ever bigger programs to be shared among multiple users accessing ever-growing data banks. Nevertheless, networks remained largely tethered to the location of the users, who, at least theoretically, maintained both physical possession and control over the data.

The trend today is toward something different: Whereas companies may still prefer their employees to be in geographic proximity to urban centers of business and government, the cost of prime real estate, and the availability of fast online interconnectedness in many locations that would otherwise be considered remote, make cloud computing a viable and cost effective alternative. Accordingly, data and data applications that are kept in a cloud may be physically located in one or more remote servers but are nevertheless transparently available to company users.[FOOTNOTE 1]

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- Gmail, other Google apps, out of beta
- Red Hat Enterprise Linux and IBM Power Systems: Extraordinary performance and value WHITE PAPER
- Cloud security demands greater scrutiny than traditional IT

Google has bolstered the security of its office productivity tools, for example earlier this year adding a

Challenges to Adoption (continued)

Area	Specific Challenge	Ownership Dimension	
		Private Cloud	Public Cloud
Understanding of the Paradigm	Agreement on Definition	Low	Medium
	Confusion on What Provided	High	High
	Multi-Tenancy Concerns	Low to NA	Medium
	Unrealistic Vendor Claims	Medium	High
	CIO Role Changes	Low	Low
	Cloud Lock-In	Low to NA	High
Implementation/Operations	Architecture Immaturity	High	High
	Manageability	High	High
	VM Memory Limits	Low	Low
	WAN Performance	Low	Medium
	Potential Loss of Control	Low	Medium
	Provisioning	Medium	Medium
	Licensing Models	Medium	Medium
	Governance	High	High
	Confidence	Low	Medium
	Service Provider Motivation	Low	High
	Provider SLAs	Low	High
Security/Compliance	Adequate Threat Models	Medium	High
	Workable Cross-Domain Security	Low	Medium
	Data-at-Rest Security	Low	High
	Auditability	Medium	High
	Accepted Accreditation Processes	Medium	High
	Accepted Compliance Processes	Medium	High
	Physical Location	Low to NA	Medium

Challenges to Adoption (continued)

- Un
  - Definition: Lack of agreement over what exactly constitutes “cloud computing”
  - Confusion: Over what benefits cloud computing will provide, and the trade-offs
  - Multi-Tenancy:
    - How comfortable is an enterprise in storing its data in an environment shared with other customers?
    - What is the risk and the mitigation for data leakage?
    - How does this differ from what we did in the mainframe era?
  - Outrageous Vendor Claims and Obfuscation of Challenges:
    - Hinder understanding of cloud computing
    - What exactly are we buying?
    - To what is the vendor committing (especially true for a hosting vendor)?

		Ownership Dimension	
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	Physical Location	Low to NA	Medium

Challenges to Adoption (continued)

- Understanding of the Paradigm (continued)
  - Role changes: The CIO (or equivalent) may need to evolve to a general contractor in many areas.
  - Lock-In:
    - How difficult would it be to move large volumes of data to a different cloud (cloud provider)?
    - This is both a procedural and a technical issue (format, bandwidth)

Challenges to Adoption (continued)

- Implementation/Operations
  - Architecture:
    - There is much disagreement over the necessary elements for a cloud technical architecture, and the elements are not mature.
    - In addition, SOA is the best approach for interface to clouds, yet culture for SOA success is immature and poorly understood.
    - There is much discussion over common cloud APIs, but none exist
  - Manageability: from the user perspective:
    - Existing management tools do not seem to be able to track metrics for applications that may reside on a varying number of different systems (not a problem where solution is a single VM)
    - How does asset management change in the cloud?
    - Distributed Management Task Force (DMTF) has initiated a working group to address (http://www.dmtf.org/about/cloud-incubator)
  - Memory limits within VM technology: VMs, which are approaching being a requisite design element, can address less memory than the physical OS. The latest product releases largely obviate this limitation.
  - WAN performance: Many geographies still are limited in their backbone capacity.

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Challenges to Adoption (continued)

- Implementation and Operations (continued)
  - Loss of control: Will business elements of the enterprise bypass the enterprise's IT organization?
  - Governance:
    - In which deployment models and use-cases does this play?
    - Is governance antithetical to the concept of cloud?
    - Will lack of governance aggravate problems already associated with lack of SOA governance?
  - Provisioning: For SaaS, how will applications and application components be provisioned?
  - Licensing: Vendors have been slow to develop appropriate models.
  - Confidence: As to reliability, scalability, and security in public clouds (economics will also drive cloud vendors to minimize costs)

Challenges to Adoption (continued)

- Implementation and Operations (continued)
  - <u>Motivation for the Provider</u>:
    - Ideally, providers keep just ahead of demand
    - May provide motivation for providers to federate and sell capacity to each other as do utility companies. Are there lessons from the power utility companies?
    - Aggravates manageability problem
    - Is the capacity really there for surge levels? Will another tenant's surge impede your ability to do the same?
  - <u>Service-Level Agreements</u>: There have been effectively no substantive guarantees from public cloud providers.

Challenges to Adoption (continued)

- Se[illegible] Challenges
  - Threat Models: What new models arise in the cloud? Have we further aggravated issues already present within SOA and with standard computing vulnerabilities?
    - Examples:
      - Dynamic virtual machines – How much control to the user?
      - Resource isolation (appropriate isolation measures are needed):
        - VM-to-VM attacks
        - Data leakage
      - Weakened perimeter – Firewall ports enabling user access are a vulnerability
      - Patch and security control management – Becomes the user's responsibility; aggravated by VM dynamism
      - H[illegible] – Consistency of control; ensuring the user understands where their data resides
      - Administrative access across networks – A vulnerability also inconsistent with some security policies

Area	Specific Challenge	Ownership Dimension	
		Private Cloud	Public Cloud
Understanding of the Paradigm	Agreement on Definition	Low	Medium
	Confusion on What Provided	High	High
	Multi-Tenancy Concerns	Low to NA	Medium
	Unrealistic Vendor Claims	Medium	High
	CIO Role Changes	Low	Low
	Cloud Lock-In	Low to NA	High
Implementation/Operations	Architecture Immaturity	High	High
	Manageability	High	High
	VM Memory Limits	Low	Low
	WAN Performance	Low	Medium
	Potential Loss of Control	Low	Medium
	Provisioning	Medium	Medium
	Licensing Models	Medium	Medium
	Governance	High	High
	Confidence	Low	Medium
	Service Provider Motivation	Low	High
	Provider SLAs	Low	High
Security/Compliance	Adequate Threat Models	Medium	High
	Workable Cross-Domain Security	Low	Medium
	Data-at-Rest Security	Low	High
	Auditability	Medium	High
	Accepted Accreditation Processes	Medium	High
	Accepted Compliance Processes	Medium	High
	Physical Location	Low to NA	Medium

Challenges to Adoption (continued)

- Security and Compliance (continued)
  - Cross-Domain Security: How does an organization extend or federate its authentication and authorization mechanisms into the cloud?
  - Data-at-Rest Security: What encryption and segregation mechanisms are provided?
  - Auditability: Can access to the data be audited?
    - Are data storage formats even amenable to auditing (more of an issue for chunking types of storage that lose the concept of a file)?
    - Forensics, as applications are not linked to physical infrastructure and the number of physical assets in play may vary
  - Accreditation in the Cloud:
    - How can you tell a cloud is “secure”?
    - Is there governing policy and procedures to accredit a cloud?
    - What processes and controls must be in place? (Pre-accredited clouds may actually simplify this process)

Challenges to Adoption (continued)

- Security and Compliance (continued)
  - Compliance: May preclude cloud paradigm in some cases due to:
    - Physical chain of custody requirements
    - Regulatory requirements
  - Physical Location:
    - Do you know what country your cloud resides in?
    - Would you know if it changed?
    - What compliance requirements change?
    - Is there governing law that recognizes the paradigm?
- Conclusions:
  - There are many challenges to adoption of the cloud paradigm
  - Public clouds and private clouds have different sets of challenges, with some overlap

The last word

- Joni Mitchell summed it up best:

I've looked at clouds from both sides now
From up and down, and still somehow
It's cloud illusions I recall...
I really don't know clouds at all

- The cloud is a *very* complex marketplace and evolving rapidly.
  - Economics are the key
  - But nobody really understands cloud economics
  - There are many barriers to entry