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# Cloud Computing: An Overview

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## 1.1 Introduction

Cloud computing is receiving keen interest and is being widely adopted. It offers clients applications, data, computing resources, and information technology (IT) management functions as a service through the Internet or a dedicated network. Several converging and complementary factors have led to cloud computing's emergence as a popular IT service-delivery model that appeals to all stakeholders. Considered as paradigm change in IT, it is being adopted for a variety of applications – personal, academic, business, government, and more – not only for cost savings and expediency but also to meet strategic IT and business goals. It is transforming every sector of society and is having a profound impact, especially on the IT industry and on IT professionals – application developers, enterprise IT administrators, and IT executives. Driven by advances in cloud technology, the proliferation of mobile devices such as smartphones and tablets, and use of a variety of applications supported by ubiquitous broadband Internet access, the computing landscape is continuing to change. There is an accompanying paradigm shift in the way we deliver and use IT.

Cloud computing is a radical new IT delivery and business model. Users can use cloud services when and where they need them and in the quantity that they need, and pay for only the resources they use. It also offers huge computing power, on-demand scalability, and utility-like availability at low cost.

Cloud computing is no longer hype. Individuals are using cloud-based applications, such as Web mail and Web-based calendar or photo-sharing Web sites (e.g., Flickr, Picasa) and online data storage. Small- and medium-sized enterprises are using cloud-based applications for accounting, payroll processing, customer

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relationship management (CRM), business intelligence, and data mining. Large enterprises use cloud services for business functions, such as supply-chain management, data storage, big data analytics, business process management, CRM, modeling and simulation, and application development. Research studies reveal that users give convenience, flexibility, the ability to share information, and data safety as major reasons for engaging in cloud computing activities.

As cloud computing is moving towards mainstream adoption, there is considerable excitement and optimism, as well as concerns and criticism. Many people have incomplete information or are confused about cloud computing's real benefits and key risks, which matter to them. Given its transformational potential and significance, it is important that students, IT professionals, business managers and government leaders have an informed, holistic understanding of cloud computing and how they can embrace it.

In this chapter, we present an overview of cloud computing concepts, cloud services, cloud-hosting models, and applications. We also outline the benefits and limitations of cloud computing, identify its potential risks, and discuss the prospects for the cloud and what businesses and individuals can do to embrace cloud computing successfully. Finally, we discuss the prospects and implications of cloud computing for businesses, the IT industry, and IT professionals.

## 1.2 Cloud Computing

In its evolution since the mid-1970s, computing has passed through several stages – from mainframe computers to minicomputers to personal computers to network computing, client-server computing, and distributed computing. Now, coming full circle, computing is migrating outward to the clouds, to distant computing resources reached through the Internet.

Depending on how you view cloud computing, it can be described in different ways. There are several definitions, but the National Institute of Standards and Technology (NIST) offers a classic definition that encompasses the key elements and characteristics of cloud computing (Mell and Grance, 2011):

> Cloud computing is 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.

The International Organization for Standardization (ISO) provides a similar definition, choosing to call cloud computing an "evolving paradigm": "Cloud computing is a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand" (ISO/IEC DIS 17789:2014, 2014).

Gartner defines cloud computing in simplistic terms as "A style of computing where scalable and elastic IT-enabled capabilities are provided as a service to multiple customers using Internet technologies" (http://www.gartner.com/it-glossary/cloud-computing, accessed November 25, 2015).

Another definition encompasses several key characteristics of cloud computing and presents a broader and practical view of it (Vaquero *et al.,* 2009):

> Clouds [are] a large pool of easily usable and accessible virtualized resources such as hardware, development platforms and/or services. These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLAs [service-level agreements].

***Table 1.1*** *Cloud characteristics*

| Cloud characteristic | Description |
|---|---|
| On-demand self-service | Computing capabilities (e.g. server time and network storage) can be unilaterally automatically provisioned as needed). |
| Broad network access | Capabilities are accessible through heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations). |
| Resource pooling | Computing resources (e.g. storage, processing, memory, and bandwidth) are pooled to serve multiple consumers, and are dynamically assigned and reassigned according to demand. Customers have no control over the exact location of resources, but may be able to specify location (e.g., country, state, or datacenter). |
| Rapid elasticity | Capabilities can be elastically provisioned and released commensurate with demand. Available capabilities often appear to be unlimited. |
| Measured service | Resource use is automatically controlled and optimized through metering capabilities, appropriate to type of service (e.g., storage, processing, bandwidth, and active user accounts). |
| Multitenancy | Cloud computing is a shared resource that draws on resource pooling as an important feature. It implies use of same resources by multiple consumers, called tenants. |

### 1.2.1 Key Cloud Characteristics

Cloud computing has the following key distinguishing characteristics:

- on-demand self-service;
- broad network access;
- resource pooling;
- rapid elasticity and scalability;
- measured service;
- multitenancy.

These characteristics, briefly outlined in Table 1.1, differentiate cloud computing from other forms of traditional computing.

The cloud draws on some of the older foundations of IT such as centralized, shared resource pooling, utility computing, and virtualization, and incorporates new mechanisms for resource provisioning and dynamic scaling. It adopts new business and revenue models and incorporates monitoring provisions for charging for the resources used. Cloud computing became more widely available only with the adoption of broadband Internet access and advances in virtualization and datacenter design and operation. Philosophical and attitude changes by IT vendors and users were also drivers for cloud's popularity.

### 1.2.2 Cloud computing attributes

Computing clouds have several distinguishing attributes. They:

- have massive resources at their disposal and support several users simultaneously;
- support on-demand scalability of users' computational needs;

- offer ubiquitous access – stored data and applications are accessible by authorized users anywhere, anytime;
- facilitate data sharing, enterprise-wide data analysis, and collaboration;
- are generally self-healing, and can self-reconfigure providing continuous availability in case of failure of their computing resources;
- offer enhanced user experience via a simplified Web-browser user interface.

## 1.3 Cloud Service Models

A computational or network resource, an application or any other kind of IT service offered to a user by a cloud is called a cloud service. Cloud services range from simple applications such as e-mail, calendar, word processing, and photo sharing to various types of complex enterprise applications and computing resources offered as services by major providers. For comprehensive information on cloud offerings currently available from several vendors, see the Cloud Computing Directory (http://www.cloudbook.net/directories/product-services/cloud-computing-directory, accessed November 25, 2015) and also refer to Chapter 2.

Depending on the type of services offered, cloud services can be classified into three major categories (see Table 1.2): software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). In addition to these foundational services, several cloud support services, such as security as a service and identity and access management as a service, are on offer. Each service category can be used independently or used in combination with others.

### 1.3.1 Software as a Service

"Software as a service" clouds are also called *software clouds*. In the SaaS model, an application is hosted by a cloud vendor and delivered as a service to users, primarily via the Internet or a dedicated network. It eliminates the need to install and run the application locally, on a user's computer, and thereby also relieves the users from the burden of hardware and software maintenance and upgrades. The software license is not

***Table 1.2*** *Cloud service models*

| Service model | Capability offered to the user | Controllability by users |
|---|---|---|
| Software as a service (SaaS) | Use of applications that run on the cloud. | Limited application configuration settings, but no control over underlying cloud infrastructure – network, servers, operating systems, storage, or individual application capabilities. |
| Platform as a service (PaaS) | Deployment of applications on the cloud infrastructure; may use supported programming languages, libraries, services, and tools. | The user has control of deployed applications and their environment settings, but no control of cloud infrastructure – network, servers, operating systems, or storage. |
| Infrastructure as a service (IaaS) | Provisioning of processing, storage, networks, etc.; may deploy and run operating systems, applications, etc. | The user has control of operating systems, storage, and deployed applications running on virtualized resources assigned to the user, but no control over underlying cloud infrastructure. |

owned by the user. Users are billed for the service(s) used, depending on their usage. Hence, costs to use a service become a continuous expense rather than a huge up-front capital expense at the time of purchase. Examples of SaaS include Webmail, Google Apps, Force.com CRM, Quicken online accounting, NetSuite's Business Software Suite**,** Sun Java Communications Suite, and Paychex payroll management system.

### 1.3.2 Platform as a Service

In the PaaS model, the platform and tools for application development and middleware systems are hosted by a vendor and offered to application developers, allowing them simply to code and deploy without directly interacting with the underlying infrastructure. The platform provides most of the tools and facilities required for building and delivering applications and services such as workflow facilities for application design, development, testing, deployment, and hosting, as well as application services such as Web service integration, database integration, security, storage, application versioning, and team communication and collaboration. Examples of PaaS include Google App Engine, Microsoft Azure, Amazon's Web services and Sun Microsystems NetBeans IDE. The PaaS cloud is also called *platform cloud or cloudware*.

### 1.3.3 Infrastructure as a Service

In an IaaS cloud, raw computer infrastructure, such as servers, CPU, storage, network equipment, and datacenter facilities, are delivered as a service on demand. Rather than purchasing these resources, clients get them as a fully outsourced service for the duration that they need them. The service is billed according to the resources consumed. Amazon Elastic Compute Cloud (EC2), GoGrid, and FlexiScale are some of the examples of IaaS clouds. This type of cloud is also called a *utility cloud* or *infrastructure cloud*.

An IaaS cloud exhibits the following characteristics:

- availability of a huge volume of computational resources such as servers, network equipment, memory, CPU, disk space and datacenter facilities on demand;
- use of enterprise-grade infrastructure at reduced cost (pay for the use), allowing small and midsize enterprises to benefit from the aggregate compute resource pools;
- dynamic scalability of infrastructure; on-demand capacity can be easily scaled up and down based on resource requirements.

### 1.3.4 Cloud Support Services

In order to embrace the promise of clouds fully and successfully, adopters must use one or more of the three foundational cloud services – software as a service (SaaS), infrastructure as a service (IaaS), and platform as a service (PaaS). But they must also address several other related factors, such as security, privacy, user access management, compliance requirements, and business continuity. Furthermore, would-be adopters may have to use services from more than one service provider, aggregate those services, and integrate them with each other and with the organization's legacy applications / systems. Thus they need to create a cloud-based system to meet their specific requirements. To assist them in this, and to facilitate transition to the cloud, a cloud ecosystem is emerging that aims to offer a spectrum of new cloud support services that augment, complement, or assist the popular SaaS, IaaS, and PaaS offerings. Examples of such cloud support services are data storage as a service (DSaaS), analytics as service (AaaS), desktop as a service (DAAS), security as a service (SecaaS), identity and access management as a service (IAMaaS), and monitoring as a service (MaaS).

#### *1.3.4.1 Data Storage as a Service (DSaaS)*

With cloud storage, data is stored in multiple third-party servers, rather than on dedicated servers used in traditional networked storage, and users access a virtual storage. The actual storage location may change as the cloud dynamically manages available storage space; however, the users see a static location for their data. Key advantages of cloud storage are reduced cost and better data safety and availability. Virtual resources in the cloud are typically cheaper than dedicated physical resources connected to a PC or the network. Data stored in a cloud is generally safe against accidental erasure or hard-drive failures as Cloud Service Providers (CSPs) keep multiple copies of data across multiple physical machines continually. If one machine crashes, the data that was on that machine can be retrieved from other machine(s) in the cloud. Cloud vendors generally offer better security measures than a small business could afford. Enterprise data storage in clouds, however, raises some concerns, which are discussed later.

#### *1.3.4.2 Analytics as a Service (AaaS)*

Analytics as a service (AaaS), also known as data analytics as a service (DAaaS), refers to the provision of analytics platforms – software and tools – on a cloud for analysis and mining of large volumes of data (big data). Several vendors, such as IBM, Amazon, Alpine Data Labs, and Kontagent, offer such services. Customers can feed their data into the platform and get back useful analytic insights. It lets clients use particular analytic software for as long as it is needed and they pay only for the resources used. As a general analytic solution, AaaS has potential use cases in a range of areas and offers businesses an alternative to developing costly in-house high-performance systems for business analytics. An AaaS platform is extensible and scalable and can handle various potential use cases. It lets businesses get their data analytics initiatives up and running quickly.

#### *1.3.4.3 Desktop as a Service (DaaS)*

Desktop as a Service (DaaS) is a cloud service in which the back-end of a virtual desktop infrastructure (VDI) is hosted by a cloud service provider. It provides users with the ability to build, configure, manage, store, execute, and deliver their desktop functions remotely. Examples of such service are VMware Horizon Air, Amazon WorkSpaces and Citrix XenDesktop. Clients can purchase DaaS on a subscription basis and the service provider manages the back-end responsibilities of data storage, backup, security and upgrades. DaaS is well suited for a small or mid-size businesses that want to provide their users with a virtual desktop infrastructure (VDI), but find that deploying a VDI in-house is not feasible due to cost, implementation, staffing and other constraints.

#### *1.3.4.4 Security as a Service (SecaaS)*

Security as a Service (SecaaS) refers to the provision of security applications and services via the cloud, either to cloud-based infrastructure and software or from the cloud to the customers' on-premises systems. This enables enterprises to make use of security services in new ways, or in ways that would not be cost effective if provisioned locally. The services provided include authentication, virus detection, antimalware/spyware, intrusion detection, encryption, e-mail security, Web security, and security event management.

#### *1.3.4.5 Identity and Access Management as Service (IAMaaS)*

Identity and access management as a service (IAMaaS) offers cloud-based IAM services to clients and requires minimal or no on-premises presence of hardware or software. Services include user provisioning, authentication, authorization, self-service, password management, and deprovisioning.

#### *1.3.4.6 Monitoring as a Service (MaaS)*

Monitoring-as-a-service (MaaS) facilitates the deployment of monitoring functionalities for various other services and applications within the cloud. Monitoring focuses on how services are performing. The common application for MaaS is online state monitoring, which continuously tracks certain states of applications, networks, systems, instances or any element that may be deployable within the cloud.

## 1.4 Cloud Computing Deployment Models

Based on where the cloud is deployed and by whom, who owns and manages it, and who its primary users are, clouds are classified into five categories: public cloud, private cloud, virtual private cloud, community cloud, and hybrid cloud.

### 1.4.1 Public Cloud

The public cloud is the most common and widely known form of cloud, and is open for anyone – business, industry, government, nonprofit organizations and individuals – to use. The cloud infrastructure is, however, owned and managed by the cloud service provider – the organization that offers the cloud services. Public cloud services are offered on a pay-per-usage model; however, some applications on public clouds are accessible for free.

### 1.4.2 Private Cloud

A private cloud is deployed, provided, and controlled by an enterprise behind its firewall for its own use. Unwilling to head into public clouds because of concerns surrounding them and compliance requirements, some enterprises deploy their own cloud computing environments for their own (and their business partners') exclusive use. Thus, by having their own cloud, they gain operational efficiencies, effectively use their existing resources, if any, and have full control over the cloud, the applications, and data on the cloud.

### 1.4.3 Virtual Private Cloud

A virtual private cloud (VPC) is a segment of a public cloud, designated for a user with additional provisions and features for meeting that user's specific security and compliance requirements. Virtual private clouds provide users with more control over the resources they use than a pure public cloud does. An example of this type of cloud is Amazon's VPC.

### 1.4.4 Community Cloud

A community cloud is known as an industry cloud or vertical cloud. It is optimized and specially deployed for use by a particular industry sector or a group of users so that it meets specific requirements to address issues that are crucial to them. AcademyOne's Navigator Suite (aimed at academics and students) and Asite Solutions (specifically designed for construction industry) are examples of these types of clouds.

### 1.4.5 Hybrid Clouds

A hybrid cloud is a combination of two or more of the above cloud models. In this model, an enterprise makes use of both public and private clouds – deploying its less critical, low-risk services on a public cloud and business-critical core applications on its internal private cloud. A hybrid model allows for selective

implementation addressing concerns about security, compliance, and loss of control, as well as enabling adoption of public clouds that offer cost benefits and more application options.

## 1.5 Benefits, Limitations, and Concerns associated with Cloud Computing

Cloud computing offers several substantial benefits to its users – individuals and enterprises. But it also has limitations and poses some risks, the effects of which depend on the application type and liabilities involved. In embracing cloud computing, therefore, users must understand, acknowledge, and address its limitations and risks.

### 1.5.1 Benefits of Cloud Computing

The key benefits of embracing a cloud include reduced capital and operational cost, improved flexibility, on-demand scalability, easier and quicker application deployment, ease of use, and availability of vast cloud resources for every kind of application or use. Many applications, including e-mail, office document creation, and much data storage continue to move into the clouds to reap the benefits of this new paradigm in IT.

Cloud computing frees users and businesses from the limitations of local computing resources and allows them to access the vast computational resources and computation power out in the cloud. For users to make use of cloud resources from anywhere in the world at any time, all that is needed is an Internet connection and a Web browser. The cloud lets the users run even computationally intensive or storage-intensive applications, as all of their computing and storage needs are sourced from the cloud.

Public clouds eliminate significant capital expenses for hardware and upfront license fees for software, as well as the headaches of hardware and software maintenance and upgrade by users. Cloud applications can be deployed instantly and simultaneously to thousands of users in different locations around the world, and can be regularly updated easily. Further, as clouds provide improved business continuity and data safety, they are particularly attractive to small- and medium-size enterprises, as well as enterprises in disaster-prone areas. Startups and application developers can use computing clouds to try their ideas without having to invest in their own infrastructure.

Other benefits of using a cloud are:

- lower operational and service cost to users – they pay for what they use;
- on-demand scalability to meet peak and uncertain computing demands;
- shared access to data/application-supporting collaboration and teamwork;
- greater data safety than most businesses can provide and manage in their own on-premises IT systems;
- ease of, and quicker, application deployment;
- freedom to use a vast array of computational resources on the cloud.

### 1.5.2 Limitations of Cloud Computing

There are a few limitations that users must consider before moving to the cloud. The key limitations of the cloud are:

- need for a reliable, always-available high-speed network access to connect to clouds;
- possibility of slow response at times due to increased traffic or uncertainties on the network, or higher load on computers in the cloud;
- additional vulnerabilities to security of data and processes on clouds;
- risk of unauthorized access to users' data;

- loss of data due to cloud failure (despite replication across multiple machines);
- reliability and continued availability of services offered by cloud service providers.

### 1.5.3 Cloud Concerns

Despite its promises, cloud computing's mainstream adoption is constrained by perceived and real barriers and concerns. Security and privacy of data and applications on the cloud are two of the top concerns of users in moving into clouds followed by reliability and availability of cloud services, as well as adherence to compliance requirements, where applicable. External clouds raise additional concerns about loss of control and sharing data outside the enterprise firewall.

Many people think that because they don't know where their data is stored remotely, and because the applications are accessed over the Internet, cloud services are insecure. They believe that if data and applications were physically housed in computers under their control, they would protect them better. But this is not necessarily the case as economies of scale allow a CSP to offer more sophisticated security, disaster recovery, and service reliability than an individual institution (particularly a small enterprise) can afford to deploy on its own.

Cloud computing security concerns and requirements can differ considerably among the stakeholders – end-user service consumers, cloud service providers and cloud infrastructure providers – and are determined by the specific services they provide or consume. The Cloud Security Alliance (CSA) has identified seven top cloud security threats and outlined impact of those threats as well as remediation for them (Cloud Security Alliance, 2009, 2010).

They are:

1. Abuse and nefarious use of cloud computing.
2. Insecure application programming interfaces.
3. Malicious insiders.
4. Shared technology vulnerabilities.
5. Data loss/leakage.
6. Account, service & traffic hijacking.
7. Unknown risk profile.

Based on a 2013 survey, CSA has also identified nine critical threats to data security in the order of severity:

1. Data breaches.
2. Data loss.
3. Account hijacking.
4. Insecure APIs.
5. Denial of service.
6. Malicious insiders.
7. Abuse of cloud services.
8. Insufficient due diligence.
9. Shared technology issues. (Cloud Security Alliance, 2013)

Many enterprise computing applications must meet compliance requirements, which depend on the type of business and customer base. To better ensure the desired level of service delivery and to limit liabilities, service level agreements (SLAs) with the cloud vendors are highly recommended when consuming cloud services. A cloud SLA specifies terms and conditions as well as expectations and obligations of the cloud service provider and the user.

By careful planning and incorporating the user's requirements into cloud service offerings, both the cloud vendors and users can reduce risk and reap the rewards of cloud-based hosted services.

## 1.6 Migrating to Clouds

A new mindset is needed to embrace cloud computing. To use and benefit from clouds successfully, an enterprise must prepare itself strategically, culturally and organizationally, and take a holistic view of cloud computing. It must develop its strategic plan and follow a phased, pragmatic, step-by-step approach that provides a business context for its cloud adoption. It must choose a cloud option that is appropriate for the application, considering and managing the risks of migrating to clouds by applying safeguards. Moving into clouds is not just about technology; the cloud migration should also factor in the role of people, processes, and services, and the change-management process. Migration to clouds will also demand a new kind of IT management and governance framework.

### 1.6.1 Choosing your Cloud

A major decision that IT managers and enterprises have to make is the type of cloud – public clouds, private clouds, or variations of them – that is well suited for their application. To arrive at a better decision, they have to understand the differences between these deployments, and understand the risks associated with each in the context of the characteristics and requirements of their applications. They also have to consider:

- performance requirements, security requirements, and cloud service availability and continuity;
- amount of data transfer between the user and the clouds and/or between the clouds;
- sensitive nature of the applications;
- control of their application and data;
- total costs involved;
- whether the external cloud providers are trusted;
- terms and conditions imposed by the external cloud providers; and
- in-house technical capabilities. (Claybrook, 2010)

## 1.7 Cloud Prospects and Implications

Computing clouds are powerful change-agents and enablers. Soon the core competency for most enterprises would be using IT services and infrastructure that cloud computing offers as hosted services, not building their own IT infrastructure. Cloud computing will profoundly change the way people and enterprises use computers and their work practices, as well as how companies and governments deploy their computer applications. It is transforming the way we think about computing environments and will drastically improve access to information for all, as well as cutting IT costs. Ongoing developments – the increasing maturity of clouds, the introduction of new cloud computing platforms and applications, the growth in adoption of cloud computing services, and the emergence of open standards for cloud computing – will boost cloud computing's appeal to both cloud providers and users.

Clouds will enable open-source and freelance developers to deploy their applications in the clouds and profit from their developments. As a result, more open-source software will be published in the cloud. Clouds will also help close the digital divide prevalent in emerging and underdeveloped economies and may help save our planet by providing a greener computing environment.

Major stumbling blocks for enterprises moving their applications into the cloud in a big way are reliability, performance, bandwidth requirements, trust, and security issues. However, these barriers are gradually being lowered or removed. Government regulations and other compliance requirements lag behind market developments and demand, and these aspects need to be addressed swiftly.

Driven by economic imperatives and the promise of flexibility and convenience, cloud computing will gain wider acceptance. Like the Internet, cloud computing is a transformational technology. It will mature rapidly, as vendors and enterprises come to grip with the opportunities and challenges that it presents.

Cloud computing creates new possibilities for businesses – IT and non-IT – and there will be new investments. Researchers will be better able to run experiments quickly on clouds, share their data globally, and perform complex analysis and simulations. Universities and training institutions will offer new courses and programs, focused on cloud computing.

Some IT professionals, particularly those who work with on-premises IT systems, might be afraid of losing their jobs because of the ongoing adoption of cloud computing. The truth is that while some might lose their current job, they might be absorbed in other roles. So, they should be prepared to learn new skills and evolve in these new roles. They might need to learn how to deploy and manage applications in the cloud and minimize risks, as well as how to work with cloud providers. There will be a need for professionals to develop new kinds of cloud applications and to design, deploy, and maintain computing clouds.

Cloud service providers, the IT industry, professional and industry associations, governments, and IT professionals all have a role to play in shaping, fostering, and harnessing the full potential of the cloud ecosystem.

## 1.8 Conclusions

The cloud ecosystem is evolving to provide a vast array of services that support and aid deployment of cloud-based solutions for a variety of applications across many different domains. Further, new types of cloud deployments, new models that deliver value-added services, and new costing and business models are on the horizon. Besides cloud service providers and users, many new players that perform niche roles are getting into the cloud arena. Cloud-based applications are being adopted widely by individuals and businesses in developed countries, and even more so in developing economies such as India, South Africa, and China. Governments in many countries are promoting adoption of clouds by businesses – particularly micro, small, and medium enterprises, as well as individuals. As a result, a new bigger cloud ecosystem is emerging.

## References

Claybrook, B. (2010) Cloud vs. in-house: Where to run that app? *Computer World*, http://www.computerworld.com/article/2520140/networking/cloud-vs--in-house--where-to-run-that-app-.html (accessed November 25, 2015).

Cloud Security Alliance (2009) *Security Guidance for Critical Areas of Focus in Cloud Computing V2.1*, https://cloudsecurityalliance.org/csaguide.pdf (accessed November 25, 2015).

Cloud Security Alliance (2010) *Top Threats to Cloud Computing V1.0*, http://cloudsecurityalliance.org/topthreats/csathreats.v1.0.pdf (accessed November 25, 2015).

Cloud Security Alliance (2013) The Notorious Nine: Cloud Computing Top Threats in 2013, Cloud Security Alliance, https://downloads.cloudsecurityalliance.org/initiatives/top_threats/The_Notorious_Nine_Cloud_Computing_Top_Threats_in_2013.pdf (accessed November 25, 2015).

ISO/IEC DIS 17789:2014 (2014) *Information Technology – Cloud Computing – Reference Architecture*, International Organization for Standardization, Geneva.

Mell, P. M., and Grance, T. (2011) *The NIST Definition of Cloud Computing*. Special Publication 800-145. NIST, Gaithersburg, MD, http://www.nist.gov/customcf/get_pdf.cfm?pub_id=909616 (accessed November 25, 2015).
Vaquero, L. M, Rodino-Merino, L., Caceres, J., and Lindner, M. (2009) A break in the clouds: Towards a cloud definition. *ACM SIGCOMM Computer Communication Review* **39**(1), 50–55.

## Cloud Vocabulary

The following are some of the key terms commonly used in cloud computing:

**Cloudburst.** The term is used in a positive and a negative sense. Cloudburst (positive) refers to the dynamic deployment of a software application that runs on an enterprise's in-house computing resources to a public cloud to address a spike in demand. But cloudburst (negative) conveys the failure of a cloud computing environment due to its inability to handle a spike in demand.
**Cloudstorming.** This term refers to the act of connecting multiple cloud computing environments.
**Cloudware.** This is a general term referring to a variety of software, typically at the infrastructure level, which enables building, deploying, running, or managing applications in a cloud computing environment.
**Cloud provider.** A cloud provider is an organization that makes a cloud computing environment available to others, such as an external or public cloud.
**Cloud enabler.** This term refers to an organization or a vendor that is not a cloud provider per se but makes technology and services available, such as cloudware, which enables cloud computing.
**Cloud portability.** This term refers to the ability to move applications (and often their associated data) across cloud computing environments from different cloud providers, as well as across private or internal cloud and public or external clouds.
**Cloud interoperability.** This term refers to the ability of two or more systems or applications to exchange information and to use the information that has been exchanged together.
**Cloud sourcing.** This term refers to leveraging services in the network cloud – raw computing, storage, messaging, or more structured capabilities, such as vertical and horizontal business applications, even community – to provide external computing capabilities, often to replace more expensive local IT capabilities. While it might provide significant economic benefits, there are some attendant tradeoffs, such as security and performance. These services are delivered over the network but generally behave as if they are local.