Cloud Computing in Support of Applied Learning: A Baseline Study of Infrastructure Design at Southern Polytechnic State University

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Abstract

Cloud computing represents an architecture and paradigm of computing designed to deliver infrastructure, platforms, and software as constructible computing resources on demand to networked users. As campuses are challenged to better accommodate academic needs for applications and computing environments, cloud computing can provide an accommodating solution for mobile, campus laboratory, and distance computing. The need for ubiquitous software deployments, virtual environments, software acceleration, economies of scale, and on-demand services points to cloud computing solutions for expedient network access to a pool of shared resources. In this baseline study, as part of a nascent research track, the researchers examine a proposed design for cloud computing at Southern Polytechnic State University to support action research, applied learning and practical, real-world student experiences at the university. Access to university cloud computing resources via an academic research network, physically isolated from the current production network, is proposed. Following a system development life-cycle methodology, design criteria are derived from an analysis of focus group data involving questions related to academic research, applied instruction, and experiential and service learning. Presentation of findings occurs in the form of a use case and architectural topology rendering to be used as a basis for follow-on study in this research track. Physical implementation of cloud computing models at the University can follow this roadmap as the research track unfolds and data are collected to analyze and evaluate for optimal cloud architecture in support of research and education.

Keywords: cloud computing, virtualization, infrastructure, platforms, software delivery, applied learning

1. INTRODUCTION

According to the National Institute of Standards and Technology (2009), the term cloud computing refers to "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction." Higher education institutions today are considering and deploying cloud computing models to lower the cost of technology implementations, increase access to technology infrastructure, platforms, and software, and develop an environment in which experiential learning, experimentation, and discovery can occur (Ercan, 2010). Using Internet technologies, server clustering, block storage, and virtualization software, institutions can construct private clouds that transparently interconnect end-users with applications, platforms, content, data, and other users in support of research and education goals (Erickson et al., 2009; Nicholson, 2009; Thomas, 2009).

Cloud Computing Development Models

Four cloud computing development models are generally acknowledged: (i) public cloud, (ii) private cloud, (iii) community cloud, and (iv) hybrid cloud. According to Bozelli (2009) and Zhang et al. (2010), public cloud computing can result in security risks not associated with private cloud computing. Public clouds involve a public service provider who offers free or pay-per-service fee structures. Using the Internet for connectivity, public cloud providers operate and maintain the infrastructure. Private clouds normally involve hosting by a single provider to deliver one or more service models to the organization (Youseff, Butrico & Da Silva, 2008). Community cloud models involve shared infrastructure between communities with similar interests (e.g., information security) such that cost sharing is possible (Wyld, 2009). Hybrid clouds can be hosted by a combination of public, private, and community cloud models where end-users can enjoy the benefits of all three (Rayport & Heyward, 2009).

2. FOUNDATION AND PROBLEM STATEMENT

Southern Polytechnic State University currently operates one production network with access to existing cloud computing resources. As a result, testing and experimentation, instruction, and prototype development of information technologies and systems are difficult. The University requires clear separation of development, test, and production environments from which to operate stable administrative and academic application environments, yet accommodates the instructional, research, and development needs of faculty and students involved in computing and information sciences.

Access to cloud resources is currently limited to a single production network, thus creating the problem under investigation in this study: What network topology best facilitates use of a cloud-computing paradigm in support of research and education? Cloud resources exist and reside in the University central data center, School of Computer and Software Engineering data center, and in the planned School of Architecture and Construction Management computing center. Students and faculty in each aforementioned area require distinct technological environments to accommodate mobile computing, experiential learning, action research, and applied instruction. What we want to know is how best to support these requirements using an academic research network model.

3. LITERATURE REVIEW

The term cloud computing represents a continuation of past computing paradigms and has evolved progressively over the past 19 years since the term was introduced by Ramnath Chellappa, Associate Professor of Management Information Systems at Emory University. In 1997, building on seminal concepts of computation as a “public service” or “public utility” put forth by John McCarthy, Chellappa joined an existing telecommunications industry term (cloud) used to describe large Asynchronous Transfer Mode (ATM) networks with the notion of ubiquitous computing. Thus, the term is used to describe older concepts in new ways (i.e., the new normal).

Moreover, technology thought-leaders (e.g., Vest, 2006), note the emergence of a meta-university concept that works in concert with a cloud computing paradigm. The meta-university, as defined by Vest (2006), describes the future concept of higher education as a transcendent, accessible, empowering, dynamic, communally constructed framework of open materials and platforms on which much of higher education worldwide can be constructed or enhanced. Cloud computing works in concert with the sharing of knowledge and resources, a millennium- refined value of academia.

As a computing model, cloud computing follows traditional topological norms such as mainframe, client-server, distributed, multi-processing, n-tier, and grid computing, yet yields potential to support next generation computing paradigms (Delic & Riley, 2009). According to Khmelevsky and Voytenko (2010), cloud computing represents the most significant advancement in information technology since the elevation of the global Internet network. Following mainframe computing, personal computing, client-server computing, and the World Wide Web, cloud computing is considered by many to be the fifth major paradigm shift in computing. Academic institutions continue to embrace the paradigm as a means of: (a) improving return-on-investment for technology infrastructure, (b) improving resource sharing, (c) enabling interactivity, collaboration and innovation among stakeholders of Web content and resources, (d) supporting mobile computing and e-learning, and (e) delivering virtual environments (Sultan, 2010).

Based on Pocatilu, Alecu, Vetrici (2010), cloud computing architecture involves three service model abstractions: (a) infrastructure as a service (IaaS), (b) platform as a Service (PaaS), and (c) Software as a Service (SaaS). IaaS layers servers, storage, and network infrastructure into a pool of computing, storage, and connectivity capabilities that are delivered via the network as services that provide a flexible, standard, and virtualized operating environment. IaaS can be used to establish a foundation for PaaS and SaaS (Banerjee, 2009).

Normally, IaaS provides a standardized virtual machine hosted on a server cluster (Noor, Mustafa, Chowdhury, Hossain, and Jaigirdar, 2010). IaaS consumers have responsibility for configuration and operations of the Operating System (OS), software, and Database (DB). Network delivered services (such as performance, bandwidth, and storage access) also can be maintained via service management strategies that cover the performance and availability of the virtualized infrastructure (Mell & Grance, 2009).

PaaS provides executable environments such as application runtimes, storage, and application integration. Moreover, PaaS provides an efficient and agile method to instantiate scale-out applications in a predictable and cost-efficient manner. Tout, Sverdlik, and Lawver (2009) note that information technology service levels and operational risks are mutual as a result of the consumer taking responsibility for the stability, architectural compliance, and overall operations of the application while the provider delivers the platform capability.

SaaS provides business processes and applications (e.g., e-mail, groupware, and/or collaboration tools) as services where the provider assumes all operational risks. Significant delivery and cost efficiencies are possible as all infrastructure and information technologies are abstracted away from the consumer (Mircea & Andreescu, 2011).

Cloud infrastructure is typically supported by block storage in the form of direct attached storage (DAS), network attached storage (NAS), or a storage area network (SAN). Additionally, server clusters to support virtual machines (VMs), and in some cases high-end computing devices, are all considered part of cloud infrastructure (Sasikala & Prema, 2010). Centers hosting cloud infrastructure (e.g., computing centers or data centers) can have managed host capability as a provider option. Secure and available network and internetworking components provide access to the cloud (Brunette & Mogull, 2009; Mell & Grance, 2009). Internetworking architecture can support cloud *partners* such as affiliated computing and data centers (Armbrust et al., 2009; Khmelevsky, Govorov, & Burge, 2009).

Use of cloud computing within higher education is proliferating, as noted by Pocatilu, Alecu, and Vetrici (2010); Khmelevsky and Voytenko (2010); Noor et al. (2010); and Mircea and Andreescu (2011). Prototype initiatives, such as seen at Okanagan College and the University of British Columbia Okanagan, King's University College, University of California, Washington State University's School of Electrical Engineering and Computer Science, and North Carolina State University, reflect academic use and success with cloud computing paradigms. According to Bozzelli (2009) and Mircea and Andreescu (2011), over the last few years higher education institutions have begun to transition to more research and ongoing update of information technology infrastructure as a foundation for education activities and science research.

Moreover, academic institutions are finding compatibility between cloud computing and other major academic initiatives. For example, Thomas (2009) notes the use of cloud computing in support of the Scholarship of Teaching and Learning (SoTL); Pocatilu, Alecu, and Vetrici (2010) report on cloud computing in support of e-learning; Khmelevsky and Voytenko (2010) research how cloud computing is used in experiential and project-based learning; and Mircea and Andreescu (2011) couple cloud computing with strategies to reduce the cost of education.

Cloud architecture also is associated with higher education institution challenges. According to Goldestein (2009) and McCrea (2009), challenges include technology limitations, interoperability issues, network capacity, end-user perceptions, and adoption of cloud computing concepts. Additionally, policy and control issues, demand for services, and legacy constraints represent challenges when moving to a cloud computing paradigm (Katz, Goldstein, & Yanosky, 2012). Of similar concern, Mircea and Andreescu (2011) note that migration to cloud computing requires a well-defined strategy. Sheelvant (2009) agrees and suggests that successful cloud computing initiatives are dependent on alignment of cloud computing capabilities with higher education research and education needs, as well as clearly stating the architectural vision for infrastructure, platform, and software service delivery (Golden, 2010).

4. RESEARCH METHODOLOGY

In this preliminary study, the researchers used a qualitative approach to collect data. Two focus groups involving University stakeholders with interest in academic cloud computing, primarily faculty, were organized and conducted to elicit responses in five domains: curriculum and instruction, scholarship, research, virtual environments, and access. Focus group A included six faculty members and one technical support personnel, and focus group B included eight faculty members and one administrative personnel.

During each focus group session, participants were asked to respond to ten questions, organized into domains, related to the use of cloud computing features and attributes associated with the domains. The curriculum and instruction domain questions (1-2) concentrated on models of instruction using technology and use of digitized content. The scholarship domain and research domain questions (3-7) were designed to determine how faculty could use cloud computing constructs for experimentation, testing, development, applied instruction, personal learning, and the Scholarship of Teaching and Learning (SoTL). The final two domains assessed, virtual environments and access, focused on questions (8-10) related to use of virtual desktop integration (VDI), mobile network access to cloud components, bring-your-own-device (BYOD) design, and interdisciplinary approaches to the study of information technology and systems using cloud computing resources.

Focus group comments were captured and organized by domain for coding and analysis. Stakeholder input, in the form of focus group qualitative comments and responses to specific questions, resulted in the data set used to reach findings with respect to this preliminary study question. In response to the qualitative data analysis, the researchers constructed a use case (Figure 1) to illustrate the interaction of stakeholders with the abstractions of cloud computing infrastructure. Moreover, analysis of the qualitative data was used to formalize the proposed cloud architecture (Figure 2) accessible via a discrete academic research network (ARN), including a strategy for service management and governance.

5. QUALITATIVE DATA ANALYSIS

Focus Group Data

Focus group data were recorded in narrative form without personally identifying the respondent. The treatment of the data in this research is that of anonymous data. Following the numeric sequence of questions organized by domain, qualitative data in the form of verbal responses were captured without guidance other than the questions presented in written form. Each question was presented and exhaustively addressed by the focus group before moving to the subsequent question. Data analysis involved a coding scheme to determine existence of themes, patterns, and behaviors in the qualitative data. Moreover, an examination of the collected data narratives was examined via a tag cloud engine for comparative analysis with the coding scheme results.

Regarding curriculum and instruction, the data suggest that faculty are interested in and require technology to enable multiple paradigms of course delivery, including hybrid, Web-enhanced, Web simulcast, online, and convergent instruction. Additionally, the data suggest that faculty currently create and use digital content, and view a robust digital learning object repository to accommodate all four quadrants of file types as a necessary element of instruction.

In the domains of scholarship and research, the data suggest the technology services to accommodate advanced content delivery, personal learning, and experimentation, testing, and development as an adjunct to instruction are required and not currently available. Moderate interest in the use of technologies to support SoTL (Thomas, 2009) existed, and awareness creation and adoption of the concept were of value going forward.

Finally, data collected regarding virtual environments and access indicated a high level of interest and need to virtualize desktops, better enable mobile computing, and work collaboratively across the University to enable and enhance the study of information technology and systems. Virtual access and mobile access were dominant, recurring themes in the data. Specific accommodation for technology to support shared storage, virtual machine server clusters, control over Web access, and network management all emerged as major themes and patterns in the data analysis.

Cloud Technology Consumers

Information technology and system stakeholders at the University include students, administrative staff, developers, and faculty lecturers and researchers. Figure 1 illustrates the interactions between University stakeholders and cloud service model abstractions. Based on the qualitative data collected, a use case for University stakeholders and private cloud services illustrates the following: (i) students benefit from SaaS and IaaS, (ii) faculty lecturers benefit from Saas and Iaas, (iii) administrative staff benefit from SaaS and Iaas, (iv) faculty researchers benefit from IaaS and PaaS, and developers benefit from PaaS.

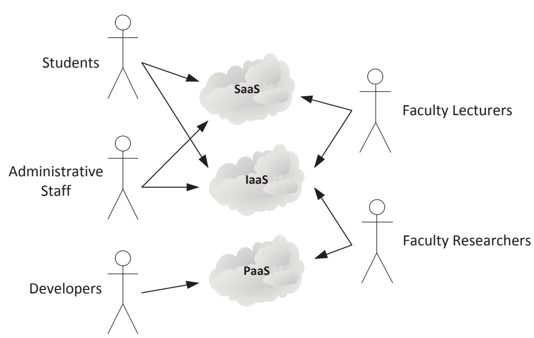

Figure 1: Use Case for Cloud Computing at Southern Polytechnic State University

Service delivery via an academic research network (ARN) requires separate infrastructure and construction of lighted pathways outside of the University's production network, including Internet. The academic value of the network connecting to a private cloud is realized in the ability to develop, test, demonstrate, and experiment. The use case can serve as a model for access and authentication to cloud resources.

6. PROPOSED ARCHITECTURE

Cloud Architecture

The development model (Figure 2) for the proposed architecture is that of a four-tier private cloud, hosted and managed by internal University resources. Access to the cloud resources via an ARN portal allows for secure authentication to cloud resources. Using an authenticated portal for enterprise application integration, cloud services will be available to consumers of SaaS, IaaS, and PaaS. Tier one provides for authenticated access, navigation, application integration, information, and self-service. Tier two, the application tier (i.e., SaaS), provides for utilities, tools, and applications to support collaboration, service management, projects, virtualization, and user administration.

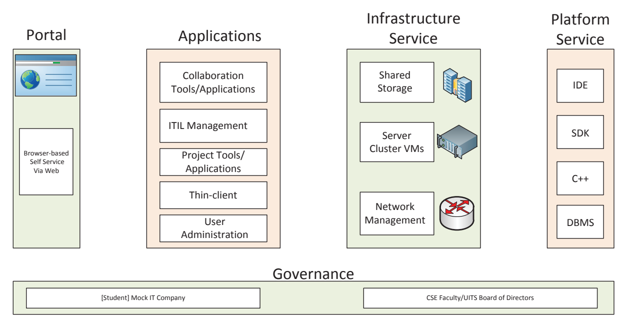

Figure 2: Southern Polytechnic State University Proposed Cloud Architecture for Academic Research and Education

Tier three infrastructure services (i.e., IaaS) provide for shared storage, virtual machines, and network security and traffic management. PaaS is represented in the fourth tier and can provide development, testing, and experimentation platforms for a variety of environments (e.g., an Integrated Development Environment, Software Development Kit, or Database Management System). A proposed governance substrate explores the use of student-led mock Information Technology organization reporting to a jointly composed University information technology and school faculty board.

7. CONCLUSIONS

Support for Research and Education

Based on data analysis and findings from this preliminary baseline study, the researchers concluded the following:

(i) existing cloud computing infrastructure can be advanced to promote applied instruction in the School of Computing and Software Engineering and others based on the interdisciplinary study of information technology and systems;
(ii) construction of an ARN to promote testing, development, and research can best leverage cloud computing resources;
(iii) the proposed cloud architecture is feasible, scalable, and tractable; and
(iv) further study is indicated to fully assess and implement cloud computing in support of interdisciplinary approaches to information technology and systems.

Next Steps and Follow-on Study

Conclusions in this study will be used to advance the research track by informing design of the ARN to access and interoperate with cloud computing resources, including the central University information technology infrastructure, School of Computing and Software Engineering Data Center, and School of Architecture and Construction Management Computing Center. This separate and distinct network initially will be challenged to support School of Computing and Software Engineering and School of Architecture and Construction Management faculty and students and ultimately interdisciplinary studies of information technology and systems University-wide.

The follow-on studies for this research track involve best practices in integration of cloud computing and instructional design (McCrea, 2009), use of cloud computing to evolve innovative paradigms of instruction (Pocatilu, Alecu, & Vetrici, 2009; Pocatilu, Alecu, & Vetrici, 2010), and examination of global research and education capabilities and opportunities via an ARN supported by cloud computing (Lazowska et al., 2008; Liyoshi & Kumar, 2008). The researchers will advance the research track through expanded university involvement, construction of an ARN to provide services and shared resources, and promotion of the interdisciplinary nature of information technology and systems.

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