Cloud Computing – A Comprehensive Definition

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Abstract—Cloud computing is an evolving technology that is consistently generating impact in IT industry and academia. It performs all computational tasks over Internet by using virtualization techniques and remains isolated from intricate vast hardware and software infrastructures. The aim of this paper is to glance through the background and evolutions of cloud computing, its architecture and services to develop cumulative knowledge for future research extension and evaluation.

Keywords: cloud characteristics, cloud computing, cloud deployment models, cloud services

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1 Introduction

Cloud computing is becoming dominant day by day. It is the most happening trend that makes companies to use the term in their marketing campaign in order to draw people more into their products. Companies use their data in so many ways to meet business needs, and so, computing technologies must be able to process and store the on-demand business data consistently and effectively. Since traditional distributed computing architecture lacks in delivering flexibility, scalability, elasticity and faster processing speed, companies are diverging into cloud technologies for huge data storage and load-balancing availability [1].

Cloud computing is basically a philosophy and design concept of computing architecture, while, its much more complicated but yet so much simpler. The basic concept is to separate the Applications, Operating System and Hardware from each other. In case of any failure or a virus attack, for example in an operating system, instead of shutting down the whole system, the application can just be migrated automatically to another server by using virtualization technology. Each physical server can host several virtual servers and each cloud user can have one or more virtual instances to store or host their data on the cloud servers. A study by IEEE members, Youseff, Butrico and Silva [2], view cloud computing as a re-conceptualized and advancement in technology rather than disruptive innovation and they also view as the assembly of pre-existing technologies and components. According to National Institute of Standards and Technology (NIST), cloud computing can be implemented in distinctive architectural forms by using existing service and deployment models, which is integrated with other technical components and software tools [3]. The introduction by Office of the Privacy Commissioner of Canada (OPC) stated that cloud computing is a very inexpensive approach as it saves costs from expensive real-estate, electricity cabling, cooling equipment, hardware, network-bandwidth, operational costs, physical security, just to name a few [4].

No human resources are needed for IT infrastructure maintenances as it provides outsourcing facilities. It helps organizations to rent services for a short period of time to accomplish a large task for their business purpose and hence allows organization to focus more on business innovation and product development. Cloud based business applications is an inexpensive approach. Cloud service providers bill for each instance, like pay-as-you-go, so better accountability and transparency of costs [5].A cloud user is being charged based on the subscription model, i.e, one pay for what one uses, hence cost transparency and better accountability. It is scalable and consumes less time to start up. As an example, New York Times converted 11 million articles to portable document files (pdf) by renting Amazon E2C servers for a day at a much lower cost, that would have required weeks or even months to complete the task [6].

Many studies [1-6, 15, 21, 29-32, 40-43] have been conducted on cloud computing from different perspectives, such as, definition, technology, architecture, services and deployment models. Apparently, none of the study has covered all perspectives together in one particular study. For example, in terms of cloud characteristics, which are eight in nature; some studies have covered only six, five, four, or even two, respectively [29, 21, 31, 30, 2]. Another example in terms of deployement models, some studies have discussed private, public, community and hybrid cloud [3,17, 24, 29, 31, 36], while another study has introduced virtual private cloud [21]. This paper covers all the possible defintions of cloud characterisctics, architecture, deployment models and services. The aim is to provide a complete overview of how cloud entities work together with a solid ground of technical infrastructure, which will enable any researchers to develop cumulative knowledge for future research extension and evaluation.

2 Cloud Computing Background

IT industrialists have defined cloud computing from

their respective business perspectives. US National Institute of Standards and Technology (NIST) defined as, "Cloud Computing is a model for enabling 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" [3]. According to Varia [7], technology evangelist of Amazon Web Services, "Cloud Architectures are designs of software applications that use Internet-accessible on-demand services. Applications built on Cloud Architectures are such that the underlying computing infrastructure is used only when it is needed (for example to process a user request), draw the necessary resources on-demand (like compute servers or storage), perform a specific job, then relinquish the unneeded resources and often dispose themselves after the job is done. While in operation the application scales up or down elastically based on resource needs." According to IBM, "The concept of cloud computing has developed from earlier ideas such as grid and utility computing, and aims to provide a completely Internet driven, dynamic and scalable service-oriented IT environment, which can be accessed from anywhere using any Web-capable device" [8]. Microsoft defined as, "Cloud computing represents the platform for the next generation of business. Cloud computing is driving the transformation of the IT industry across the entire stack: hardware model delivering incredibly powerful and efficient hardware at a fraction of the cost; application model allowing developers to rapidly create highly available secure cloud applications; operations model keeping cloud applications available 24X7 with 9-to-5 management" [9]. Sun views cloud as, "a set of services that are encapsulated, have an API, and are available over the network. This definition encompasses using both compute and storage resources as services" [10]. VMware finds cloud computing as, "is best understood from the perspective of the consumer of services provided by such a computing approach. The following four attributes are core to cloud computing based services: radically improved economics through shared infrastructure; pricing based on consumption: You only pay for what you use; flexible access; a lightweight entry and exit service acquisition model" [11]. Xiao and Xiao, senior member of IEEE, defined cloud computing as, "A large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically- scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet" [12]. They further mentioned that several literatures have given different definitions for cloud computing but none has been recognized extensively. In another research by Voas and Zhang [13] stated that cloud computing is influencing significant changes to the use of IT resources over Internet with a standard interfaces. It is considered as a killer technology that takes the best features from prior technologies and trades them off to convert a new solution [14].

In general, a cloud comprises of memory, data centre, distributed storage, virtual machines, web applications, processing and network. It has compatibility with loosely coupled CPU clusters. According to the requirement of various organizational services, cloud can be deployed as any of the three main models, such as, Public clouds (available to general public), Private clouds (owned by one or groups of organizations) or combination of both as Hybrid clouds. The deployment can also be modeled as Domain Specific clouds or Community clouds. The cloud architecture consists of abstract layers to provide three different types of services as Infrastructure as a Service, Platform as a Service and Software as a Service.

2.1 Evolution of Cloud Computing Services

Cloud computing is driven from modern technological features in order to create a novel computing environment that can serve various growing business requirement with greater flexibility, integrity and agility [15]. Various literatures relate cloud computing to prior paradigms as Cluster Computing, Grid Computing, Virtualization, Utility Computing and Service Oriented Architecture [2,16, 17, 18, 19, 20]. Others refer cloud computing as a new paradigm and emerging technology [21]. Larry Ellison, chief Executive of Oracle Corporation, said at a financial analyst conference in 2008 that, "The interesting thing about cloud computing is that we've redefined cloud computing to include everything we already do" [22]. The increased amount of data and high level of connectivity has made information technology providers to establish data centers that help for dynamic load balancing, distributing and replicating data across servers on demand [15].

Eric Schmidt, the executive chairman of Google, is probably the first person to introduce the concept of cloud computing "as a whole" in his talk at a conference of Search Engine Strategies [23] cited by [24]. Prior to that, the journey of cloud computing has started by Salesforce.com in 1999 with limited specific software packages [22]. They later introduced integrated set of tools, Force.com, which can be used by other organizations to build their business applications and share the same infrastructure that delivers the Salesforce CRM applications [25]. From 2003 to 2006, Google has published some research papers on Platform as a Service (PaaS) cloud computing and later launched its service to the public as Google App Engine (GAE) in 2008 [24]. GAE provides SaaS services as office productivity tools, including e-mail, calendar, and word processing and more in the area of electronic corporate communications [25]. By the end of 2013, Google has launched its on-demand Infrastructure as a Service as Google Compute Engine (GCE) and distributed storage system as Bigtable. The GCE is hosted on Google server and has an environment based on Python programming language. Cloud users access GCE platform to build and host web applications.During 2006 and 2007, Amazon has started offering a suite of several services under

the name of Amazon Web Services (AWS) [24]. It includes cloud computing as Elastic Compute Cloud (EC2) [26] with no constraint on the programming language type of software application [22], structure data storage as SimpleDB [26], object storage service or Simple Storage Service (S3), a web service for content delivery as CloudFront, a hosted service for storing messages as Simple Queue Service [25] and more, in which, data storage are priced by the GB monthly and computing capacity by the CPU hour [28]. AWS is completely based on server virtualization technology and has made Google the pioneer of Infrastructure as a Service (IaaS) provider [24].

At the end of 2008, Microsoft Azure was introduced to the public with services that includes BLOB object storage and SQL services. It uses Window Azure Hypervisor (WAH) as the core infrastructure with the capability of server virtualization, and .Net as the application container with existing software and applications compatibility [24]. In 2010, Windows Azure operating system PaaS was launched to provide Azure services as Live, SQL, SharePoint, .Net and Microsoft Dynamic CRM [25].

In 2011, Apple released iCloud that act as an Internet repository. iCloud synchronizes all the data, files, applications and other items among user's devices, like laptop, mobile etc. so that the devices can share the same data with no redundancy [27].

Since 2007 number of companies started walking through the journey. Cloud computing has become the key strategy of IT industries, ISP and telecom service providers. Following are the name of some cloud service providers: IBM Blue Cloud infrastructure, Joyent (Accelerator), OpenNebula, Cisco UCS, Hadoop, Navajo SaaS, GoGrid (Xen), Apache HBase, Verizon CaaS (VMware), Heroku (Ruby), EMC Atmos, AT&T Synaptic (VMware) [24,28]. Some of the key cloud computing technology providers are Apache, Cisco and EMC. Example of service support providers are CapGemini, RigthScale and Vordel [25].

3 CLOUD CHARACTERISTICS

Cloud computing has some key characteristics that depict their features of similarity and differences from conventional computing operations. The first five essential characteristics described below are defined by NIST [3] and CSA [29]. Other relevant studies have also identified a number of salient features of cloud computing, and they are summarized as follows:

3.1 On-demand Self-service:

The cloud users have control over computing resources that can be allocated or de-allocated and customized according to their needs at anytime from anywhere without any intervention from cloud service provider. They are empowered to manage the resources and have administrative privileges to configure the parameters of computing power, servers, storage and network. Such automated resource management provides greater flexibility and fast response to rapid changes on service demand [3, 21, 29].

3.2 Broad Network Access:

The cloud users can access the services over the network or Internet through standard interfaces of heterogeneous thin or thick client platforms, e.g. mobile phones, PDAs, tablets and laptops [29, 30, 31].

3.3 Resource Pooling or Provisioning:

The cloud service providers use multi-tenant model by pooling computing resources to serve multiple customers. Resources include virtual machines, storage, processing, memory and network bandwidth. The feature allows these resources to dynamically assign or reassign according to the customers demand that can be configured to appear as a distinctive platform for individual customer [3, 21, 29].

3.4 Rapid Elasticity and Scalability:

The scalability of the available resources appears to be unlimited at any time for better services. Nodes in the network can be added or dropped with less alteration to infrastructure setup. It is acquired and released automatically corresponding with the customers demand [29, 30, 31].

3.5 Measured service or Utility-based pricing:

Resource usage can be monitored, controlled, metered and reported in order to provide transparency for both the cloud service providers and users. The cloud services are automatically measured at different level of abstraction to the type of service layers (e.g., storage, memory, servers, user applications, active accounts etc.) using appropriate metering systems and are billed accordingly [29, 30]. The pricing scheme in cloud computing is like pay-as-you-go and may vary from service to service. As an example, a cloud customer can rent a virtual machine on per-hour basis. Such utility based pricing model cuts down service operating costs [21].

3.6 Location Independence:

Usually, the cloud customer has no knowledge about the exact geographical location of the rented resources from service providers. In order to provide maximum service utility and high network performances, many service providers set up their data centres at different regions around the globe. And may specify the location to the customers only at higher level of abstraction, as in like, country or state [21, 29, 31].

3.7 Cost Effectiveness:

The cloud can be deployed near to economical power station and in inexpensive real estate [31].

3.8 Multi-tenancy:

The cloud service provider can rent out a single infrastructure as a service to multiple customers by providing appropriate technical partitions [21, 32] named

multi-tenancy and location independence as a Shared Infrastructure characteristic and has defined that the cloud customers use physical services as virtualized software model in accordance to their demand.

4 Cloud Computing Architecture

Cloud computing is a promising revolutionary of the contemporary distributed computing resources. These resources are accessible as services by cloud users from cloud service providers. According to different business needs, cloud architecture can be categories

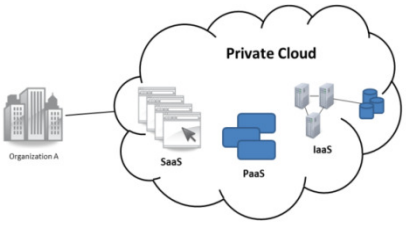

Fig. 1. Private Cloud

into four basic types of deployment models and three types of service models. Each service has distinctive fundamental characteristics, with its own benefits and weaknesses. NIST and CSA have outlined the cloud architecture in [3, 29], which are discussed below.

4.1 Deployment Models

4.1.1 Private Cloud

The private cloud infrastructure is configured solely for a single organization or a third party by using virtualization and automated management technologies to ensure highest degree of controls over security, reliability and performance. It is built, deployed, customized, managed, operated and used by either a single or group of organization as client and supervised by cloud service provider. It is not made available to the general public [33]. Figure 1 shows an example of a Private Cloud model.

The model may exist on or off premises and offers a new architecture for improved efficiency and can be used to provide enterprise level computing services or B2B interactions, such as ERP applications, online collaboration, email, calendaring etc., unlike conventional servers that are dedicated only for certain applications. Customer can maximize or optimize the resource utilization when needed; no data privacy concern and can always control business critical activities within network firewalls [34]. The Aberdeen Group [35] has claimed in a report that organizations operating using private cloud are leading by about 12% in cost than organizations operating in public cloud [3, 17, 21, 29, 31].

4.1.2 Public Cloud

The cloud infrastructure is configured by the cloud service providers and made available to general public or external parties to use over Internet. It is owned, managed, operated by the cloud service provider and exist on their premises. Figure 2 shows an example of a Public Cloud model.

The model offers flexibility and easy access of computing services to general public or industry group without letting them to invest huge capital on infrastructure. Despite of major benefits, public cloud has prone to get malicious attack or leak of information, as the security level in public cloud lacks fine-grained control mechanisms [3, 17, 29, 31, 36].

4.1.3 Virtual Private Cloud

Virtual Private cloud is one of the emerging cloud infrastructures that have started to gain popularity since its establishment in 2009 [21]. The model is configured to run on public cloud but in a private way. It uses the computing resources in public cloud and allows connection with consumer's computing resources by using virtual private network (VPN) technology. Hence, better security settings options that can virtualize not only the servers and applications but also the underlying communication network [21]. Google and Amazon provide services as Virtual Private cloud (VPC), which is a virtual platform operating on public cloud and is shared by different organizations [17].

4.1.4 Hybrid Cloud

The cloud infrastructure is a combination of two or more distinct cloud infrastructures (public, private or

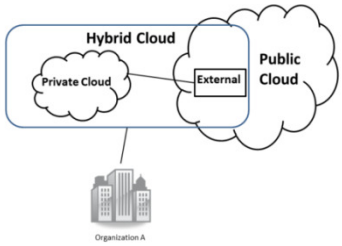

Fig. 3. Hybrid Cloud

community) and is considered as a single model. It is configured by standardized or proprietary technologies to share resources between clouds over a flexible controlled and secured network. The cloud users offload their application processes and data to acquire benefit of scalability and cost effectiveness, e.g. cloud bursting for load balancing [29]. It has more flexibility over other cloud infrastructures by allowing highly confidential applications to run in private cloud while for general peak loads or computation in public cloud [37]. Figure 3 shows an example of a Hybrid Cloud model.

In other words, less critical information is compute into the public cloud, while the business critical information is stored within the private cloud [26]. Basically, B2B or B2C interactions can be performed, by using portability techniques over computing resources amongst different clouds [37]. Despite facilitating on-demand service expansion and contraction,

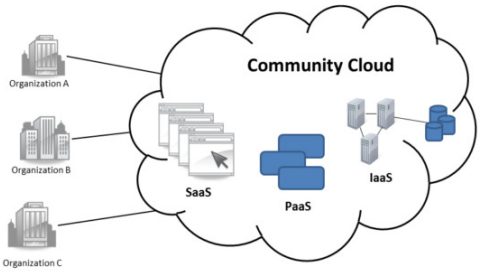

Fig. 4. Community Cloud

the partition between clouds infrastructure need to be done very cautiously in order to form hybrid cloud [21, 24]. The concept of the development and interoperability of hybrid cloud is still at an early stage and needs major consideration to overcome any additional complexities over usual tools and technologies that are used to manage public or private cloud [3, 24, 31, 36].

4.1.5 Community Cloud

The cloud infrastructure is configured and shared by several organizations that share similar domain of business, for example, financial services, healthcare services, mission or security services, policy or compliance considerations. Figure 4 shows an example of a Community Cloud model.

The model is owned, managed and operated by an organization or a third party and may exist on or off premises. The level of security is much higher than a public cloud and less than a private cloud [3, 29, 31].

4.2 Cloud Services

The U.S. National Institute of Standards and Technol-

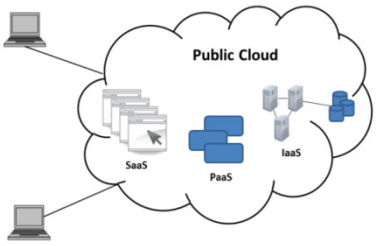

Fig. 2. Public Cloud

ogy (NIST) has classified the cloud service models into three categories namely Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Each service model has its own capabilities and corresponds to serve as an organizational scope and depict a level of abstraction over the computational environment [30, 38, 39]. On the other hand, a research conducted by Youseff, Butrico and Da Silva [2] depicted that the cloud computing architecture falls into five layers as Cloud Applications (SaaS), Cloud Software Environment (PaaS), Cloud Software Infrastructure (Computational Resources as Iaas), Storage as (DaaS), Communications as (CaaS), Software Kernel and Hardware or Firmware (HaaS). Each layer corresponds a level of abstraction that hides all underlying complex components and provides simplified access of the resources to the cloud customers. Youseff, et al., [2] were among the first to attempt a unified ontology of cloud computing. The novel facilitates a comprehensive understanding of cloud technology and its relevant components so to assist the scientific community in constructing more efficient functionalities and features for the cloud (cited by [40]). Followings are the cloud service models described:

4.2.1 Software as a Service (SaaS)

It is an on-demand software delivery model with the highest level of abstraction in the cloud [41]. The customers' applications and data are typically stored in the cloud and are accessed from various users' devices (laptop, smart phone, iPad) through thin client interfaces as web browser over the network, typically Internet. These ready-made web-based or desktop applications are range from basic online email accounts like Hotmail or Gmail to complex tools like CRM applications [41]. A SaaS model is implemented to provide benefits of commercially licensed enterprise level business application at a very low cost [42]. This model appears to be most appealing to cloud customers because of the reduction of software and system maintenance expenditures or upfront costs into hardware and software licenses. Additionally, there is no hassle for software upgrade as patches and features can be deployed centrally [40]. The service provider manages and controls the core cloud infrastructure including servers, storage, network, operating systems, applications and even the security clauses for the customers' information, while, the customer only administers some limited application configuration settings [30, 31, 38, 43]. A SaaS model provides multi-tenant applications, which are shared, but logically distinctive, to multiple customers [39].

Examples of SaaS applications: Facebook, GmailTM, Yahoo user applications, Google Docs, Microsoft online services and more [37, 43]. Examples of SaaS providers include Salesforce.com (provides online CRM), Windows Live Mesh, Rackspace and SAP Business By-Design, Google Drive (online storage), SpringCM (content or document management), Oracle (on-demand for CRM), Ning (social networks), Zaora (billing), Google Apps or MS Office (desktop productivity), StreetSmarts (sales), Xero (financials) and DropBox (collaboration) [21, 29, 41].

4.2.2 Platform as a Service (PaaS)

It is an on-demand computing platform and solution stack [29] service delivery model with a medium level of abstraction that helps to speed up the development process. The cloud customers can deploy their own applications or can personalize applications by using programming languages and database tools (e.g. J2EE, Java Spring, Ruby on Rails, .NET, PHP) on the development environment of the platform [30, 31]. There is no need to install any developing tools on customer's computer. The PaaS platform provides set of well-defined Application Programming Interfaces (API), with services of configuration management, to interact with other cloud applications [39, 40, 42]. While developing application, the developers take advantages from features as authentication services, communications services, automatic scaling, load balancing, graphical user interfaces and more [40]. The cloud service provider controls and manages all the underlying cloud physical infrastructure including housing, network, storage, servers and operating systems [29, 31], while, the cloud customer controls over the hosting configurations of the deployed applications and can avoid concerning about such expenditures [29, 36, 38]. The cloud service provider is responsible to ensure the security of rented services to the customers and their applications on the platform [39].

Examples of PaaS providers: Microsoft AzureTM Service platform, Google App Engine, Amazon Web Services (AWS) Elastic Beanstalk, Amazon SimpleDB or RDS for database, SOASTA for development and testing, MS Azure or Force.com for general purpose, Amazon SQS, SNS, IBM Cast Iron or Informatica on-demand for integration and Cloud9 Analytics for business intelligence [29, 39, 40, 41, 43].

4.2.3 Infrastructure as a Service (IaaS)

It is an on-demand service of an abstracted computing infrastructure or a virtualization platform [39] that provides servers, operating systems, storage and network to develop, host and execute applications [29, 30]. Infrastructure layer, also known as the virtualization layer, is the most imperative aspect in cloud computing, as the physical resources are partitioned by virtualization technologies and are used more efficiently, for example, dynamic resource assignment, Xen, KVM and VMware [21]. Instead of purchasing expensive housing, processing power, data-centre, software, complex hardware and network equipments, the cloud customers use the IaaS resources as virtualized objects that can be monitored through a service interface. Except basic underlying infrastructure, the cloud customers are responsible for security provisions of the entire setup of applications or the leased infrastructure [39]. They manage and have control over operating systems, storage, deployed applications, hosting firewalls and possibly some limited network setup configurations [29, 30, 31]. The cloud users install, configure and operate the virtual machines rented from the cloud providers, in which, they can install any operating system [41] and their own added services for external or internal use [42]. However, the cloud users can also use pre-installed and configured VMs as a base setup by the IaaS providers [41]. In parallel to computational resources, data storage is also offered as a service, Storage as a Service, that provides cloud customers on-demand remote access flexible storage capability. The service providers typically provide assurances for high availability, data consistency, redundancy, performance and reliability.

Examples are Amazon's Elastice Block Storage (EBS) or Simple Storage Service (S3) and Rackspace's Cloud Files. In addition, data are also provided as services. For example Amazon provides human genome or US census data sets for analytics services [40]. Organizations with one-time data processing demands and very large data storage use IaaS services [43]. Others can simply rent a server time, memory or have an operating system run on top with their own applications [42].

Example of IaaS service providers: Flexiscale, GoGrid, Amazon Web ServicesTM, Kaavo for cloud broker, Amazon CloudWatch or VPC for services management, Verizon CaaS, Rackspace Cloud Servers, Serve Path GoGrid or Amazon EC2 for compute and Amazon S3 & EBS for storage, Amazon's Elastic Compute Cloud, Enomalism Elastic Computing Infrastructure [21, 29, 37, 39, 40, 41, 43].

4.2.4 Communication as a Service (CaaS)

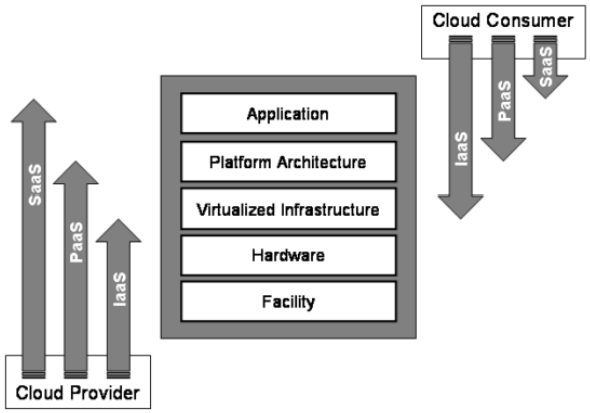

Fig. 5. Scopes and Control (NIST)

Youseff, et al. [2] has also defined a new idea of service as Communication as a Service (CaaS) that will ensure quality communication services like network security, virtual overlays for traffic isolation or dedicated bandwidth, communication encryption, message delay and network monitoring.

4.2.5 Software Kernel Layer

Youseff, et al. [2] defined a kernel layer as a basic software management for the physical servers that can be implemented as OS kernel, hypervisor, VM monitor or cluster middleware.

4.2.6 Hardware as a Service (HaaS)

It provides almost similar services as IaaS, only hardware and VMs are rented in respective services [41]. The HaaS providers leased out physical resources, which forms the backbone of cloud computing, like computers, servers, switches, routers, firewalls, load-balancer, power or cooling systems [21]. The cloud users have full control over rented HaaS resources [41] and they perform maintenance include hardware configuration, fault tolerance, traffic management, power and cooling resource management, through the Internet. Typically, HaaS is put into operation in a data centre which contains thousands of servers in rows and that they are interconnected through switches, routers etc. [21].

Example of HaaS service provider: NewServers [41], IBM's Managed Hosting service [40].

According to NIST, cloud infrastructure can be divided in five distinct conceptual layers as shown in Figure 5 below:

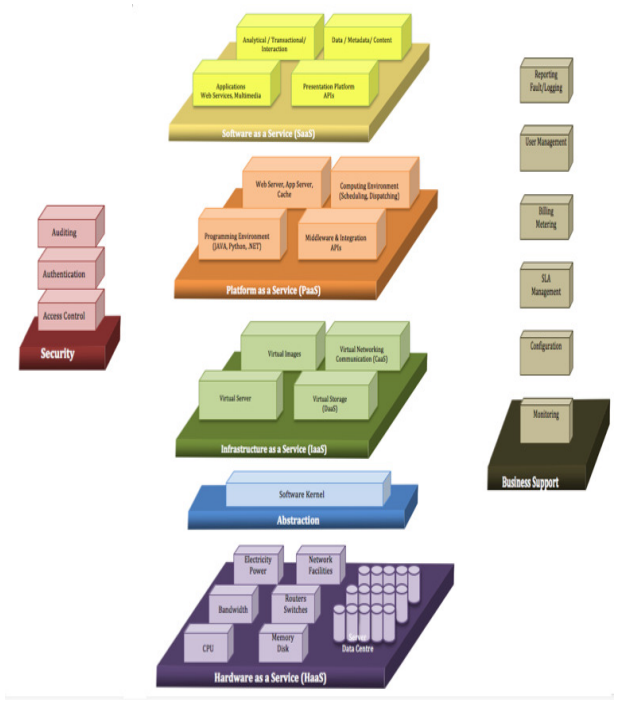

Fig. 6. Cloud Service Models and Business Support

NIST has illustratedthe prospects of scope and control between the cloud providers and customers over each layer of service models. Facility layer includes heating, air cooler, ventilation,power, communications and related physical plant, while Hardware layer includes computers, network, storageand related physical computing infrastructures. Facility and Hardware layers can be both termed as HaaS. The Virtualization Infrastructure layer or IaaS includes the logical elements to establish computing platform, such as, virtual machines, virtual storage and virtual network. The Platform layer or PaaS includes compilers, libraries, middleware, utilities and other software development and deployment tools. The Application layer or SaaS provides the application for the end-user or other programs. Cloud computing encompasses with a service provider side and a client side. The left and the right arrows in the Figure 6 represent the range of scope and control over the service layers by the cloud service provider and customer respectively. In general, the higher the levels of service layers are consumed by the customer, the more scope and control the customer has over the system. However, the cloud provider has full control over the two bottom physical layers [30].

Unlike conventional hosting service environments, the cloud architecture is very much modular and the layers are loosely coupled from one another to provide flexibility for advancement. Such modularity helps cloud computing to comply with various APIs and thus cutting down in management and maintenance expenses [21].

Figure 6 shows a Cloud computing architecture in a visual form with layers of service models. The figure has been visualized from the defined cloud architecture by different regulatory bodies and research works [2, 3, 12, 21, 24, 29, 42, 44].

Terminologies from Figure 6:
SaaS is built on top of PaaS stacks and provides presentational platform and self-contained operating environment through applications and management capabilities. PaaS resides above IaaS stacks and provides programming environment, system integration and virtualization middleware capabilities. IaaS provides entire infrastructure resource stacks and deliver physical and logical connectivity within these resources. Software kernel manages software integration over physical hardware. HaaS provides basic physical resources CPUs, routers, memory, disk, power and more. Business Support provides deployment, configuration, scheduling, performance review, monitoring, software lifecycle management, fault and logging, user management, authentication, metering and billing [12, 24, 29]. As innovation compels rapid standard product development, the cloud stakeholders will benefit from various ways of interacting service models for developing applications and interfaces. Such flexible capabilities allow cloud customers to customize the service models that work best for their business requirements.

5 Conclusion

Cloud based business applications can be an inexpensive approach as it reduces the overall complexity and saves costs from expensive real-estate, hardware, network bandwidth, cooling equipment, electricity, operational costs, software licenses, physical security and human resources. Cloud service providers bill for each instance, like pay-as-you-go, so better accounta-

bility and transparency of costs. Unlike traditional computing, it is scalable and consumes less time to start up. General public can access these hosted data or application from cloud servers over Internet through their devices. It delivers quality services at much lower costs that often discourage small firms to invest in expensive computing resources. Instead, they can concentrate more on customer requirements, which in terms effect in competitive advantage, and produce solutions that can contribute to make new innovations.

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