Mapping cloud computing in university e-governance system

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Abstract

Purpose – The purpose of this paper is to propose a model to map the on-premise computing system of the university with cloud computing for achieving an effective and reliable university e-governance (e-gov) system.

Design/methodology/approach – The proposed model incorporates the university's internal e-gov system with cloud computing in order to achieve better reliability, accessibility and availability of e-gov services while keeping the recurring expenditure low. This model has been implemented (and tested on a university e-gov system) in the 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 (HA) with operational ease, apart from continuing to have the necessary security in place to maintain confidential information such as student details, grades, etc.

Practical implications – The implication of this study is to achieve HA and to 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-gov system, the proposed mapping model through this paper closes this gap and provides guidelines to implement a hybrid-mapped e-gov model for universities while keeping the recurring expenditure on cloud computing minimal. The paper provides the perceptions of its adoption at UOK for achieving high reliability, accessibility and uptime of its e-gov applications while keeping the recurring expenditure on cloud computing minimal.

Keywords Universities, Cloud computing, Cloud services, Hybrid computing, Mapped computing, University e-governance

Paper type 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 *et al.*, 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 the government setup. E-gov involves new ways of governance, leadership, debating, delivery, investment, transparency, etc. (Qadri, 2014). With e-gov, citizens have round-the-clock access to government information, and interaction with government setup has become easy.

Similarly, an education system is benefited by the use of technology; the way information is disseminated; and knowledge is shared between students, researchers and faculty. Faculty-student interaction is not limited to classrooms only. Transparency, efficiency, and accountability in academic processes particularly for admission and examination systems are what students demand in modern times. To achieve these characteristics, e-gov in the

university system needs to be applied. E-gov can make universities more efficient and more effective, and can bring other benefits too to attain quality in academics. The three main contributions of e-gov include: improving governance processes (e-administration), connecting to students (e-students and e-services), and building external interactions (e-society). However, most e-gov initiatives fail. Institutions therefore face two challenges. First, the strategic challenge of e-readiness. Second, the tactical challenge of closing design-reality gaps: adopting the best practice in e-gov projects. In order to avoid failure and to achieve success in ensuring smooth and efficient performance of the e-gov system, many challenges may creep in, e.g. storing and computing huge databases pertaining to student admission, courses, and grades require strong computing 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. A cloud-based e-gov system provides many benefits to academic institutions such as reduced cost, distributed storage of data, getting more resources at lower cost, and managing security, scalability, accountability, and modifiability (Smitha *et al.*, 2012). A cloud computing model can offer an easy means of achieving the unified application model across all educational domains with multi-tenancy. To achieve an optimal or suboptimal allocation for immediate cloud services, the cloud environment with security is the best option. Cloud computing exhibits remarkable potential to provide cost effective, easy to manage, elastic, and powerful resources on the 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 of the business processes to the cloud (Duan *et al.*, 2012). Since its inception, the cloud computing paradigm has gained widespread popularity in the industry and academia (Sadiku *et al.,* 2014). Cloud computing attracts the attention of the research community due to its potential to provide tremendous benefits to the industry and the community (Aslam *et. al.,* 2012; Sadiku *et al.,* 2014). Cloud computing can provide a good basis to address some of the traditional challenges. Customers can use resources provided by the cloud and pay according to the use and cloud providers can reuse resources as soon as they are released by a particular user resulting in improved resource utilization (Prasad and Rao, 2014). Ease of use of cloud computing is that it does not 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, cloud provider, etc. All these decisions are highly strategic in nature, as they 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 the education sector before identifying and adopting the specific type of the cloud computing model for deployment.

This paper proposes a model to map universities on-premise deployment with the cloud while providing a way to maintain adequate cost savings and achieve high availability (HA) 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 the application of cloud computing in the education sector is also carried out 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 is done. Later, the implementation of the proposed model is described and validated through an applied case at a university. Finally, the paper ends with the results discussion and conclusion.

2. Cloud computing and 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 paradigm aims to provide 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 fulfills these requirements. The NIST identified the following characteristics that every cloud service must have:

- it must be an on-demand self-service which allows customer self-provisioning (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 on applications or users; and

- it must be a measured service, metered by performance with a pay-as-you-go pricing model.

Characteristics =	On-Demand Self-Service	Internet Accessibility	Pooled Resources	Elastic Capacity	Usage-Based Billing

Cloud-computing architecture, therefore, comprises 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), and Infrastructure as a Service (IaaS). In addition, to deploying cloud computing services, there are four primary models: public, private, hybrid, and community (Mell and Grance, 2011). Figure 1 illustrates the cloud service models and Figure 2 illustrates the cloud deployment models.

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, the IT departments save on

Figure 1.
Cloud service models

Source: KPMG India cloud publication: changing the ecosystem

Figure 2.
Cloud deployment models

Source: KPMG India cloud publication: changing the ecosystem

application development, deployments, security, and maintenance time, and costs, while benefiting from economies of scale. "Green computing" and saving costs are key focus points for organizations. Cloud computing helps organizations to reduce power, cooling, storage and space usage and thereby facilitates more sustainable, environmentally responsible data centers. Moving to the cloud further frees up the existing infrastructure and resources that can be allocated to more strategic tasks.

The main driver for cloud computing adoption is 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 (e.g. some older applications may not be "cloud-ready"), and its staff and management capabilities. In higher education (HE), 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 HE IT managers will face. Table I 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 and Qamar (2013), Das *et al.* (2011), Liang (2012), Rastogi (2010), Chandra and Bhadoria (2012); Sharma *et al.* (2012), Bellamy (2013), Bhisikar (2011), Kundra (2010), Zwattendorfer and 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 and Qamar (2013), Bansal, *et al.* (2012), Craig *et al.* (2009), Das *et al.* (2011), Liang (2012), Rastogi (2010), Sharma *et al.* (2011, 2012), Bellamy (2013), Kundra (2010), Zwattendorfer and Tauber (2013)
Scalability	When a user loads increase, organizations need not to fulfill additional hardware and software, but can instead add and subtract network load capacity	Alshomrani and Qamar (2013), Tripathi and Parihar (2011), Das *et al.* (2011), Liang (2012), Rastogi (2010), Sharma *et al.* (2012), Bhisikar (2011), Zwattendorfer and Tauber (2013)
Accessibility and greater mobility	Cloud computing can increase staff mobility by enabling access to information and services from anywhere and a wide range of devices	Alshomrani and Qamar (2013), Das *et al.* (2011), Liang (2012), Rastogi (2010), Sharma *et al.* (2012), Bellamy (2013), Bhisikar (2011), Zwattendorfer and 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 and 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), Sharma *et al.* (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), Sharma *et al.* (2012), Kundra (2010)
Backup and 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 *et al.* (2014)

Table I.
Benefits of cloud
computing

3. Cloud-based university e-gov 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 and Grance, 2010).

Cloud-based e-gov represents an emerging paradigm for distributed computing of e-gov applications that utilize services as fundamental elements in building agile networks of collaborating applications distributed within and across government boundaries (Smitha *et al.*, 2012). E-gov 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 the government to reduce duplicate

efforts and increase utilization of resources. This helps the government in going green, reducing pollution, and in effective waste management.

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Cloud computing is capable of resolving several issues in e-gov. Cloud computing offers several benefits to e-gov (Varma, 2010), some of them are the following:

3.1 Data scaling
The databases should be scalable, to deal with large data over the years for e-gov 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 cannot be achieved simply by scaling up.

3.2 Auditing and logging
Traceability to any changes to information content in e-gov 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 and 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 security, thereby making the applications reliable and available.

3.3 Rolling out new instances, replication, and migration
Traditionally, applications in e-gov 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-gov. 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.

3.4 Disaster recovery
Natural disasters such as floods, earthquakes, wars, and internal disturbances could cause e-gov applications not only lose 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 are 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 another. Cloud virtualization technologies allow backups and restoring. It offers application migration seamlessly compared with the traditional data center.

3.5 Performance and scalability
The architecture and technology adopted for e-gov initiatives should be scalable and common across the delivery channels. It is required to meet the growing numbers and demands of citizens. If implemented, the e-gov portals could become the biggest users and beneficiaries of information technology. With cloud architectures, scalability is inbuilt.

Typically, e-gov applications can be scaled vertically by moving to a more powerful machine that can offer more memory, CPU, and storage. A simpler solution is to cluster the applications and scale horizontally by adding resources.

3.6 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 need to be monitored and reported for better utilization of resources. It minimizes costs and helps to plan well. Profiling data enable 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 fits well in cloud architectures. Applications can mine huge volumes of real time and historic data to make better decisions to offer better services.

3.7 Policy management

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

3.8 Systems integration and legacy software

The applications that are already deployed and providing services are to be moved to the cloud, and 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 end users. Cloud is built on SOA principles and can offer excellent solutions for the integration of various applications. Also, applications can be seamlessly easily moved into the cloud.

3.9 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-gov.

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 and 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 postgraduate 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-gov applications; and

- provide students, faculty, and staff e-mail services and hosting space to other campuses/departments/centers 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 the cloud and can be ideally accessed through the Web. Highly sensitive and mission critical applications/services can be continued with the on-premise deployment; also campus/s will have an on-premise facility (live environment) for the testing of e-gov applications developed using agile methodology. An agile development methodology is recommended for e-gov development (Quadri *et al.*, 2014).

3.10 Risks and 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-gov. Benefits of cloud computing in university have been discussed in the above sections and among the cons, concerns are the risks on the use of cloud computing in a university system. Tests should be done in order to mitigate the challenges and risks of migrating business to the cloud (Farooq and 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 centers. Risks associated with policy changes and implementation of a new technology service delivery model include policy changes, implementation of dynamic applications, and securing the dynamic environment need to be mitigated (Paquette *et al.*, 2010).

Universities hesitate in deploying e-gov databases processing critical data pertaining to admissions and 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 following 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:

(1) Khmelevsky and Voytenko (2010) evaluated 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.

(2) 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, and administrators can use SaaS and IaaS, while the 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.

(3) Alabbadi (2011) proposed a conceptual framework called "Education and Learning as a Service" (ELaaS) to highlight the utility of cloud computing within the 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 resulting in a conceptual framework for ELaaS.

(4) 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 that both the private and public educational institutes can adopt the same. They noted that the educational institutes thus can outsource noncore services (i.e. the IT services) and better concentrate on offering students, teachers, faculty, and staff the essential tools to help them succeed.

(5) Tan and Kim (2011) demonstrated how "Google Docs," an application that is enabled by cloud-computing technology is utilized by a group of students pursuing a higher degree in 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 use these technologies quite often in the future too.

(6) Saidhbi (2012), in the research on Cloud Computing Framework for Ethiopian HE 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.

(7) Pardeshi (2014) proposed a cloud-based IT architecture, consisting of various deployment and 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 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 a five-step knowledge: persuasion, decision, implementation, and confirmation.

(8) Ramachandran *et al.* (2014), in their case study on "selecting a suitable cloud computing technology deployment for an academic institute," used a multi-criteria decision-making model – namely, the analytic hierarchy process 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 the education sector across the world, it is not so prevalent in developing countries such as India.

(9) 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 analyzing cloud-computing adoption model for universities.

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

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

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

(1) 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 has 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.

(2) Outsourcing of noncore 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 a group of students pursuing a higher degree on 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).

(3) Alabbadi (2011) proposed a conceptual framework called ELaaS for adopting cloud computing in Education and Learning organizations. 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 the cloud and keep continuing with high sensitive and high mission critical services on-premises. To implement such framework (ELaaS), the need for an applied prototype is felt.

(4) Saidhbi (2012) proposed the deployment of a 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.

(5) There is dearth of conceptual model/s for applying cloud computing in the education sector on e-gov systems.

From the above inferences, it can be found that the primary concern of academic institutions is to prevent privacy leakage and maintain the integrity of educational data especially confidential information such as student's details, grades, etc. Identifying and analyzing the sensitive and mission critical IT activities carried out at the institution is essential, and migration to the 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 the cloud. We are proposing a mapping algorithm for university e-gov systems ensuring privacy of sensitive data, performance, apart from a 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 HA and backup solutions. Accordingly, a model which is financially viable and enabling achieve HA, reliability, and accessibility while maintaining privacy and security of the university e-gov system is required.

The proposed mapped model in the next section closes this gap (between theory and practice) and provides algorithm/guidelines to implement the 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 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 the mapping model.

6. The proposed mapping model

Universities have many departments and units spread across large campuses; they establish the 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 LANs 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 center facilities at its premises, operated and maintained by its IT service department. In addition to the academic and scientific computational processes carried out on internal IT deployments, hosting/deploying the universities web portal and e-gov applications on intranet and internet is also done at its on-premise data center or server room/s. Applications deployed live at the university data center/server room/s cannot afford downtimes. These services have to be up 24/7/365 days and operating and maintaining these services require 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, HA is a challenging task and on moving entirely to cloud universities have data privacy, security, data theft, leakages on cloud, vendor lock-in, etc. among the prime concerns. Migrating university e-gov system exclusively to the 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-gov application catering to library services processing issue/return of books is taking place and all of sudden university's internet links go down for quite some time. The e-governed applications deployed exclusively on the 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 the 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 (below Figure 3) for university e-gov system so as to establish a better and reliable e-gov system and achieving low billing on cloud subscription. Depending on the availability of compute resources (processors, memory, storage, bandwidth, etc.) at the university, the university can either deploy all or only their mission critical e-gov applications on in-house servers and instances of those applications can be deployed on the cloud to takeover on failover under the HA mode.
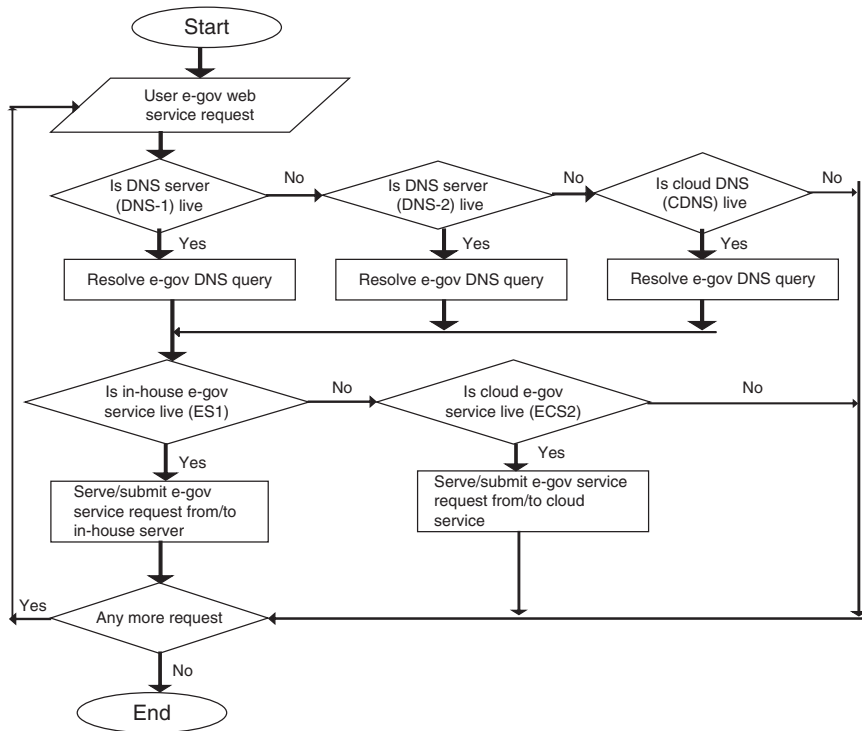
Essentially, universities subscribe to two internet links from multiple internet service providers (ISP's) for their campus requirements (for research and data center operations), which enable them to have failover link in case their primary link goes down. In India, government-owned universities are provided high-speed, dedicated internet under the national knowledge network (NKN) project, its main role being to facilitate an ultra-high-speed e-gov 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 ISPs. The name resolution and pointing to university e-gov system, domain name system (DNS) services (DNS-1 and DNS-2 as in Figure 3) are established in-house at the university and the third DNS service (CDNS in Figure 3) is deployed on the cloud. DNS-1 is deployed as the primary DNS service, DNS-2 as the secondary DNS service-1, and cloud DNS (CDNS) service as the secondary DNS service-2.

Based on the preference set with Time-To-Live 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 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 requests are routed to CDNS service only when both DNS-1 and DNS-2 fail or are down.

In this proposed model, all the e-gov services in the 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-gov databases on both services (ES1 & ECS2) are synced. Database on ES1 is set as the principal database and on ECS2 is set as the 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 the principal database. Upon service restoration on ES1, its database takes over back as the principal database and starts back serving/submitting users e-gov web service requests.

6.1 Algorithm of the 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 the above-proposed mapped model.

(4) Each request is routed to an internal primary DNS service.

(5) If the internal primary DNS isn't available, then the request is routed to an internal secondary DNS service.

(6) If internal secondary DNS isn't available, then the request is routed to the CDNS service.

(7) After DNS resolution, the request is pointed to an internal e-gov service.
//for user access.

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

The above algorithm describes the working process of the mapped algorithm for university e-gov services.

7. The UOK: case study

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

The UOK has more than 15,000 students enrolled for the postgraduate (PG) program and 2,50000 students enrolled for undergraduate program (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, UOK 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 UOK have not only brought improvement in the functioning of the system, but 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 UOK e-gov

The UOK's entire e-gov solutions are designed and developed in-house and are deployed at the on-premise data center, 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 the university under the NKN project and another subscribed by the university through an alternative service provider. Also, the university has a huge wide area network (KUWAN) spread across its different campuses and affiliated government colleges in the different districts of the state (Jammu and Kashmir (J&K), India). The e-governed services at these campuses and colleges are accessible through KUWAN.

Ensuring HA, accessibility of these e-governed services not only depends on operating and maintaining 24/7 the on-premise data center but also depends on HA/uptime of internet links which due to the hilly terrain and harsh weather in the state of J&K 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 the availability and accessibility of e-gov services of the university; relying entirely on internal deployments does not allow achieving HA, efficiency, and reliability.

Moving all its e-gov services completely on cloud is also a matter of concern for the UOK 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 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 and mapping of 'Google suite for education' for cloud mail solution

Applying the concept of the above-proposed model, UOK chose to move its mailing solution to "Google suite for education" from its internal mailing system. The internal mailing system by way of establishing a mail server on-premise was initially deployed. There was reliability and availability concerns among the users and were abandoning the internal mail service in favor of their personal e-mail system. Every time the university had link failure, external mails would bounce back and delivery to university mail server failed. Official communication through e-mails with the external world would come to a standstill and only internal mail receive and sent worked which lead to a 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 the university mailing solution and users opted back to services on university domains "@kashmiruniversity.ac.in or @uok.edu.in." These services which were earlier confined to the faculty and staff only because of limitations on internal deployment were extended to students and researchers post-deployment of the cloud. This facilitated the students and researchers to have a recognized digital identity under university domain and their digital connect with the faculty became stronger with facilities like of drive storage, classroom, mail, calendar, vault, docs, sheets, slides, sites, etc.

8.1.1 Method of deployment (Google suite on education). The mail exchange(MX) records of these two domain names are pointed through two internal DNS servers (DNS-1 and DNS-2) of the University and are supported by the Google CDNS service to the google service for mail solution. Primarily, MX requests are served/resolved by internal DNS servers and in case internal DNS services are not available, requests are served/resolved by the Google DNS service. These requests being primarily served/resolved through on-premise DNS services help maintain low monthly billing on CDNS. Figure 4 depicts the flow of the Google e-mail service mapped through internal DNS (DNS-1 and DNS-2) and Google CDNS.

The migration using the mapped model not only enabled achieve HA of e-mail solution, but also extended other valuable features with "Google suite for education."
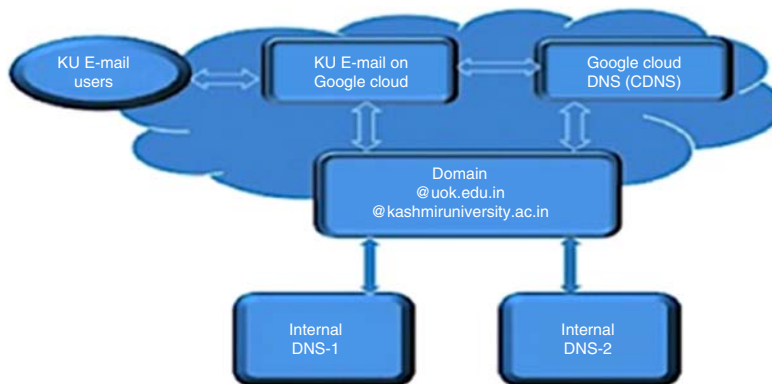
8.2 Mapping of university e-gov system

Applying, the proposed conceptual mapped model for mapping on-premise deployment with cloud computing, the university mapped its e-gov system with cloud computing. Figure 5 shows the working and flow of the mapped model implemented at the UOK.

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

8.2.1 Method for mapping of the university e-gov system. Primarily, the user requests for university e-gov service are routed to the primary DNS service (DNS-1, ns1. kashmiruniversity.ac.in), if the DNS-1 is available, the requests are resolved by the 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 is not available, then the requests are routed to Google 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) is not 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 do not respond.

It helps adopt cloud computing at the 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 and discussions

The results for implementation of the 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-gov 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 as follows:
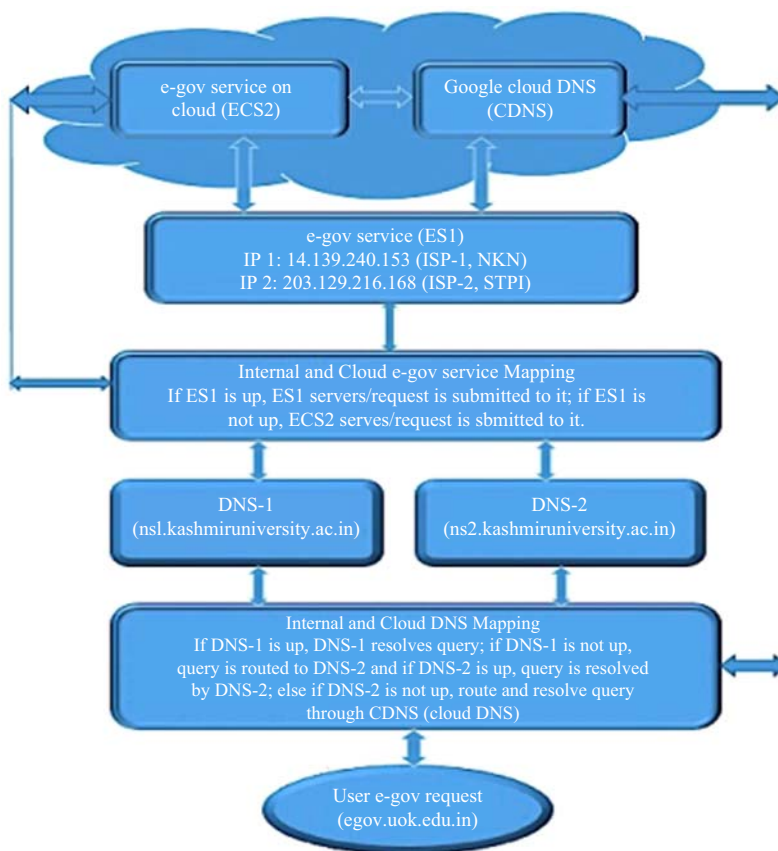
- 99.9 percent uptime;

Figure 5.
The mapped model
implemented at the
University of Kashmir
(bottom up)

- 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 and upgrading IT infra for e-mail, drive, vault, etc. solutions; and

- on-premise man power for maintaining and supporting mail services not required anymore.

Second, with the deployment of the mapped model for the e-gov system at the case university, enabled the university to get away with the concerns highlighted in Section 3.1, especially the complete blackout faced during their on-premise service failures. The universities' e-gov 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 the number of queries/requests received/served. The minute services are turned off, paying for that service also stops. Figure 6 illustrates the Google cloud pricing for the 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

Figure 6.
Google pricing for DNS cloud and compute engine subscribed by university

The number of e-gov requests to external cloud service with the case institution stay low as they are primarily served by on-premise deployment (e-gov services deployed on internal data center 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.

Figure 7 illustrates the real-time usage statistics of the CDNS and compute engine usage for a month during peak traffic in view of admissions, registration processes of students.

As is evident from the statistics illustrated in Figure 8, the maximum number of queries served by the CDNS during on-premise DNS (DNS-1, DNS-2) non availability is 10 totaling to 42 for the month from CNDS. Similarly, Figure 8 illustrates the usage statistics of the cloud compute engine deployed through the mapped model. The compute engine has served approximately 2,200 queries on an average each day, during March 2017 for university e-gov services mostly pertaining to student admission and registration processes. However, on March 31, 2017, the cloud compute engine has served 566 queries, as all services on that day were served by the on-premise e-gov 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).

The average OpEx on services deployed on cloud computing through the mapped model has been mostly under three dollars (USD). Table II illustrates the statistics of queries/counts during few months and its charges billed by Google.
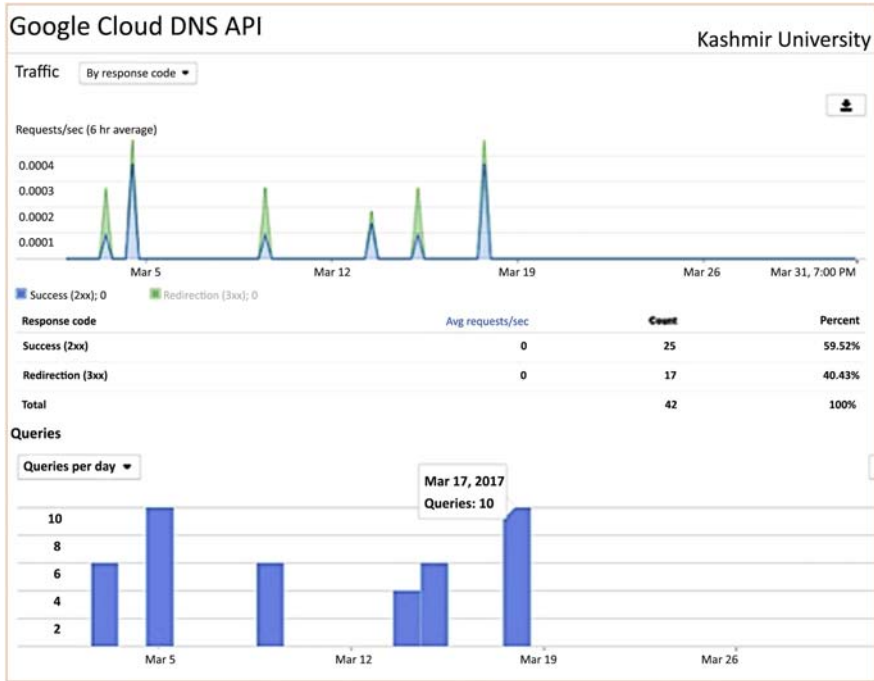
By just incurring few dollars on the cloud, the availability and cost effectiveness achieved on the university e-gov system are as follows:

- 99.9% uptime;

- cost of using service is just few dollars a month; and

- no complete blackouts on e-gov services during link/on-premise deployment failure.

10. Conclusion (outcome)

Implementing the above-proposed mapped model has helped UOK achieve e-gov 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-gov services (especially examination related) are continued to be deployed on the 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, e-mail are completely subscribed through the cloud as these services are offered free by Google.

The model implemented at the UOK has increased efficiency, reliability, and availability of the university e-gov 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.
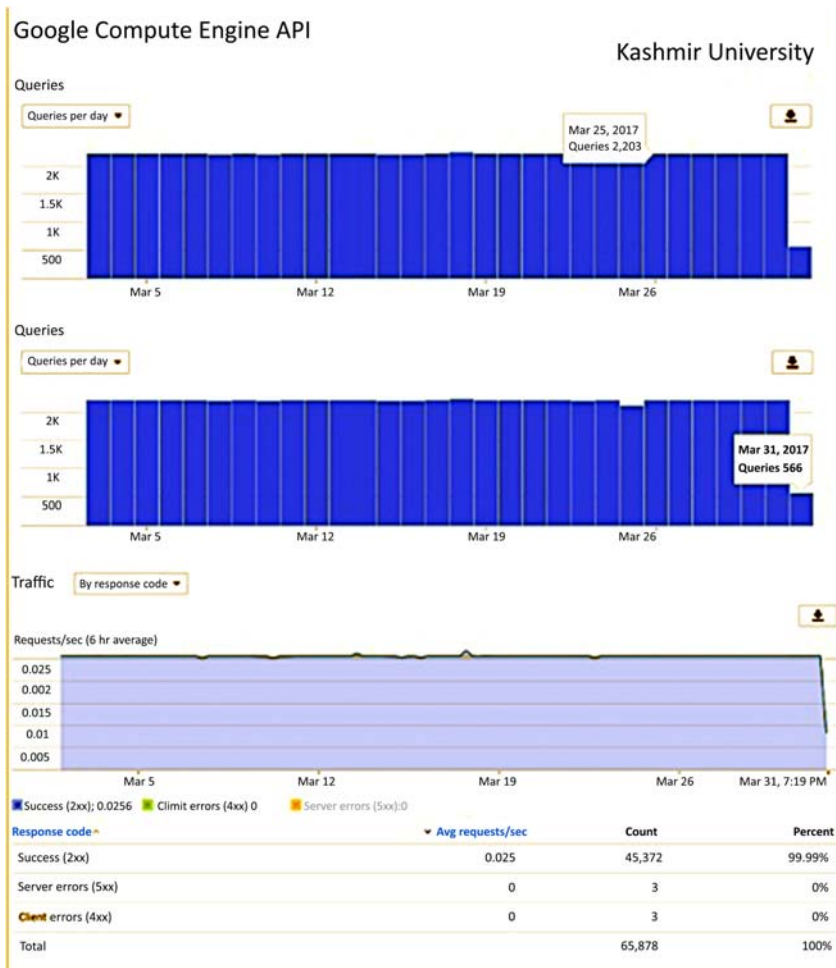
Figure 8.
Google cloud compute
engine usage statistics

	August 2016	September 2016	October 2016	February 2017
No. of requests/counts	1,697,292	1,430,358	1,480,148	3,703,002
Operating expenses (on billing)	$1.68	$1.57	$1.59	$2.46

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

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 J&K, India are common due to the hilly terrain, rough weather, and political uncertainty. Internet services are suspended every now and then, and so UOK relying completely on the cloud is not a feasible.

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