CLOUD COMPUTING IN THE AGE OF THE FOURTH INDUSTRIAL REVOLUTION: NEW SERVICES AND ECONOMIC ACQUISITION DECISIONS

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Abstract

As cloud computing penetrates rapidly into enterprise computing markets, the paradigm of enterprise computing shifts from client-server data centers to cloud-based data centers. The advent of the Fourth Industrial Revolution is accelerating this paradigm shift. Along with the rapid growth of cloud services market, cloud computing acquisition decisions have been challenging for managers due to lack of proper assessment tools and methods. This paper will discuss the evolution of cloud computing, service options, and economic acquisition decisions for enterprises. This paper will help managers deepen their understanding of the current technology environment and business value of cloud computing in the context of the Fourth Industrial Revolution.

Keywords*: Cloud computing; Web services; Grid computing; Fourth Industrial Revolution; Data centers; SaaS; Economic Acquisition*

1. Rise of Cloud Computing

Cloud computing is one of the most significant paradigm shifts in information technology. The term “cloud” refers to the Internet, based on the way people draw the Internet in a cloud-like symbol, and is an abstraction of the complex infrastructure it hides (Erdogmus, 2009). A growing number of companies are using public cloud services that offer the advantages of cost, elasticity, mobility, and scalability of computing. Cloud computing has shifted the location of the infrastructure to large networked data centers, contributing to the reduction of costs by pooling hardware and software resources and providing greater flexibility and access to users (Dikaiakos et al., 2009; Vaquero et al., 2009).

Cloud computing providers such as Amazon, Microsoft, IBM, and HP develop a number of service models, deployment options, and pricing schemes that are flexibly integrated with each other to meet unique users’ computing needs. They provide a large number of enterprises and individual users with the network access, application software, processing capability, data storage, and security from their data centers. For example, individual users use smartphones to access a wide choice of apps and data services available in the cloud with little costs. According to Gartner (2017), the worldwide public cloud services market is expected to grow 18 percent in 2017 to total $246.8 billion. The highest growth is expected to come from infrastructure as a service (IaaS) with a projected growth of 36.8 percent in 2017 to reach $34.6 billion. Software as a service (SaaS) is expected to grow 20.1 percent to reach $46.3 billion.

Cloud computing is a game-changing breakthrough on the continuum of evolution in computing technologies. The history of cloud computing goes back to the 1960s when multi-users accessed the mainframe computers and shared computing resources via dumb terminals. Since then, cloud computing has evolved along with a number of milestone technologies. The development of personal computers in the 1980s contributed to the diffusion of computers to individual users as well as enterprise users and evolved into the client-server computing in the 1990s, which partitioned tasks or workloads between the servers and client computers. In the 2000s, the rapid growth of e-commerce, mobile computing, and social media led to the rise of cloud computing after numerous attempts at pooling and sharing large-scale computing resources.

The Fourth Industrial Revolution was the theme of the 2016 annual meeting in the World Economic Forum. The Fourth Industrial Revolution is seen as a deeply interconnected world of technologies such as artificial intelligence (AI), robotics, the Internet of Things (IoT), big data and data analytics, and cloud computing (Schwab, 2016). The cloud computing became a key enabler of the Fourth Industrial Revolution by providing the essential computing infrastructure for the key technologies. The impact of the Fourth Industrial Revolution on the cloud market is palpable due to rising demand from computation-intensive workloads for AI, data analytics, and the IoT.

Gartner (2017) predicts that through 2020, cloud adoption strategies will influence more than 50 percent of IT outsourcing deals due to the multi-layered value of cloud services such as elasticity, scalability, cost reduction, mobility and agile business development. In the age of the Fourth Industrial Revolution, cloud computing is a key enabler for new business models and rapid technology integration. Manufacturing industries are moving to smart manufacturing by utilizing machine-generated data and robots. Financial industries are utilizing AI and bots to replace face-to-face customer interactions. Retailers are also collecting and analyzing a massive amount of customer data from online sources to provide personalized services.

While cloud computing is leading technological innovations to a new level, many managers are not yet fully realizing the true potential of cloud computing. Our paper will review predecessor technologies of cloud computing, present critical cloud building blocks, discuss needs of cloud computing in the age of the Fourth Industrial Revolution, and propose an economic assessment method for service acquisition decisions. This paper will help managers deepen their understanding of the current technology environment and business value of cloud computing in the context of the Fourth Industrial Revolution.

2. Predecessor Technologies of Cloud Computing

Cloud computing has been built on top of several predecessor technologies including web services, utility computing, and grid computing. Convergence of these technologies led to the rapid growth of cloud computing. To put cloud computing in the proper context, this section reviews three major predecessor technologies.

Web Services

Web services refers to self-contained software that encapsulates some kind of functionality and provides a standardized way of integrating web-based applications using a set of open standards over the Internet (Fremantle, Weerawarana, & Khalaf, 2002). Web services can be described, advertised and discovered using standard languages, and interacted through Internet-based protocols (Sheng et al., 2014). From a business perspective, web services are all the commercial services available on the web or the Internet. From a technological perspective, web services are Internet-based application components published using standard interface description languages and are universally available via uniform communication protocols. A service-oriented architecture (SOA), a popular architecture to implement web services, is a technology that allows applications to communicate with each other in a platform and programming language independent manner.

Google and Yahoo have provided the web service APIs (application programming interface) allowing other applications to integrate Google's and Yahoo's map and satellite images. In 2002, Amazon started to provide Amazon Web Services (AWS) such as a storage service and shopping cart functionality for other web sites or applications. Salesforce is another well-known web services provider that offers a web service version of customer relationship management (CRM) software and other web-based software services. As of August 2017, Salesforce is one of the most highly valued American cloud computing companies with an annual $10 billion revenue run rate. While these companies started to offer web services, they are now providing cloud services which evolved from their web services from the 2000s. For example, in 2006, Amazon launched its Elastic Compute Cloud (EC2) as a commercial web service that allows small companies and individuals to rent computers on which to run their own computer applications.

Utility Computing

Utility computing is a technology-based business model in which computing resources to users are available on an as-needed basis, similar to electricity, telephone services, and gas. Without having to invest heavily in or maintain their own computing infrastructure, users employ utility computing services offered by third-party providers (Yeo et al., 2010). The utility computing market took shape with a number of service providers that offer a range of service options in the 2000s. Leading firms in the computing industry such as IBM, Sun Microsystems, and Hewlett-Packard pursued their own versions of utility computing services. These companies have vast capabilities of technical staff, computers, software, data storage, and networks that are frequently underutilized and can readily sell the underutilized IT resources to other enterprise customers.

Utility computing focuses on the business model in which customers pay for the computing services based on their service consumption. Utility computing reduces the financial and technological risks involved in direct ownership of information technology for companies whose underutilization wastes precious corporate resources. The value proposition of utility computing has evolved from a cost-oriented approach whose purpose is to drive down the total cost of computing to a strategy-oriented approach in which computing resources are economically utilized in meeting computing demands and quick to respond to changes in the business environment. Utility computing has been further developed into public clouds for which pooling of computing resources and various pricing schemes for services were developed. While public clouds are directly related to utility computing, cloud computing encompasses the private cloud as well as the public cloud.

Grid Computing

The term grid is adopted from the power grid which provides transparent access to electric power to users regardless of its source location. The vision of the grid was formulated in the mid-1990s as a computing and data platform that is ubiquitous, uninterrupted, and has uniform user access, which is similar to the power grid (Foster, Kesselman, & Tuecke. 2001). The availability of high-performance computers and high-speed network technologies was a driver to pool loosely-coupled, dispersed, and heterogeneous computers as a single, unified computing resource. Grids have been successfully used for many application areas, such as physics, bioinformatics, earth sciences, life sciences, finance, space engineering (Iosup, & Epema, 2010).

Grid computing integrates multiple resources operating on operating systems, local resource management, and security infrastructure. Interoperability and security are the primary concerns for grid computing, as resources may come from different organizations that have global and local resource usage policies, different hardware and software configurations and platforms, and vary in availability and capacity (Foster et al., 2008). To utilize grids effectively, efficient allocation algorithms have been developed to distribute and assign service tasks to grid resources. Grid computing serves as one pillar infrastructure of cloud computing, as it can support a large number of applications and storage needs in a scalable and consistent manner.

3. Building Blocks of Cloud Computing

Mell & Grance (2011) defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. According to Sharma et al. (2012), three factors are contributing to rapid growth of cloud computing: (1) decrease of hardware cost, increase in computing power and storage capacity, advances in multi-processor architecture and modern supercomputers, (2) the exponentially growing data volume in scientific instrumentation/simulation and web publishing and archiving, and (3) the wide adoption of services computing and web 2.0 applications. To realize the capabilities of on-demand service, broad network access, resource pooling, elasticity and scalability, and metered service, cloud computing needs to develop service models, deployment models, pricing models, and infrastructure.

Services Models

Widely publicized cloud services include Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). In the SaaS model, software applications are provided by service provides, and users can access the cloudified software from their local computers. The service provider is responsible for developing and maintaining the software. SaaS has many advantages, such as low software expenses, availability of updated software, elasticity, accessibility, and compatibility. SaaS eliminates the need to install and run the application on the client computer. Some of leading SaaS are Salesforce's CRM and Google's apps.

PaaS is a service which includes operating systems, application development environments, and database development technologies. PaaS facilitates the development and deployment of applications, as application developers can rent expensive sophisticated computing platforms to develop their platform-dependent applications. Google app engine and Microsoft Azure are leading PaaS.

IaaS is a service model in which computers are offered as physical or virtual machines to support users' operations. The service provider is responsible for developing and maintaining computing infrastructure and the services such as hardware, firewalls, and virtual local area networks (VLANs). Service providers lease the virtualized machines to customers and customers are typically charged for the amount of resources consumed. Google Compute Engine (GCE) is the IaaS component of the Google Cloud Platform that is built on the global infrastructure that runs Google's search engine, Gmail, YouTube, and other services. Amazon Elastic Compute Cloud is another IaaS in which storage, processing, and network capacity are offered as a service.

While SaaS, PaaS, and IaaS are the mainstays of cloud services, many niche service models have also been developed for segmented markets such as Storage as a Service (STaaS), Security as a Service (SECaaS), and Test Environment as a Service (TEaaS), to name a few. In STaaS, a service provider leases storage to users for data collection and management. In SECaaS, the security service of a service provider is integrated with the user's computing systems to help protect users' computing systems. TEaaS is another service provided to users in which test environments and their data are provided to users.

Pricing Scheme

Different service providers employ different schemes and models for pricing (Al-Roomi et al., 2013). Commercial success of cloud computing can be achieved by developing adequate pricing models that establish an efficient way to allocate and valuate a variety of services (Weinhardt et al., 2009). Service providers may use fixed or dynamic pricing schemes for service provisions. When using the fixed pricing scheme, the service provider sets a predefined price for each service or resource type. When using the dynamic pricing scheme, the service provider sets the price for the service or resource type dynamically reflecting the changing demand and supply.

The following are the most pertinent factors that influence pricing in cloud computing. (Sharma et al., 2012): (1) Initial costs: the amount of money that the service provider spends to acquire resources; (2) Lease period: the period in which the customer will lease resources from the service provider; (3) quality of service (QoS): the set of technologies and techniques offered by the service provider to enhance the user experience, such as data privacy and resource availability; (4) Age of resources: the age of the resources employed by the service provider; (5) Cost of maintenance: the amount of money that the service provider spends on maintaining and upgrading the cloud.

A pay-as-you-go approach for services is one of the most popular pricing scheme in which a user pays only for the individual services he/she consumes without requiring long-term contracts or complex licensing. It is similar to how people pay for utilities such as water or electricity. One advantage of the pay-as-you-go pricing approach is to easily adapt to changing business needs without overcommitting budgets. Reservation (or subscription) of capacity is another pricing scheme. With reservation, a user can enjoy a reduced unit price from volume discount. However, without accurate forecasts and stable demand over time, there is a risk of over- or under-reservation. Volume based discount is another poplar pricing scheme. Savings from deeper discounts can be realized as users' usage increases. For example, if usage goes over a predetermined threshold level, one will get a scheduled discount over the pay-as-you-go price.

Pricing may depend on the service level such as downtime guarantee and security. A service level agreement (SLA), an essential part of cloud computing, is a contract between a service provider and a cloud customer that specifies the level of cloud service delivery in a measurable term in such areas as cloud governance, security, compliance, and performance and uptime statistics. For example, as of August 2017, Microsoft Azure guarantees at least 99.9% availability of the Azure Active Directory Basic and Premium services as a part of their SLA.

Deployment Models

Main deployment models include the public cloud, private cloud, community cloud, and hybrid cloud. The most well-known cloud deployment model is the public cloud model. A public cloud is a cloud computing model in which a service provider provides scalable and elastic IT resources, such as applications, computational services, and storage to the users over the Internet. A public cloud is a cost-effective way to deploy IT solutions, especially for small or medium sized businesses. According to IDC (2016), worldwide spending on public cloud services is expected to grow from $96.5 billion in 2016 to more than $195 billion in 2020 at a compound annual growth rate (CAGR) of 20.4% over the 2015-2020 period.

A private cloud delivers similar advantages to a public cloud, including scalability and self-service, but through a proprietary architecture. Unlike public clouds, which deliver services to multiple organizations, a private cloud is dedicated to a single organization. A private cloud offers many of the benefits of a public cloud computing environment, such as being elastic and scalable, but is managed and provided within an organization. A private cloud provides greater control over the cloud infrastructure and operations, and is often suitable for large-size computing demands. A private cloud can be managed by either a third-party provider or an enterprise user.

A community cloud is shared by multiple organizations with common or similar purposes of cloud deployment. For example, a community cloud is managed and used by a group of organizations that have shared interests, such as specific security requirements or a common interest.

A hybrid cloud, a tailed combination of a public and private cloud, is a cloud environment in which an organization owns and manages their internal private cloud and leverages a public cloud or a community cloud provided externally. In a typical hybrid cloud environment, non-critical applications are outsourced to the public cloud, while mission-critical applications and data are kept within the realm of the organization.

According to a recent IBM survey (2016), hybrid clouds are expected to be widely useful across industries. Each organization's unique business conditions and requirements will define its optimal hybrid mix of private and public cloud technology. 54 percent of surveyed executives cited lowering the total ownership cost of technology as the most important reason for implementing hybrid cloud solutions. The total computing cost can be reduced by avoiding excessive equipment purchase and letting public cloud providers bear part of the fixed infrastructure cost. When the computing demands exceed the private cloud capacity, the hybrid cloud shifts the computing demands to the public cloud with a capability called 'cloud bursting' in which an application runs in a private cloud or data center bursts into a public cloud when the demand spikes.

Cloud Infrastructure

Enterprises need to invest in cloud infrastructure to build and manage cloud computing resources. A well-developed cloud infrastructure can increase the benefits of cloud computing. Cloud infrastructure typically include the following: cloud servers, virtualization technologies, storage devices, cloud network, and disaster prevention, recovery, and backup systems. A cloud server is a logical server that is built, shared, and delivered through server virtualization over the Internet. The physical server underlies logical servers, each of which has a separate operating system, user interface, and application services.

Virtualization technologies make it possible to run multiple operating systems and multiple applications on the same physical server at the same time or combine multiple physical servers into a cluster. A cloud network is a network where network management functions are in the cloud so that fewer network devices are needed to manage the scalable and elastic cloud network. Reliable disaster prevention and recovery systems need to be established to minimize disruptions and unexpected downtime which can cause a severe damage to business operations. Multiple levels of redundant disaster prevention, disaster recovery, data storage, and backup capabilities are needed for mission-critical systems.

4. New Cloud Services in the Age of the Fourth Industrial Revolution

Key technologies of the Fourth Industrial Revolution include big data, the IoT, and AI. These technologies require a great amount of computing resources and human IT expertise. The fast integration of these technologies into new products and services is required of any enterprises that try to keep up with the fast-paced innovation cycle of the Fourth Industrial Revolution. The following discusses new services provided with the cloudification of these technologies.

Big Data as a Service (BDaaS)

While structured data is an essential part of big data, more and more data are created in unstructured video and image forms (Lee, 2017). The current architecture of the data center is not prepared to deal with the heterogeneous nature of personal and enterprise data (Gartner, 2015). In the age of the Fourth Industrial Revolution, few firms will be able to invest in the full-scale in-house development of data storage and analytics to store and process all the big data collected from various sources. Along with the challenge of collecting and analyzing massive amounts of data from web and social media, data security and privacy issues have become challenges to enterprises. Cloud computing provides the scalability of computing resources that can meet the sudden bursts of big data, and properly addresses data security and privacy concerns. Furthermore, cloud service providers are able to reduce the cost of big data management through the mixed use of open source and proprietary tools.

A costly development of big data infrastructure can be avoided by adopting Big Data as a Service (BDaaS) developed by major cloud service providers. BDaaS refers to a delivery of a wide variety of cloudified big data and analytics tools to clients. It can range from the access of data, to the provision of data analytics with which to analyze the data, to the real-time monitoring of data stream. For example, IBM Insights for Twitter service on Bluemix provides enterprise clients with access to data and analytics on Twitter data streams. Some BDaaS providers also include consulting and advisory services along within their provision of BDaaS.

Internet of Things as a Service (TaaS)

The IoT is a global network of interacting machines and devices over the Internet. It is becoming a mainstream technology with a new computing paradigm of machine-to-machine and human-to-machine interactions. Assisted living, smart homes, e-health, and enhanced learning are a few examples of applications in which the IoT plays a leading role (Atzori et al., 2010). Lee and Lee (2015) identify three IoT categories for enterprise applications: (1) monitoring and control, (2) big data and business analytics, and (3) information sharing and collaboration. These IoT applications require massive data storage, huge processing speed to enable the real-time decision making, and high-speed broadband networks to stream data, audio, or video. Hence, any serious in-house development of the proprietary IoT applications is an expensive time-consuming proposal for an enterprise.

Internet of Things as a Service (TaaS) provides an ideal backend solution for handling huge data streams and processing them for a large number of IoT devices and humans. Hadoop and Spark cloud services can be delivered via TaaS to process the data generated by IoT-enabled sensor networks. TaaS also offers platform and infrastructure services for enterprises that need to develop IoT solutions for various sensor devices, device-to-device networking and communications, and business analytics. Amazon IoT, IBM Watson IoT, and Microsoft Azure IoT Hub are some of the public cloud IoT PaaS offered to customers. Through TaaS, enterprises can securely configure machine-to-machine communication without heavy time-consuming investment in the IoT infrastructure and improve their productivity.

AI-as-a-Service (AIaaS)

Although AI has been around since the 1950s, recent advances in graphics processing units (GPUs) and big data, along with the advent of the Fourth Industrial Revolution, have put it into the spotlight in the world of business. The popularity of AI surged rapidly in 2000s with a series of widely publicized human-computer competitions. Most surveys of the technology trends of 2017 list AI or machine learning, and/or deep learning as part of near future technologies. Some experts believe the inflection point was reached in the advancement of AI and rapid progress lies ahead.

AI is recognized as one of the enablers of the Fourth Industrial Revolution. Self-driving cars, image/video recognition, and robots all apply AI methods which use a massive number of CPUs and big data for proper learning. It is proven that the more computing power and the more data the AI system uses, the better the performance is for machine learning such as image recognition and automated text translation. Shipping companies, such as FedEx and UPS, want to figure out the most efficient and cost-effective way to deliver the most packages. AI is needed to solve these complex problems as well as the IoT and big data analytics.

However, the investment in this technology is prohibitive for most companies that want to develop AI solutions for their businesses, let alone the lack of qualified data scientists. AI-as-a-Service (AIaaS) is a good option for resource-strained enterprises. Major cloud providers are currently offering AIaaS with high-performance CPUs and big data for machine learning to enterprise clients who cannot afford to invest in the infrastructure of the AI systems themselves. Nvidia is a manufacturer of high-performance graphical processing units (GPUs) that have been used to accelerate the training of AI systems. Noting that training on traditional CPU processors takes too much time and electrical power, Nvidia is renting their proprietary GPUs to AI application developers. Microsoft offers more than 20 cognitive services such as analyzing images, known as computer vision, and language comprehension. Amazon's in-house AI expertise, such as for predictive analytics, is available on Amazon Web Services (AWS) via its Machine Learning Service. Google Cloud Platform offers a number of AI capabilities, such as predictive analytics, speech recognition, translation and image content identification. IBM's Watson Developer Cloud enables developers to incorporate Watson intelligence in their apps and provides its Watson AI engine as a cloud-based analytics service.

Through AIaaS, any business or developer can build and operate powerful AI applications with a fraction of cost needed for the full in-house AI application development. Furthermore, AIaaS becomes more intelligent over time by learning continuously with the new sets of data and updates their services real-time to clients. In the near future, AI applications will become strategic necessity in many industries, and AIaaS will be widely used by enterprises that want to stay ahead of the innovation cycle and gain competitive advantage.

5. An Economic Service Acquisition Approach

With such large potential value (as well as risks) to be had in the acquisition of cloud computing, enterprises need an appropriate measure to properly assess value of the service. Resource underutilization is typical in enterprises as computing resources are dedicated to specific applications in the anticipation of peak-load demand over a multi-year life cycle of resources. In general, enterprises request proposals from multiple service providers and select the best service provider based on service needs, financial constraints, and other requirements. While all the cloud service/pricing options may have had value arising from shared resources, the amount of benefits may be different on specific patterns of computing demand and pricing. This section presents an economic acquisition approach to cloud service acquisition, and compares three acquisition options for BDaaS. This section uses the following scenarios to discuss the approach.

Lets' assume that a company considers a subscription or pay-as-you-go BdaaS to store and process big data about their customers and competitors collected from various social media sites. One cloud service provider offers two pricing options for BDaaS: the pay-as-you-go and the subscription. The choice the company will make is whether they go along with (1) the pay-as-you-go only, (2) the subscription only, or (3) a mix of the pay-as-you-go and subscription. The following computing needs are assumed to assess each option.

It is assumed that the company has a wide range of peaks and troughs in computing needs. In a pricing situation of BDaaS, the unit computing price of the subscription is lower than that of the pay-as-you-go. However, to buy the enough subscriptions to cover the peak demand would result in a high number of subscriptions and an overall low utilization rate of the subscriptions in time of normal demands or trough demands. As a result, the subscription only option is likely to incur high overall BDaaS usage costs as they pay for the subscriptions even when they do not actually use it. On the other hand, the pay-as-you-go only option may lead to high overall computing costs by paying high service fees to a public cloud provider, as the pay-as-you-go price is higher than a subscription price in terms of the unit-to-unit price comparison. This economic acquisition approach shows how managers can find the best BDaaS usage plan to minimize the total usage costs by comparing the pay-as-you-go only, the subscription only, and a mix of the subscription and the pay-as-you-go.

As an illustration, Figure 1 shows the simplified hypothetical demand probability distribution of BDaaS usage in a given time unit. The expected BDaaS usage demand is given by: $\sum_{n=1}^{10} P(d_n) \cdot d_n$ where d_n is a BDaaS usage demand of level n and $P(d_n)$ is a probability of BDaaS usage demand of level n. In this case, the expected BDaaS usage demand is 324 instances. If the subscription covers 100 instances, then the utilization rate of the subscription is 100%. However, if the demand comes as 200, then an additional 100 pay-as-you-go BDaaS instances are needed. If the demand comes with 1,000, 900 pay-as-you-go BDaaS instances are needed. If the subscription is purchased for 200 instances, the subscription can cover up to

200 BDaaS instances. However, if the demand comes as 300, then 100 pay-as-you-go BDaaS instances are needed. The company needs to develop an economic acquisition plan for the BDaaS demands.

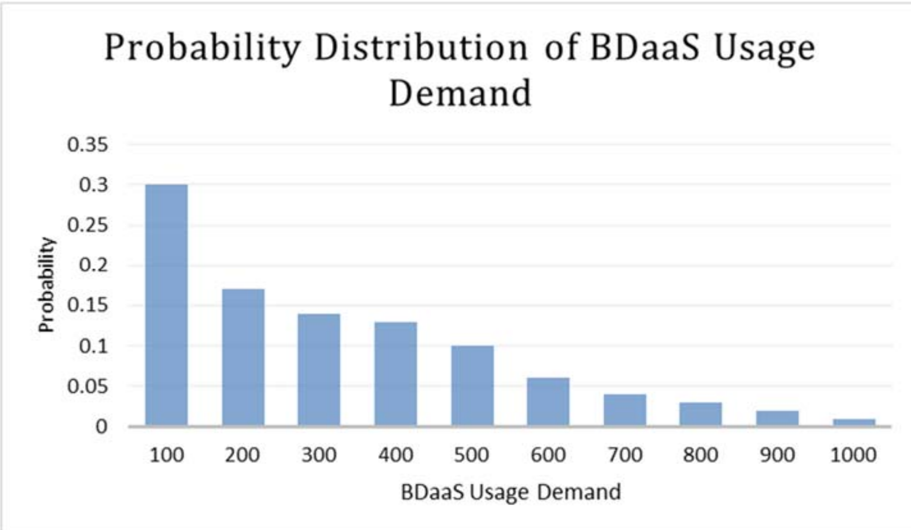

Figure 1. Hypothetical Demand Probability Distribution of BDaaS Usage

Let's assume the subscription is for 200 working days. Then, unit subscription price times the number of subscriptions is the total subscription cost: $S*c$ where S is a unit subscription price and c is the number of subscriptions. Assume S is \$50 and the c is 200, then the total subscription cost is \$10,000 per a 200-day period. Let's assume the unit price of pay-as-you-go is \$1.50 per day. Assuming the number of subscription is 200, the *expected total cost* of the pay-as-you-go is the total daily usage fee times 200 working days: $(\sum_{n=3}^{10} P(d_n) \cdot (d_n - 200) \cdot u) \cdot 200$ where u is the unit price of the pay-as-you-go and $P(d_n)$ is a probability of BDaaS usage demand of level n.

Table 1 and Figure 2 show the expected total usage cost under different mixes of subscription and pay-as-you-go. It shows that when the number of subscription is 500, the expected total usage cost is minimized at \$35,800. On the other hand, if the company chooses "pay-as-you-go only", the expected total cost is \$97,200 (i.e., 324 * \$1.5 * 200 days). If the company chooses "subscription only," it is \$50,000 (\$50 per subscription * 1,000 subscriptions). A significant cost savings of \$14,200 (i.e., \$50,000 - \$35,800) occurs due to the switching flexibility of cloud computing where excessive computing demand can be switched instantly to the pay-as-you-go mode when the computing demand exceeds the number of subscriptions acquired.

Table 1. The Number of Subscriptions and Expected Total BDaaS Usage Costs

Number of BDaaS Subscriptions	Total BDaaS Usage Cost
100	\$72,200
200	\$56,200
300	\$45,300
400	\$38,600

500	$***35,800***
600	$36,000
700	$38,000
800	$41,200
900	$45,300
1,000	$50,000

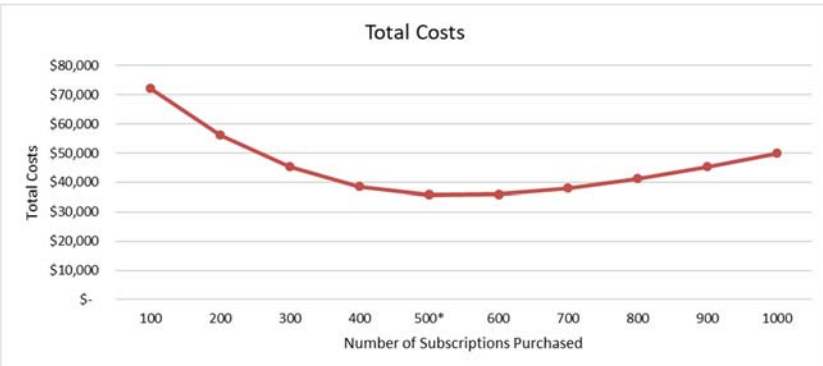

Figure 2. The Expected Total Cost under Different Mixes of Subscription and Pay-as-You-Go.

Now, we evaluate the value of switching flexibility of cloud computing with three scenarios: (1) Scenario 1: increase of BDaaS prices over time, (2) Scenario 2: increase of computing demand over time, (3) Scenario 3: increase of both BDaaS price and computing demand over time. We evaluate these scenarios with three periods.

Scenario 1: Increase of BDaaS Prices Over Time

Assume that Period 1 is the same as the above example. Assume that in Period 2, the price of pay-as-you-go goes up by 30% to $1.95 and in Period 3, the price of subscription goes up by 30% to $65. Table 2 shows the total costs of the three BDaaS acquisition options. While there is a cost increase of $10,744 from the mix, two other options have much larger cost increases as prices of both subscription and pay-as-you-go options increase.

Table 2. The Expected Total Costs of Three BDaaS Acquisition Options (Scenario 1)

	Period 1 Price of Subscription: $50 Price of pay-as-you-go: $1.5 Expected demand: 324	**Period 2** Price of Subscription: $50 Price of pay-as-you-go: $1.95 Expected demand: 324	**Period 3** Price of Subscription: $65 Price of pay-as-you-go: $1.95 Expected demand: 324	**Cost Increase from Period 1 to Period 3**
Mix	$35,800 at 500	$37,800 at 600	$46,540 at 500	$10,744
Subscription Only	$50,000	$50,000	$65,000	$15,000
Pay-as-you-go only	$97,200	$126,360	$126,360	$29,160

Scenario 2: Increase of Computing Demand Over Time

In Scenario 2, we assume that in Period 2, the computing demand goes up by 30% from the demand of Period 1, and in Period 3, the computing demand goes up by 30% from the demand of Period 2. Table 3 shows the expected total costs of the three options. Again, while there is a cost increase of $24,702 from the mix option, two other options have much larger cost increases as BDaaS demand increases over time.

Table 3. The Expected Total Costs of Three BDaaS Acquisition Options (Scenario 2)

	Period 1 Expected demand: 324	**Period 2** Expected demand: 421	**Period 3** Expected demand: 548	**Cost Increase from Period 1 to Period 3**
Mix	$35,800 at 500	$46,540 at 650	$60,502 at 845	$24,702
Subscription Only	$50,000	$65,000	$84,500	$34,500
Pay-as-you-go only	$97,200	$126,360	$164,268	$67,068

Scenario 3: Increase of Both BDaaS Price and Computing Demand Over Time

In Scenario 3, we assume that in Period 2, the price of pay-as-you-go goes up by 30% to $1.95 and the computing demand goes up by 30% from the demand of Period 1. In Period 3, the price of subscription goes up by 30% to $65 and the computing demand goes up by 30% from the demand of Period 2. Table 4 shows the expected total costs of the three options. Again, while there is a cost increase of $42,852 from the mix option, the two other options have much larger cost increases as both the BDaaS price and the computing demand increase over time.

Table 4. The Expected Total Costs of Three BDaaS Acquisition Options (Scenario 3)

	Period 1 Price of Subscription: $50 Price of pay-as-you-go: $1.5 Expected demand: 324	**Period 2** Price of Subscription: $50 Price of pay-as-you-go: $1.95 Expected demand: 421	**Period 3** Price of Subscription: $65 Price of pay-as-you-go: $1.95 Expected demand: 548	**Cost Increase from Period 1 to Period 3**
Mix	$35,800 at 500	$49,140 at 780	$78,652 at 845	$42,852
Subscription Only	$50,000	$65,000	$109,850	$59,850
Pay-as-you-go only	$97,200	$164,268	$213,548	$116,348

Managerial Lessons Learned

It was observed that the value of switching flexibility via the mix of the two BDaaS acquisition options is high when there are increases in computing demand and price increases over time. In all scenarios, the cost benefit of the mix of the two BDaaS acquisition options became far greater than the "subscription only" or the "pay-as-you-go only." This cost saving can be attributed to the fact that the mix ratios of the two BDaaS acquisition options are flexibly adjusted based on price and computing demand changes. These scenarios are more likely to occur in the age of the Fourth Industrial Revolution. For example, prices of cloud services are on the rise due to the rapid demand increase. As enterprises migrate to the cloud, they have no choice but to pay higher prices. However, the shock of the price increase may become much greater when the acquisition of the service is not carefully evaluated, as seen in our scenarios.

While these scenarios were simplified for readers who are not well-versed in finance or accounting, more complicated scenarios can be developed and analyzed with the same principles, perhaps with the assistance of colleagues in the finance area. Nevertheless, our illustration highlights the value of the scenario-based service acquisition approach to cloud computing and provides valuable guides to managers in their acquisition decisions. While the mixed option for BDaaS was illustrated in this paper, the suggested approach can be extended to the acquisition of other types of cloud services.

6. Conclusion

Cloud computing has offered many services to enterprises and individuals. The Fourth Industrial Revolution will drive the growth of the cloud services market of big data, the IoT, and AI applications. Emerging services such as BDaaS, TaaS, and AIaaS have been offered by major service providers. Due to a lack of a proper acquisition approach to cloud computing, cloud computing acquisition decisions have been a challenge for managers. This paper reviewed predecessor technologies of cloud computing, presented building blocks of cloud computing and provided an overview of the emerging cloud services in the age of the Fourth Industrial Revolution. This paper presented a scenario-based economic acquisition approach to cloud services from enterprise customers' perspectives. While our scenarios used BDaaS as an illustration and compared the subscription only, the pay-as-you-go only, and a mix of them, the same methods can be easily applied to an SaaS, IaaS, PaaS, or other specialty service acquisition situation.

To make judicious decisions, managers need to monitor advances in cloud technologies as well as the prices of the cloud market and the computing demand of their company. For example, open source cloud services will continue to gain relevance, and more commercialized services based on open source platforms may be available in the future. The open source cloud services may shift the cloud ecosystem by weakening the market dominance of some proprietary cloud technologies and providing a wide range of choices. Many enterprises will invest in private clouds as well as public clouds to reduce management complexity and operating costs. In the age of the Fourth Industrial Revolution, enterprises are expected to achieve competitive advantage through flexible and effective utilization of the best of breed in the cloud space. Therefore, managers need to be well versed in the management activities involved in the planning, analysis and design, acquisition, deployment, and operation of cloud computing.

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