Cloud computing related variables

1. Cloud Service Models

Depending on how technology is provided and used, the researchers listed the three main types of services offered by cloud computing: infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS) (Despotović-Zrakić, Simić, Labus, Milić, & Jovanić, 2013; González-Martínez, Bote-Lorenzo, Gómez-Sánchez, & Cano-Parra, 2015; Lakshminarayanan, Kumar, & Raju, 2013; Sultan, 2010). As you may remember from other edX Cloud Computing classes, services in the cloud can be delivered to the customer at three basic levels, which differ by what components of the hardware/software stack are maintained and managed by the cloud provider, and which by the customer.

1.1. Infrastructure as a Service (IaaS)

Infrastructure as a Service (IaaS) is the backbone of all cloud services, providing on-demand physical and virtual computing resources –storage, network, firewall, load balancers, etc. – available to customers. In this model customers install operating system on the machines as well as their application software by themselves. IaaS can be used to satisfy the infrastructure needs of the students, faculties or researcher globally or locally with some specific hardware configuration for a specific task.

1.2. Platform as a Service (PaaS)

Platform as a Service (PaaS) allows its customers to develop, run, and manage applications without worrying about the underlying infrastructure. The cloud provider provides customers with a complete development environment involving programming language compilers and runtimes, editors, necessary middleware, and development lifecycle supporting tools like requirement maintenance software, design tools, testing and deployment frameworks. Customers can simply focus on building their own applications without the cost and complexity of buying and managing the underlying infrastructure.

1.3. Software as a Service (SaaS)

Software as a Service (SaaS) is nowadays the best-known model. The application service provider is hosting the application which runs and interacts through web browser, hosted desktop or remote client. It eliminates the need to install and run the application on customer's own computer and simplifying maintenance and support. Based on the demand the consumer can choose his software to use. Organizations that operate on SaaS are not burdened with the time-consuming and costly task of managing software updates, security patches and a host of other administrative duties for on-premise software solutions. SaaS ensures that these tasks are managed quickly, efficiently and affordably on the back-end. This type of cloud service offers a complete application functionality that ranges from productivity (e.g., office-type) applications to programs such as those for Customer Relationship Management (CRM) or enterprise-resource management.

2. Cloud Deployment Models

There are four deployment models with derivative variations that address specific requirements: Public Cloud, Private Cloud, Community Cloud and Hybrid Cloud (Despotović-Zrakić et al., 2013; González-Martínez et al., 2015; Lakshminarayanan et al., 2013).

2.1. Public Cloud

The most popular deployment model is a public cloud. In this model, the physical cloud infrastructure is located on cloud provider's premises, and it is shared by all cloud customers. Educational institutions do not need to invest and house large IT infrastructures for educational and research purposes. It is open to the public and anybody can use it after swiping the credit card.

2.2. Private Cloud

Opposite the public cloud model, the cloud infrastructure is provisioned for the exclusive use by a single customer. Private cloud enables educational institutions to have complete control of services, data security, applications and resources. The customer can outsource cloud creation and management to a third-party vendor, or do it by themselves, or some combination of them. The infrastructure can be located on premise or off premise with the customer.

2.3. Community Cloud

The cloud infrastructure is provisioned for exclusive use by several customers of the same group that have shared their cloud resources and concerns (e.g., mission, security requirements, policy, and compliance considerations). The infrastructure of the cloud can be hosted by a third-party vendor or within one of the customers in the community.

2.4. Hybrid Cloud

Hybrid Cloud is a combination of two or more different cloud infrastructures (public, private, or community). Customers are bound together by standardized or proprietary technology that enables data and application portability (e.g., a more advanced network setup to ensure safe and efficient on-off premises communications). In order to optimize the resource and to utilize core competency customers use the hybrid cloud.

3. Aggregation models

Three models for aggregating IT above-campus services are particularly suited to higher education: Commercial Sourcing, Institutional Sourcing, and Consortium Sourcing. These models seek efficiencies through economies of scale in IT service provision and on-demand IT capacity as needed and seek improvement through a vibrant ecology of innovation. The three models do not ignore the very real necessity of institutional policy compliance and risk assessment, and they presume some disparity of choice and strategy among different institutions (Wheeler & Waggener, 2009).

3.1. Commercial Sourcing

Commercial Sourcing is the best-understood aggregation model, because of its long history. It is an aspect of traditional outsourcing represented. The Commercial Sourcing model uses sales and marketing to garner contracts to aggregate cash sales and then to leverage the cost of operations over many customers and products. Commercial Sourcing can be an agile, efficient means to support an academic department or campus in creating its own solutions, with little need for large up-front technology investments.

3.2. Institutional Sourcing

Institutional Sourcing is a model of aggregation that draws on the cooperative, cultural uniqueness of higher education. In this model, one or more institutions become a direct service provider to other institutions on a cost-recovery basis. For institutions that are formally members of university or college systems, this model is very common, with services often provided by the largest member to other campuses of the system. Externally, this may be as simple as a bilateral no-cost agreement between two institutions for a particular service need. For example, Stanford University and Duke University have a bilateral agreement to provide backup DNS services should either experience a sustained outage.

3.3. Consortium Sourcing

The Consortium Sourcing model is a not-for-profit means of aggregating demand for above-campus IT services and then matching that demand with supply. A Consortium Sourcing model can then operate IT services itself through its own staff and systems or can choose to contract with an institution or a commercial provider. This model provides resiliency for sustaining aggregated demand and participant collaboration while varying the sourcing of operations as situations change over time. For example, ETUDES (http://www.etudes.org) operates as a not-for-profit membership consortium among twenty-three California community colleges.

4. Cloud Computing Tools

Since cloud computing tools were mostly used for different collaborative purposes and activities. Based on the nature of its utilization in a blended-specific situation, these tools were categorized into three types: synchronized tools, Learning Management System (LMS) tools, and social networking tools (Al-Samarraie & Saeed, 2018).

4.1. Synchronized tools

Engaging students in active learning experience via synchronized web applications is accompanied by the progressive development of system functionalities to accommodate certain collaborative learning goals. These applications were mainly used to provide an online means, such as through the online word processor, spreadsheet, and presentation applications, which enable students to carry out various synchronous and asynchronous editing, comment writing, and peer-review sessions in coordinating interactions and to communicate freely (ÓBroin & Raftery, 2011).

4.2. LMS tools

Most of the commonly used LMS have facilities to offer varied forms of communication for collaborative knowledge construction. LMS tools consist of using university systems (such as Moodle and Blackboard) to support group of learners to document, track, and report on various educational activities.

4.3. Social networking tools

The social networking tools were used for interpersonal communication, sharing, and discussing views on certain topics. The use of social media tools allows users to view, like, comment, and exchange ideas, thus leading to close collaboration and engagement between team members.

5. Support for mobile learning

The cloud can help to overcome the current limitations in mobile learning (m-learning) regarding the limited processing and storage capabilities of the devices (Chen, Liu, Han, & Xu, 2010), mainly through the affordances of availability of enough computing resources and scalability of the cloud. This way, learning applications can run on students' mobile devices while the heaviest computing tasks take place in the cloud (Chen, Lin, & Zhang, 2011). Students can also use their mobile phones to access, accumulate, share, and synchronize learning contents in the virtually unlimited storage resources that cloud computing provides (Shuai, 2011). As a result, students can use m-learning services and applications that are rich and useful (multimedia, real-time, context-aware, etc.) with the adequate Quality of Service (QoS) and they can access them anywhere any time they need them (Chen et al., 2011), provided they have network connectivity.

6. Scalability of learning systems and applications

The demand of computing resources of educational applications varies during a course (there are peaks, especially during enrolment periods, assignment deadlines, before exams, publishing of grades, etc.) (Caminero, Ros, Hernandez, Robles-Gomez, & Pastor, 2011). In a traditional approach, the service is seriously affected if the demand exceeds the alloted computing resources (Adler, 2011). The scalability features of cloud computing enable the adaptation of resources to the changing conditions in order to meet the expected QoS requirements without the need of over-provisioning computing infrastructure (Mousannif, Khalil, & Kotsis, 2012; Rajendran & Veilumuthu, 2011). This is relevant for many learning scenarios, like MOOCs, in which a very large number of students access online courses concurrently and require a large amount of resources to cater for a quick change in demand (Fernández, Peralta, Herrera, & Benítez, 2012). If scaling is performed automatically, greater cost savings will be produced and, at the same time, the infrastructure will conform to QoS requirements as the demand varies. In educational settings, when new computing resources are needed during class time, its provision needs to be fast. Automatic scalability is also desirable in scenarios where resources are needed quickly to respond to a sudden demand variation, such as in MOOCs.

7. Security and privacy

Protection of sensitive data is key in the educational domain, and there is a special concern about how cloud computing deals with this issue (Bristow, Dodds, Northam, & Plugge, 2010; Johnson et al., 2012). To mitigate the aforementioned security risks, the literature proposes technical, legal and training measures.

8. Reliability

Broadband connections should be available for users to enjoy an adequate learning experience. Since broadband networks such as optical fiber or leased lines are needed (Masud & Huang, 2012), there will be users (e.g. those in deprived areas, without sufficient bandwidth) with difficulties to adopt cloud computing (Bhatia & Lala, 2012; Le Roux & Evans, 2011). On the other hand, hiring more capacity for broadband lines in educational institutions may increase the expenses of communication services compromising the promises of cost savings.

9. Interoperability of educational clouds

Interoperability among clouds is a desirable characteristic in the educational realm both to avoid vendor lock-in and to interact with other educational platforms and systems. Educational clouds scattered along different campuses or premises can provide different online services and computing resources for students. In this scenario, interoperability among clouds is wanted to provide the most suitable educational service or resource or to reallocate e-learning services to foreign clouds.

10. Other specific metrics

Currently, most of the metrics monitored are related to cloud computing, but other education-related higher-level metrics should be considered, such as How many enrollments/registers are on Online learning platforms? How many users/learners are on Online learning platforms? (How many learners have completed a course or earned a certificate on Online learning platforms)? How many courses are on Online learning platforms? How many instructors do Online learning platforms have? How many partners collaborate with Online learning platforms? How many languages are used in courses of Online learning platforms?

Reference

Al-Samarraie, H., & Saeed, N. (2018). A systematic review of cloud computing tools for collaborative learning: Opportunities and challenges to the blended-learning environment. *Computers and Education*, *124*, 77–91. https://doi.org/10.1016/j.compedu.2018.05.016

Despotović-Zrakić, M., Simić, K., Labus, A., Milić, A., & Jovanić, B. (2013). Scaffolding environment for e-learning through cloud computing. *Educational Technology and Society*, *16*(3), 301–314.

Fernández, A., Peralta, D., Herrera, F., & Benítez, J. M. (2012). An overview of e-learning in cloud computing. *Advances in Intelligent Systems and Computing*, *173 AISC*, 35–46. https://doi.org/10.1007/978-3-642-30859-8_4

González-Martínez, J. A., Bote-Lorenzo, M. L., Gómez-Sánchez, E., & Cano-Parra, R. (2015). Cloud computing and education: A state-of-the-art survey. *Computers and Education*, *80*, 132–151. https://doi.org/10.1016/j.compedu.2014.08.017

Lakshminarayanan, R., Kumar, B., & Raju, M. (2013). Cloud Computing Benefits for Educational Institutions. *Computer Science*, 1–7.

Sultan, N. (2010). Cloud computing for education: A new dawn? *International Journal of Information Management*, *30*(2), 109–116. https://doi.org/10.1016/j.ijinfomgt.2009.09.004

Wheeler, B., & Waggener, S. (2009). Above-Campus Services: Shaping the Promise of Cloud Computing for Higher Education. *Educause Review*, *44*(6), 1–16.