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Envisioning the Cloud: The Next Computing Paradigm

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Executive Summary

Every dozen or so years, a revolution changes the way we use computers: huge mainframes in the 1960s, minicomputers in the 1970s, personal computers in the 1980s, cell phones and smart phones in the last decade, and now the emergence of cloud computing.

What technologists like to call "the cloud" is the idea of computing on demand. Just as you turn on a faucet to get water or plug into a wall to get electricity, the features and functions of stand-alone computers today can be streamed to you over the Internet. The cloud is changing the possibilities for computing by giving individuals and small and mid-sized businesses access to an array of powerful applications and services through the Internet that were once unavailable to all but the largest enterprises.

The cloud is accessible through any digital device – a laptop, a cell phone, or a smartphone – that can connect to the Internet. And with 1.5 billion people around the world connected to the Internet, cloud-based services like web-mail, social networking, photo sharing, and video viewing are already interwoven into the fabric of our daily lives. It is also driving a shift in the way businesses and institutions of all sizes use technology to do everything from inventing new products to managing back-office finances.

In the cloud, applications are accessible anywhere, anytime, and storage becomes, for all intents and purposes, infinite. In this sense, the cloud is not an island, but a global connector of the world's information and users. But while this vision of a powerful, low-cost, and energy-efficient approach to future computing is a rosy one, complex policy issues will shape the cloud's development.

On the one hand, widespread adoption of the cloud will require broad-based consensus on standards and protocols for everything from data security to consumer privacy. On the other hand, any attempt to "mandate" consensus will disrupt a market that is already developing practical responses on its own, without the mediation of legislators and regulators. Ideally, what governments can do best is to clear the road, not pave it.

Understanding the Cloud

The definitions of cloud computing are nearly as numerous as its applications. Here is the definition we propose in this paper:

Cloud computing *represents a new way to deploy computing technology to give users the ability to access, work on, share, and store information using the Internet. The cloud itself is a network of data centers – each composed of many thousands of computers working together – that can perform the functions of software on a personal or business computer by providing users access to powerful applications, platforms, and services delivered over the Internet.*

By altering the basic economics of access to computing and storage, the cloud has the potential to reshape how U.S. and global businesses are organized and operate:

- Technology start-ups would have lower capital requirements to get up and running.
- Big companies would manage IT resources without tying up capital in IT capacity, while managing energy resources more efficiently.
- Individual consumers would have access to an endless array of powerful applications at low cost.
- Software developers could allocate time and talent to innovation rather than to building and maintaining IT infrastructure.
- Organizations of all kinds would have new platforms to foster cooperation and collaboration, without the coordination costs typically associated with bringing people and work together.
- And governments would have new ways to connect to citizens, deliver services, and share network-based tools, knowledge, and information.

Benefits of the Cloud

It is hard to argue with the logic that supports a network-based model for computing because of the appeal of ubiquitous computing services and the efficiency of centralizing such services. In many industries, however, ubiquity and centralization have resulted in homogeneity or "one size fits all" solutions.

With cloud computing, there is potential for the opposite result: an explosion in creativity, diversity, and democratization predicated on creating ubiquitous access to high-powered computing resources and related software and services. As cloud computing has taken hold, there are six major benefits that have become clear:

- **Anywhere/anytime access** – the cloud promises "universal" access to high-powered computing and storage resources for anyone with a network access device.
- **Specialization and customization of applications** – the cloud is a platform of enormous potential for building software to address a diversity of tasks and challenges.
- **Collaboration among users** – the cloud represents an environment in which users can develop software-based services and from which they can deliver them.
- **Processing power on demand** – the cloud is an "always on" computing resource that enables users to tailor consumption to their specific needs.
- **Storage as a universal service** – the cloud represents a remote but scalable storage resource for users anywhere and everywhere.
- **Cost benefits** – the cloud promises to deliver computing power and services at a lower cost.

Enabling the Cloud

Despite such an exhaustive array of benefits and the already high rates of consumer adoption, the cloud remains in its early stage of development. To become the next computing paradigm – democratizing computing resources for the masses – the cloud will demand an ecosystem. That ecosystem will go far beyond the obvious examples of providers of cloud services (operators of data centers) and their customers (individuals and organizations). It will require sustained innovation from digital device manufacturers, bandwidth providers (cable companies and telcos), and content companies (media, content, and software makers), among others.

To promote the cloud ecosystem, it will be critical for policy-makers and business people alike to understand the enablers and barriers that will shape the future of cloud computing, as well as many of the legal and regulatory issues cloud computing may raise.

There are eight fundamental elements for "enabling" the cloud and realizing its full potential:

- **Universal connectivity** – users must have near-ubiquitous access to the Internet
- **Open access** – users must have fair, non-discriminatory access to the Internet
- **Reliability** – the cloud must function at levels equal to or better than current stand-alone systems
- **Interoperability and user choice** – users must be able to move among cloud platforms
- **Security** – users' data must be safe
- **Privacy** – users' rights to their data must be clearly defined and protected
- **Economic value** – the cloud must deliver tangible savings and benefits
- **Sustainability** – the cloud must raise energy efficiency and reduce ecological impact

Policy and the Cloud

The final "enabler" of a flourishing cloud is enlightened public policy. If cloud computing can democratize technology by making the same computing power available to individuals and small- and medium-sized businesses that the largest enterprises enjoy, elected officials have the opportunity to assure delivery of its enormous benefits to their constituents.

In fact, Washington can help determine how quickly the cloud grows; whether it realizes its full potential; and perhaps, equally important, whether the United States becomes the vital center of a global cloud ecosystem.

For the United States to lead, a delicate balance must be struck. On the one hand, policy-makers can play an important role by helping to ensure universal connectivity to broadband, policing cyber-crime, removing obstacles to fair and open Internet access, and making sure government itself adopts cloud services. Government should also examine (or re-examine) pending and established policy in light of the changing nature of information ownership and storage.

On the other hand, the competitive marketplace will heavily influence and likely determine the future of cloud computing. For the cloud to grow naturally, the majority of experts consulted for this paper advocated that government take a "wait and see" approach before rushing in to legislate and regulate this dynamic new space.

In short, what government can do best is clear the road for the cloud's expansion, not pave it.

As avatars of a high-growth industry, cloud providers could foment a dramatic expansion of the U.S. economy, as major players serve the needs of our nation and the world.

As this country seeks to redefine its future, the cloud may be one avenue for the United States to assert economic and technology leadership on a global stage – and to create wealth for American citizens while deploying assets to benefit a global population. It's high time to ensure that the cloud's promise as an opportunity for U.S. wealth generation, job creation, and business and technology leadership does not pass our country by.

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Introduction

Once every dozen or so years, a revolution transpires that changes the way we use computers. Huge mainframes with dumb terminals in the 1960s, minicomputers in the 1970's, the first personal computers in the 1980s, and then, over the last decade, laptops, cell phones and smartphones, and now the emergence of cloud computing.

What technologists like to call "the cloud" is the idea of computing power on demand. Just the way you turn on a faucet to get water or plug into a wall to get electricity, most of the features and functions of stand-alone computers today can be streamed to you over the Internet. That's the concept of cloud computing; it's an idea that's changing the possibilities for computing by giving individual users access to an array of powerful applications and services through the Internet.

The underlying technology may seem impenetrable to all but those who build and maintain it, but the user experience is already widespread. Cloud computing is an essential element of the future that's arrived in aspects of everyday life. For example, fans of online e-mail services such as Yahoo! Mail, Google's Gmail, or Microsoft's Hotmail are accessing cloud-based services. So is everyone who is organizing or building social connections on MySpace or Facebook in the United States, Orkut in Brazil, Bebo in the UK, Mixi in Japan, and CyWorld in Korea (to name only a few social networking sites). Same for business people organizing their contacts on LinkedIn or Plaxo. Even mapping services, such as AOL's MapQuest and Google Maps, operate from the cloud. The same is true for most sites targeting specialized user needs, from TheKnot.com (for weddings), to BabyCenter.com (for new parents), to CarePages.com (for family members coordinating care for someone in the hospital).

Consumers, small- and mid-sized businesses, large-scale enterprises, and government all use the cloud. And it is accessible through any digital device – a laptop, a cell phone, or a smartphone – that can connect to the Internet.

Cloud-based services have become so interwoven into our lives that many users don't know they're participating in a technology revolution. But for most of the 1.5 billion people around the world who are connected to the Internet, the cloud has arrived.[1]

There is game-changing potential inherent in moving more of the world's computing to the cloud. Ultimately, the cloud could make high-powered computing available to anyone and everyone.

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[1] *World Internet Users and Population Stats*. Internet World Stats, 2008

It's the new expression of a time-honored American idea: "universal service" – a core concept in the history of telecommunications regulation since the early days of the Bell System. This is the ultimate promise of the cloud: a world in which "pervasive computing" is everywhere on demand and always available.

In the cloud, applications are accessible anywhere, anytime, and storage becomes, for all intents and purposes, infinite. In this sense, the cloud is not an island, but a global connector to the world's information and users. The result is a dramatic advance for users in accessibility, specialization, collaboration, and ubiquitous access to computing power and storage.

Such centralized computing resources could make available massive computing power and storage to millions of users at a fraction of the costs they incur today – if they could even access such resources at all. By altering the basic economics of access to computing and storage, the cloud could reshape how our national economy is organized and operates:

- Technology start-ups would have lower capital requirements to get up and running.
- Big companies would manage IT resources without tying up capital in IT capacity, while managing energy resources more efficiently.
- Individual consumers would have access to endless arrays of powerful applications at extremely low cost.
- Software developers would allocate time and talent to innovation rather than to building and maintaining infrastructure.
- Organizations of all kinds would have new platforms on which to foster cooperation and collaboration, without the coordination costs typically associated with bringing work and people together.
- And governments would have new ways to connect to citizens, deliver services, and share network-based tools, knowledge, and information.[2]

But while these visions of a powerful, low-cost, and energy-efficient approach to future computing are rosy ones, there is complexity from a policy standpoint to realize that vision as a reality.

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[2] Nick Carr, *The Big Switch Rewiring the World, from Edison to Google* (W. W. Norton: January 7, 2008).

On one hand, it's clear that roll-out of the cloud will require broad-based consensus on standards and protocols governing issues ranging from data security to consumer privacy. On the other hand, it's also clear that any rapid-fire policy action by the government to "mandate" consensus will prove both disruptive and unnecessary to a market that is already developing practical responses on its own, without the mediation of legislators and regulators. Policy-makers should clear the way for the cloud's expansion, not aim to "manage" it.

That makes it high time to understand what the cloud means for the United States, the U.S. economy, and the world. Cloud computing is here to stay. Whether, and how fast, it becomes the next dominant paradigm in computing is the question at hand.

Understanding the cloud

The definitions of cloud computing are nearly as numerous as its applications. Here is the definition we propose in this paper:

Cloud computing *represents a new way to deploy computing technology to give users the ability to access, work on, share, and store information using the Internet. The cloud itself is a network of data centers – each composed of many thousands of computers working together – that can perform the functions of software on a personal or business computer by providing users access to powerful applications, platforms, and services delivered over the Internet.*

The very notion of cloud computing is, at once, familiar and radical. For readers old enough to remember the early days of computing, shared resources were the rule of the day. Before semiconductor technology made computers small, powerful, and affordable, there were mainframes. These early machines of the 1950s and 1960s were expensive to own and operate, creating incentives for users to share them, accessing computing services from "dumb terminals" over phone lines on a "time-sharing" basis. In those days, the computer (or "server") was all-powerful, and the terminal (or "client") was extremely limited in what it could do.

In most cases, time-sharing terminals possessed no actual processing power (they were input/output devices, with keyboards and a teletype) and no memory (users uploaded "code" using paper or magnetic tape readers). As mainframes gave way to minicomputers in the 1970s, and minicomputers gave way to personal computers, or PCs, in the 1980s and 1990s, computer processing and storage became distributed.[3]

[3] Note: Reference to "PCs" in this paper includes any desktop or laptop computer

Over time, PCs were so affordable that it was reasonable to talk about them as just another rapidly evolving category of consumer electronics. Widespread PC adoption enabled the so-called distributed model of computing, where individual users (whether at home or on the job) possessed a complete set of computing resources "in a box," no longer needing to access centralized computing power and storage from a large shared machine or a group of machines.

There are now more than 1.5 billion PCs and one billion laptops in active use in the world today – nearly a PC or PC-equivalent for one of every three human beings on earth. Many of these machines are more powerful than the mainframes of earlier eras. And that's not counting consumer game consoles from companies such as Nintendo, Microsoft, and Sony, which are some of the most powerful "personal" computers ever marketed and sold.

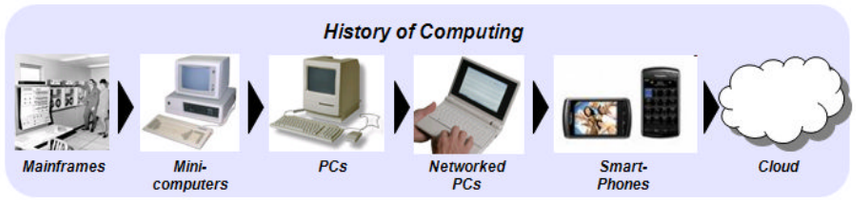
"The cloud allows us to deliver user experiences that were off the table for a long time."

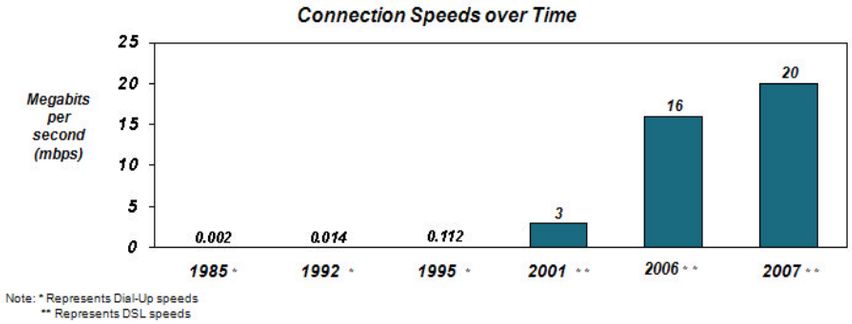
Russ Daniels, Vice President and CTO of Cloud Services Strategy, HP

Starting in the mid-1990s, only 15 years into the PC era, the Internet revolution changed the computing paradigm again. The popularization and commercialization of Internet use with the advent of the World Wide Web made the Internet a consumer-friendly, intuitive place where individuals and businesses alike could connect, communicate, and transact business. The web gave the otherwise arcane Internet – previously, largely the exclusive domain of basic sciences, government, and university communities – an interface that appealed to a mass market.

Consumer uptake of online access spurred economic development of online media and commerce at a breakneck pace through 2000 and beyond. Use of the web was further propelled by the advent in the 1990s of commercial Internet service providers (ISPs), which made online connections more widely available, and more recently with the rise of broadband ISPs, which provided high-speed, "always on" connections through digital service lines (DSL) offered by the major telephone companies and cable modems offered by the nation's cable television operators.

The presence of those high-speed always on connections, in turn, changed how consumers related to PCs. Patterns of usage predicated on slow-speed dial-up connections required powerful computing capacity at the machine level and only small bursts of data exchanged over the network. With the advent of broadband, this pattern became inverted.





Now massive amounts of data could flow to and from the network, a change which required less data, software, and applications to reside on any individual machine. Empowered with broadband access, consumers could tap into web resources for new tools and services. As Russ Daniels, Vice President and Chief Technology Officer of Cloud Services Strategy at Hewlett-Packard, observes: "The cloud allows us to deliver user experiences that were off the table for a long time."

As the network gets more powerful, the potential for variety and specialization of devices becomes endless – and how consumers integrate those devices into their lives can evolve in radical ways. *The Economist* notes: "While most people depend on personal computers more and more at home and at work, we are using them in far different ways than we did 10 or even five years ago. We are using less data and software that sit on our hard-drive and spending more time in our web browsers accessing data and applications that stream through the web. We are more recently seeing the transition of services from PCs to any device with Internet connections, including more portable devices like mobile phones. This is just the beginning."[4]

[4] *Microsoft after Bill Gates* (The *Economist*: June 26, 2008).

The network is the (very big, very powerful) computer

In the last several years, the impact of these trends has become increasingly clear: we've come full circle, and, for many users, the PC has become a terminal. It's emerged as a gateway to the network. As Eric Schmidt, Google's CEO, observed back at the dawn of the web era in 1993, "When the network becomes as fast as the processor, the computer hollows out and spreads across the network." This is the transition we are witnessing today as cloud services take hold. By furnishing applications through the network (software such as Word or PowerPoint that normally runs on PCs), platforms (computing environments or operating systems such as Windows or Linux), and infrastructure (processing power and storage), cloud providers are hollowing out the PC.

That means the PC can not only become smaller and cheaper, but also morph entirely: the Apple iPhone is a powerful computer, but it in no way resembles a PC, it costs less than a PC, it's much smaller, it uses less energy, and it's easier to use. (The Apple App Store, which accounted for roughly half of all software downloads to mobile devices in mid-2008, serves as a dramatic reminder that the iPhone is a computer.) The rise of Netbooks (see sidebar), a new class of super-portable computers designed for web connectivity, also reinforces the notion that cloud computing is poised for explosive growth.

The capabilities of the cloud as a centralized resource can be built at industrial scale. That means that processing power involving tens of thousands of machines embedded in a network has surpassed even stand-alone high-performance machines, such as so-called supercomputers. By making this technology available through the network on an on-demand and as-needed basis, the cloud holds the promise of giving individuals, businesses, organizations, and governments around the world access to extraordinary computing power from any location and any device.

Netbooks

Netbooks are a class of laptops designed for wireless communication and access to the Internet. Netbooks typically are smaller, lighter, and cheaper than general purpose laptops and are primarily designed for web browsing and web-based applications. These small PC's are altering the laptop landscape and reinforcing the acceptance of cloud computing in the lives of consumers.

International Data Corporation estimates that Netbooks will claim 12 percent of the world's entire laptop market in 2009 at 20.6M units. ABI Research projects even stronger unit sales for Netbooks – up to 35 million sold in 2009 and an astonishing (if realized) 139 million in 2013.

Netbooks illustrate the idea that solid, broadband connections to the Internet are more important than large hard drives or ultra-fast processors for most users. In the March issue of Wired, Clive Thompson writes:

"Netbooks are evidence that we now know what personal computers are for. Which is to say, a pretty small list of things that are conducted almost entirely online…Netbooks prove that the 'cloud' is no longer just hype. It is now reasonable to design computers that outsource the difficult work to someone else. The cloud tail is wagging the hardware dog."

Source: Clive Thompson, *The Netbook Effect* (Wired: February 23, 2009).

A complete vision of the cloud involves three "levels" of computing functionality:

Variants of the Cloud

Taken together, these three elements of cloud computing have substantial implications for businesses and organizations. As Microsoft pointed out in a recent white paper, there are several operational considerations at play: first, the cloud shifts "ownership" of software from the user to a third-party provider, which means that software ceases to be an expensive product but rather becomes a pay-as-you-go service. Second, by creating economies of scale in managing the cloud, access to powerful software and applications is no longer limited to large corporations, meaning that small ventures and individuals can access the same powerful applications as global enterprise players. Third, the cloud's acceptance has inspired thousands of developers to create specialized software for niche markets that previously proved commercially unattractive to serve.[5]

[5] Frederick Chong and Gianpaolo Carraro, *Architecture Strategies for Catching the Long Tail* (Microsoft: April, 2006).

On a small scale, this has already happened: we as consumers walk around every day with multiple computers on our persons, from cell phones, Blackberrys, and iPods, to quartz watches, calculators, and GPS devices. Similarly, our cars run on dozens of microprocessors; the performance of many automobiles is determined more by software and systems than by suspensions, transmissions, or drive-trains. The more than 25,000 applications available from the Apple App Store for iPhones and some newer iPods illustrate the reach and power of the cloud.[6] Until now, developing thousands of applications for small groups of users seldom made business sense. Now, vast libraries of software built by third-party developers on Apple's cloud "platform" are available to iPhone users. Small devices like the iPhone or Amazon's Kindle e-book reader are examples of what the computer industry calls a "thin client." The iPhone's success is arguably a function not only of brilliant design, but also of the appeal of cloud services when packaged intuitively and attractively for consumers.

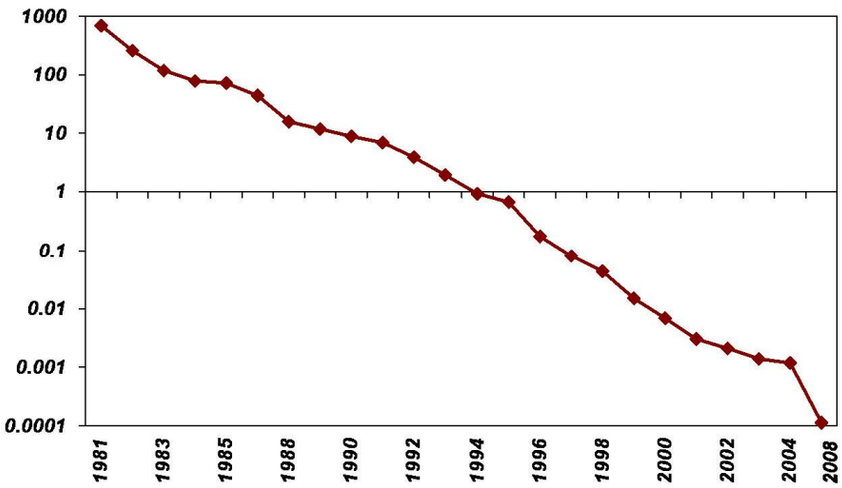
How the data center became possible

The evolution of devices (mainframes, minicomputers, PCs, mobiles) and connectivity (dial-up, DSL, cable modem) is only one part of the cloud story. Technology has also undergone enormous change at the other end of the wire. It's easiest to summarize what's changed according to two well-known "laws," based on the observations of leading technologists. Moore's Law states that semiconductor-based processing power doubles every 18 months, and Kryder's Law states that computer memory, or storage technologies, doubles as a function of price every 12 months. It's noteworthy that these laws, important as they are, apply only to stand-alone machines.

A third observation, known as Grove's Law (after Andy Grove, the former CEO of Intel), posited that the world's supply of bandwidth (or the information-carrying capacity of global communications networks) doubled only every 100 years. That implied that the world was locked into a computing model that required decentralized resources – because connectivity was scarce, expensive, and slow.

[6] *Apple's App Store: 25,000 apps and counting* (Fortune.com Apple.2.0 blog: March 5, 2009).

Worldwide Cost of Storage ($ per Megabyte)[7,8]



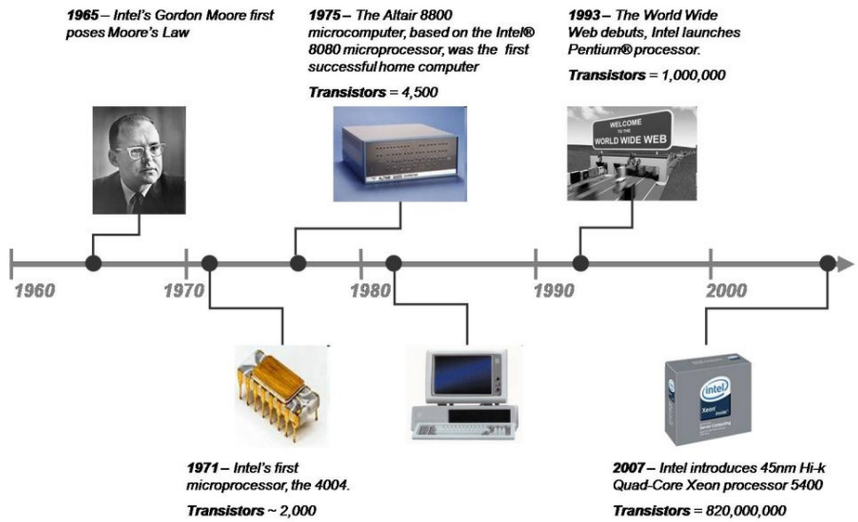
Only recently has all that changed. In the technology boom of the 1990s, massive build-outs of fiber-optic networks essentially invalidated Grove's Law. Even as business models imploded with the bursting of the technology bubble, the new bandwidth remained. The result was a dramatically changed computing landscape: suddenly, connectivity was abundant, fast, and cheap. For the first-time since time-sharing, shared computing resources made sense.

Moreover, it was relevant to ask anew where computing resources should reside in systems of distributed but interconnected users and machines. Advances in processing power, storage, and bandwidth had changed how individual machines could work together.

[7] *Historical Notes about the Cost of Hard Drive Storage Space* (Littlepetshoppe.com)

[8] 2008 Statistic from Amazon Simple Storage Prices

Timeline of Moore's Law [9]



A new model for machine collaboration gave rise to the enabling and fundamental building block of cloud computing – the Data Center. Data centers are, in effect, massive parallel processing machines, composed of tens and sometimes hundreds of thousands of PC-like computers (or servers), networked together in a web of ubiquitous connections. Core to the data center model is the idea that it is easier to generate enormous processing power by linking thousands of generic PC-like machines (or servers) in parallel than to invest in stand-alone high-powered machines, like supercomputers. The whole is significantly greater than the sum of the parts. In a typical data center, the servers are unremarkable commodity PCs. They are cheap and easy to repair or replace; they're easy to modify and upgrade. When thousands of such machines operate in parallel, sharing labor across their "network" within the data center, their computational output can prove breathtaking.

This is how Google and other search engines deliver results pages with such blinding speed. A simple search query typed into Google's search bar travels over an Internet connection to a network of hundreds of thousands of interlinked computers located in several of Google's data centers that sort through a database of billions of web pages to find specific links that match the keywords. The computers then sort those links by relevance (using Google's PageRank algorithm), and send them back to the user in the form of search results.

[9] Intel Timeline of Moore's Law

Google and its brethren perform these enormous tasks of information processing in less than a second. No single machine could do this so comprehensively or so fast, nor could any small cluster of machines. In this way, the technology and scale of the data center trumps stand-alone machines, and it does so without the high costs of traditional computing.

The passengers are driving the bus

Examples of the cloud in action are by no means limited to business applications. Indeed, consumers have undergone what is perhaps the more profound shift in perspective based on the availability of cloud services. Technologist Clay Shirky observes this among the consumers he tracks. "What is driving this shift," he says, "is a change in perspective from seeing the computer as a box to seeing the computer as a door."

> *"What is driving this shift is a change in perspective from seeing the computer as a box to seeing the computer as a door."*
>
> Clay Shirky, Technologist

Distinguishing between the computer and the network is increasingly less relevant – if not irrelevant – from a user's perspective. Popular consumer-oriented cloud services – such as web-mail, social networking, photo sharing, video viewing, and instant messaging – already count users in the hundreds of millions, and most of these services are social media that have rapidly become interwoven into the fabric of consumers' lives.

As Dennis Quan, a computer scientist in IBM's software group observes: "End users in a sense are really driving this next phase of computing, because of the huge growth in demand for everything from mobile banking to video, accessed from any device with a web browser from cell phones to PCs."[10] Mobile use of the cloud by consumers has already exploded: 58% of smartphone users and 85% of iPhone users regularly access the web from their phones.[11] Because mobile devices are intrinsically limited by size, weight, and cost in processing power and storage, they must rely on cloud-based resources to deliver an expanding array of services to their subscribers. Thus, as global penetration of smartphones continues to grow, mobile is positioned to become a dominant entry point into the cloud.

This robust demand from consumers is, in turn, working its way into how small- and medium-sized enterprises manage their organizations and their businesses; it's also part of what's inducing large-scale enterprises and government agencies to follow suit.

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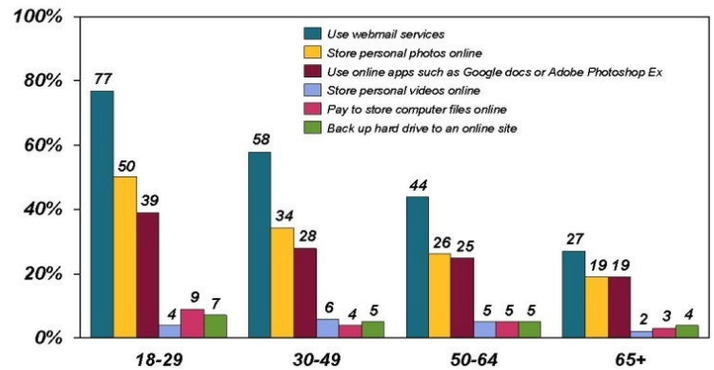
[10] Steve Lohr, *Commercializing the Cloud* (The New York Times: August 1, 2008).

[11] *Survey of U.S .mobile subscribers* (M:Metrics, Inc.: March 18, 2008).

Cloud Computing Activities[12]
(% by age cohort who perform the following online activities)



	18-29	30-49	50-64	65+
Done at least one activity	87%	71%	59%	46%
Done at least two activities	59%	39%	31%	21%

Where we go from here

The emergence of the cloud may define a seminal, if delicate, moment in the history of computing. Despite impressive examples of consumer uptake, many experts like Shelton Shugar, Yahoo!'s Senior Vice President in charge of Cloud Computing and Data Infrastructure, argue that cloud computing is still "in its infancy." As he notes, "This could be the start of a broad-based operating system for the Internet, [but] exactly how [it] will play out is anyone's guess." One thing is certain: If cloud computing does get established as the new paradigm for computing – a seismic shift, as author of *The Big Switch*, Nick Carr, argues (see sidebar) – it implies potentially tremendous change for how business, government, and society function in the future.

For some, the most intuitive way to understand cloud computing is to compare its stage of development today with the web in the early 1990s. The web was an appealing, easy-to-use, and accessible user interface that transformed a (then) 25-year-old innovation called the Internet into a media platform that appealed well beyond the research community. Consumer uptake of the web created an online marketplace that has, in turn, reshaped the U.S. economy. It also drove a period of wealth creation in the United States and positioned this country as a technology leader around the world.

***Nick Carr's* The Big Switch**

In his 2008 book, The Big Switch, *Nick Carr, a former executive editor of the Harvard Business Review, created a useful metaphor to describe cloud computing.*

In the late 19th century, businesses of all sizes stopped generating their own power with steam engines and dynamos, instead coming to rely upon a newly built electric grid to access power resources. Cheap power from electric utilities changed the way businesses operated and set off a chain reaction of economic and social transformations.

Today, Carr argues, a similar revolution is underway as consumers and businesses tap into the Internet's massive computing grid through high-speed connections for information, processing, and storage. Like electricity 100 years ago, computing is turning into a utility with massive consequences, many yet to be seen.

While the electricity analogy is useful in helping to explain how the cloud delivers computing power on demand, the comparison goes only so far. The electric power grid has become a regulated monopoly that, as we will discuss, is not the optimal model for cloud computing.

Source: Nick Carr, *The Big Switch* (W.W. Norton: 2008).

[12] *Pew Internet & American Life Project April-May 2008 Survey*, N=1,553

Today, the cloud is a computing innovation that has proven its appeal to the mass market, even if few consumer users are aware they're using cloud services, and it is showing potential as an enabler of economic growth. Arguably, the web has recently reached a tipping point: it has become the technology platform of choice because it is open, built by the people who use it and not controlled by any one entity. It transcends devices, operating systems, browsers – and all of their quirks. The future of the web is being built in the open for all to see and accessible for any who wish to contribute.

The promise of cloud computing could be bigger than the web. Objectively speaking, it's a substantially more profound development, as it arguably extends the ultimate promise of an interconnected world to deliver the benefits of high-powered computers and communications to all.

The questions about cloud computing's future – whether it succeeds broadly or narrowly, quickly or slowly, nationally or globally, or not at all – are intimately interconnected with a diverse array of economic and public policy issues. Policy makers, in particular, must understand the cloud. As avatars of a high-growth industry, cloud providers could foment a dramatic expansion of the U.S. economy, as major players serve the needs of the nation and the world.

The potential benefits and challenges inherent in realizing the cloud's promise frame the essential issues addressed in the remainder of this paper.

Benefits and Opportunities in the Cloud

It is hard to argue with the ineluctable logic that leads to a network-based model for computing – in part because of the appeal of ubiquitous computing services, in part because of the efficiency of centralizing such services. That's why the analogy of the power grid has proven so compelling to adherents of the cloud. In many industries, however, ubiquity and centralization have resulted in undesirable outcomes, such as homogeneity or "one size fits all" solutions. With cloud computing, it seems, there is potential for the opposite: an explosion in creativity, diversity, and democratization predicated on high-powered computing resources and relevant related software and services. Indeed, as the reality of cloud computing has taken hold, six major benefits have become manifest:

- Anywhere/anytime access to cloud-based software
- Specialization and customization of applications built on cloud platforms
- Collaboration among users of cloud-based services
- Cloud-enabled processing power on demand
- Cloud-enabled storage as a universal service
- Cost advantages predicated on cloud efficiencies

Anywhere/anytime access to software

As Timothy B. Lee of the Cato Institute observes, "The big benefit of cloud computing is ubiquity. The downside of traditional computing is you need your computer with you to access [your] data. With cloud computing, you can have your environment…available from any interconnected terminal." When the personal computer becomes a "terminal," the specific attributes of any one machine cease to matter. What was PC functionality becomes a set of resources spread across the network. It diminishes a user's dependency on specific devices; and it means that devices themselves are less subject to hardware limitations.

Part and parcel of ubiquitous access to such resources is the diminishing importance of any one end-user machine. Because applications can move from machine to machine, or run across multiple machines and multiple data centers simultaneously, there's redundancy, reliability, and flexibility built into the cloud. In the PC era, the theft, loss, or destruction of a business person's laptop could range from the inconvenient (a day's work gone), to hazardous (a security breach), to disastrous (mission critical data missing). When users back up personal machines regularly, they minimize the risks of such catastrophic loss, but most consumers, and many corporate users, don't back up regularly.

Moreover, backing up data doesn't protect against security breaches, when hard drives fall into the wrong hands, which is something businesses (such as TJX), government (the FBI), and the military (U.S. Central Command) have learned the hard way in recent years.[13]

Accessing rich media – such as videos, photos, MP3 files, and graphics-heavy documents – is a great benefit of the digital age. As we know, consumers have developed a ferocious appetite in recent years for media in digital formats, resulting in sky-rocketing demands for bandwidth, computational power, and storage. It has historically meant that users required ever more expensive machines to store and manipulate their "curated" collections. Until now. The cloud's built-in efficiencies – including centralized processing and storage – can help level the playing field for users who don't own and maintain high-powered machines.

The business world is rife with offerings that use a cloud model to make anywhere/anytime access to software applications a reality. Here are some noteworthy examples:

Salesforce.com – Salesforce (see sidebar) is a business-to-business application that in February 2008 became the first cloud-based service to generate $1 billion in annual revenues.[14] Salesforce puts high-powered applications in the hands of its customers without their needing to own or operate a single server – just an array of network access devices.

Flickr is a photo-sharing site, acquired by Yahoo!, that started as an online platform for users to post digital photos, but rapidly became a video hosting website, an online community, and a suite of web services to enable users to organize, tag, and manipulate their online photos. Flickr's popularity, combined with Yahoo!'s traffic, has driven impressive growth; in late 2007, the site was hosting more than two billion images for its users.

Microsoft Online Services, Google Apps, and **Apple's MobileMe** are services that provide individual consumers with subscription-based sets of web applications representing the functional equivalent of Microsoft Exchange (e-mail, calendar, tasks, and contacts) without running a server.

Using programming languages including AJAX and Dynamic html (programming languages of the web), cloud services simulate the look and feel of PC desktop applications inside a standard web browser.

Salesforce.com

Salesforce.com, founded by former Oracle executive Marc Benioff, opened for business in 1999 declaring the "end of software." The company was founded on the premise that software for enterprise can become the source of logistical and financial distractions, including custom installation of complex software on a company's servers, upfront and on-going license fees, and systems that require continual and costly maintenance.

Salesforce targets these pain points by offering a cloud-based version of Customer Relationship Management (CRM) software.

Rather than running CRM systems on their own networks, clients can use a standard browser to launch Salesforce CRM. They pay a monthly fee based on the number of users. The CRM offering automates aspects of sales force management, marketing, customer service, and support.

Salesforce, with more than 51,000 customers, now serves both large enterprises (like Dow-Jones) and start-ups, by enabling clients to customize its software for themselves to create new capabilities and tools.

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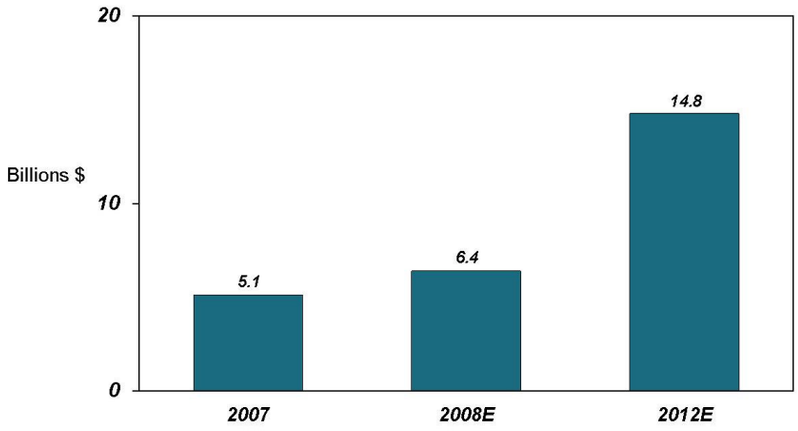
[13] *A Chronology of Data Breaches* (Privacy Rights Clearing House: Last updated March 9, 2009).

[14] Erick Schoenfeld, *Salesforce Hits $1 Billion Dollars In Annual Revenues* (TechCrunch: Feb. 25, 2009).

These services also enable users to share photos, videos, and documents with one another. According to Stephen Elop, President of Microsoft's Business Division, the company is moving aggressively into the cloud, testing browser-based versions of programs such as Word, Excel, and PowerPoint within its Office product (see sidebar). By turning productivity software into a service, these offerings liberate users from any single device.

Software-as-a-Service Revenue Forecast[15]



Many other companies, like Netsuite and Zoho (see sidebar), offer prime examples of how anywhere/anytime access to software can benefit small- and medium-sized business.

Such offerings hold the promise of true "independence of device and location," as analyst Jonathan Yarmis notes.[16] And they create potentially vast consumer and business markets for new generations of digital devices, such as Amazon's Kindle Reader (already a hit) and Netbooks, which we referenced earlier. Intel has even developed a new line of chips (called Atom) to power these devices.

Microsoft in the Cloud

Microsoft signaled a growing commitment to the cloud with its introduction of Windows Azure at Microsoft's Professional Developer Conference in October 2008. Unlike the company's traditional software business, Azure delivers software as a service over the Internet from its own data centers, hosting familiar "products" such as Microsoft Live; SQL, .Net, and SharePoint services; and Dynamics CRM.

Championed by Ray Ozzie, the creator of Lotus Notes who is now Microsoft's chief software architect, Azure aims to provide Net-based companies with the scalability to handle mass-market capacity with lean teams of employees serving them. Azure is designed to be Microsoft's cloud OS solution - their new foundation for web-based services.

As port of Microsoft's cloud commitment, Office web applications – lightweight versions of Word, Excel, PowerPoint and OneNote – will be available through a browser. With these new applications, people can use a browser to create, edit, and collaborate on Office documents.

Zoho

Zoho offers a suite of web-based applications that comprise practically every productivity tool that's relevant for small -and medium-sized business, including word processing, spreadsheets, presentations, databases, wikis, customer relationship management software, and receivables tracking programs.

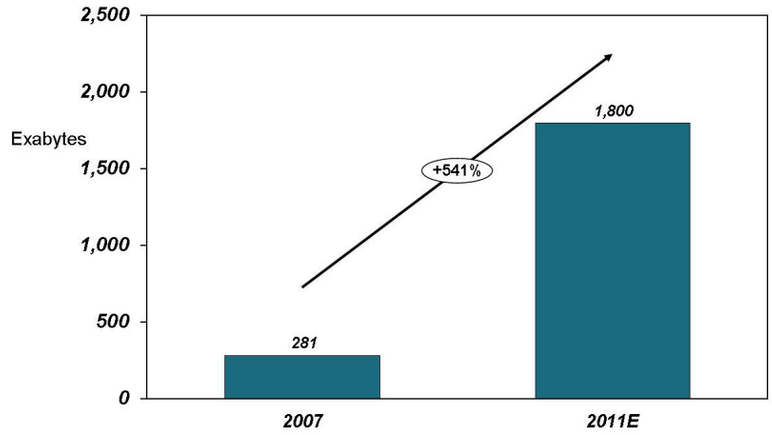
Because Zoho's services are built on the web, they are compatible with any PC operating system, making it possible for users to read and write files that work with Microsoft Office applications, as well as less mainstream formats (such as OpenOffice.org).

Users can integrate its applications online (for example, easily combining spreadsheets with presentations), and they can store work on Zoho's drives or on those of various partners providing cloud storage services (such as box.net and Omnidrive) which enable synchronization back to a user's PC.

[15] Gartner: October, 2008

[16] Dan Farber, *The new geek chic: the data center* (CNET.com: June, 2008).

Worldwide Growth of Digital Information*[17]



* Note: The Digital Universe includes information that is either created, captured, or replicated in digital form

Specialization and customization of applications

One influential technology blog, GigaOm, talks about cloud computing at the platform level as driving a "seismic shift in information technology" that will transform not only business models but also "the underlying architecture of how we develop, deploy, and deliver software applications."[18] For companies that today must build and maintain required infrastructure and security systems, cloud computing offers a way to overcome obstacles to develop and test products. One provider of platforms in the cloud claims in a 2008 white paper that now "businesses can by-pass traditional problems of software purchase, maintenance, and systems integration, by moving the entire application lifecycle to an online unified development and deployment platform."[19]

Complementary to delivering software applications over the web, the cloud also enables software developers to build highly specialized applications more quickly and efficiently, using cloud-based "platforms." You might call this benefit of the cloud a "development environment on demand."

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[17] *A Diverse and Exploding Digital Universe: An Updated Forecast of Worldwide Information Growth through 2011* (IDC whitepaper sponsored by EMC, March 2008).

[18] *How Cloud & Utility Computing Are Different* (GiGaOm.com, February 28, 2008).

[19] Dion Hinchcliffe, *The Next Evolution in Web Apps: Platform-as-a-Service* (Hinchliffe and Company, sponsored by BungeeLabs: 2008).

Outsourcing their programming platforms means that developers can save time, money, and headaches by building and testing applications that run on, and are delivered from, the cloud provider's servers.

Sidestepping operating complexity is only one benefit the cloud can offer its customers. First, by providing platforms for developers, cloud providers simplify the programming task, making it possible to build applications not by writing code but by assembling drag-and-drop software modules, which means that a company can look beyond its team of hard-core developers for innovative software solutions. As Polly Sumner, President, Platform, Alliances and Services for Saleforce.com, observes, with the cloud, "anyone can innovate." Facebook, for example, "[has] built a very good platform for people to easily build social networking applications." Companies like Facebook and Apple have released Software Development Kits (SDKs) that make it easier for third-party developers to build customized applications on top of common platforms.

Second, online development environments make it possible to integrate applications by linking one provider's cloud to another's. Third, because every online user has global access to the cloud, developers working on a cloud platform can gather talent and labor from all over the world. That dramatically broadens the potential resources from which a company can draw to build software. Fourth, tapping the cloud for development platforms is not a one-way street. Users can create software in the cloud and contribute it to the cloud community.

Reusability is the key concept, and it scales dramatically as the number of users who work on a shared platform increases. Developers can build applications in integrated development environments, while gaining access to applications and resources built by others. Finally, as illustrated by companies like Apttus (see sidebar), there is virtually no investment required to access web-based development tools, other than the platform subscription itself. The important effect is a lower cost of innovation for businesses and a lower bar to participation for users.

With the time and energy *not* consumed by administering programming environments, the cloud enables companies to make better use of developer talent and expands the pool of potential workers who could master the tools to come up with innovative ideas. As Alan Eustace, Senior Vice President of Engineering & Research at Google, comments, "[Imagine the] innovation that you're going to get in an ecosystem where you don't have to be Google, you don't have to build your own data centers, you don't have to build your own networking, you don't have to build your own racks, you don't have to build your own servers, you don't have to figure out your own operating system."

Apttus

Apttus is a fast-growing start-up enabled by the cloud. It sells a web service called Contract Management Suite, which provides corporate clients with an "on demand" contract and proposal management system.

Its founders built a prototype in a "couple of weekends" using Salesforce's Force.com platform. After three months Apttus had developed an enterprise class system with more functionality than competing systems and was ready to deliver globally.

Within six months, Apttus closed its first million dollar deal, and the company was profitable within nine months. Because Apttus used a cloud platform, it incurred no costs for infrastructure. That, in turn, meant the founders could take the company from start-up to profitability without tapping outside funding.

Without having to buy or build systems architecture, development and test environments, and firewalls and security systems, the start-up team could focus on customer needs – relentlessly.

Likewise, Richard Zippel, Vice President of Technology at Sun Microsystems, observes, "With cloud computing developers can do something more creative and focused; it frees them up to do what they need to do by giving them the resources so they don't get caught up in the weeds."

Of course, not everyone shares these rosy views. Harvard Law School's Jonathan Zittrain is concerned that any move away from the stand-alone PC to the centralized cloud could actually stifle innovation. He notes that one response to viruses, spam, and cyber attacks that plague PC computing has been the adoption of "locked" devices like the iPhone and Xbox, which only allow innovation with their makers' stamp of approval. This kind of reaction to malware threats, Zittrain submits, will lead to a plethora of thin clients that do specific things well, but that are ultimately sterile and inhibit software and service innovation.[20] That said, in making this argument, Zittrain overlooks the outpouring of creativity that the Apple App Store has unleashed among tens of thousands of third-party developers who are "writing" for Apple's cloud. Cloud-based development platforms fueled by the release of open APIs from, among others, Apple, Facebook, and MySpace argue against Zittrain's point. In addition, Apple did not develop the iPhone, or Microsoft the Xbox, in order to protect consumers from malware.

While the cloud provides a platform to develop, test, deploy, host, and maintain applications in a single integrated environment, it's perhaps a statement of the obvious that the same platform also provides an infinitely scalable and accessible channel to the market. Why? The cloud is as accessible as the web itself. Any services developed *in* the cloud can be made immediately available to users *from* the cloud.

In that sense, the cloud can serve as both a development and a hosting platform for a company's service offerings. As GigaOM observes, the cloud "allows users to develop, deploy, and run applications that can easily grow capacity (scalability), work fast (performance), and never – or at least rarely – fail (reliability), all without any concern as to the nature and location of the underlying infrastructure."

There are a variety of leading platform-in-the-cloud providers that furnish clients with scalability, performance, and reliability, without having to invest in their own infrastructure. Meanwhile, several larger players, such as Amazon Web Services (see sidebar) and Google App Engine, provide users with access to the same development environments and hosting platforms that these companies use to power their own businesses.

IBM Innovation Jam

The world's largest online brainstorming session took place when IBM hosted its Innovation Jam in 2006. The goal of the Innovation Jam, which ran in two phases conducted in July and September, was to share IBM's most advanced research concepts and technologies to explore ways to address real-world problems and create new business opportunities.

The scale of collaboration was vast: Relying on IBM's cloud for hosting, the Jam brought together over 150,000 participants from 104 countries. The online community included IBM employees and their families; researchers from universities, laboratories, and think tanks; many of the company's business partners; and clients from 67 companies around the world.

Based on ideas proposed and developed during the 2006 Jam, 10 new IBM businesses were launched with seed investment totaling $100 million.

Source: *IBM Invests $100 Million in Collaborative Innovation Ideas* (IBM Press Release: November 14, 2006).

Amazon Web Services

Amazon, like all retailers, is subject to seasonal demand – often registering half its sales for the year in the month of December. Amazon must maintain computing and storage capacity to handle the peak traffic volumes it experiences at year-end, meaning that it operates well below its actual capacity for most of the year.

That's why Amazon launched a new business to offer third parties access to its computing capacity on an on-demand basis. With Amazon Web Services (AWS), firms contract with Amazon to "plug into the cloud," gaining access to processing power, storage, and data when needed.

***Amazon's EC2** service (Elastic Compute cloud) enables users to request machines for use, load them with custom applications, manage network access permissions, and run applications on Amazon's servers and machines.*

***Amazon's S3** (Simple Storage Service) offers storage space on Amazon's servers, which lowers the costs to a third party of building and maintaining physical infrastructure. The uptake of these services– especially small- and medium-sized enterprises – has proven compelling to the company's clients. So much so that as of early 2008, AWS consumed more capacity in Amazon's data centers than Amazon's own retail business.*

Source: *Josh Catone, Amazon Web Services: Bigger Than Amazon* (ReadWriteWeb.com: January 30, 2008).

[20] Jonathan Zittrain, *The Future of the Internet and How to Stop it* (Yale University Press: April, 2008).

"We were already building these really incredible, robust services for ourselves," says Andy Jassy, who wrote the business plan for AWS and runs it today."It wasn't a huge leap to realize they could be valuable to other people."[21]

Collaboration

The social dynamic implicit in a shared software model points to a third benefit of the cloud; the opportunity for users to share readily with one another, and hence to collaborate more efficiently and effectively. The PC and its applications were conceived to increase individual productivity, while cloud-based applications and services – by dint of their residing on a shared platform – favor teamwork and collaboration. In that sense, as content and communication converge in the cloud, every application becomes a social application.

That's a profound concept, especially for geographically dispersed organizations such as multi-national corporations, or many of today's small- and medium-size businesses which make use of virtual work teams. An integrated, consistent, and reliable set of offerings to the market, supported by efficient teamwork, is one of the critical ways that companies large and small compete. Clay Shirky, for one, agrees: "The amount of collaborative value that can be tapped entirely among your own employees can be quite significant. For all the rhetoric about letting everything be open and free, there's a large pool of collaborative talent behind the firewall, and that's a really good place to look for coordinated value."

In addition to mainstream examples of collaboration in the cloud – from Flickr to Salesforce to Wikipedia (see sidebar), there are others that have the potential to reshape how work gets done in companies and by the government. The intelligence and national security communities have developed collaborative models that provide secure password-protected areas for document sharing, participating in forums, and collaboration. Each also requires users to have a Common Access Card and services ID number.

As the focus of national intelligence shifts from countering a monolithic Cold War nemesis to disabling countless networks of terrorist groups, the idea of "open source" intelligence has not only taken hold, but also describes a fundamentally new way to bolster national security.

Wikipedia and Intellipedia

Wikipedia – a user-created online encyclopedia run by a non-profit foundation – has become one of the world's leading sources of information accessed on the web. Built and developed by more than two million contributors around the world in multiple languages, Wikipedia represents 100 million hours of human labor.

The intelligence community uses a resource called Intellipedia. With more than 35,000 active users, the site operates on the same software as Wikipedia. Participants post more than 5,000 contributions a day to a platform that operates three networks – unclassified, classified, and top secret.

Source: Chris Kanaracus, *CIA Uses Wiki Technology to Share Information* (IDG News Service: June 10, 2008)

[21] *Cloud Computing. Available at Amazon.com Today* (Wired: April 21, 2008).

For example, the Office of the Director of National Intelligence has taken a page from YouTube's playbook. It has established a restricted site called iVideo for posting, sharing, and discussing intelligence videos for professionals in the community. To date, "users" from the intelligence community have posted hundreds of videos. Sharing is the obvious goal, but only within a secure environment. As a result, parts of the site are classified "top secret" and accessible only to small numbers of individuals with high-level security clearances. Others are "secret" and available only to certain Departments of Defense and State employees. Still others are "sensitive" and may be accessed by a wider range of government employees.[22]

Even more sophisticated is the Defense Department's new cloud platform called TiGRNET. Previously, "incident reports" were delayed by document preparation that traveled through multiple steps up the chain of command; with TiGRNET, the information is available in near real time online. The system supports soldiers in combat with a comprehensive view of battlefield conditions by hosting reports from the front lines. For example, soldiers returning from a patrol can file a field briefing, upload digital images, identify incident coordinates, share maps, and disseminate other intelligence. The platform integrates in-bound reporting with satellite images, area reports, and other pertinent information.[23]

"You don't generate your own electricity. Why generate your own computing?"

Jeff Bezos,
CEO Amazon

Processing power on demand

Arguably, from a business standpoint, cloud computing's most important benefit is offering infrastructure on demand. This variant of the cloud takes two forms: access to processing power and access to storage. Tapping a cloud provider's infrastructure means an enterprise can run virtually any software application or configuration – processing, storage, messaging, software development, and, in more sophisticated cloud platforms, databases – off-premises, while paying only for the capacity and services it actually consumes.

The advantages to enterprise of outsourcing computing infrastructure are myriad. Amazon CEO Jeff Bezos remarks, "You don't generate your own electricity. Why generate your own computing?" While Bezos, who is in the business of selling such services, does not offer an impartial voice, the economic realities of owning and operating in-house computing resources are objectively sobering.

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[22] Ben Bain, *YouTube for the intell community* (FCW.com: March 14, 2008).

[23] William Matthews, *Web 2.0 Systems Are Redesigning U.S. Defense* (Defense News, The Americas: August 18, 2008)

New York Times and Animoto

*The **New York Times** was looking for a way to make 150 years of its archives available to readers online. The digitization challenge was formidable, as were the storage requirements. The archives comprised 11 million articles representing 1.5 terabytes of memory (a terabyte is equal to 1000 gigabytes).*

Started as an internal project, the Times soon concluded it needed industrial-strength infrastructure and turned to Amazon's S3. The result is the Times-Machine. Users can view scanned PDF-format images of newspapers from as far back as the 19th century, zooming in on particular articles, photos, or advertisements. According to the Times, the setup costs were negligible, and ongoing fees are modest and entirely based on traffic.

***Animoto**, was a start-up that provides cloud-based tools for users who want to create presentations using photos and music they've uploaded to the web. Early in 2008, the company was seeing roughly 5,000 visitors a day on its site, but traffic spiked to 750,000 a day after a successful Facebook marketing campaign. Normally, to deal with such traffic, Animoto would have expanded its server capacity 100-fold. But because it was using Amazon's cloud, Animoto added capacity on Amazon infrastructure at a cost of 10 cents per server per hour, along with additional expenses for bandwidth, storage, and related services.*

Source: Michael Fitzgerald *Cloud Computing so you don't have to stand still* (New York Times: May 25, 2008).

For example, the typical corporate data center has an average utilization of 55 percent, both because facilities must be equipped for an organization's theoretical peak demand and because of long cycle times required to design, build, and maintain such centers.

Such evidence of overbuilding and inefficiency will come as no surprise. Businesses seldom reach their peak demand, which makes underutilization inevitable. Thanks to Moore's Law and other virtuous effects, technology in data centers becomes obsolete in rapid cycles, which requires a never-ending process of upgrading software and equipment. As companies add server capabilities and applications, they need ever more staff to manage increasingly complex systems.

And the variability of costs associated with data centers is a headache for CFOs. As Dan Israel of Google Enterprise points out, cost predictability is nearly as important as cost savings. Data centers, like most technology projects, have huge upfront costs, which are followed by spikes in cost driven by upgrades and expansions. A pay-as-you-go model takes the cost variability out of the picture, with fees based on usage that companies and governments can model from one year to the next.

The cloud also enables increased productivity. IT professionals can refocus their efforts on primary business tasks when their time and energy are not consumed by operating computing facilities. Gartner Group estimates that $8 of every $10 in corporate spending on technology goes to data center operations and maintenance, not business functions or innovation. In addition, few businesses run state-of-the-art data centers.[24] That means that in-house technology talent is often constrained with respect to processing power, systems scalability, and storage. As *Business Week* writes, "The key promise of cloud computing at the infrastructure level is to leverage the power of the supercomputers and massive data centers that live in the 'cloud' down to the SMB, enterprise, and consumer level."[25]

When large-scale computing power winds up the hands of individuals or employees, there is ample evidence that amazing things can happen. For example, the world's largest database of prime numbers, PrimeGrid, was built on a cloud platform (the Berkeley Open Infrastructure for Network Computing) single-handedly by an 18-year-old engineer from Lithuania. A task like this might require tens of trillions of calculations a second, and there's no free-standing machine, let alone a PC, that can deliver at that level.

Forbes Study on Server Utilization

Forbes estimates that a rule of thumb for organizations with 5,000 servers is that 30 percent of them are technologically obsolete – that's 1,500 servers that could be unplugged with little or no impact on performance.

If unplugged, those servers would represent a $12 million to $23 million reduction in such an organization's annualized cost of capacity; $700,000 annual savings in electrical costs and 6,000 tons of reduced greenhouse gas emissions a year.

Source: Kenneth G. Brill, *Servers: Why Thrifty Isn't Nifty* (Forbes: August 11, 2008).

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[24] Rachael King, *How Cloud Computing Is Changing the World* (BusinessWeek: August 4, 2008).

[25] Aaron Ricadela, *Computing Heads for the Clouds* (BusinessWeek.com: November 16, 2007).

For many businesses today, infrastructure in the cloud is already a game-changer. Take the example of CODA - a business of Netherlands-based Unit 4 Agresso NV - that provides enterprise-class financial systems from the cloud, enabling small- and medium-sized businesses to deploy a topflight financial software package (called ICoda2go) for initial pricing of $125 per user per month. Built on Force.com, a cloud-based platform provided by Salesforce, CODA draws on its design knowledge of financial software systems from its high-end work serving multi-national corporations and relies on the cloud for infrastructure to deliver it to small businesses. As CODA's CEO Jeremy Roche observes, "As part of the cloud, we can offer higher complexity applications at a cheaper price point. They're simpler, but not so simple they can't be used by a multinational."

"As part of the cloud, we can offer higher complexity applications at a cheaper price point. They're simpler, but not so simple they can't be used by a multinational."

Jeremy Roche,
CEO CODA

There are a host of new players entering the market to provide infrastructure on demand, so the build-out of the "ecosystem" has only just begun. Some industry observers use the metaphor of an ocean reef to describe how the emergent cloud economy must develop. It will take a variety of players to make the cloud ecosystem sufficiently rich in resources to help generate new business models, venture opportunities, and wealth creation. The race is on.

Storage as a universal service

The benefits for individuals and enterprises large and small to shift to a new model for handling data storage needs is clear. Building and maintaining storage infrastructure is costly and complex. Tapping into massive data centers for storage capacity has all the benefits of reliability and flexibility from a user standpoint – with the added benefit of substantial economies of scale.

That's one reason several popular online e-mail services offer storage for free – virtually unlimited storage in the case of Yahoo! or Google. Between scale efficiencies and subsidies from online advertising, the cost for such companies to provide storage to users is near zero. It's also why Google Book Search, which started by scanning the contents of major research libraries around the world in partnership with Google, can envision web access to an estimated 50 million to 100 million books in fully searchable formats. While the market for cloud storage is developing, there are a variety of established consumer services online primarily aimed at providing storage and backup for PC users.

Cost savings in the cloud

All of these benefits together have the *added* benefit of saving money. It is simply more efficient to treat software, development platforms, and applications as "services" that users "rent" rather than "products" they have to build and maintain themselves. As we've seen, enterprises save time and money by paying just for the processing power or storage capacity they need for specific projects or peak periods. The cost of collaboration, particularly for global companies, declines as colleagues share resources in the cloud. As for individuals, they already benefit from free, ad-supported, cloud-based services like e-mail from Yahoo! and Google.

As more applications and even operating systems move into the cloud, and as big technology companies compete to provide them, customers stand to realize even greater savings.

Despite this exhaustive array of benefits and the high rates of consumer adoption of selected offerings, the cloud remains in its infancy from a development standpoint. To become the next dominant computing paradigm – to succeed in democratizing computing resources for the masses – will require a cloud ecosystem. That ecosystem will go far beyond the obvious examples of cloud service providers and their customers. It will require sustained innovation from device manufacturers, bandwidth providers (cable companies and telcos), and content companies (media conglomerates and software makers), to name a few. It could unleash a tidal wave of innovation.

But for that to happen, it will be critical for policy-makers and business people alike to understand the enablers and barriers that will shape the future of cloud computing, as well as many of the legal, regulatory, and security issues cloud computing may raise.

Enabling the Cloud

For cloud computing to deliver all of the benefits we've described, its "customers" – from ordinary consumers to small and large businesses to government agencies – will need to accept the notion that their data is always accessible and totally secure and that the cloud offers significant economic advantages over their current computing models.

A series of significant data breaches could heighten user fears about whether data is, indeed, "safe" in the cloud. A tangled web of confusing and conflicting laws in the United States and internationally could aggravate concerns about privacy and discourage enterprise from entrusting its data to the cloud. The economic benefits of the cloud could fail to materialize; without measurable ROI, big business will have much less incentive to abandon traditional IT solutions. And if cloud providers fall short of their promise to create more energy-efficient data centers, this could spark a backlash from environmentalists, policy-makers, and enterprises concerned about the huge drain on global energy resources.

These are significant hurdles for proponents of the shift to the cloud to overcome, and acceptance by the largest cloud users is likely to lag behind the technology. Put simply, cloud computing will be ready for prime time before many of its biggest potential customers are – especially big business. How software and hardware providers effectively adapt their business practices to the fundamental changes the cloud represents– from selling physical products to selling services – will go a long way in determining its success and its adoption by enterprises. And the role government plays – or chooses *not* to play – will be critical to the outcome.

There are eight fundamental elements for "enabling" the cloud and realizing its full potential:

- Full connectivity
- Open access
- Reliability
- Interoperability and user choice
- Security
- Privacy
- Economic value
- Sustainability

"[Net Neutrality] means non-discriminatory access to the Internet.... The point here is that no one should be denied access to these various [online resources] because of who they are, or if they're a competitor they shouldn't be denied access to those [resources]. So this is a fairness issue more than anything else. It doesn't mean you can't manage your net, it means you have to do it in a fair way."

Vint Cerf, considered one of the "fathers" of the Internet and now Google's Chief Internet Evangelist

Full connectivity

The first requirement for delivering the full benefits of cloud computing is ubiquitous connectivity. Users have to be connected to the Internet for cloud-based services to flourish – all users, all the time.

The simplest way to measure connectivity is by the number of households and businesses that have broadband connections or can access the web through wireless mobile networks, as assessed in light of the speed and cost of these connections. By these measures, the United States is by no means the world leader.

Broadband penetration, and Internet connectivity, in general, are expanding rapidly in the United States, but progress is most pronounced in Asian markets like Japan and South Korea.

The United States was 4th in the world in broadband penetration in 2001; by 2007, it had slipped to 15th, according to a June 2008 report by the International Organization for Economic Co-operation and Development (OECD).[26] The worldwide leaders are: Denmark, the Netherlands, Iceland, Norway, Switzerland, Korea - 90% of South Korean households have a broadband connection – and Sweden. In addition, there are "value for money" considerations that are creating an uneven playing field around the world: average broadband speeds in the United States are less than 1/10th of speeds in Japan, and U.S. consumers pay four times as much to access broadband services.

Wireless networks are expanding rapidly, driven in part by the explosion in mobile technology and adoption. A new study from Juniper Research estimates that there will be 1.7 billion mobile web users worldwide by 2013.[27]

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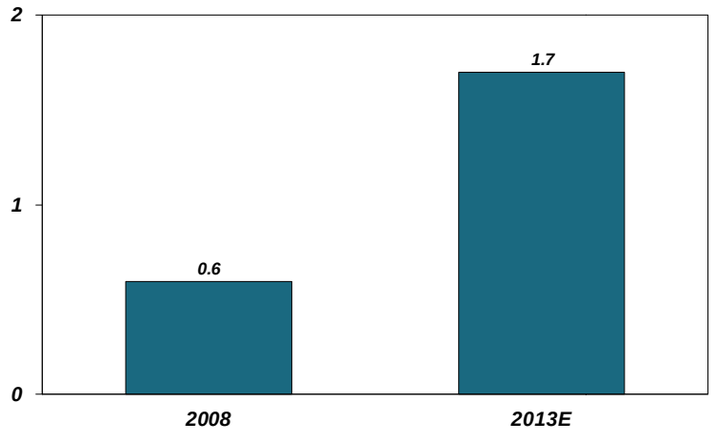
[26] *Broadband Growth and Policies in OECD Countries* (OECD: June 2008).

[27] Matt Kapko, *5.2B Mobile Subscribers by 2011* (Washington Post: August 7, 2008).

Mobile Web Users [28]



In the emerging world, mobile technology in many instances represents a leapfrog opportunity, with consumers and business people adopting mobiles – increasingly, smartphones – to reach the Internet without investing in an expensive, general purpose desktop or laptop computer.

That, however, is a long way from "ubiquitous connectivity" – especially as it applies to the high-speed connections required to use and deploy cloud computing effectively. According to a Gartner research report, there will be 499 million in-home consumer broadband connections worldwide by 2012 – an extraordinary number, but it represents only 25% of the world's households.[29] Even in North America, basic Internet connectivity (not broadband) has flat lined at about 71 percent of the population.[30]

This is an area where lawmakers, particularly those representing rural constituencies, are likely to intervene to ensure universal access to the Internet, cloud or no cloud. Through a combination of tax incentives to technology providers, regulation of the wireless spectrum, and potential subsidies to low-income users, government can encourage availability and adoption of affordable connections to the web. The Obama administration's $787 billion stimulus bill includes a $7.2 billion provision to extend high-speed Internet service to rural and other underserved areas.[31]

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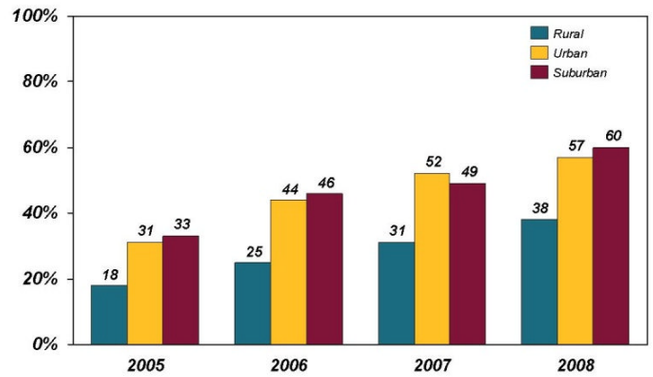
[28] Matt Kapko, *5.2B Mobile Subscribers by 2011* (Washington Post: August 7, 2008).

[29] Gartner, *Gartner Says 17 Countries to Surpass 60 Percent Broadband Penetration into the Home by 2012* (Gartner press release, July 24, 2008).

[30] *Internet World Stats, Internet Usage Statistics (Internet World Stats, 2008).*

[31] Stephanie Condon, *Telecoms oppose tighter Net neutrality rules for stimulus funds* (CNET: Feb. 26, 2009).

U.S. Broadband Connectivity by Community Type [32]



Cloud providers have a strong motive to push for policies and incentives that promote greater connectivity; to the extent that the United States falls short of universal access, the cloud's benefits as a democratizer of computing will fall short as well.

Open access

Giving every potential user open access to the cloud and an equal opportunity to benefit from it is a second challenge. Put another way, proponents argue that access to the basic infrastructure of the cloud should not be based on discriminatory pricing or provide an unfair advantage to certain users.

Inevitably, this simple-sounding principle raises the complex set of issues that has emerged in the nettlesome debate over "net neutrality." There are powerful commercial interests at stake. Internet access providers, like cable system operators and the major telephone companies that provide Internet connections to homes and businesses, want to manage their networks as they see fit and to the benefit of their shareholders. Moreover, they argue that their substantial capital investment makes it only fair that they share in the revenues for transactions and services that take place over their "pipes." And finally, they often offer services of their own that compete directly with other companies that use their infrastructure without many, if any, limitations.

[32] Pew Internet & American Life Project, *Home Broadband Adoption 2005-2008 Studies*

Providers of Internet-based services, on the other hand, who have their own economic interests to consider, argue that once a customer has paid for access to the Internet, the provider should impose no restrictions or conditions on what services he or she uses, even if they are a competitor's services. They argue that, in order to retain its role as an engine of economic growth, the Internet must allow all comers to compete freely and fairly.

On the issue of so-called "cloud neutrality" – the notion that Internet service providers must offer fair, open, non-discriminatory access to the cloud – the stalled efforts to pass "net neutrality" legislation suggest that the markets might be more effective than Congress in "punishing" providers who try to set up proprietary roadblocks, although the FCC will be patrolling the highway in any case. "Regulating 'cloud neutrality' laws is even harder than regulating Net neutrality," says Georgetown Visiting Professor of Internet Studies Michael R. Nelson, who argues that users will apply sufficient pressure on providers to ensure open access for all.

The net neutrality debate is beyond the scope of this paper, but any barriers that restrict access to the Internet or discourage its use limit the potential for cloud computing to flourish.

Reliability

Even assuming near-universal connectivity and equal access for all, cloud computing also requires rock-solid reliability. Users must rely on the cloud as much, or more, than they currently rely on their own desktop or company network. Kevin Kelly, founding executive editor of *Wired* magazine, believes that the success of cloud computing is intimately tied to how users perceive its reliability. "It is not just about being 'always on'; it is this idea of reliability. If this is reliable that's a big thing. If it isn't, then what do we turn to?" said Kelly.

Mike Elgan, a respected technology columnist and blogger, fears that hype about cloud computing masks valid concerns about reliability: "[The term cloud computing] was coined to put a new coat of paint on something old, and to add vagueness to specific, well-understood technologies." Elgan argues that the danger is that "companies get excited about, grow comfortable with, and ultimately embrace what they think is the shiny new world of 'cloud computing,'" without recognizing what he believes to be a potential loss of reliability for computing services.[33]

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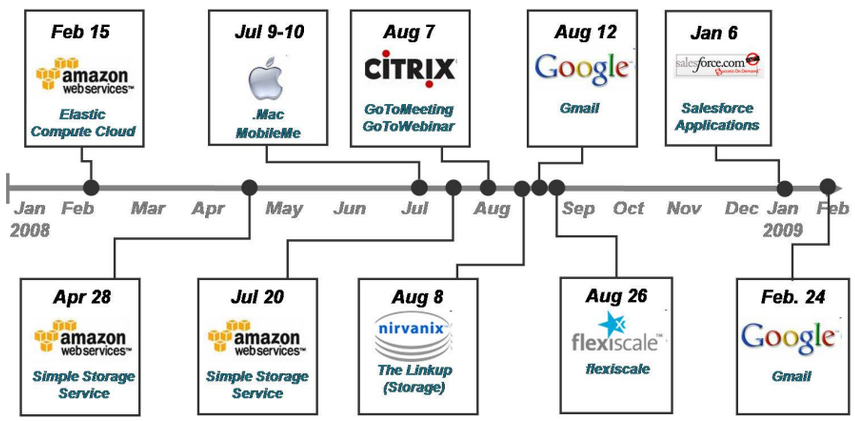
[33] Mike Elgan, *Why 'Cloud Computing' is for the Birds* (IT Management: August 18, 2008).

Indeed, service that comes close to 100 percent reliability is a prerequisite for widespread adoption of cloud computing. Most of us have experienced the frustration first-hand of an Internet-based service (like e-mail) going down temporarily. As more services and applications move to the cloud, and as larger companies and government agencies increasingly rely on them, such problems take on greater significance. Cloud providers acknowledge that reliability is a critical component of their success, but they argue that, managed properly, cloud-based solutions can be demonstrably *more* reliable than current client-based systems.

That said, even the best-known providers of cloud services fail from time to time – and with potentially serious consequences for users of all kinds. For example, Amazon's S3 storage system had two significant failures in 2008. That same year, two of Citrix's popular cloud-based services – GoToMeeting and GoToWebinar – experienced outages; and Steve Jobs himself acknowledged the unacceptably rocky launch of Apple's MobileMe service in the cloud.[34] Google's Gmail went down in August 2008, also affecting the Google Apps suite of cloud-based applications. In February 2009, it happened again: Gmail had a worldwide outage of four hours, which had some bloggers warning about the dangers of counting on the cloud.

Timeline of Major Outages



Failures like these will stiffen the resistance of corporate IT departments, already wary of losing their influence and personnel to cloud-based platforms and infrastructure.

[34] Michael Krigsman, *Jobs acknowledges MobileMe failure* (ZDNet: August 5, 2008).

But the cloud has no monopoly on failures and downtime: the January 2009 five hour outage for the White House's Outlook e-mail system is just one of many reminders of the vulnerability of traditional on-premise systems.[35] And while the breakdown at the White House was widely publicized, most failures of proprietary systems go unnoticed by all except those directly affected. In the cloud, on the other hand, there is far greater transparency: incidents of "downtime" are there for all to see.

The related issue of accountability – who's to blame when things go wrong – potentially gets more confusing as computing services move to the Internet. That's why major providers like Amazon, Google, and Salesforce.com are starting to offer service level agreements (SLA's) to customers, spelling out specific areas of responsibility and in effect guaranteeing near 100% "uptime." Google actually guarantees to corporate customers who pay to use Google Apps that Gmail will be available 99.9% of the time, or Google will compensate them through penalty payments; the company says it hasn't had to shell out yet.

Polly Sumner, President, Platform, Alliances and Services for Salesforce.com, believes that shared best practices and a standardization of contracts among cloud-based-service providers will speed migration to the cloud. But whether industry leaders agree on common standards for cloud reliability, or the market punishes the laggards and rewards the high performers, cloud providers like Salesforce.com argue that because they are delivering an ongoing service rather than a shrink-wrapped product in a box, they will be held accountable, and the "bad guys" will be "weeded out." Says Sumner: "If a customer doesn't like our service, they can cancel."

Interoperability and user choice

The future of cloud computing also rests on a critical assumption: that users will have a choice among competitive providers and be able to switch from service to service. This notion of interoperability is an essential enabler of cloud computing at every level: users of services like e-mail, IT/infrastructure functions such as storage, and platforms on which developers create specific applications.

If software and infrastructure users can't take their data somewhere else, if they are "locked in" once they commit to one vendor, the incentives for cloud providers to offer ever improving service and innovation melt away, and the customers, big or small, lose their leverage.

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[35] Michael D. Shear, *White House E-Mail System Goes Down* (WashingtonPost.com: January 26, 2009).

"A critical advantage will be the ability of people to rapidly collaborate ahead of the competition. If cloud computing becomes that undergirding infrastructure, it is important that it not balkanize communities."

Dan Atkins, former Director of the NSF Office of Cyber-infrastructure

"Why not cloud today? I get concerned about making choices that lock us in long term," says Richard Mickool, the executive director and CTO of information services at Northeastern University in Boston. "I want to be able to fire [the cloud provider] in three minutes if I need to."[36]

Moreover, the potential for cloud computing to facilitate collaboration in real time or to encourage developers to create new applications quickly and efficiently depends in part on different clouds becoming compatible.

Dan Atkins, former Director of the National Science Foundation Office of Cyberinfrastructure, says, "A critical advantage will be the ability of people to rapidly collaborate ahead of the competition. If cloud computing becomes that undergirding infrastructure, it is important that it not balkanize communities." The key to interoperability is some combination of common standards and open standards.

Not surprisingly, it is relatively small players like 3Tera (see sidebar) who are pushing for common standards. Right now, the big players like Amazon, Google, and Yahoo!, operate proprietary cloud infrastructures, with varying degrees of open standards.

In fact, leading cloud services like Amazon may resist a common standard for fear of losing their proprietary lock on early customers: there is an obvious tension between the notion of interoperability – free consumer movement from one service to the next – and the business incentive for cloud service providers to create a system that enables them to differentiate themselves from competitors and to lock in users. Some cloud skeptics, like Richard Stallman, founder of the Free Software Foundation, suspect that cloud providers are pushing a closed rather than open model by creating proprietary clouds that are islands unto themselves. Stallman warns that consumers and their data are being lured into a "lock-in" relationship involving proprietary, non-open source software. "If you use a proprietary program or someone else's server, you're defenseless," Stallman says. "You're putty in the hands of whoever developed that software…. It's worse than stupidity: it's [falling victim to] a marketing hype campaign."[37]

3Tera

3Tera - creators of AppLogic, a commercially available cloud computing platform that removes the cost and complexity associated with infrastructure - is among those companies pushing for more user choice.

In 2008, 3Tera called for the standardization of cloud computing, naming it "Open Cloud" and saying it would allow a company's IT systems to be shared between different cloud computing services and move freely between them. It's not an altruistic move, but rather a bet that common standards among cloud service companies will expand the cloud, which is good for business, including 3Tera's.

Source: Andy Greenberg, *Bridging The Clouds* (Forbes: June 30, 2008).

[36] John Foley, *CIOs on Cloud Computing* (Information Week: August 19, 2008).

[37] Bobbie Johnson, *Cloud computing is a trap, warns GNU founder Richard Stallman* (The Guardian: September 29, 2008).

A more standardized cloud-computing market could hurt today's leaders by removing competitive advantages and leveling the playing field, says Nick Carr. "Right now, Amazon and Google can compete based on their reliability or other factors," says Carr. "But the long-run danger for standard utility computing service is that it becomes a commodity and your only way to compete is on price."[38]

In the ideal scenario, cloud providers will compete on the basis of service, not proprietary systems, and with specialized applications that operate on a standardized platform. The hope is that while cloud platforms are open and easily interchangeable, companies can create value for themselves and their customers with the distinctive tools and services they create "above the cloud."

Most experts predict that the likely outcome is a combination of closed- and open-source applications. The more specialized the services, the more likely users are to accept a degree of "lock-in." The more generic the services – like e-mail or word processing – the more consumers will demand the ability to move from one provider to another, taking their data with them. Along the same lines, there will be specialized clouds in narrower fields, like health care, side by side with interoperable clouds for more commonplace uses.

Over time the market's industry leaders will determine the appropriate balance between differentiation and standardization, proprietary systems and open standards, competition and cooperation. Yahoo!'s Senior Vice President in charge of Cloud Computing and Data Infrastructure, Shelton Shugar, believes that the market will favor open standards, because they level the competitive playing field for cloud-based applications and services: "One of the benefits with open source is that there will be more small companies getting started off that infrastructure."

The history of the Internet suggests that a degree of cooperation and common standards is essential for cloud computing to come into its own, says Danny Weitzner, Technology and Society Policy Director of the World Wide Web Consortium.

Weitzner points out that the browser wars between Microsoft and Netscape actually threatened the development of the Internet, until "everyone else in the marketplace got together and told them they have to get their act together and come to the table and work out these standards in an open forum."

Specialized Clouds

"You are going to see thousands of clouds emerge over the next three or four years. The cloud isn't here to do one thing. Computer service isn't just a utility that comes out of the wall. Some processes require huge processing bandwidth and some storage bandwidth. One size doesn't fit all…. You still get competitive advantage by serving specific markets. We think of it as puffs of clouds."

Andy Rhodes, Head of Global Marketing Dell's Datacenter Solutions Division

Evolution of Open Standards

Understanding the early days of the Internet may be instructive in predicting the future of the cloud. When RAND and the U.S. Air Force (USAF) first conceived of the idea of the Internet, they initially went to AT&T and IBM for help to build its infrastructure. RAND and USAF ultimately rejected AT&T, because AT&T wanted to "own" the grid. IBM rejected the offer, because it viewed the Internet as a threat to its mainframe business.

The Internet eventually grew into the network we recognize today through the work of the Defense Advanced Research Projects Agency (DARPA); Bolt Beranek Newman (BBN) an organization of former MIT faculty and students; and the National Science Foundation.

Critical to the success of the Internet was the fact that these government agencies worked to ensure an open, interoperable Internet, despite the subsequent efforts, many years later, of companies like Microsoft, AOL, and WorldCom, which attempted to break up the Internet into separate, proprietary networks.

Source: Janet Abbatte, *Inventing the Internet* (MIT Press: June, 1999).

[38] Nick Carr, *The Big Switch Rewiring the World, from Edison to Google* (W. W. Norton: January 7, 2008).

Today, given the existing investment by consumers and enterprise in the cloud, government will not have to subsidize the cloud's growth as it did with the Internet. Government should, however, be prepared to ensure that market forces foster the open environment that the creators of the Internet mandated as the Internet took shape.

> *"I don't think today we need government intervention to ensure that open environment. But it is important that [government understand] that success will be based on an open environment."*
>
> Danny Weitzner, Technology and Society Policy Director of the World Wide Web Consortium

For now, the consensus among most of the experts interviewed for this study is to let the market speak before Congress or regulators intervene. We share the view that providers who try to create proprietary systems – and, in effect, start acting like monopolists – will lose out to their more open competitors. Regulators ought best to wait and see whether the market does indeed favor sufficient interoperability and user choice.

Cloud evangelists like Dan Burton, Senior Vice President of Global Public Policy at Salesforce.com, believe market forces will in fact prove sufficient to "do the right thing" and that the winners will be those cloud providers who offer the best services at the best price; he agrees that consumers will exercise leverage, giving competitive advantage to higher quality players. "The market momentum is [moving] towards interoperability," says Burton. "If Google tries to tilt the field, people will go to a different field," adds Georgetown's Michael R. Nelson.

In any case, given the speed at which technology is evolving, the notion that government officials can write meaningful standards on interoperability seems far-fetched. "I don't know how the government would mandate standards," says Andy Rhodes, Head of Global Marketing for Datacenter Solutions at Dell. "The industry will mandate it and those who listen to the industry solve interoperability, freedom to move and management will win. Interoperability will drive openness more than the government."

"I don't think today we need government intervention to ensure that open environment," says Danny Weitzner of the World Wide Web Consortium. "But it is important that [government understand] that success will be based on an open environment."

If any of the large providers tries to dominate the market with a proprietary infrastructure of closed clouds, it will be difficult to realize the full potential of cloud computing.

Security

Despite assurances from cloud service providers, concerns about security remain a potentially significant obstacle to widespread adoption, Just as banks once had to convince potential customers that their money was safer in the vault than stuffed under the mattress, cloud providers must make a compelling case to users that their data is safe, even if it's no longer sitting on their hard drive or their company's own servers.

The notion of making a third party responsible and accountable for keeping data safe will continue to provoke debates in corporate IT departments during these relatively early stages of cloud computing. Against that backdrop, almost any widely publicized failures would be a serious setback for cloud proponents.

In most cases, the widespread acceptance of cloud computing discussed in this paper does not grow from a deep understanding of the underlying technology; chances are many if not most individual users of these services haven't even thought about where their data is stored and what makes it safe to put it there. Wendy Seltzer of Harvard's Berkman Center for Internet and Society is "continually surprised that people aren't more concerned about data security," and she argues that over time, the market will mandate that consumers have increasing visibility into how secure their data is.

Of course, business and government users cannot afford to be as casual as individual consumers have been so far. Carolyn Lawson, Chief Information Officer of the San Francisco-based California Public Utilities Commission, says that while the clouds can deliver services to the public, organizations like hers that hold personal data are reluctant to move to the cloud. "From the government perspective, I don't see a time when we will move all of our information into the cloud, because [our data] includes Social Security numbers, driver's licenses; we know where your children go to school…, and the public gives us this information and expects us to protect it," Lawson says.

"If we give this data to a cloud computing company, and there is a security breach or if that company gets sold, how do we address that? I am accountable."[39] Ironically, well-publicized breaches *not* involving cloud providers have raised anxieties about the security of data stored by third parties (see sidebar).

The challenge in selling to users like California's Carolyn Lawson will be convincing them that their data is not just safe in the cloud, but safer. The most obvious argument is that you are better off entrusting your data to the cloud, with its built-in backups and safeguards, than keeping it on your own hard drive, say – the modern equivalent of stuffing money in a mattress.

In theory, as cloud-based services expand to include most of the ways we use computers today, we need never worry about a lost laptop or fried hard-drive again. Cloud providers add that there is, in effect, safety in numbers: just as the cloud extends the benefits of scale to smaller players, it also offers the benefits of the highest-end security to anyone who uses it.

Take the example of "patches"—software updates to fix security flaws and other problems. In a traditional proprietary IT system, every time there's a patch from a software vendor (and there are lots of patches), it's incumbent on the customer to learn about the patch, and expend the resources to install it. This can take weeks if not months, during which time there are security holes which are open for exploitation. In the cloud, when a patch is released, all customers are patched immediately. Says Polly Sumner of Salesforce.com: "The more participants, while it creates greater incident risk, it also creates a much more secure system for everybody… This is sometimes difficult for people to get…. The security as a scale play is inherently more secure and all network participants benefit."

"Ultimately, the specialized data centers will be much more secure than [what] any company can do in-house."

Barry Lynn,
CEO 3Tera

What's more, cloud providers say they offer expertise that few individual companies can match. "One of the positions we have, if you are a cloud operator, and this is your main business, you are much more likely to be using the latest and greatest technologies to protect data and security, than, say, a Fortune 100 company", says 3Tera's CEO Barry Lynn. "Ultimately, the specialized data centers will be much more secure than [what] any company can do in-house."

Non-Cloud Privacy Breaches

Examples of highly public non-cloud data breaches:

*July 2006 - **AOL** posted on a public web site data on 20 million web queries from 650,000 users. Some search records exposed SSNs, credit card numbers, or other pieces of sensitive information.*

*September 2006 - a **General Electric** employee's laptop computer holding the names and Social Security numbers of approximately 50,000 current and former GE employees was stolen from a locked hotel room while he was traveling for business.*

*December 2006 - **TJX Companies Inc.** experienced an "unauthorized intrusion" into its computer systems that process and store customer transactions including credit card, debit card, check, and merchandise returns. In 2007 SEC filings, the company reported 45.7M credit and debit card numbers were hacked, along with 455,000 merchandise return records containing customers' driver's license numbers, Military ID numbers or Social Security numbers.*

*December 2008 -**RBS WorldPay** admitted that hackers broke into their systems. In the US, 1.5M financial and 1.1M personal records including SSN's were compromised. On November 8, 2008 hackers orchestrated a highly coordinated, global attack on ATM cards involving the theft of $9 million from ATMs in 49 cities worldwide.*

[39] Bridget Botelho, *Google et al. pitch cloud computing to wary IT pros* (SearchDataCenter: June 12, 2008).

But providers of cloud services will have to do more than argue their case. Dan Burton of Salesforce.com envisions international agreements on common standards for keeping information secure, so as to encourage "the free flow of secure data around the world."

Aggressive enforcement of cyber-crime laws by the United States and other governments is critical, too. "Go after fraud and cybercrime," says Timothy B. Lee of the Cato Institute. "The FTC has gone after spyware vendors; it is legitimate for government to be doing that kind of thing. As cloud computing becomes more common, we will have more crime related to cloud computing." However, if cloud providers can't convince consumers and businesses that data is secure, there's not much the government can do to help.

Finally, it's worth noting that there are risks inherent in every business, and there is no way to eliminate risk entirely – just to mitigate it to acceptable levels. A thoughtful and measured regime among cloud providers that builds trust among consumers and business is essential.

Privacy

In addition to guarding against an accidental release of private or confidential information, cloud providers also need to address three specific concerns about privacy: protecting data from unauthorized access by government, restricting its exploitation for commercial purposes, and safeguarding it from the prying eyes of competitors.

The World Privacy Forum *Privacy in the Clouds* report, released in February 2009, offers a comprehensive and potentially alarming analysis of privacy and confidentiality in cloud computing environments. Saul Hansell wrote in *The New York* Times, "As people and businesses take advantage of all sorts of Internet-based services, they may well find trade secrets in the hands of competitors, private medical records made public, and e-mail correspondence in the hands of government investigators without any prior notice."[40]

The level of privacy the cloud provides will depend not only on where you store your data, but also on the country in which you live. In the United States, for example, the law treats personal information differently once it's voluntarily handed over to a third party, like a cloud provider.

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[40] Saul Hansell, *Does Cloud Computing Mean More Risks to Privacy?* (NYT.com Bits Blog: February 23, 2009).

So while you might consider a message in your Gmail "cloud" to be just as private as one on your PC, law enforcement authorities could be allowed to search through your e-mails in the cloud without a warrant, which they would not be allowed to do on your laptop. "There are serious differences between privacy when you have files stored on your own machines and privacy you have when you give up data to a third party," warns Berkman's Wendy Seltzer. "You have less by law when you cede information to a third party, even if the third party promises you something."

Other critics agree that unchecked hype about the cloud encourages businesses and consumers to move mission critical data to the cloud before the industry has established a proper legal framework to protect data privacy. Danny Weitzner of the World Wide Web Consortium notes, "A legal argument now could be made that there isn't enough privacy protection for hosted services, as there is for [information] stored on our own servers. One of the problems we have is that laws written today are based on [computer] architecture [designed] circa 1986."

To complicate matters further, data centers that power the cloud are located all over the world, so an individual's private information may actually be under the jurisdiction of another country, with laws very different from the United States. "You don't know which laws your documents are subject to," says the Cato Institute's Timothy B. Lee. "You may think you have deleted something, but there's a copy on a server somewhere else, you may have a different jurisdiction [with] someone else (or some other government, more likely) getting access."

Ironically, passage of the Patriot Act, which gives U.S. intelligence services "legal" access to information flowing over U.S. soil without necessarily requiring "due process," has compelled some large users to route Internet traffic away from U.S. jurisdictions and to store their data outside the United States.[41]

SWIFT, which manages international money transfers for banks, has announced its intention to build a data center in Switzerland to keep European information on the Continent, free from potential inquiries by the U.S. government. According to *Le Monde*, French authorities banned use of "Le Blackberry" by government officials, for fear that U.S. and British national security agents could gain access to sensitive French e-mails passing through servers in their countries.[42]

HIPAA

HIPAA – the Health Insurance Portability and Accountability Act of 1996 – may be affected significantly by more widespread adoption of cloud computing.

Under the act, the government set standards for electronic maintenance and transmission of consumer health records. Health plan administrators, providers, and clearinghouses must protect any individually identifiable health-related information, specifically that which is stored or transmitted electronically.

The law is not clear as to whether third parties who store this information in data centers would be categorized as healthcare clearinghouses and thus required to adhere to the standards of the act.

Until this is made clear, Clay Shirky argues, one can imagine a scenario in which Congress effectively subjects cloud data centers to HIPAA terms – a potentially unwieldy situation in a world where blocks of data may be anonymously stored and widely dispersed.

[41] *Computers without Borders*, (The Economist: October 23, 2008).

[42] Associated Press, *France Bans Blackberry Use by Government Officials* (Associated Press: June 22, 2007).

"The best medicine is accountability and transparency. Vendors are held accountable for their actions. Do they stay within the parameters of their user agreements, and if these agreements are breached [can they] be prosecuted?"

Dan Burton,
Senior VP of
Global Public
Policy
Salesforce.com

Blackberry's maker, Research In Motion, denies that this sort of snooping is even possible, but a German software-industry group – perhaps somewhat self-servingly – asked its government to enact a similar Blackberry ban and switch to German providers, so as to keep e-mail traffic within national borders.[43] The Canadian government has also prohibited some of its projects from using US-based servers, for fear that its data would be subject to unwelcome scrutiny by the United States.[44]

One step in allaying such concerns might be for the major cloud providers to agree on common standards for security and privacy, much as the major issuers of credit cards did in 2005. MasterCard, Visa, AMEX, Discover, and the JCB International Credit Card Company formed a consortium to establish adequate and consistent data security measures to be used by banks, merchants, and service providers that store, process, or transmit cardholder data.

The experts also say that cloud providers will have to offer much more complete disclosure of how information is protected, and when and how it can be used or shared with others. Third parties are already beginning to run audits on cloud providers' data protection standards, a sign of a maturing marketplace. Google provides services like Gmail free of charge, for example, in exchange for the ability to serve targeted ads to users based on keywords in their e-mails. Privacy advocates we spoke to push for greater transparency about exactly what cloud providers propose to do with users' information.

This sort of disclosure would also cover the circumstances under which a cloud provider would cooperate with government investigations. "A big discussion going on in the privacy community is about accountability," says Salesforce.com's Dan Burton. "The best medicine is accountability and transparency. Vendors are held accountable for their actions. Do they stay within the parameters of their user agreements, and if these agreements are breached [can they] be prosecuted?"

Governments will no doubt have to adapt as well; laws will have to extend the protection of locally-stored data to information stored remotely, and policy-makers may have to coordinate with their international counterparts. Ironically, one of Congress's principal challenges may be to assess how current laws and regulations, including some designed specifically to protect user data, need to evolve so as to take advantage of opportunities in the cloud – or, at the very least, so as not to impede technological advances that consumers and constituents want.

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[43] Wolfgang Gruener, *German government asked to ditch Blackberrys* (TG Daily: June 22, 2007).

[44] Bill Thomson, *Storm warning for Cloud Computing* (BBC.com, May 27, 2008).

There is growing momentum in Congress for omnibus privacy legislation that defines and protects consumer's rights with respect to their personal information. One potential goal of such legislation would be to shield consumer data from inappropriate government scrutiny and to define what rights companies have to exploit data about their users for commercial purposes.

As we noted, privacy advocates stress that data submitted to a third party – for example, an e-mail service operating in the cloud– may not enjoy legal protection comparable to data sitting on a user's hard drive. For the cloud to flourish, that must change. "What I think has to happen is that very clear and strong privacy protections have to be established for private information held by third-party cloud providers," says Danny Weitzner of the World Wide Web Consortium. "Ultimately, I think Congress [may have] to balance [the] interests of privacy advocates, industry players, and law enforcement officials."

On the other hand, over-regulating the cloud risks impeding innovation and improvements that constituents want (see sidebar). As *Wired* magazine's Kevin Kelly says, "The law is like having a sidewalk and a path that consumers use. Eventually after seeing how consumers walk, they [regulators] pave that as the new path. I think we are going to be in period of great uncertainty, experimentally trying to sort this out…I think that there is still a lot of work to be done before regulators get involved because we just don't know these outcomes [that consumers want] yet."

"The law is like having a sidewalk and a path that consumers use. Eventually after seeing how consumers walk, they [regulators] pave that as the new path."

Kevin Kelly, Founding Executive Editor of *Wired* Magazine

Companies innovate by providing new products and services to please their users. When users find issue with these changes, they can pressure companies to respond to their demands or suffer the consequences, as we've seen with Facebook. This is a form of ethical discipline for companies provided by market forces, not government regulation.

Economic value

Cloud-based applications have already caught on with consumers through a combination of ease of use, the powerful lure of sharing and networking, and the negligible costs involved.

Further adoption will depend on whether applications and services (everything from word-processing to storage) are cheaper than and at least as useful as what customers can buy in a shrink-wrapped box. For small businesses, the cloud offers a level of computing power that otherwise would have required too much capital and technical knowledge.

Facebook

The Cato Institute's Timothy B. Lee cites the example of Facebook to illustrate the power of market forces to ensure ethical behavior on privacy: when Facebook has stepped out of line, consumer outrage has knocked it back into place.

In the face of consumer outrage and an organized campaign from MoveOn.org, Facebook quickly scaled back Beacon, a program that publishes information about members' activities on other websites and uses that information to serve them targeted ads.

Similarly, Facebook backed down within hours in early 2009 when it proposed a change to its users' ownership rights with respect to their own posted information: the company claimed that it "owned" any and all information on its site, rather than the users who posted it. This was a reversal of pre-existing policy – and the immediate reaction of hundreds of thousands of Facebook users handed the company another Beacon-like embarrassment.

On the other hand, the "Newsfeed" feature on Facebook, while also controversial initially, has become a popular feature with privacy controls.

Source: *Facebook backs down, reverses on user information policy* (CNN.com: February 18, 2009).

Genentech

'The economics of the cloud certainly appealed to Genentech. So much so that they turned to Google Apps to meet the needs of their 16, 000 + strong workforce. Based on the number of Genentech employees granted Google software accounts, the South San Francisco-based biotech company is paying at least $800,000 per year for the online Google Apps package.

However, this cost is much less than what buying and maintaining a software package from Microsoft, Oracle or IBM would have run the company.

Additionally, Genentech figures to save a lot more money in the long run. According to CIO, Todd Pierce, the company would have had to eventually invest up to $80 million in building a data center and hire many more engineers to meet its computing needs.

Source: *Cloud computing looms large on corporate horizon* (Associated Press: December 22, 2008).

SMB's using cloud applications such as Google Apps, Salesforce.com, and Zoho Office have already capitalized on this new computing power that was out of reach before the emergence of the cloud. And as we've discussed, accessible platforms allow developers to create highly specialized consumer applications built on a common technology – witness the explosion of targeted applications for the iPhone. The extent to which new applications built on open cloud-based platforms are useful and affordable will help drive the growth of the cloud.

But the real test of value will be at the enterprise level (see sidebar on economic benefits). Cloud advocates like to refer sarcastically to traditional IT managers as "server huggers," clinging to their proprietary technology. Cloud evangelists like Kirk Krappe, CEO of Apttus, believe the model of software, platform, and infrastructure as a *service* is so compelling that increasing adoption by businesses is inevitable. "We eliminate that 12 months of infrastructure and architecture – and critical decisions like UI and usability – even all that is gone…. It's so extraordinarily attractive and appealing on every front. In 30 years we will look back and say it was ridiculous that there was even any debate on doing this – speaking from someone inside industry who has been in both models."

Believers like Russ Daniels of HP see the potential for cloud-based technology to open up new markets: "The classic challenge of addressing a new market is to do it at a lower cost, make things available where they could not previously be delivered, or remove complexity – make things simpler and easier to use. We think the cloud can address all three of those."

Sustainability

At a time when enterprises are under increasing pressure to adopt "green" strategies, sustainability will become a critical factor in determining the viability of cloud computing. Because of their concentration of processing power and storage, data centers are voracious users of electrical power –and most Global 1000 companies have their own data centers. According to the Environmental Protection Agency, in 2006 data centers consumed 1.5% of all the electricity used in the United States – 61 billion kilowatt hours at a cost of $4.5B a year.[45] Experts have compared this volume of consumption to the electricity demands of the entire state of Mississippi.[46]

Potential Economic Benefits of the Cloud

- Create new business opportunities and new markets by offering high-end computing power at lower cost.
- Eliminate or reduce start-up and maintenance costs for the expensive and proprietary data centers companies rely on now.
- Eliminate the need to build infrastructure for infrequent peak periods by making extra capacity available on demand.
- Increase productivity by allowing businesses to focus on their core competencies and customer offerings rather than IT infrastructure and maintenance.
- Enable faster and cheaper innovation by providing an existing platform for developers to build on, and making the cost of launching new initiatives more predictable.
- Enable collaboration in real time across different specialties and time zones.
- Create economies of scale through use of data centers that are energy efficient and powered by renewable energy sources.

[45] U.S. Environmental Protective Agency, *Report to Congress on Server and Data Center Efficiency* (U.S. EPA, Energy Star Program: August 2, 2007).

[46] Steven Shankland, *U.S. servers slurp more power than Mississippi* (CNET: February 15, 2007).

That's double the consumption for data centers in 2000 – and the number is expected to double again in the next five years (at a cost of $7.4 billion per year). Globally, data centers are already responsible for more carbon dioxide emissions per year than Argentina or the Netherlands, according to a joint study by McKinsey and the Uptime Institute. If today's trends hold, these emissions will have grown four-fold from today's levels by 2020. By some estimates, *The Economist* reports, the carbon footprint of cloud computing will overtake that of the aviation industry.

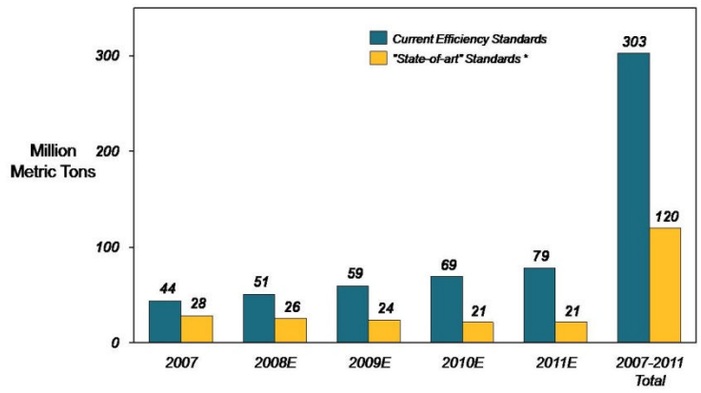
While these figures are daunting – and even worrying from the standpoint of sustainability – they underline the imperative for efficient energy management in meeting our nations' computing needs. The EPA's report to Congress on data center energy efficiency is, in effect, an endorsement of cloud computing's potential to drive up energy efficiency by eliminating the redundancy and waste that results when every enterprise runs its own servers. The EPA estimates that consolidating computing power into shared, energy-efficient servers and storage could result in a reduction of electricity use by up to 55% as compared to current trends – a savings of 74 billion kilowatt hours by 2011 that would cut energy costs by $5.1 billion and reduce carbon dioxide emissions by 47 million metric tons.

So the cloud model appears to be a better answer for the environment. That fact creates added incentive for cloud providers to make their large-scale data centers even more environmentally "friendly"– which will serve as a high-voltage argument for enterprises under pressure to adopt more responsible and sustainable business practices by shifting their IT infrastructure demands to the cloud.

Google's data centers, for example, now use considerably less energy than the industry average: average energy-weighted overhead across all Google-built data centers is 19% versus the average of 96% reported by the EPA in 2007. According to many observers, Google can achieve such energy efficiency because its massive scale allows it to acquire efficient equipment that might be too costly for other companies, but this is only part of the story. Google has invested considerably in research and innovation to "green" its data centers. This extends beyond just electricity consumption to the water Google uses to cool its centers; by 2010, Google expects recycled water to provide 80% of its total data center water consumption.[47]

[47] Randy H. Katz, *Tech Titans Building Room* (IEEE Spectrum: February, 2009).

Projected Co_2 Emissions Associated with Electricity Use of U.S. Servers and Data Centers 2007-2011* [48]



* Note: The "state-of-the-art" scenario identifies the maximum energy-efficiency savings that could be achieved using available technologies. This scenario assumes that U.S. servers and data centers will be operated at maximum possible energy efficiency using only the most efficient technologies and best management practices available today.

[48] U.S. Environmental Protective Agency, *Report to Congress on Server and Data Center Efficiency* (U.S. EPA, Energy Star Program: August 2, 2007).

Government and the Cloud

The final "enabler" of a flourishing cloud is enlightened public policy and government investment. We share the view, along with virtually all of the experts we interviewed, that the competitive marketplace will heavily influence and probably determine the future of cloud computing. Unlike the growth of the Internet, which was fueled by the government and academia long before market forces took over, private enterprise and consumer behavior are key drivers of cloud computing. However, policy-makers can play an important role in creating optimal conditions for the cloud to flourish – helping to ensure universal connectivity to broadband, policing cyber-crime, clearing away potential obstacles to fair and open Internet access, and ideally helping to lead the way with government's own adoption of cloud services.

In contrast, over-regulation could create a climate that impedes the cloud's growth. As questions about the cloud revolve around *when* and *how*, but not *whether*, it will be realized, it is essential that the United States get this balance right to help advance and benefit from this coming revolution. If, as argued, cloud computing represents a potentially transformative democratization of technology by making the same computing power available to individuals and small- and medium-sized businesses that the largest enterprises enjoy, elected officials have the opportunity to help deliver its enormous benefits to the full diversity of their constituents.

In fact, through its actions in the next few years, Washington can help determine how quickly the cloud grows; whether it realizes its full potential; and perhaps, equally important, whether the United States becomes the vital center of a global cloud ecosystem.

As with the Internet, government's most important role may ultimately be a simple and obvious one: promote the benefits of the cloud by becoming an early adopter of cloud-based services. At a basic level, the government can insist on sustainability standards for its cloud vendors' data centers (or require compliance with EPA "best practice" recommendations, including the use of renewable energy sources), and lead by example with respect to privacy, security, openness, and interoperability. The government might also finance research into aspects of the cloud's potential that enterprise might not fund. Former Director of the National Science Foundation Office of Cyberinfrastructure Dan Atkins says, "You may not find private companies willing to invest in the highest end of cloud computing for the needs of science and contemporary research. A government and private enterprise partnership could be set up to build sustainable infrastructure that would serve these needs."

The benefits of a thriving cloud have the potential to transform how government does business, both internally and with its constituents, including voters and taxpayers. Government agencies, including the Department of Defense, are already moving some activities to the cloud. But cloud proponents like Google's Director of Public Policy and Government Affairs, Andrew McLaughlin, who is hopeful about a more prominent role for technological innovation in the new administration, offers a more sweeping vision: "Coupled with entrepreneurial CTOs or CIOs at key agencies, a cloud computing platform could unleash creative innovation by federal agencies and employees in the services they provide, the data they make available, and the tools they use to collaborate and solve problems. They would build applications and publish databases [that] would, in turn, serve as platforms for collaboration, self-organization, decision-making, and untold, unpredictable innovative uses by American citizens as well as federal employees."

For the United States to lead in this space, a delicate balance must be struck. Government will need to monitor the growth of the cloud and exercise influence as a user of cloud services and as a convener of cloud stakeholders, to help bring about a secure, open, and interoperable cloud. Government should also examine (or re-examine) pending and established policy in light of a future where previous notions of information ownership and jurisdiction will necessarily change.

These are areas, however, where government must be mindful not to overstep its bounds: the majority of experts we consulted advocated a "wait and see" approach before rushing in to legislate and regulate this dynamic new space. As Kevin Kelly of *Wired* magazine puts it, "If we had a really good understanding of this – then we could say the law should be set this way and we should lead. I don't see a comprehensive sense of where we should lead. I think experimentally we will work to sort this out."

Concluding Thoughts

The promise of the cloud

It's noteworthy that the cloud has few actual detractors. Similar to the impact of the Internet combined with the web, the cloud appears, in many ways, to represent an inevitable next stage in the evolution of computing infrastructure. As observed, decentralized computing was the logical outcome of a world in which semiconductor-based processing power was growing faster than the speed or capacity of available information networks. If individuals or enterprise needed computational resources of any scale, they had to own them – first as mainframes, then as minicomputers, and later as PCs. The network was too slow, scarce, or unreliable to do otherwise.

Today, accessible or "always on" connectivity is increasingly available to consumers and businesses around the world. Thanks to growing Internet penetration, ubiquitous data networks are becoming a fixture of modern life. From cable modems and DSL in the home to fiber-optics in corporate offices, the communications bottleneck that once existed with respect to speed and cost is easing. With 3G wireless standards (and beyond), even wireless communication has gone high-speed. That means computing resources no longer need exist as islands unto themselves: they can, and will, become shared utilities – accessible for nearly anyone from any location, like water and electricity, with minimal investment in local hardware and equipment.

As noted, the cloud is already a reality for many consumers, whether they know it or not. A growing array of web-based services – including e-mail, photo-sharing, video streaming, and social networking – have taken consumer mass markets by storm. Every one of them is an instance of a cloud-based service. That means consumers have already begun to benefit from shared computing resources, and entrepreneurial ventures are creating value by marketing new cloud-based services. As the cloud paradigm increasingly enters the realm of large-scale enterprise IT, it's clear that it will become the "new normal" in large corporations. The advantages in optimal use of computing power, deployment of IT talent, and energy efficiency are too attractive to ignore. The benefits to small- and medium-sized business in establishing a more level playing field in IT resources and reducing the capital intensity of launching new ventures have also become obvious.

Living with the Cloud

There is another essential economic rationale for the Cloud to compel the attention of the United States. This country has played a signal role in global business and technology leadership since the mid-19th century. It was in the United States that modern capitalism expanded most dramatically, enabled by the creation of far-reaching communications networks based on the telegraph and telephone; continent-spanning transportation networks starting with canals and railroads, succeeded by airplane travel and superhighways; and, finally, the Internet. It was in the United States that the world got its first glimpse of mass production, which demanded the twin innovations of mass marketing and mass distribution. As this country seeks to redefine its future in a changed world, it seems reasonable to propose that the cloud is one avenue for the United States to re-assert economic and technology leadership on a global stage – and to create wealth for American citizens while deploying assets to benefit the world.

The cloud is a development that sits comfortably in the realm of technology or business. By definition, the Internet, on which the cloud is based, is a global medium. In theory, it transcends legal and regulatory boundaries and supersedes demarcations of national sovereignty. In reality, as recent history has made clear, the global reach of the Internet is nonetheless eminently subject to sovereign jurisdictions.

The Chinese government, for example, censors search engine results served by that nation's dominant search portal, Baidu, along with non-Chinese portal or search services: in August of 2008 it shut down Apple's iTunes

service to block access to certain cultural content. Other countries have attempted to eliminate use of the Internet entirely. As cloud computing expands, it will require a global platform that's committed – both philosophically and operationally – to the free flow of information and capital.

The United States is ideally suited to "host" the development of the cloud economy. After all, it was the Internet, created by US-led investment through DARPA in the late 1960s, it established the basis for the World Wide Web, which achieved its first, and arguably fullest, flowering in this country in the 1990s. Despite the dot-com boom and bust, the wealth in jobs and capital created as a result of this country's leadership on the web became, in the last decade of the 20th century, a beacon of innovation for the world.

"What government can do best is to clear the road, not to pave it."

As promising and important as a robust roll-out of the cloud may be, it does not warrant government action. Most industry experts believe that the most productive public policy in support of the Cloud is one of care and caution on the part of both regulators and legislators. As Clay Shirky notes, "The cloud can take care of itself. If it isn't an economic opportunity today, there's little that the government [can] do to make it work." From commercial, social, or cultural perspectives, the cloud is unfolding of its own accord, and industry, in particular, is addressing the economic and organizational implications of this transition in real time.

The cloud will demand clarity in the form of common standards of information exchange, consensus on intellectual property rights, and guidelines for information ownership and access. It will surely require careful consideration of standards for data security and consumer privacy. But it does not require our government to "pick winners and losers" or to invest outright in development of the cloud. What government can do best is to clear the road, not to pave it.

The advantages to this country of having the cloud flourish on these shores are myriad. If it's the next paradigm of computing, then the opportunities for U.S. business leadership and wealth creation are obvious. But the vision goes beyond that. If the United States became a global platform for cloud services, every data center could stimulate some limited degree of local economic development where it's situated. More importantly, the presence of such computing power in locations across the United States would, in turn, attract top scientific, engineering, and technology talent from around the world to American universities, corporations, and start-ups. This unique combination of talent and business activity could give rise to new economic activity among, to name a few, cloud services resellers, specialized cloud services providers, and integrators of cloud platforms and applications.

That, in turn, would provide companies doing business in the United States with the potential for most favored access to the world's best computing infrastructure as well as the "ecosystem" surrounding it.

If the United States wants to participate in the wealth creation of a new cloud economy, it must ensure that it's positioned to become a "moderator" of the global cloud and a guardian of its integrity. One of Congress's principal challenges may be to assess how current laws and regulations, including some designed specifically to protect user data, need to evolve to take advantage of opportunities in the cloud – or, at the very least, not impede technological advances that consumers and constituents want.

One key aspect is an assurance of due process with respect to information access. This is an area where national sensitivities – ours and others – understandably run high, and the United States can play a crucial role in achieving global unity of purpose around the cloud. The reality is that the cloud, as a utility, must operate according to accepted and open global standards. Anyone who violates those standards, including the United States, runs the risk of being excluded by others from the cloud on a de facto basis. "[This is] no different from any other infrastructure that a country needs," notes K.C. Claffy, a research scientist at the University of California's San Diego Supercomputer Center. "You wouldn't want someone owning your roads, either." In short, the cloud will require not just a global base of talent, resources, and infrastructure; it will also need a national host environment with legal and regulatory clarity, due process, and transparency of principles and actions.

Today, the potential for U.S. leadership in technology is at risk. While Internet usage around the world has grown, the dominance of the United States as a platform for data traffic has diminished substantially since the 1970s. Now is the time for U.S. action to clear the way for cloud computing. Countries like China and India are investing in next-generation Internet technology to support their own sky-rocketing consumption of computing services, and to take advantage of shifts in Internet traffic away from the United States. "America needs a wake-up call," argues former Harvard Business School professor and entrepreneur, John Kao. "We don't have a national strategy, and…having no strategy is not satisfactory."

It is especially not satisfactory when opportunity as mammoth as the cloud beckons, and government need help only by clearing the way. There are 1.5 billion PCs, one billion laptops, and 3.8 billion mobile phones in use around the world. Each is a small computer, most are networked, and nearly all rely already on aspects of the cloud. It's time to ensure that what the cloud promises as an opportunity for U.S. wealth generation, job creation, and technology as well as commercial leadership does not pass our country by.

Industry Experts Interviewed

Over the course of this engagement, Marketspace conducted extensive interviews with the following industry, corporate, and academic experts:

1. **Polly Sumner**
   President, Platform, Alliances and Services, Saleforce.com
2. **Dan Burton**
   Senior VP of Global Public Policy Saleforce.com
3. **Russ Daniels**
   VP and CTO, Hewlett Packard
4. **Shelton Shugar**
   SVP of Cloud Computing, Yahoo!
5. **Richard Zippel**
   VP of Technology, Sun Microsystems
6. **Drew Clark**
   Director of Strategy VC group, IBM
7. **Andy Rhodes**
   Head of Global Marketing - Datacenter Solutions, Dell
8. **Anthony Dina**
   Director of Enterprise PG Strategy & Business Planning, Dell
9. **Barry Lynn**
   Chairman and CEO, 3Tera
10. **Peter Nickolov**
    President, COO and CTO, 3Tera
11. **Dave Girouard**
    President of Enterprise, Google
12. **Alan Eustace**
    SVP Engineering and Research, Google
13. **Kirk Krappe**
    CEO, Apptus
14. **Jeremy Roche**
    CEO, CODA
15. **Timothy B. Lee**
    Adjunct Scholar, Cato Institute
16. **Clay Shirky**
    Technologist and Author of *Here Comes Everybody: The Power of Organizing Without Organizations*
17. **Kevin Kelly,**
    Founding Executive Editor of *Wired*
18. **Michael R. Nelson**
    Visiting Professor of Internet Studies Georgetown University
19. **Wendy Seltzer**
    Research Fellow, Berkman Center
20. **Ethan Zuckerman**
    Research Fellow, Berkman Center
21. **Danny Weitzner**
    Policy Director of Technology and Society activities World Wide Web Consortium
22. **Dan Atkins**
    Former Director, NSF Office of Cyberinfrastructure
23. **Vinton G. Cerf**
    Chief Internet Evangelist, Google
24. **Andrew McLaughlin**
    Director of Public Policy and Government Affairs, Google