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Basic to Futuristic Cloud Enabled LMS Architectures in nutshell

Prof Kamal K Vyas, Dr Sandhya Vyas

ABSTRACT

This Exploratory Paper describes the current status and futuristic Learning Management System (LMS), paying particular attention to its use in e-Learning. The goal of the paper is to provide decision-makers with information to evaluate the efficacy of LMS platforms for adoption and implementation considerations. The paper further outlines the present state of standardization efforts and confronts technical standards. It is necessary to confront the reader with the enormous gap between present standardization efforts and the requirements of human learning processes because these processes need to be supported by LMSs and need to provide individual learners with the resources to ascend to higher levels of knowledge and competency. Cloud computing describes a broad movement toward the use of wide area networks (WANs), such as the Internet, to enable interaction between information technology (IT) service providers of many types and consumers. Service providers are expanding their offerings to include the entire traditional IT stack, ranging from foundational hardware and platforms to application components, soft ware services, and whole soft ware applications, thus the "Cloud based LMS" become the reality today.

INDEX TERM : LMS, CMS, e-learning Standards, SCORM, Cloud Computing Architecture & Benefits, Service Layer in Cloud Computing, SaaS, PaaS, IaaS, DaaS, SOA & its benefits.

1. INTRODUCTION

Recesso [2] state "Learning Management Systems (LMS) play a central role in the Web-based e-learning scenario. It connects learning contents and learners together in a standardized manner. It manages users, learning materials (in the form of objects in Content Management System (CMS)) and learning events. It manages and administers learning progress and keep track on learning performance. It manages and administers administrative tasks. LMS is a software system designed to facilitate administrative tasks as well as student participation in e-learning materials". Digital technologies continue to influence the way we find, create, share, and negotiate information, ideas and ways we think about knowledge itself. Learning, education, and training continue to extend the reach of classrooms and training rooms by including a more organic, integrated array of learning experiences and support – available "anywhere anytime for anybody". Work styles are shifting from individual accomplishment to teams, communities of practice, and collaboration. In the midst of all these changes, the LMS is the foundation for e-model and matures from its 1.0, "publishing Web" antecedents to accommodate the demands of the 2.0, "participative Web" possibilities. With the emergence of web service based tools, the expectations of learning itself is in a state of transformation. These tools include RIAs, (rich internet applications), social media, SaaS (software as a service), BPMS (business process management systems), UGC (user-generated content, including photos, slideshows, and videos), the growth of commercially published apps and e-books, ECM (enterprise content management), semantic tools like Twine, and socially bookmarked resource sites like Delicious. The best learning organizations will take a holistic approach to causing shifts, through delivering content, creating access channels, and supporting dynamic containers, social networks, and resource locators. Today's emerging LMS architecture allows enterprises to offer services, support inquiry, and track user behavior across a wide variety of sites and sets of devices. Comprehensively and simultaneously tracking success of informal and traditional learning activities creates an opportunity for new management solutions to take a foothold in a previously traditional market.

- ***Prof Kamal K Vyas**, Director SIET (SGI), Sikar, India. E-mail ID: kamalkvyas@gmail.com.*
- ***Dr Sandhya Vyas**, HOD (S&H), BBVP, Pilani. E-mail ID: profsandhyavyas @gmail.com*

2. EMERGING LMS ISSUES -

This exploratory paper reveals top ten evolving LMS issues[1] derived from the diverse perspectives and resources:

1. "Home-grown" LMSs are on the decline
2. Standards based LMS like Moodle moves to the front of the LMS adoption pack
3. Hosted options for LMSs are achieving popularity
4. Open source, open applications, and open education resources are on the rise
5. Blackboard gains corporate LMS market share
6. Commercial LMS customers: less formal, more holistic
7. Extensibility matters
8. Campuses and business alike are slow to adopt "Enterprise 2.0"
9. The recession continues to constrain
10. Revising standards, specifications, and structures

Previously standard was driving force for LMS core design, later structures and security become the decision drivers for the next generation of learning containers. Learners are exploring new sites and resources daily, and IT executives are wondering how to leverage the power of social media while continuing to protect data and keep information behind the firewall. Another new understanding in the ROI conversation is a renewed focus on reusable, modular, and shared content.

Literature Review by Allen [3] suggests that there might be a trade-off between LO maintainability and context-related learning, which requires more complex RLOs. Further Clark/Mayer [3] point to the results of a large number of empirical media comparison studies, which indicate that the type of media used in instruction does (in most cases) not have an effect on learning outcomes: "When the instructional methods remain essentially the same, so does the learning, no matter how the instruction is delivered."

Further the pressure is mounting to design complex LMSs for efficiently conveying knowledge together with real life context to a dynamically growing number of individual learners.

3. STANDARDIZATION REVIEW

There are a number of organizations involved in the development of e-learning standards. Sometimes these organizations are working in parallel and their activities. Major standards bodies [3] are -

- AICC – Aviation Industry CBT Committee (CBT Guideline; CMI Guidelines for Interoperability between Web-based courseware and LMSs; AGRs Guidelines and Recommendations).
- ADL – Advanced Distributed Learning Initiative (CAM Content Aggregation Model, RTE Run-Time Environment, SN Sequencing and Navigation; SCORM Sharable Content Object Reference Model).
- IMS Instructional Management Systems Project – IMS Global Learning Consortium (Learning Resources Meta-Data Specification, Content and Packaging Specification, Question and Test Interoperability Specification, Learner Profiles Specification, Simple Sequencing Specification).
- IEEE/LTSC – Institute of Electrical and Electronics Engineers – Learning Technology Standards Committee (LOM Learning Objects Metadata Schemas).
- DCMI – Dublin Core Metadata Initiative (Dublin Core Metadata Record, metadata standards for RLO discovery across domains, metadata interoperability frameworks).
- ARIADNE Foundation – Alliance of Remote Instructional Authoring and Distribution Networks for Europe.

While the number of different organizations working towards e-learning standards and the complexity of their proposed concepts are challenging but there is significant cooperation amongst them. For e.g. - ADL was founded by the U.S. Department of Defense and the White House Office of Science and Technology Policy and its SCORM project draw on the following standards -

- Content aggregation model – metadata derived from IEEE LOM 1484.12, content structure derived from AICC, content packaging and sequencing model derived from IMS.
- Sequencing and navigation – sequencing information and behavior derived from IMS.
- Run-time environment – based on IEEE API 1484.11.2, IEEE Data Model 1484.11.1.

Fig. 1 gives an example which outlines relationships between ICT functions/subsystems of learning systems and selected standards for content structuring and transmission.

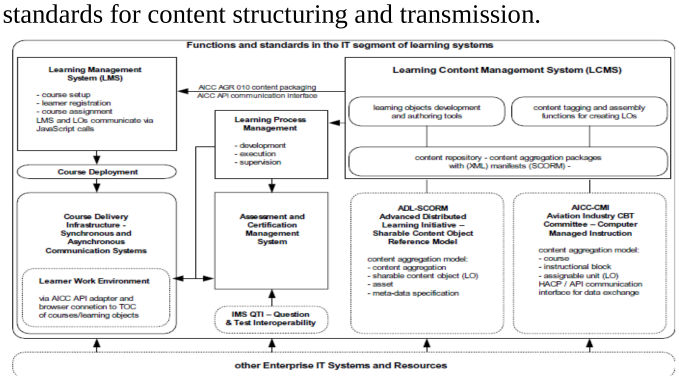

Fig 1 [3]

The learning content management system (LCMS) – containing the content repository – could be based on ADL-SCORM or on AICC-CMI. In the case of an ADL-SCORM-based system, the content aggregations contain "sharable content objects" (SCOs -- the RLOs in the SCORM [13,14] content aggregation model), the assets (e.g., multimedia objects used by SCOs), and the manifest ("meta-data specification"), which describes the content aggregation. To design and package SCOs, appropriate development and authoring tools are required (e.g., MacroMedia Authorware, IBM Authoring Tool). [3,14] For course deployment, SCOs are transferred from the LCMS to the LMS via modules which conform to the AICC packaging and communication standards. LMSs have functions for the deployment of courses, learner registration etc.. RLOs are able to communicate with the LMS via JavaScript calls. While there are standards for simple types of assessments (IMS QTI – Question and Test Interoperability), standards for learning process supervision and management provide rather basic functionality: Individual learner behavior (e.g., time spent working on a RLO or test results) is tracked by the RLO and communicated to the LMS.

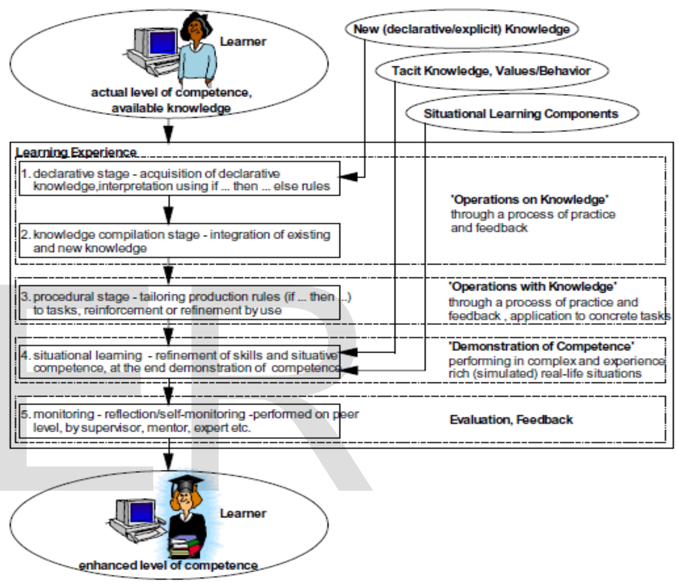

Fig 2 [3]

The co-constructivist learning model explained above was developed by the Finke [3] for adult learners who want to enhance job-related competencies. Figure 2 outlines a model for structuring a personalized learning experience – a single step forward on the individual learners more extensive journey towards a higher level of knowledge and competency – as a cognitive process. The learning experience then is structured into several consecutive steps in which the learner at first acquires new knowledge (steps 1 and 2 – operations on knowledge) and afterwards (step 3 -- operations with knowledge) applies the knowledge to more theoretical problems to integrate it efficiently with already available cognitive constructs. In step 4, the learner demonstrates his level of competency by tackling (usually simulated) complex real-life problems. Because explicit knowledge (hard facts) sometime might be "only the tip of the iceberg", tacit knowledge ("highly personal and hard to formalize" knowledge form) has to be learned. Social components of the learning process (interaction with instructors, tutors, or more knowledgeable peers) are indispensable.

The co-constructivist learning model [3] explored above, is based on the assumption that learners gain additional knowledge or competencies not by the simple reception of blocks of knowledge, but by constructing or re-constructing their individual cognitive concepts and learning to apply them to real-world situations via rich interactivity: Besides access to learning materials (delivered via RLOs), collaboration with other learners, learn teams, learning communities, learning facilitators, or with the complex environment itself are vital ingredients of the co-constructivist learning process.

4. CLOUD COMPUTING ARCHITECTURE

As per Wikipedia, the Cloud computing architecture refers to the components and subcomponents required for cloud computing. These components typically consist of a front end platform (fat client, thin client, mobile device), back end platforms (servers, storage), a cloud based delivery, and a network (Internet, Intranet, Intercloud). Combined, these components make up cloud computing architecture. Cloud computing architectures [18] consist of front-end platforms called clients or cloud clients. These clients comprise servers, fat (or thick) clients, thin clients, zero clients, tablets and mobile devices. These client platforms interact with the cloud data storage via an application (middleware), via a web browser, or through a virtual session.

National Institute of Standards and Technology (*NIST)* [7] defines cloud computing as "… a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

5. BENEFITS OF THE CLOUD ARCHITECTURE

Some of the benefits [8] that cloud computing brings are as follows:

Reduced Cost: Cost is a clear benefit of cloud computing, both in terms of (Capital Expenses) CapEx[8] and (Operating Expenses) OpEx[8,14].

Flexibility: Flexibility benefits derive from rapid provisioning of new capacity and rapid relocation or migration of workloads.

Improved Automation: Cloud computing is based on the premise that services can not only be provisioned, but also de-provisioned in a highly automated fashion. This specific attribute offers significant efficiencies to enterprises.

Focus on Core Competency: Government agencies can reap the benefits of cloud computing in order to focus on its core mission and core objectives and leverage IT resources as a means to provide services to citizens.

Sustainability: The poor energy efficiency of most existing data centers, due to poor design or poor asset utilization, is now understood to be environmentally and economically unsustainable. Through leveraging economies of scale and the capacity to manage assets more efficiently, cloud computing consumes far less energy and other resources than a traditional IT data center.

6. ARCHITECTURAL CONSIDERATIONS FOR CLOUD COMPUTING

Government agencies need to consider several infrastructural models [8] when evaluating cloud-computing architecture. There are four categories [10, 15] of cloud currently in the marketplace or emerging in the near future: public clouds, private clouds, virtual private clouds, and eventually inter-clouds.

Public Clouds

Public clouds are "stand-alone," or proprietary, clouds mostly off-premise, run by third party companies such as Google, Amazon, Microsoft, and others.

Private Clouds

Private clouds are typically designed and managed by an IT department within an organization.

Virtual Private Clouds

Virtual private clouds allow service providers to offer unique services to private cloud users. These services allow customers to consume infrastructure services as part of their private clouds.

Inter-cloud

The inter-cloud emerges as a public, open, and decoupled cloud-computing internetwork, much like the Internet. In a sense, the inter-cloud would be an enhancement and extension of the Internet itself.

7. SERVICE LAYERS IN CLOUD ARCHITECTURES

Software as a Service Model (SaaS) - This service-model involves the cloud provider installing and maintaining software in the cloud and users running the software from their cloud clients over the Internet (or Intranet). The users' client machines require no installation of any application-specific software - cloud applications run on the server (in the cloud).

Platform as a service (PaaS) – It is a cloud computing service which provides the users with application platforms and databases as a service. This is equivalent to middleware in the traditional (non-cloud computing) delivery of application platforms and databases.

Infrastructure as a service (IaaS)- It is taking the physical hardware and going completely virtual (e.g. all servers, networks, storage, and system management all existing in the cloud). This is the equivalent to infrastructure and hardware in the traditional (non-cloud computing) method running in the cloud.

Development as a service (DaaS)- It is web based, community shared development tools. This is the equivalent to locally installed development tools in the traditional (non-cloud computing) delivery of development tools.

Cloud computing is a significant advancement in the delivery of information technology and services. By providing on demand access to a shared pool of computing resources in a self-service, dynamically scaled and metered manner, Cloud computing offers compelling advantages [6] in cost, speed, and efficiency. Oracle in its white paper [6] suggested Enterprise level architecture shown in fig 3.

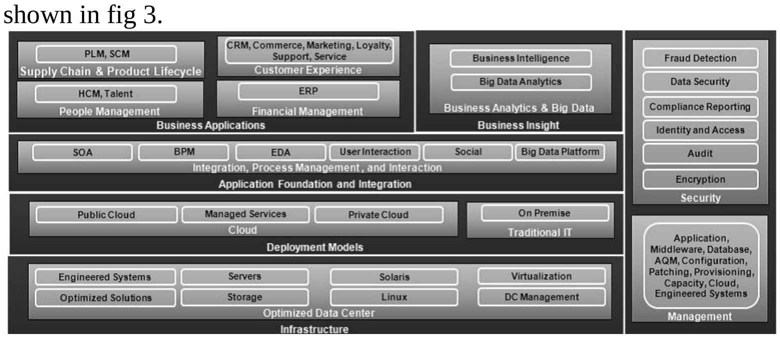

Fig 3 [6]

Cloud services and management capabilities need to be identified and prioritized in a Cloud solution portfolio. The ITSO Oracle Practitioner Guide, "A Pragmatic Approach to Cloud Adoption" defines an approach for Cloud adoption

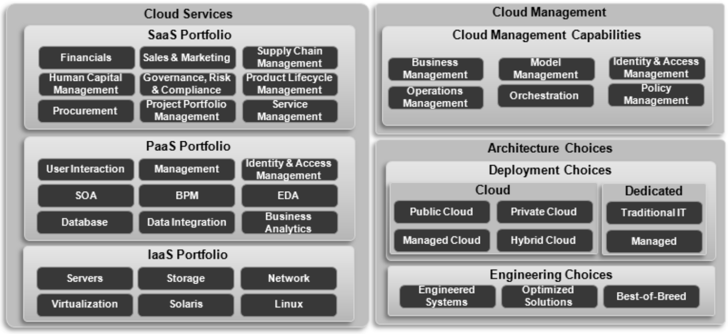

Fig 4 [6]

and describes the "Cloud Candidate Selection Tool (CCST)" that can be used in this process. Fig 4 defines a Cloud solution portfolio that illustrates the following characteristics –

- A broad spectrum of business applications.
- Platforms and frameworks to develop and run custom processes.
- Reliable and Highly Available infrastructure components to support the quality of service.
- Capabilities to support the build-time and runtime Cloud management operations including business management, operations management, model management, orchestration, provisioning, security and policy management.
- Choice of architecture in terms of deployment and engineering. Deployment choices should include on-premise and off-premise deployment models.

Cloud adoption requires a conceptual understanding of the basic roles [6] involved and the relationship between them. Fig 5 shows the basic (macro level) roles involved in building, deploying to, and using the Cloud, this diagram also shows the services, management capabilities, and integration points.

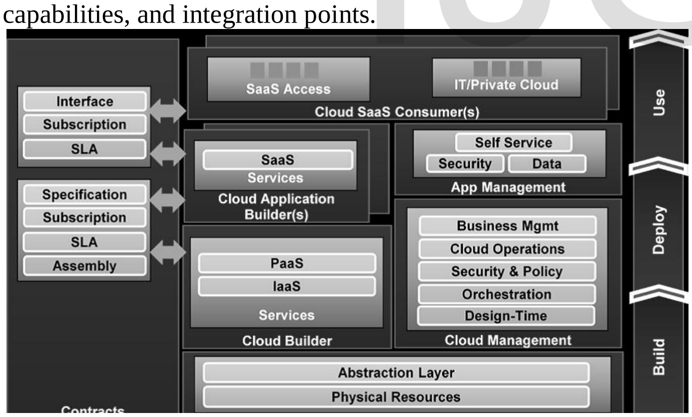

Fig 5 [6]

Above Fig 5 [6, 10] shows the typical key components of the Cloud infrastructure which comprises -

• Physical resources supporting the Cloud infrastructure and the logical abstraction layer that pools the physical resources.

• Cloud Builder builds and operates the Cloud infrastructure and platforms as a Service.

• Cloud Application Builder that develops applications for the Cloud and deploys them on the PaaS platform and offer as SaaS services. Cloud Builders support multiple application builders and applications.

• SaaS consume the software services. Cloud Application Builders support multiple SaaS consumers.

• Cloud Management infrastructure supporting the Cloud Builder and Cloud Application Builder.

• Application management includes the self service capabilities provided by the Cloud Builder to provision and manage applications deployed on the Cloud.

8. SECURITY IN CLOUD ARCHITECTURE

In general, we are applying appropriate security primitives [16] to the interfaces, the services, and the objects in the control and management planes. Because this work is focused on management, the security of the data plane (for example, the security of the run-time interactions between the users and the applications running on the IaaS platform) is out of the scope of the provider interface. Figure 6 [7] shows the security context, the flow of information through the cloud service provider interface, and the objects secured. The cloud service provider (CSP) interface provides access to the logical endpoints, including the security manager, service manager, and the service catalog. These endpoints provide the various services to interact with service entities (such as VMs, volumes, networks, and composite applications), get audit reports, and perform a host of other activities required to fulfill and maintain a cloud infrastructure. The major categories of objects that are managed by the service manager are control, monitor, and report objects, access to which may be controlled by role-based access control (RBAC).

The Constraints, Rules, and Policies objects are consumed by the cloud infrastructure, and the function of the provider interface is to manage the content of these policy-related elements. The cloud infrastructure (IaaS) is a "black box" to the provider interface, and how the policies are implemented is left to the cloud service provider. But the fact that the various constraints, rules, and policies are being implemented is verified by the audit events.

The two categories of actors who interact with the CSP interface are human users and application programs (such as management, automatic provisioning, billing, or audit applications). The human user might also be interacting through a portal interface, usually using a web browser. The portal interface will be developed using the cloud service provider interfaces. Both actors would be authenticated at the CSP interface by the security manager or present an identity token to the security manager.

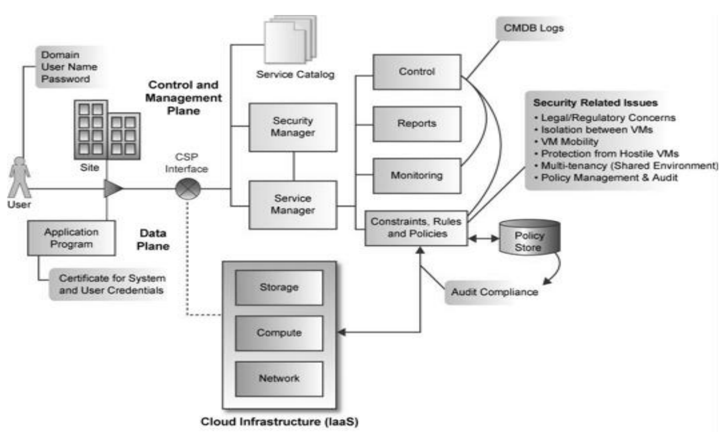

Fig 6 [7]

Traditionally, the human user uses a user name and password as credentials for authentication; however, stronger mechanisms (identity federation and assertion provisioning) should be used. Commonly, an application program uses certificates. However, it is deemed insecure to embed user names and passwords in application programs. In this case as well, tokenized identity can be profitably used to provide a higher standard of security.

9. SERVICE ORIENTED ARCHITECTURE (SOA)

SOA [5] builds on computer engineering approaches of the past to offer an architectural approach for enterprise systems, oriented around the offering of services on a network of consumers. A focus of this service-oriented approach is on the definition of service interfaces and predictable service behaviors. The service-based architecture mainly defines interfaces for the interaction of functional system components represented by loosely coupled distributed services [9]. Services that represent functional components of the distributed LMS are called e-learning services. In addition, underlying infrastructure services provide supportive functionality such as service-lookup within an institution. Users access the system using an LMS portal component [11] that acts as a front-end for the LMS services. SOA, as implemented through the common Web Services standards, offers Federal senior leadership teams a path forward, given the diverse and complex IT portfolio that they have inherited, allowing for incremental and focused improvement of their IT support systems. The base interface for e-learning services is derived from the basic service interface (figure 7)[9]. E-learning services mainly represent functional components of the distributed learning management system. As e-learning services communicate across instance boundaries they are accessible through an additional web-service interface.

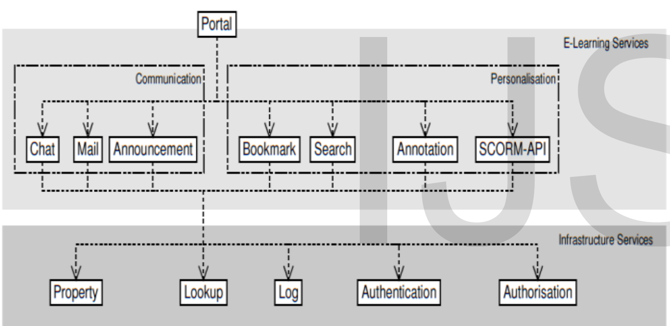

Fig 7 [9]

A service implementing the SCORM API has been added to the LMS e-learning services because SCORM (Sharable Content Object Reference Model)[19] is one of the most important approaches for realizing interactive LMS content.

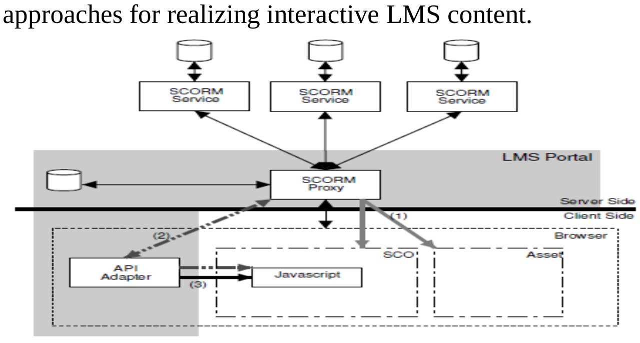

Fig 8 [9]

Figure 8 [9, 11] depicts a typical architecture of the SCORM service [13] used in SOA Architecture. The LMS search service provides a generic search interface which can be refined by service vendors in order to enrich it with additional functionality. The LMS portal component acts as a proxy for user requests and allows LMS services to present the functionality they offer to users using a common look & feel. The portal connects to the available LMS e-learning services and processes user requests according to the guidelines stored in the property service. E-learning services may rely on the existence of a minimum set of infrastructure services, namely, a lookup service, a logging service, a property service, and a security service. In addition to these infrastructure services, the prototype contains implementations of the e-learning services like - Annotation service, Bookmark service, Search services (Web, digital library) etc.

10. SOA BENEFITS

• **Language-neutral integration:** The foundational contemporary Web Services standards use eXtensible Markup Language, which is focused on the creation and consumption of delimited text.

Component reuse: Given current Web Service technology, once an organization has built a soft ware component and offered it as a service, the rest of the organization can then utilize that service.

• **Organizational agility:** SOA defines building blocks of soft ware capability in terms of offered services that meet some portion of the organization's requirements. These building blocks, once defined and reliably operated, can be recombined and integrated rapidly.

• **Leveraging existing systems:** One common use of SOA is to define elements or functions of existing application systems and make them available to the enterprise in a standard agreed-upon way, leveraging the substantial investment already made in existing applications.

11. SOA NUTSHELL

Like cloud computing, SOA brings with it a number of key benefits [5,15] and risks, including –

Dependence on the network: SOA is fundamentally dependent on the network to connect the service provider with the consumer.

Provider costs: The cost of reuse shifts to the service providers, which benefits [14] the consumers.

Enterprise standards: it helps everyone involved if the interfaces across services have some commonality in structure and security access mechanisms. Choosing and communicating a comprehensive set of enterprise standards is a responsible approach to aid in enterprise SOA.

Agility: When we discuss "agility" [17] as it relates to SOA, we are often referring to organizational agility, or the ability to more rapidly adapt a Federal organization's tools to meet their current requirements.

"SOA and Cloud Computing" [5] are complementary activities and both will play important roles in e-Education. Cloud computing and SOA can be pursued independently or concurrently. In summary, both cloud computing and SOA can support good engineering practices by enabling fundamental concepts such as abstraction, loose coupling, and encapsulation. Both approaches rely on the definition of clear and unambiguous interfaces, predictable performance and behavior, interface standards selection, and clear separations of functionality. Finally, cloud computing and SOA can be pursued independently, or concurrently as complementary activities.

12. CONCLUSION

The LMS industry is clearly at a tipping point in its evolution, with transformation taking place on two distinct fronts. On the technological front, expectations of the learning and IT marketplaces are bringing pressures to provide a better experience than that provided by systems designed to monitor and distribute online courses tracked by a departmental-level database that stores course files, some student records, test results, and course syllabi. In other words, learners expect to have as good an online learning experience as they have when satisfying online consumer experiences. The Evolution of the LMS from Management to deep analysis of trend, shaping the future of e-Learning.

When LMSs first appeared in the learning world, they emerged to serve specific requirements for managing online courseware assets, tracking results of student tests and content completion, and making sure that the content used to represent the course itself is accurate and available on demand. They contributed to the value propositions of serving course content in a scalable, reliable, and consistent way to distributed learners, while making sure to keep track of the results of online learning sessions and making that data available to help target the learning programs more effectively. When LMSs first emerged, vendors had many opportunities to offer a wide variety of learning management features and solutions that eventually did help define our collective expectations for learning management. In the second phase of LMS evolution, customers started getting smarter about the value that they wanted their LMS to drive; consequently the market has compressed itself. Today, according to Brandon Hall Research, there are approximately 92 viable LMS platforms, offering essentially the same menu of features, with a number of attempts represented in different platforms to deal with the building blocks of online learning experience – content, assessments, collaboration, and operational artifacts. The emerging “next gen” LMS environment will need to accommodate user-navigated resources made up of commercial and user-generated content, working as “small pieces, loosely joined,” connected by topical and pedagogical scaffolds, and held together by links and connections from social and semantic media.

Enterprise mobility, the growing use of semantic tools for personalizing and training search queries, techniques for navigating the many conditions faced by today’s learners as they move from formal training programs to immersions, simulations, and just-in-time performance support, will all have significant impact on the systems that management provides for learning experience and assets. The next generation LMS will facilitate knowledge creation and sharing, such that learners come to the experience ready to use and embrace the systems that their employers deem necessary. It won’t matter whether those employers use the systems to manage their compliance requirements, facilitate a learning culture, or create a workforce that benefits from traditional e-Learning, social networking, immersive experience, or whatever the next wave of content explosion brings. Using the appropriate media to best support learning is paramount, and while the learning professionals and the management systems they use have not necessarily managed to determine the best way to incorporate new interactive and social experiences, using technology makes this a more realizable LMS possibility.

The post-LMS era now shifting the “Computing” from Product based Economy to Service based Economy. Recent trends further suggest that Cloud computing influences data center and operational models, and applications must be designed with a Cloud model in mind. In order to achieve this, consumer enterprises must partner with a leader in the Cloud Computing that offers a broad portfolio of business applications and platforms through a variety of deployment models including public, private, and managed & customizable services. Successful Cloud adoption requires not only products to build the Cloud but also guidance around planning and execution of the Cloud initiative. Adopting a Cloud strategy may have impacts that span beyond just the technology architecture, influencing business and organizational strategies. Organizations new to Cloud look for tools, processes, and best practices to guide them with decisions around Cloud strategy, migration, and implementation along with outsourcing help.

The main aim of SOA is cross-service personalization of the resulting run-time system and support for institutional collaboration. The architecture focuses on modularity, configurability and extensibility of the LMS services and supports institutional cooperation by allowing remote-access to LMS services.

REFERENCES

1. The Evolution of LMS from Management to Learning, Beth Davis, Colleen Carmean, Ellen D. Wagner, Saga Road Solution, 2009.
2. Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools, Ellen Ambakisye Kalinga, 2008.
3. Basic LMS Architecture for Learner-Centric Learn Flow, Wolfgang F Finke, 2004, 308-328.
4. http://en.wikipedia.org/ wiki/ Cloud computing architecture.
5. Cloud Computing & Service Oriented Architecture (SOA), Geoffrey Raines, MITRE.
6. Oracle White Paper, Nov 2012, Cloud Ref Architecture.
7. Architecture for Managing Clouds - A White Paper from the Open Cloud Standards Incubator, DMTF, 2010.
8. Cisco Cloud Computing - Data Center Strategy, Architecture, and Solutions Point of View White Paper for U.S. Public Sector, 2009.
9. A Service-Based Architecture for Learning Management Systems which Supports Personalization and Collaboration, Markus Schmid, 2004.
10. NIST Cloud Computing Reference Architecture, SPl pub 500-292, Liu, Tong, Mao, Bohn, Messino, Badger & Leaf, Sept 2011.
11. Service Oriented Cloud Computing Architecture, Wei-Tek Tsai*, Xin Sun, Janaka Balasooriya, Department of Computer Science, Arizona State University, 978-0-7695-3984-3/10, 2010 IEEE.
12. Building Learning Management Systems Using IMS Standards-Architecture of a Manifest Driven Approach, José Luis Sierra*, Pablo Moreno-Ger, Iván Martínez-Ortiz, Javier López-Moratalla, Baltasar Fernández-Manjón*,http://www.e-ucm.es/publications/articles.html.
13. LearningOnWeb – development of a SCORM compliant Learning, Management System, Norberto Henriques, Damyan Slavov and António José Mendes, Compusystech 2004.
14. Architectural Aspects for LMS based Higher Education Model, IJSER, Vol 3, Issue 10, 2012.
15. The Cloud, Changing the Business Eco System, KPMG, 2011.
16. Enterprise Level Learning Management System for the University of Southern, California, October 2012.
17. Adobe Cloud Computing, Adobe® LiveCycle® ES White Paper, 2011.
18. Cloud Infrastructure & Applications – CloudIA, Anthony Sulistio, Christoph Reich and Frank Doelitzscher.
19. A learning style – driven architecture build on open source LMS’s infrastructure for creation of psycho-pedagogically – ‘savvy’ personalized learning paths, Tania Al. Kerkiri , Angela-M. Paleologou, Dimitris Konetas and Kostantinos Chatzinikolaou.