A strategic approach to providing cloud services for research and education community

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***Abstract*— The emergence of cloud services and technologies is providing the education and research community with many new and innovative ways to help institutions meet their user's requirements. Cloud services bring many opportunities and benefits but are complex and present many challenges and risks. A well-defined strategy is essential to define the right approach to navigate through the many options and decisions required to provide successful cloud services. In this paper we do not propose a strategy for adopting cloud services for research and education institutions. Instead, we propose a methodology to guideline policy makers in research and education institutions to define an effective strategy to help ensure success in adopting cloud services.**

I. INTRODUCTION

The explosion of the cloud phenomenon over recent years, has provided users with the possibility to acquire and consume high-quality services in new and innovative ways, while at the same time bringing the need to handle an ever increasing volume of data produced and exchanged using an increasing number of devices.

Many research and educational institutions are already using public cloud services (such as email, collaboration and productivity tools) extensively, some have implemented local cloud provisioning, some are planning to deal with cloud services in the near future, while others are still unaware, uninterested or puzzled about the potential of cloud computing.

For the above reasons, it is important for each institution to define its approach to dealing with cloud computing and position its role in providing users with cloud services for research and education in the form of a medium-term strategy. This is a process which requires thorough analysis, planning and decision making, most probably resulting in changes in the organization (skills, technology, business model, working practice etc.) and possibly significant investment in time and money with long term consequences.

The motivation of our work was to help research and education institutions to successfully adopt and provide cloud services for they users. We achieve this by proposing a comprehensive methodology conducted in three stages: firstly the analysis of relevant information, secondly a synthesis phase to identify strategic goals and make crucial decisions, and finally addressing the implementation issues.

The rest of the paper is organized as follows. Section 2 briefly highlights the related work in the field of cloud computing. Section 3 describes cloud strategy analysis process, while Section 4 addresses synthesis of cloud strategy. Section 5 deals with the implementation issues while Section 6 gives the main conclusions of the study.

II. RELATED WORK

In many policy documents cloud computing is recognized as an emerging paradigm that can facilitate innovative research and education. The Digital Agenda for Europe [1] underlines the need to develop EU-wide strategy in order to adopt cloud computing, while the e-Infrastructure Reflection Group (e-IRG) in its study [2] makes the recommendation to establish and promote the necessary policy, rules and legal framework at national and European level. The review of the organizational and institutional implications of cloud computing in higher and further education [3] analyzes the changes to institutional governance, policies, procedures and skills required by adoption of cloud computing. The cloud computing toolkit [4] gives a practical guidance for outsourcing information to the cloud as a starting point for the development of a cloud strategy for higher education institutions. Using cloud computing in higher education is also analysed in [5] as a strategy to improve agility in the current environment caused by the global financial crisis.

The pan-European research and education network – GÉANT [6] that interconnects Europe's National Research and Education Networks (NRENs) and connects over 50 million users at 10,000 institutions across Europe, has aligned its effort with the EC cloud vision. It is achieved by establishing GÉANT's Service Activity group - SA7 Support to Clouds. The recent survey carried out by the SA7 Cloud Strategy Task group has clearly identified that the majority of NRENs perceive cloud services as a fundamental shift which NRENs must recognise and adapt their business, service and even organisation models to accordingly.

This paper presents the results of GÉANT's SA7 Cloud Strategy Task group delivered through GN3plus FP7 project. It is policy oriented paper, with its purpose being to help decision makers in the research and education community to successfully provide cloud services for their users. This strategic approach to cloud computing can be applied at a national level to cover the broad research and education community, targeting funding bodies (research councils, ministries) and e-Infrastructure organizations,

such as NRENs, GRID/HPC initiatives, and nationally operated computer centres.

III. CLOUD STRATEGY ANALYSIS

In the cloud analysis phase, a wide range of information must be gathered and analysed in order to define strategic goals. We propose an analytical process which involves the following steps:

- Understanding the values of key stakeholders (research and educational institutions, individual users, ministries, funding bodies, the NREN);
- Analyse user business processes, needs and demands in relation to the potential of cloud services;
- Analyse the drivers and benefits of using various cloud services from the user perspective;
- Analyse barriers, potential risks and other issues which need to be resolved in order to exploit the benefits;
- Analyse external influences, consisting of many aspects, such as political, economic, social, technological, legal and environmental;
- Analyse internal influences, addressing the institution capabilities to implement the strategy, including internal strengths and weaknesses.

For successful adoption of cloud services the analysis of the above issues from the user perspective is of the most importance, which is described in the rest of this section.

A. User needs and demands

The user community in a typical institution will generate a demand for general computing, network, storage, and application resources to meet common requirements such as email, office productivity applications, video-conferencing, storage, file print and share, CRM, database hosting, web-hosting and the typical needs common to most organisations.

In the educational and research community there is also a significant additional need for more specialized computing and storage resources, that is driven by use-cases specific to the nature of work carried out by the sector. The differences found between the requirements of the two user communities are shown in Table I.

TABLE I.
DIFFERENCES BETWEEN GENERAL AND SCIENCE COMPUTING

General computing	Science computing
Requirements are common to many organizations	Requirements, like performance, are specific
Load varies on daily and weekly cycles e.g. low night use.	Load is high during scientific experiments that can take weeks
Availability may be critical for business normal functions	Availability isn't usually critical (experiments can be restarted a day later in the near future)
Long term predictable use-cases (stable configuration and requirements)	Configurations may vary dramatically according to running experiments

These two user environments have very different requirements and possibly different solutions, so in defining a strategy for cloud services, it is recommended to carefully consider these different requirements.

B. Advantages and benefits

The list of potential advantages and benefits of using cloud computing is outlined below. It is a list of the generally accepted reasons for adopting cloud computing services, but needs to be analysed in relation to the specific business processes in research and education context.

- Cost effective – One of the most attractive benefits of cloud computing is the potential for significantly reducing capital investment requirements. From the perspective of research projects the financing is well balanced, moving the funding from capital investment to operational cost (from Capex to Opex) and exploiting "pay-as-you-go" and "on-demand" payment models.
- Easy and fast deployment (more agility) - The researchers can focus more efficiently on pure research and scientific activities and innovation. In the educational area, for example, students can also easily and quickly obtain the resources to complete their educational activities and release it after that.
- More flexibility and scalability – Research projects and scientific experiments often require capacity which is not always predictable. In a cloud based environment this is not a concern as users can easily increase and decrease capacity.
- Ease of use and access – Simplified usage and universal access from any location with Internet connectivity resulting in improved productivity in the science and research areas, and more efficient learning environments.
- Improved research collaboration – With improved accessibility and data sharing in real time from any location, collaboration is improved both internally in the institution and externally with other local or international partners, such as for example a pan-European project consortium (for instance in the context of Horizon 2020).
- Energy efficient – The adoption of cloud computing results in more optimised usage of computing resources which leads to reduced power consumption, contributing to the greening of the global ICT world.
- Business continuity – Instead of institutions investing in their own disaster recovery facility, significant cost saving can be achieved using external cloud services, which inherently provide high availability and reliability.
- Internal IT transformation – The research and education institution can lower the operational cost for IT maintenance or rather shift the IT focus from system/service administration and maintenance "keeping the lights on" to more valuable tasks such as innovation and support to core research and education processes.

C. Barriers and challenges

Cloud computing as a new technology also brings new challenges, barriers and risks that need to be identified and considered in the cloud strategy and, if possible, be resolved in the implementation phase in order to exploit the benefits of cloud services.

- Security – Security is the biggest concern of most organisations in the adoption of cloud services. The Cloud Security Alliance (CSA) has identified 14 domains to be addressed as part of its security guidance in Cloud Computing [7]. From the users' point of view the areas of biggest concern are the following:
  - Legal and compliance challenges, such as security breach disclosure laws, regulatory requirements, privacy requirements, international laws, intellectual property etc.
  - Information management, including data confidentiality, integrity, and availability, data protection, especially protection of personal data.
  - Identity and access management – since the cloud services are accessible from anywhere and usually are organized in a multitenant environment, users are concerned about how identity and access protection is provided and managed by cloud providers.
- Compliance with existing policies – Using cloud services often involves the outsourcing of sensitive information to the provider's physical location. The concern is significantly higher if the cloud infrastructure is located in a different country under a different legal jurisdiction.
- Lack of control – Moving information and processes to the cloud may involve a significant part of existing responsibilities and control being transferred to the cloud provider. In general, the higher the cloud service is in the deployment stack (going up from IaaS to SaaS) the less control remains with the user over the information management.
- Resistance to new working practices – Most of the technological changes have a positive impact however some resistance to new ways of working may occur, as it may require new roles, responsibilities and skills.
- Skillsets and resources - Depending on the cloud solution e.g. to build or buy cloud services, new skillsets and resources may be required, as the following: legal and contractual expertise, service management, technical expertise, security management, billing and commercial.
- Internal IT transformation – Aside from lowering the cost of IT operation by adopting cloud services, losing in-house IT skills, experience and capacity built up over time, in the long run could lead the institution into a position that would be very difficult and expensive to revert back.
- Integration with in-house systems – Cloud Services in general need to co-exist and integrate with other established IT systems (networks, management & monitoring, backup systems, security systems, federation etc.), which in many cases can be a complex task.
- Technology immaturity - Cloud technologies are evolving rapidly, but are generally regarded as immature, except in the case of some of the major SaaS providers.
- Vendor lock-in - Cloud computing is still faced with the lack of standardization and readiness of commercial cloud providers to fully support interoperability. The users are exposed to the risk of being locked-in to a specific cloud provider with limited or no choices or freedom to move to another one.
- Funding risk - Cloud services in general require complex infrastructure, significant resources and skillsets and consequently significant funding. The startup costs to build a new service may be high and the funding for this may pose a major barrier to progress.

IV. Cloud Strategy Synthesis

Based on the comprehensive set of information, collected and analysed during the strategic analysis process, the next step in cloud strategy formation is to setup strategic goals, which reflect the vision with regard to user requirements. Different business cases, solutions and implementation scenarios need to be investigated to validate if the goals are realistic, feasible and achievable, and therefore if investment is justified. It is an iterative process of strategic thinking with feedback loops where some solutions and options can be, and most probably will be discarded, while new ideas and possibilities will appear. At the end, one or just a few of the more preferred solutions should be identified which represent the best opportunity for cloud deployment with maximum advantages in the most cost effective way.

Setting the goals and making strategic decisions needs to be aligned with the institution's vision and existing strategy and with other policy documents, such as constitutional acts, bylaws, management and operational principles. This policy environment differs for many organisations, but there are a number of initial questions in the context of cloud computing that should be raised in order to drive the strategic thinking:

- What does the institution expect of itself?
- What do others (users, funding bodies, wider community) expect of the institution?
- What is the institution hoping to accomplish?
- What is required to move forward and achieve the goals?

There are many answers to the above questions and therefore many possibilities to further develop the cloud strategy. The strategy development needs to be based on the inputs from the previously performed analysis and driven by user requirements and business cases rather than technical challenges. The specific results of this process are the choices and decisions made on the basis of the following key questions:

- Which user community is targeted - ordinary researchers, "long tail of sciences" researchers, teachers, students etc.?
- Which user needs should be addressed - commodity computing or high performance computing, storage or backup service, collaboration and productivity tools, eLearning, file sharing etc.?

- Which cloud service model(s) to choose – SaaS, PaaS, IaaS or some other?

There are a wide range of combinations of the above possibilities and all are focused on which cloud service to provide for the user community.

Once the cloud service is selected, the next focus of the strategic thinking process is how to provide the cloud service, with two essential questions in defining the cloud solution:

- Which cloud deployment model to implement or support – Public cloud, Private cloud, Community cloud or Hybrid cloud?
- What will be the role of commercial cloud providers in cloud service provisioning?

Answering these questions finally leads the institution to the central point of the cloud strategy:

- What will be the role of the institution in the cloud provisioning?

The rest of the section further discusses these topics that will shape the cloud solution.

A. Cloud Deployment Models

A cloud strategy needs to achieve a balance between the benefits and risks for the institution and make a decision between the different cloud deployment model options [8].

1) Public cloud

Public cloud infrastructure is made available to the general public and the service provision is owned by the institution selling cloud services, e.g. commercial cloud provider. A broad range of public cloud services have been already widely adopted by clients, including the NRENs' community (Gmail, Office365, Salesforce, Amazon Web Services - AWS, HP Cloud, Dropbox etc.). Many of these cloud services are offered for free with limited capacity or functionality, which is often enough for individual usage. At the institutional level the commercial usage of public cloud services is an increasing trend in the research and education community.

2) Private Cloud

An institution may wish to consider providing private cloud infrastructure solely to its internal users (researches, teachers, students). An example of these services is IaaS Compute (VMs) and Storage for scientific experiments, or SaaS services such as a Moodle VLE service for students.

3) Community Cloud

As an extension of internal private cloud, research and education institutions can, possibly by combining their efforts, provide a cloud service to the wider research and education community. NREN and other national e-Infrastructure organisations can play a leading role in providing such a community cloud service(s).

The platform for community cloud is typically quite similar to private cloud e.g. OpenStack, VMware vCloud but providing a community service will add extra requirements and complexity, such as:

- supporting a multitenant environment;
- security requirements to segregate and protect different client environments;
- billing/charging functionality and pricing models
- data protection considerations e.g. data privacy, backups, archiving of client data;
- need to integrate with clients' environment at a network or application level;
- service requirements of clients e.g. SLAs, Service Management Resources; and
- support for AAI

4) Hybrid cloud

The Hybrid cloud model could be an extension of the Private and Community cloud model whereby resources and services available in public cloud(s) can be used in a complementary fashion. An example of this is where compute resources in the private/community cloud can be supplemented by those from a public cloud at particularly busy or peak times.

B. Institution role in cloud provisioning

Cloud services are in general highly complex and bespoke and require significant organisational resources for development and support activities. While some of the building blocks of such services are well known and often use core skillsets of IT staff in research and education community, the additional layers of functionality, such as elasticity, self-service, on demand usage and billing, bring new challenges. While many organisations have the skillsets to develop cloud services and support them in a production environment, for many others this is not feasible. These elements will determine the roles in cloud provisioning, which are analysed below.

1) Public cloud user

Going beyond widely used free but limited usage of public cloud services (mostly SaaS), individual researches, on-going projects or institutional departments can easily purchase public cloud services on the global cloud market. Virtual resources can be elastically scaled up to meet demand and released when no longer needed, while the payment is on a utility basis i.e. "pay-as-you-go" as users consume resources (storage, network traffic, VM size, IP addresses etc.). However, using commercial public services at an organization level must be based on the results of the cloud strategy followed by all the considerations which come with such a decision. It opens up the issues of integration with other institutional services and in-house systems, management of information and processes outsourced to cloud, legal and contractual challenges, other security issues etc.

2) Cloud brokerage

Another level of engagement in the provision of cloud services is to act as a broker for third-party cloud services. It means that a single institution, usually NREN or other e-Infrastructure organisation, negotiate attractive deals from leading suppliers on behalf of the wider research and education community. They do not deliver cloud services directly to their own users as a provider, but instead organize, promote or manage cloud services from the commercial service providers to the user community.

Acting at the national level, NRENs are in position to act as an aggregator and take the lead in the field of cloud brokering and cloud middleware infrastructures, and be able to connect the clouds and provide added value to their members. Reusing existing cloud middleware infrastructures, like AAI, are clear benefits for the user community.

Brokering cloud service offerings should provide clear information to the user, about updated and reliable service descriptions and service levels. Where possible a legal framework for public acquisitions should be made available to NREN users, tailored to the specific community requirements. These objectives lead to an unavoidable vendor management requirement and coordination that should also be availed of to promote inter-operability requirements between different public clouds in order to avoid vendor lock-in traps.

In practice, however, there are some limitations: Leading suppliers already know how to sell to enterprises and don't like additional "middlemen", although competing suppliers may be grateful for help entering the market.

C. *Cloud provider*

There are many possibilities for research and education institutions to deliver their own cloud services, acting as a provider for own users, but commercial cloud providers can still play a significant role. Moreover, the options to deliver a cloud service are determined by the roles and responsibilities of these two main actors – the institution itself and a third party cloud provider, relating to the following key issues in cloud service deployment:

- Ownership – who owns the cloud infrastructure, which includes physical assets, licences, supporting hardware etc.?
- Management – who is responsible for cloud infrastructure governance, operations, monitoring, security provisioning, compliances etc.?
- Location – is the cloud infrastructure located on the organisation's data centre (on-premises) or under the responsibility of the commercial provider (off-premises)?

These three dimensions reflect how the roles and responsibilities are shared between the institution and the third party cloud provider as depicted by the following cube model shown in Figure 1.

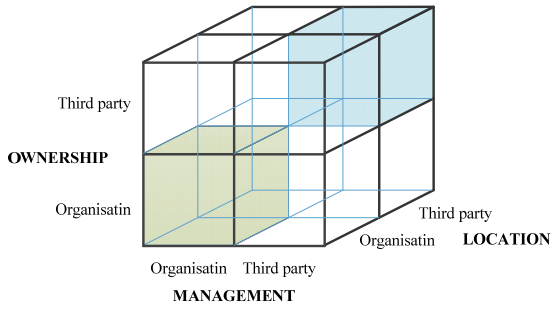

Figure 1: Cloud Provider options

In the extreme case (bottom-left-front corner), the cloud service is fully in-house delivered and provided through a private/community cloud model, developed and managed by the institution itself, running on its own equipment and premises. On the other extreme of the spectrum (top-right-back corner), the cloud service is fully outsourced to a third party provider, who builds and manages the cloud service on its own infrastructure and datacentre.

It is worth to note that in all cases the cloud service is considered to be under the institution ownership and branding.

A safe approach to consider is to use a commercial cloud provider to deliver a dedicated managed service. In this case the institution can use a commercial cloud provider to provide the resources and expertise to build and operate a cloud service, but with the service still being an institution's service. With this approach the cloud provider is effectively providing a managed service. Since a cloud environment is based on multi-layered infrastructure, the roles and responsibilities of cloud infrastructure management in the above cloud provider model can be subdivided and shared across the layers of the cloud stack – from the physical hardware, virtualization platform, up to the application level. The advantages of this approach are that the institution is in a position to provide a new service without having to invest in building up in-house dedicated technical resources and expertise. This could potentially speed up the process of launching new services by avoiding the time, cost and effort of building specialised teams and reduces the financial risk. There are also potential disadvantages with this approach as there is a risk of vendor lock-in as well as increased dependency on a commercial vendor and their ability and commitment to continuing to provide the managed service at a competitive cost.

V. Implementation Issues

A. *Roadmap development*

To ensure that the cloud strategy is successful, a roadmap is needed to define the major activities and resources needed to achieve the strategic goals with acceptable cost, time and efforts. The roadmap would consist of the following three major phases:

- Preparation phase – includes activities to prepare the project team, establish budget and procurement, as well as technical activities to specify technical requirements, acceptance criteria, and design the service with all necessary details to achieve the specification.
- Implementation phase – the activities needed to bring the service live, which includes conducting the procurement, technical installation, configuration, testing and onboarding, as well as supporting activities, such as project management.
- Operational phase – long term activities that includes day to day service operation, monitoring, reporting, maintenance, support, helpdesk, training, promotion marketing etc.

B. *Risk management*

Implementation of a cloud strategy is likely to be challenging due to the potential risks involved regardless to how well the plan is defined and detailed. Cloud strategy therefore needs to include proper risk management in order to anticipate possible risks at an early stage, analyse their impact, and plan mitigation approaches. The goal is to minimize the negative impacts of these unwanted events if they occur, take better decisions and, if possible, turn them into opportunities. To do so, the risk management approach needs to identify possible risks and develop corresponding actions that are incorporated into the initial project plan and budget.

C. Organizational changes

To be able to deliver on its cloud strategy, research and education institution will need to develop the appropriate level of internal competencies to cover the full lifecycle of potential new services from concept to production. This may include some or all of the following capabilities:

- Technical skills in cloud technologies appropriate to the relevant cloud services e.g. platform specific skills to test, implement and operate cloud services, storage, billing etc.
- Security skills to address data protection, identity and access management, compliance to standards and other management and operational security issues.
- Governance, commercial, legal and contractual skills.
- Service management skills to manage an institution's own cloud service or to manage external service providers.

Research and education institutions may have some or all of these competencies in-house but the organisation structure may need to change to reflect the strategy and impact of cloud services on skillsets and resources.

D. Service Branding

The cloud services world is a crowded arena with many service providers competing to get the attention and potential business of institutions. While the research and education community are in general loyal to internal IT infrastructure and services, there is no guarantee that they will choose or even understand the cloud services being offered. The research and education institution will need to compete with strong messages from commercial providers to ensure its users do understand its strategy in relation to cloud services and the key benefits. To ensure its messages reach the right audience it is important to consider:

- The service branding and key messages.
- A communication strategy to deliver the key messages.

The above topics are no different to those facing the commercial providers and the approach is similar. The branding of a cloud service helps users understand its positioning and the unique value that the service brings to research and education community e.g. low cost, high performance, ease of use, security, integration with existing in-house systems (AAI, monitoring) etc.

VI. Conclusion

A strategic approach is essential to ensure successful adoption of cloud services and this paper seeks to help policymakers navigate through the complexity and define a clear strategy for the provision of cloud services. Our study proposes the methodology for the development of a cloud strategy for institutions conducted in three stages.

The initial stage of the strategy development is to conduct an extensive analysis of the needs of both the institution and its users who may have relatively generic and/or highly specific requirements. The analysis stage should also address potential benefits of cloud computing, as well as barriers to the adoption cloud services.

The next stage is the cloud strategy synthesis where the outcome of the analysis stage is used as a foundation to identify strategic goals for those cloud services which are consistent with the organisations' overall strategy and vision. The identification of strategic goals should address the requirements of stakeholders and identify what specific services are required, appropriate service delivery model (SaaS, PaaS, IaaS) and deployment model (Public, Private, Community, Hybrid). We have demonstrated that the role of the institution and the appropriate level of involvement in the delivery of cloud services is a key decision. This role can vary from a full internal develop, build and deploy model to the opposite extreme of a full external managed or brokered service using an external cloud provider and its infrastructure and resources.

The final stage in the development of the cloud strategy needs to focus clearly on how the service(s) should be implemented. It should provide a clear roadmap which defines all the major activities and resources needed to achieve the strategic goals with acceptable cost, time and efforts. The implementation should consider the risk assessment and management as well as the organisational impact such as the requirement for new skills, resources or activities. Finally the institution needs to consider service branding and how it positions and communicates the new cloud service(s) with users.

In summary, cloud services present many opportunities and benefits but also significant challenges and risks. A methodology to define a cloud strategy as outlined in this paper is essential to ensure that right services are identified, designed and delivered using the most appropriate approach that best fits the user and organisation requirements and capabilities consistent with the overall institutional strategy and vision.

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