The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public Policy (*)

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Abstract: We contend that cloud computing is historically unique by simultaneously being an innovation ecosystem, production platform, and global marketplace. In the 1st Part we define cloud computing as a 'dynamic' utility, listing key characteristics of what it is and what it is not, both from providers' and users' vantages. In the 2nd Part we characterize three competitive battles in the broader cloud ecosystem - winning the User (cloud providers), the search for value (network providers), and the device wars (device providers). We then provide a new and simple, but powerful and practically applicable typology that combines the type of providers with the commonly understood architecture types. The 3rd Part applies this framework to analyze the business strategies of global cloud service providers and select others in the broader ecosystem. We conclude with policy implications and where to take research from here.

Key words: cloud computing, industry analysis, business models, policy.

■ Introduction: cloud computing, the new computing platform

Cloud computing is rapidly emerging as the new platform for computing. It is, however, much more than simply a new set of technologies and business models. Cloud computing transforms how consumers, companies,

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and governments store information, how they process that information, and how they utilize computing power. It raises new policy issues and reopens old debates as the technological logic of cloud computing services moves the location of computing and data across more national and organizational boundaries far more than ever before. However, much of the discussions about cloud computing in the academic and policy worlds, as well as the non-specialist business community, suffer from a markedly nebulous understanding of the actual industry dynamics underlying the exponentially growing cloud business ecosystem. What exactly is cloud computing? Who are the actors in the emerging ecosystem, and what are their business model trajectories? What do the actors and business models tell us about policy issues? These are the questions this paper addresses.

There is a growing volume of analysis about the technical underpinnings and various typologies of cloud computing, along with emerging policy issues (YOUSEFF, BUTRICO *et al*., 2008; KUSHIDA, BREZNITZ *et al*., 2010; ZHANG, CHENG *et al*., 2010; KUSHIDA, MURRAY *et al*., 2011). However, compelling characterizations and frameworks for understanding how the various actors are converging from different origins, though different trajectories, to a range of positions in the broader cloud computing ecosystem has yet to be articulated. Unlike other analyses, we start with firms and their business models to draw significant implications for policy, and how cloud computing will drive broader economic transformations.

At the broadest level, we contend that cloud computing is historically unique by simultaneously being an innovation ecosystem, production platform, and global marketplace. In the 1st Part we define cloud computing as a dynamic utility, listing key characteristics of what it is and what it is not, both from providers' and users' vantages. Then, we characterize three competitive battles in the broader cloud ecosystem-Winning the User (cloud providers), The search for value (network providers), and the device wars (device providers). We then provide a new and simple, but powerful and practically applicable typology that combines the type of providers with the commonly understood architecture types. The 3rd Part applies the framework to analyze the business strategies of global cloud service providers and select others in the broader ecosystem. We conclude with policy implications and where to take research from here.

■ Understanding cloud computing: what is new, and why is it important?

First, what exactly is cloud computing? Currently overused, the term is too often appropriated by marketers to include all online services. In doing so, it loses meaning. In our vantage:

> Cloud computing delivers computing services - data storage, computation and networking - to users at the time, to the location and in the quantity they wish to consume, with costs based only on the resources used.

Key characteristics emerge from influential existing conceptions (ARMBRUST, FOX *et al*., 2009; NIST, 2012) as well as our own interviews and experiences:

- users procure the "amount of computing" they want without investing in their own infrastructure. Only an Internet connection is required;
- cloud services provide the illusion of infinite resources on demand available to users, regardless of their size and number;
- applications allocate compute, memory and storage resources without reference to underlying physical infrastructures-virtualization. This also decouples the physical location of users and the cloud datacenters;
- cloud services transform computing from a capital expense to an operating expense. This changes the role of IT expenditures within the firm;
- providers can dynamically add, remove, or modify hardware resources without reconfiguring the services that depend on them. This is a major difference from traditional datacenter outsourcing;
- cloud computing changes the location of data processing. Processing moves from the "edge" of the network, in PCs and private data centers, towards the center of the network, in shared cloud datacenters;
- only a few firms are able to offer truly global-scale cloud infrastructure (eg., Amazon, Google, Microsoft), with each firm requiring numerous datacenters costing more than $500 million each, worldwide.

There are a few things that cloud computing is not.

- cloud computing is not simply all datacenter outsourcing, and a large enterprise with a single datacenter is not a cloud service provider. The real power is in the dynamic allocation of resources and the 'illusion' of infinite scale;
- cloud computing does not automatically imply dumb terminals or "thin" clients with little power at the user's end. Many cloud services depend on

powerful client processing capabilities. Network latency remains an issue, and processing power and storage capacity on user devices (smartphones, PCs) continues to improve in line with Moore's law.

For users, cloud computing is a dynamic utility

We contend that for users, cloud computing is a dynamic utility. As with a traditional utility, cloud computing resources are always available, they are paid for according to the amount consumed, and can be consumed in any quantity. (More precisely, there are contractual levels of availability and reliability.) Services are delivered through Internet connections, and the provider does not care about the device used to consume the service. Users do not care about how providers technically configure or operate the service on the back end as long as quality and price are acceptable, and users are free to use the resources as they see fit. Cloud providers, like utility providers, are large companies operating at significant scale, serving small users as well as giant corporations. Aggregate demand can then be amortized over this highly scalable infrastructure and sold back to the user at a much lower - per unit resource - cost than users could provide themselves. Cloud computing is poised to become part of societies' critical infrastructure, as an increasingly dominant means through which the world's computational demands are met. It will approach the level of economic critical dependency as electricity, gas, water and telephony. These utility-like characteristics create incentives for national governments - particularly non-US government for whom the major global services providers are foreign - to search for regulatory frameworks that approach cloud services as critical national infrastructure.

For providers, cloud computing is a competitive proposition

The competitiveness of cloud computing service provision critically depends on providers' ability to build out capacity at a scale far greater than any individual user or firm could afford. For providers, cloud services are not utilities; they are competitive propositions that differ from utilities in several important ways, and providers would certainly resist being regulated as utilities.

First, cloud services are not commodities-goods offering little value-added, that are interchangeable with others, and which compete primarily on the basis of price. Cloud providers are competing on value-based differentiation on attributes such as service level and functionality. Second,

cloud providers do not enjoy inherent - geographic - lock-in of users. Public utility providers are granted local monopolies, but cloud services are not geographically bound. Therefore, cloud providers face pressure to create their own service level lock-in mechanisms. Third, the actual data bits delivered in cloud services are not interchangeable in the manner of electrons, or molecules in traditional utilities. Users care a great deal about the whereabouts of the bits carrying sensitive personal or mission-critical corporate data, but far less about the location of the constituent bits of a photo or video. Datacenters are not inherently tied to specific locations close to the markets they serve. Other factors such as real estate, electricity, and access to network infrastructure, factor greatly in decisions. Arguably the biggest difference between cloud services and traditional utilities lies in the degree to which cloud services are uniquely and dynamically configured to the needs of each application and class of user. Cloud services are built from a common set of building blocks, but unlike the electricity provider, cloud providers configure them in unique ways for each specific application. For example, the building block configuration for a global public email system differs from an airline reservation system.

Cloud computing as an innovation ecosystem, production environment, and marketplace

We contend that cloud computing is uniquely new by simultaneously being an innovation ecosystem, a production environment, and a marketplace, despite many technologies and concepts underlying cloud computing, such as virtualization, and applications residing on remote servers, not being new. Cloud computing feeds the innovation ecosystem by lowering the bar for new entrants and facilitating experimentation. Most startup firms no longer require substantial capital outlays to build ICT capabilities. They can rapidly scale up or scale down operations as needed, and they can experiment with highly computing intensive tasks. Cloud-based tools further lower startup costs. Larger enterprises with pre-existing datacenters can also utilize cloud resources for bursts of computing capacity for experimentation. Within their own datacenters, cloud computing-style architectures increase allocation efficiency of internal IT resources-to the extent possible with their corporate organization. Cloud computing is becoming the baseline for efficiency and functionality for firms' IT infrastructure. Global cloud providers' scale enables far lower total operating costs than consumers' own infrastructure. Since cloud providers can upgrade services in real-time, users who do incur costly IT infrastructure upgrades. This accelerates the implementation of new technologies, to the

detriment of those who do not adopt cloud services. Cloud computing is also quickly becoming a production environment. We are now in an era when IT services are best considered part of production; systems are built, which then deliver services via IT networks (ZYSMAN, FELDMAN *et al*., forthcoming). Cloud services, including raw storage and processing power, and platform-level tools, provide the building blocks for creating systems. For example, popular file synchronization and storage service Dropbox, and Netflix's video streaming service, both use Amazon's cloud infrastructure. Google and Microsoft's powerful developer tools the ability to automatically generate cloud based services and applications. Cloud services extend the innovation platforms worldwide, becoming marketplaces with global reach. This is accentuated by the spread of Apps for smartphones, tablets, and browsers, putting within reach powerful building blocks, tools, and entire ecosystems of third party tools to anywhere with an Internet connection.

For advanced industrial countries, cloud computing provides new opportunities for innovation and entrepreneurship, and promises substantial efficiency gains. For developing countries, cloud services open up new possibilities to enter international markets and find niches in global value networks. As with the previous computing platforms - mainframes, PCs, and networks of PCs - cloud computing is becoming a baseline for national and corporate IT infrastructure against which other forms of infrastructure and service delivery must be measured. There are, of course, still unresolved questions and potential risks associated with cloud computing services-business resumption strategies in the event of a catastrophic failure, though unlikely, of the cloud providers' services, for example. While many larger firms will choose to retain some on-premise capacity, smaller firms may not have that luxury, becoming entirely dependent on one or more cloud providers. Cloud service reliability also critically depends on network service provision; no network, no cloud. This raises serious implications about different national contexts, with different regulatory regimes governing which can provide network infrastructure and the rules under which they operate.

■ Analyzing the cloud ecosystem

A concrete understanding of the business ecosystem surrounding cloud Computing is critical not only to understand how the competition unfolds, but to understand the relevant policy issues by diverse government agencies across various jurisdictions.

Battles are raging over capturing value in the broader cloud ecosystem, and business models are in flux. Competitors from previously distinct sectors are now in competition, ranging from consumer online services firms such as Google, Microsoft and Amazon, established technology companies such as IBM and HP, cloud-based startups such as Salesforce.com and Rackspace, incumbent telecom carriers such as AT&T and Verizon, and other major computer-related companies such as Apple. Each bring different strengths, creating sharply contrasting vantages on the best sources of value added activity - which areas are most lucrative, and how can firms carve out a sustainable market positions. As in all markets, commercial battles in cloud computing revolve around controlling the end user relationship and the ability to extract value.

The cloud services framework and competitive battles

We now turn to our "cloud services framework." It has two axes: provider types (horizontal) and three layers of technical architecture - vertical (see figure 1). There are three provider types engaged in particular forms of competition. Some firms competing in multiple areas, as shown later.

- Cloud providers create, configure, run and distribute services from their cloud datacenters. Major cloud providers such as Microsoft, Google, Amazon, SalesForce.com, and a plethora of smaller players, are vying for consumers, firms, and developers with an ever-widening and overlapping set of service offerings -"winning the user".

- Network Providers offer Access Networks enabling the distribution of cloud services from the cloud providers to access devices. Traditional telecom carriers, as predominant network providers, face ever-intensifying pressure to find value and relevance, as cloud services and new Access Devices place ever-increasing demands on network bandwidth and infrastructure -"the search for network value".

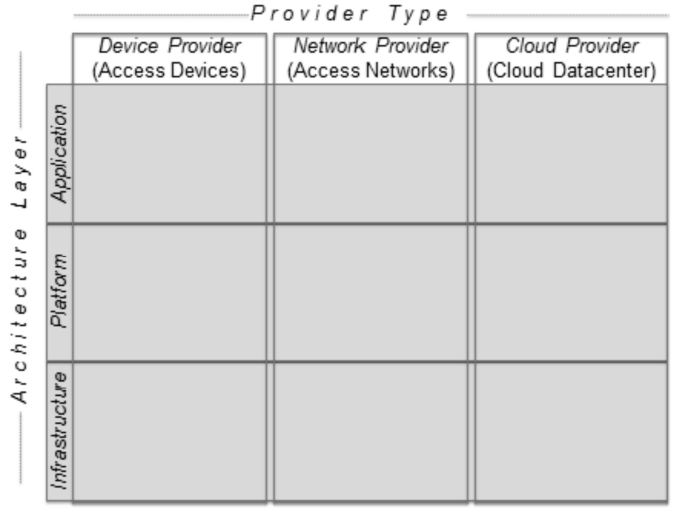
- Device Providers offer the Access Devices such as smartphones, tablets and PCs through which users access cloud services. A new generation of devices, and the operating systems on which they run, are pitted against each other with contrasting business models - "the device wars".

The three layers of technical architecture include:

- infrastructure, encompassing the hardware, networks and operating systems managing resources such as data storage, computation and network bandwidth;

- platforms, providing a set of common services, such as databases, messaging, and business rules engines shared by applications. Platforms also insulate application developers from the complexity of the underlying infrastructure through a set of higher level Application Programing Interfaces (APIs);
- applications, providing the mechanism through which users interact with the cloud applications - often through a web browser or more recently through small downloadable programs, Apps. Applications run in the cloud datacenter, (including many Apps, which are front-ends for datacenter-based content.)

Figure 1 - The "cloud services stack"

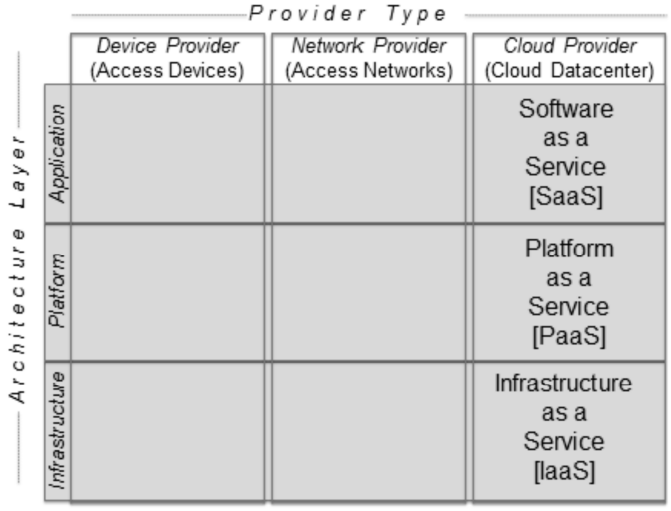


Now we turn to each element in detail. Significantly, regulatory issues differ by type of actor.

Cloud providers: provisioning cloud services

Cloud services fall into three broad types according to their technical architecture (see figure 2). Each entails distinct business models. Infrastructure services - commonly referred to as Infrastructure as a Service (IaaS) - are virtual, cloud-based replacements for physical hardware such as processors and hard drives. Amazon's virtual servers are the paradigmatic example. Standalone IaaS services constitute building blocks for other services and tools.

Figure 2 - Cloud services types



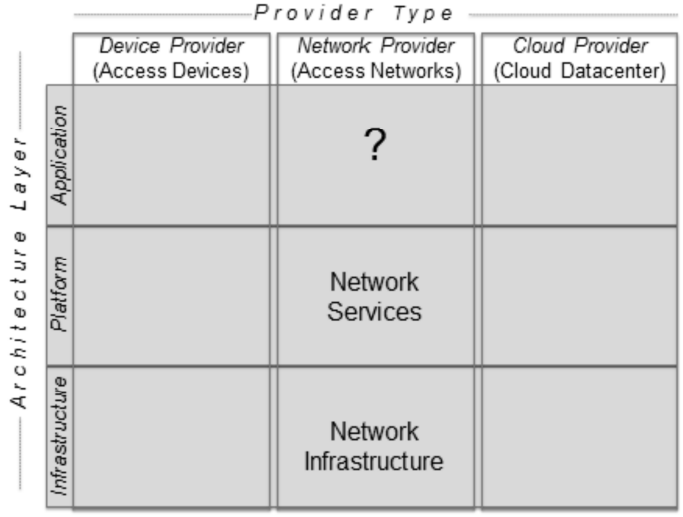
IaaS providers therefore benefit from growth of the broader ecosystem. However, IaaS offerings are commoditized more easily, since switching storage or processing power is relatively easy, creating pressure to attain massive scale to lower costs. Platform as a Service (PaaS) provides 3rd party developers with programmatic access - *via* standardized frameworks and interfaces - to the massive scalability and dynamic resource allocation offered by cloud datacenters. Examples include Microsoft's Windows Azure platform, Salesforce.com's Force.com, Google's App Engine and new entrants such as Tier 3's Enterprise Cloud Platform. PaaS providers' competitiveness depends on the richness of the ecosystem of applications that leverage its unique frameworks and interfaces. Microsoft's dominance of the PC platform with the Windows platform is the paradigmatic example. PaaS providers compete over their platform's unique attributes, the potential efficiency of application development, and user and developer population size. Most PaaS providers monetize their services by charging developers to use the underlying processing power, storage and network capacity utilization, and other higher level services such as billing, optimized content delivery, and service-level guarantees. Others, such as SalesForce.com, have created third party application markets to enhance their service offering itself. Applications and Content Services (Software as a Service - SaaS) are the actual services, such as office productivity (Google Apps, Microsoft Office365, etc.), email, Customer Relationships Management (CRM), and Enterprise Resource Planning (ERP). Cloud services eliminate the operational complexity and cost of installing,

maintaining and upgrading complex IT systems in the users own environment. The faster a cloud provider can grow its customer base and achieve scale, the faster it can lower the per transaction cost of offering the service. This scale efficiency can provide a significant competitive advantage to early movers who attract a large customer base.

Network providers: connecting the user to the cloud

Network Providers provide the connectivity enabling users to consume the services provisioned and served from cloud datacenters (see figure 3). These Access Networks are strongly shaped by national government policies, particularly telecommunications regulations and information access laws.

Figure 3 - Network service types



The Infrastructure layer includes the physical means, landline and wireless, by which network services are delivered. Government policy strongly shapes the deployment of these technologies, determining the network environment available for user connection to cloud services. Insufficiently developed connectivity can hinder users from benefiting from cloud services available elsewhere, but having the fastest networks does not necessarily confer countries with an automatic advantage (KUSHIDA & ZYSMAN, 2009).

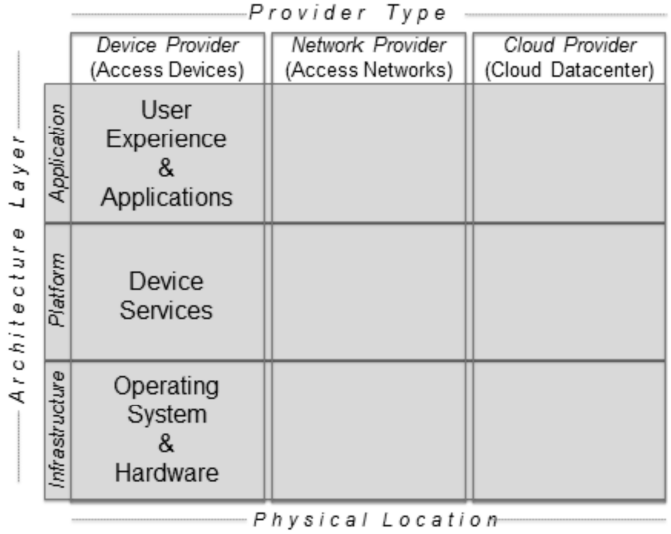
Telecommunications carriers, which own most of the network infrastructure, are highly regulated. In some cases, regulation precludes them from extending their reach to become Device Providers. Free from the regulations imposed on network providers, cloud providers such as Google and Microsoft have been free to enter all three domains - cloud services, access networks and access devices. They have deployed substantial network infrastructures, not only lowering costs, but also increasing opportunities for experimentation. For example, in 2009 Google ranked third worldwide in the total volume of Internet traffic carried over its own private networks, displacing AT&T and Sprint (LABOVITZ, LEKEL-JOHNSON *et al*., 2009), and it invested in undersea fiber optic cables linking Asia to North America. With global cloud providers offering major Voice over IP (VoIP) services that bypass the conventional telephone infrastructure - Microsoft's Skype and Google Voice - incumbent telecom carriers may raise policy disputes of cloud providers' extensive network infrastructure deployments.

The critical business challenge for incumbent network providers is how to participate in the application and platform layers of the cloud ecosystem. The ongoing debate about network neutrality in various countries is really a debate about who gets to extract value at these layers. Cloud providers argue for equal treatment of all bits flowing through network providers' networks but this commoditizes the latter. Network providers argue for deregulation enabling differential tariffs or service levels depending on the type of data and cloud providers' willingness to pay. Incumbent telecom carriers also tend to comply with governmental surveillance activities - both formal and informal. In the US, for example, carriers such as Verizon shared customer records with the US government after the Patriot Act was passed following the 2001 terrorist attacks. As these carriers enter cloud services by offering IaaS such as storage and processing capacity, their intimate relationships with government security agencies can seriously concern users.

Device providers: not your grandmother's telephone

Today's Access Devices derive their lineage from computing equipment, and they have become an intensely competitive battleground. Winners will not only define end user experiences, but may also shape the nature and success of cloud services. The direct lineage from PCs suggest the likelihood of similar competitive battles: at the infrastructure layer over operating systems, processors and hardware; at the platform layer for developers; and at the application layer for end user loyalty (see figure 4).

Figure 4 - Devices provider services



The advent of cloud service access has reshaped the nature of hardware competition, an ever-expanding category, currently including traditional PCs, netbooks, smart phones and tablet devices (such as the Apple iPad, Kindle Fire, and Samsung Galaxy Tab) as manufacturers experiment with new form factors that serve various cloud-enabled uses. It is important to reflect that both PC hardware and traditional mobile handsets were rapidly becoming commoditized by the mid-2000s, with a new generation of smart phones devices with cloud access, spearheaded by Apple's iPhone and then the iPad, that reignited interest in - and reimagined - the role of access devices. Below that surface, aggressive competition for the central processing units (CPUs) is unfolding. Unlike in PCs, Intel is the underdog against multiple vendors producing processors based on ARM Holding's architecture.

Apple's control of its products over all three layers of architecture - from device hardware to platform to user experience - for both the iPhone and iPad differentiates it from other players in the market, and clearly factors in its popularity. Others, including HP and RIM, are discovering their positions untenable in tablets due to their choice of weak platforms or limited services.

In operating systems as well, old battles from the PC era are playing out, and again, with the PC era's dominant player, in this case Microsoft, as the underdog. Google's Android and Apple's iOS are battling for dominance, and Nokia adopted Microsoft's Windows Phone 7 after abandoning its own.

Multiple business models are vying for market share (KENNEY & PON, 2011). Apple's iOS operating system is integrated into its devices, only available on Apple products, and Apple takes revenue from third party Apps. Microsoft offers PC style-licensing with its operating system, charging manufacturers per unit. Google's Android, by contrast, is free and largely open source, with Google extracting value through increased penetration of its cloud services and advertising revenue streams on Android-based devices. For PCs, Microsoft's dominance of operating systems became a policy issue in the US and Europe. Microsoft's bundling of its Internet Explorer operating system into Windows PC was the focal point of antitrust action. In the cloud computing ecosystem, policy issues may develop around linkages between operating systems and search. While a Windows/PC-style domination is unlikely, the ability for Google or Apple to leverage dominant positions in one market to gain advantage in another is already causing regulatory scrutiny. Another platform layer service becoming the focal point of competition is the AppStore service, with offerings from each major device and operating system provider, and even some network providers. Offerings entail a cloud service to browse applications, commerce infrastructure, and distribution, license management and update services. This end-to-end capability requires services in each of the device, network and cloud layers. We can expect investments in platform layer common services, bound to backend cloud services, will become a major competitive point of leverage for device providers.

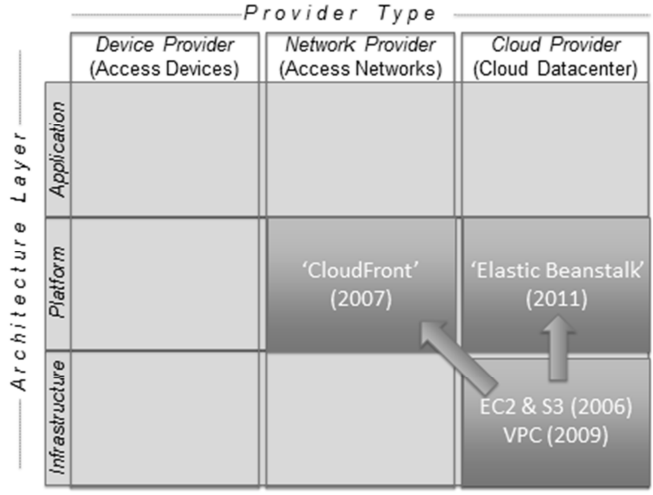
■ The battle for the cloud: business strategies of global cloud providers

We now apply our "cloud services framework" to the battleground surrounding the cloud ecosystem. Understanding the broad historical trajectories of providers' development is critical to capturing their contrasting strategies and vantages. Today's cloud offerings emerged from major providers' infrastructures for core businesses: Amazon's online retailing; Google's search and advertising; Microsoft's global web email and small business services; and SalesForce.com's online CRM. These firms shared the IT challenge of delivering continuously reliable, responsive service at global scale and low cost. Their distinct technology infrastructure starting points and development trajectories led to a set of common cloud services with quite distinct technical implementations. They compete on the basis of these differences in implementation.

In tracing the strategies of Amazon, Google, Microsoft, Salesforce.com, and Apple, we also consider target users and providers' core businesses. The preferences and needs of consumers/small-medium sized firms, and large corporations and government organizations contrast sharply. The former are usually more price conscious and less concerned about performance guarantees. The latter invest millions of dollars in their IT systems and need to balance cost considerations against a wide range of factors including reliability, security and performance, and are subject to regulations surrounding the handling of information. For large firms, integrating cloud services with existing IT infrastructure and datacenters is also a major issue. Despite these challenges, however, the substantial IT budgets of large enterprises represent arguably the largest new market cloud service providers are aiming for.

Amazon

Figure 5 - Amazon's strategy



Amazon pioneered infrastructure cloud services, initially out of its need to manage retail demand peaks. Amazon prioritized building IT infrastructure capacity to comfortably handle the peak Christmas holiday season. To monetize the idle capacity for the rest of the year, it introduced Amazon's 'Elastic Compute Cloud' (EC2) service in 2006. Amazon's rapid success with EC2 and S3, a data storage services, opened up an entirely new cloud computing business for the company. Moving well beyond excess capacity from retail, they now drive substantial new investments in datacenters and

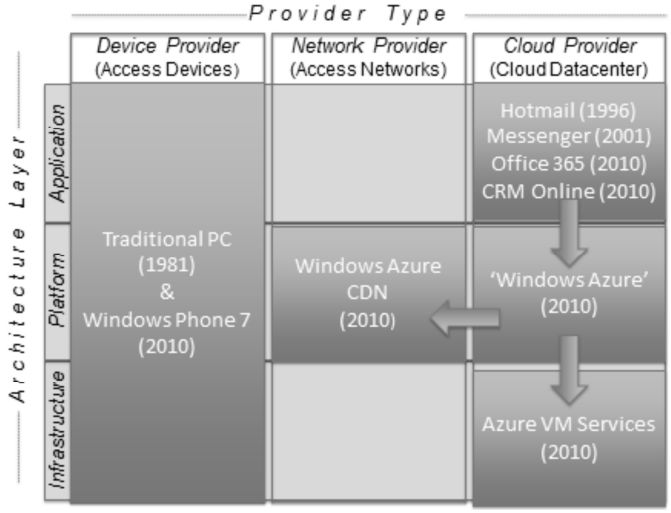
services. Amazon has continued to build out from its IaaS roots to higher layers within cloud datacenter, and across into access networks (see figure 5). In 2007 Amazon introduced CloudFront, a Content Distribution Network (CDN) service. (A CDN distributes copies of commonly requested information across several geographically dispersed datacenters, accelerating response times.) By 2011, Amazon's major datacenter locations outside the US included the UK, Ireland, Netherlands, and Germany in Europe, and Singapore and Japan in Asia. Amazon strengthened its offerings to enterprises in 2009 with its Virtual Private Cloud (VPC) service, which facilitates linking users' legacy IT system and new cloud-based services.

Increasing competition in the IaaS layer from smaller firms including RackSpace, CloudSigma, and others intensifies cost pressures. From the top, Google and Microsoft are also broadening their SaaS and PaaS offerings, expanding into IaaS. Amazon's "Elastic Beanstalk" PaaS in 2011 was a direct response, aiming to provide a foundation for complex cloud applications - pitting Amazon squarely against Google and Microsoft for cloud application developers.

Microsoft

Microsoft is moving into almost all areas of cloud services. Microsoft's need to decrease cost and increase scale in its (often free) online services such as Hotmail and MSN Messenger, which predate any conception of cloud computing by 5 to 10 years, catalyzed its cloud strategy. Until recently, these massively scalable services with several hundred million global users, did not share a common infrastructure inside Microsoft. The drive to reduce operating costs and increase service flexibility led Microsoft to develop the underlying platform technologies for its current cloud service strategy. Microsoft has been in the platform business since Windows (see figure 6). In the early 2000's Microsoft introduced a new set of platform technologies for web and Internet based developers. In 2008, facing growing competitive pressure from Google and Amazon, Microsoft introduced its Azure platform, enabling developers to build cloud-based applications. Windows Azure charges for consumption of underlying computing, storage and network resources on a per unit basis - a significant change in Microsoft's business model since Microsoft received a one-time payment for each sale of Windows without revenue streams from 3rd party applications. The new revenue streams in part drive Microsoft's strategic emphasis on cloud.

Figure 6 - Microsoft's strategy



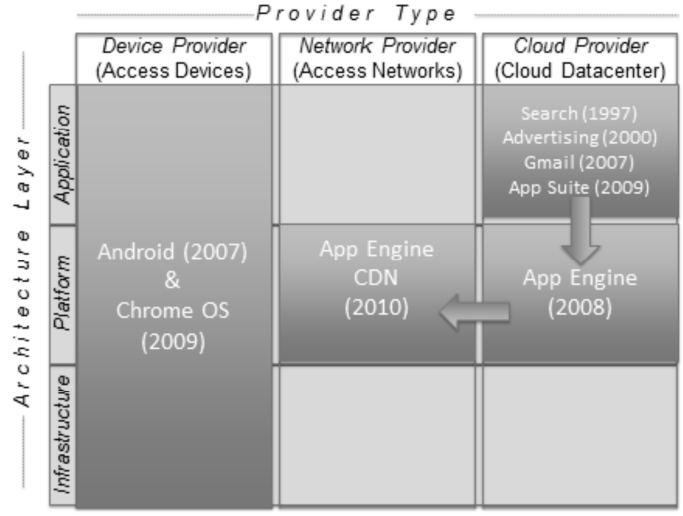
Microsoft also continues to develop its SaaS suite such as Office 365 and Dynamics CRM Online, both to broaden Microsoft's user audiences, and as defensive strategies to retain existing customers migrating to the cloud. The company is extending downward in the architecture stack, introducing an IaaS service supporting 'virtual machines' on Windows Azure. It is also extending horizontally into network services, providing CDN services for Azure developers. Finally, Microsoft's dominance in PC operating systems and applications faces serious pressure with Access Devices that do not run Microsoft's operating systems - most notably Apple products and the plethora of devices running Google's Android. Microsoft was early in categories such as mobile phone operating systems and tablets running traditional Windows, but fell behind the competition. The success of its new attempts, Windows Phone 7 and Windows 8 Tablets, remain unclear. Microsoft has invested billions of dollars in global cloud services data center infrastructure. Though tightlipped about their locations in early 2011 it was thought to be operating in around 18 locations worldwide.

Google

Google, though with a different starting point, now overlaps considerably with Microsoft in its range of cloud services, though with quite different business models. Google's wild success in monetizing search through advertising provided the capital to experiment and expand. The company's massive investments into datacenters and access networks underpinning its

search and advertising business provided the launch point for a range of additional cloud services. Google began with the introduction of Google Apps, which provided a cloud-based alternative to Microsoft's ubiquitous office applications (see figure 7). Google Apps are true cloud-based applications, delivered from Google's datacenters, consumed via a web browser, with users' files stored in the cloud.

Figure 7 - Google's strategy



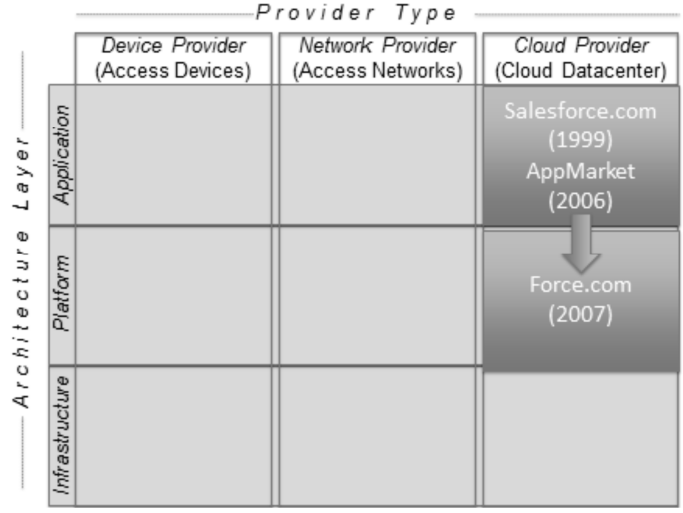
While originating as consumer offerings, Google has moved quickly to add features to attract firms of all sizes, including large enterprises and governments. Google, like Microsoft, is moving down the stack to attract the cloud developer community. In 2008 Google introduced its App Engine PaaS offering, allowing developers to leverage some of the powerful underlying services Google developed for its own search and advertising businesses. Google's App Engine is more limited in its user configurability than PaaS services by Microsoft and Amazon, and it remains to be seen whether Google offers a more generalized service, including IaaS. In 2008, Google released its Android mobile operating system which moved it firmly into the Access Devices stack. In 2010, Google experimented by directly offering a handset, the NexusOne handset, manufactured by Taiwanese firm HTC. It attempted to decouple handsets from network provider channels by offering a new direct online retail channel, though it folded the store later that year. In 2011, Google purchased Motorola's former mobile handset division, Motorola Mobility, for over $10 billion, historically its largest acquisition. Although Google's strategy is unclear from the outside, whether it valued the

vast trove of patents held by Motorola to secure the intellectual property underpinnings of Android, or to solidify its expansion into the Access Devices, Google is clearly poised to continue as a major player.

Salesforce.com

Salesforce.com, by far the smallest cloud provider here, pioneered the "Software as a Service" (SaaS) business model. It was founded in 1999 offering CRM over the web with a pay-as-you-go fee structure. Dominant competitors such as Siebel Systems, cost several tens of millions of dollars for large customers, was largely driven by the technical complexity of integrating on-premise CRM software with customers' existing systems. Salesforce delivered the same functionality as a service, avoiding on-premise implementations, and was wildly successful.

Figure 8 - Salesforce.com strategy



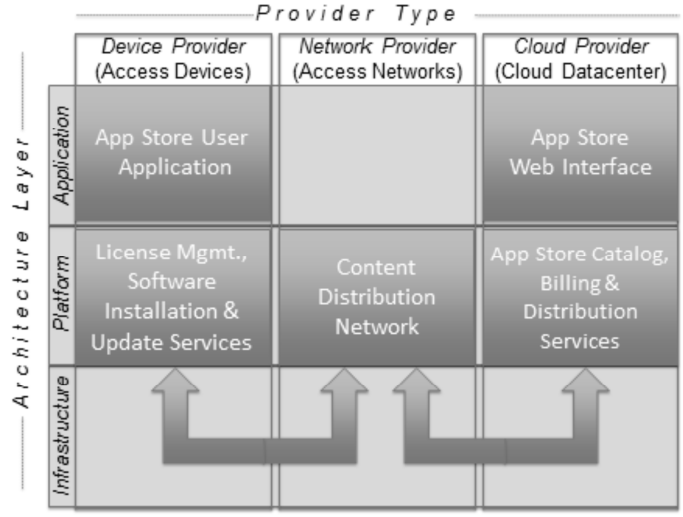
Salesforce's CRM was initially attractive to smaller users, offering low upfront costs and the ability to quickly scale usage up or down. The company soon expanded to larger users as it expanded functionality. (BENIOFF & ADLER, 2009). Salesforce moved into a platform business by focusing on its core CRMS services while encouraging the development of a supporting ecosystem of software developers for specific industries and niche markets. In 2006, Saleforce introduced its AppExchange marketplace, which provided marketing, commerce and distribution service for third-party developers to extend the core CRM application. Its success became a major

competitive strength, offering a rich portfolio of third party applications. In 2007 Saleforce.com formalized this platform with Force.com, (see figure 8) which extended AppMarket with a set of tools and lower level services for developers, making it easier to develop applications for the Salesforce.com ecosystem, and for which Salesforce.com would provide the hosting and distribution. Thus, Salesforce.com, like Google and Microsoft, started in the SaaS layer, moving to PaaS.

Apple

Apple is now clearly a major player in the cloud ecosystem. It began by revolutionizing Access Devices with its vertically integrated offerings iPhone and iPad, and tying them to Datacenter-based services and content. Many Apps, whether news, music, or certain types of games, initiate a connection with a cloud SaaS layer service which provides core content or live information. An 'App' is often the user interface to a cloud service accessed through the Internet. Apps are provisioned on users devices through the AppStore infrastructure - a large-scale cloud service that leverages multiple layers of the cloud datacenter, access network and access device stacks (see figure 9).

Figure 9 - Apple's cloud service architecture



Apple is unique as a cloud provider in using cloud to primarily serve the needs of its own vertically integrated ecosystem. The AppStore is not available for non-Apple devices and therefore other operating systems.

iTunes is also a very large-scale cloud service which enables you to browse, buy and download music and videos from multiple operating systems, including Windows. In 2011, Apple revamped its MobileMe service into iCloud, providing a range of cloud-based capabilities including, email, music storage and device management in an offering closely tied to its devices. Apple began its resurgence in the late 1990s by focusing on the consumer market, but as the iPad and iPhone are increasingly adopted by corporate users, Apple has strengthened security measures. Its recent billion dollar investment in a North Carolina cloud datacenter speaks loudly about its future ambitions.

The broader cloud provider ecosystem

Cloud computing has become the buzzword de jour for the marketing department of any self-respecting technology company. The problem for external observes is separating true cloud providers from those simply re-branding more traditional and less flexible offerings. We consider a number of other players in the broader cloud ecosystem to clarify their strategic positioning.

IT infrastructure vendors: VMWare, Cisco, EMC

EMC, known for data storage, Cisco, primarily a provider of infrastructure equipment, and VMware, famous for its virtualization solutions, are important providers of the basic components upon which others can build cloud-architecture service infrastructures. Each faces significant competition in their core markets: Microsoft's virtualization offerings with VMWare; Juniper Networks and others with Cisco for core networking infrastructure; and HP and others with EMC for storage technology. The VCE Coalition between EMC, Cisco, and VMware is an attempt to offer a one-stop-shop for companies building out their own cloud service capabilities. The combination of VMware, Cisco and EMC will likely remain a formidable force in the provision of cloud infrastructure components in the years ahead.

Major IT outsourcing vendors: IBM, EDS, CSC

Ten years ago, the buzzword in IT infrastructure circles was outsourcing. Major IT vendors such as IBM, EDS, and CSC competed to take over management of large industrial clients' IT infrastructures, with newswires awash with multi-million dollar contract announcements. However, the outsourcing providers quickly discovered it was far harder to reduce

operational costs as initially anticipated. Clients rapidly discovered that providers' motivations to lower costs resulted in infrastructures far less adaptable to changing business conditions than they needed. The root problem lay with the inflexibility and complexity of traditional vertically integrated IT infrastructure. These traditional outsourcing providers were quick to rebrand themselves as cloud providers, but the reality requires scrutiny. To provide cloud services for clients, these vendors would need to offer IaaS and PaaS services with the dynamic scaling, management and configuration capabilities, and a pay-as-you-go consumption pricing model, as offered by the likes of Google, Microsoft and Amazon. Many are currently focused on integrating or linking clients' existing infrastructures with global service providers' services.

■ Conclusion and policy issues

Cloud computing delivers computing services - data storage, computation and networking - to users at the time, to the location and in the quantity they wish to consume, with costs based only on the resources used. Aspects of cloud have been available for some time, but cloud as a pervasive system is new. It is a dynamic utility from the vantage of users, and a competitive proposition from the vantage of providers. Cloud computing reopens classic policy debates and puts new issues on the table. Classic debates include those surrounding data privacy (who is allowed to access whose data), data security (how to protect data from unauthorized access and manipulation), data sovereignty (to whom does what data belong), and rules over interoperability (JAEGER, LIN *et al*., 2008; NEWMAN, 2008; SLUIJS, LAROUCHE *et al*., 2011). Our cloud services framework can usefully sort out the distinct issues surrounding device providers, network providers, and cloud services providers, which we alluded to in each respective Section.

Core features of cloud as offered by the major providers, changes the classic debates. First, the globally distributed character of storage and computation forces a discussion of whose rules on privacy and security should apply. The traditional collision of European and American privacy rules is one instance, but the requirements of the Patriot Act, in which the US government can demand not only data passing through the US, but from all multinational firms with a presence in the US, make that privacy debate all the more acute (KUSHIDA, MURRAY *et al*., 2011). Second, portability of activity from one cloud environment to another is likely to be a matter of

contention. The global scale cloud offerings have emerged as extensions of the core business of companies such as Amazon Google and Microsoft. Consequently, to one degree or another, users risk being locked in one cloud environment.

New debates, we anticipate, will emerge from the link between cloud services and economic development. We have argued that cloud computing is rapidly becoming an innovation ecosystem, a production environment, and a marketplace. As an innovation ecosystem, it lowers entry barriers to experimentations, permitting small firms to experiment, scale up and down and to adapt existing operations to rapidly reallocate computing resources. As a production environment, cloud providers' platforms, tools, and services are building blocks for innovative service offerings and indeed influence actual manufacturing as well as manufacturing logistics. As a marketplace, the easy accessibility and global reach of cloud services extends the reach of local activity, but also makes any locality all the more exposed to global innovations. For advanced countries it provides opportunities for innovation, entrepreneurship, and efficiency gains. For developing countries it offers new possibility to enter international markets and find niches in global value networks. The result will be an intense debate within countries about the availability of the computing and communication infrastructure required for local firms and government units to advantage themselves of the cloud possibilities. It will likewise make "places" all the more concerned about the governance of the global cloud system as that governance will inevitability influence, in ever deeper ways, the core fabric of the local economy. Regardless of the precise characterization of cloud services, the tension between reliance on global service providers, and global cloud services emerging as critical business infrastructure for national economic development, will trigger policy discussions around the world.

Another area that cloud services will affect is the notion surrounding clustering in economic development. The traditional notions of clustering entail connections of some sort between actors requiring geographic proximity to sustain innovation (PORTER, 1998). With the unprecedented level of dispersion in computing, tools, and markets, the nature of these linkages changes-they do not disappear, but their nature becomes less obvious. Regardless of the precise outcomes of each new and classic debates, it is clear that cloud services will shape a wide range of policy debates surrounding the role of information. The diffusion of cloud services around the globe will also be shaped by the outcomes of many of these debates in the years to come.

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