Mapping cloud computing in university e-Governance system

Maroof Naieem Qadri*

PG Department of Computer Science, University of Kashmir, Hazratbal, Srinagar 190006, J&K, India
mnq.scholar@uok.edu.in

S M K Quadri

Department of Computer Science, Jamia Millia Islamia, New Delhi 110025, India
quadrismk@jmi.ac.in

Received 21 November 2016
Revised 03 April 2017, 20 June 2017, 16 July 2017
Accepted 20 November 2017

Abstract

Purpose- The aim of this paper is to propose a model to map on-premise computing system of the university with cloud computing for achieving effective and reliable university e-governance (e-gov) system.
Design/Methodology/Approach-The proposed model incorporates the university's internal e-governance system with cloud computing in order to achieve better reliability, accessibility and availability of e-governance services while keeping the recurring expenditure low. This model has been implemented (and tested on university e-governance system) in University of Kashmir (UOK), case study of this implementation has been chosen as the research methodology to discuss and demonstrate the proposed model.
Findings-According to the results based on practical implementation, the proposed model is ideal for e-governed systems as it provided adequate cost savings and high availability with operational ease, apart from continuing to have necessary security in place to maintain confidential information such as student details, grades, etc.
Practical implications-To achieve high availability and reduce the cost from using external clouds, mapping internal IT servers of the University with the external cloud computing services.
Originality/value- Because no established mapping model for universities has been provided for effective, low cost, highly available university e-governance system, the proposed mapping model through this paper closes this gap and provides guidelines to implement hybrid mapped e-governance model for universities while keeping the recurring expenditure on cloud computing at minimal. Also, it provides the perceptions of its adoption at University of Kashmir for achieving high reliability, accessibility and uptime of its e-governance applications while keeping the recurring expenditure on cloud computing at minimal.

Keywords Cloud Computing; Cloud Services; Hybrid Computing; University e-governance; Universities; Mapped Computing.
Paper type: Applied Research Paper

1. Introduction

Our lives have considerably transformed with the use of technology, the way we interact, communicate, learn and work. Most of the business is carried out through internet now and one seems to be handicapped today without technology. The internet is evolving so quickly, from a traditional medium of merely providing information to users, to an indispensable requirement for the users who want to perform computing, store data and even run software applications at any given moment of time from any part of the world (Ramachandran N, 2014). Traditional accessing of government services is also being made available through electronic media under the banner 'e-governance' (e-gov) giving up the need to go through many procedures and formalities at government setup. E-governance involves new ways of governance, leadership, debating, delivery, investment, transparency, etc. (Qadri, 2014). With e-governance, citizens have round the clock access to government information and interaction with government setup has become easy.

Similarly, education system is benefited by use of technology, the way information is disseminated and knowledge is shared between students, researchers and faculty. Faculty-student interaction is not limited to class room only. Transparency, efficiency and accountability in academic processes particularly for admission and examination system is what students demand in modern times. To achieve these characteristics, e-governance in university system needs to be applied. e-Governance can make universities more efficient and more effective, and bring other benefits too to attain quality in academics. The three main contributions of e-governance: improving governance processes (e-administration); connecting to students (e-students and e-services); and building external interactions (e-society). However, most e-governance initiatives fail. Institutions therefore face two challenges. First, the strategic challenge of e-readiness. Second, the tactical challenge of closing design—reality gaps: adopting best practice in e-governance projects. In order to avoid failure and to achieve success in ensuring smooth and efficient performance of the e-governance system many challenges creep-in like e.g. storing, computing huge databases pertaining to student admission, courses and grades require strong compute power with scalability and putting security feature/s in place. Moreover, keeping the services up round the clock, throughout the year with high reliability and efficiency is a challenging task and is now achieved with the advent of technologies such as "Cloud Computing". Cloud computing is a new way of accepting and providing services over internet. Cloud based e-governance system provides many benefits to academic institutions like reduced cost, distributed storage of data, gets more resources at lower cost, manages security, scalability, accountability and modifiability (Smitha et al., 2012). Cloud computing model can offer an easy means of achieving the unified application model across all educational domain with multi-tenancy. To achieve an optimal or sub optimal allocation for immediate cloud services, the cloud environment with security is the best option. The cloud computing exhibits, remarkable potential to provide cost effective, easy to manage, elastic and powerful resources on fly, over the internet. The economical, scalable, expedient, ubiquitous, and on-demand access to shared resources are some of the characteristics of the cloud that have resulted in shifting

the business processes to cloud (Duan *et. al*., 2012). Since its inception, the cloud computing paradigm has gained the widespread popularity in the industry and academia (M. Sadiku *et. al.,* 2014). The cloud computing attracts the attention of research community due to its potential to provide tremendous benefits to the industry and the community (Aslam *et. al.,*2012 and Sadiku *et. al.,*2014). Cloud computing can provide a good basis to hope that some of the traditional challenges can be addressed, customers use resources provided by the cloud and pay according to the use and on the other hand, cloud providers can re-use resources as soon as they are released by a particular user resulting in improved resource utilization (Prasad & Rao 2014). Ease of use of cloud computing is that, it doesn't require the customer to possess extraordinary expertise pertaining to cloud specific technologies (Ali *et. al.* 2015). However, any organization attempting to switch over to cloud computing requires to assess carefully the option/s available for selecting a suitable service, deployment model and cloud provider, etc. All these decisions are highly strategic in nature, as it would involve time and resources apart from changing the conventional way of operations and hence these decisions are of obvious importance. Unfortunately, in the developing countries unlike developed countries, these decisions are not given adequate importance particularly in educational sector before identifying and adopting specific type of cloud computing model for deployment.

This paper proposes a model to map universities on-premise deployment with the cloud while providing way to maintain adequate cost savings and achieve high availability with operational ease, apart from having security in place to maintain confidential information such as student details, grades, etc. The following section provides information on cloud computing architectural framework, security concerns and challenges. Literature review related to application of cloud computing in educational sector is also done to understand the background work already done in this field apart from identifying the research gaps. Further, discussion on the proposed model and its constructs etc. is done. Later, implementation of the proposed model tis described and validated through an applied case at university. Finally, the paper ends with the results discussion and conclusion.

2. *Cloud computing & its architectural framework*.

Cloud Computing is considered to be the fifth generation of computing after mainframe computing, personal computing, client-server computing and the web. According to a widely accepted definition of the US National Institute for Standards and Technology (NIST), cloud computing is a model for providing ubiquitous, adequate and on-demand network access to a shared pool of configurable computing resources (e.g. servers, networks, storage, applications and services) with minimal effort and service provider interaction (Mell and Grance, 2011).

The building blocks of cloud computing are hardware and software architectures that enable infrastructure scaling and virtualization. The new paradigms aimed is providing a huge amount of computing power in a completely virtualized manner, by combining all computing resources and services in a single system. The cloud computing environment with the virtualization concept fulfils these requirements. National Institute of Standards

and Technology (NIST), identified the following characteristics that every cloud service must have:

- It must be an on-demand self-service in which a customer can self-provision compute, storage, etc., without human interaction.
- It must contain broad network access with reachability and platform options (including thin and thick clients, phones, tablets).
- It must be a multi-tenant (pooled resources) environment fostering location-independence.
- It must support rapid elasticity with the ability to grow and shrink based on policy, with no impact to applications or users.
- It must be a measured service, metered by performance with a pay-as-you-go pricing model.

Cloud computing architecture therefore comprises of cloud services delivered by cloud service providers to cloud consumers over a networked infrastructure. According to the capabilities of cloud computing, cloud computing is divided into three service models (Rajaraman,2014; Sultan, 2010; Yuvaraj, 2015). Cloud service model is considered as a service-oriented architecture that describes cloud services at several levels of abstraction (Mell and Grance, 2011). These models are Software as a Service(SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS). In addition, to deploy cloud computing services, there are four primary models: public, private, hybrid and community (Mell and Grance, 2011). Fig. 1a illustrates the cloud service models and fig. 1b illustrates the cloud deployment models.

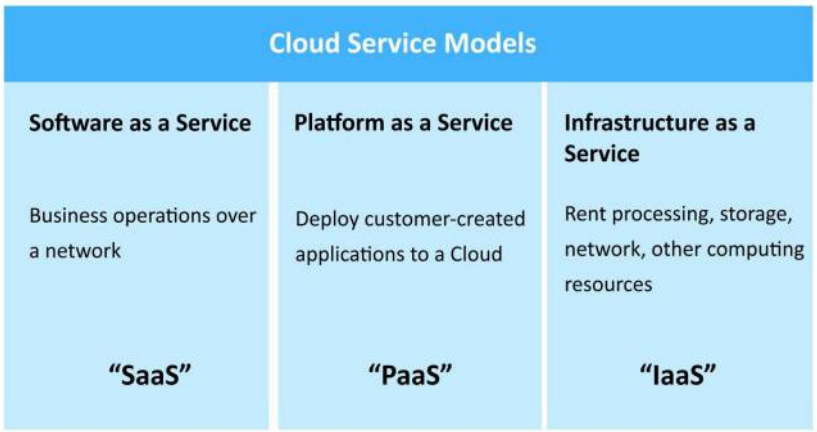


Fig. 1a: Cloud service models.
Source: KPMG India Cloud Publication: Changing the ecosystem

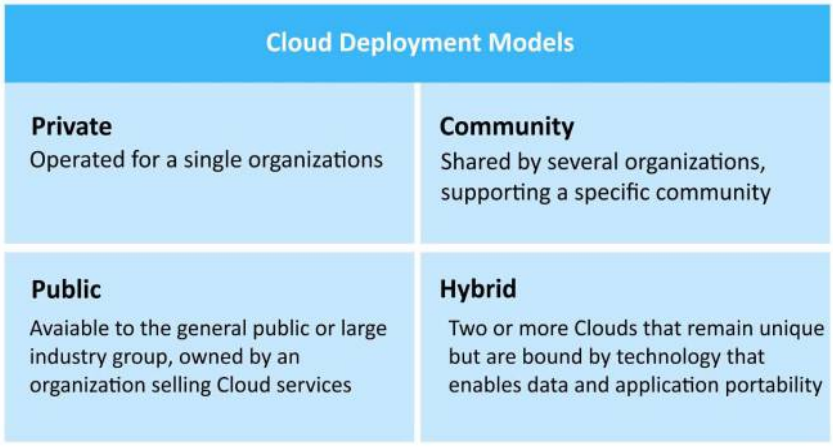


Fig. 1b: Cloud deployment models.

SOURCE: KPMG INDIA CLOUD PUBLICATION: CHANGING THE ECOSYSTEM

2.1 Benefits of cloud computing

Cloud computing provides compelling savings in IT related costs including lower implementation and maintenance costs; less hardware to purchase and support; the elimination of the cost of power, cooling, floor space and storage as resources are moved to a service provider; a reduction in operational costs; and paying only for what is used (pay-as-you-go). Cloud computing also enables organizations to become more competitive due to flexible and agile computing platforms, providing for scalability and high-performance resources, easily accessible, highly reliable and available applications and data, paves way for establishing efficient backup and recovery options at times of primary services failure due to sudden breakdown or power failure. Through cloud computing, IT departments save on application development, deployments, security, and maintenance time and costs, while benefiting from economies of scale. 'Green computing' and saving costs are a key focus point for organizations. Cloud computing helps organizations to reduce power, cooling, storage and space usage and thereby facilitates more sustainable, environmentally responsible data centres. Moving to the cloud further frees up existing infrastructure and resources that can be allocated to more strategic tasks.

The main driver for cloud computing adoption is the cost efficiency besides other benefits as described. It is important to note that the scale of such benefits, the ability to capture them, and the cost/benefit ratio achieved depend on many unique factors and will vary significantly. These benefits include where an organization sits in its IT CapEx and systems-development cycle, its current hardware and software architecture (for example, some older applications may not be "cloud-ready"), and its staff and management capabilities. In higher education, legal and policy constraints may be especially

important. Benefit realization will also depend on the chosen cloud-computing deployment model. It should be clear that the choice of a cloud model is not an all-or-nothing proposition, in the short to medium term, the selection of a cloud deployment model is one of the most important decisions higher education IT managers will face. Table 1 describes briefly the benefits of cloud computing with related references.

The Benefit	***Description***	***References***
Ease of Implementation	Public sector organizations can easily deploy cloud computing without the need to have heavy hardware, buy software licenses, or implement applications.	(Alshomrani & Qamar, 2013; Das, et al., 2011; Liang, 2012; Rastogi, 2010; Chandra & Bhadoria, 2012; R. Sharma, et al., 2012; Bellamy, 2013; Bhisikar, 2011; Kundra, 2010; Zwattendorfer & Tauber, 2013)
Cost Savings	Organizations can save or even eliminate ICT capital costs and decrease operational costs by paying only for the used services and reducing or redeploying ICT staff.	(Alshomrani & Qamar, 2013; Bansal, et al., 2012; Craig, et al., 2009; Das, et al., 2011; Liang, 2012; Rastogi, 2010; R. Sharma, et al., 2012; Bellamy, 2013; Kundra, 2010; Zwattendorfer & Tauber, 2013; Rashmi Sharma,2011)
Scalability	When a user loads increase, organizations need not to fulfil additional hardware and software, but can instead add and subtract network load capacity.	(Alshomrani & Qamar, 2013; Tripathi & Parihar, 2011; Das, et al., 2011; Liang, 2012; Rastogi, 2010; R. Sharma, et al., 2012; Bhisikar, 2011; Zwattendorfer & Tauber, 2013)
Accessibility & Greater Mobility	Cloud computing can increase staff mobility by enabling access to information and services from anywhere and a wide range of devices.	(Alshomrani & Qamar, 2013; Das, et al., 2011; Liang, 2012; Rastogi, 2010; R. Sharma, et al., 2012; Bellamy, 2013; Bhisikar, 2011; Zwattendorfer & Tauber, 2013)
Access to IT Capabilities	Cloud computing allows smaller organizations to access powerful hardware, software, and ICT staff.	(Bansal, et al., 2012; Liang, 2012; Bellamy, 2013; Zwattendorfer & Tauber, 2013)
IT Staff Redeployment and Focusing on Core Competencies	Cloud computing can make it easier to reduce or shed functionalities like running data centers, developing and managing software applications, allowing organizations to focus on critical issues like policy development and public services design and delivery.	(Yeh, et al., 2010; Kundra, 2010; Rashmi Sharma, 2011)
Green computing	Cloud computing is good for the environment as it uses very less amount resources. So, it requires very less power consumption.	(Bansal, et al., 2012; Das, et al., 2011; R. Sharma, et al., 2012; Kundra, 2010)
Backup & Recovery	Cloud computing delivers faster recovery times and multi-site availability at a fraction of the cost of conventional disaster recovery and has efficient backup support.	(Mansuri A M et al,2014)

Table 1: Benefits of cloud computing

3. Cloud based university e-governance system

In academia, cloud computing is a powerful tool that offers great scalability and flexibility, making it possible for students, staff, faculties, administrators, and other campus users access file storage, databases, and other university applications anywhere

anytime (Jain and Pandey,2013). The cloud computing technology has been termed as the "silver bullet" in the field of educational technology (Mell & Grance,2010).

Cloud based e-governance represents an emerging paradigm for distributed computing of e-governance applications that utilizes services as fundamental elements in building agile networks of collaborating applications distributed within and across government boundaries (Smitha et al., 2012). e-Governance with cloud computing offers integration management with automated problem resolution, manages security end-to-end, and helps budget based on actual usage of data. At a global level, cloud architectures can benefit government to reduce duplicate efforts and increase utilization of resources. This helps the government going green, reducing pollution and effective waste management.

It offers integration management with automated problem resolution, manages security end-to-end, and helps expenditure control based on actual usage of data. At a global level, cloud architectures can benefit government to reduce duplicate efforts and increase utilization of resources. This helps the government going green, reducing pollution and effective waste management.

Cloud computing can be capable of resolving several issues in e-governance. Cloud computing offers several benefits to e-governance (Varma, 2010), some of them are

- *Data Scaling*

The databases should be scalable, to deal with large data over the years for e-governance applications. Where relational databases ensure the integrity of data at the lowest level, cloud databases could be scaled and can be used for such type of applications. Cloud databases available for deployment offer unprecedented level of scaling without compromising on the performance. Cloud databases must be considered if the foremost concern is on-demand, high-end scalability – that is, large scale, distributed scalability, the kind that can't be achieved simply by scaling up.

- *Auditing and logging*

Traceability to any changes to information content in e-governance services is required. Corruption in government organizations can be controlled by using Information Technology services, by keeping the providers of the services accountable. Process audits, security audits must be done periodically to ensure the security of the system. Cloud can help in analyzing huge volumes of data and detecting any fraud. It can help in building and placing defense mechanisms to enhance the security, thereby making the applications reliable and available.

- *Rolling out new Instances, Replication and Migration*

Traditionally, applications in e-governance work for department states and municipalities and hence take more time, effort, resources and budget. This happens for all the instances of these applications. Capabilities must exist to replicate these to include another municipality or e-court as part of e-governance. Cloud architectures offer excellent features to create an instance of application for rolling out a new municipality. Cloud can reduce the time to deploy new application instances.

- *Disaster Recovery*

Natural disasters like floods, earthquakes, wars and internal disturbances could cause the e-governance applications not only loose data, but also make services unavailable. Multiple installations in geographically separated locations with complete backup and recovery solutions must exist. This could create huge problems. Disaster recovery procedures must be in place and practiced from time to time. Applications and data must be redundant and should be available on a short notice to switch from one data center to center. Cloud virtualization technologies allow backups and restoring. It offers application migration seamlessly compared to traditional data center.

- *Performance and Scalability*

The architecture and technology adopted for the e-governance initiatives should be scalable and common across delivery channels. It is required to meet growing numbers and demands of citizens. If implemented, the e-governance portals could become the biggest users and beneficiaries of Information Technology. With cloud architectures, scalability is inbuilt. Typically, e-governance applications can be scaled vertically by moving to a more powerful machine that can offer more memory, CPU, storage. A simpler solution is to cluster the applications and scale horizontally by adding resources.

- *Reporting and Intelligence (Better governance)*

Data center usage (CPU, storage, network etc.), peak loads, consumption levels, power usage along with time are some of the factors that needs to be monitored and reported for better utilization of resources. It minimizes costs and plan well. Profiling data enables better visibility into various services provided by the government. Cloud offers better Business Intelligence infrastructure compared to traditional ones because of its sheer size and capabilities. Cloud computing offers seamless integration with frameworks like MapReduce (Apache Hadoop) that fit well in cloud architectures. Applications can mine huge volumes of real time and historic data to make better decisions to offer better services.

- *Policy management*

e-Governance applications have to adhere and implement policies of the governments in terms of dealing with citizens. Along with the infrastructure and data center policies has to be enforced for day to day operations. Cloud architectures help a great deal in implementing policies in data center. Policies with respect to security, application deployment etc. can be formalized and enforced in the data center. With cloud, e-governance applications can manage the policies well by providing security and adoptability. Various e-governance applications can be integrated easily.

- *Systems Integration and Legacy Software*

Not only the applications that are already deployed and providing services are to be moved to the cloud, but also integrate with applications deployed in the cloud. The power of Information Technology comes in co-relating the data across applications and pass messages across different systems to provide faster services to the end users. Cloud is built on SOA principles and can offer excellent solutions for integration of various applications. Also, applications can be seamlessly easily moved into cloud.

- *Obsolete Technologies and Migration to New Technologies*

Technology migration is the biggest challenge. Moving to different versions of software, applying application and security patches is the key to maintaining a secure data center for e-governance.

Universities not subscribing and utilizing cloud services have to otherwise establish their own on-premise deployment that caters to the needs of students, scholars, faculty and management, research staff and software / web developers. All these demands have to be met by the internal IT service and support department whose job is to:

- provide students, researchers and staff with software (e.g. operating system, office, antivirus, malware detectors & cleaners etc.) and hardware (e.g. desktops, servers, etc.);
- provide students, researchers, faculty file storage for their documentation, e-tutorial and e-learning purposes;
- provide researchers and post graduate students with the required special software and hardware to run experiments that are likely to involve a great deal of computational power;
- provide software / web developers with development tools needed to write and host e-governance applications;
- Provide students, faculty and staff email services and hosting space to other campuses / departments / centres of the University.

These requirements need continuous upgrades, patches and result in putting recurring financial burden on the institution. However, this can be reduced drastically by migrating most of the services to cloud and can be ideally accessed through web. Highly sensitive and mission critical applications / services can be continued with the on-premise deployment, also campus/s will have a facility (live environment) on-premise for the testing of e-governance applications developed using agile methodology. Agile development methodology is recommended for e-governance development (Quadri *et. al.* 2014).

3.1 Risks & sensitivity specific to university use of cloud computing

Introduction of any technology to an organization has its pros and cons so are with implementing cloud computing in University e-governance. Benefits of cloud computing in university have been discussed in the above sections and among the cons, concerns are, the risks on use of cloud computing in University system. Tests should be done in order to mitigate the challenges and risks of migrating business to the cloud (Farooq & Quadri, 2016). Although the potential for cost savings on infrastructure is a strong selling point for migrating to a cloud computing environment, the costs associated with additional systems risks need to be understood and accepted.

Implementing a cloud computing platform incurs different risks than dedicated data centres. Risks associated with policy changes, implementation of a new technology service delivery model include policy changes, implementation of dynamic applications, and securing the dynamic environment need to be mitigated (Scott Paquette et. al., 2010). Universities hesitate in deploying e-governance databases processing critical data pertaining to admissions & examination on cloud in order to prevent any data theft, leakages on cloud and prevent vendor lock-in. They prefer keeping such services of highly sensitive databases under their own in-house, closed umbrella and look for a solution which safeguards their above concerns.

4. Literature review of related work

The below review gives insight about the papers related to the work which is followed by inferences drawn, further the model has been proposed based on the gaps in the related work.

i. Khmelevsky and Voytenko (2010), evaluated the successful implementations of cloud computing models at educational institutions and developed a research and education prototype of a cloud computing model. They demonstrated a real-life prototype of cloud computing infrastructure which was developed for effective sharing and utilization of computing resources available with King's University College and Okanagan College, Kelowna, Canada.

ii. Sultan (2010), provided adequate answers to those questioning the feasibility of implementing cloud computing by discussing how the main users of IT services in a typical university can be migrated to the use of cloud computing environment. He noted that students, lecturers, administrators can use SaaS and IaaS, while developers can use PaaS. Furthermore, he also dealt with the economics behind the existing IT support and highlighted about the flexibility and cost reduction that can be obtained by migrating to cloud computing. He demonstrated the same using the case of University of Westminster, UK.

iii. Alabbadi (2011), proposed a conceptual framework called "Education and Learning as a Service" (ELaaS) to highlight the utility of Cloud computing within education sector. The IT activities in the educational and learning organizations were classified with respect to the two criteria: mission criticality and sensitivity. Each class is then mapped into the appropriate position in the proposed Complete Cloud Computing Formations (C3F) resulting in a conceptual framework for ELaaS.

iv. Manro *et al.* (2011), attempted to answer whether the services of cloud computing are significant in the education sector – especially in the Indian scenario and concluded both the private and public educational institute can adopt the same. They noted that the educational institutes thus can outsource non-core services (i.e. the IT services) and better concentrate on offering students, teachers, faculty and staff the essential tools to help them succeed.

v. Tan and Kim (2011), demonstrated how "Google Docs", an application that is enabled by cloud computing technology is utilized by the group of students pursuing a higher degree on Master of Business Administration (MBA) in a

University at North Eastern US for carrying out their project needs. They found that it was really helpful for the students, who expressed they would be willing to these technologies quite often in the future too.

vi. Saidhbi (2012), in the research Cloud Computing Framework for Ethiopian Higher Education Institutions proposed the implementation of a central hybrid cloud computing infrastructure that combines both the current local infrastructure of the universities as the private cloud and public cloud to enable the sharing of educational resources and collaboration within all universities in Ethiopia and the global educational community, so that Ethiopian higher institutions can enjoy the benefits of ICT in an efficient and affordable way. The research further states that by deploying the proposed hybrid cloud model, the risks of privacy and other security challenges can be avoided as critical and sensitive data will be housed in a private cloud.

vii. Pardeshi (2014), proposed a cloud based IT architecture consisting of various deployment & service models, the IaaS as a foundation layer, with PaaS build upon IaaS, and followed by SaaS build upon PaaS for implementing cloud in the Higher Education(HE) institute. A five step framework based on Roger's Innovation-Diffusion model has been suggested for adopting cloud in HE institutes. The model consists of five step knowledge, persuasion, decision, implementation and confirmation.

viii. Ramachandran *et al.* (2014), in their case study on 'selecting a suitable cloud computing technology deployment for an academic institute' used Multi-Criteria Decision Making(MCDM) model –namely, the Analytic Hierarchy Process(AHP) for the decision making process found that private cloud is the best suited for the case institute (Indian Institute of Management Kozhikode-IIMK, Kozhikode, India) as it would provide adequate cost savings, apart from providing necessary security to maintain confidentiality on student details, grades, etc. They concluded in their study that although applications of cloud computing technology are picking up in education sector across the world, it is no so prevalent in the developing countries such as India.

ix. Okai *et al.* (2014), proposed a road map for successful adoption of cloud computing for a safer and more enjoyable user experience at the university level. The road map consists of Planning, choosing the right deployment model, choosing the most suitable service delivery model, vendor selection, negotiating SLA, migration and integration for analysing cloud computing adoption model at for universities.

x. Mohammed and Ibrahim (2015), while reviewing the literature on the proposed models of cloud computing for adoption in e-government systems, found 42% are component based models, 29% are layered based model, 17% are step based model and only 12% are conceptual / theoretical model. It revealed that there is a lack of theoretical models that empirically investigate the influencing factors on applying cloud computing in the e-government context.

xi. Mohammed *et al.*(2016), proposed a theoretical model to explore and measure the factors influencing cloud computing adoption as a part of developing countries'

alternatives to implement e-government services. By considering theoretical constructs' literature, cloud computing characteristics and e-government context, they developed an instrument to measure IT experts' perspective of the fit and viability of cloud computing for e-government services. Their result show that the scale measurements meet the conventional criteria reliability and validity.

After doing the literature review of the related work, following inferences can be made:

I. It was found that applications of cloud computing are made for educational sector deployments, supporting e-learning facilities for facilitating students pursuing studies through interactive learning or internet-based learning methods. Resource sharing have been deployed for sharing across different institutions (Khmelevsky and Voytenko, 2010). SaaS and IaaS cloud models have been suggested for students, lecturers, administrators, while PaaS for developers (Sultan, 2010), thus suggesting a hybrid model for educational requirements.

II. Outsourcing of non-core services (i.e. the IT services) and concentrating on offering students, teachers, faculty and staff the essential tools to help them succeed has been emphasized (Manro et al.,2011). Demonstration on how "Google Docs", an application that is enabled by cloud computing technology is utilized by the group of students pursuing a higher degree on Master of Business Administration (MBA) in a University at North Eastern US for carrying out their project needs was found really helpful for the students (Tan and Kim,2011).

III. Alabbadi (2011), proposed a conceptual framework called ELaaS for adopting cloud computing in Education and Learning organization. The framework is equipped with two principles (outward and inward) based on mission criticality and sensitivity. Accordingly, the author has categorized IT activities / services in the educational and learning organizations as low and high for simplicity and decision making. The universities can therefore identify sensitive and mission critical IT activities as low and high and accordingly move low sensitive and low mission critical services to cloud and keep continuing with high sensitive and high mission critical services on-premises. In order to implement such framework (ELaaS), need for applied prototype is felt.

IV. Saidhbi (2012), proposed the deployment of hybrid cloud model in higher education so that the risks of privacy and other security challenges can be avoided, as critical and sensitive data will be housed in a private cloud.

V. There is dearth of conceptual model/s for applying cloud computing in the education sector on e-governance systems.

From the above inferences, it can be found that all the academic institutions primary concern is to prevent privacy leakage and maintain the integrity of educational data especially confidential information such as student's details, grades etc. Identifying and analysing the sensitive and mission critical IT activities carried out at the institution is essential, migration to cloud should be gradual and not all at once.

The models proposed so far are hypothetical lacking implementation, organizations including academic institutions / universities have no concrete model for mapping on-

premise deployments with cloud. We are proposing a mapping algorithm for university e-governance system ensuring privacy of sensitive data, performance, apart from financially viable solution.

5. Methodology

Cloud comes at a price and moving entire services with large data to the cloud will cost heavily on the university, as state funded institutions are not in a position to afford such a price however institutions cannot afford to remain without high availability and backup solutions. Accordingly, model which is financially viable and enabling achieve high availability, reliability and accessibility while maintaining privacy and security of the university e-governance system is required.

The proposed mapped model in the next section closes this gap (between theory and practice) and provides algorithm / guidelines to implement hybrid mapped model for universities, it helps adopt cloud computing at university while maintaining confidentiality of sensitive e-services through on-premise deployment, mapped with external cloud computing for achieving high reliability, accessibility, apart from maintaining the cost effectiveness.

Case study implementation of the proposed mapped model will give the insight of high reliability achieved on e-services deployed on-premises when backed-up through mapping model.

6. Proposed Mapping model

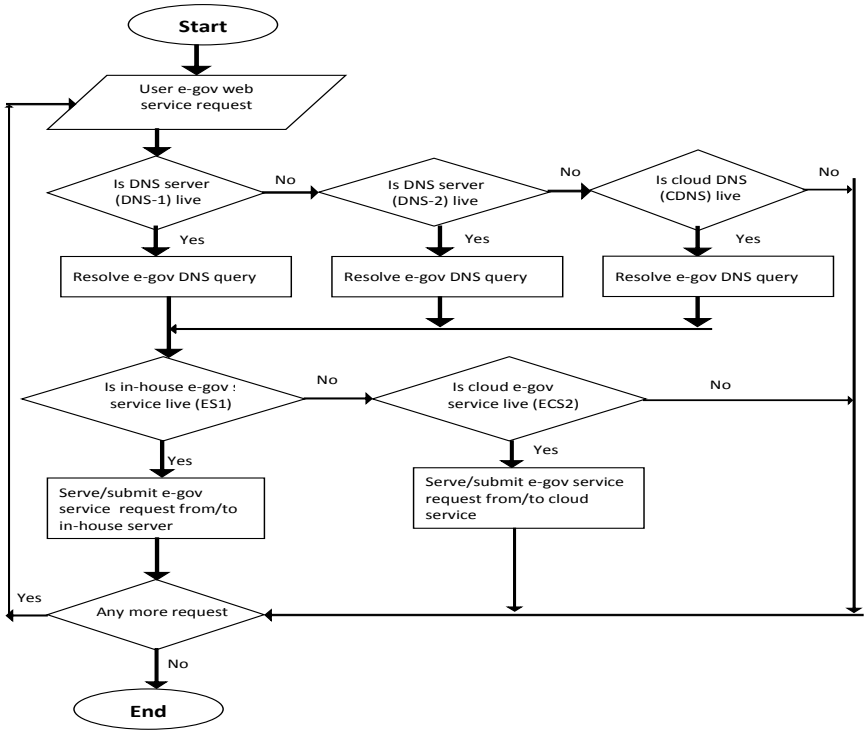


Fig 2: Proposed mapped cloud computing model for University e-governance system

Universities have many departments and units spread across large campuses, they establish internal IT service department to cater to the IT services and support activities. Almost all universities in todays' technological times have well established high speed LAN's with dedicated internet for academic and research activities. Some of the activities require compute power, storage with privacy and security features and for such requirements, campuses have been building IT infra with data centre facilities at its premises, operated and maintained by its IT service department. In addition to the academic and scientific computational processes carried out on the internal IT deployments, hosting / deploying the universities web portal and e-governance applications on intranet & internet is also done at its on-premise data centre or server room/s. Applications deployed live at the university data centre / server room/s cannot afford downtimes, these services have to be up 24/7/365 days and operating and maintaining these services requires 24/7/365 monitoring. Also, the growing requirements demand upgrading the on-premise IT infra from time to time and funds for this CapEx and OpEx are required to be earmarked. Universities relying completely on internal deployments for achieving high reliability, high availability is a challenging task and on moving entirely to cloud universities have data privacy, security, data theft, leakages on cloud and vendor lock-in etc. among the prime concerns. Migrating university e-governance system exclusively to cloud can lead to hampering of services at times when there is either internet breakdown at university campus/s or the cloud service providers' services fail due to some technical snag or undertake some scheduled maintenance.

Considering for example a scenario where e-governance application catering to library services processing issue / return of books is taking place and all of sudden university's internet links goes down for quite some time. The e-governed applications deployed exclusively on cloud will not be accessible for the campus/s and during this downtime no activity will take place at the campus. However, if the application is deployed on the servers at its on-premise data center or server room, the application will continue to serve on intranet of the campus/s. Similarly, other such critical e-governed services (e.g. student admissions and examination related) deployed exclusively on cloud will come to halt at the university side during internet link failures.

Keeping all these factors in view, a mapped cloud computing model is proposed (above Fig. 2) for university e-governance system so as to establish a better and reliable e-governance system and achieving low billing on cloud subscription. Depending on availability of compute resources (processors, memory, storage, bandwidth etc.) at university, university can either deploy all or only their mission critical e-governance applications on in-house servers and instances of those applications can be deployed on cloud to takeover on fail over under high availability (HA) mode.

Essentially, universities subscribe to two internet links from multiple Internet Service Providers (ISP's) for their campus requirements (for research and data center operations)

which enable them to have fail over link in case their primary link goes down. In India, government owned universities are provided high speed dedicated internet under National Knowledge Network (NKN) project, its main role being to facilitate an ultra-high speed e-governance backbone [source www.nkn.in].

The proposed cloud computing model is explained using two dedicated internet (leased) links of the university, subscribed through two different ISP's. The name resolution and pointing to university e-governance system, DNS (Domain Name System) services (DNS-1 and DNS-2 as in fig. 2 above) are established in-house at the university and the third DNS service (CDNS in fig. 2 above) is deployed on cloud. DNS-1 is deployed as primary DNS service, DNS-2 as secondary DNS service-1 and cloud DNS service (CDNS) as secondary DNS service-2.

Based on the preference set with Time-To-Live (TTL) of A (address) records in the e-gov DNS services, user e-gov web request is routed to DNS-1, if DNS-1 is up, the DNS resolution is done by DNS-1. In case DNS-1 is down, the request is routed to DNS-2 for resolution and if DNS-2 is up, the DNS resolution is done by DNS-2 otherwise the request is routed to cloud DNS (CDNS) for resolution / pointing details. All the internal (intranet) and external (internet) e-gov DNS requests are routed by internal DNS services (DNS-1 & DNS-2) during their availability and request is routed to Cloud DNS service only when both DNS-1 and DNS-2 fail or are down.

In this proposed model, all the e-gov services in the Domain Name System (DNS) are primarily pointed to in-house e-gov service (ES1) through internal leased links and secondary pointing is made to the mirrored e-gov service on cloud at ECS2. E-governance databases on both services (ES1 & ECS2) are synced. Database on ES1 is set as principle database and on ECS2 is set as mirror database. User e-gov requests are primarily served by e-gov services on ES1 and in case the service on ES1 is not accessible, the cloud service on ECS2 serves / submits the users web service request and during this period database on ECS2 takes over as principle database. Upon service restoration on ES1, its database takes over back as principle database and starts back serving / submitting users e-gov web service requests.

6.1 Algorithm of proposed mapped model

Algorithm

1. Define n is user request to access the e-gov resources.
2. Define x is the number of DNS services available for e-gov resources.
   // three DNS services in case of above proposed mapped model.
3. Define z is the number of e-gov service available.
   //two e-gov services (internal & cloud) in case of above proposed mapped model.
4. Each request is routed to internal primary DNS service.
5. If internal primary DNS isn't available, then request is routed to internal secondary DNS service.
6. If internal secondary DNS isn't available, then request is routed to cloud DNS service.
7. After DNS resolution, request is pointed to internal e-gov service.
   //for user access.

8. If internal e-gov service is not available, then request is pointed to cloud e-gov service. //for user access.

Above algorithm describes the working process of mapped algorithm for University e-gov services.

7. The University of Kashmir: Case study

Founded in year 1948, the University of Kashmir (UOK) offers programmes in all the major faculties; Arts, Business & Management Studies, Education, Law, Applied Sciences & Technology, Biological Sciences, Physical & Material Sciences, Social Sciences, Medicine, Dentistry, Engineering, Oriental Learning and Music & Fine Arts. It has been constantly introducing innovative / new programmes to cater to the needs and demands of the students and the society. [source www.uok.edu.in].

The University of Kashmir (UOK) has more than 15,000 students enrolled for post graduate (PG) programme and 2,50000 students enrolled for undergraduate programme (UG). PG courses are taught at university campuses and UG courses at affiliated (govt. and pvt.) colleges of the university. In order to improve efficiency and bring transparency in the university system, University of Kashmir established e-governed services catering to highly critical processes of the university involving student admissions processes from online form submission to compilation of results and preparation of merit lists, online examination forms, awards and results compilation, academic and administrative processes.

The e-gov initiatives taken by University of Kashmir have not only brought improvement in the functioning of the system, these e-governed services have also made information available to the citizens round the clock in a convenient, efficient and transparent manner resulting in good governance by attaining its eight major characteristics - Participation, Transparency, Effectiveness and Efficiency, Responsiveness, Accountability, Equity and Inclusiveness, Rule of Law, as in for the effective and efficient governance (Qadri, 2014).

7.1 Internal deployment and cloud concerns for University of Kashmir e-governance

The University of Kashmir's entire e-governance solutions are designed & developed in-house and are deployed at the on-premise data centre, established in the main campus. These e-governed services are accessible to users through two dedicated internet leased links of the University, one provided to University under National Knowledge Network project and another subscribed by university through an alternative service provider. Also, university has a huge wide area network (KUWAN) spread across its different campuses and affiliated govt. colleges in the different districts of the state (Jammu and Kashmir, India). The e-governed services at these campuses and colleges are accessible through KUWAN.

Ensuring high availability, accessibility of these e-governed services not only depends on operating and maintaining 24/7 the on-premise data centre but also depends on high availability/uptime of internet links which due to hilly terrain and harsh weather in the state of Jammu and Kashmir is effected and is not like connectivity to other states of the country. Also, at times internet to this part of the world is barred due to political

uncertainty and these factors have a huge impact on availability and accessibility of e-governance services of the university, relying entirely on internal deployments doesn't allow achieving high availability, efficiency and reliability.

Moving all its e-gov services completely on cloud are also matter of concern for the University of Kashmir as is for many other academic institutions, especially concerns relating to privacy, security, control, vendor lock and high recurring expenditures. However, ignoring cloud completely is also not a possible, in case the university wants to overcome the problems and issues faced with their internal deployments. The mapped model illustrated above has been implemented at the university after and is illuminated in the proceeding section.

8. Mapping of University services with cloud

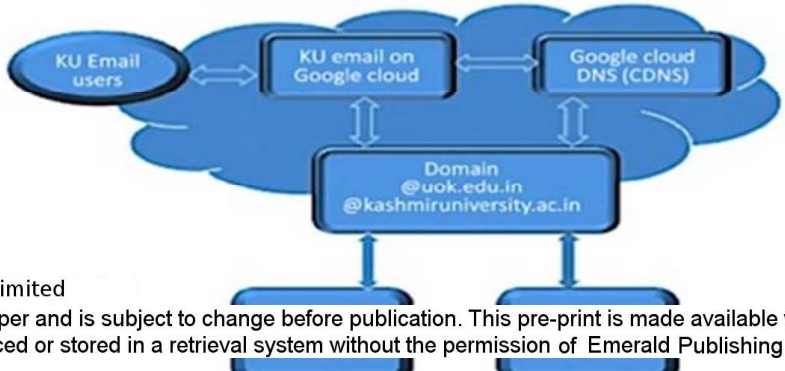
8.1 Deployment & mapping of 'Google suite for education' for cloud mail solution.

Applying the concept of the above proposed model, University of Kashmir choose to move its mailing solution to 'Google suite for education' from its internal mailing system. The internal mailing system by way of establishing mail server on-premise was initially deployed. There was reliability & availability concerns among the users and were abandoning the internal mail service in favour of their personal email system. Every time university had link failure, external mails would bounce back and delivery to university mail server failed. Official communication through emails with external world would come to standstill and only internal mail receive and sent worked which lead to hue and cry during downtimes. Other issues like spam identification and growing storage demand also started creeping in, moving to Google cloud helped achieve credibility of university mailing solution and users opted back to services on university domains '@kashmiruniversity.ac.in or @uok.edu.in'. These services which were confined to faculty and staff only earlier because of limitations on internal deployment, also were extended to students and researchers post deployment of cloud. This facilitated the students and researchers to have a recognized digital identity under university domain and there digital connect with faculty became stronger with the facilities like of drive storage, classroom, mail, calendar, vault, docs, sheets, slides, sites.

8.1.1 Method of deployment (Google suite on education)

The Mail Exchange records (MX) of these two domain names are pointed through two internal DNS servers (DNS-1 & DNS-2) of the University and are supported by Google cloud DNS services(CDNS) to the google service for mail solution. Primarily, MX requests are served / resolved by the internal DNS servers and in case internal DNS services are not available, requests are served/resolved by Google DNS service. These requests being primarily served/resolved through on-premise DNS services helps maintain low monthly billing on cloud DNS. Fig. 3 below depicts the flow of the google email service mapped through internal DNS (DNS-1 & DNS-2) and google cloud DNS (CDNS).

The migration using the mapped model not only enabled achieve high availability of email solution but also extended other valuable features with 'Google suite for education'.



8.2 Mapping of University e-governance system

Applying, the conceptual mapped model proposed above for mapping on-premise deployment with cloud computing, university mapped its e-governance system with cloud computing mapping. Fig. 4 below shows the working and flow of the mapped model implemented at University of Kashmir.

The internal e-governed services of the university are deployed live (on internet) using its two dedicated internet leased links, one provided under National Knowledge Network(NKN) programme, having bandwidth of 1Gbps and another subscribed from Software Technology Park of India (STPI) having a bandwidth of 80Mbps (1:1). These links cater to the requests / submissions received on university e-governed services.

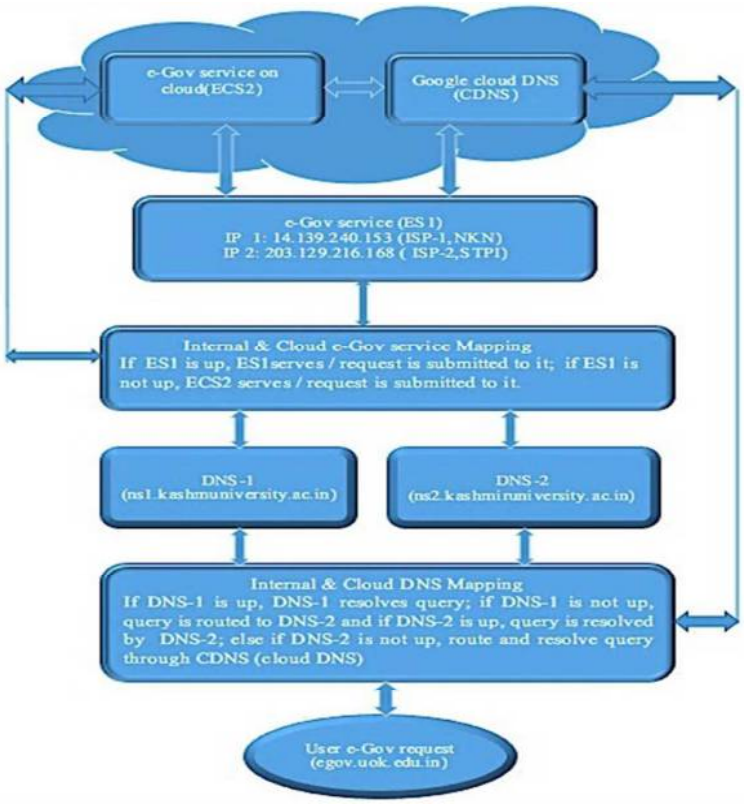


Fig. 4: Mapped model implemented at University of Kashmir (bottom up).

8.2.1 Method for Mapping of University e-governance system

Primarily, the user requests for university e-gov service, are routed to the Primary DNS service (DNS-1, ns1.kashmiruniversity.ac.in), if DNS-1 is available, requests are resolved by internal DNS service (DNS-1), if DNS-1 is not available, they are routed to DNS-2 (ns2.kashmiruniversity.ac.in) for resolution, if DNS-2 isn't available, then the requests are routed to Google Cloud DNS(CDNS) for resolution. Upon DNS query resolution, the requests are pointed to internal e-gov server (ES1) for submission / serving users e-gov request/s, in case the internal e-gov server (ES1) isn't available, the requests are then routed to cloud e-gov service(ECS2) for serving / submission. The requests to cloud e-gov service are routed only when the services on internal on-premise deployment fail or don't respond.
It helps adopt cloud computing at university while maintaining confidentiality of sensitive e-services through on-premise deployment, mapped with external cloud computing for achieving high reliability, accessibility, apart from maintaining the cost effectiveness.

9. Results & discussions

The results from implementation of model at the case institution have provided initial support for the proposed mapped model and algorithm in the adoption of cloud computing for university e-governance system and e-services. The reliability of the model has been established.

First with the deployment of 'Google suite for education' at the case university, enabled the university to establish a reliable and hassle free services (classroom, mail, drive, calendar, vault, docs, etc.) for students, researchers, faculty and administrative staff. Faculty is able to create lessons, distribute assignments, send feedback and see everything in one place, instant and paperless. Also, students and teachers have immediate conversations and collaborate on assignments.

Reliability, availability and cost effectiveness achieved are:

- 99.9% uptime
- Apps work on any computer, tablet or phone.
- No advertisements.
- 24/7 support at no additional cost.
- Cost of using 'Google suite for education' is free.
- Eliminating the need to invest on building & upgrading IT infra for email, drive, vault etc. solutions.
- On-premise man power for maintaining and supporting mail services not required anymore.

Second with the deployment of mapped model for e-governance system at case university, enabled the university to get away with the concerns highlighted in section 3.1

above, especially the complete blackout faced during their on-premise service failures. The universities e-governance system achieved effective, high reliability and availability and maintained cost effectiveness.

Charges on Google cloud service are based on pay-as-you-go and therefore are calculated on usage (pay per use) as per number of queries/requests received / served. The minute services are turned off, paying for that service also stops. Fig. 5 illustrates the google cloud pricing for DNS service and other services like storage etc. are also charged based on the same model i.e. pay-as-you-go.

Google Cloud DNS Pricing

Metric	Price
Queries: 0-1 billion	$0.40 per million queries per month.
Queries: over 1 billion	$0.20 per million queries per month
Managed Zones*:0-25	$0.20 per million queries per month
Managed Zones*: 26-10000	$0.10 per managed zone per month for each additional zone after 25.
Managed Zones*: over 10000	$0.03 per managed zone per month for each additional zone after 10000.

Google Compute Engine Pricing

US ▾ Monthly Hourly

Machine type	Virtual CPUs	Memory	Price (USD)	Preemptible price (USD)
n1-standard-1	1	3.75GB	$0.0475	$0.0100
n1-standard-2	2	7.5GB	$0.0950	$0.0200
n1-standard-4	4	15GB	$0.1900	$0.0400
n1-standard-8	8	30GB	$0.3800	$0.0800
n1-standard-16	16	60GB	$0.7600	$0.1600
n1-standard-32[1]	32	120GB	$1.5200	$0.3200

Fig. 5: Google pricing for DNS cloud and compute engine subscribed by university:

The number of e-gov requests to external cloud service with case institution stay low as they are primarily served by on-premise deployment (e-gov services deployed on internal data centre of the university) and come into play only when on-premises services fail. Hence preventing the blackout phase during on-premise link or service failures.

The fig. 6a below illustrates the real time usage statistics of the cloud DNS and compute engine usage for a month during peak traffic in view of admissions, registration processes of students.

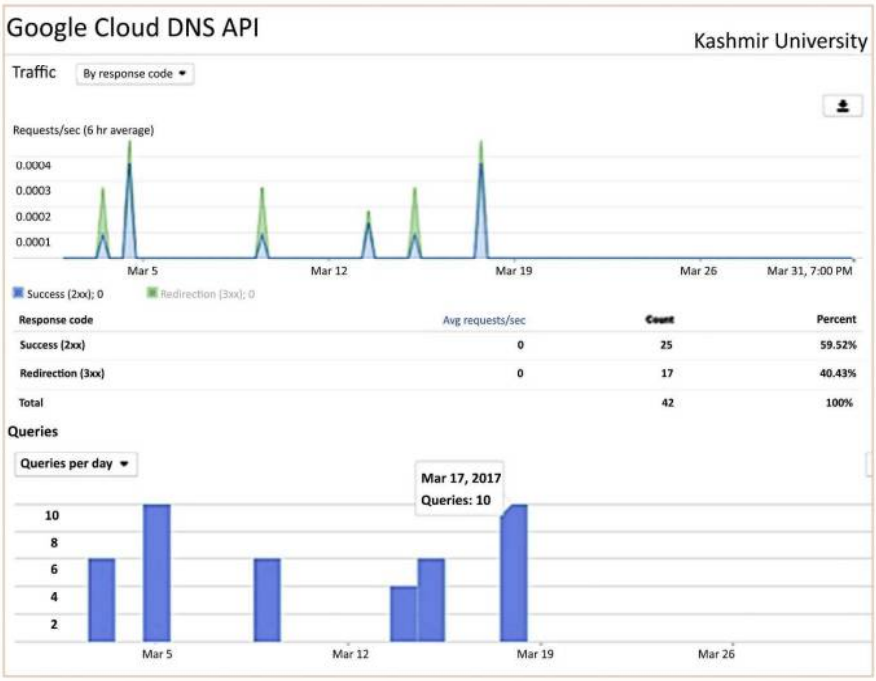


Fig. 6a: Google cloud DNS usage statistics.

As is evident from statistics illustrated in the above fig. 6a, the maximum number of queries served by cloud DNS (CDNS) during on-premise DNS (DNS-1, DNS-2) non availability is ten totaling to forty-two for the month from CNDS. Similarly, the fig. 6b below illustrates the usage statistics of the cloud compute engine deployed through mapped model. The compute engine has served approximately 2200 queries on-an average each day, during the month of march-2017 for university e-governance services mostly pertaining to student admission and registration processes. However, on 31st March, 2017, the cloud compute engine has served 566 queries, as all services on that day where served by on-premise e-governance system and required no traffic load balancing through cloud service. The total request count on compute engine for e-gov services has been 65,878 for the month, costing around two dollars (USD).

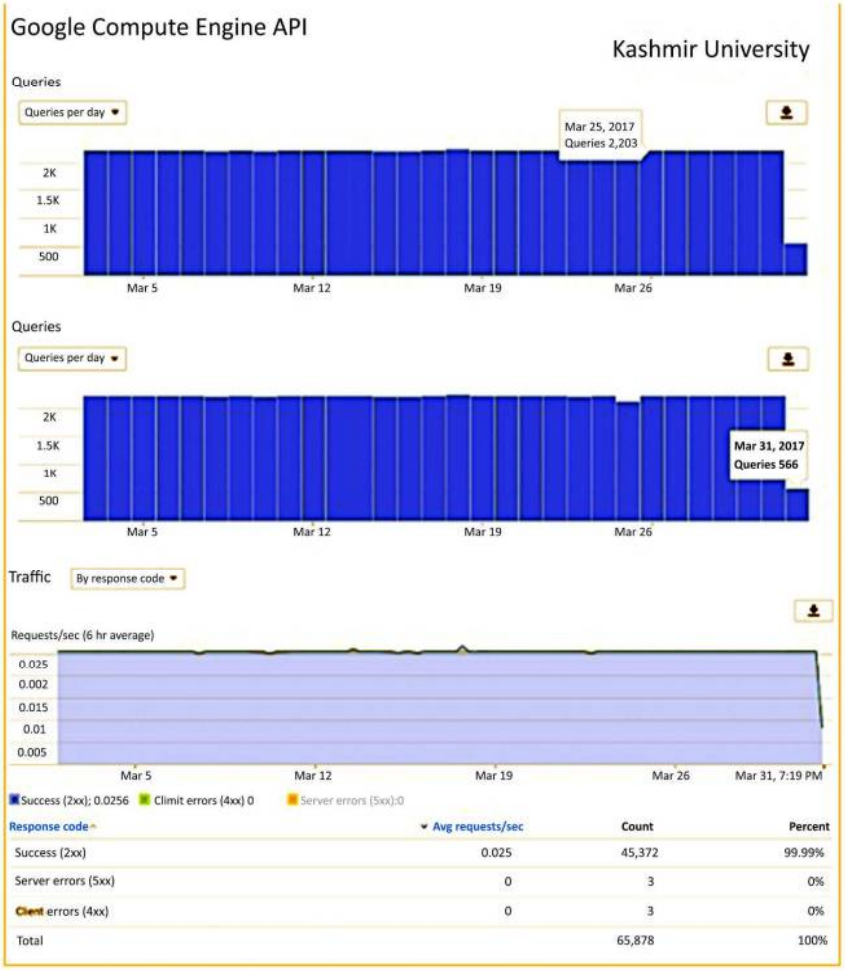


Fig. 6b: Google cloud compute engine usage statistics.

The average OpEx on services deployed on cloud computing through the mapped model has been mostly under three dollars (USD). Table 2 below illustrates the statistics of queries / counts during few months and its charges billed by Google.

	Aug-2016	***Sept-2016***	***Oct-2016***	***Feb 2017***
No. of requests / counts	*1697292*	*1430358*	*1480148*	*3703002*
Operating Expenses(on billing)	*$ 1.68*	*$ 1.57*	*$ 1.59*	*$ 2.46*

Table 2: Statistics of queries / counts during few months and its charges billed by Google.

By just incurring few dollars on the cloud, the availability and cost effectiveness achieved on university e-governance system are:

- 99.9% uptime.
- Cost of using service is just few dollars a month.
- No complete blackouts on e-gov services during link / on-premise deployment failure.

10. Conclusion (Outcome)

Implementing above proposed mapped model has helped University of Kashmir achieve e-governance services with competitive advantages. Mapping on-premise resources of the university with external cloud services has been more promising for the university than either exclusively relying on on-premise resources or external clouds. The concerns of control, vendor lock, security, privacy and reliability in-case of shifting completely to cloud have also died, apart from no blackouts on e-gov services during link failures.

Highly confidential university e-governance services (especially examination related) are continued to be deployed on internal cloud (on-premise data centers / servers) of the university and the intranet services remain uninterrupted in the campus during internet link failures. Low sensitive services like student document storage, email are completely subscribed through cloud as these services are offered free by Google.

The model implemented at University of Kashmir has increased efficiency, reliability and availability of university e-governance system while maintaining the low monthly billing on external cloud services since most of the time requests are served by on-premise deployment of the campus.

Also, during peak load times (e.g. admission and exam seasons) dynamically provisioning / reconfiguring to adjust to a variable load(scale) is a factor. This mapping also allows routing the traffic to both internal e-gov services and external e-gov services on cloud. Scaling up resources during peak loads does not require huge investment on upgrading internal infrastructure as they can be easily scaled up on cloud services.

Frequent internet link failures / gag in the state of Jammu and Kashmir (J&K), India are common due to hilly terrain, rough weather and political uncertainty. Internet services are suspended every now-and-then, University of Kashmir relying completely on cloud is not a feasible.

11. References

Alabbadi, M.M., 2011, September. Cloud computing for education and learning: Education and learning as a service (ELaaS). In *Interactive Collaborative Learning (ICL), 2011 14th International Conference on* Interactive Collaborative Learning-11th International Conference Virtual University (vu'11), (pp. 589-594). IEEE.

Ali, M., Dhamotharan, R., Khan, E., Khan, S.U., Vasilakos, A.V., Li, K. and Zomaya, A.Y., 2015. SeDaSC: secure data sharing in clouds. *IEEE Systems Journal*.

Alshomrani, S. and Qamar, S., 2013. Cloud based e-government: benefits and challenges. *International Journal of Multidisciplinary Sciences and Engineering*, *4*(6), pp.1-7.

Aslam, M., Gehrmann, C. and Björkman, M., 2012, June. Security and trust preserving VM migrations in public clouds. In *Trust, Security and Privacy in Computing and Communications (TrustCom), 2012 IEEE 11th International Conference on* (pp. 869-876). IEEE.

Bansal, K.L., Sharma, S.K. and Sood, S., 2012. Impact of cloud computing in implementing cost effective e-governance operations. *Gian Jyoti E-Journal*, *1*(2), p.P10.

Bellamy, M., 2013, June. Adoption of Cloud Computing services by public sector organisations. In *Services (SERVICES), 203 IEEE Ninth World Congress on* (pp. 201-208). IEEE.

Bhisikar, A., 2011. G-Cloud: new paradigm shift for online public services. *International Journal of Computer Applications*, *22*(8), pp.24-29.

Chandra, D.G. and Bhadoria, R.S., 2012, November. Cloud computing model for National E-governance Plan (NeGP). In *Computational Intelligence and Communication Networks (CICN), 2012 Fourth International Conference on*(pp. 520-524). IEEE.

Craig, R., Frazier, J., Jacknis, N., Murphy, S., Purcell, C., Spencer, P. and Stanley, J., 2009. Cloud computing in the public sector: Public

manager's guide to evaluating and adopting cloud computing. *White Paper. Cisco Internet Business Solutions Group*.

Das, R.K., Patnaik, S. and Misro, A.K., 2011. Adoption of cloud computing in e-governance. *Advanced computing*, pp.161-172.Springer Berlin Heidelberg.

Duan, Q., Yan, Y. and Vasilakos, A.V., 2012. A survey on service-oriented network virtualization toward convergence of networking and cloud computing. *IEEE Transactions on Network and Service Management*, *9*(4), pp.373-392.

Farooq, S. U., & Quadri, S. M. K., 2016. Test cloud before cloud test. *Modern Software Engineering Methodologies for Mobile and Cloud Environments. IGI Global*, pp. 89-101.

Jain, A. and Pandey, U.S., 2013. Role of Cloud computing in higher education. *International Journal of Advanced Research in Computer Science and Software Engineering*, *3*(7).

Khmelevsky, Y. and Voytenko, V., 2010, May. Cloud computing infrastructure prototype for university education and research. In *Proceedings of the 15th Western Canadian Conference on Computing Education* (p. 8). ACM.

Kundra, V., 2010. State of public sector cloud computing. *Washington, DC: CIO Council*.

Liang, J., 2012, May. Government cloud: enhancing efficiency of e-government and providing better public services. In *Service sciences (IJCSS), 2012 international joint conference on* (pp. 261-265). IEEE.

Manro, S., Singh, J. and Manro, R., 2011. Cloud computing in education: Make India better with the emerging trends. In *High Performance Architecture and Grid Computing* (pp. 131-139). Springer Berlin Heidelberg.

Mansuri, A.M., Verma, M. and Laxkar, P., 2014. Benefit of cloud computing for educational institutions and online marketing. *Information Security and Computer Fraud*, *2*(1), pp.5-9.

Mell, P. and Grance, T., 2010. The NIST definition of cloud computing.

Mell, P. and Grance, T., 2011. The NIST definition of cloud computing. NIST Special Publication 800-145.Available at: http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf (accessed 13 July 2017).

Mohammed, F. and Ibrahim, O., 2015. Models of adopting cloud computing in the e-government context: a review. Jurnal Teknologi, 73(2), pp.51-59.

Mohammed, F., Mohammed, F., Ibrahim, O., Ibrahim, O., Ithnin, N. and Ithnin, N., 2016. Factors influencing cloud computing adoption for e-government implementation in developing countries: Instrument development. Journal of Systems and Information Technology, 18(3), pp.297-327.

Okai, S., Uddin, M., Arshad, A., Alsaqour, R. and Shah, A., 2014. Cloud computing adoption model for universities to increase ICT proficiency. *SAGE Open*, *4*(3), p.2158244014546461.

Paquette, S., Jaeger, P.T. and Wilson, S.C., 2010. Identifying the security risks associated with governmental use of cloud computing. *Government information quarterly*, *27*(3), pp.245-253.

Pardeshi, V., 2014. Architecture and Adoption Model for Cloud in Higher Education: Indian Perspective. *Bonfring International Journal of Industrial Engineering and Management Science*, *4*(2), p.43.

Prasad, A.S. and Rao, S., 2014. A mechanism design approach to resource procurement in cloud computing. *IEEE Transactions on Computers*, *63*(1), pp.17-30.

Qadri, E.M.N., 2014. e-Governance at University of Kashmir: Bringing Efficiency & Transparency. *International Journal of Information and Computation Technology*, *4*(2), pp.119-126.

Quadri, S. M., Zaman, M. and Qadri M. N., 2014. e-Governance Development: Agile Perspective. *International Conference on Recent Trends in Computer Science & Engineering*, 8-9 Feb, Patna, India.

Rajaraman, V. 2014. Cloud computing. *Resonance Vol. 19 No.3*,pp.242-258.

Ramachandran, N., Sivaprakasam, P., Thangamani, G. and Anand, G., 2014. Selecting a suitable Cloud Computing technology deployment model for an academic institute. *Campus-Wide Information Systems*.

Rastogi, A., 2010. A model based approach to implement cloud computing in e-Governance. *International Journal of Computer Applications*, *9*(7), pp.15-18.

Sadiku, M.N., Musa, S.M. and Momoh, O.D., 2014. Cloud computing: opportunities and challenges. *IEEE potentials*, *33*(1), pp.34-36.

Saidhbi, S., 2012. A cloud computing framework for Ethiopian Higher Education Institutions. *IOSR Journal of Computer engineering*, *6*(6), pp.01-09.

Sharma, R., Sharma, A. and Pandey, U.S., 2011. E-governance: a successful implementation of government policies using cloud computing. In *IJCA Proceedings on International Conference on Web Services Computing* (Vol. 1, pp. 27-29).

Sharma, R., Sharma, A. and Singh, R.R., 2012. E-governance & cloud computing: technology oriented government policies. *International Journal of Research in IT & Management*, *2*(2), pp.584-593.

Smitha, K.K., Thomas, T. and Chitharanjan, K., 2012. Cloud based e-governance system: A survey. *Procedia Engineering*, *38*, pp.3816-3823.

Sultan, N., 2010. Cloud computing for education: A new dawn?. *International Journal of Information Management*, *30*(2), pp.109-116.

Tan, X. and Kim, Y., 2011, July. Cloud computing for education: A case of using google docs in mba group projects. In *Business Computing and Global Informatization (BCGIN), 2011 International Conference on* (pp. 641-644). IEEE.

Tripathi, A. and Parihar, B., 2011, June. E-governance challenges and cloud benefits. In *Computer Science and Automation Engineering (CSAE), 2011 IEEE International Conference on* (Vol. 1, pp. 351-354). IEEE.

Varma, V., 2010. Cloud computing for e-governance. A white paper, IIT Hyderabad, India. Available at: http://search.iiit.ac.in/uploads/CloudComputingForEGovernance.pdf (accessed 14 July 2017).

Yeh, C., Zhou, Y., Yu, H. and Wang, H., 2010, December. Analysis of E-government service platform based on cloud computing. In *Information Science and Engineering (ICISE), 2010 2nd International Conference on* (pp. 997-1000). IEEE.

Yuvaraj, M., 2015. Problems and prospects of implementing cloud computing in university libraries: A case study of Banaras Hindu University library system. *Library Review*, *64*(8/9), pp.567-582.

Zwattendorfer, B. and Tauber, A., 2013. The public cloud for e-government. *International Journal of Distributed Systems and Technologies (IJDST)*, *4*(4), pp.1-14.

About authors

Maroof Naieem Qadri is pursuing Ph.D in the Post Graduate Department of Computer Sciences at University of Kashmir. He is working as IT Scientist in the University of Kashmir and is presently Director of Information Technology & Support System at University of Kashmir. Has been head of e-Governance at University of Kashmir and has implemented several e-Governed projects at the University. His specialization covers the broad field of information systems, e-Governance, building IT infrastructure, data centre & cloud computing deployment and operations, including network and security.

Maroof is the corresponding author and can be contacted at: maroof@uok.edu.in or mnq.scholar@uok.edu.in

Prof. S. M K Quadri is Professor in Computer Science at Jamia Millia Islamia. He previously worked as Professor in Post Graduate Department of Computer Sciences at University of Kashmir. Has been Head of Department in the Post Graduate Department of Computer Sciences and Director Information Technology & Support System at University of Kashmir. His area of specialization is software engineering. He can be contacted at: quadrismk@jmi.ac.in