Structuring and implementing the Brazilian Academic Cloud: strategy, modelling, challenges and services

José Luiz RIBEIRO FILHO[1], Antônio Carlos Fernandes NUNES[1], Ricardo NOBUYOSHI DOS SANTOS. MAKINO[1], Gorgonio BARRETO ARAÚJO[1], Graciela MACHADO LEOPOLDINO MARTINS[1], Leandro Marcos DE OLIVEIRA GUIMARÃES[1]

[1]*Rede Nacional de Ensino e Pesquisa (RNP), Rua Lauro Müller, 116 sala 1103, Botafogo 22290-906 Rio de Janeiro, Brazil*

Tel: + 55 21 2102-9660, Fax: + 55 21 2279-3731, Email: jose.luiz@rnp.br, antonio.nunes@rnp.br, ricardo.makino@rnp.br, gorgonio.araujo@rnp.br, graciela.martins@rnp.br, leandro.guimaraes@rnp.br

Abstract

This paper presents an overview of the strategies currently adopted by some National Research and Education Networks (NREN) to implement and offer scientific cloud computing services. It describes the constraints, opportunities and the strategy chosen by the Brazilian NREN – Rede Nacional de Ensino e Pesquisa (RNP) to plan, deploy and operate cloud services to and in collaboration with Brazilian public universities and research institutes. The hybrid, community and federated strategy was chosen as the most flexible and suitable for the current Brazilian NREN operation and funding models. It describes the cloud services that are in production or in a pilot phase, their status and next steps planned. Cloud service planning, deployment and operation are discussed, the alternatives considered and the chosen options. At the end, the cloud services deployed by RNP are presented and discussed, considering the technologies and benefits to the academic community in Brazil.

Keywords

cloud strategies, scientific cloud, cloud services, research and education network, hybrid and community cloud, federated cloud.

Introduction

The Brazilian National Research and Education Network (NREN) – Rede Nacional de Ensino e Pesquisa (RNP) [1], is the organization that plans, designs, deploys and operates a nationwide networking infrastructure under a contract with the Ministry for Science, Technology and Innovation (MCTI). A governmental program that currently includes four ministries – MCTI, Education (MEC), Culture (MinC) and Health (MS) defines, on an annual basis, the contract objectives and its funding. The program governance committee represents the four ministries, which supervises the program's execution. Among the program's objectives are the connections of university, research institutes, hospitals, museums, and many other public Research and Education (R&E) institutions through RNP's nationwide network infrastructure – Rede Ipê, shown in figure 1.

[1] RNP - the Brazilian National Research and Education Network (NREN) - http://www.rnp.br.

Besides connecting more than 1.300 points, of around 350 public and private institutions (universities and research institutes) through an advanced multi-gigabit national backbone, and more than 41 metropolitan area networks (through owned infrastructure[2]) connected over more than 2.100 km of optical cables. RNP also offers advanced services on top of this network, potentially benefiting more than 3.5 million users. Advanced services include VoIP, web conferencing, video conferencing and telepresence rooms, video on demand (VoD), live streaming, federated authentication for most of the services and eduroam. RNP also hosts in its data center several partner institutions' strategic applications such as the *CAPES Portal de Periódicos* – a federated web portal that offers access to a large variety of international scientific journals to all public universities in the country.

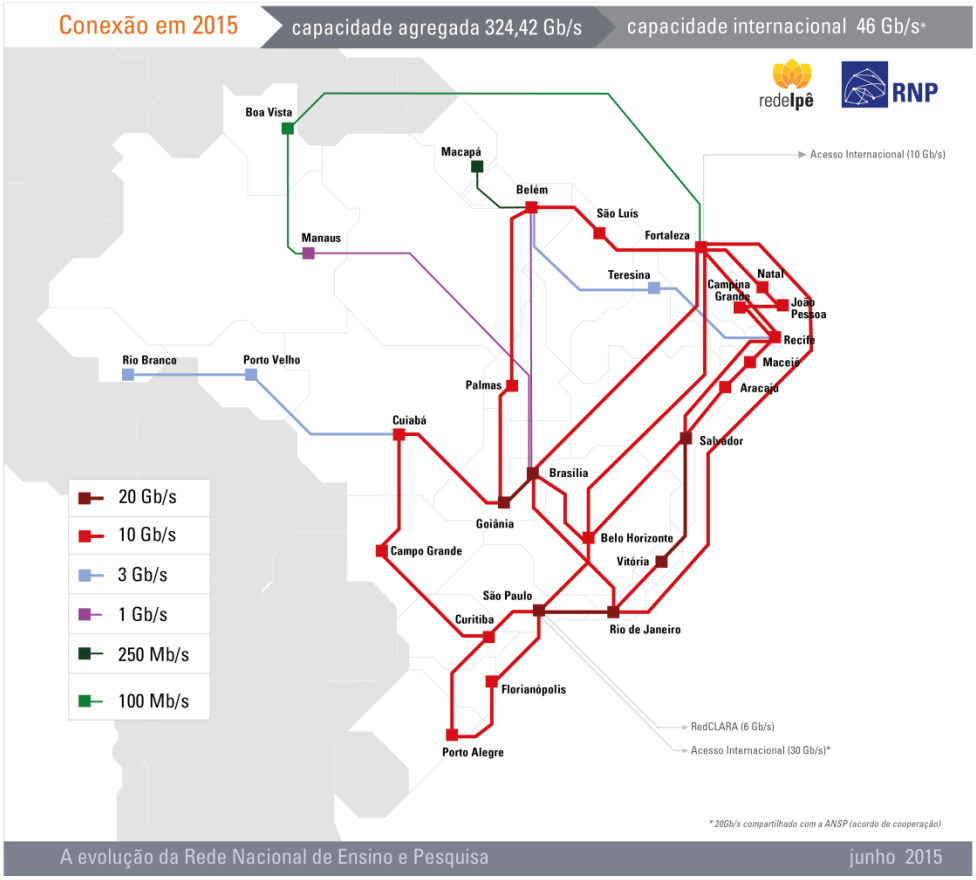

Figure 1: RNP's national network backbone – Rede Ipê.

One of the main goals of RNP's mission is to provide those and new advanced Information and Communication Technology (ICT) services to the Brazilian academic community. To achieve this goal, RNP is permanently seeking new technologies, products, services and processes, through partnerships and collaboration with the academy, industry and the world's leading NRENs.

The ever-increasing production of scientific data (e.g. environmental monitoring, biodiversity data bases, a variety of simulation and visualization systems like climate forecast, high energy physics data collection, astronomy and cosmology), cultural related data (e.g. historical and rare collections, audio-visual content, also as a means of data preservation) and

[2] REDECOMEP (Metropolitan Community Education and Research Networks) – a fiber optics infrastructure build by RNP in more than 35 cities to connect R&E institutions to RNP's backbone -. http://www.redecomep.rnp.br/.

management data (e.g. government ICT policies and R&E programs execution, assessment and management indicators, data bases and big data processing) requires a scalable, sustainable and high available datacenter infrastructure to support the demands. These facilities must be located in a distributed way and in places that provide telecommunication, energy and security services, as well as appropriate physical space/infrastructure. For most of the mentioned demands, cloud computing technology and services offers a cost effective solution.

This paper presents the strategy defined by RNP to plan, deploy and operate cloud services to and in collaboration with Brazilian public universities and research institutes. It is also describes the cloud services that are in production or in a pilot phase. The overall strategy is explained in the next sections, starting with a brief survey of current cloud strategies and services adopted by other NRENs. After that, cloud service planning, deployment and operation are discussed, taking into account the alternatives considered and the chosen options. In the last section, the cloud services deployed by RNP are presented and discussed, considering the technologies and benefits to the academic community in Brazil.

NRENs Cloud Strategies

The first step was a survey that looked at what other NRENs have been planning and doing, regarding their strategies about cloud computing services and infrastructure. Many NRENs are already offering cloud services in a variety of degrees and through different business models. However, in Europe, the Trans-European Research and Education Networking Association (TERENA/GÉANT Association) has been following closely the European NRENs strategies to offer storage/cloud computing services and infrastructure. Its annual TERENA/GÉANT Association Compendium (Terena, 2014) presents comprehensive information about all European and other NRENs in the world, where one can see how cloud computing deployment and services are evolving over time. Besides the annual compendium, TERENA also publishes studies produced by its working groups. A 2011 green paper which discussed the European NRENs strategic perspective on storage and cloud computing [2] was very influential in RNP's own cloud strategy definition, presented here.

The study considered two basic scenarios:

a) Universities and higher education institutes outsource services to public clouds or to their NREN
b) NRENs and research organizations outsource services or sub-services to public clouds; and a question to a panel of experts – "What kind of services, sub-services or functions can be outsourced by Universities and/or NRENs to public cloud service providers, how, and under what conditions and circumstances?"

The panel discussed issues such as privacy, application types (commodity and specialized), data protection, risks, costs, thrust (on public commercial providers x NRENs) and the conclusion was as follows:

- The outsourcing of commodity application services (e.g. student e-mails and document sharing) from universities to public clouds can be done with low risk. Moreover, significant cost benefits can be achieved through a NREN coordinated and centralized contracting process.
- For infrastructure related services (e.g. computing and storage) outsourcing to public clouds, it was considered that the risks concerning service operation, data

protection, authentication and access control were an issue for individual universities. However, outsourcing these services to NRENs were considered acceptable, due to the established relationship and thrust between NRENs and universities.

- In case of the NREN itself, the outsourcing of commodity application services (e.g. calendar system) to commercial clouds seemed straightforward.
- Finally, for infrastructure related services (e.g. network operation, storage, videoconferencing, computing), the mixing of the NRENs own infrastructure with public clouds was considered a value-added IaaS scenario.

Figure 2: Cloud strategy decision tree.

Figure 2 shows a simplified strategy decision tree for NRENs that came out of the TERENA discussions (Szegedi, P. 2011) Regarding application services, NRENs can develop and provide their own services or can exploit the joint buying force of their users and brokering towards commercial cloud service providers. Regarding infrastructure services, NRENs can build their own cloud infrastructure or can aggregate user demands and channel them in to commercial cloud infrastructures.

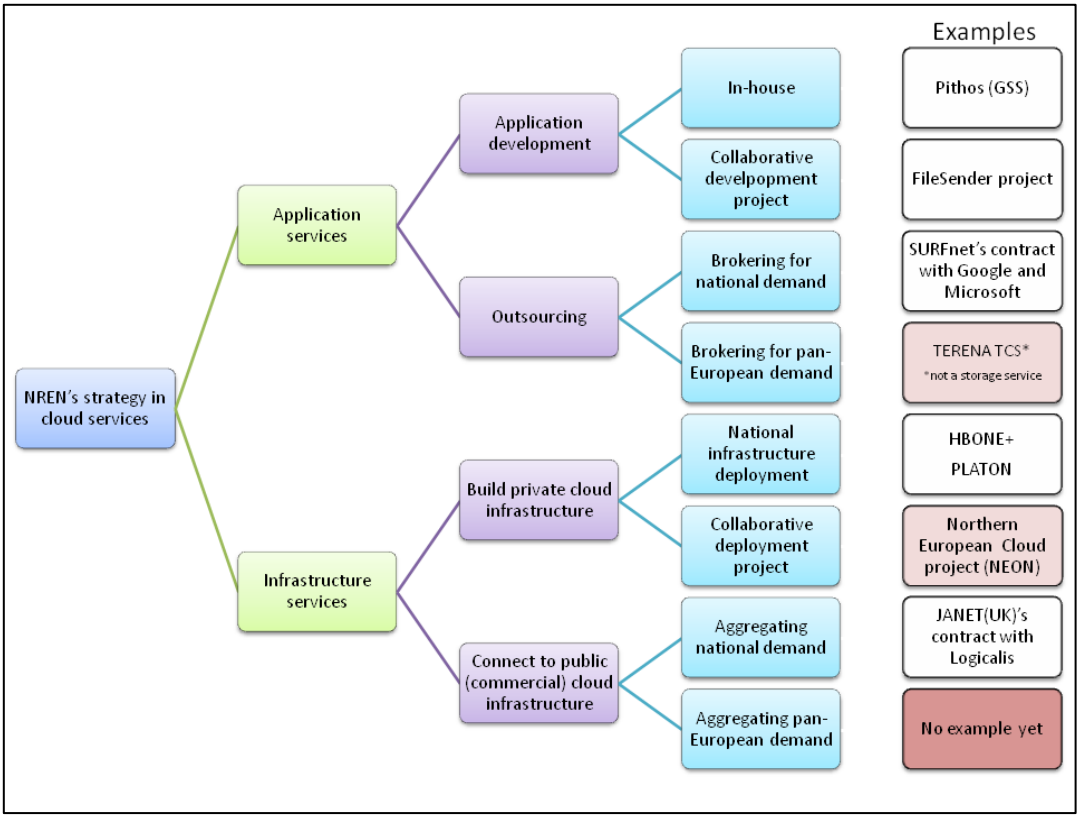

Figure 2: Cloud strategy decision tree.

Based on user demands, networking capabilities, funding schemes and the above conclusions, NRENs have adopted three major national deployment strategies for e-infrastructure services offerings:

- Building private storage/cloud infrastructure on top of the national R&E network;
- Connecting public (commercial) storage/cloud infrastructure via the national R&E network;

- Creating hybrid storage/cloud infrastructure (a mix of public and private infrastructures) connected via the national R&E network.

At the end of 2012, as a result of "A Study on the Prospects of the Internet for Research and Education (ASPIRE)" form TERENA - a foresight study for exploring the implications of potential developments of the Internet up until 2020 and assessing their impact for the Research and Education networking community, the results of "The Adoption of Cloud Services" (ASPIRE (2012) was published. This study was another important resource to RNP's own cloud strategy.

Finally, in 2014, at the TERENA Networking Conference 2014 (TNC2014), the Ireland's NREN (HEAnet) presented its cloud strategy (Boyle, B. et al, 2014), which showed interesting similarities with the strategy planned by RNP, strengthening some points that were our plans or already under development.

The next section presents RNP's cloud strategy, as planned and under deployment, based on the strategy alternatives already discussed in this document.

RNP Cloud Strategy

The cloud services/infrastructure strategy chosen by RNP came out of a process, which was guided and constrained by the demands of the Brazilian R&E community, RNP operation and funding models, as explained above, as well as other NREN cloud strategies also discussed in the previous section.

Additionally, four main stakeholders that play major roles in the strategy definition and implementation were identified: public R&E institutions (universities and research institutes), research groups, RNP and R&E funding agencies. The Brazilian academic cloud strategy was then built around those stakeholders' requirements. The R&D institutions can be, at the same time or separately, customers and providers of infrastructure and services. RNP has the coordination role, being responsible for the cloud architecture definition, contracting and operating its services, to develop and deploy applications, and the coordination of the partnerships with other stakeholders. The research groups contribute with their scientific application's requirements as well as with the development of new functionalities and the cloud funding, through and proportionally to their use of the national cloud. Finally, the strategy includes the R&E funding agencies to help them promote a change in the current research-funding model. The proposed funding model will take the portion of the money granted to research projects, destined to ICT infrastructure (including servers, storage and networking equipment, basic software and even some specialized applications), and transfer it directly to a National Scientific Cloud Program. Instead of having to build a usually expensive and fragile ICT infrastructure, which also takes time to buy and deploy, granted projects would receive an equivalent quota of the required platforms as services from the national scientific cloud.

Another dimension considered in our work pointed out to two main classes of user profiles: institutional users (represented by IT managers of R&E institutions) and individuals (e.g. researchers and their labs). These two user classes have specific requirements for cloud services and infrastructure, which can be grouped according to the three layers of cloud services: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Institutional users demand mainly SaaS services such as staff e-mail, student

registration, ERP platform and storage/backup services. They may also want to mirror some parts of their local IT infrastructure to a private cloud, like virtual machines and block storage, corresponding to the IaaS service. On the other hand, research groups show the desire to have more control over the cloud infrastructure, therefore requiring mainly an IaaS service, which allows them to develop, test and run their own applications and services on top of a virtualized infrastructure (e.g. processing, storage /backup and networking). They might also need PaaS services to deploy applications and databases in a fast way, where collaboration projects using wiki, distributed version control system (DVCS), are some examples. Besides these two user classes, RNP itself can migrate most of its current advanced services to the cloud infrastructure, including VoD/media streaming, web and videoconferencing, and some of its partners services like the *CAPES Portal de Periodicos*[3] scientific journal web portal.

Because of the above-described "environment" and NREN's major national deployment strategies for e-infrastructure services, discussed in the previous section, the best strategy that emerged for RNP's cloud service/infrastructure was a hybrid, community and federated cloud, shown in Figure 3. The hybrid model allows RNP to act as a public (commercial) contract broker for "low risk" services, such as student e-mail, collaboration, etc. Through the community model, universities and research institutes can offer their own data center infrastructure (in full or partially) to the national cloud. They should be able to dynamically change the amount of resources shared with the national cloud and receive privileged access to other partner's infrastructure (virtual processors and storage) in return. Finally, the federated model ensures the required level of security and trustiness among all the partners as well as to the users through RNP's federated services. This strategy is also an answer to the geographical distribution requirement for a redundant and reliable cloud, once the partner institutions are distributed nationwide.

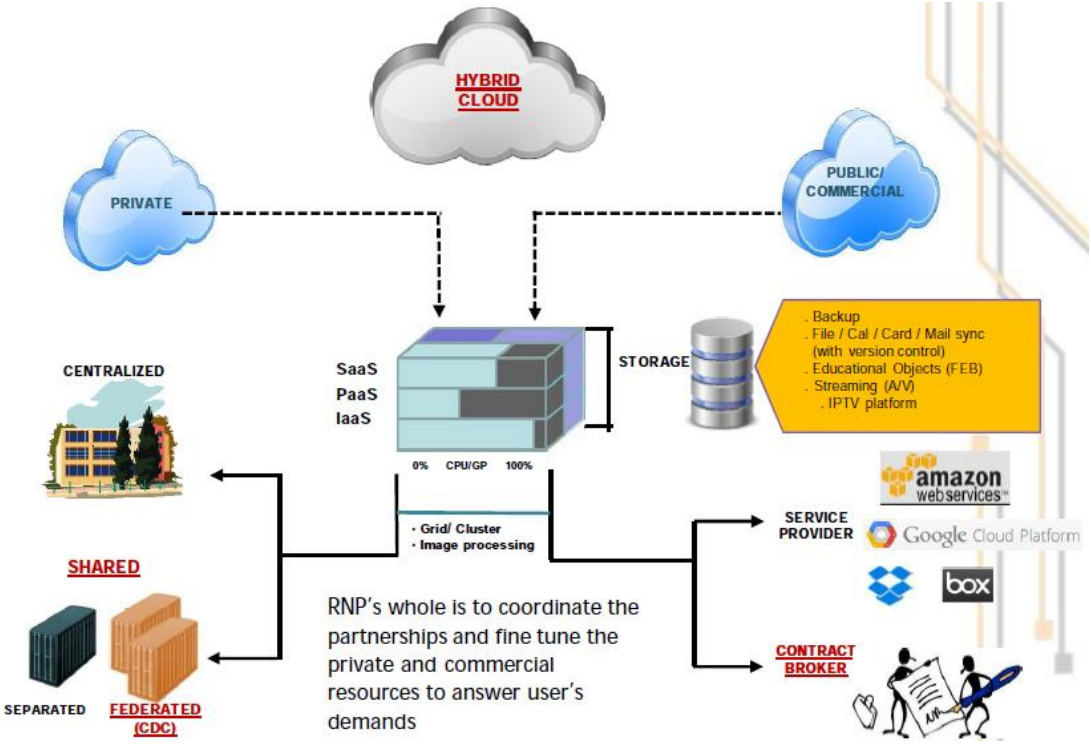

Figure 3: RNP cloud strategy.

[3] http://www.periodicos.capes.gov.br.

The strategy also includes other definitions such as an Acceptable Use Policy (AUP) for the national cloud, the basic operation model (required to all partner institutions), the national cloud sustainability model, user interfaces and APIs, application migration support, to mention a few. Another concept defined in RNP's cloud strategy is the shared data center component, the CDC (Centro de Dados Compartilhados). The CDC is a physical structure that hosts all required infrastructure for a Tier 2 datacenter, including redundant energy (also with power generators and UPS), fire detection and suppression systems, independent and redundant HVAC systems, unified management platform (that collects data related to temperature, humidity, smoke, etc.), and access control systems. RNP has already installed two CDC sites, one at Instituto Nacional de Pesquisas da Amazônia (INPA) in the North Region (Manaus/AM) (Centro de Dados Compartilhados é inaugurado em Manaus, 2014) [5] and other at the Instituto Federal de Educação, Ciência e Tecnologia de Pernambuco (IFPE) in the Northeast Region (Recife/PE) of Brazil respectively(Programa Centros de Dados Compartilhados é inaugurado em Recife (PE), 2014) , as shown in figure 4.

Figure 4: CDC (Centro de Dados Compartilhados) sites.

To make this model work seamlessly to the users and partners, a middleware is required to provide an isolation layer between the cloud service user interface, as well as the application program interface (API), and the specific physical and virtualized resources offered by the community/federated infrastructure providers, including contracted public (commercial) cloud providers. This middleware is under development by some cloud computing research groups and the goal is to provide a high-level abstraction layer to allow the integration of resources, and let users access cloud services and infrastructure unaware of its management and operation details. On the other hand, when required, users should be able to choose where they intend run their virtual machines, host their applications, store and backup their files or move them from one cloud node to another, regardless of where the cloud nodes are geographically located. The challenge to implement these features nowadays derives from the high heterogeneity of cloud provider's infrastructure and the lack of standards in the platforms.

Implementation and Service Definition

After the definition of the national cloud services and infrastructure strategy, RNP started in 2013 a pilot project, comprising the deployment of two container-based CDC. The platform is the Huawei IDS1000-A (All-in-one), at the INPA site and IDS1000-C (Cluster) at the IFPE site. The IDS1000 provides a flexible, mixing and modular design concept, committed to help customers to build green cloud computing data center infrastructure, and realize the availability, safety, agility, scalability and an optimal TCO. The IDS1000-A and IDS1000-C can grow horizontally or vertically providing a path for rapid infrastructure expansion. The Chinese company donated the datacenter infrastructure and the ICT equipment to the Brazilian government (Computerworld (2011)) The smallest configuration, installed in INPA, comprises two container modules: one with the HVAC systems, power generators and UPS system and the other hosts the ICT equipment. It currently has 132 physical processors cores and 0.6PB of storage. The other CDC has three container modules separated in HVAC systems, UPS and PDU systems and ICT equipment's. Additionally, an external power generator was installed. It currently has 612 physical processors cores and 1.1PB of storage, as shown in figure 5.

Figure 5: CDC (Centro de Dados Compartilhados) deployed at IFPE in Recife.

Based on the already installed ICT infrastructure, considering the RNP cloud strategy and the types of users: institutional users (represented by IT managers of R&E institutions) and individuals (e.g. researchers and their labs), the process was started to design the cloud services that RNP can host and offer on these datacenters. The first step was to listen to RNP's users and understand their needs and requirements for research and corporate services that the cloud services should provide. After that, the project team drew an implementation plan based on the most desired cloud services, as shown in Figure 6, considering their complexity, costs and knowledge required to implement, operate and support the services.

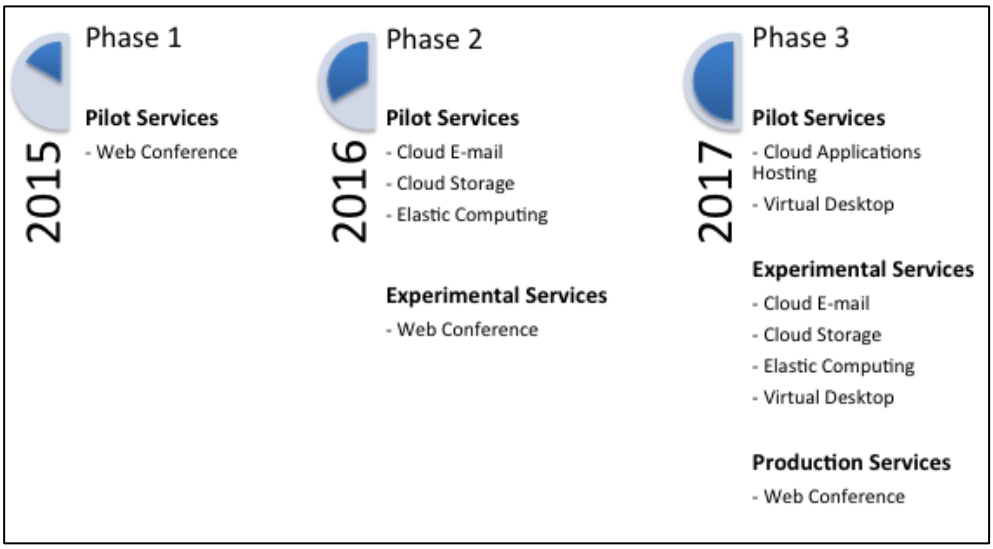

Figure 6: Cloud services implementation plan.

Based on the service implementation plan, RNP's team made an extensive evaluation of available open source software and technologies to support and deploy cloud services. For virtualization platform, oVirt (oVirt, nd) and XenServer (XenServer, ndwere considered, for the orchestration platform, OpenStack (OpenStack, 2015) and CloudStack (Apache, 2015) and cloud storage backend, like Openstack Swift (OpenStack Swift, 2015and Ceph (Ceph, 2015) were also evaluated. RNP's team based the evaluations on a list of requirements for each type of service, such as elastic computing, cloud storage, cloud e-mail, etc. The team also described some use cases for each service to facilitate the service modeling and prioritize requirements to develop or implement the services. Last, but not least, the team considered the legal aspects, which can affect public R&E institutions, like the Presidential Decree nº 8.135/2013 and the Interministerial Administrative Directive nº 141/2014 that impose public R&E institutions to host e-mail, VoIP, Web Conference and other communication services in organizations and entities of the Federal Government's datacenters. Decreto nº 8.135 (2015) Portaria Interministerial MP/MC/MD no 141 (2014) ,].

Additionally, some platforms developed by open source communities did not provide the requirements and quality which a NREN cloud services needs, like huge scale, federated authentication to mention a few. In order to solve these issues, RNP is working with research groups from universities to improve and accelerate the development and customization of open source solutions. For example, Big Blue Button(2015)which is a Web Conference platform, and OwnCloud (2015), a web front end to store files, had many improvements (most of the modifications returned to the community and were distributed in the open source version of these software). It is noteworthy that this action reinforces the commitment of RNP to the innovation and dissemination of knowledge.

RNP Cloud Services Status

Regarding the implementation plan, the first phase defined the Web Conference as the pilot service for 2015. RNP already had Web Conference service, but this service was based on proprietary software that had some license restrictions, constraints for the development of new features, and no flexibility to let this service "cloud ready", so the decision was to develop a new service. To deploy this service RNP adopted a solution developed by a Brazilian research group called Mconf, shown in the Figures 7 and 8. The main goal of this project was to create a Web Conference system based on open source software with the

ability to interoperate seamlessly between computers and web-connected mobile devices with many new features (Mconf, 2015)

Figure 7: Mconf web conference interface.

The conception of Mconf comply with the RNP requirements of a cloud based Web Conference, such like:

- Self-service Model – users can create communities, manage other users on communities, delegate administration of communities, record and manage web conference sessions and more;
- Elasticity - Mconf was designed in a distributed architecture that are load balanced among datacenters in various points in the country which can be scaled up in an easy way;
- Accounting – all sessions and activities are logged, bringing accounting capabilities to manage the use and the health of the service.

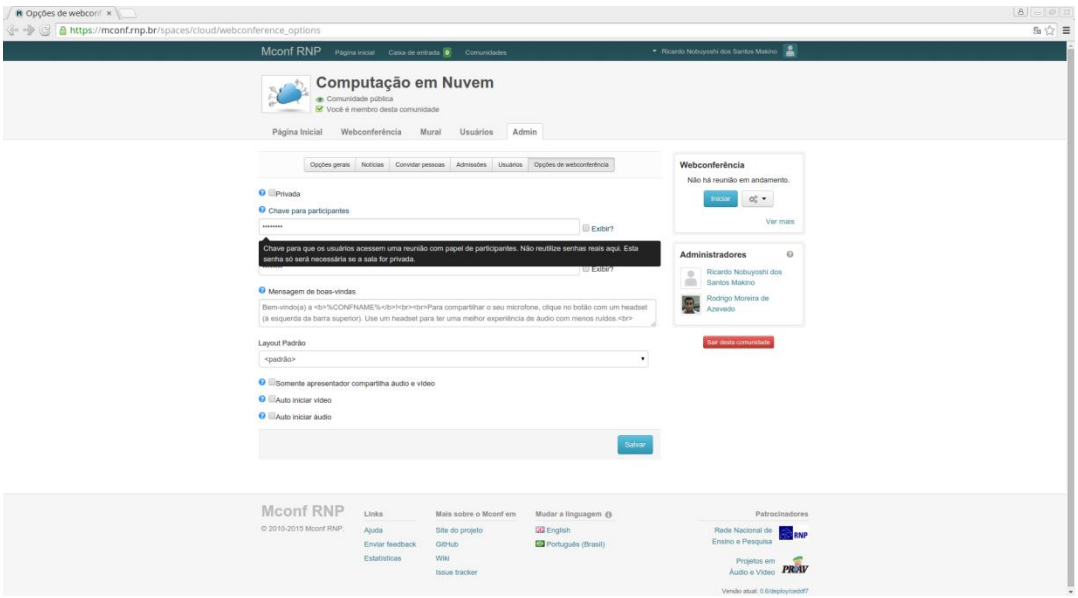

Figure 8: Mconf community administration interface.

Mconf has been running as a pilot service for RNP's staff since October 2014. It will replace the old platform in 2016, with the expectation of being offered to institutions nationwide in 2017. During the pilot and experimental service many enhancements were implemented, such as a better user interface, a WebRTC[4] module to improve the audio quality, a mobile app, etc.

In the second phase the pilot will deploy three services: Cloud Storage, Elastic Computing and Cloud e-mail. The first pilot to be deployed in 2016 is Cloud Storage, with Cloud Computing for Science (CNC) (Grupos de Trabalho da RNP ,2015) platform, a solution also developed by a research group funded by RNP. This service is divided in three parts:

- Storage Backend – composed by the nodes that will store user files and are responsible to guarantee file integrity, confidentiality and availability. OpenStack Swift[5] was chosen to achieve these requirements.
- Web Frontend – will present the service to the user through the web, as shown in Figure 9. This frontend is based on the OwnCloud platform, but like Mconf, it was necessary to improve the open source code to meet the requirements and quality necessary to provide the service. To do this, another research group, also funded by RNP, made all the improvements, which is also being offered back to the community as our contribution.
- Desktop and Mobile Apps – the last part was to provide desktop and mobile apps. OwnCloud already has clients for most types of mobile and desktop operating systems, and these clients are ready to support authentication using the CAFe Federation[6], used to authenticate the RNP's and academic community users. The only issue is that iOS client is paid. To solve this issue RNP developed a free iOS client to the academic community.

[4] WebRTC is a free, open project that provides browsers and mobile applications with Real-Time Communications (RTC) capabilities via simple APIs. The WebRTC components have been optimized to best serve this purpose.

[5] Swift is a highly available, distributed, eventually consistent object/blob store. Organizations can use Swift to store many data efficiently, safely, and cheaply.

[6] The Federated Academic Community (Comunidade Acadêmica Federada - CAFe) is an identity management system that gathers Brazilian education and research institutions, through their databases integration.

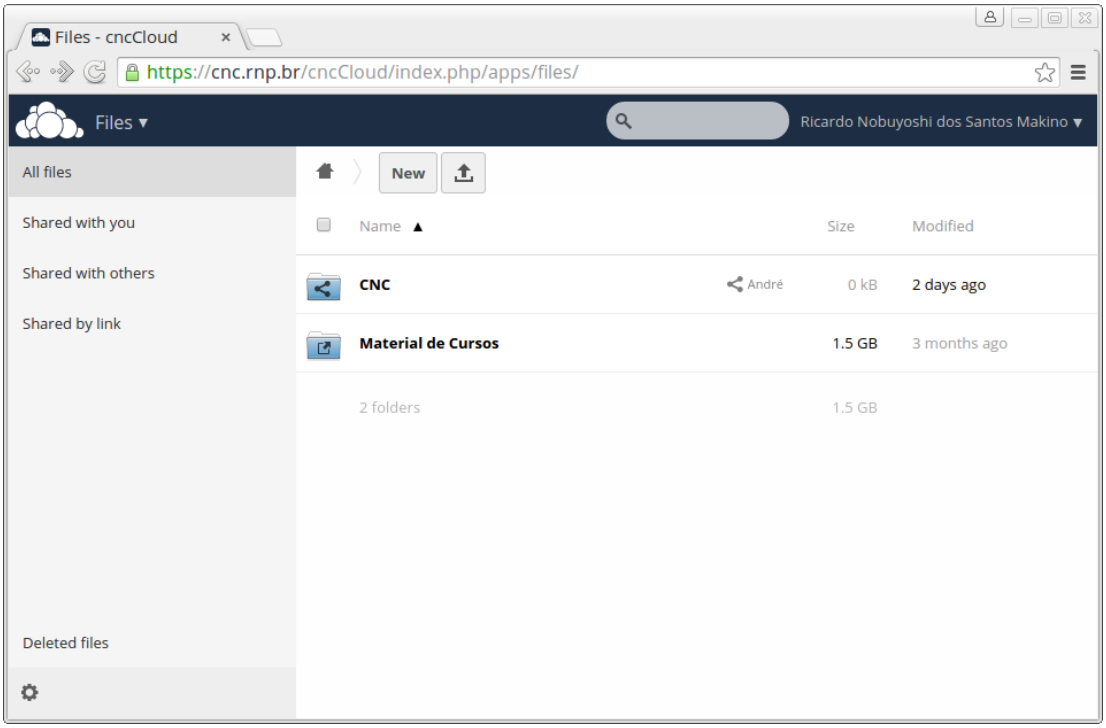

Figure 9: CNC user dashboard.

CNC will start the pilot for RNP staff only in 2016, with an expectation to go as an experimental service in 2017. During the pilot and experimental service phases, the main goal is to correct bugs, identify enhancements to implement before going live to all users. They will also allow improve the security and finalize the integration between desktop and mobile clients with the CAFe Federation. The CNC user management interface is shown in Figure 10.

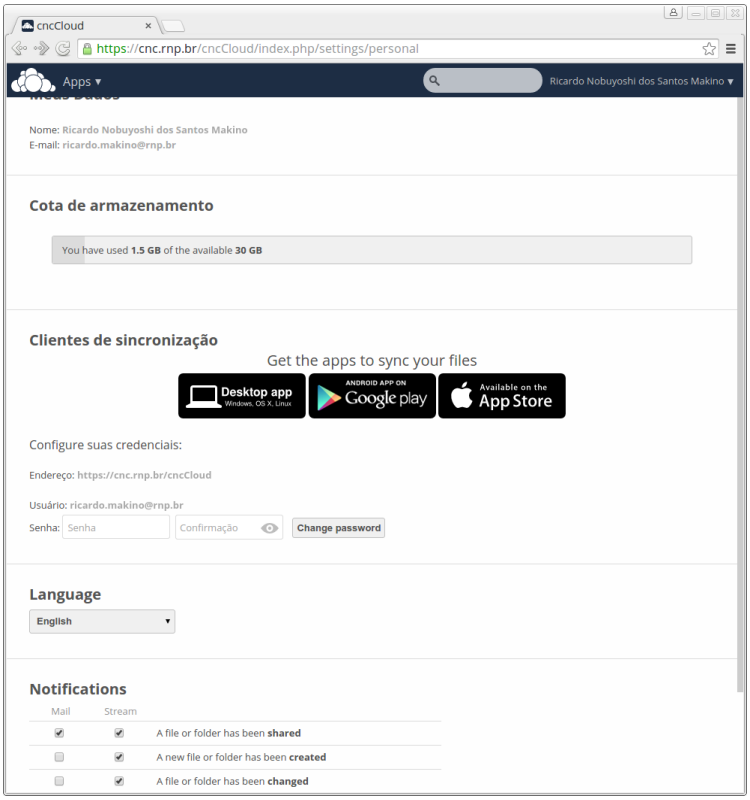

Figure 10: CNC user management interface.

The second cloud service pilot planned to be started in 2016 is the Elastic Compute service, provisionally called compute@RNP, this service aims to provide virtual machines to the R&E community, allowing researchers to accelerate tests and simulations, which today depends of the acquirement of new hardware, which in some cases impact their research.
To achieve this, RNP defined some basic requirements to the platform that will support this service:

- Self-service Model - each user should be able to create, modify and destroy virtual machines, network and storage blocks at any time. This should be done through a Web Interface and/or via an API service, to allow and facilitate process automation.
- Elasticity – this service should be designed in a distributed architecture, which could be load balanced among participating datacenters and scale-up or scale-down in an easy way. These requirements should be extended to the users, so it will be possible to scale-up or scale-down virtual machines resources, virtual networks and storage space.
- Accounting – all sessions and activities should be logged to bring accounting capabilities to users and the administrators.
- Integration – the platform should integrate with other systems, allowing RNP to provide several services over this cloud platform, such as Cloud Application Hosting and others.

The service plans to start the pilot in the first half of 2016. RNP chooses Apache CloudStack as the software platform that will provide the service. It was chosen after a thorough evaluation of a list of requirements and a lot of discussion with the R&E community. The project team has ended the deployment of all systems and finished the test and homologation phase, as shown in Figure 11.

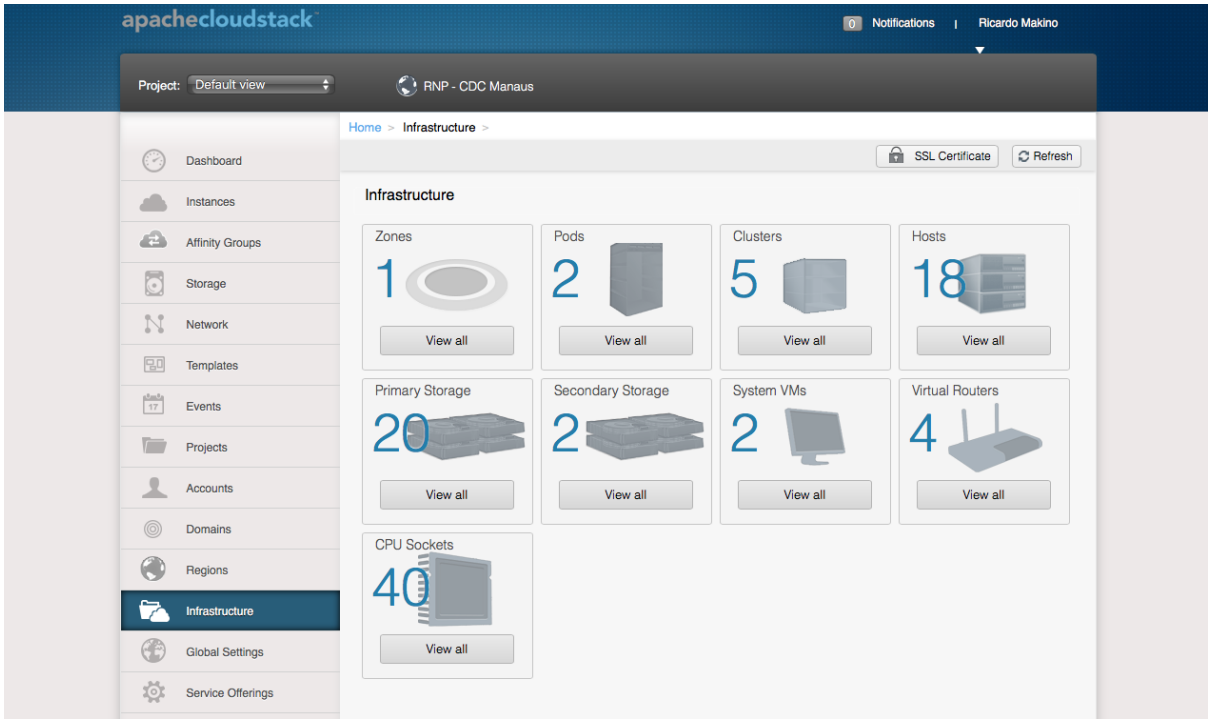

Figure 11: compute@RNP management dashboard.

The service will support federated authentication by default, as shown in Figure 12, and will provide a variety of service offerings, like compute offerings since 1vCPU and 512MB of RAM to 6vCPU and 12GB of RAM, disk offerings from 10 GB to 2 TB of capacity, network offerings with firewall, load balance, DNS, NAT, VPN and others.

Figure 12: Federated authentication at compute@RNP.

The third cloud service pilot planned to be deployed in 2016 is the Cloud e-mail service. This service is under construction and the main goal of the service is to provide a cloud based mail service that will allow the R&E community to host e-mail boxes to their staff, lecturers, researchers and postgraduate students. To achieve this goal, some requirements were defined:

- Self-service Model - each institution that subscribe the service will be able to set their own domain, manage their users, connect own LDAP database, manage spam white and black lists, customize their web interface for the users, manage message features like attachment size, etc.
- Elasticity – the service should be designed in a distributed architecture that is load balanced among datacenters and can scale-up or scale-down in an easy way, to guarantee high availability and integrity.
- Accounting – all sessions and activities should be logged to bring accounting

capabilities to users, administrators and also to RNP.

The Cloud e-mail service is planned to go pilot with some institutions at the first half of 2016. Currently RNP has defined the software platform that will provide the service. It was chosen after a careful evaluation of requirements that led to the Zimbra Enterprise (Zimbra , 2015) platform. The project team has ended the deployment of all systems and finished the test and homologation phase, as shown in Figure 13.

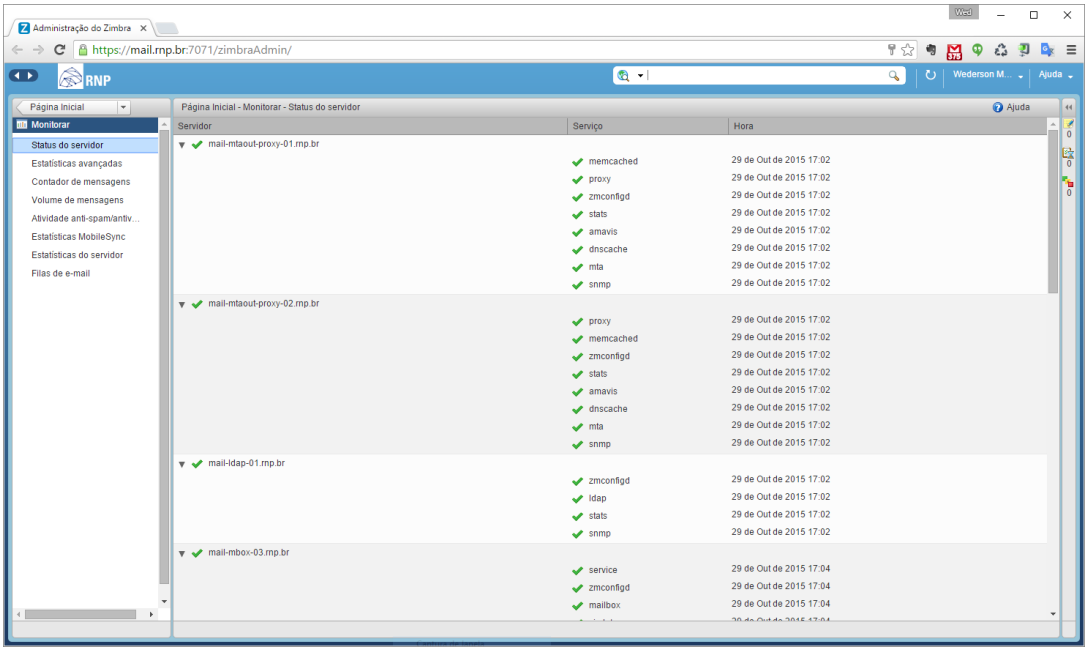

Figure 13: Zimbra enterprise management dashboard.

The next steps to start the cloud e-mail service pilot is to finish the business and management models and start to migrate the accounts from some R&D institutions to validate the processes and procedures and improve the service.

Conclusion

This paper presented a brief description of NREN's cloud strategies and the scenario chosen by the Brazilian National Research and Education Network, RNP, for the Brazilian academic cloud. The hybrid, community and federated strategy were chosen as the most flexible and suitable for the current Brazilian NREN operation and funding models.

The cloud implementation and services selected to be initially offered were presented, as well as their current status and next steps planned.

RNP believes that the Brazilian academic cloud will augment the security and the national sovereignty. It will also reduce current fragilities that many public R&E institutions demonstrate regarding the safety of an ever-increasing amount of strategic and vital information, as a consequence of a lack of adequate e-infrastructure services and support.

Acknowledgment

The authors thank RNP and the Ministry for Science, Technology and Innovation (MCTI)

and the Ministry for Education (MEC) for the support to the academic cloud program and the partners of the CDC project, including INPA, IFPE and Huawei.

References

Apache (2015)*Apache CloudStack Documentation*: http://docs.cloudstack.apache.org/en/master/ [accessed 10 April 2015].

ASPIRE (2012) *The adoption of cloud services* https://www.terena.org/activities/aspire/docs/ASPIRE-clouds.pdf [accessed 8 April 2015].

BigBlueButton (2015) *Mconf Contributions to BigBlueButton*: http://mconf.org/m/about/mconf-and-bigbluebutton [accessed 7 April 2015].

Boyle, B., Byrne, R. & Nisbet, B. (2014) 'HEAnet's multi-layered cloud services strategy'. *TERENA Networking Conference 2014*: https://tnc2014.terena.org/getfile/1007 [accessed 9 April 2015].

Centro de Dados Compartilhados é inaugurado em Manaus (2014): http://www.brasil.gov.br/ciencia-e-tecnologia/2014/05/programa-centros-de-dados-compartilhados-e-inaugurado [accessed 10 April 2015].

Ceph (2015)*Ceph Documentation*: http://ceph.com/docs/master/ [accessed 8 April 2015].

Computerworld (2011) *Governo assina contrato com Huawei para projeto em nuvem* (December): http://computerworld.com.br/tecnologia/2011/12/01/governo-assina-contrato-com-huawei-para-projeto-em-nuvem [accessed 13 April 2015].

Decreto nº 8.135 (2015) *Decreto nº 8.135, de 4 de novembro de 2013*. http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2013/Decreto/D8135.htm [accessed 10 April 2015].

Grupos de Trabalho da RNP (2015) http://www.rnp.br/pesquisa-e-desenvolvimento/grupos-trabalho [accessed 26 June 2015].

Mconf (2015) Mconf – Multiconferência WEB e dispositivos móveis: http://www.inf.ufrgs.br/prav/mconf.htm [accessed 8 April 2015].

OpenStack (2015) *OpenStack Documentation*: http://docs.openstack.org/ [accessed 8 April 2015].

OpenStack Swift (2015) *OpenStack Swift Documentation*: http://docs.openstack.org/developer/swift/ [accessed 19 June 2015].

oVirt (nd) *oVirt Documentation*: http://www.ovirt.org/Documentation [accessed 16 April 2015].

ownCloud (2015) *ownCloud Documentation*: https://doc.owncloud.org/ [accessed 26 April 2015].

Portaria Interministerial MP/MC/MD no 141 (2014) *Portaria Interministerial MP/MC/MD no 141 de 02/05/2014*: http://www.legisweb.com.br/legislacao/?id=269793 [accessed 8 April 2015].

Programa Centros de Dados Compartilhados é inaugurado em Recife (PE)(2014) http://www.rnp.br/destaques/programa-centros-dados-compartilhados-e-inaugurado-recife-pe [accessed 15 April 2015].
Szegedi, P. (2011) *NRENs' strategic perspective on storage and cloud "buy or build"* http://www.terena.org/activities/tf-storage/Storage-and-cloud-v5.pdf. [accessed 7 March 2016)
Terena (2014). GÉANT Association Compendium: http://www.terena.org/activities/compendium/ [accessed 10 April 2015].
XenServer (nd) *XenServer Documentation:* http://support.citrix.com/proddocs/topic/xenserver/xs-wrapper-62.html [accessed 13 April 2015].
Zimbra (2015) Z*imbra Documentation,* https://www.zimbra.com/documentation [accessed 26 May 2015].

Biographies

José Luiz Ribeiro Filho holds a Ph.D. degree in Computer Science from the London University, a M.Sc. degree in Computer Science from COPPE/UFRJ and is graduated in Eletronic Engineering at Universidade Federal do Rio de Janeiro. He started his career as researcher at Núcleo de Computação Eletrônica (UFRJ) in the 80's, having taken part and leadership in several computer architecture and computer networks projects. Between 1996 and 2000 was responsible for the consolidation of the Brazilian National Research and Education Network (RNP). In the next four years José Luiz had activities in the private sector at Telemar and HP Brazil. Back at RNP in 2005, José Luiz was responsible for starting several national projects such as Redecomep and Rute, and lead the creation of the services and solutions area at RNP. He is currently the director of this area. He was counselor of the Brazilian Internet Steering Committee (CGI.br) in 1998-2000 and between 2011-2014, representing the academic community. He has also represented the country and RNP in various international forums.

Antônio Carlos Fernandes Nunes is MSc in Electrical Engineering at Federal University of Rio de Janeiro (COPPE/UFRJ), and graduated in Systems Engineering and Computer at Rio de Janeiro State University (UERJ). He joined RNP (Brazilian NREN) in May 1998 where he has worked in operations, administration and systems development. As Special Projects Manager of the General Directory he has led and worked on several projects inter-ministerial, and has driven the emergence and growth of the Federal Point of Interconnection Networks (FIX), and Coordinator of the Brasilia PTT Metro project in CGI.br, Supervisor of Midwest Community Networks for Education and Research project (Redecomep) and responsible for RNP's Internet Data Center. Since 2009 he is Service Management Deputy Director of RNP being in charge of advanced services portfolio. He has

CCNA certificate, Relationship Marketing by Ibmec, and has published articles in the areas of networks, service management, technological innovation, and science and technology policies. He has also represented RNP in the ELCIRA project coordinating actions for AAI between the EU and Latin America, and promoting the deployment of eduroam services, and currently coordinates the RNP's actions in the MAGIC project (Middleware for Applications and Global Virtual Communities Collaborative) with global reach.

Ricardo Nobuyoshi dos Santos Makino is a computer Engineer and MBA in Information Security. Has a strong knowledge in cloud computing, cloud security and virtualization. Has a strong background in computer forensics, incident handling, web application security and network security. Nowadays, work as Cloud Computing Expert at RNP and is responsible for mapping demands related to strategic projects in cloud computing, manage and execute technical activities related to cloud, prepare feasibility analysis and technical advices to the executive staff. Additionally, help community projects like Cloud Security Alliance and ABNT (Brazilian Standard Organization) Work Groups for cloud computing and security standards.

Gorgonio Barreto Araújo is Solutions Management Deputy Director of RNP of the Brazilian National Research and Education Network (RNP). Master's degree in Administration by UFBA and Master and Bachelor of Science in Electrical Engineering from the State University of Campinas (Unicamp). He was Executive Director at Nexos Information Security, teacher of the Distributed Systems Laboratory (LaSiD) at the Federal University of Bahia (UFBA), and post graduation professor at the School Rui Barbosa (FRB). Gorgonio was Special Projects Coordinator and Information Infrastructure and Telecommunications Coordinator of the Information Society Program (SocInfo) of the Ministry of Science and Technology (MCT) / United Nations Development Programme (UNDP). Collaborated with the preparation of the Green Paper SocInfo. He was a consultant of the Ministry of Health (MOH) / United Nations Educational, Scientific and Cultural Organization (UNESCO) in the Project National Health Card (CNS). He was Network Engineer and later consultant RNP/UNDP, upon the implementation of the first Brazilian Internet backbone. Gave a series of extension courses from Unicamp, UFBa and Nexos in area Information and Communication Technology (ICT). It Leader auditor certified by IRCA in ISO / IEC 27001 is certified by EXIN ITIL Foundation.

Graciela Machado Leopoldino Martins is M.Sc. degree in Computer Science at Universidade de São Paulo (USP) and is graduated in Computer Science at Universidade Estadual Paulista (UNESP). She has a specialization in Strategic Management of Technological Innovation from UNICAMP since 2008 and is certified Project Management Professional (PMP) by the Project Management Institute (PMI) since 2013. She joined RNP (Brazilian NREN) in July 1998 where she worked with management

systems and networks, as a specialist in communication and collaboration applications on the Internet. Currently, she acts as a Project Manager at RNP working with modeling and implementation of information and communication technology (ICT) solutions.

Leandro Marcos de Oliveira Guimarães has been Service Manager of RNP since May, 2010. He is responsible for communication and collaboration services, identity management services and strategic hosting services, and currently is member of the GeGC (Global eduroam Governance Committee) and acts as secretary of the Latin American eduroam Committee. He has worked for over fifteen years in Information Technology areas, focusing on projects, planning and operation. He has an MBA in Project Management from IBMEC and another MBA in Information Security from IBPINET - RJ-FUNCEFET. He is certificated as PMP by PMI, COBIT Foundation by ISACA, the EXIN ITIL v3, Cloud Computing Foundation by EXIN and the MCSO (Modulo Certified Security Officer) by Modulo. With a Degree in Computer Networks from University Estacio de Sa, Leandro has worked in large companies such as Petrobras, TIM, Claro and Xerox Brazil. He has also managed RNP's activities in the ELCIRA project coordinating actions for AAI between EU and LA, and promoting the deployment of eduroam services, and currently manages the RNP's work package about platforms for mobility in the MAGIC project (Middleware for Applications and Global Virtual Communities Collaborative).