Private-Cloud Computing Services for an Interactive Multi-Campus University

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Abdel Rahman Alzoubaidi
Al Balqa Applied University, Salt, Jordan

Abstract—**Cloud computing is an environment where computing resources, such as processing power, storage, network resources, applications, and other IT services, are provided to users as a computing utility. This paper presents the university distributed databases consolidation and relocation to the cloud for the provision of Database as a Service (DBaaS), through their deployment into High Availability, interactive, secure private cloud setup utilizing Al-Balqa Applied University (BAU) Private-Cloud. This solution involves several transitions, and represents the main key step in BAU journey to the cloud to allow the university to achieve greater efficiency in terms of database services, and to improve performance, availability, interactivity, and security. The resulted service also reduces operating, management and capital costs.**

Index Terms—**Private-Cloud migration, interactivity, consolidation, virtualization, DBaaS, multi-campus universities.**

I. Introduction

Cloud computing is defined as the provision of computing hardware and software resources as a service rather than a product, whereby resources are provided to users as a metered service over the Internet [1, 2]. It is very motivating to perceive how multi-campus universities can benefit from cloud computing and ease the many challenges that are facing them to meet their faculties, students, and administration staff IT demands with highest possible quality-of-service (QoS) [3-5]. Cloud computing provides many types of services; these include: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). However, some other types of services among many are recently evolved, such as database as a service (DBaaS) and Information Technology as a Service (ITaaS) [6].

There are two types of basic cloud-based solutions, these are; public-cloud and private-cloud solutions [7, 8]. The first one is defined above and it has a number of advantages, including lower capital expenditures, employees work anywhere and focus on business not technology, no applications upgrades concerns, instant implementations, lower upfront and operation and maintenance costs, predictable spending, guaranteed service-level agreements, pay only for the required services, and provide guaranteed availability and scalability. However, in this solution, computing services are usually provided as a service by a Cloud Service Provider (CSP), which makes security and privacy are big concerns. Private-cloud is similar to public-cloud as it delivers the same services except it offers its services through a proprietary infrastructure through which users can control the level of security and privacy they would like to have [9].

BAU is a multi-campus university having 13 distinct locations in Jordan involving extensive interactivity in their services. It serves more than 40,000 undergraduate and postgraduate students and continues to grow. It has its main campus in Salt, which is the center for all educational and administrative functions and services for all campuses. BAU adopted an ambitious program to migrate from using regional Conventional Data Center (CDC) at each of its regional campuses to accommodate its IT resources to private-cloud infrastructure for accommodating its IT resources, which is described in details by Alzoubaidi in [5]. In particular, BAU consolidates the existing CDCs into two Virtualized Data Centers (VDCs), namely, Salt main campus and campus of the Faculty of Engineering and Technology (FET) located around 30 Km apart, aiming at the provision of high available and secure ITaaS within its premises [5].

This paper describes the consolidation of BAU campuses databases and schemas into Virtual Machines (VM) mobility within BPC infrastructure; to eliminate services' overhead, ensure reliability, availability, interactivity, and remove the existing single points of failures. Practically, this paper represents a continuation to a previous research paper by the same author that describes BPC migration phases and infrastructure [5].

BPC main objective is the consolidation of BAU IT resources onto a shared pool resource in a private-cloud to allow for management and delivery of corporate database resources and services. Moreover, the new BPC setup mitigates the problem of single points of failures at each CDC level concerning its physical servers, WAN connectivity with the main CDC; local and remote backups from remote campuses to the central CDC that is continuously increasing computing and storage resources. Furthermore, BPC preserves control on services delivery, and security and privacy policies [5].

BAU regional campuses have deployed individual databases and applications onto dedicated server infrastructure for its different campuses and colleges. This kind of segmented arrangement of technology to business functions results in severe underutilization of the technology infrastructure and inefficient utilization of administrative resources. Additionally, such inflexible deployments inhibit the ability of IT organizations to respond quickly to changing business needs [5].

This paper is divided into five sections. Section 1 introduces the main theme of the paper. Section 2 reviews the most recent and related work regarding database consolidation. Section 3 presents a detailed description of the existing database services at BAU. Section 4 is devoted for the description of the consolidation phases from distributed databases to private-cloud infrastructure. Finally, in Section 5, conclusions and recommendations for future work are pointed-out.

II. LITERATURE REVIEW

A. Cloud Computing Definition

Cloud computing is a model for enabling suitable, on-demand network access to a shared pool of configurable computing resources (e.g., servers, storage, applications, and services), which can be rapidly provisioned and released with minimal management effort or service provider interaction. It is also defined as a model of hardware and software deployment where the software application is hosted on extremely high performance hardware, and provided as a service to users through the Internet [1].

Eliminating the need to install, configure and run applications on the users' own servers or premises contributes significantly to reduce the burden of software maintenance, and ongoing operation and support. Required IT resources are paid for through a subscription instead of a license; where businesses no longer require procuring and installing high cost IT resources on their premises [2].

Cloud computing provides cost-effective IT infrastructure procurement, installation, operation, maintenance, and management; because cloud computing users do not have to buy high specs hardware and software infrastructure to be underutilized, hence planned for peek time workload operations. Users just need to buy the required computing hardware and software services, which can be accessed online, from any CSP. Accordingly, users can save initial investment on hardware and software purchase, and help business owners to spend more money on the core areas of their business. Currently, users receiving high QoS cloud computing, because most major hardware and software brands, such as: HP, DELL, Amazon, IBM, Google, and Microsoft, are CSPs [10-14].

B. Cloud Computing in Educational Institutions

One of the most important applications of cloud computing is educational cloud. In the new globalized economy, educational institutions (e.g., universities) must provide high quality IT learning infrastructure and prepare students for the challenges of the 21st Century cost-effectively. This is especially true in multi-campus universities that have various campuses distributed across wide areas, where such IT infrastructure must be provided for each campus [15].

It has been recognized that cloud computing is well suited for multi-campus educational institutions; as it provides high availability, scalability, high performance, up-to date hardware, instant software updates, and a wide access to different academic resources, applications, and educational tools. It also provides cost-effective solution to the learning process, more agility, and foster development by improving collaboration between students and educators, more efficient administration and less expenditure on operation, maintenance, and management [16].

Cloud computing opens a new era and improves the quality and effectiveness of social applications in universities, such as a cloud-based storage of social academic networks between faculties, students, researchers, and staff. They can share common interests, joint publications, and locate academic library resources effectively [17].

Cloud computing can play a big role in developing one of the most promising paradigms for education, namely, e-learning [18], which requires high performance and consequently costly IT infrastructure [19]. Cloud computing is a better solution, providing low costs, higher performance, instant software updates and a wide access to different academic resources, applications and educational tools. To complete tasks and assessments, the users can run the applications from cloud through their PC, mobile phones, tablet PC, etc.

Divya and Prakasam [20] developed cloud computing based architecture for e-learning and discussed the security issues in cloud computing, which have to be checked before moving e-learning into the cloud. Mustafee [21] examined three different distributed computing technologies in the context of e-science research; these are: grid computing, desktop grids, and cloud computing. His was cloud computing and desktop grid computing will gain in prominence, while traditional cluster-based grid computing may remain dormant. Shunye et al. [22] analyzed the development of the cloud computing in education, proposed a new e-learning architecture based on private-cloud, and presented the expected benefits from the proposed architecture. They conclude that educational institutions can significantly benefit from cloud computing by increasing the benefits of students, teachers and administration staff.

Getso and Ahmed [4] reviewed the services that can be provided by cloud computing infrastructure in the educational arena, especially in the universities where the use of computers are more intensive and what can be done to increase the benefits of common applications for students and teachers, and how to develop the system that can be work in any time of cloud like private-cloud, public-cloud, and hybrid-cloud. Praveena and Betsy [23] provided a comprehensive introduction to the application of cloud computing in universities.

For more detailed information concerning the emergence and popularity, essential characteristics, services and deployment models, advantages and disadvantages of cloud computing and private-cloud can be found in [24-26].

III. BAU CURRENT DATABASE SERVICES

BAU existing databases are designed for campus-based services as shown in Figure 1, where each campus has its own database and application services. Previously, BAU employs CDC dedicated to host local database and application servers equipped with and internal or external storage units. There are 13 CDCs with physical computing and storage resources dedicated to host databases and related applications either to serve all campuses or replicated to serve individual campus.

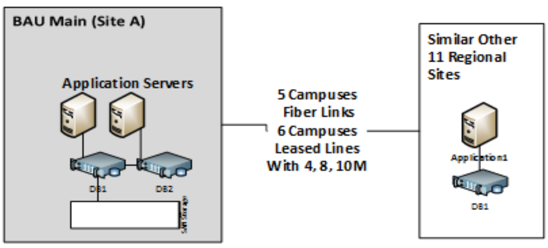

Figure 1. BAU main campus CDC and regional campuses CDCs database servers, storage and application services.

A. Limitations and Challenges

BAU database consolidation into BPC is driven by the cost reduction, increased agility, reduced complexity, business drivers, availability, reliability, security, capacity, maintenance, and technical challenges. Existing campus-based database service at BAU is unreliable, inflexible and inefficient to suit current services demands and requirements.

For multi-campus universities, camps- based dedicated databases usually lack the agility, elasticity, rapid deployment and QoS necessary to serve the rapidly changing university communities' requirements. The hardware, software, application, and computing resources duplication at the campuses is also a major disadvantage.

Based on the above discussion, there are institutional and technology related motives for BAU to move its present databases from campus-based to its BPC [5, 10]. This implies less cost of entry, reduced risk of IT infrastructure failure, quick responses to changes in demand, rapid deployment, increased security, and ability to focus on teaching, learning, and research.

To address these challenges, BAU pursuing its journey to the cloud migration to realize cost savings while increasing business agility. BAU moves to cloud computing model involve a phased approach for smooth transition. DBaaS is one of the key steps in this journey to a accomplish reliable, highly available, agile BPC, on-demand services, and allows the university to attain greater efficiencies in their operations by improving resources utilization, and lowering both capital and operational expenditures.

IV. DBAAS DEPLOYMENT

This section describes the procedures to deploy DBaaS for database consolidation at BAU, which is the second key step in BAU journey to the cloud. The first step was the infrastructure consolidation to develop BPC described in [5]. This step aims for the utilization of BPC infrastructure to deploy a consolidated database infrastructure based on a systematic assessment of the existing databases and related applications. The assessment process was looking for the consolidation of the existing databases and applications into a managed BPC for the provision of DBaaS. There are many issues that should be considered and made sensible decisions about before deciding on the optimum solution to overcome the limitations and meet the challenges discussed in the previous section.

BPC is the base of our solution to consolidate the databases and deploy them into virtualized infrastructures to offer DBaaS to allow the use of common IT resources and management whereas reducing database redundancies and services overhead. The cloud technology service models, mainly DBaaS offer an excellent solution to overcome BAU current business and technical challenges and limitations [1-5].

The main issues that have been considered to ensure maximum possible QoS or meet the QoS requirements include: cloud connectivity, system recovery, data replication, multi-tenancy, and redundant components and network paths [23-25].

A. Database Consolidation

Figure 1 presents BAU CDCs used to host 13 individual databases to serve the university branches with database and applications related electronic services. BPC depicted in Figure 2 shows the consolidated virtualized legacy BAU regional data centers into BPC. It shows BPC main two VDCs located at two of the BAU campuses data centers, namely; BAU main Site A and FET Site B around 30 Km a part. The basic model for private-cloud provision is applied to offer regional campuses the best mix for their database workload needs through the provision of cloud managed services; BPC adopted a fully managed private-cloud that includes the services above and below the hypervisor. Also, it will feature reusable service profiles that can store configurations, which can adapt to new requirements and provide a pool of networkable compute and storage system service that is on demand, accessible, measured pool of service, provided in an elastic and scalable fashion on BAU premises [5].

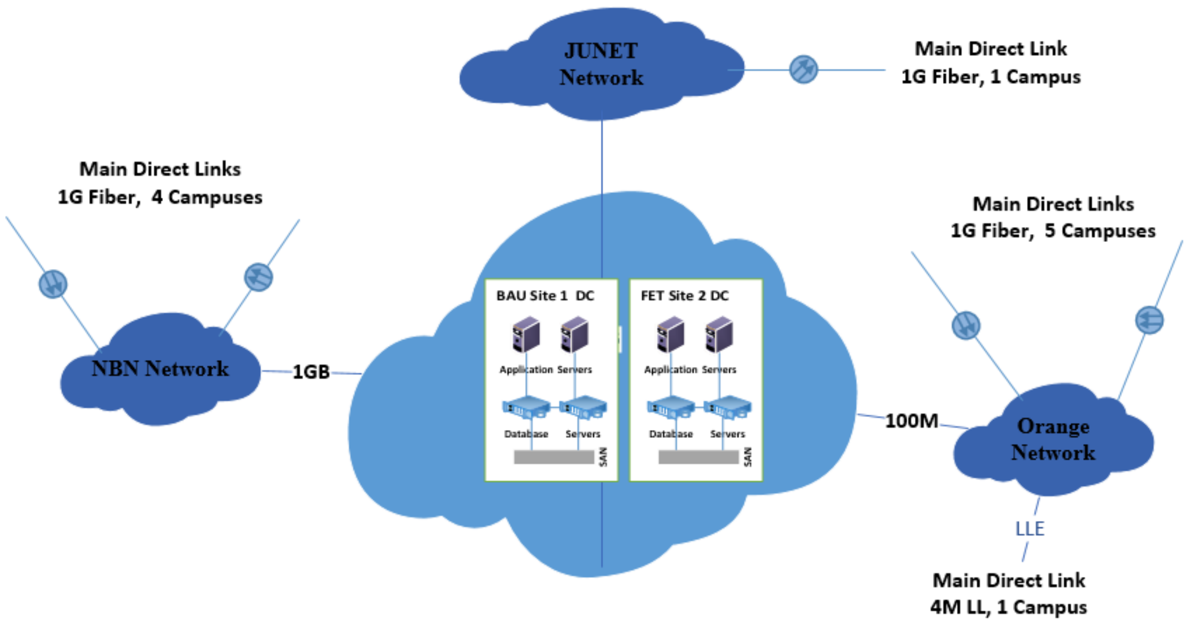

Figure 2. BAU private-cloud (BPC).

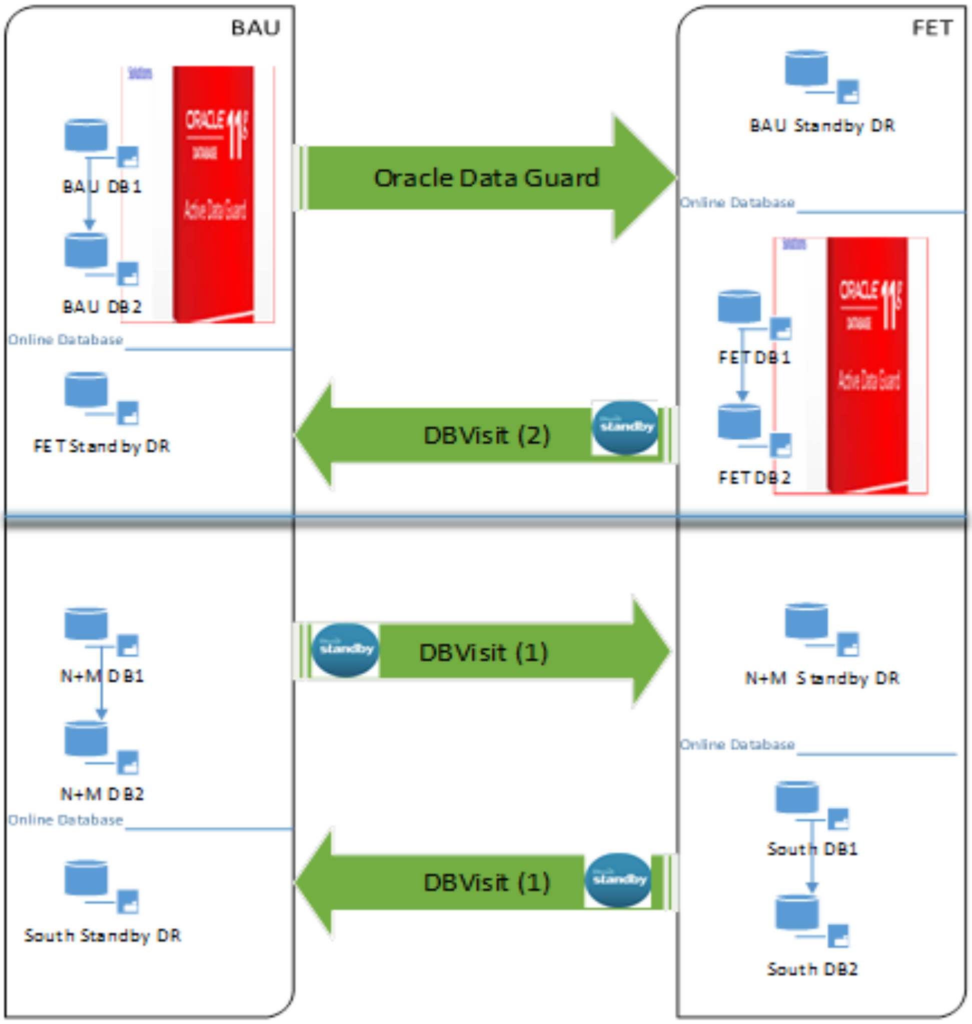

Figure 3. BAU Private-Cloud (BPC) Database consolidation, DRs and Replication

BAU journey to private cloud migration secured a reliable interconnection network as one of the major prerequisites for building a reliable cloud service [5]. Thus, based on availability of a reliable inter cloud (inter campuses) interconnection network, we found that we are in a position to move campuses' individual databases in phases to BPC and lunch our DBaaS, with full confident, as shown in Figure 2. The consolidated databases form the core of BPC migration infrastructure for provisioning of DBaaS cloud service.

The databases for all the 13 campuses are hosted at VM in one site, which is replicated instantly using, Oracle Data Guard or DBVisit, on the other site. VMs mobility is assumed to be handled by BPC management to achieve availability and BC. Moreover, each site has a disaster recovery (DR) at the other site, namely, BAU standby DR and FET standby DR to guarantee BPC DBaaS service business continuity requirements as shown in Figure 3. It is worth mentioning here that DBVisit replication software is deployed for further cost saving, by eliminating the huge cost to upgrade Oracle Data Guard licenses [27]. Basically, each site has two database servers employing Oracle RAC for active-active availability services and two application servers. For BPC replication services, Oracle Data Guard and DBVisit are employed [28, 29].

For business continuity (BC) demands and smooth transition with zero service interruption a phased based approach is adopted to consolidate individual databases to BPC. Campuses database is migrated to either Site A, or Site B according to the respective campus work-load and the computing resources load balancing. The main criteria to move a campus database to BPC is the availability of a redundant reliable inter-cloud connectivity DCs sites to BPC sites as follows:

A. Phase #1: Data Base Consolidation

In Phase #1, the main BPC Sites A and B are virtualized, create the necessary VMs to host consolidated databases, database migration, implantation and testing for Oracle active-active RAC, and database replication for Site A and Site B from traditional CDCs to VDCs as shown in Figure 4.

It can be clearly seen from Figure 4 that the main BPC sites are reliable utilizing active-active RAC setup, and flexible to provide DBaaS for the two BAU major campuses, which forms the core BPC compute, storage and network resources for secure, agile, reliable, and on demand services for their students, faculty, staff, admin and for the regional campuses. Moreover, the core data centers eliminate the problem of single point of failure of the old CDC setup. However, the other 11 CDCs are unchanged, due to the unavailability of reliable inter-campuses/inter-cloud interconnections to all campuses.

B. Phase #2: Database Migration

In Phase #2, after successful operation of Phase #1, operated as active-active for each site and active-passive for each other's, as more reliable high speed links are available for BAU inter-cloud interconnecting regional campuses to BPC network more campuses DBaaS are migrated. Consequently, six campuses databases from Phase #1. In this phase, the databases are consolidated and relocated to their corresponding VMs as shown in Figure 5.

Upon completion of Phase #2, six databases and a DR for the other site are located at both sites to ensure higher service provision reliability and continuous availability. Figure 5 shows that the single point of failure for the databases in Figure 1 is eliminated. In particular, a standby database replica is available in case of failure.

C. Migration Phase #3

For computing business continuity requirements BPC necessitates reliable interconnection for the provision of centralized DBaaS service to all campuses. In this direction, in Phase #3, we establish a backup connection link to all campuses. The primary campus interconnections are 1 Gbps speed links among regional campuses. To achieve the desired high availability services requirement a 4 Mbps backup redundant links are in place as presented in Fig. 5 to support BPC high availability and eliminate inter-campus (BAU inter-cloud) dis connectivity.

Upon completion of Phase #3, all regional campuses Database are consolidated either to Site A or Site B, except one campus due to the unavailability of high speed and a backup inter-cloud connection with either main sites, for the provision of DBaaS accomplishing flexibility, higher reliability, availability and increasing corporate agility.

V. CONCLUSIONS

This paper presents BAU database consolidation and migration to private-could, which is foreseen as a model for multi-campus universities. Moving to BPC is a leapfrog shift from using individual database services to building a centralized private cloud for the provision of interactive DBaaS utilizing BPC. This solution reduces the universities' IT administration, maintenance, and software licensing costs, at the same time, private and sensitive information are locally protected.

The phase-based development approach adopted in service consolidation proves to be the best approach to follow due to limitation in resources as well as to ensure uninterrupted university e-services, where faculties, students, and staff need to access IT resources. It provides us with distinct milestones to test and evaluate the migration process and ensure smooth transition.

The successful databases consolidation achievement, deployment, and DBaaS running through BPC, removed physical resources redundancy and cater for utilizing backups scheduling, active-active service at BPC core sites, and mutual DR services for each site in the other site. Finally, for business continuity and high availability with manual configuration the main two core sites works as active-passive. The achieved migration setup is another step in BAU journey to the cloud target to provide ITaaS with business continuity and high availability for all regional campuses. Accordingly, uses the gained expe-

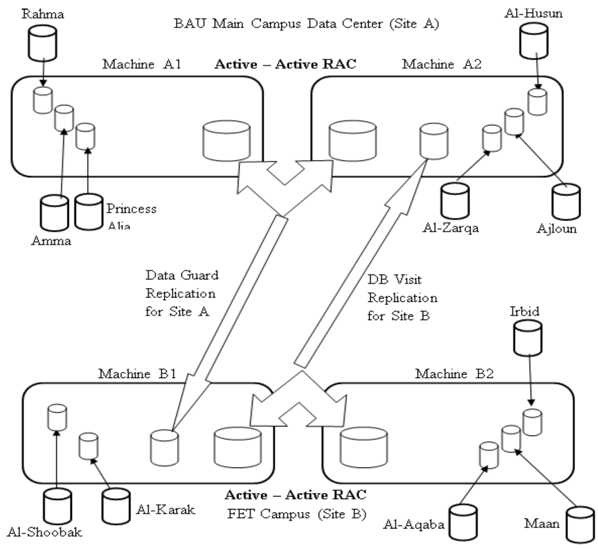

Figure 4. Phase #1 Database consolidation.

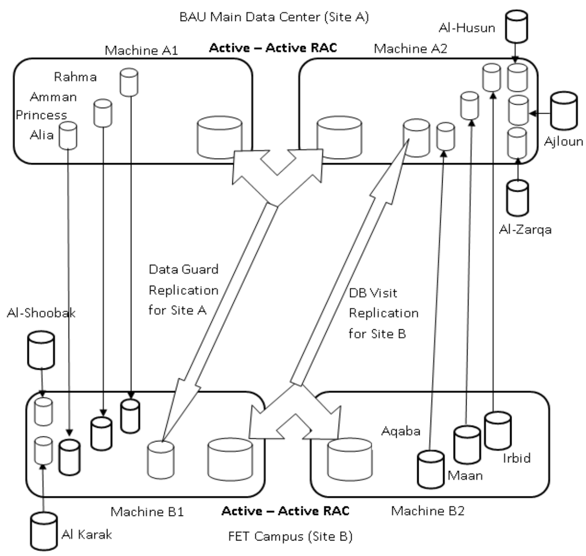

Figure 5. Phase #2 Database migration.

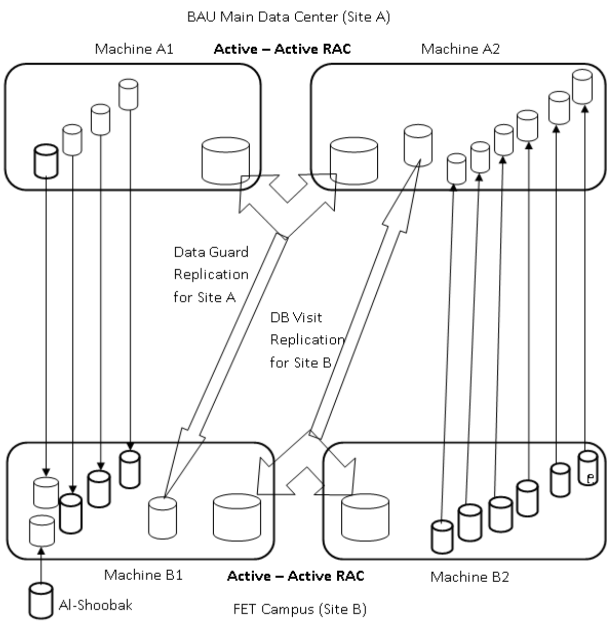

Figure 6. Phase #3 Databases consolidation.

rience and views as to how to implement secure shared configurable private-cloud computing resources to provide a key step for providing IaaS, SaaS, PaaS, and ITaaS across a multi-campus university or a consortium of universities.

Future research work focus is to implement business continuity and high availability active-active and VMs mobility setup for the main core data centers sites of BPC to secure automatic failover scheme instead of actual manual intervention. Hence, in case of failure manual intervention is essential to resume operations. Failover mechanism procedure is performed manually with high cost RTO and RPO.

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Author

Abdel Rahman Alzoubaidi is Associate Professor at Computer Systems Engineering Department and Computer Center Director at Al-Balqa Applied University. Alzoubaidi studied Automations and Computer Engineering at the Technical University of Iasi and then left for Mu'tah University where he worked as teaching assistant on a scholarship where he obtained his MPhil and DPhil in data Communications and Computer Networks in 1996 under the supervision of Professor Ed. Powner. He subsequently joined the Department of Computer Engineering at Mu'tah University as faculty where he became Associate Professor in 2004 and served as Director of Computer Center from 1996 to 2007. He was appointed President's Assistant for ICT. His research interests center on improving the understanding, design, and performance evaluation of networked computer systems, Cloud Computing, eLearning, Cyber Security, Wireless and Ad-hoc networks. He worked as Information and Communication Technology consultant for the Ministry of Education. He designed and implemented many innovative ICT projects in Jordan. He has given numerous invited talks and tutorials, and is a consultant to companies involved in Internet technologies. (alzoubaidi@bau.edu.jo).

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