# Disruptive Technology Business Models in Cloud Computing

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*To my wife, Ann,*
*for her support, inspiration, and love.*

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# ABSTRACT

Cloud computing, a term whose origins have been in existence for more than a decade, has come into fruition due to technological capabilities and marketplace demands. Cloud computing can be defined as a scalable and flexible shared computing solution in which third-party suppliers use virtualization technologies to create and distribute computing resources to customers on-demand, via the Internet browser. Cloud computing is steadily replacing more rigid software and services licensing models in both small/medium business (SMB) and in the enterprise.

This analysis poses a twofold examination of cloud computing as a disruptive technology. First, cloud computing has replaced existing software and services licensing business models, owing to its scalability, flexibility, and utility-based pricing. Second, as cloud computing takes hold as the prominent computing services business paradigm, other disruptive forces will surface to further integrate and differentiate the cloud computing landscape. These forces include the customer-driven need to create hybrid clouds between private and public cloud domains, vendor-agnostic solutions in the cloud, along with open standards to make cloud computing ubiquitous.

Three criteria are assessed in characterizing cloud computing as a disruptive technology (Christensen, 2002).[1] First, cloud computing as an innovation, must enable less-skilled and/or less-wealthy individuals to receive the same utility as only the more-skilled and/or more-wealthy intermediaries could formerly attain. Second, cloud computing must target customers at the low end of a market with modest demands on performance, but with a performance trajectory capable of exceeding those demands and thus taking over markets, tier by tier. As a corollary to this second criterion, the cloud computing business model allows the disruptive innovator to achieve attractive returns at prices that are unattractive to the incumbents. Third, an ecosystem in the form of a fully-integrated single entity or a set of modular entities is required to successfully support the disruptive innovation.

The analysis has shown that cloud computing is replacing traditional outsourcing and premise-based data centers for software applications and services delivery. Scalability, flexibility, virtualization, and cost are essential business drivers. However, current cloud computing solutions, especially in the enterprise, lack sufficient security and customer control. This gives rise to numerous subordinate disruptive business solutions which enable the enterprise and emerging demographics to develop and deploy their applications and services in a secure, controlled, profitable, and ubiquitous environment.


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[1] Clayton Christensen, "The Rules of Innovation", *Technology Review*, (June 2002): 33-38.

# CHAPTER I: INTRODUCTION

## Cloud Computing Defined

Cloud computing, despite all its promise as one of the most compelling technologies in the first decade of the twenty-first century, is often a misunderstood technology. Cloud computing is indeed a disruptive technology (Christensen, 1997) as this analysis will defend.[2] However, cloud computing is not a "one-size-fits-all" computing paradigm. Rather it is a continuum of service delivery options, often referred to as Software-as-a-Service, Platform-as-a-Service, and Infrastructure-as-a-Service. There are also subordinate delivery services under the cloud computing *"xyz-as-a-service"* umbrella including: Storage-as-a-Service, Backup-as-as-Service, Computing-as-a-Service, along with a litany of other specialized services.

The Information Technology (IT) industry has sought to standardize the definition of cloud computing by identifying its relevant attributes. Forrester Research, Inc. has proposed the following definition of cloud computing.

> *"A standardized IT capability such as software, application platform, or infrastructure, delivered via Internet technologies in a pay-per-use and self-service way."*[3]

The pricing model furnished by the service provider is a key value proposition to the enterprise, the small/medium business (SMB), and the end-user. Forrester succinctly provides a corollary to this definition with the financial community and CFO as the primary audience.

> *"Buying IT capacity and applications as needed from a utility services provider"*[4]

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[2] Clayton Christensen, *The Innovator's Dilemma*, (Harvard Business School Press. Boston, 1997): viii-xviii.

[3] James Staten, Ted Schadler, John R. Rymer, Chenzi Wang. "Q&A: By 2011, CIOs Must Answer The Question, 'Why Not Run in the Cloud'?' ", *Forrester Research, Inc.* (August 14, 2009): 1-11.

[4] Ted Schadler, Matthew Brown, Michael A. Doyle, Frank E. Gillett, Sara Burnes. "Talking To Your CFO About Cloud Computing", *Forrester Research Inc.* (October 28, 2008): 1-9.

The definitions above address the *"what"* of cloud computing in terms of capacity, applications, and pay-per-use or utility pricing. What is lacking is *"how"* these attributes of capacity and applications are delivered along with both the uniqueness of cloud computing and the ubiquity it offers to its customers. Stratecast (a division of Frost & Sullivan) elaborates on the definition of cloud computing below.

> *"Cloud computing is a flexible and scalable shared environment in which third-party suppliers use virtualization technologies to create and distribute computing resources to customers on an as-needed basis, via the Internet browser."*[5]

The elements of scalability, virtualization, sharing, and access via the Internet are essential to cloud computing and differentiate its use from traditional computing practices such as private data centers and hosting services. The concept of virtualization has broad technical implications. In the context of cloud computing, virtualization refers to the use of software to decouple applications from the physical hardware, supporting multiple applications and operating systems.[6] Also, the concept of hosting deserves further elaboration. While cloud computing typically resides in a hosted, 3rd-party environment, the notion of "hosting" is not solely relegated to cloud computing. Hosting can include non-cloud services such as traditional outsourcing, dedicated and managed hosting, and 3rd-party managed services. These elements will be discussed shortly along with the driving forces from both the customer and provider perspectives, which make cloud computing a prominent computing alternative today.

However, before making a foray into the technical and business drivers of scalability and virtualization, cloud computing parallels can be drawn from other industries and eras. In one example, from Nicholas Carr's book, *The Big Switch,* a parallel is drawn between today's Internet computing paradigm and the power

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[5] Lynda Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", *Stratecast (a division of Frost & Sullivan). Business Communications Services*, Volume 2, Number 10. (November, 2008): 1-23.

[6] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 9.

distribution grid during the early 1900s.[7] Carr argues that in both cases, pure economic motivations, not the advent of technological progress, are the key drivers to the adoption of power distribution and information management.[8] While cloud computing has compelling cost and price models, these models are far from perfect owing to the types of applications hosted in a cloud computing environment. Furthermore, Carr asserts that the so-called *"public cloud"* will cause the extinction of private data centers. Forrester Research, Inc. emphatically states that this will not be the case.[9] As will be discussed later, the type of data management implementation will be predicated by the application and the specific customer needs for that application.

In another example, cloud computing can be compared to the 1960 adoption of modular freight containers designed by Malcolm McLean.[10]

> *"The widespread introduction of Mclean's new system (the freight container) saw port costs plummet over the next few decades. If international freight had been cheap before 1960, afterwards it became practically free—in the unlovely jargon of economics, 'frictionless'. Freed of burdensome tariffs and shipping costs, goods began circulating more freely around the globe".*

As Forrester Research, Inc. points out, the goal of any IT organization is to make applications "frictionless". That is, to make applications come and go, expand and contract. The observations of McLean's cost savings are not far from today's cost/price realities of cloud computing. Storage costs and transfer costs are merely pennies per terabyte (TB) and gigabyte (GB), respectively. Subscription fees for a suite of applications available via cloud computing are just tens of dollars per year, as evidenced

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[7] Nicholas Carr, *The Big Switch: Rewiring the World, from Edison to Google*, (W.W. Norton & Company, New York, 2008).

[8] Everett M. Rogers. "Chapter 7: Innovativeness and Adopter Categories", *Diffusion of Innovations. Fourth Edition.* (The Free Press. New York. 1995), 252-280.

[9] James Staten, Simon Yates, John Rymer, Lauren Nelson, "Which Cloud Computing Platform is Right for You?", *Forrester Research, Inc*, (April 13, 2009): 6.

[10] Source: William Bernstein, *In a Splendid Exchange; How Trade Shaped The World,* (Grove/Atlantic, 2008).

by Google Apps.[11] Finally, owing to the scalability of cloud computing, other services offered through cloud computing, such as disaster recovery, are available at minimal cost. Drawing parallels from Nicholas Carr and Malcolm McLean, these are the key attributes of today's *public* cloud computing: scalability, virtualization, sharing, modularization, flexibility, and utility pricing—all controlled from the Internet browser. At this point, an important distinction must be made about the difference between *public* clouds and *private* clouds. A private cloud defines an architecture similar to that of a public cloud; however, in a private cloud, the clusters of computing resources are dedicated within and among the applications of a single enterprise or SMB.[12] The requisite building blocks of cloud computing—Infrastructure-as-as-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service—are presented first.

**Cloud Computing Building Blocks**

Cloud computing has it's origins as a production model, not a consumption model.[13] From its inception, cloud computing was designed as a means to deliver software applications to end-users. As part of the software deployment and delivery mechanism, cloud computing was designed to bring operational efficiency to providers, not consumers. Along that vein, cloud computing architects created the "cloud" as a production model to manage data centers (IaaS), create application and service development platforms (PaaS), and finally, to provide a deployment vehicle for application and services (SaaS). As shown in Figure 1, the provider's view of cloud computing is a 3-tiered model, widely accepted in the IT industry.[14]

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[11] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", *Stratecast (a division of Frost & Sullivan), Business Communications Services*, (September 2009): 1-20.

[12] Lynda Stadrmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", *Stratecast (a division of Frost & Sullivan), Business Communications Services*, Volume 2, Number 10, (November 2008): 22.

[13] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 6.

[14] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 7.

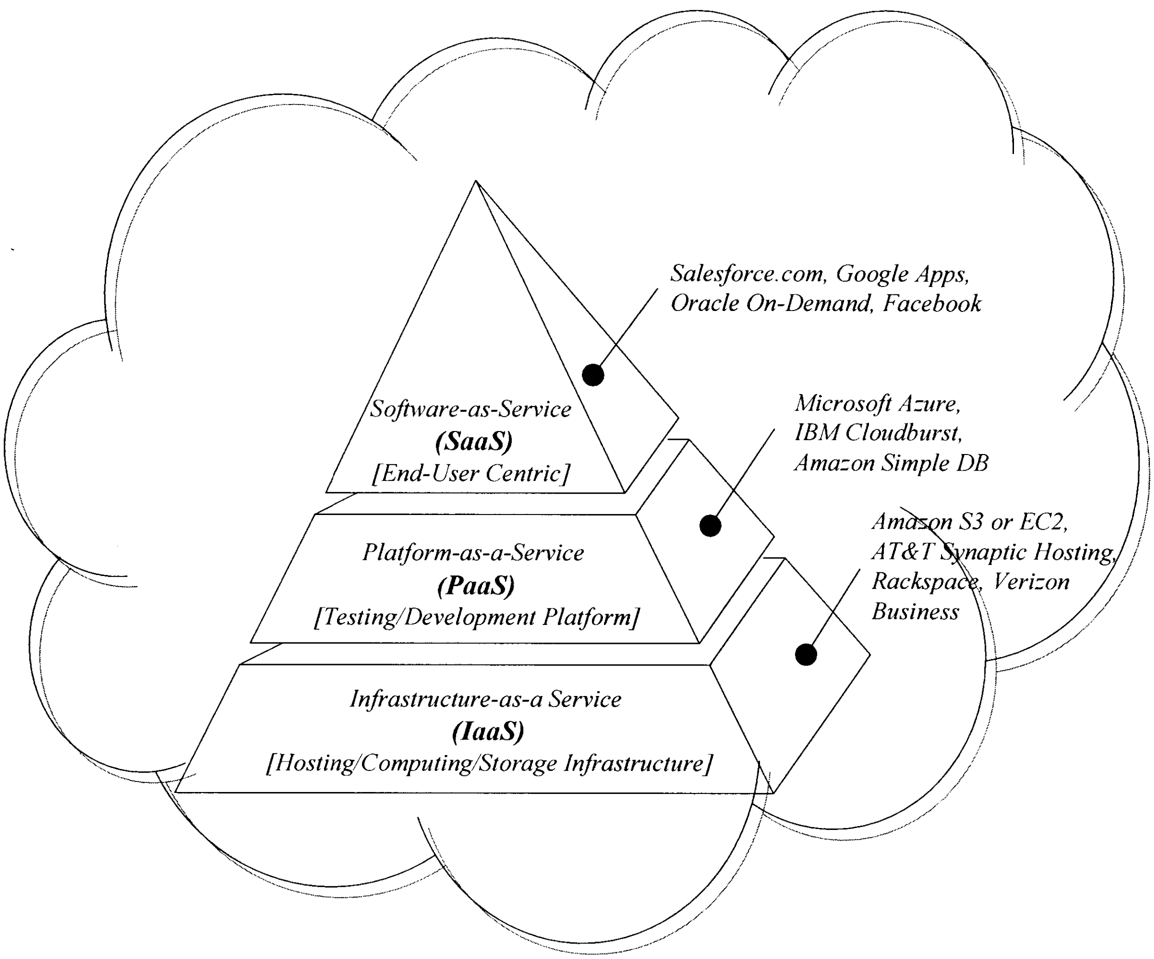


Figure 1: Provider View of Cloud Computing (IaaS, PaaS, SaaS)

At the bottom of the cloud computing pyramid is the ***Infrastructure Layer (IaaS)***. This layer contains massive grids and data centers of standard servers and computing infrastructure intended to share the computing load. These grids and data centers are often hosted by a 3rd-party provider, which can be deployed locally, regionally, and internationally. The *Infrastructure Layer* can be deployed in two important ways. The first way is via a *private cloud*, which are dedicated servers and equipment on the client's premises or within the confines of a 3rd-party provider. The second way is via the *public cloud*, which are shared multi-customer (multi-tenant) servers and equipment hosted exclusively by a 3rd-party provider. IaaS is an essential element of the cloud computing pyramid. The ability of IaaS to provide flexible and powerful computational power is critical to both large enterprises and SMBs.[15]

At the middle of the cloud computing pyramid is the ***Development Platform Layer (PaaS)***. Many analysts subscribe to the adage that the battle for the cloud will be won in the development layer.[16] This layer allows a given application to function properly within a specific cloud environment hosted by a 3rd-party provider. The PaaS layer is populated by proprietary protocols, middleware, and operating systems, and other tools, which assist in the development of platform-specific applications. With the advent of PaaS, customers can rent or lease computing capacity and run their applications in a PaaS provider's data center, instead of installing the application platform on premise. Forrester Research, Inc. defines PaaS as follows.

> *"An externally hosted service providing a complete platform to create, run, and operate applications, including development tools, administration and management tools, runtime engine(s), data management engine(s), security facilities, and user-management services. PaaS is based on Internet protocols and patterns."*[17]

The providers of the development platform typically provide these services at no charge to the software developers to build, test, and deploy their applications. The PaaS provider has a competitive advantage to have a content-rich suite of applications and services, which attracts the end-user. In most cases, however, the application only functions properly within a specific provider's platform, otherwise known as *vendor lock-in.*[18] Integrating PaaS into a customer's development platform is not a foregone conclusion. There are tradeoffs in performance, flexibility, security, cost, and control, between PaaS and on-premise solutions. Four important changes in the near future will

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[15] Frank E. Gillett, "Conventional Wisdom Is Wrong About Cloud IaaS", *Forrester Research, Inc.*, (May 29, 2009): 1-13.

[16] Lynda Stadtmueller, "IBM Cloud Services: An Enterprise-Grade Cloud at Last", *Stratecast (a division of Frost & Sullivan, Business Communications Services*, (July, 2009): 3.

[17] Randy Heffner, "Taking The Fog Out Of Cloud Computing: Platform-As-A-Service", *Forrester Research, Inc.*, (February 10, 2009): 1-6.

[18] Randy Heffner, "Taking The Fog Out Of Cloud Computing: Platform-As-A-Service", 3.

enable PaaS to become a more attractive solution, enabling a fundamental shift from an on-premise solution to true externally-hosted development layer platform.[19] The first change is that PaaS offerings will have fewer restrictions, thereby allowing providers to serve a broader range of applications within given platforms. The second change is improved PaaS vendor collaboration to fully integrate enterprise and SMB IT requirements. The third change is to bring the same industry support levels to PaaS, which have been prevalent in on-premise development layer solutions. The fourth and final change is to bring interoperability between PaaS providers themselves and between PaaS and on-premise solutions. PaaS is likely to undergo a transformation using open standards to remedy vendor lock-in and make these applications accessible irrespective of the provider's development platform. Firms including IBM and Citrix are likely to pioneer the development of open standards in the PaaS arena.

At the top of the cloud computing pyramid is the ***Application Layer (SaaS)***, where specially architected applications have been developed to operate in a cloud environment.[20] SaaS is characterized by software applications that are hosted and maintained in a 3rd-party application-provider's environment, instead of at the customer's site. Both consumer-oriented and business-oriented applications are accessed in this layer. Access to applications is made through the Internet browser and SaaS software is provided to a given customer via a single instance where a customer's data is segmented within a shared server environment. To date, SaaS has been the central focus of the cloud's formidable impact on application deployment, including social-networking applications. SaaS applications may be priced by the new cloud-based "pay-per-use" model, or by the traditional per-user subscription model. SaaS applications have traditionally shown limited flexibility to scale applications due to the software architecture and contractual agreements. Google Apps and a variety of Customer Relationship Management (CRM) tools from Salesforce.com have dominated the application layer.

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[19] Randy Heffner, "Taking The Fog Out Of Cloud Computing: Platform-As-A-Service", 5.

[20] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 7.

In summary, with IaaS, PaaS, and SaaS, it should be noted that the cloud computing customer is an appreciative, albeit passive, consumer of these services. It so happens that the strengths and weaknesses of today's cloud computing solution are primarily predicated on the current state-of-the-art technology. The end-user customer rarely cares about the nuances and artifacts of cloud computing. Rather, the end-user customer just cares about the reliable, accessible, and low-cost (and sometimes no-cost) delivery of their favorite applications. It does not make a difference to an end-user customer whether an application is based in a low-cost cloud computing environment, or based in the incumbent advertising-support model, which has been in existence for most of the past decade.[21]

**Cloud Computing Attributes**

The public cloud is differentiated from on-premise computing solutions by several attributes including: scalability, virtualization, flexibility, sharing, and utility-based pricing.[22] Many IT experts and analysts broadly contend that cloud computing is "any computing that takes place outside the corporate firewall", which is emblematic of traditional Business Process Operations (BPO) and Software-as-a-Service.[23] Others assert that that cloud computing is restricted to a shared environment in which software developers can create, test, and deploy their applications in both test and production environments. Finally, there are those partial to a school of thought that true cloud computing does not exist today, at least in the enterprise, owing to vulnerabilities in security and control.

**Shared Environment:** A shared environment is an essential attribute of public cloud computing. Here, a 3rd-party vendor maximizes economies of scale in both hardware and software solutions. Third-party providers amass investments in server grids and appliances which are shared among end-user customers. Virtualization software assists in the efficient deployment and management of applications among fixed

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[21] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 8.

[22] Lynda Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 8.

[23] Lynda Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 7.

physical resources in the form of servers and appliances. Economies of scale in both hardware and software enable the provider to both successfully gain occupancy rates and defray costs by spreading infrastructure costs to many subscribers. It should also be noted that the notion of a *shared* computing environment is anathema to those architects and customers who need a *private* cloud for security and enterprise control motivations. These motivations will be discussed, as cloud computing strategies are developed later in this analysis.

**Pay-Per-Use:** Pay-per-use is a fundamental attribute of cloud computing. Instead of a pay-up-front software licensing model that has dominated the software landscape for decades, a pay-per-use model has surfaced for cloud computing. The end-user customer can pay for applications on an as-needed basis. This pay-as-you-go, or in the parlance of the cloud, *pay-as-you-grow* model, has enabled end-users to rent computing and application resources as needed. Some of the exceptions to this model are application providers such as Google Apps, which charge a low subscription-based fee.

**Scalability:** The ability to scale resources and applications to meet the needs of the enterprise and the SMB is a hallmark of cloud computing. The IT departments of various enterprises are freed from the need to buy and install servers, install network connections, power and test appliances, and load the client's software. The computing grid facilitates the needs of the customer to efficiently start and stop operations. This makes cloud computing a truly dynamic environment capable of meeting the needs of variable and seasonal businesses, organizations that need cloud-bursting capabilities, and firms specializing in disaster recovery.

**Virtualization Technologies**: Cloud computing is economical and viable as a consequence of virtualization technologies. Virtualization software in the cloud computing environment decouples the software from the physical hardware. This allows the physical servers to be divided into multiple virtual environments, each of which is isolated, thereby supporting multiple operating systems and applications. Virtualization is the technological driving force behind maximizing available computing capacity and enables enhanced flexibility and scalability in configuring fixed data center resources to meet the needs of the enterprise. However, one significant drawback with current virtualization technologies is that security capabilities are not sufficient to meet the security needs of enterprises and SMBs that handle customer-sensitive data. This is especially prevalent when security standards are enforced by government and corporate mandates. It is expected that virtualization technologies coupled with security information management (SIM) practices will remedy these security requirements in the coming years.

**Cloud Computing Market Drivers & Market Restraints**

**Market Drivers:** There is significant motivation for enterprise and SMB customers to place their operations in the control of a 3rd-party data center. Presently, 85% of all computing resources are located in private data centers. Therefore, there is a tremendous opportunity, driven by the market to seek a cloud-based 3rd-party computing solution, as shown in Table 1 below.[24]

*Increase in Market Driver Impact*

| MARKET DRIVER | 1 YEAR | 2-3 YEARS | 4-5 YEARS |
|---|---|---|---|
| Reduction in enterprise capital IT budgets | HIGH | HIGH | HIGH |
| Increase in fast, flexible solutions for deployment and bursting | HIGH | HIGH | HIGH |
| Increase in computing performance for "fatter" applications | MEDIUM | HIGH | HIGH |
| Increase in available cloud-based or Saas business applications | MEDIUM | MEDIUM | HIGH |
| Increase in popularity of full end-to-end managed application performance services | MEDIUM | MEDIUM | HIGH |
| Increase in access of applications by a geographically dispersed audience via multiple devices | MEDIUM | MEDIUM | MEDIUM |
| Increase in cloud computing solutions for disaster recovery | LOW | MEDIUM | HIGH |
| Increase in "green" technologies within the enterprise | LOW | MEDIUM | MEDIUM |

Table 1: Cloud Computing Market Drivers, 2009-2014 (Source: Frost & Sullivan)

[24] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 11.

From Table 1 above, the criticality for enterprises moving to a cloud-based solution is shown in one-year, two-to-three-year, and four-to-five-year increments. All market drivers are significant and the top three are worthy of detailed discussion.

Budget considerations in the enterprise are the top market driver across the entire five-year horizon. IT departments are increasingly moving away from a *capital expense (capex)* financial model to a more fluid *operating expense (opex)* financial model. With the advent of cloud computing, capital equipment in the form of servers and appliances are purchased by the 3rd-party provider and located in their data centers. Cloud computing also relieves enterprises and SMBs from excessive headcount, where 3rd-party providers take responsibility for hiring and maintaining an operations staff, whose costs are defrayed among multiple subscribers.

Fast and flexible deployment of applications is another critical market driver. Enterprises and SMBs are highly motivated to near-instantaneously deploy their applications and services. IT departments that formerly deployed applications in months and years can now enlist a cloud computing provider to deploy these same applications in minutes. With scalability and virtualization, 3rd-party cloud computing providers can expand and contract these services at will. Furthermore, IT departments no longer have to buy and install equipment which adds both expense and delays to the enterprise's go-to-market plans. Cloud computing providers are responsible for procuring, managing, and maintaining the data center, which by design, is intended to be a win-win strategy for the enterprise and the 3rd-party provider.

Enhanced computing power in the form of bandwidth and resources complete the top three market drivers for cloud computing. Moore's Law states that computing power double every 18 months, or a related exponential factor depending on the technology segment.[25] The market need for computing power in the cloud computing arena is growing at a faster rate, owing to "fatter" applications which require additional

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[25] Wikipedia, Moore's Law: http://en.wikipedia.org/wiki/Moore%27s_law

computing resources and the requisite bandwidth to support those applications.[26] The computing power of data centers is reaching obsolescence faster and faster, as applications place increasing demands on computing and storage performance. IT organizations in both the enterprise and SMB are increasingly motivated to secure these resources and exploit the pay-as-you-go capabilities of a 3rd-party cloud computing provider.

There exists a separate class of market drivers, orthogonal to the aforementioned market drivers, which are prevalent in today's economy as a consequence of the current demographical, political, and economic landscape. Small business is, and will continue to be, a major market driver in the next decade.[27] By 2017, over 40 million small businesses will be in operation in the United States, of which 32 million will be personal businesses.[28] Both small businesses and large enterprises will be drawn to cloud computing and take advantage of its tiers in IaaS, PaaS, and SaaS.[29]

Small business interest in the cloud computing arena will be influenced by four major demographic dependencies within the United States in the next decade.[30] The first dependency is the increasing number of highly-skilled, retired baby boomers, who will not be able to secure corporate jobs, but will be drawn to the cloud to start small businesses. The second dependency is the increasing number of highly-skilled stay-at-home parents that will take advantage of cloud computing as small business owners or sole proprietorships. The third dependency is the emergence of Generation Y workers who are increasingly distrustful of large corporations. Generation Y workers are nearly three times more likely to work for themselves as opposed to work for someone else.[31] The fourth demographic dependency is the growing immigrant workforce. Immigrants

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[26] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 12.

[27] Steve King, "The New Artisan Economy: Economic Decentralization and the Growth of Small Business", *Emergent Research*, ( 2009): 1-22.

[28] King, 8.

[29] Frank E. Gillett, "Conventional Wisdom Is Wrong About Cloud IaaS", 1-13.

[30] King, 14-20.

[31] King, 16.

will be drawn to the benefits of cloud computing, as they are nearly 71% more inclined to enter into small entrepreneurial businesses than their native-born counterparts.[32]

The demographic landscape outlined above will favor small businesses in a niche, variable-cost model. This is a perfect fit for the beneficiaries of clouding computing, which mentioned previously is a variable-cost, opex model for both large enterprises and small business. The operating regime for these small business demographics is shown in Figure 2, where limited production in niche markets will dominate.[33]

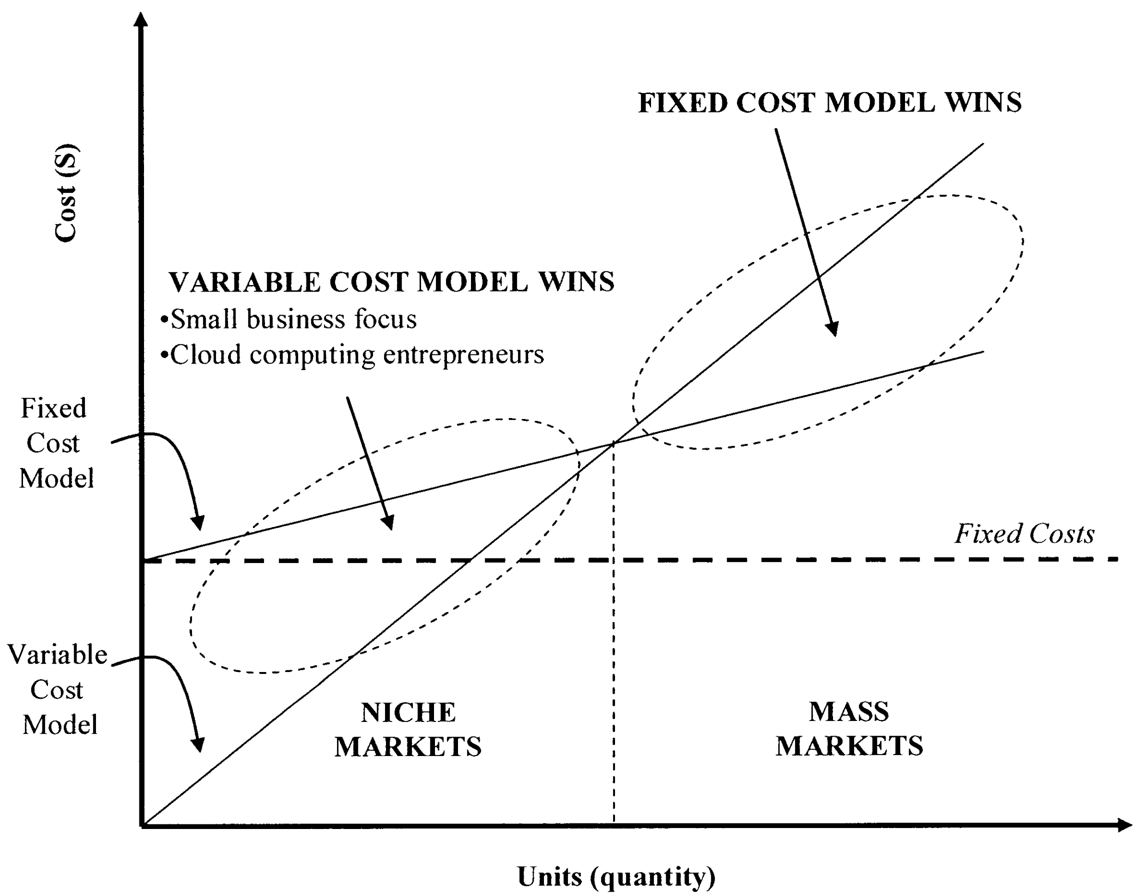


Figure 2: Appeal of Variable Cost Model to Cloud Computing Entrepreneurs

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[32] King, 17.

[33] King, 13.

There are two additional orthogonal market drivers for cloud computing. First, stimulus funding for data centers and small business start-ups under The American Recovery and Reinvestment Act will draw attention to cloud computing.[34] Nearly $40 billion has been allocated to broadband, healthcare IT, federal IT infrastructure, next-generation classrooms, and IT security upgrades. These investments have a tremendous impact on IT and data center infrastructure, digital security, disaster recovery, and remote access. Another $35 billion has been allocated for upgrading education and the smart electricity grid. The smart electricity grid project will connect the grid infrastructure to the Internet, generating new efficiencies and circumventing potential power outages. Second, there is a strong market driver to "Go Green" in cloud computing. Power consumption in cloud computing has caught the attention of providers and governments worldwide. Cloud computing firms and data center providers are leading the eco-friendly movement to build more energy-efficient facilities. Data centers consume one-half of one percent of the world's electrical power supply.[35] In the United Kingdom, this figure exceeds 1.5 percent of all electrical power, which has been the impetus to pass the UK Climate Change Act.[36] This legislation requires a 26% reduction in UK carbon emissions by 2020 and 80% by 2050. Hewlett-Packard, Microsoft, and Google have employed new energy saving technologies in their data centers beyond what their customers could provide on their own.[37]

**Market Restraints:** As a nascent technology and business, cloud computing has numerous market restraints as shown in Table 2.[38] The public cloud has drawbacks in security, regulatory compliance, enterprise control, vendor lock-in, and resource contention as a result of a shared environment. In its current implementation, there are

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[34] Elka Popova, Melanie Turek, "Delivering Communications in a Down Economy: Is SaaS the Answer?", Analyst Briefing, *Frost & Sullivan*, (May 2009): 1-22.

[35] Lynda Stadtmueller, "Five Things to Love About Cloud Computing", *Stratecast, (a division of Frost & Sullivan), Business Communication Services*, ( January, 2009): 1-6.

[36] Lynda Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprise Data Center Dollars", *Stratecast (a division of Frost & Sullivan), Business Communication Services*, Volume 3, Number 1, (February 2009): 8.

[37] Stadtmueller, "Five Things to Love About Cloud Computing", 1-6.

[38] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 13.

schools of thought that preferentially assign cloud computing to either the enterprise or the SMB, or to both.[39] Enterprises are more likely to require a more secure and compliance-rich environment for sensitive applications pertaining to financial, medical, and defense-related records. Furthermore, the variety of cross-industry, cross-disciplinary applications predicate how and if they will be used in the cloud. The hybrid cloud, linking private and public cloud environments, is a restraint today, owing to its complexity. However the hybrid cloud will be a significant market driver and motivator in next-generation cloud computing, introducing a seemingly endless number of new services.

*Increase in Market Restraint Impact*

| MARKET RESTRAINT | 1 YEAR | 2-3 YEARS | 4-5 YEARS |
|---|---|---|---|
| Increase in actual and perceived security risks from shared cloud computing environments | HIGH | HIGH | HIGH |
| Increase in regulatory and industry compliance risks associated with cloud/shared server environments | HIGH | HIGH | MEDIUM |
| Increased sensitivity in IT culture to hand control of data center to 3rd-party provider | HIGH | HIGH | MEDIUM |
| Increased "vendor lock-in": Lack of open platform standards inhibits management across providers | HIGH | HIGH | MEDIUM |
| Dimished support for hybrid (private cloud/public cloud) environment | MEDIUM | HIGH | MEDIUM |
| Increased contention for shared server resources dimish application performance | MEDIUM | MEDIUM | HIGH |
| Increased ease of entry into cloud adds risk to virtual machine (VM) proliferation and "renegade apps" | LOW | MEDIUM | MEDIUM |

Table 2: Cloud Computing Market Restraints, 2009-2014 (Source: Frost & Sullivan)

From Table 2, security, compliance, and control are the dominant market restraints in cloud computing. With the advent of shared data stores, virtualization, and scalability, many enterprises are dissuaded from the public cloud for security reasons. Enterprises with sensitive customer data need to know where their data is and need to ensure that their data isn't shared on servers and networks used by another customer. In

[39] Frank E. Gillett, "Conventional Wisdom Is Wrong About Cloud IaaS", 1-13.

consumer enterprises, security is important, but is not a top priority. In financial, medical, and defense enterprises, security is a top priority, especially when enforced by legislative mandates. Compliance requirements are a natural segue from the security arena. PCI (Payment Card Industry), HIPAA (Health Insurance Portability and Accountability Act), and SOX (Sarbanes Oxley) legislation requires strict compliance standards in cloud computing.[40] Enterprises and SMBs more aligned with consumer services such as email and web services are more inclined to engage a 3rd-party cloud computing provider. Enterprises and SMBs entrenched in highly confidential information have relied more heavily on secure data centers. Finally, a lack of corporate IT control is a significant deterrent to the wholesale adoption of cloud computing. IT departments desire to maintain a level of control in form of testing, revision control, patch management, maintenance, and deployment of applications and services.

**Cloud Computing: Analysis Trajectory**

Thus far, cloud computing has been defined along with its historical benchmarks. The IaaS, PaaS, and SaaS building blocks along with key elements of sharing, scalability, virtualization, and utility pricing have also been presented. Market drivers and market restraints shape the adoption of cloud computing as a viable business model.

This analysis focuses on cloud computing as a disruptive technology business model. The criteria for disruptive technologies and disruptive markets will be defined next. Most importantly, these criteria will be assessed in two main areas. The first area is cloud computing as disruptive technology in the current non-utility based software and services industry. The second area is next-generation cloud computing disruptive technologies once the public cloud has taken hold as the dominant computing paradigm.

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[40] Lynda Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 14.

# CHAPTER II: ANALYSIS CRITERIA

## Cloud Computing: A Disruptive Technology

The strategic intent of this analysis is to demonstrate that cloud computing, both in its present form as a threat to traditional software licensing and in its future implementation as a ubiquitous hybrid private/public cloud model, is a disruptive technology. Disruptive technologies (Christensen, 1997) emerge once the performance trajectories of incumbent firms outstrip the demand and capability of the market to absorb these levels of performance.[41] At that instance, emergent firms enter the fray, offering modular, disintegrated solutions at lower performance levels, but armed with the capability to provide advantages in cost, convenience, and flexibility—all within the envelope of a promising new performance trajectory.

The emergence of a disruptive technology as a function of time and performance,

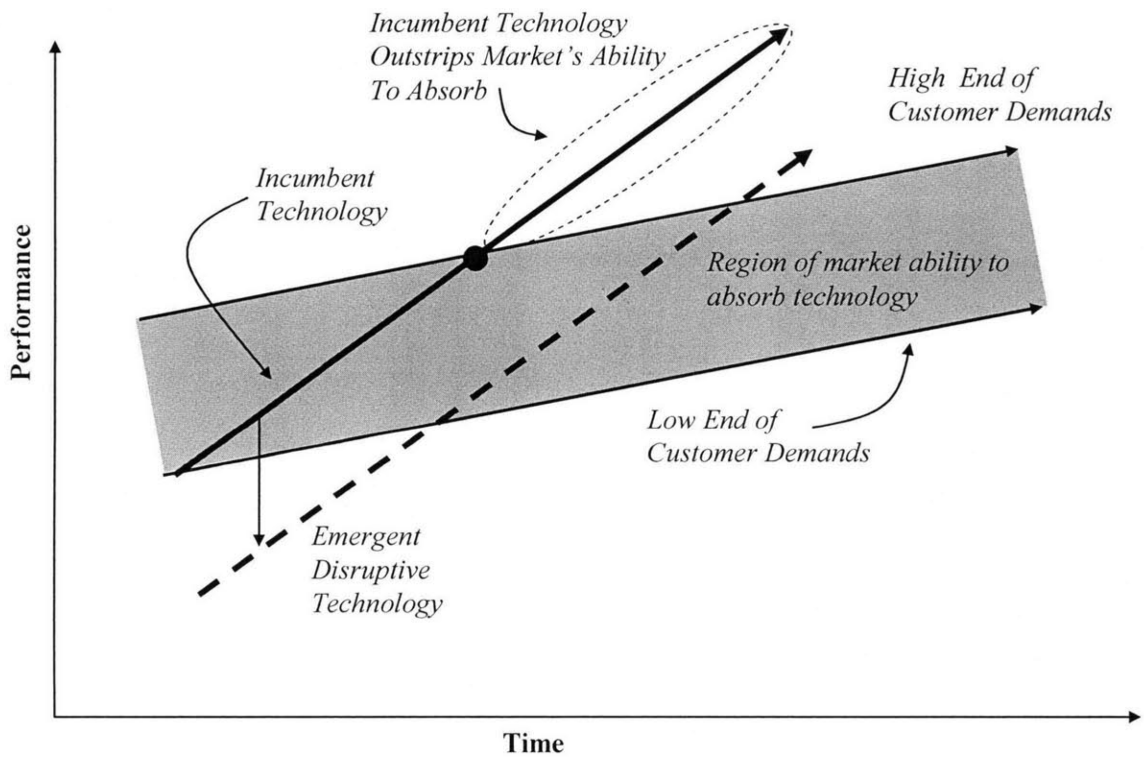


Figure 3: The Disruptive Technology Model in Relation to Incumbent Technology

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[41] Christensen, *The Innovators Dilemma*: ix-xxiv

in relation to incumbent technology and market demand, is shown in Figure 3.[42] In this figure, the shaded region represents the upper and lower performance boundaries, which the mainstream market is willing and capable to absorb. Performance improvements in the incumbent technology are primarily expedited by sustaining improvements in component technology. There is no clear first-mover advantage among firms driven by improvements in component technologies.[43] Performance improvements by emergent disruptive technologies have their roots in architectural changes where there is a clear first-mover advantage.[44] Subsequent performance improvements over time, even by disruptive technologies, are primarily sustaining in nature.

Upon further evaluation of the disruptive technology model in Figure 3, the performance improvement trajectories of both the incumbent and disruptive technologies are not guaranteed to be either continuous or maintain the same trajectory over time. The key point is that the disruptive technology usually represents an architectural change, with an initial performance deficit in relation to the incumbent technology. However, the disruptive technology addresses the needs of nascent markets, offers improvements in convenience, flexibility, and price, along with the promise for a new performance trajectory to meet and exceed market demands.

This analysis focuses on cloud computing as a disruptive technology in two important technological eras. The first era is the present state of cloud computing technology, which has emerged as a threat to conventional software and services licensing models owing to improved convenience, flexibility, and price. The second era is the future state of cloud computing within the next one to five years. Within this time frame, new disruptive cloud computing technologies and markets will emerge to remedy the drawbacks of today's public cloud computing environment which lacks open standards and application management. However, three criteria must first be established

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[42] Clayton Christensen, Michael Raynor, Matthew Verlinden, "Skate to Where the Money Will Be", *Harvard Business Review*, Volume 79, Issue 10, November 2001, 71-81.

[43] Clayton Christensen. "Exploring the Limits of the Technology S-Curve. Part I: Component Technologies". *Product and Operations Management*, Volume I, No. 40, Fall 1992, 334-357.

[44] Clayton Christensen. "Exploring the Limits of the Technology S-Curve. Part II: Architectural Technologies". *Product and Operations Management*, Volume I, No. 40, Fall 1992, 358-366.

to defend the assertion of cloud computing as a disruptive technology in the two eras presented above.

### Cloud Computing: Disruptive Technology Criteria

There are three criteria that must be satisfied to defend the assertion of cloud computing as a disruptive technology. The first two criteria focus on the requisite market conditions to support cloud computing as a disruptive technology. The third criterion focuses on business ecosystem requirements to support cloud computing as disruptive technology.

**Criterion #1—Enablement of New Customers:** Innovations in cloud computing must be able to support the needs of a new customer base that formerly could not benefit from conventional software and service licensing models or from industry-standard cloud computing models. Christensen states this criterion as follows.

> *"Does the innovation enable less-skilled or less-wealthy customers to do for themselves things that only the wealthy or skilled intermediaries could previously do?"*[45]

Even if the disruptive innovation cannot fulfill all of the performance attributes of the incumbent technology, the disruptive innovation enables a new customer base to enter into what was once an unattainable market. Christensen calls this, *creative creation.*[46] As will be discussed in the next two chapters, cloud computing allows sole proprietorships, SMBs, and large enterprises to access computing resources that were once cost-prohibitive.

**Criterion #2—Enablement of Low-End Markets with Attractive Returns:** Innovations in cloud computing must be able support the low end of the market even with some sacrifice of performance and functionality. Furthermore, emerging cloud computing providers must be able to earn attractive returns at prices which are

[45] Clayton Christensen, "The Rules of Innovation", Technology Review, June 2002, 33-38.

[46] Christensen, "The Rules of Innovation", 34.

historically unattractive to providers of private data centers and hosted services. Christensen states this second criterion as follows.

> *"Does the innovation target customers at the low end of a market who don't need all the functionality of current products? And does the business model enable the disruptive innovator to earn attractive returns at discount prices unattractive to the incumbents?"*[47]

Cloud computing provides convenience, flexibility, and frees customers from costly capital equipment expenditures. In the current implementation of cloud computing, some performance attributes of security and control lag those of conventional data centers. However, the low-cost utility pricing model of cloud computing targets those customers who formerly could not access software and services resources in the first place. While targeting customers of various socio-economic levels, including the low-end of the market, cloud computing providers are able to derive attractive returns attributable to economies of scale. The use of this criterion in defending cloud computing as a disruptive technology will be presented in the following two chapters.

**Criterion #3—Enablement of Disruptive Technology Ecosystem:** An innovation cannot emerge without an integrated solution, where Christensen boldly states, "The bedrock principle is this: Those who control the interdependent links in a value chain capture the most profit".[48] This applies to both a single firm with a complete, fully-integrated, and interdependent end-to-end solution (Christensen, 2001)[49], or a modular solution with integration driven firmly into its modular components (Christensen, 2001; Baldwin & Clark, 1997) [50]. The emergent disruptive technology may be in the form of a business enterprise with a complete end-to-solution or in the form of modular components that bring functional excellence and price competitiveness to the disruptive market. Nonetheless, the effective disruptive technology has an ecosystem

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[47] Christensen, "The Rules of Innovation", 35.

[48] Christensen, Raynor, Verlinden, "Skate to Where the Money Will Be", 76.

[49] Christensen, Raynor, Verlinden, "Skate to Where the Money Will Be", 75.

[50] Carliss Baldwin, Kim Clark, "Managing in an Age of Modularity", *Harvard Business Review*, Volume 75, Issue 5, September 1997, 127-135.

which has a fully-integrated and interdependent solution, either as a single entity or as a host of modular enterprises.

A viable ecosystem is an essential requirement for any business enterprise to thrive, from birth, to expansion, to leadership, and finally to rebirth.[51] Inside the ecosystem is a spirit of competition and cooperation irrespective if functional operations are housed inside a single firm or provided in a modular implementation. Figure 4 illustrates the general ecosystem model, whether it is the PC and the disc-drive industries of the 1980s and 1990s, or the cloud computing industry of the early part of the twenty-first century.[52]

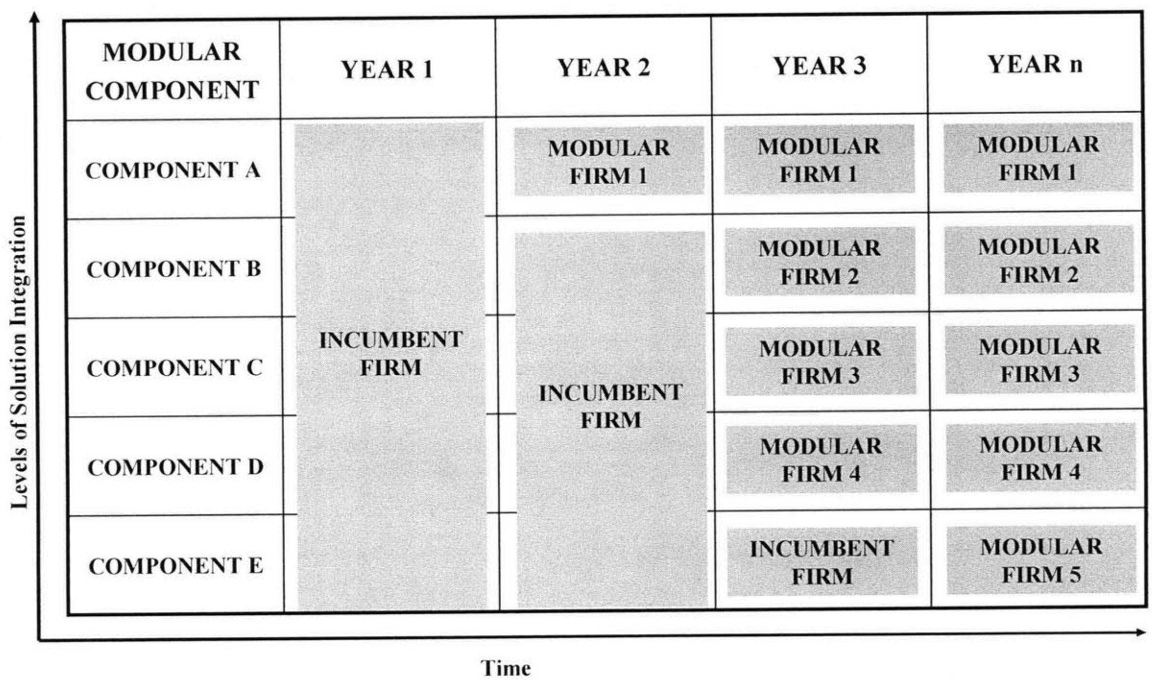


Figure 4: Ecosystem Models for Fully-Integrated and Modular Organizations

From Figure 4, fully-integrated and interdependent firms tend to dominate burgeoning industries, as IBM did in the computer industry in the 1960s and 1970s. This is particularly prevalent when the technology "isn't good enough" and the only recourse the

[51] James F. Moore, "Predators and Prey: A New Ecology of Competition", *Harvard Business Review*, Volume 71, Issue 3, May-June 1993, 75-86.

[52] Clayton M. Christensen, Michael E. Raynor, Matt Verlinden, "Skate to Where the Money Will Be", *Harvard Business Review*, Volume 79, Issue 10, November 2001, 72-81.

firm has is to develop technology internally within its highly-skilled functional areas.[53] However, when the technology "is good enough", architectural changes emerge in the form of modularity to address gaps in market needs, flexibility, and convenience. Integration and interdependence are then driven into these modular components themselves, to enable improvements in performance. While the performance of these disruptive technologies is initially lower than that of the incumbent technology and the market demands, the performance trajectory is sufficient to take over market, tier by tier. As Figure 4 illustrates, an ecosystem built from a single entity migrates into modular components as disruption takes hold. The analysis in the following two chapters will shed light on the cloud computing ecosystem.

Another essential driving force in the development of an ecosystem is the adoption of a disruptive technology in the marketplace. As Geoffrey Moore points out, the most critical point of adoption is in the "chasm" between the *Early Adopters* and the *Early Majority* as shown in Figure 5.[54]

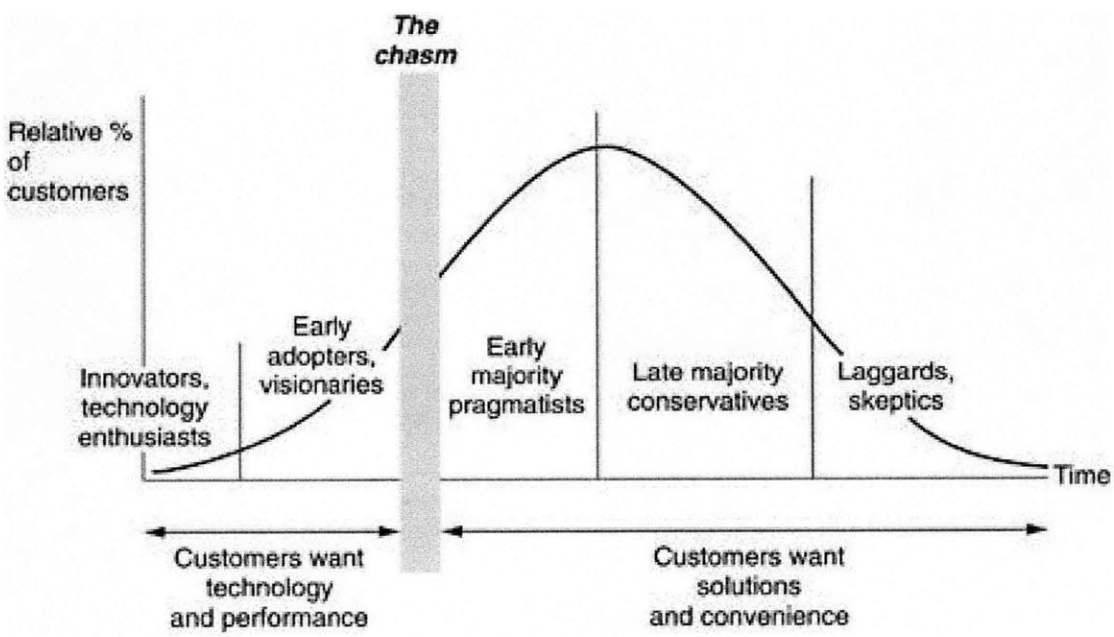


Figure 5: Chasm—Early Adopters and Early Majority (Source: Geoffrey Moore)

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[53] Christensen, Raynor, Verlinden, "Skate to Where the Money Will Be", 72.

[54] Geoffrey Moore, "High Tech Marketing Illusion", *Crossing the Chasm*, (New York, Harper Collins, 1999), 19-25

The success of the adoption of cloud computing within the diffusion model hinges on the transition from the *Early Adopter* phase to the *Early Majority* phase. *Early Adopters* are change agents and the *Early Majority* are productivity improvement agents, where the latter has all the credibility in crossing the chasm. As Geoffrey Moore point outs:

> *"...early adopters do not make good references for the early majority. And because of the early majority's concern to not disrupt their organizations, good references are critical to their buying decisions. So what we have here is a catch-22. The only suitable reference for an early majority customer, as it turns out, is another member of the early majority..."*[55]

These assertions on technology adoption within the diffusion model will be tested on cloud computing as a disruptive technology. For the cloud computing ecosystem to gain traction, this disruptive industry must make its way through the technology adoption process. As will be developed in the following chapters, cloud computing entrants into the *Early Majority* play a vital role in evangelizing cloud computing to *other* constituents of the *Early Majority.* Adoption helps strengthen the business ecosystem, which is a vital criterion in establishing cloud computing as a disruptive technology.

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[55] Geoffrey Moore, *"High Tech Marketing Illusion", Crossing the Chasm*, 20.

## CHAPTER III: THE INCEPTION OF CLOUD COMPUTING
### *(Cloud Computing as a Disruptive Technology)*

### Cloud Computing: Competitive Landscape

At a first glance, cloud computing represents an emergent disruptive technology to the conventional "pay-up-front", on-premise, enterprise-controlled, and license-based software and services business model. The performance of the license-based model has outstripped the capabilities of a large portion of the market to absorb its technology trajectory, owing to the complexities of software releases, patch management, and the human toll of managing services between the provider and the enterprise. The license-based model also has commensurate increases in cost, alienating and even excluding a significant portion of the market as well. In summary, the software and services license model was ripe for disruption.

From its inception, cloud computing provides a scalable, virtualized, flexible, and utility-based model which satisfies the first two market-oriented criteria presented in the previous chapter. Less-skilled and/or less-wealthy individuals could now gain access to the same software and services products that only their more-skilled and more-wealthy counterparts could formerly attain. Furthermore, while the early cloud computing models lack some of the performance capabilities of incumbent licensed-based models, the low-end of the market was successfully addressed. Cloud computing providers could earn attractive returns, albeit at lower prices than the incumbents, by virtue of economies of scale in data center management, virtualization, and shared computing resources. Amazon affirms its own attractive returns while citing one of its customers saved 66% in operating expenses for moving its applications from a premised-based environment to the Amazon platform.[56] However, the breakdown of these savings attributed to virtualized technologies and the shared grid environment, both inherent in the cloud, are undetermined at this time.[57]

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[56] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", *Stratecast (a Division of Frost & Sullivan), Business Communication Services*, Volume 2, Number 10, (November 2008): 13.

[57] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 13.

Cloud computing, as a nascent business, also satisfies the third criterion for a disruptive technology—it has a formidable ecosystem. Early entrants into the cloud computing arena, including IBM and Amazon, built complete fully-integrated, end-to-end solutions with IaaS, PaaS, and SaaS architectures.[58] Both IBM and Amazon employ the use of scalable and virtualized data centers, utility pricing, and managed services. IBM has now expanded its cloud computing footprint with the addition of over 100,000 square feet in data center capability.[59] IBM, Citrix, and 3Tera are also championing the development of open standards to manage any vendor's cloud through an Application Programmable Interface (API).[60] Hewlett-Packard has now joined the cloud computing industry and is poised to be the most formidable competitor because of its robust end-to-end solution. With the HP's acquisition of EDS in 2008 and 3Com in 2009, HP has added data centers, services, and networking capabilities to its prior core competencies of diversified computer systems, storage, and IO.

Cloud computing also has modular, disintegrated entrants as part of its ecosystem. Firms such as Telx (co-location facilities), Citrix (open standards and virtualization), 3Tera (cloud interoperability), and Akamai (Internet delivery) are part of the emerging, modularized ecosystem of cloud computing. To make these modular components an effective part of the cloud computing ecosystem, the themes of integration and interdependency are incorporated at these modular levels.[61] Integration and interdependency are fostered under the veil of strong corporate branding and especially by the proliferation of open standards.[62]

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[58] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 6-19.

[59] Lynda Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", *Stratecast (a division of Frost & Sullivan), Business Communication Services*, Volume 3, Number 1, February 2009,

[60] Lynda Stadtmueller, "IBM Cloud Services: An Enterprise-Grade Cloud at Last?", *Stratecast (a division of Frost & Sullivan), Business Communication Services*, July 9, 2009. 4.

[61] Clayton M. Christensen, Michael E. Raynor, and Matt Verlinden, "Skate to Where the Money Will Be", *Harvard Business Review*, Volume 79, Issue 10, (November 2001): 72-81.

[62] Carl Shapiro, Hal Varian, "The Art of Standards Wars", *California Management Review*, Volume 41, Number 2, (Winter 1999).

The competitive landscape of the inception of cloud computing is best illustrated by Michael Porter's five competitive forces of: 1) *Current Competitive Landscape*, 2) threat of *Buyers*, 3) threat of *Suppliers*, 4) threat of *New Entrants*, and 5) the threat of *Low-Cost Substitutes*.[63] These five forces are dynamic, regenerative, and play a vital role in not only supporting the current business ecosystem, but also threatening it with viable disruptive technology solutions including cloud computing.

The *Current Competitive Landscape* in the software and services industry focuses on providers entrenched in a pay-up-front licensing model, that include Microsoft, Adobe, Oracle, and numerous other software and services providers. The rivalry among these license-oriented providers has been in place for decades. The *Buyers* consist of large enterprises, SMBs, sole proprietorships, and end-users. These buyers can *reverse-integrate* into the software and services landscape. Telcos such as AT&T, Verizon Business, along with distributed IT companies such as IBM, have precisely done just that.[64] The *Suppliers* comprise 3rd-party software and service providers, co-location data center facilities, and contractors. Many of these suppliers, such as Rackspace and Telx, have *forward-integrated* into the software and services arena by providing an array of modular solution components for cloud computing. *New Entrants* provide the most logical and substantive threat to the mature software licensing, on-premise data center, and outsourcing models. These *New Entrants* have a vested interest in data center management including: private, co-location, public cloud, dedicated hosting, and managed hosting services. *New Entrants* include existing customers and buyers, such as Amazon, IBM, HP, and numerous firms specializing in modular data center solutions. Finally, *Low-Cost Substitutes* are providers of unmanaged data centers, facilities, and 3rd-party software. The depiction of these five competitive forces is shown in Figure 6 below.

[63] Michael Porter, *Competitive Advantage*, (The Free Press, New York, 1985), 4-50.

[64] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", *Stratecast, (a division of Frost & Sullivan), Business Communication Services*, Volume 2, Number 10, November 2008, 15-24.

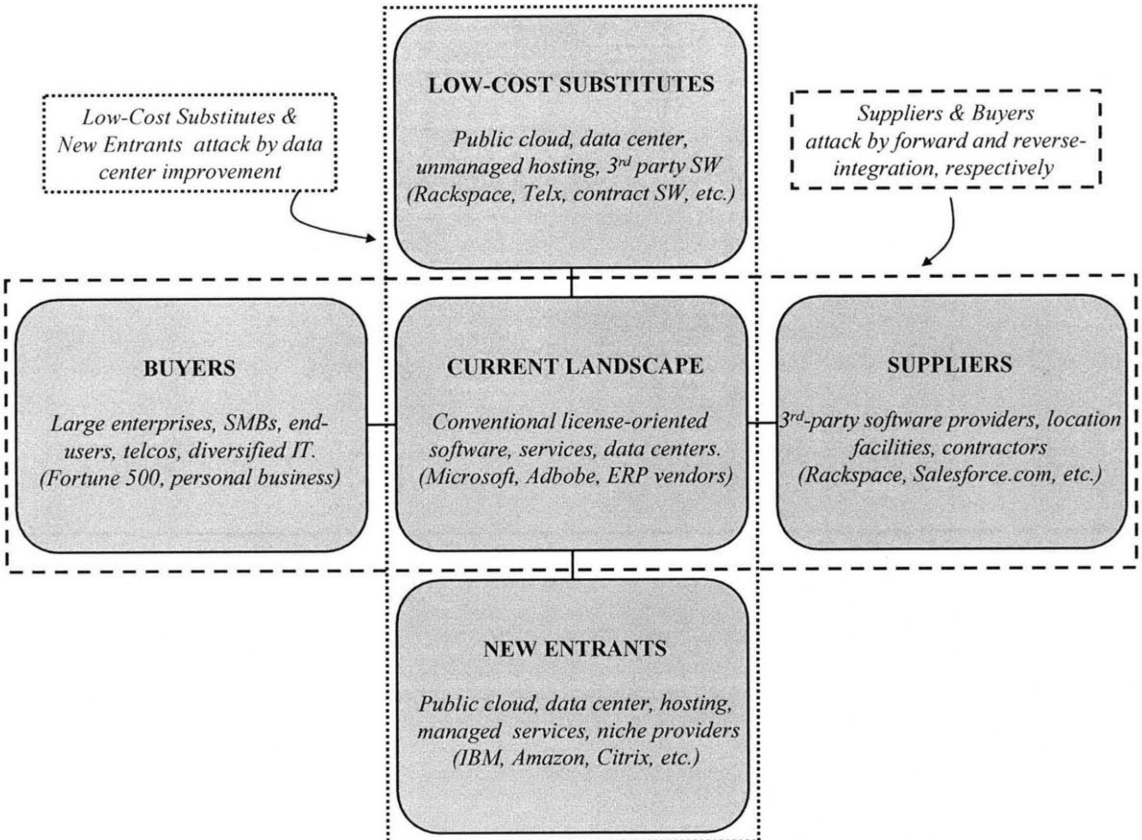


Figure 6: Porter's Five Competitive Forces for Inception of Cloud Computing

From Porter's five competitive forces in Figure 6, all constituent forces play a role in the adoption of cloud computing as a disruptive technology from the software and services licensing model. Of particular interest are the *New Entrants* and *Low-Cost Substitutes,* which play a vital role in re-architecting data centers to meet the needs of the data center providers and the customer to manage a vast of array of applications and services. This topic will be discussed next.

## Public and Private Clouds

This chapter focuses on disruptive technology models in *public* clouds as shown in Figure 7 using a premised-based and hosted framework.[65]

[65] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 9.

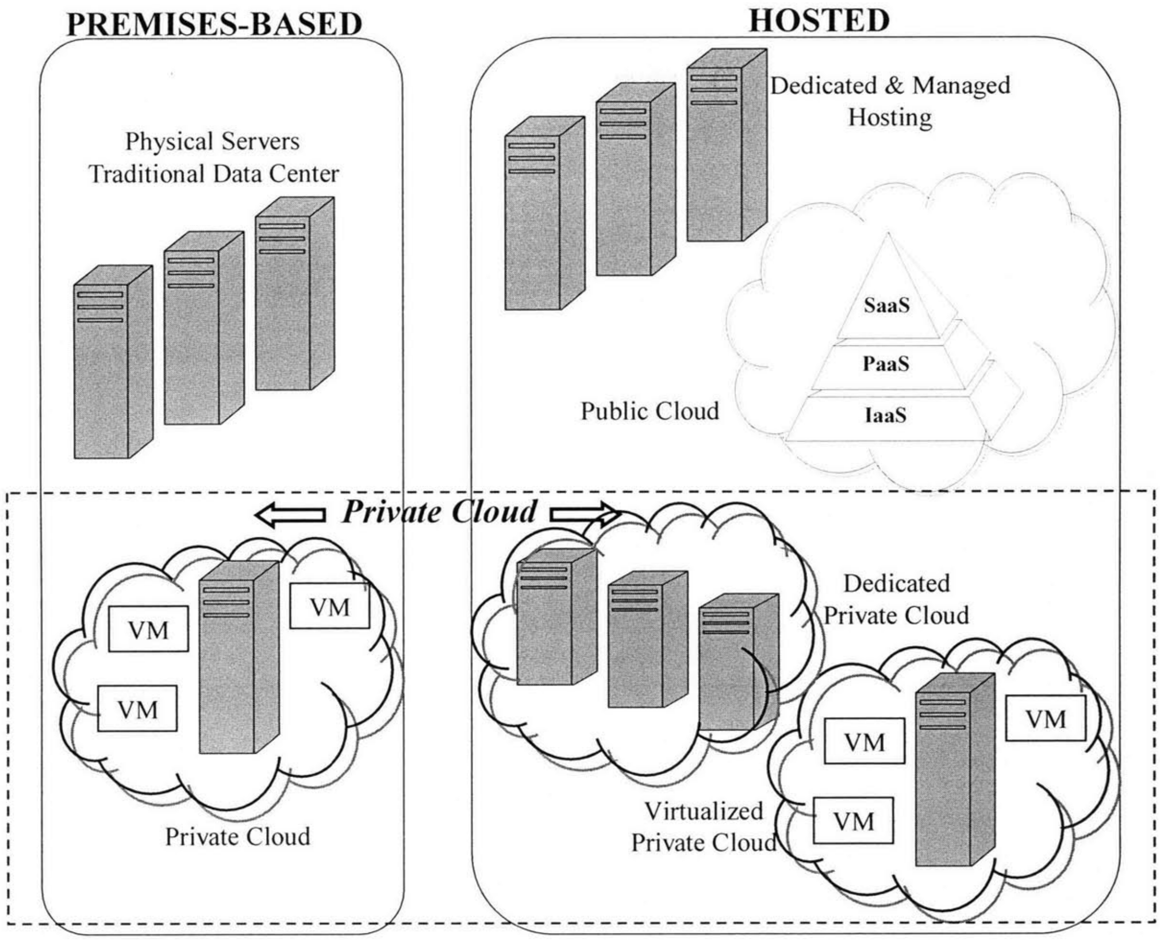


Figure 7: Public and Private Clouds in Premise-Based and Hosted Environments

The primary emphasis of this chapter is the *public* cloud in a hosted environment, which is shared, scalable, flexible, and has utility-based pricing based on usage. The *private* cloud can be implemented on-premise with scalability and virtualization (VM), or in a hosted environment as a *dedicated* physical private cloud or as a virtualized private cloud, where servers are *dedicated* to a specific enterprise customer.[66]

**Data Center Architecture: Disruptive Technology Opportunities**

The evaluation of data center architecture provides remarkable insight as to why the three disruptive technology criteria for cloud computing are satisfied. As previously stated, cloud computing is a production model, satisfying the needs of providers to store,

[66] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 9.

develop, and deliver applications and services. However, it is also a consumer model, where the customer's interests in obtaining a pay-as-you-go, scalable, and flexible environment are key drivers to data center architecture.

Building on the Porter analysis from Figure 6, today's data center options, dominated by *New Entrants* and *Low-Cost Substitutes* include: private data centers, co-location facilities, public cloud computing, dedicated hosting, and managed hosting. These five options are presented in Figure 8 below where private data centers have the strongest dependency on the enterprise and managed hosting services have the strongest dependency on the 3rd-party provider.[67]

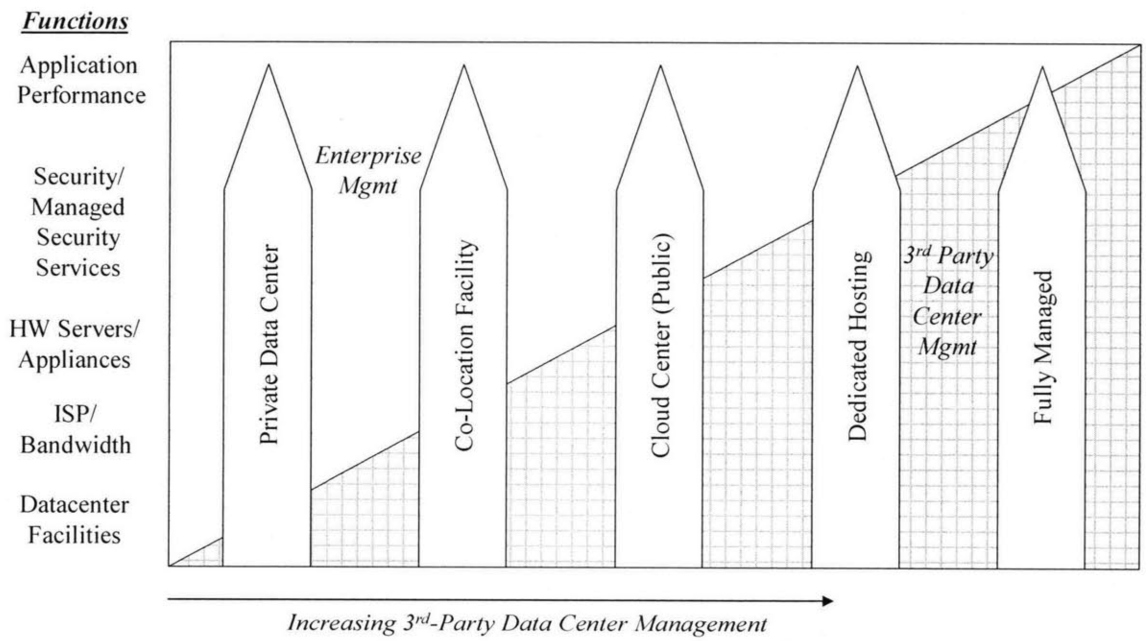


Figure 8: Data Centers and Dependency on Enterprise and 3rd-Party Management

The enterprise or the 3rd-party provider is tasked with creating an ecosystem with the following functions: 1) data center facilities, 2) ISP/bandwidth, 3) hardware services and appliances, 4) security and managed security services, and 5) application performance. This gives insight to the dependency each type of data center has on the enterprise and on the 3rd-party provider. For private on-premise data centers, which have been in existence for decades, the enterprise is responsible for virtually all functions. Only recently have

[67] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 11.

private data centers relied on facilities from $3^{rd}$-party providers. At the other end of the spectrum, managed hosting owns all data center responsibilities. In some cases these responsibilities are shared between the enterprise and the $3^{rd}$-party provider. In the center is cloud computing, where more than half of the data center functions reside with the $3^{rd}$-party provider. Security and application performance reside with the enterprise. However, the enterprise can exert very little control over these needed functions. In summary, those functions in Figure 7, which have historically been owned by the enterprise, are now breeding grounds for hosted, cloud-based disruptive technologies.

Data center decision factors, from a customer point view, are presented in Table 3 with choice points around security, enterprise resource and control, scalability, and cost.[68]

| | Data Center Attributes | | | | |
|---|---|---|---|---|---|
| **Data Center Option** | **Security Risk (from Shared Facilities)** | **Enterprise Resources Required** | **Enterprise Control** | **Scalability Performance** | **Total Cost** |
| **Private Data Center** | LOW | HIGH | HIGH | LOW | HIGH |
| **Co-Location Facility** | LOW | HIGH | HIGH | HIGH | LOW |
| **Cloud Services (Public)** | HIGH | LOW | LOW-MEDIUM | HIGH | LOW |
| **Dedicated Hosting** | MEDIUM | LOW-MEDIUM | LOW-MEDIUM | MEDIUM | LOW |
| **Managed Hosting** | MEDIUM | LOW-MEDIUM | HIGH-LOW | HIGH | HIGH |

Table 3: Data Center Choice Points

From Table 3, it is apparent that at this time, there is no composite score for data center performance. Different customers have different needs and of course, different weighting factors for these choice points. In disc drives (Christensen 1992), the performance

[68] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 11.

metric was *Areal Density* (in millions of bits per square inch).[69] For the purposes of a performance trajectory, separate performance metrics are available for parameters such as security, scalability, latency, etc. However a composite cloud computing performance metric has not been widely accepted by the IT industry. Suffice it so say, that such a metric is dependent on the application requirements and market segments, where its trajectory over time has a positive slope.

Another representation for these data in Table 3 is presented in Figure 9 below.

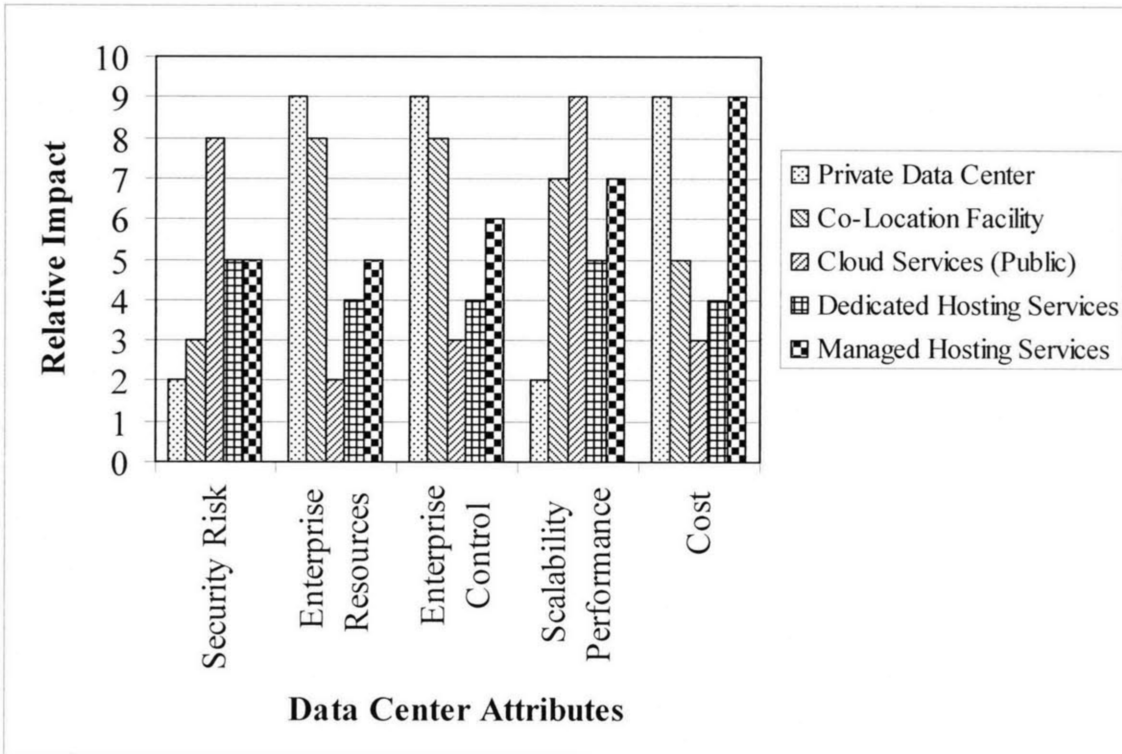


Figure 9: Quantitative Data Center Choice Points (approximated impact)

These data presented in Figure 9 are derived, in part, from the qualitative results shown in Table 3. However, quantitative scores are approximated from the comparison of each data center solution.[70] From Figure 9, it is apparent that the public cloud offers the desired customer-driven features of scalability and utility pricing (cost), but lacks in areas

[69] Clayton Christensen, Joseph Bower, "Disruptive Technologies: Catching the Wave", *Harvard Business Review*, Volume 73, Issue 1, January 1995, 43-53.

[70] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 1-21.

such as security and enterprise (customer) control. The battle over enterprise control versus 3rd-party control should not be minimized; they spawn new and disruptive architectures in data center and cloud computing design. In summary—security, enterprise resources and control, scalability, and cost—are all disruptive opportunities, as an analysis of each type of data center will reveal.

### *Private Data Center*

The private data center has been in existence for decades. More than 85% of the world's data resources are housed in privately-owned and privately-managed data centers.[71] The private data center and the technology that governs it, predate cloud computing and managed hosting. The motivation for the private data center is the element of enterprise control as shown in Table 4.[72] This type of data center is controlled, operated, and owned by the enterprise or SMB.

| Private Data Center | Provided by Enterprise | Provided by 3rd-Party Provider |
|---|---|---|
| **Facilities**<br>Building space, Power, Heating/Cooling, Physical Security | ✔ | |
| **Network Capabilities**<br>Bandwidth | ✔ | *No 3rd-party dependencies. Purely enterprise & SMB driven.* |
| **Equipment (HW)**<br>Servers/Switches | ✔ | |
| **Physical or Virtual Appliances**<br>Security Capability/Traffic Mgmt | ✔ | *A disruptive technology opportunity* |
| **Application Performance Management**<br>End-to-End Performance Mgmt | ✔ | |

Table 4: Private Data Center Responsibilities: Enterprise & 3rd-Party

Consistent with Figure 8, Table 4 sheds light on the fact that all elements of the private data center are controlled by the enterprise or SMB. IT within the private data center is staffed by the enterprise itself, which can respond to business priorities and redeploy resources as needed. In fact, enterprise resources are required in private data centers.

[71] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 12.
[72] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 12.

There are no 3rd-party dependencies, which brings forth a plethora of disruptive opportunities. This is no surprise because the private data center and the traditional software licensing model are of the same vintage and operating model.

The private data center is highly secure. It has no shared resources or equipment and is typically located behind the customer's firewall. However, the enterprise or SMB must be able to protect against Distributed Denial of Service attacks (DDOS), and have security features to protect data that is both at rest and in transit. Private data centers are not particularly scalable, as these footprints are static. To meet the growing computing needs of the enterprise, additional equipment has to be added, which impacts cost and time. Expanding the footprint can be difficult and expensive if the needs of the enterprise expand regionally and internationally. As anticipated, the acquisition and operation of private data centers are expensive. The capital investment in data centers can easily cost tens of millions of dollars, where construction costs in China approach $2000 per square foot.[73] Equipment upgrades can be expected every three to four years, excluding costs for maintenance, real estate taxes, electricity, heating, and cooling. Private data center design services are offered by IBM, Sun, and HP.

***Disruptive Elements of Private Data Centers:*** Private data centers provide an opportunity for emergent disruptive technologies to address deficiencies in its scalability, flexibility, virtualization, and cost. As currently implemented, private data centers exclude the low end of the market and are price prohibitive to many enterprises, SMBs, and end-user customers. Private data centers have attractive returns, but only at premium pricing. Private data centers are the most expensive data center option and do not qualify as a viable disruptive technology based on price. The ecosystem of private data centers is vertically integrated within the enterprise, by design. Any modifications to this data center design would require expansion into co-location, cloud computing, or some degree of hosting. Modular changes are most likely if the private data center is to be altered.

[73] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 7.

***Co-Location***

In co-location facilities, the enterprise furnishes the equipment and technical resources, which are located in a leased facility owned by a 3$^{rd}$-party provider. The facility is shared among numerous customers. The co-location facility can earn attractive returns through economies of scale by defraying power, bandwidth, and real estates costs among those customers. This data center adds value to the enterprise by furnishing interconnect facilities, which improve latency by eliminating the local loop delay. Co-location facilities require a substantial amount of enterprise resources and control. IT specialists from the enterprise are required to install and maintain equipment, as well as manage applications. The segregation of enterprise and 3$^{rd}$-party responsibilities for the co-location facility is provided in Table 5 below.[74]

| Co-Location Facilities | Provided by Enterprise | Provided by 3$^{rd}$-Party Provider |
|---|---|---|
| **Facilities**<br>Building space, Power, Heating/Cooling, Physical Security | | ✔ |
| **Network Capabilities**<br>Bandwidth | ✔ | ✔ |
| **Equipment (HW)**<br>Servers/Switches | ✔ | *HW & mgmt owned by enterprise/SMB.*<br><br>*A disruptive technology opportunity* |
| **Physical or Virtual Appliances**<br>Security Capability/Traffic Mgmt | ✔ | |
| **Application Performance Management**<br>End-to-End Performance Mgmt | ✔ | |

Table 5: Co-Location Data Center Responsibilities: Enterprise & 3$^{rd}$-Party

As shown in Table 5, the facility and network capabilities are largely provided by the 3$^{rd}$-party. Equipment, physical and virtual appliances, along with application management are owned and managed by the enterprise. Co-location data centers are vulnerable to disruptive 3$^{rd}$-party providers, which can add elements of convenience and flexibility by managing equipment and applications.

[74] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 14.

Co-location facilities are more scalable than private data centers—equipment can be added by the enterprise at the enterprise's expense, provided there is sufficient space in the facility. Space can be rented by the "rack" for industry standard servers or by the "cage" for a wired enclosure. Scalability is not instantaneous, however. It requires approval of the co-location facility, set-up, and additional resources from the enterprise. Co-location facilities are considered quite safe, even though all customers have access to the facility. The enterprise owns its equipment in the data center, which is not shared by any other customer. Providers of co-location facilities include Telx and The Planet, as well as telecommunications firms including Verizon Business and AT&T.

***Disruptive Elements of Co-Location Facilities:*** Firms specializing in co-location are targets of disruption in equipment, appliances, and application management. Costs are lower in co-location facilities than in private data centers. Therefore, co-location is viable to more markets, but is not considered viable in the low end. The enterprise still has to purchase and manage equipment, appliances, and applications. In addition, co-location facilities fall short of the mark when it comes to convenience, speed, and flexibility, which are essential for a disruptive technology to emerge.

The ecosystem of co-location data centers is partially integrated within the enterprise and partially integrated within modular components. The enterprise is still vertically integrated with equipment, resources, and management functions. The co-location facility owns the modular components of space and networking, which are far more flexible than if owned and managed by the enterprise.

***Cloud Computing***

Clouding computing, for the purposes of this data center analysis, is restricted to the *public* cloud. The *public* cloud is distinguished from the *private* cloud by *shared*, not *dedicated* equipment and resources. The private cloud does indeed have a cloud-like architecture, where clusters of servers, appliances, and other resources are shared within and among the applications of a single enterprise.[75] In addition, public clouds employ utility-based pricing and are more scalable than private clouds.

Cloud computing (or cloud hosting) uses massive server grids operated by 3rd-party providers through virtualization software, called "hypervisors" which include Citrix's XenServer, Microsoft's Hyper-V, and VMWare.[76] A driving force behind cloud computing is the creation and standardization of virtualization as an enterprise-scale technology.[77] Virtualization technology provides the mechanism to "dynamically provision, allocate, and manage multiple heterogeneous machine instances in a single piece of hardware".[78] As a consequence of virtualization, the data center is better utilized and is more flexible.

Enterprises have little control and few degrees of freedom in a cloud computing environment. Enterprises manage their data and applications virtually—with limited access to the physical server or the 3rd-party data center in which the applications reside. This is perceived to be both a strength and weakness of cloud computing. In fact, many analysts argue that current cloud computing and hosting models are not enterprise-worthy.[79] Customization options by the enterprise are limited. Enterprises are not able to control security, Quality of Service, or other performance criteria once applications are hosted in the cloud.[80] Most cloud computing providers offer limited resources in the form of application management. That task is left to the enterprise; however, there are limited tools to manage these applications remotely. Many enterprises and SMBs having applications that do not require management and monitoring, are delighted to have them hosted in the cloud. The division of responsibilities in cloud computing between the enterprise and the 3rd-party provider is shown in Table 6.[81]

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[75] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 22.

[76] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 9.

[77] Source: CITTIO Cloud Monitoring Solution – Position Paper 2009, 1-11.

[78] Source: CITTIO Cloud Monitoring Solution – Position Paper 2009, 2.

[79] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 16.

[80] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 18

[81] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 16.

<table>
<tr><th>Cloud Computing Center</th><th>Provided by Enterprise</th><th>Provided by 3rd-Party Provider</th></tr>
<tr><td>Facilities<br>Building space, Power, Heating/Cooling, Physical Security</td><td></td><td>✔</td></tr>
<tr><td>Network Capabilities<br>Bandwidth</td><td>✔</td><td>✔</td></tr>
<tr><td>Equipment (HW)<br>Servers/Switches</td><td></td><td>✔</td></tr>
<tr><td>Physical or Virtual Appliances<br>Security Capability/Traffic Mgmt</td><td>✔</td><td rowspan="2">Disruptive technology opportunity for security and mgmt providers</td></tr>
<tr><td>Application Performance Management<br>End-to-End Performance Mgmt</td><td>✔</td></tr>
</table>

Table 6: Cloud Computing Data Center Responsibilities: Enterprise & 3rd-Party

Security is a major concern in cloud computing and has discouraged many enterprises from adopting this model. Economies of scale in the form shared facilities and virtualization open the door to security risks. Applications and databases for a given customer may be shared among multiple shared servers. Enterprises with sensitive data and the need to meet compliance requirements are reluctant to adopt the public cloud. Improvements in virtualization technology, open standards, and security information management (SIM) are likely to significantly mitigate these security threats within the next five years.

Cloud computing is the most scalable of all data center options. Grid architectures, which can span regional and international boundaries, can accommodate usage fluctuations. As mentioned previously, virtualization software is used to decouple applications from physical servers and operating systems, enabling greater flexibility in the use of fixed hardware assets in the data center. Fees are based on a utility-pricing model for storage and bandwidth. Cloud computing has CPU usage standards where vendor-specific designations are adopted, such as “compute units” (Amazon) and “compute cycles” (Rackspace).[82] For Amazon’s Simple Storage Service (S3) IaaS business, the firm charges a fee based on capacity and data transfer, which are merely pennies per TB/month and GB/month, respectively.

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[82] Stadtmueller, “Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars”, 15.

***Disruptive Elements of Cloud Computing:*** The current implementation of the public cloud is a disruptive technology for the current software and services licensing model and the on-premise private data center. In the classic Christensen disruptive model, cloud computing allows the low end of the market to obtain software and services and at a lower price point, with a concomitant lower initial performance, but possessing a performance trajectory capable of meeting and exceeding market demands. The utility-based, pay-as-you go cloud computing model is substantially less than procuring software licenses and enterprise-owned data center facilities up-front. The drawbacks in the initial cloud computing offering are related to performance. Security is a major concern for enterprises handling sensitive HIPAA, PCI, and SOX data. With shared services and virtualization technology, a customer's data may be in a number of shared server environments. When access is made through an Internet browser rather than a secure VPN environment, the possibility for contamination exists. Many analysts contend that the public cloud is better suited for email and web services, rather than for highly sensitive data.[83] Other analysts assert that SMBs are turning to 3rd-party cloud computing providers because of, not despite, 3rd-party's security capabilities.[84] A top-tier cloud computing provider can provide a more robust security solution than most SMBs can provide on their own.

The classic Christensen disruptive technology model is presented below in Figure 10 for the emergence of cloud computing in relation to a license-driven software and services environment coupled with on-premise private data centers.[85]

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[83] Chenxi Wang, Jonathan Penn, Allison Herald, "How Secure is Your Cloud?", *Forrester Research, Inc.* August 4, 2009. 1-13.

[84] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 14.

[85] Christensen, Bower, "Disruptive Technologies: Catching the Wave", 43-53.

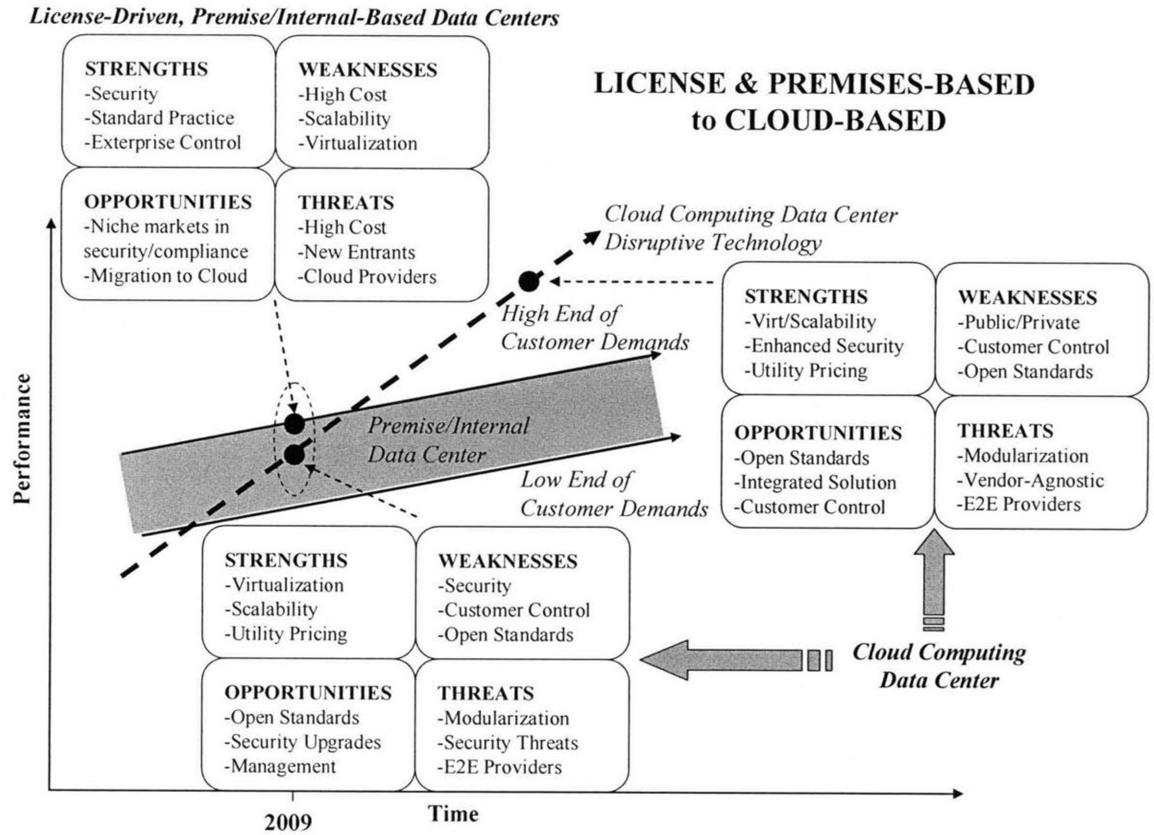


Figure 10: Cloud Computing Disruptive Technology Model

In Figure 10, the shaded region is depicted as the upper and lower boundaries of the market's ability to assimilate a given technology. In this case, it is services provided by on-premise data centers and the license-driven software and services industry. As cloud computing emerges as a new disruptive technology, its performance is initially below that of the market demand, but its performance trajectory is sufficient to take over the market, tier by tier.

In Figure 10, the current license-driven, on-premise data center technology is compared to cloud computing with respect to strengths, weaknesses, opportunities, and threats (SWOT Diagram). For the license-driven, on-premise technology, the strengths are security and standards, whereas the weaknesses are cost, scalability, and virtualization. This industry is depicted at the top end of the market's ability to absorb this technology, where disruption becomes fertile. On-premise data centers are vulnerable to cloud computing as a disruptive technology, as it offers improved cost, convenience, and scalability. The SWOT diagrams for cloud computing are presented concurrently with the on-premise offering and also in the future, as cloud computing evolves and even exceeds the market's ability to absorb the technological advances of the cloud.

Concurrent with the on-premise offering, cloud computing offers improved cost, scalability, and virtualization. However, it is weak on security, enterprise control, and open standards. Cloud computing is vulnerable to *New Entrants* and *Low-Cost Substitutes* that can remedy security threats, have an integrated end-to-end solution, and have an effective modular niche components. In the future, cloud computing may indeed outstrip the market's ability to absorb its own technological progress. However, next-generation clouding computing is likely to find an effective security solution, but be vulnerable to competitive forces that can craft hybrid public/private clouds and develop open standards. From Figure 10, it is apparent that cloud computing fits the disruptive technology model.

Cloud computing has a compelling price and return-on-investment model in relation to pay-up-front software licenses and on-premise data centers which is summarized in Table 7.[86]

| Factor | On-Premise | Cloud Computing |
|---|---|---|
| **Expenditure Type** | Capital expenditure (capex)<br>Operating expense (opex) | Operating expense (opex) |
| **Cash Flow** | Servers and software are purchased upfront | Payments are made as the service is provided |
| **Financial Risk** | Entire financial risk is taken upgront with uncertain return. | Financial risk is taken monthly and is matched to return. |
| **Income Statement** | Maintenance and depreciated capital expense | Maintenance expense only |
| **Balance Sheet** | Software and hardware are carried as a long-term capital asset | Nothing appears on the balance sheet |

Table 7: The Financial Benefits of Cloud Computing and Cloud-Based Services: (Source: Forrester Research, Inc.)

[86] Ted Schadler, Matthew Brown, Michael A. Doyle, Frank E. Gillett, Sara Burnes, "Talking To Your CFO About Cloud Computing", *Forrester Research, Inc.* (October 29, 2008): 4.

As shown in Figure 11, license-based and on-premise data center solutions require an immediate disbursement of cash from the enterprise.[87] The return on investment is subsequent to the cash outlay. Here, the customer has entered a costly capital expense (capex) model, requiring the outlay of cash for software and service licenses, as well as equipment for its own data centers. The illustration in Figure 11 is a notional model only; the revenue and return are depicted at an arbitrary time horizon subsequent to the firm's initial investment.

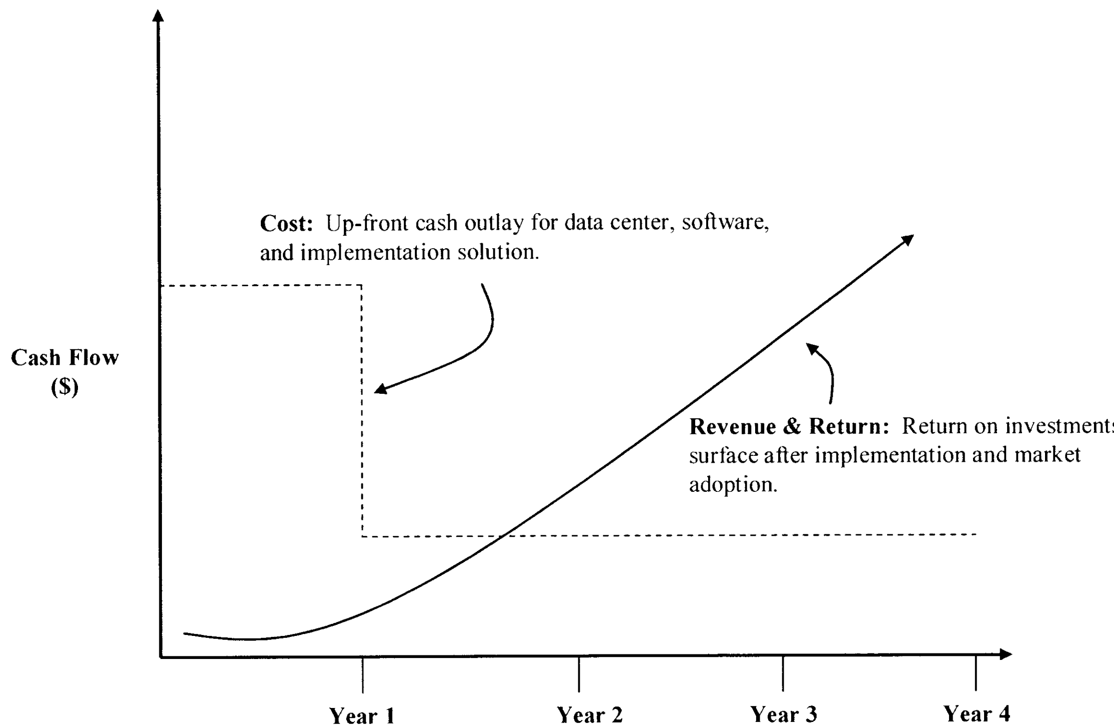


Figure 11: Cash Flow for License-Driven, On-Premise Data Centers

In contrast to software licenses and on-premise data centers which support a capex model, cloud computing offers a more customer-friendly operating expense (opex) model. In cloud computing, the customer pays for services as they are used, in a utility-based fashion. This includes the use of software and services, as well as the use of data centers. In this model there is no immediate disbursement of cash on the part of the customer, but rather a gradual cash outlay for cloud computing services which grows and

[87] Ted Schadler, Matthew Brown, Michael Doyle, Frank Gillett, Sara Burnes., "Talk To Your CFO About Cloud Computing", *Forrester Research, Inc.*, (October 29, 2008): 1-9.

contracts as the customer's business grows and contracts. This behavior is shown in Figure 12.[88] In this figure, the customer's return initially lags the investment cost. However, as the business grows over time, the revenue generated exceeds the investment. In a similar fashion to the license-based model, the cloud computing cash flow model is notional. The magnitude and time dependency of the revenue and return are conditional on the types of investments made.

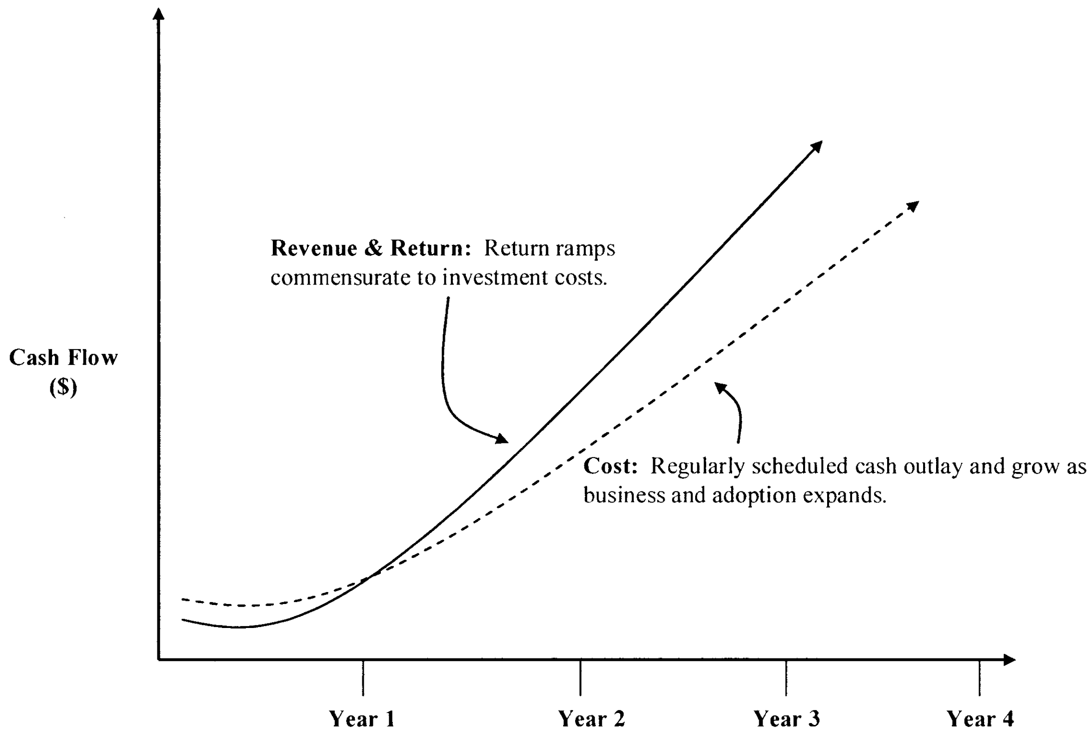


Figure 12: Cash Flow for Cloud Computing Data Centers

From Figure 11 and Figure 12, the cloud computing provider must make attractive returns at prices lower than the incumbent license-based, on-premise data center technology. The cloud computing provider can do this in two ways. The first way is to take advantage of economies of scale in terms of a shared, scalable, and virtualized computing environment where costs are defrayed among a large subscriber base. Forrester Research, Inc. cites a venture capitalist that used cloud computing to circumvent the need to buy servers, getting the "startup to market in 18 months for $5

[88] Schadler, ., "Talk To Your CFO About Cloud Computing", 5.

million rather than in three years for $15 million.[89] The second way is to lower initial set-up costs but negotiate higher monthly usage charges and longer terms.[90] Nonetheless, cloud computing appeals to the low end of the market, at initially lower performance levels, which is emblematic of a disruptive technology.

While disruptive technologies in cloud computing appeal to consumers at the low end of the market, its origins are found at the high end of the market. In the case of highly advanced license-based, on-premise solutions, even the high end of the market reaches a saturation point on its ability to absorb new software releases, new patches, and scale adequately for changing demand. This is consistent with the formalism of Christensen's observation on disruptive technologies. Eventually, the incumbent technology will reach a performance level which outstrips the market's ability to absorb that technology. As shown in the Porter analysis in Figure 6, *New Entrants* and *Low-Cost Substitutes* in cloud computing provide alternative data center solutions at attractive price points to take over the incumbent market, tier by tier.

The cloud computing ecosystem can support either a single, vertically-integrated firm or a host of modular components. The firms that have the most compelling, vertically-integrated solutions are HP, IBM, and Amazon. Modular firms include: Citrix, which specializes in virtualization and optimization; Telx, which specializes co-location facilities; and 3Tera, which specializes in open standards and virtual data centers.

Another important characteristic that defines cloud computing as a disruptive technology is disaster recovery (DR). Enterprises cannot afford downtime, whether it is in a cloud or non-cloud environment. The observed behavior is an inverse, linear relationship between time-to-recovery (TTR) and cost. Shorter time-to-recovery metrics are accompanied by higher costs. As shown in Figure 13, inexpensive tape recovery

[89] Schadler, ., "Talk To Your CFO About Cloud Computing", 2.

[90] Schadler, ., "Talk To Your CFO About Cloud Computing", 7.

mechanisms are accompanied by higher TTRs, whereas more expensive synchronous and asynchronous replication mechanisms yield lower TTRs.[91]

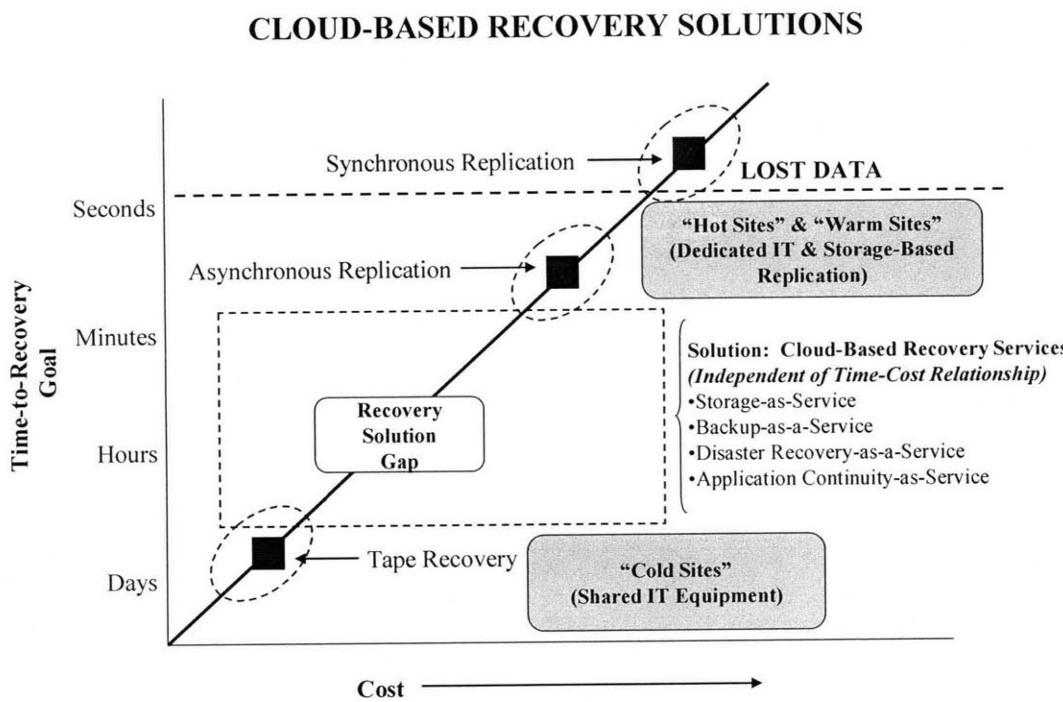


Figure 13: Cloud-Based Disaster Recovery Solutions

In the event of a disaster declaration, cloud-based recovery mechanisms can replicate the enterprise's servers as virtual servers hosted in the 3rd-party provider's environment. Recovery is complete within hours. But most importantly, the cost is minimal and independent of TTR, as a consequence of the provider's virtualized environment. This is a crucial element of a disruptive technology—while performance is initially lower than the incumbent solution, the low price point enables individuals at the low end of the market to obtain DR services that were once financially prohibitive.

### *Dedicated Hosting*

Third-party hosting has long provided a secure environment for the enterprise and SMB. In a dedicated hosting environment, the 3rd-party provider furnishes the servers, appliances, and firewalls per the customer's requirements. The 3rd-party provider

[91] Stephanie Balaouras, Simon Yates, James Staten, and Christian Kane, "How The Cloud Will Transform Disaster Recovery Services", *Forrester Research, Inc.* July, 24, 2009, 1-12.

manages this infrastructure from its own location. The equipment is *dedicated* to each customer, and kept in a separate location from another customer's equipment. The responsibilities assigned to enterprise and to the 3rd party provider are shown in Table 8.[92]

| Dedicated Hosting | Provided by Enterprise | Provided by 3rd-Party Provider |
|---|---|---|
| **Facilities**<br>Building space, Power, Heating/Cooling, Physical Security | | ✔ |
| **Network Capabilities**<br>Bandwidth | | ✔ |
| **Equipment (HW)**<br>Servers/Switches | | ✔ |
| **Physical or Virtual Appliances**<br>Security Capability/Traffic Mgmt | | ✔ |
| **Application Performance Management**<br>End-to-End Performance Mgmt | ✔ | *Disruptive mgmt opportunity* |

Table 8: Dedicated Hosting Center Responsibilities: Enterprise & 3rd-Party

From Table 8, the preponderance of responsibilities resides with the 3rd-party provider. The enterprise does not control any aspect of the service, but provides instructions to the provider. The enterprise may choose to manage the provider and ensure that performance metrics are achieved through a Service Level Agreement (SLA).

Dedicated hosting is far less scalable that cloud computing, where computing resources are contracted by the enterprise. Servers are custom-configured for the needs of the enterprise. If the needs of the enterprise change in terms of its scale, contracts will need to be renegotiated, adding time and expense to the enterprise. Dedicated hosting can be more costly than the public cloud solution. The enterprise chooses from a list equipment and services which are provided by a 3rd-party. The enterprise ensures that performance metrics are met through mutually agreed upon SLAs. Dedicated hosting

[92] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 17.

poses one of the most secure environments. Equipment and data are kept separate from those of other customers, and there is minimal risk of contamination.

***Disruptive Elements of Dedicated Hosting:*** Virtually all elements of dedicated hosting are provided by a 3rd-party. Dedicated hosting centers appeal to niche customers, who want a secure environment at a low to moderate cost. In many cases, dedicated hosting is considered a lower-touch, lower-cost option than cloud computing or managed hosting.[93] Customers will have to sacrifice scalability. The seeds of disruption are evident in dedicated hosting. A disruptive technology can emerge from dedicated hosting to move more in the direction of cloud computing. Cloud computing would then have to undergo subsequent refinement to appeal to the needs of customers seeking a more secure solution. Dedicated hosting providers can earn an excellent return as a result of the provider's ability to defray real estate and operating costs among numerous customers.

The ecosystem of dedicated hosting resides almost exclusively within a vertically-integrated 3rd party provider. This provider manages virtually all aspects of this service where the enterprise plays a role in generating requirements and ensuring that SLAs are enforced. Many providers of cloud computing and managed hosting also provide services in dedicated hosting, which include AT&T, IBM, Savvis, Verizon Business, and Rackspace.

***Managed Hosting***

Managed hosting by a 3rd-party provider can rival full-scale outsourcing. Similar to dedicated hosting, the 3rd-party provider furnishes the servers, firewalls, and associated equipment. However, in managed hosting, the 3rd-party provider fully manages this infrastructure from its own location, including end-to-end application delivery and performance, network management, and security.[94]

In managed hosting, the enterprise enters into a partnership with the 3rd-party provider. The enterprise sets requirements and modifies the hosting environment to

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[93] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 18.

[94] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 18.

ensure that end-to-end performance is achieved per SLAs. The enterprise has limited control of the hosting center's operation, as all management responsibilities are handed over to the 3rd-party provider. A strong partnership between the enterprise and 3rd-party provider is the best policy for change management. The division of enterprise and 3rd-party responsibilities is shown in Table 9.[95]

| Managed Hosting | Provided by Enterprise | Provided by 3rd-Party Provider |
|---|---|---|
| **Facilities**<br>Building space, Power, Heating/Cooling, Physical Security | | ✔ |
| **Network Capabilities**<br>Bandwidth | | ✔ |
| **Equipment (HW)**<br>Servers/Switches | | ✔ |
| **Physical or Virtual Appliances**<br>Security Capability/Traffic Mgmt | ✔ | ✔ |
| **Application Performance Management**<br>End-to-End Performance Mgmt | ✔ | ✔ |

*Shared enterprise and 3rd-party solution adds flexibility but adds complexity and cost*

Table 9: Managed Hosting Center Responsibilities: Enterprise & 3rd-Party

Costs can be prohibitive for managed hosting, where client engagements often exceed $1 million per year.[96] Enterprises can choose from a menu of management options. Some of the services, such as security and end-to-end performance management are shared between the enterprise and the 3rd-party provider. However, this adds to complexity and cost. Managed hosting is not particularly scalable as services and resources are dedicated to each enterprise by contractual agreement using customized configurations. The 3rd-party provider is amenable to make changes initiated by the enterprise to respond to usage spikes or out-of-contract needs. However, these changes come at a high price. Security in managed hosting environments is considered among the

[95] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 19.

[96] Stadtmueller, "Buildout, Co-Lo, Hosting, or Cloud: Competing for Enterprises Data Center Dollars", 19

elite data center solutions. Yet, managed hosting resides in a shared environment with other enterprises. The client enterprise must work with the 3rd-party managed hosting provider to ensure that appropriate levels of security are implemented for each application and service. Providers in this space include HP, IBM, Savvis, Rackspace, Verizon Business, and AT&T.

***Disruptive Elements of Managed Hosting:*** Managed hosting is a disruptive technology to licensed-based and on-premise data centers. While the costs are similar, managed hosting provides improved scalability. For managed hosting to become a more effective disruptive technology, it should join dedicated hosting, in its journey to become more like cloud computing to appeal to the low end of the market. However, managed hosting does indeed appeal to a niche market of enterprises and SMBs that value scalability and managed services, albeit at a very high price.

The ecosystem of managed hosting is self-contained within fully integrated, end-to-end firms. After all, the business model behind managed hosting is to provide an end-to-end managed service to the enterprise. As time progresses, managed hosting will enter into the age of modularization as the technology matures.[97]

**Summary: Cloud Computing Disruptive Technology**

Cloud computing—along with many other solutions in the continuum of data center options—represents an emerging disruptive technology threat to license-based computing and on-premise data centers. Cloud computing enables less-skilled and/or less-wealthy individuals to secure the same computing resources as their more-skilled and more-wealthy counterparts could formerly obtain. In addition, cloud computing enables the low end of the market to gain traction as a result of utility-based pricing. Cloud computing firms also earn attractive returns at lower prices than the incumbents, as a result of economies of scale, aided by virtualization technology and the sharing of resources among a broad customer base.

[97] Christensen, Raynor, Verlinden, "Skate to Where the Money Will Be", 72-81.

Cloud computing also has one of the most compelling ecosystems, which is needed for a disruptive technology to take hold. Evidence has shown that ecosystems can flourish as single, highly-integrated firms such as Amazon, HP, and IBM—or as modular firms such as Citrix, Telx, and Akamai.

In conclusion, the five data centers discussed thus far have the following relative performance measures in terms of "economies of skill" and "economies of scale" as shown in Figure 14.[98]

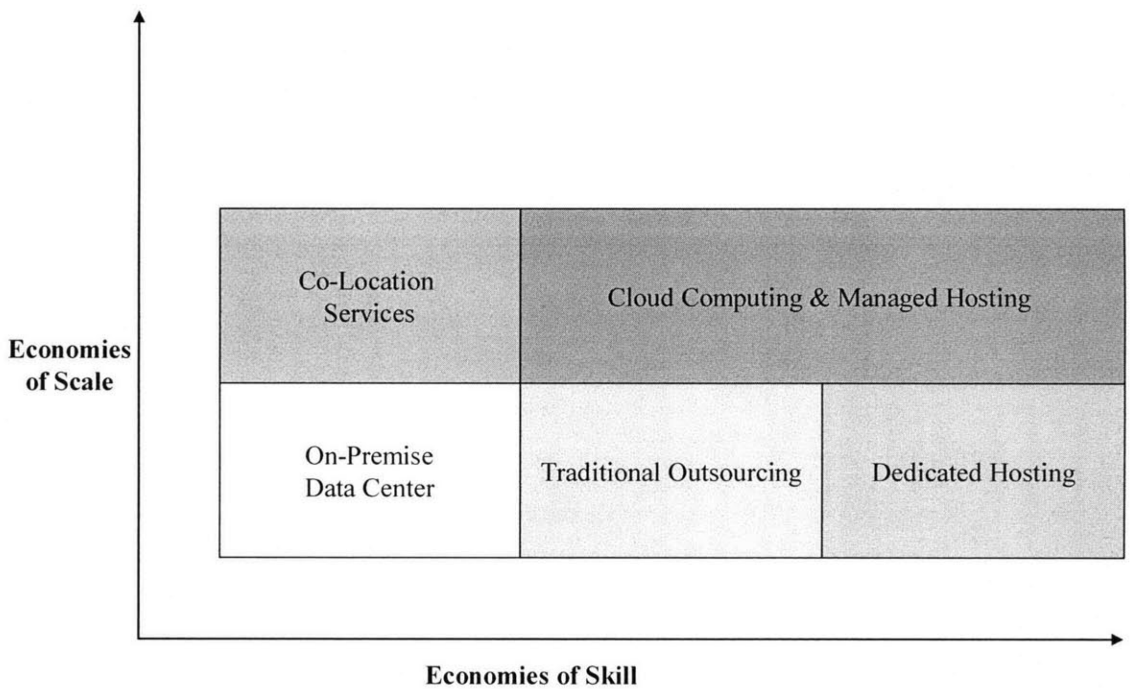


Figure 14: Summary of Data Center Economies of Skill and Economies and Scale

On-premise data centers have the lowest economies of skill and economies of scale but are offered at the highest price point. On-premise data centers are static solutions with fixed computing resources and capabilities. Traditional outsourcing and dedicated hosting have the same level of economies of scale, but have greater economies of skill than on-premise data centers due to the higher level of customer intimacy and attention given to the enterprise at a hosted site. Co-location facilities have the same economies of

[98] Staten, Schadler, Rymer, Wang, "Q&A: By 2011, CIOs Must Answer The Question, "Why Not Run In The Cloud?", 3.

skill as the on-premise data center, owing to enterprise-controlled hardware and management. However, co-location services offer the capability to expand the customer's computing footprint, provided the co-location facility has sufficient space. Also, most co-location facilities provide networking services, thereby reducing latency and increasing performance. Cloud computing and managed hosting have the highest degree of economies of skill and economies of scale due to the levels of customer service and the capability to scale to the needs of the customer—though by different means. The public cloud is the most convenient, flexible, and auto-scalable data center option. Managed hosting can achieve similar levels of scalability and service by customizing its data center to meet the needs of the customer.

***Next-Generation Models***

Next-generation disruptive cloud computing needs to be evaluated as the public cloud takes hold as the dominant computing paradigm. The public cloud offers scalability, virtualization, flexibility, and utility pricing. However, public clouds are not particularly secure and lack interoperability between independent clouds and vendors. These vulnerabilities give rise to next-generation disruptive cloud computing technologies. These disruptive threats are in the form of virtual private clouds, hybrid clouds, ultra-modular computing, and open standards that make vendor solutions interoperable. This topic is discussed next.

# CHAPTER IV: NEXT-GENERATION CLOUD COMPUTING
*(New Disruptive Technology Opportunities)*

## Next-Generation Cloud Computing: Beyond the Public Cloud

The public cloud has been presented as a viable disruptive technology, which has transformed the conventional pay-as-you-go software and services licensing model, as a consequence of its shared, scalable, virtual, and utility-based pricing capabilities. Third-party providers create and distribute these computing resources to customers as needed, defraying its fixed data center costs among its subscriber base. The public cloud has shown to enable many individuals, especially at the low end of the market, to secure data computing services that only individuals at the high end of the market could previously obtain. The public cloud has already shown to possess formidable ecosystems. Ecosystems are in the form of single end-to-end firms and modular sub-system entities. Both types of ecosystems foster highly integrated and interdependent characteristics, which are requirements for a disruptive technology to gain traction in the marketplace.

While today's public cloud enjoys seemingly endless accolades, it does have serious drawbacks. The public cloud is not yet deemed a sufficiently secure environment for enterprises dealing with sensitive data subject to rigorous compliance standards. The public cloud is also detached from enterprise resources and control—adding fear, uncertainty, and doubt to enterprise IT departments. Furthermore, the public cloud is not interoperable between private clouds and other public clouds. Open standards and management between separate vendor's clouds are conspicuously lacking in today's public cloud architecture.

Cloud computing market drivers and market restraints have been presented (Table 1 and Table 2 in Chapter I). The market drivers stimulated demand for the inception of the public cloud. The market restraints posed barriers to entry. However, in the formulation of next-generation cloud computing, these same market restraints are particularly insightful. These market restraints for the inception of cloud computing are market motivators for next-generation cloud computing.

The market motivators for next-generation cloud computing are reconstructed in Table 10 below along with the likelihood that these market motivators will have viable solutions within the next one to five years.[99]

*Increase in Market Impact* ↑

| MARKET MOTIVATION (Next-Generation Cloud Computing) [derived from Table 2] | 1 YEAR | 2-3 YEARS | 4-5 YEARS | Likelihood Of Solution |
|---|---|---|---|---|
| Increase in actual and perceived security risks from shared cloud computing environments | HIGH | HIGH | HIGH | Very Likely |
| Increase in regulatory and industry compliance risks associated with cloud/shared server environments | HIGH | HIGH | MEDIUM | Likely |
| Increased sensitivity in IT culture to hand control of data center to 3rd-party provider | HIGH | HIGH | MEDIUM | Unlikely |
| Increased "vendor lock-in": Lack of open platform standards inhibits management across providers | HIGH | HIGH | MEDIUM | Likely |
| Dimished support for hybrid (private cloud/public cloud) environment | MEDIUM | HIGH | MEDIUM | Very Likely |
| Increased contention for shared server resources dimish application performance | MEDIUM | MEDIUM | HIGH | Likely |
| Increased ease of entry into cloud adds risk to virtual machine (VM) proliferation and "renegade apps" | LOW | MEDIUM | MEDIUM | Likely |

Table 10: Next Generation Cloud Computing Market Motivators

**Security Risks:** Security and data protection are top concerns for enterprises and SMBs considering the use of wholesale cloud computing. These security concerns are expected to become more prevalent in next-generation cloud computing. As a consequence of the shared and virtualized environment in cloud computing, the customer does not know where its data resides. This is problematic for sensitive data such as financial and medical records, as well as data that require a high degree of regulatory compliance. Third-party cloud computing providers are expected to protect enterprises and SMBs from data corruption and Internet-borne attacks.

A burgeoning industry in cloud computing will be security information and event management (SIEM).[100] SIEM services are provided by a 3rd-party, which collects and

[99] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 5.

monitors events and data logs from routers, switches, along with other active and passive devices. Correlations are established between events and actual threats. Once a true threat is identified, the 3rd-party SIEM provider can take action to mitigate that threat. SIEM is currently used in many enterprises with on-premises equipment. A logical implementation of SIEM is to integrate this threat detection and protection technology in software and services cloud environments. SIEM is already being deployed in the cloud as a security information management tool for many enterprises and SMBs.

Many SMBs are content with the security capabilities of the major cloud computing providers. After all, SMBs themselves have either marginal access to security resources or none at all due to the attendant costs and resources. However, SMBs are likely to become more discerning on their security solutions in the future, especially if they expect to gain a more sophisticated client base, beyond the consumer market.

**Regulatory Compliance:** Along the same vein of security information management, enterprises and SMBs are concerned with adhering to governmental compliance requirements.[101] As previously mentioned, these regulatory requirements are embodied in U.S. legislation including SOX, HIPAA, and PCI. Other governments have their own platforms of regulatory compliance requirements, which often include a disclosure of where sensitive data resides. In fact, many countries prohibit the transfer of data on network services or at the very least, require that such data reside in servers within the country itself. In addition to governmental compliance laws, private firms have their own compliance requirements to which cloud computing must adhere. SIEM providers will play an instrumental role in next-generation cloud computing to mitigate the risks of compliance violations. SIEM providers have the ability to manage and trace data logs, but thus far no cloud provider has been able to develop a complete end-to-end compliance solution on their own. It would behoove 3rd-party cloud computing providers to partner with SIEM providers such as ArcSight, Computer Associates, and others to develop a competitive advantage in security and regulatory compliance. This

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[100] Thomas Raschke, "The Forrester Wave: Managed Security Services, Q4 2007" *Forrester Research, Inc.* , October 4, 2007, 1-13.

[101] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 14.

will not only meet the needs of regulatory agencies, but also increase consumer confidence so as to boost commerce in many industries and countries where cloud computing was either marginalized or totally restricted.

**Enterprise IT Control:** Corporate IT departments desire to exert a measured degree of control on applications and services, even if they are hosted in the cloud. That is not expected to change in next-generation cloud computing. IT departments expect to manage, monitor, and maintain software and services deployments. However, it is unlikely that these IT departments will have a larger role in next-generation cloud computing. Third-party providers of cloud computing will likely do a better job in providing their own brand of IT services and application management. However, conventional enterprise IT departments will play a more diminished role in the cloud and be relegated to partnerships with dedicated and managed hosting providers.

**Vendor Lock-In:** There is an adage in today's cloud computing environment which can be paraphrased as follows, "When someone speaks of the cloud, they mean *their* cloud". Cloud computing is considered a ubiquitous software and services platform, but clouds are independently owned by the vendor. IBM's cloud is separate from Amazon's cloud. Interoperability is not a particular strength in today's cloud computing environment—each cloud is built on a different development platform (PaaS). Vendor-agnostic solutions are not readily available today even though IBM is striving to build interoperable capabilities with APIs. Interoperability hinges on the ability to manage applications independent of the server infrastructure and/or 3rd-party provider, thus creating a virtual data center. This solution may be as many as five years away. Modular firms such as Citrix and a 3Tera, along with fully-integrated firms such as Savvis and IBM, are pioneers in the development open standards, geared at the creation of "one cloud".[102] The intent is to have interoperability among multiple, globally dispersed clouds. In conclusion, those firms are that successful in opening up the development platform will secure competitive advantage.

[102] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 16

**Hybrid Solutions:** Most analysts agree that hybrid clouds are a significant driving force in next-generation cloud computing.[103] Hybrid clouds bring together the best of both worlds in private clouds and public clouds. Hybrid clouds enable private data centers to access the scalable and virtualized capabilities of the public cloud. This enables functions such as "bursting"—allowing the private data center to secure more storage and computing resources at will. The creation of hybrid environments is easier said than done. Open standards along with the development new hypervisor architecture will ultimately enable the seamless communication between different types of clouds hosted among different vendors. It is likely and necessary that significant strides will be made in this arena within the next five years.

**VM (Virtual Machine) Proliferation:** As identity theft has become a major problem owing to the relative ease of information accessibility—the proliferation of spurious, renegade applications and charges will likely surface due to virtualization.[104] Virtual applications are run on virtual machines, where traceability in the data center is difficult. This is not a significant deterrent, but advances will have to be made to control "VM sprawl" in the next-generation of cloud computing.

**Application Performance:** Application performance in a cloud environment may suffer for two important reasons.[105] The first reason is that a shared, public cloud is fraught with resource contention. When an application shares CPU and memory resources with other applications, its performance is likely to suffer when those resources are not available or lack sufficient capacity. The second reason is that today's virtualization and hypervisor technologies add latency to application performance. It is likely that virtualization improvement in an IaaS environment is two to five years away.

As an aside, enterprises are more likely to deploy low-risk, "stateless" applications in the cloud, which don't have to retain immediate information to

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[103] James Staten, "Which Cloud Computing Platform Is Right For You?". *Forrester Research, Inc.* (April 13, 2009): 1-9.

[104] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 15.

[105] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 15.

function.[106] Web applications, email, backup/recovery, information services, and collaboration applications are good candidates for the cloud. On the other side, applications which are sensitive or retain "state" are not the best candidates for the current cloud but are better suited for next-generation architectural improvements.[107] These applications require the retention of "state" in the form of required information about prior operations (user session information, intermediate data transactions, etc.). These types of applications do not scale as easily on cloud architectures as "stateless" applications do. Applications which require the retention of "state" include user-interface portals and ERP (Enterprise Resource Planning) software.

In summary, the above market motivators, derived from the market restraints from the initial implementation of the public cloud, are expected to undergo significant improvement in next-generation cloud computing by end of 2011.[108] However, it is likely that the majority of the enterprise's core applications, which generate and manage its revenue stream, will remain in dedicated, on-premise data centers at least through 2013.[109] These factors aid in defining next-generation cloud computing in a disruptive context. Having secured new markets at compelling price points, next-generation cloud computing will be characterized by an improved performance trajectory meeting and perhaps exceeding market demand.

**Next-Generation Cloud Computing: Competitive Landscape**

Leaders among 3rd-party cloud computing providers have expertise in providing a fully-integrated, end-to-end solution. Companies such as Amazon and IBM have proficiency in IaaS, PaaS, and SaaS. These firms have built self-contained ecosystems providing data centers, development platforms, and software delivery mechanisms within the walls of their organizations. They have acquired core competency in scalability,

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[106] Staten, Schadler, Rymer, Wang, "Q&A: By 2011, CIOs Must Answer The Question, "Why Not Run In The Cloud, 7.

[107] Staten, Schadler, Rymer, Wang, "Q&A: By 2011, CIOs Must Answer The Question, "Why Not Run In The Cloud, 7.

[108] Stadtmueller, , "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 15.

[109] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 16.

virtualization, and utility pricing. Hewlett-Packard is also poised to become a formidable player as an end-to-provider with the acquisition of EDS (data centers and services) in 2008 and 3Com (networking) in 2009. Coupled with HP's own core competency in workstations, servers, storage, and IO, HP now has a fully-integrated vertical solution. The competition among these end-to-end solution providers is shown in Porter's five competitive forces at the center of Figure 15 under *Current Landscape*.[110]

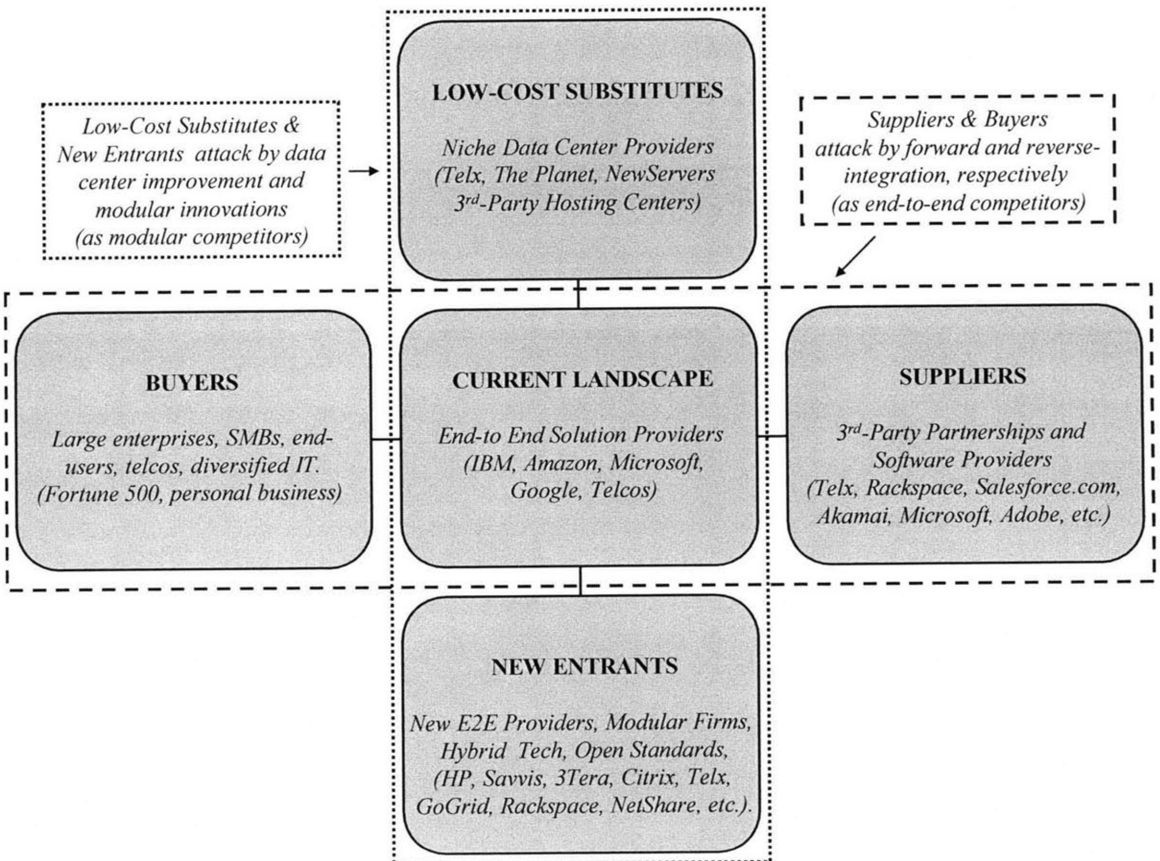


Figure 15: Porter's Five Competitive Forces for Next-Generation Cloud Computing

The threat of *Suppliers* consists of 3rd-party data centers, software applications, SaaS, and Internet delivery providers into the current competitive end-to-end landscape. Firms such as Akamai improve the efficiency of the Internet by providing application acceleration and optimization services for both web services and IP (Internet Protocol) applications.[111] Akamai offers its own cloud-based solutions, but the firm primarily

[110] Porter, *Competitive Advantage*, 4-50.

[111] Stadtmueller, ", "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 21.

contributes to the expansion of the cloud by enabling the seamless delivery of applications over the Internet. Firms such as Telx are both *Suppliers* and *New Entrants*, which furnish co-location facilities with access to network carriers. Finally, the application providers including Microsoft, Adobe, and Salesforce.com, etc., furnish applications and delivery systems to the end-to-end competitors themselves. All agents in this supplier space can *forward-integrate* into the current competitive landscape. Some firms, including Rackspace, a leader in managed hosting services, have done so to a large extent. Rackspace's cloud serves the enterprise with a complement of computing, storage, web hosting, and content distribution offers.[112]

The threat of *Buyers* includes large enterprises, SMBs, and small end-user customers that consume the public cloud. They include many industries, most notably telcos, distributed IT, and diversified computer systems firms. These firms can and have *reverse-integrated* into the end-to-end competitive landscape. Telcos such as AT&T and Verizon Business are buyers of the public cloud but have reverse-integrated to become end-to-end providers. AT&T's Synaptic Hosting and Synaptic Storage use its network to dynamically activate and deliver applications and server capacity as needed.[113] AT&T's solution is more of an expansion of its managed hosting business rather than full-scale cloud computing. Verizon Business's Computing-as-a-Service (CaaS) solution offers shared and dedicated environments. This is an end-to-end solution where customers can provision and manage their applications or have Verizon Business provide these services. Verizon Business has one of the few cloud products with the option for some degree of enterprise control. IBM, a distributed IT and diversified computer systems company, now has reverse-integrated into a complete end-to-end solution provider in the cloud. IBM has a complete IaaS, PaaS, and SaaS offering. The firm relies on ISVs (Independent Software Vendor) for the expansion of its cloud services. Also, IBM offers PaaS and IaaS development tools to enterprises and data centers to build their own cloud

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[112] Stadtmueller, Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 17.

[113] Stadtmueller, , "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 19.

environments using the IBM "Blue Cloud".[114] As can be observed in this section of *Buyers*, the potential for reverse-integration into the space of complete end-to-end cloud solution providers has been demonstrated.

*New Entrants* largely consist of new and emerging end-to-end and modular solution providers in the virtualization and data center space. Hewlett-Packard, with its recent acquisitions of EDS and 3Com in the services and networking domains, finds few barriers to entry as an end-to-end cloud provider. Savvis is another emerging end-to-end hosting and cloud provider, but has differentiated itself by allowing the enterprise a significant level of control. Savvis is a pioneer in the development of virtual private data centers that link clouds and allow the enterprise to build and deploy virtualized data centers with multi-tiered levels of Quality of Service (QoS).[115]

Citrix is a new entrant focusing on hypervisor virtualization products to add higher performance, scalability, and even security to the cloud. The firm champions open standards and hybrid clouds to bridge private data centers and the public cloud. Finally, 3Tera is another new entrant committed open standards with the goal of facilitating enterprises to migrate applications among multiple clouds and multiple vendors. GoGrid is another entrant in the hybrid cloud domain which bridges the public cloud with more security and compliance-rich, dedicated data centers. Hybrid clouds constructed as such, appeal to enterprises with sensitive applications, which benefit from the scalability of public clouds and the security of private data centers. New entrants, including Citrix, 3Tera, and GoGrid form the backbone of a modularized ecosystem, characterizing next-generation cloud computing as a disruptive technology.

*Low-Cost Substitutes* continue to emerge as threats to the end-to-end solution leaders in the public cloud. Firms including Telx, NewServers, and The Planet provide effective and low-cost solutions for next-generation cloud computing. Telx serves a growing number of 3rd-party cloud providers and leverages its core competency in grid

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[114] Stadtmueller, , "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 20.

[115] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 19.

architecture coupled with co-location and interconnect facilities. NewServers is a non-virtualized cloud provider. This firm offers all the benefits of low utility pricing and scalability in a fully dedicated environment. These *Low-Cost Substitutes*, similar to the *New Entrants*, offer modularized options at a competitive price point with the incumbent public cloud leaders.

In summary, two key findings are revealed in the next-generation cloud computing through the analysis of Porter's five competitive forces. The first finding is that *Buyers* and *Suppliers* attack the incumbent leaders with viable end-to-end solution ecosystems. The second finding is that *New Entrants* and *Low-Cost Substitutes* attack the incumbent leaders as modularized ecosystem components. Thus a key criterion in defining next-generation cloud computing as a disruptive technology is satisfied through these end-to-end and modularized alternative ecosystems in the Porter analysis. Further discussion of ecosystems as a criterion for disruptive technologies will be presently later in this analysis.

**Next Generation Cloud Computing: Market Criteria for Disruptive Technology**

Next-generation cloud computing focuses on improving the public cloud by addressing its deficiencies including: security, enterprise control, and open standards which connect different types of clouds among different vendors. Next-generation cloud computing is indeed a disruptive technology as it successfully addresses both market criteria set forth by Christensen.[116] Figure 16 illustrates the next-generation disruptive technology model in relation to the current public cloud and market demands.

First, next-generation cloud computing allows less-skilled and/or less-wealthy customers to obtain the same goods and services that only the more-skilled and more-wealthy intermediaries could previously obtain. Prior to the advent of hybrid clouds, private data centers could not be linked with cost-competitive public clouds. Virtualization and the movement to adopt open standards have facilitated next-generation cloud computing to meet this criterion.

[116] Christensen, "The Rules of Innovation", 33-38.

Second, next-generation cloud computing facilitates the low end of the market, and does so at attractive returns for the emerging disruptive technology entrants. The low end of the market was formerly only able to use low-cost public clouds for applications which did not require high levels of security. The high end of the market could afford on-premise data centers and dedicated private clouds at much higher costs. With the introduction of hybrid clouds using virtualization, open standards, and in particular, virtual private clouds, the low end of the market has a more ubiquitous cloud computing solution. Furthermore, with the hybrid cloud linkage among different types of clouds, next-generation cloud computing providers are able to obtain attractive returns.

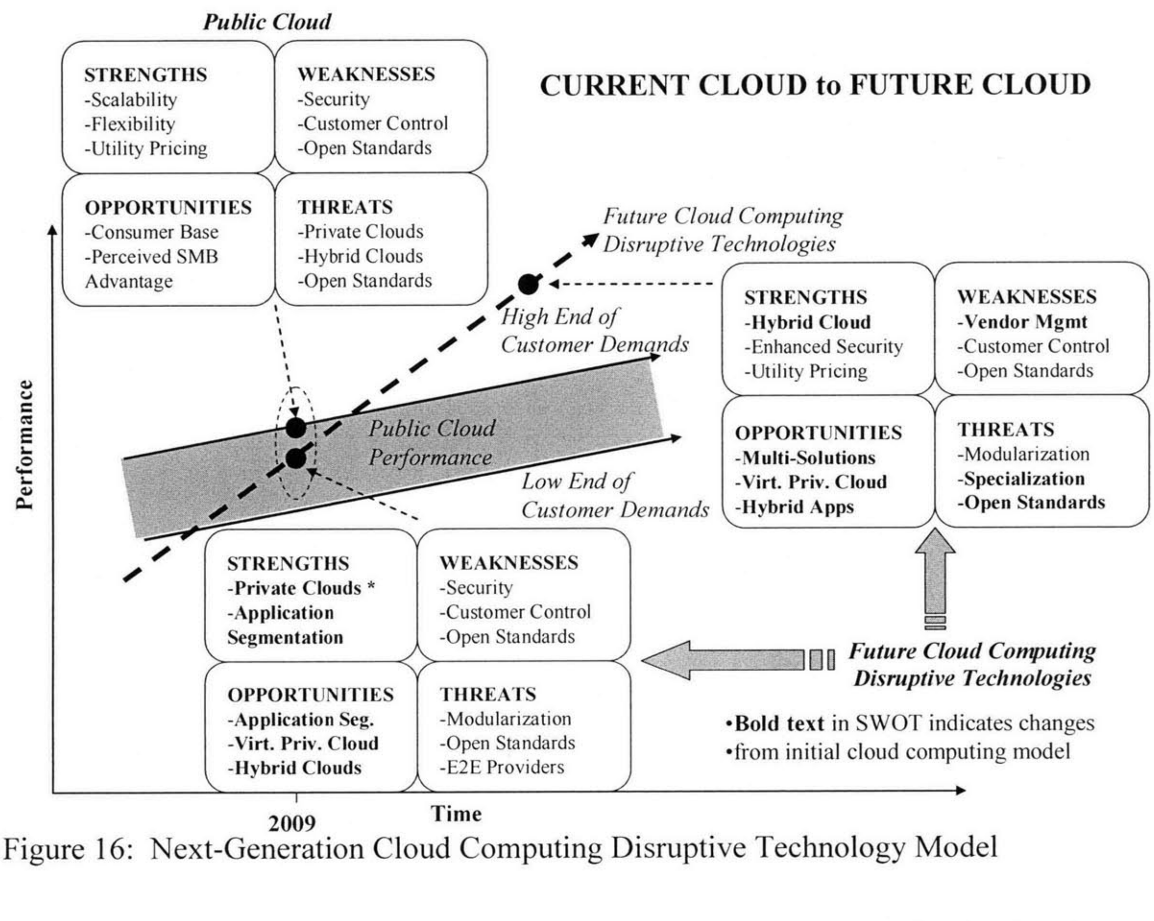

Figure 16: Next-Generation Cloud Computing Disruptive Technology Model

The disruptive technology model in Figure 16 depicts the public cloud and next-generation cloud computing advances. The market's ability to absorb the performance of the public cloud is once again shown in the shaded region. The public cloud's current performance is arbitrarily shown at the top end of the customer demand profile. Increases in the performance of the public cloud beyond the market's ability to assimilate that technology will create a fertile environment for the next generation of cloud computing. The public cloud, which replaces conventional pay-up-front software licenses and on-premise solutions, has a performance dashboard represented by the SWOT diagram in Figure 16. The public cloud has strengths in scalability, multi-tenant virtualized infrastructure, and low-cost utility pricing. The public cloud is able to deliver superior economies of scale to its clients, as costs are defrayed among the cloud provider's client base. The multi-tenant infrastructure is homogenous in nature—all customers have the same resources. While these resources boast ease and convenience, they are also plagued by weaknesses in the form of limited configuration, limited security protection, and very few customizable options by the enterprise. The public cloud has opportunities to exploit a customer base with standard, stateless, and consumer-oriented applications. To that end, the public cloud has drawn large enterprises with security and compliance-agnostic applications and SMBs with only a consumer-oriented emphasis.[117] The largest threat for the public cloud is an ecosystem of modularized solutions. As the performance of the public cloud becomes good enough, modularized solutions take hold at lower initial price points and performance, but with the promise of a performance trajectory to meet the market demand. These modularized solutions include improvements in 1) open standards to make clouds more accessible, and 2) hybrid clouds to broaden functionality between disparate clouds. Of course, there is always the threat of fully-integrated single end-to-end cloud providers that own the ecosystem and effectively execute the complete solution. As discussed previously, Hewlett-Packard is poised as the dominant end-to-end solution provider.

The emergent next-generation cloud computing technology is shown in the SWOT diagram below that of the public cloud in Figure 16. Items in bold type in the SWOT diagram are differentiated from the SWOT(s) in Figure 10 from Chapter III. The strengths of next-generation cloud computing include private clouds and application segmentation. Private clouds can reside on the customer's premises or hosted by a third party as shown by Figure 7 in Chapter III. Virtualized private clouds are dedicated to a specific customer using scalable, virtualized technology. Virtualized private clouds are

[117] Frank E. Gillett, "Conventional Wisdom Is Wrong About Cloud IaaS", 1-13

the technology driving force behind hybrid clouds and the linkage between disparate clouds. Weaknesses include security, enterprise control, and open standards. However, significant gains have already been made in security and enterprise control through hybrid clouds and innovations in virtualization. Opportunities in next-generation cloud computing focus on what this technology can now enable—communication between separate cloud environments using hybrid clouds, where virtualized private clouds are the technology driving force. As a consequence, many different types of applications will enter the fray, meeting a wide variety of customer needs. The threats of next-generation cloud computing include modularization, end-to-end providers, and open standards. Both end-to-end solutions and modularization reflect threats impacting the existing ecosystem(s). Open standards are a driving force for "one cloud, one Internet".[118]

As cloud computing continues to evolve, its performance trajectory will increase over time. It is possible that its performance trajectory will outstrip even the highest demands of the market, at which time a new disruptive technology will emerge at more competitive price points. Looking into the cloud computing crystal ball, no one knows. However, if cloud computing tracks the expected performance trajectory, one can expect the following SWOT of the future. Strengths are likely to be marked by enhanced security, fully-functioning hybrid clouds, and more competitive utility pricing. Security is the top concern of the public cloud and it must be remedied to craft an enterprise-worthy solution. The hybrid cloud will enable new business paradigms and applications to take root. There will no excuse for disconnected clouds. Weaknesses will likely include vendor management, enterprise control, and open standards. The cloud is driven to less and less management. However, SLAs may control the extent to which vendors are required to manage applications in the cloud. These same SLAs may also strike agreements between the vendor and enterprise as to the division of responsibilities. Finally, open standards are gaining momentum, where pressure has been placed on next-generation cloud computing for interoperability. With the emergence of the hybrid cloud, opportunities will be sought in the refinement of virtual private clouds, hybrid applications, and multi-solution clouds. Functional limitations in one type of cloud do

[118] Stadtmueller, "Cloud Computing: What it Is, Where it's Going, and Who Will Lead Us There", 16.

not preclude the use of another type of cloud, in hybrid environments, to solve the customer's problems. Threats include modularization, specialization, and open standards—all disruptive threats to the existing ecosystem(s). It is likely that end-to-end integrators will cede to modular firms and niche specialists. Integration and interdependence will be driven into these modular components to improve the prospects of new disruptive technologies in cloud computing.

In summary, the competitive landscape in next generation cloud computing will include much more than the public cloud. Various types of hybrid clouds will connect private data centers, public clouds, and hosted environments to meet the needs of customers and their coveted applications. New disruptive technologies will emerge at lower initial prices points and commensurately lower initial performance levels, but with the potential performance trajectory to meet and perhaps exceed the needs of the market. These new cloud computing technologies will enable new markets, attract new constituents, and provide attractive returns to the disruptive firms, at price points that the incumbents would deem unattractive. This will we be facilitated by disruptive firms, which will make use of hybrid clouds to deploy new applications, gain new markets, and increase market share, thereby defraying costs among a growing customer base.

**Next Generation Cloud Computing: Ecosystems**

As stated previously, the successful adoption of next-generation cloud computing as a disruptive technology hinges on two important factors. The first factor is the acceptance of fully-integrated end-to-end cloud providers such as IBM, Amazon, and Hewlett-Packard. The second factor is the emergence of modular firms that can provide expertise in virtualization and open standards, such as Citrix and 3Tera, respectively. Once the technology has been "good enough" in the public cloud, the market is ready for a host of disintegrated (Christensen, 2001)[119] and modular (Baldwin and Clark, 1997) [120] competitors to drive individual solutions relevant to the ecosystem. Next-generation cloud computing necessitates the emergence of firms that are dedicated to specialized

[119] Christensen, Raynor, Verlinden, "Skate to Where the Money Will Be", 75.

[120] Baldwin, Clark, "Managing in an Age of Modularity", 127-135.

components of the ecosystem including: virtualization, open standards, security, and data centers.

One way to define the cloud computing ecosystem is to establish leaders in IaaS, PaaS, and SaaS, as shown in Figure 1 in Chapter I along with the Porter analysis presented previously. However, a detailed analysis of the PaaS and IaaS ecosystem will shed light on how next-generation cloud computing will gain traction and provide attractive price points, returns, and appeal to the low-end of the market. The PaaS and IaaS ecosystem in next-generation cloud computing may look like the model presented in Figure 17 below.

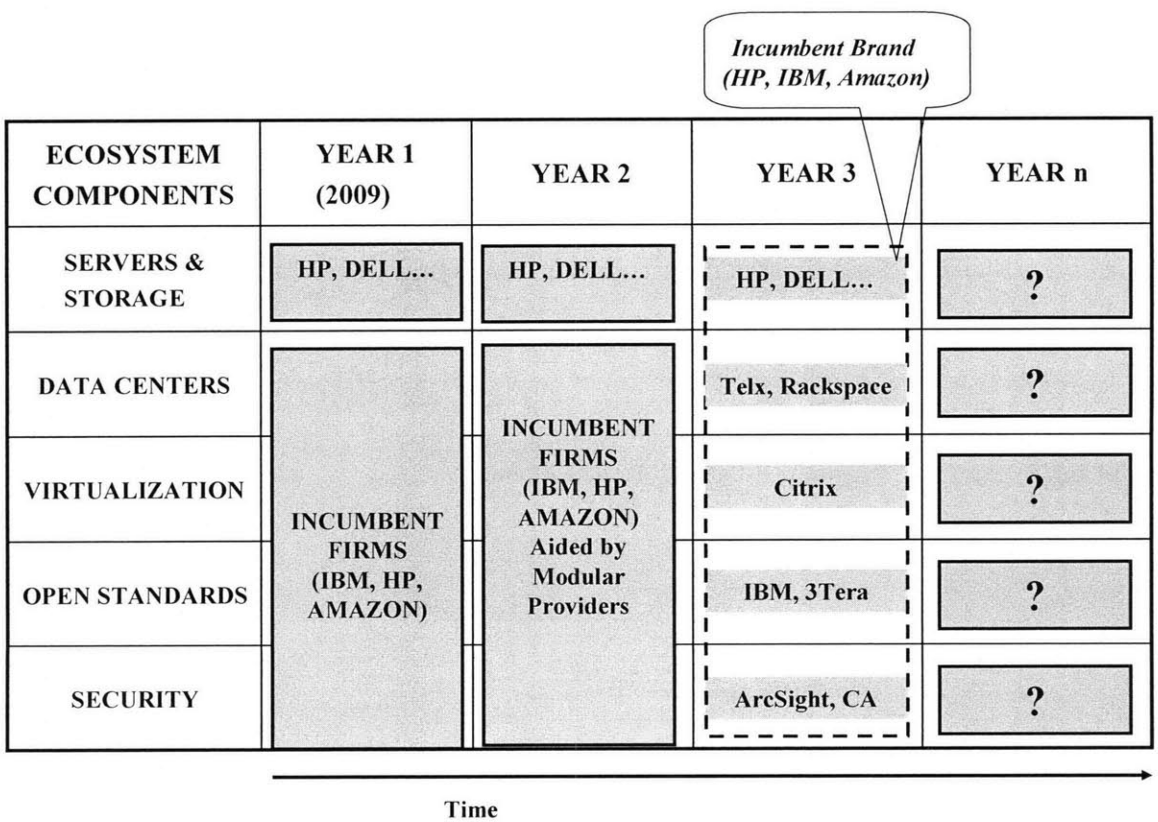


Figure 17: Next-Generation PaaS and IaaS Ecosystem

In Figure 17, the ecosystem starts with fully-integrated, end-to-end, single firms such as Amazon, IBM, and HP. When the technology isn't "good enough", these firms need to own all technology components where interdependence and integration is solely owned within those firms. As also shown in Figure 17, as the technology becomes "good enough", disintegration and modularization occurs where modular and specialty firms such as Citrix, Akamai, 3Tera, and others have more prominent roles—not just supporting roles. Integration and interdependence are driven into this modular ecosystem by necessity. It is difficult to determine how long this ecosystem will last, but for the time being, this proposed ecosystem has sustaining value. If performance of this disruptive technology overshoots market demand, then a new disruptive technology will emerge with new price points, technology, and solution providers to fulfill new roles.

In conclusion to the discussion of ecosystems, it must be noted that adoption in the marketplace is facilitated by the *Early Majority*, which plays an advocacy role for others in the *Early Majority*. IBM and telcos were once *Buyers* in the Porter model. Now they are incumbent end-to-end providers. As Geoffrey Moore points out, the chasm is between the *Early Adopters* and *Early Majority*. Those in the *Early Majority* need references from others in the *Early Majority*—not from the *Early Adopters*. Firms including IBM, AT&T, and Verizon Business are in the *Early Majority* and provide the valued references to cross the chasm.

**Next Generation Cloud Computing: What It May Look Like**

The next generation of cloud computing is likely to bridge three types of clouds, in a hybrid environment, using virtual private clouds. The component building block clouds are shown in Table 11.[121] The three types of clouds are described as follows, using virtual private clouds to take advantage of all three types. Public clouds are multi-tenant, scalable, virtualized environments with utility billing. Their main benefit is to deliver superior economies of scale and uniformity across all customers. They are managed by a 3rd-party provider. Internal clouds are multi-tenant infrastructures, which have much of the same functionality of public clouds. However, they reside at the enterprise data center and are owned and managed by the enterprise as well. Internal clouds are best suited for highly sensitive, compliance-rich data. There is tighter enterprise control and VMs are dedicated, not shared. Hosted clouds have functionality in between the two. They are multi-tenant, hosted by a 3rd-party, with servers dedicated to one customer, not shared. Hosted clouds permit greater flexibility around security and

[121] Staten, "Which Cloud Computing Platform Is Right For You?", 3.

enterprise control than public clouds. However, hosted clouds have price points closer to internal clouds, as servers are dedicated to one customer instead of shared by many.

| CLOUD ATTRIBUTE | Internal Cloud (private data center) | Hosted Cloud (dedicated) | Public Cloud (shared) |
|---|---|---|---|
| **Location of residence** | Corporate Data Center | Internet-Connected Data Centers | Internet-Connected Data Centers |
| **Tenancy Model** | Single Company | Mutiple Clents | Multiple Clients |
| **VM (virtual machine) residence** | Dedicated Infrastructure | Dedicated But Hosted | Shared Infrastructure |
| **Security** | Customer-Based | Common, With Greater Configurability | Common, With Limited Configurability |
| **Cloud Management** | IT Operations | 3rd-Party Provider or IT Operations | 3rd-Party Provider |
| **Infrastructure** | IT Operations | 3rd-Party Provider | 3rd-Party Provider |
| **Billing** | Consumption-Based | Dedicated: by Month Excess: by Consumption | Consuption-Based |

Table 11: Cloud Attributes and Deployment Options (Source: Forrester Research, Inc.)

In addition to virtual private clouds and hybrid clouds, another next-generation cloud alternative will be presented in the form of ultra-modular computing (UMC). UMC helps enterprise IT organizations build flexible and cost-efficient data centers.[122] UMC is not managed by a traditional 3rd-party provider. Rather, it resides at the enterprise, operating with the existing security and privacy infrastructure. UMC should be considered as viable choice in the development of next-generation cloud ecosystems.

Before entering into a discussion about next-generation hybrid clouds and UMC, the management structure of these computing solutions needs to be assessed. A critical success factor in the management of a hybrid cloud is the integration between its constituent components—the private and public data center environments. A hybrid cloud solution deliberately combines the convenience and scalability of the public cloud

[122] Charles Brett, Jeffrey Hammond, "Behind 'Cloud" Is Your Future Application Environment: Ultra Modular Computing", *Forrester Research, Inc.* (April 6, 2009): 1-17.

with the dedicated hosting capabilities of an on-premise solution. As the hybrid cloud expands, providers will be integrating more and more data center options. As Forrester Research, Inc. points out, the key word is "integration"—where "multiple adjacent computing environments do not constitute a hybrid environment any more than a gas-powered and electric-powered vehicle sitting side-by-side, constitute a hybrid vehicle".[123]

In the following analysis of hybrid cloud environments, a common management platform or common interface is needed to integrate public and private cloud components. The hybrid cloud is considered among the most useful cloud computing evolutions for the enterprise.[124] It enables control of the public cloud from Network Operations Centers (NOC) and enables "bursting" of capacity from on-premises data centers to the public cloud to accommodate peak demand levels. Management of hybrid cloud solutions will likely be managed by 3rd-party providers, although there is nothing that would preclude private enterprises from managing this solution, assuming the enterprise has adequate resources to do so. It is also likely that modularized solutions will be integrated in the hybrid cloud ecosystem, as these solutions have core competency in the essential components of virtualization, scalability, and security.

The management structure of UMC is owned and executed by the enterprise. UMC takes advantage of virtualization, scalability, and non-linear applications—all hosted and controlled by the enterprise. UMC gives the enterprise autonomy over 3rd-party public cloud providers and takes advantage of the enterprise's current security and compliance solutions.

Open standards will be the most significant driving force for the market adoption of inter-cloud and inter-vendor functionality in next-generation clouding.[125] Today, no cloud vendor can facilitate mobility among different cloud providers. Firms such as IBM and GoGrid can maintain and manage multiple computing environments, albeit within the

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[123] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 18.

[124] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 19.

[125] Carl Shapiro, Hal Varian, "The Art of Standards War", *California Management Review*, Volume 41, Number 2, (Winter 1999).

IBM and GoGrid hybrid cloud computing portfolios, respectively.[126] Open standards and vendor-agnostic solutions may be as many as five years away.

**Hybrid Clouds for Cloud Interconnections:** Virtual private clouds may be used to construct hybrid clouds between an internal cloud and a public cloud. The rationale is to allow a customer to have a self-service portal from a public cloud, but have deployment into a protected internal cloud that is dedicated to a single customer. This is facilitated by the virtual private cloud. A customer may wish to link two internal public clouds, or link a private data center to a number of other data center options including a public cloud. This implementation is shown in Figure 18.[127]

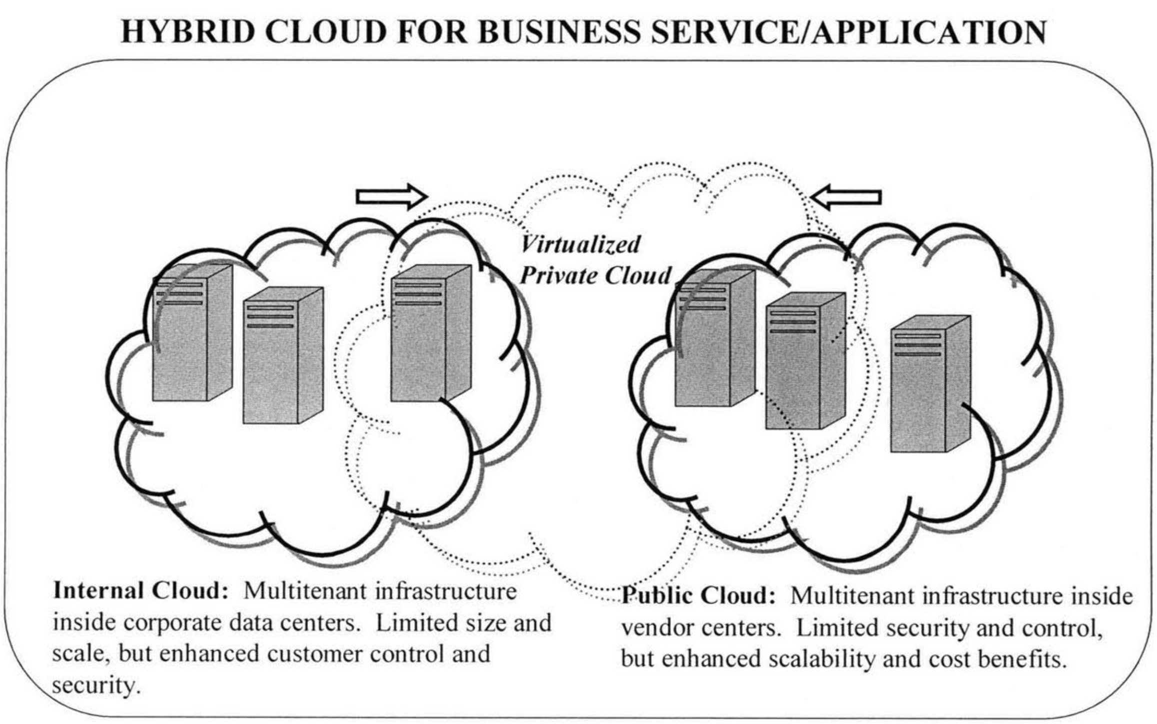


Figure 18: Hybrid Clouds Constructed by Internal and Public Clouds (Forrester)

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[126] Stadtmueller, "Market Trends in Hosted Infrastructure Services: How Enterprises are Reshaping the Cloud", 19.

[127] Staten, "Which Cloud Computing Platform Is Right For You?", 6.

**Hybrid Clouds for Cloud-Bursting:** During periods of peak consumption, private data centers can call on the use of public clouds for additional capacity. This is known as cloud-bursting. A public cloud may not be the best solution for hosting a persistent service owing to its consumption-based model. However, a private data center can get additional capacity by adding the public cloud's VMs (virtual machines) during peak loads. Cloud-bursting is shown in Figure 19 with the use of a virtual private cloud.[128] Cloud-bursting uses a virtual private cloud which spreads load balancing and a common address pool across the infrastructure, where VMs are only instantiated in the cloud at peak demand levels. This makes cloud-bursting feasible and also saves money.

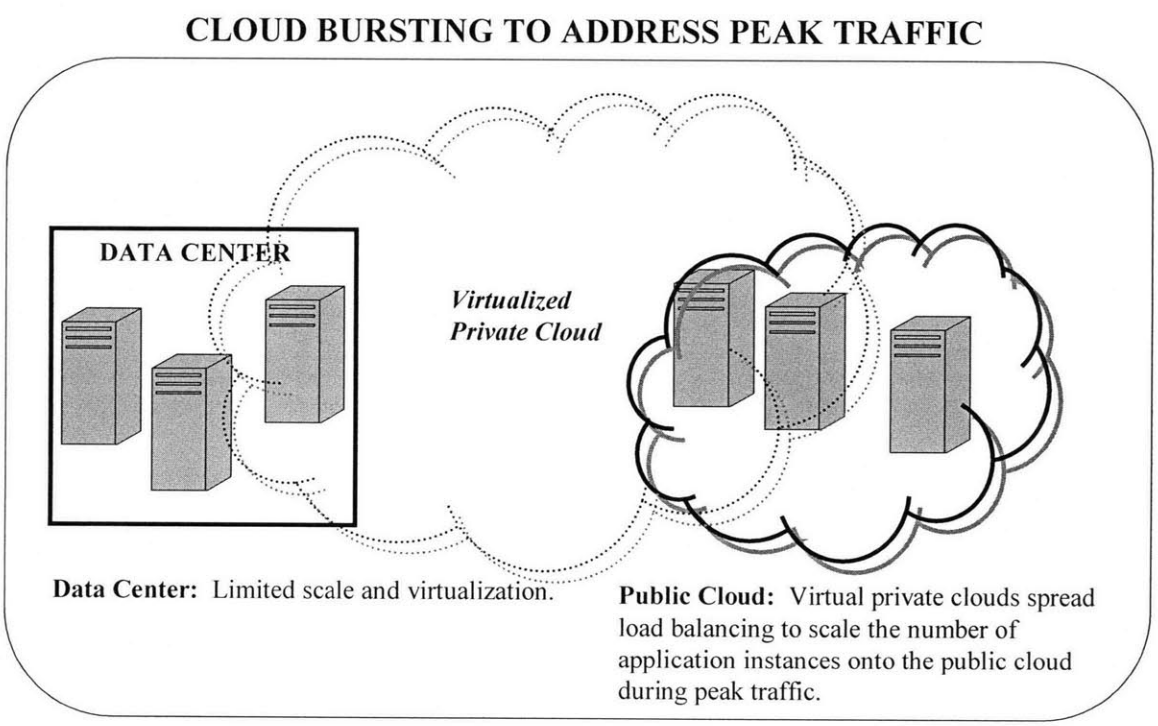


Figure 19: Cloud-Bursting Using Virtual Private Clouds (Forrester)

**Hybrid Clouds for Multicast Protocols**: IP (Internet Protocol) multicast is a technique for a "one-to-many" communication over an IP infrastructure in a network.[129] Multicast is able to scale to multiple receivers in the network without prior knowledge of the type and number of receivers. Multicast protocols make efficient use of the network

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[128] Staten, "Which Cloud Computing Platform Is Right For You?", 6.

[129] Wikipedia, Multicast: http://en.wikipedia.org/wiki/Multicast

infrastructure. Only one transmission from the source is necessary, even if the destination includes multiple receivers. The packet replication is made by the nodes in the network, which is sent to multiple receivers only when necessary.

Multicast protocols are problematic for public clouds. Multicast protocols can negatively impact network performance and these protocols are often unreliable across network and cloud boundaries. However, some applications, including caching solutions, grid engines, and clusters require the full and reliable use of multicast protocols.[130] Figure 20 shows how a virtual private cloud can safely and reliably enable the use of these multicast protocols within a public cloud deployment.[131]

**VIRTUAL PRIVATE CLOUD FOR MULTICAST PROTOCOLS**

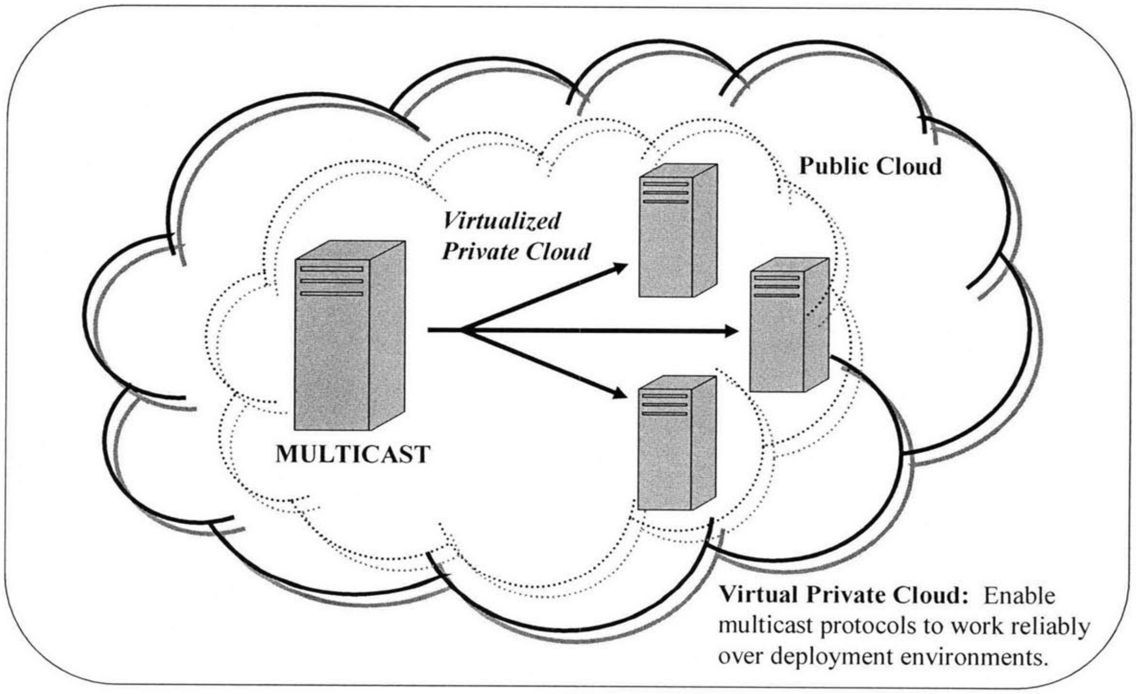


Figure 20: Virtual Private Clouds Used For Multicast Applications (Forrester)

**Virtual Clouds to Monitor Cloud Deployments:** Virtual private clouds can also be used to monitor a public cloud from a NOC (Network Operations Center), private data center, or remote service provider. In this implementation, a virtual private cloud is used

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[130] Staten, "Which Cloud Computing Platform Is Right For You?", 5.

[131] Staten, "Which Cloud Computing Platform Is Right For You?", 6.

as an overlay network. Virtual private clouds can be overlaid between different types of sources and destinations. Virtual machines (VMs) at a private or public cloud can be connected to a corporate VLAN or subset of the enterprise infrastructure. An illustration of a public cloud being monitored by a NOC is shown is shown in Figure 21.[132]

**NETWORK OPERATIONS CENTER CLOUD MANAGEMENT**

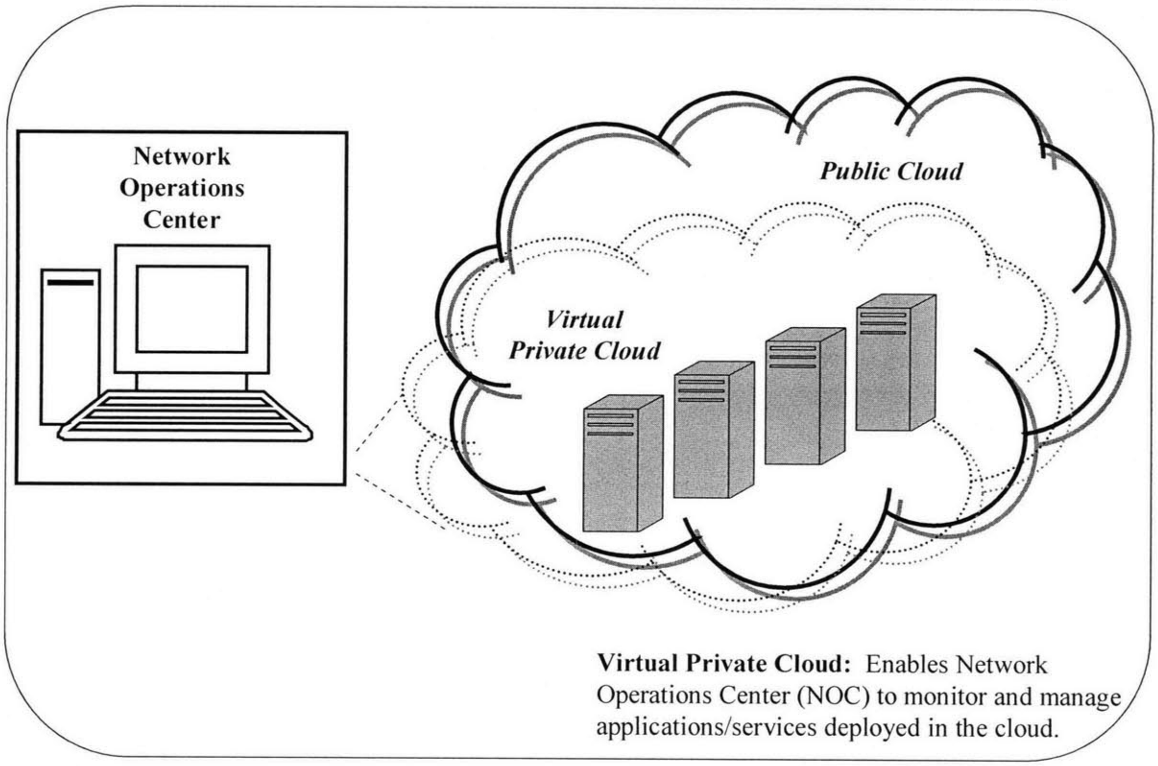


Figure 21: Monitoring Public Cloud from NOC (Forrester)

**Ultra Modular Computing:** As previously mentioned, Ultra Modular Computing (UMC) provides the enterprise with an alternative to traditional 3rd-party cloud computing. UMC enables enterprise IT organizations to build flexible and cost-efficient data centers—all within the control of the enterprise. UMC allows the foundational basis for cloud computing—virtualization, X86-based hardware, elasticity, and shared services—to become the basis for data centers owned by the enterprise.[133]

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[132] Staten, "Which Cloud Computing Platform Is Right For You?", 6.

[133] Brett, Hammond, "Behind 'Cloud' Is Your Future Application Environment: Ultra Modular Computing", *Forrester Research, Inc.* (April 6, 2009): 1-17.

Open source software is the driving force behind UMC, which allow enterprises to benefit from non-linear software licensing, software modularity, and loosely coupled applications. UMC provides the possibility for enterprises to reduce capital expenditures via low-cost hardware and automation, while keeping security and compliance core competencies in-house. This architecture is presented below in Figure 22.[134]

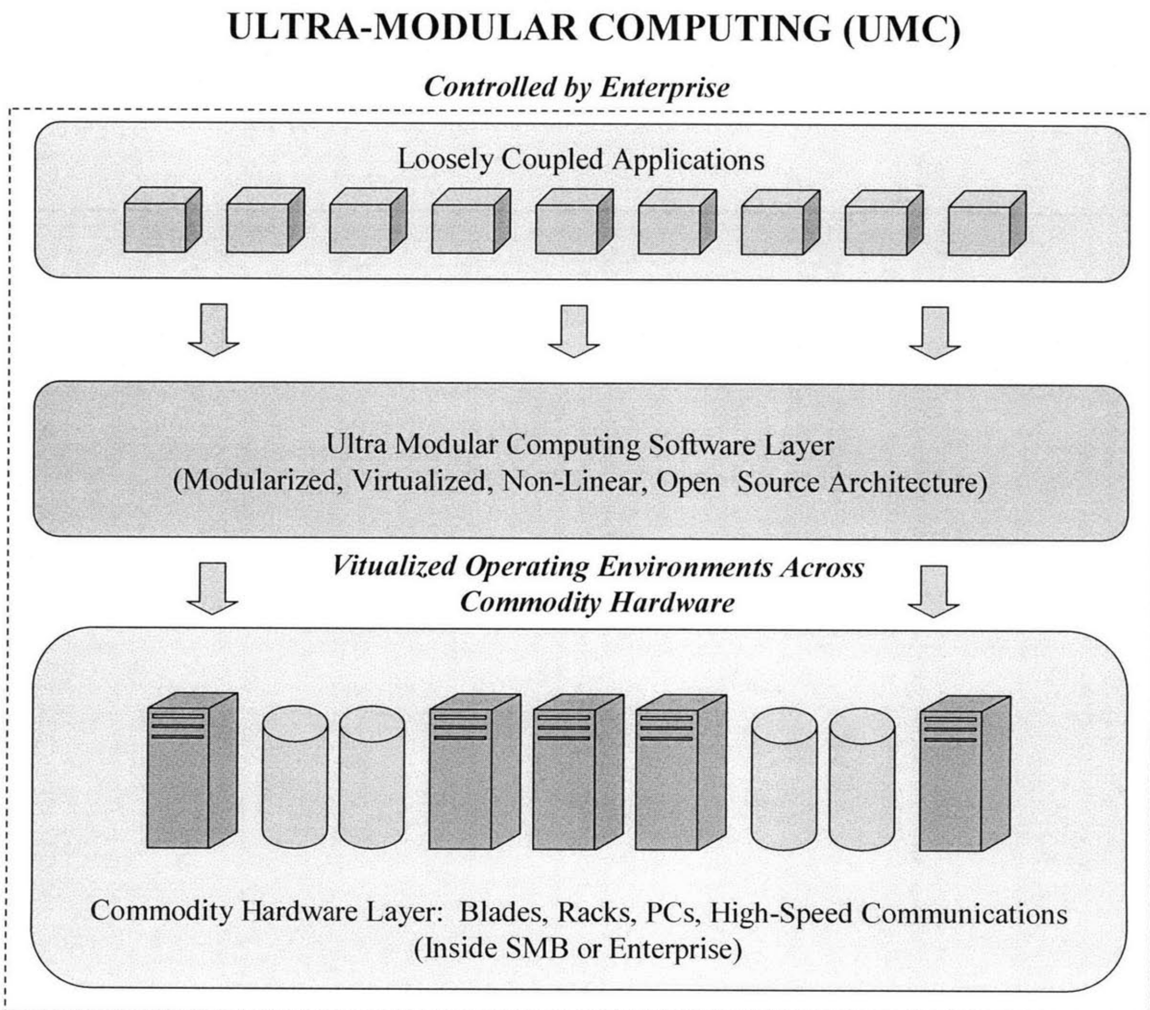


Figure 22: Ultra Modular Computing [UMC] (Source: Forrester Research, Inc.)

In summary, next-generation cloud computing will be characterized by 1) *Buyers* and *Suppliers* integrating to the general rivalry of the end-to-end incumbents, and 2) *New Entrants* and *Low-Cost Substitutes* providing integrated, modular solutions. The future

[134] Brett, Hammond, "Behind 'Cloud" Is Your Future Application Environment: Ultra Modular Computing", 7.

of cloud computing will hinge on making improvements in security, compliance, enterprise control, open standards, and hybrid environments that link disparate clouds to meet the specialized needs of customers. Next-generation cloud computing is truly a disruptive technology. With the advent of virtual private clouds and hybrid clouds, businesses and individuals that could not formerly obtain the services rendered in the cloud will be able obtain them at attractive prices points. Furthermore, new markets, particularly at the low end, will flourish as a consequence of hybrid cloud technology which yields attractive price points in public clouds while maintaining security and compliance in private ones. These disruptive technology firms in next-generation cloud computing can earn attractive returns, as a result of shared resources and customer-specific applications/services that hybrid clouds and open standards can provide.

Finally, next-generation cloud computing has great promise in the construction of viable ecosystems, which is foundational for disruptive technologies. Future cloud computing solutions will be driven by a combination of integrated end-to-end providers and modular firms. The success of these ecosystems will be promoted by high levels of integration and interdependence, either by single end-to-end providers or by a portfolio of modular firms.

# CHAPTER V: CONCLUSION

Cloud computing has been presented as a disruptive technology. The public cloud has made significant strides in replacing traditional license-based software and on-premise solutions as the dominant computing paradigm. The public cloud offers scalability, virtualization, convenience, flexibility, and low-cost utility-based pricing. Next-generation cloud computing remedies many of the drawbacks of the public cloud, offering improved price-performance, security, and a host of customer-focused solution options that were once unavailable to the low end of the market. Most importantly, next-generation cloud computing ushers in an era of hybrid clouds, which have the potential to connect not only different types of clouds, but also clouds from different vendors. Open standards are a key driving force in the future of cloud computing.

This analysis focused on three criteria to define cloud computing as a disruptive technology. First, the inception of the public cloud and its next-generation advances allow those with modest means to secure the same computing services that only those with greater means could formerly obtain. Second, the public cloud and its evolutionary improvements target the low end of the market, at an initial reduction in performance, but with a performance trajectory capable of meeting and exceeding market demands. The emergent disruptive technology firms in cloud computing are able to make attractive returns, at prices unattractive to incumbents, as a consequence the of cloud's value proposition of shared environments, which defray costs among a large subscriber base. Third, cloud computing has an ecosystem emblematic of a true disruptive technology. Leaders in cloud computing have been represented by fully-integrated end-to-end solution providers and by collections of niche, modular firms. Customer adoption in cloud computing has largely been the result of buyers of cloud services becoming providers of cloud services—offering effective testimonials to its value.

Cloud computing is moving towards greater ubiquity, as greater demands from customers and greater capabilities from providers unfold. Open standards and improved access will be hallmarks in this technology. Cloud computing will play a significant role in the way we work, the way we live, and even the way we spend our leisure time.