Journal of Theoretical and Applied Information Technology
15th March 2017. Vol.95. No 5

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

TOWARDS ENERGY EFFICIENCY IN AN INTEGRATED HEALTH CARE INFRASTRUCTURE BASED ON THE CLOUD

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ABSTRACT

Abstract The need for storage and instant access to personal data (patient or professional) in Moroccan healthcare is exponential. Thus, the access needs of health professionals to different health information necessitate continuity of care, hence an architecture based on the concept of the cloud proves necessary. Considering the increasing demands placed on healthcare providers for infrastructure, systems and support, cloud computing will be the appropriate solution to meet the needs for care coordination, collaboration and communication between the different actors in the field Of health. Cloud Computing represents an evolution of information systems. Cloud computing brings a new approach to computing, a different way of using computer resources. This development has given existence to several providers offering multiple services. Then, Cloud end users are faced with the choice of the appropriate provider in terms of supported technologies, security and access rules. So, the sector aims to create a solution that works for all types of medical facilities, be it hospitals, health centers, clinics, private health care providers. In this paper, we propose a solution based on the use of a cloud broker in an inter-cloud environment in order to allow the technological renewal of our infrastructure while reducing the time of access to the services requested by the users, the dissipation of the energy And the number of physical servers installed. Evaluation results demonstrate that our architecture achieve good performance.

Keywords: *Cloud Computing; Cloud Broker; Data Center; VM Migration; Interoperability; CompatibleOne; CloudSim.*

1. INTRODUCTION

Many efforts have been deployed to standardize the definition of "Cloud Computing", in this context, we will use the definition provided by the National Institute of Standards and Technology (NIST) [1] : " cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." However, this rapid evolution of cloud technologies will enable different cloud providers to cooperate by exchanging applications, data and even VMs. So interoperability problems arise, in particular with the vendor lock-in problem [2]. The diversification of Cloud service providers will generate the diversification of their offerings in terms of provision of resources, security and access rules. Therefore, end-users face a huge challenge while choosing the appropriate Cloud provider. This choice should be based on the provider's features such as cost optimization, security rules and compatibility with the technologies required by end users, etc. Cloud brokers will play a major role to mediate between suppliers and consumers. In fact, they will give companies the possibility to choose the right providers, determine trusted users, deploy services across multiple Clouds, and to provide cloud arbitration services that allow users to shift and to choose between existing platforms [3].

Therefore, the development of cloud computing involves the development of data centers, using data storage virtualization techniques. As a result, we need a good solution that will help reduce the energy consumption generated by the different data centers. By being aware of the minimum number of host servers needed to run workloads and knowing what savings can be achieved by disabling unused servers, we will reduce costs and improve the quality of services.

The rest of the paper is organized as follows. Section II presents related works; we define dynamics management service, cloud broker, Dynamic consolidation of virtual machines and Cloud interoperability issues. Section III will deal with the implementation details of the suggested architecture. Section IV presents an experimental evaluation to test the proposed work. Finally, Section V presents the conclusion and our future work.

2. RELATED WORK

The number of Cloud-based services has grown rapidly and strongly in the last decade, and being so, it increased the complexity of the infrastructures behind these services. User satisfaction is a focal point and the main concern for cloud providers.

2.1 Dynamic management Service

Many studies had as a goal to put in place systems that can provide the user services at a lower cost and in a timely manner with optimal QoS.

In [4], authors suggested how to select appropriate service with the optimal QoS parameters from the service pool , and focus on the dynamic characteristics of problems that can be changed dynamically in terms of network properties and service. This work presents also a complete definition of Cloud Computing Service Composition and exposes associated concepts and a reachable analysis applied to algorithms, mechanisms, framework and techniques. It also gives 14 parameters of QoS.

Also, [5] focuses on the importance of resource management techniques such as resource allocation, resource provisioning, resource mapping and resource adaptation:

- Resource provisioning: is providing a better QoS by provisioning the resource to an application or the user via load balancing and high availability mechanism.
- Resource allocation: is the allocation of proper resources in order to perform computation with minimal infrastructure cost and time.
- Resource mapping: is a system-building process that enables a community to identify existing resources then match those resources to a specify goal.
- Resource adaptation: is when a company pays a provider for used resources (pay-as-you-go) and does not need to overprovision its IT resources

In the other hand, some of the recent research works [6] estimate that the Quality of Service (QoS) will provide a smart environment of self-management components based on domain knowledge in which cloud components can be optimized to ease the transition to an advanced governance environment.

2.2 Cloud Broker

The NIST [7] defines Cloud Broker as an entity that manages the use, performance and delivery of cloud services and negotiates relationships between cloud providers and cloud consumers.

The business model for cloud brokerage is still evolving.

The services provided by the cloud broker fulfill three primary roles: (Figure.1):

- Service Intermediation: when the cloud broker modifies a given service by improving certain specific functions and also allows the services requested by consumers to be provided with added values
- Service Aggregation: This category gives the cloud broker the ability to combine and integrate multiple services into one or more new services.
- Service Arbitrage: Arbitrage is almost similar to the service of aggregation except that services in this category are flexible and not fixed so arbitrage service providers can offer adaptable options for service aggregators.

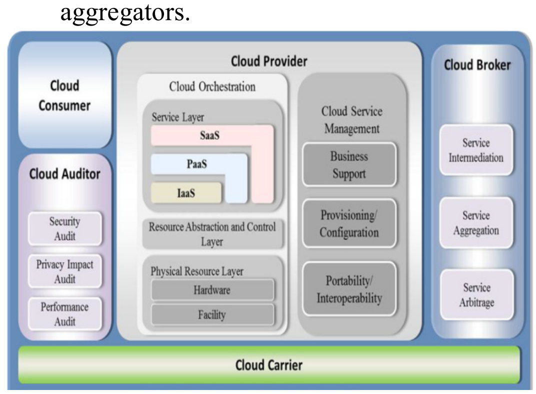

Figure 1. The Combined Conceptual Reference Diagram of Cloud Computing[6]

[8] Consider that the cloud broker, with its new functionality extensions, will bring intelligence into the Cloud, these last features of intelligence react to the change of business process in order to change the configuration of the cloud. In point of fact, it has implemented several rules to be followed by a cloud broker, in order to decide how to react facing change and determine the required actions. However, the large number of services offered by providers of cloud will generate a variety of resource providers, which influences the level of security and access rules adopted. To solve this ambiguity, the user is in perplexity to choose the right provider, ie, one that offers solid security rules, which optimizes the cost of use of resources and has compatibility with the technology required by the user.

[3] Propose Compatible One, a new Open Source Cloud Broker which offers solutions to help users choose their providers. It's composed of on interoperable middleware that describe and feder heterogeneous Clouds and resources provisioned by different Cloud providers.

Compatible One could be considered an advanced Cloud resource management and automatic provisioning software environment because it gives a model and execution platform:

- Model: called Compatible One Resource Description System, is an object based on description of Cloud applications, services and resources.
- Execution platform: called Advanced Capabilities for Compatible One Resource Description System, is a Cloud application provisioning and deploying control system.

In the same context, [9]suggests the trust evaluation of the cloud providers with the use of OPTIMIS Cloud Broker (CBR) as a mediation layer, it also presents a model cohesively working with the cloud broker in different modes using SLA and cloud characteristic parameters for evaluating the trust worthiness of the providers, and is well-placed against any attacks based on malicious entities.

2.3 Dynamic consolidation of virtual machines (VMs) issues:

The Provider aims to provide a better quality of service to the customer, which produces a high consumption of energy [10] as well as an increase in the emission of CO_2 in the cloud computing; The latter is essentially made up of virtualized data centers. In this sense, several researches work to reduce energy consumption and optimize the use of resources based on the dynamic consolidation of virtual machines (VMs) using live migration, Therefore, a placement of VM should be carried out in a continuous manner.

[10] Suggest an approach that will reduce carbon dioxide emissions through virtual machine migrations in cloud federation environment. Its allows providers to determine the best green destination to choose, where virtual machines should be migrated in order to reduce the carbon dioxide emissions of the whole federated network.

[11] Suggest a new dynamic programming algorithm which allows selecting the best VMs for migration from an overloaded PM (Physical Machine).

[12] Presented a new VM placement policy that prefers placing a VM to migrate on a host that has the minimum correlation coefficient. Its presents an improved of virtual machine selection policy to reduce the SLA violation rate that maintains a low power consumption.

[13] Suggest an algorithm based on Fuzzy VM selection method that allows selecting the VM to migrate from the source datacenter to achieve minimum energy consumption in order to fix the SLA violation at minimal level.

[14] Describe the SLA establishment and the best Cloud service provider selection using optimization algorithms Under QoS constraints and aiming to minimize the cost.

2.4 Interoperability

There are several research initiatives focusing on definition of interoperability [15], it has been a topic of concern for at least 30 years.

In the context of networked systems, interoperability is to the ability of exchanging service and information between enterprise [16]

Interoperability in a cloud environment is when localized resources on a Cloud provider communicate with resources from another provider as a user as shown in Figure 2.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

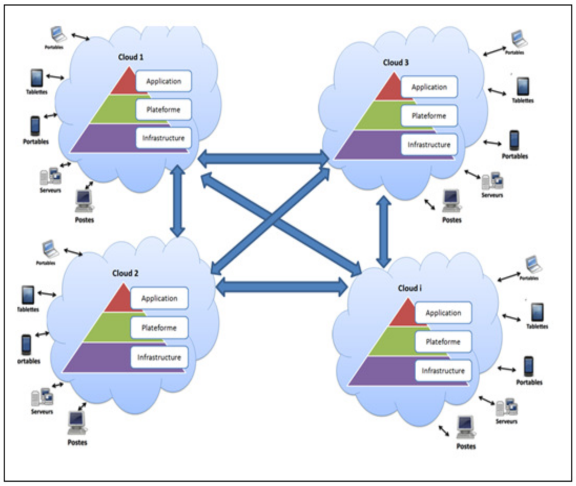

Figure 2: Interoperability in a Cloud Environment

According to [17], interoperability in a Cloud Computing systems is the ability of cloud providers to collaborate or interact with each other and create a federation of Clouds.

We must differentiate between interoperability, portability, compatibility and data migration:

- Interoperability is the possibility to communicate between two different cloud providers [18] .
- Portability can be defined as the ability to run components or systems intended for one environment in another environment. In a cloud computing environment, this includes the software and hardware (physical and virtual) .So, users can move their data and applications across multiple cloud environments with a low cost and minimal disruption [19][20].
- Compatibility is the ability is the ability that application and data can work in the same way regardless of the cloud provider[21].
- Data migration is the ability to perform the periodic transfer of data from one hardware or software to another or from one generation of computer technology to the next generation configuration. Migration is a necessary action to maintain data integrity and to allow users to search, retrieve and use data while continuing evolution of technology [20]

2.5 Cloud interoperability issues

Interoperability is very important between clouds, both cloud provider and costumers benefit from several advantages such as avoiding vendor lock-in, scalability, availability, low access latency and energy efficiency. And this, by establishing standard interfaces, protocols, formats and architectural components that allow an easy collaboration and inter-exchange between clouds[22].

According to [23], there are several approaches that allow to establish cloud interoperability as:

- Hybrid cloud: to establish an association between the public cloud and the private cloud to enable application to run in a private datacenter and to burst into a public cloud when there is a demand for computing capacity.
- Cloud federation: implies the creation of a group of aggregated provider that collaborates to share their resources in order to improve each other's service.
- Inter-cloud: all clouds are interconnected; it offers an easy migration and allows a dynamic scaling of application across multiple clouds.

The author also exposes the difference between inter-cloud and cloud federation, indeed, inter-cloud is based on the future standards and open interfaces whereas federation uses a provider version of the interface. In the same context, [19] defines the notion of horizontal federation; many cloud providers get together to create a federation cloud, it offers the advantage of choosing the cloud that offers the best QoS and cost [24].

[25]discusses the resource management functions of federated cloud architecture in which an individual cloud provider provides and consumes Infrastructure as a Service to and from other federation members also, consumers can be either federation members who rent resources from one another or regular cloud users.

[14] Suggest a new framework for resource allocation in conformance with an end-to-end service level agreement in a cloud networking environment particularly in an inter-cloud federation architecture and inter-cloud broker architecture.

[26] Propose an approach whose aim is to create a framework capable of assuring the unified coordination and distributed resource allocation which will allow customers to see one single resource. Also, in addition to providing a federated environment, it also adds to the organization features that are not allocated in clouds.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3. PROPOSED WORK

3.1 Context

Despite the benefits of cloud, there is the problem of interoperability between providers. Several studies have been done to create standards to solve the problem of security and privacy.
The following table [20], [24], [27]–[37] shows the interoperability models that exist in the cloud computing environment.

Table 1: Models Interoperability in Cloud

Cloud Computing Interoperability Models	IAAS	PAAS	SAAS
Aneka	No	Yes	No
Cloud Exchange Federated Cloud	Yes	No	No
Open Platform as a Service	No	Yes	No
Red Hat Reference Cloud Computing Architecture	No	Yes	No
Cisco Reference Cloud Computing Architecture	No	Yes	No
IBM Reference Cloud Computing Architecture	Yes	Yes	Yes
Cloud Development Stack Model	No	Yes	No
Next Generation Cloud Architecture	No	Yes	No
Elastra Cloud Computing Reference Architecture	No	Yes	No
Cloud Computing Reference Model	Yes	Yes	Yes
Cloud Computing Model	No	Yes	No
Adaptive Platform as a Service Architecture	No	Yes	No
Cloud Deployment Model	No	Yes	No
mOSAIC	Yes	No	No
CONTRAIL	Yes	Yes	No
Vision Cloud	Yes	No	No
REMICS	No	No	Yes
RESERVOIR	Yes	No	No
SITIO	No	No	Yes
NEXOF	No	No	No
Cloud@Home	Yes	No	No
SOA4All	No	No	No

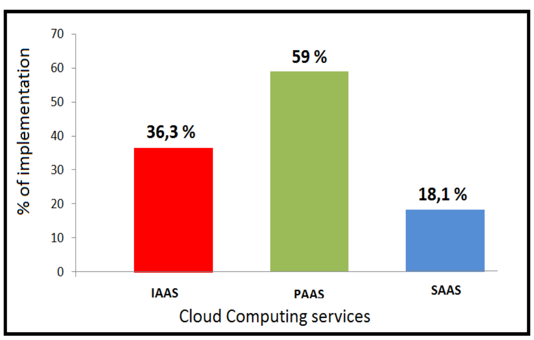

Figure 3: Distribution models of cloud interoperability

By analyzing the results in Table 1, we see that the majority of the work done focuses on PaaS cloud level with a percentage that exceeds half, by cons, we note that at the SAAS, interoperability remains a field fertile research since the models that apply to them is minimal.

From these results (figure 3), we deduce that the PAAS level of the cloud is allowing us to better parameterize the interoperability in the cloud.

3.2 Solution

The cloud environment is considered as an ultra large scale system. Ultra large scale system [38][15] presents a new generation of distributed software system, it offers the ability to manage complex systems whose architecture is heterogeneous. It is characterized by the fact that it's ensures decentralization (data, development and evolution.

However, in order to ensure the provision of these services, Cloud providers must deploy large data centers. In general, these data centers host a very large number of computers and storage servers connected by a local network. However, these data centers consume a lot of electricity and dissipate a lot of heat.

We have chosen to use CompatibleOne as a cloud broker because it is an open source software compatible with Amazon-AWS and with the Google AppEngine API and runtime, it can be deployed privately by reusing and improving components Meta-models and open source meta-languages, allowing clouds (whether private, public, or hybrid) to be interoperable. It provides open interfaces allowing both to disregard the technical and functional aspects of the cloud and to benefit as much as possible from the elasticity offered by the cloud.

The implementation of the proposed architecture is as follows (Figure 4).

The Cloud broker will act as a mediator between the users and the different cloud service providers (SP). Each SP registers itself and the status of its resources with the cloud information service (CIS), a database that will contain all the SP. The Cloud broker maps the user's requests to appropriate SP who present the Quality of service (QoS) requirements in terms of budget and response time, as required by use. It will be responsible for checking the datacenter load, communicating with federation cloud coordinators and loading migration to other clouds.

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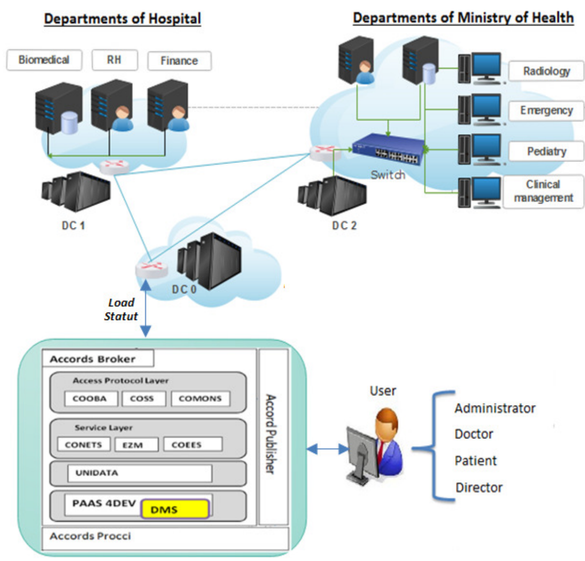

Figure 4: Proposed architecture of inter- Networking of Clouds

The COEES [39] module of Compatible One is based on a system for collecting energy consumption information and interfaces allowing access to information on the energy available in the physical elements used in the Cloud as well as on the evaluation of The energy bill and the environmental impact.
The main activities are therefore:
• Specify and implement means for collecting energy consumption information;
• Optimally distribute or distribute jobs or tasks in the real or virtual infrastructure and optimize topologies and resources based on energy consumption data collected on clouds;
• Design and provide interfaces to enable system optimization and task deployment;
• Develop post-deployment energy consumption reporting system for dynamic adaptations based on opportunities to reduce energy consumption.

3.3 Detail design

We use CloudSim as a simulator, it is an open source tool for modelling and simulation of cloud environments developed in the CLOUDS Laboratory, at the Computer Science and Software Engineering Department of the University of Melbourne [40]. CloudSim allows modeling and simulation of the cloud-based Datacenter environment, such as management interfaces dedicated to VMs, memory, storage, and bandwidth. The CloudSim layer will manage the instantiation and execution of the basic entities (VM, hosts, datacenters, applications) during the simulation period. In the upper layer of the simulation stack, there is the user code that exposes the configuration of the host functionality (eg number of machines, specifications of machines), scheduling policies of Broker, applications (ex : Number of tasks), VM, number of users.

We have developed a new java module named "DMS", it will be responsible for introducing the different services having the best Qos to the user.

For example: The user wants to use Service A, he finds that in his machine the service “ServA.exe” is not installed. He will then access to the dynamic service management (DMS) to install it.

After the choice of service, DMS will send a query to the database to check if the service exists. (In the database, we will store all services that the user has the autorization to install).

The return of the response of the BD. if the answer is positive, the DMS will memorize all the necessary service information.

The DMS will look for the target service with the optimal settings from providers.

The "ServA.exe" service will be downloading and then installed on the client’s machine by a script that will be executed automatically.

The alert module will send to the provider all of the information about the service installed and the target machine.

The DMS will be integrated at Paas 4Dev level of CompatibleOne as shown on (Figure 1).

We created java classes that will model the cloud broker within an inter-datacenter architecture. As a result of that, we created the data centers which will support the migration of the VM. And we chose two modes of migration, the first mode, without taking into consideration the network architecture, ie, first come first serve, and in second mode, we considered the migration in an environment iner cloud where the cloud Broker registers the state and the characteristics offered by each DC, and according to this data, migration of the VM takes place.

Java classes created:

The Federation Datacenter Broker class :It will play the role of broker in a network composed of the federated data center, these data centers will represent hybrid clouds interconnected. It will be responsible for Migration of VMs between DCs by checking execution

FederationDatacenter class: This class will ensure the creation of networks between different DCs.

CloudFederationTest class: this class will be based on the algorithm that will implement the migration taking into consideration the DC interconnection.

The figure 2 shows the class diagram used for our simulation

Modified java classes from Cloudsim

Cloudlet class: models these application services. In addition, CloudletScheduler is used to implement the policies that determine the processing power shared among many Cloudlets in a virtual machine.

VM class: This class models a virtual machine; it will contain all the characteristics of the VM.

Datacenter class: This class represents CloudResource whose hostlist is virtualized. It is responsible for processing VM requests (such as VM management) by setting the VmAllocationPolicy method.

Datacenter Broker class: it represents a broker acting on behalf of a user that is responsible for mediating negotiations between Cloud service provider and the customer. It hides VM management, as vm creation, submission of cloudlets to this VMs and destruction of VMs.

Datacenter Broker class: it represents a broker acting on behalf of a user that is responsible for mediating negotiations between Cloud service provider and the customer. It hides VM management, as vm creation, submission of cloudlets to this VMs and destruction of VMs.

Host class: This class is used to model actions related to management of virtual machines (e.g., creation and destruction). by this class,we can define policy for provisioning memory and bw, as well as an allocation policy for Pe's to virtual machines. A host class is associated to a datacenter class.

VMScheduler class: virtual machine scheduling strategy (allocationNuclear strategy, time, space), used to manage the implementation of tasks, realNow the task interface.

VMAllocationPolicy class: virtual machine monitor policyClass, describes the same Host on multiple virtual machines to share resourcesStrategy.

VMProvisioner class: to achieve the data center hostVirtual machine mapping.

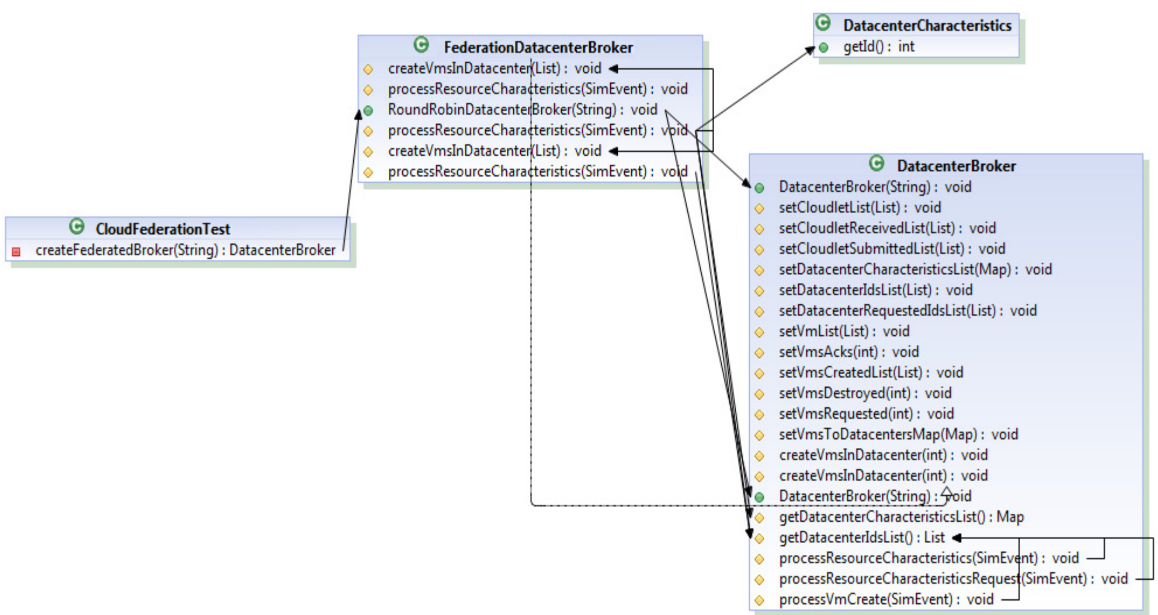

Figure 5: Class diagram

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3.4 Steps of simulation

To test our solution, we wrote an algorithm based on two algorithms; The first "VM Placement Optimization"[41] that allows to return the combined migration map that contains the information on the new VM placement of the VM selected to be migrated from both overloaded and underloaded hosts, and the second SelectTheBestVmsForMigration" which allows to find the subset of VMs in which their aggregate utilization of resource is the greatest and the aggregate migration cost of them is minimal.

In (Figure 6), we explain the simulation data flow:

Begin of simulation:

1:Each data center (DC) entities registers itself with the Cloud Information Service (CIS) registry

2:CIS provides a list of user request to suitable DC.

3:Data Center Broker (DCB) will consult the CIS for the list of clouds who offers infrastructure services that match with user's requirements

4:DCB will have all the necessary information for interconnection of DCs and their availability

5: DBC Will give the list of the requirement do not need to perform the simulation: resource architecture,Operating System, management policy, VM queries, AllocationPolicy will be instantiated

6: after recording the performance vector for each physical node, the policy of migration determinated the number of VM to migrate, which Host's is overloaded and which host has enough resources for vm.

7: once a task is scheduled, it is sent to the host's local queue or the virtual machine. For each task, it will be waiting for the task scheduling policy to allow adjustment, so that it can meet the new arrival task scheduling And minimize the energy consumption.

8-15: The simulation will be as follows (Figure. 7):

```
Foreach host in hostList do
  If allocatedHostPower not null   do
  If host has enough resources for vm then {
    Select Vm with minimal energy consumption to execute
    vmsToMigrate.add (host.getVmList ()
    migrationMap.add(getNewVmPlacement(vmsToMigrate))
    return migrationMap
    return estimatePower(host, vm)
                                        }
  If isHostOverloaded (host) then
        vmsToMigrate.add (getVmsToMigrateFromOverloadedHost (host))
        migrationMap.add (getNewVmPlacement (vmsToMigrate))
        vmsToMigrate.clear ()
Update the scheduling decision of task and remove it from Queue
```

Figure 6 : Algorithm of test

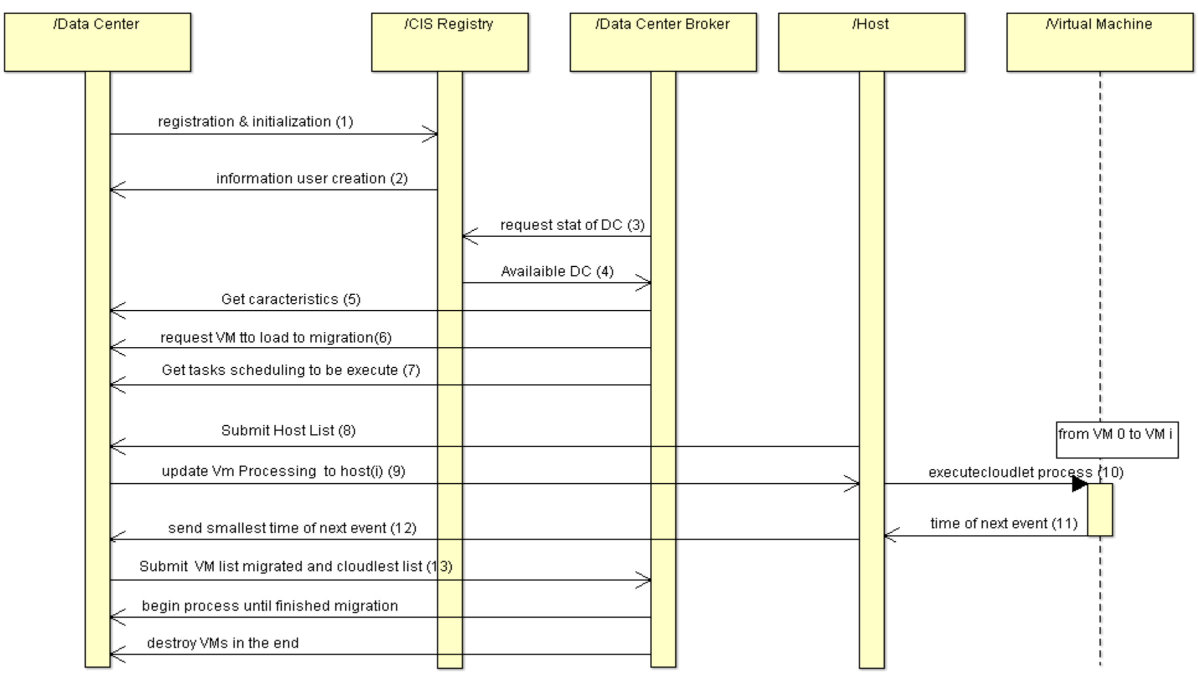

Figure 7: simulation data flow

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. PERFORMANCE ANALYSIS

The purpose of our simulation is to demonstrate that the federation of clouds is the best solution to adopt for the company; it will allow the reduction of the execution time as well as the gain in cost. In our architecture, we used a broker Open source which will be responsible to present to the user the different services desired. These services will be chosen among the different providers and we will only detain those who have the best Qos.

4.1 Implementation environment:

We chose Cloudsim 3.0 as a simulator. The experimental setup consist of three physical nodes (with 12 cores and 48GB memory), and each node can support several virtual machines. Every data center in the system is modeled to have 30 hosts, 1TB of storage,10 GB of memory, 1 processor with 1000 MIPS of capacity, and a time-shared VM scheduler. Data center Broker will instantiate a VM that required 512 MB of memory and time-shared cloudlet scheduler. The broker instantiates (10,25,50,100,150) of VMs. Each cloudlet is modeled to be having 1800000MIs. We begin simulation from datacenter0:

4.2 Results:

Our simulation takes place in two phases. The first one, we did a simulation without federation, the algorithm used selects the first available DC able to host the required VM and the second, we used our algorithm that supports the interconnection of clouds.

Table 2: Comparison Of Processing Time With And Without Federation

N° of cloudlets	Total processing Time	
	With Federation	Without Federation
10	1975,01	3930,26
25	2300,13	4587,25
50	5134,25	10219,15
100	9780,3	19482,7
150	14940,51	29721,61

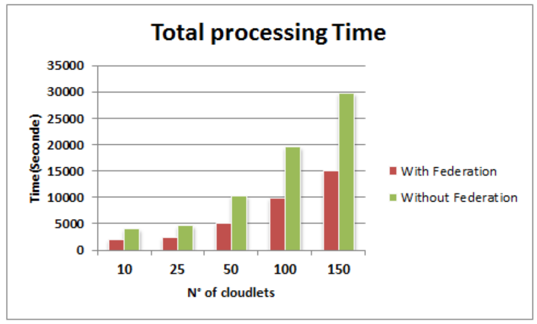

Figure 8: Comparison of processing time with and without federation

Table 3: Comparison Of Power Consumed With And Without Federation

N° of cloudlets	Power consumed	
	With Federation	Without Federation
10	26185,32	40300,5
25	65222,75	100035
50	132632,69	204050,3
100	266475,14	409900,23
150	399213,55	614220,85

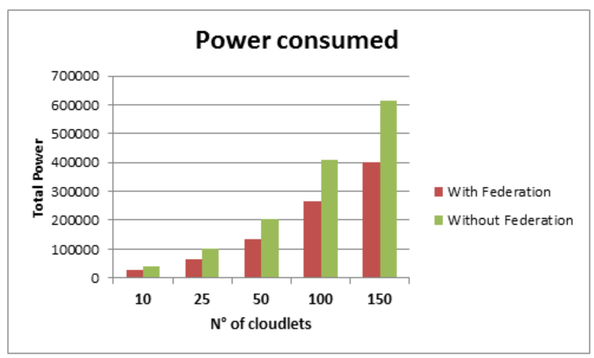

Figure 9: Comparison of power consumed with and without federation

Comparing the two tables(Table 2 & table 3), we can notice that the results obtained with the algorithm of federation are optimized compared to those obtained without federation. Indeed, the federation of the architecture allowed an average gain of time of execution of 50% and also allowed to reduce the consumption of energy of 35%.

The interconnection of the different datacenters in this architecture offers a set of network elements that will network all the existing virtual machines in the data center as in a single physical environment. Therefore, the movement of VM in operation from one datacenter to another will be done in a totally transparent way. The operating

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

system and the application running in the VM are not disrupted, only the state of the VM with its configuration is moved to the target host, respecting the compatibility of the hardware (CPU, Network card, Storage , RAM). Once the VM is migrated, it is managed by the new host. The hosts that are in a low-use period will be put on standby automatically, which will optimize energy consumption and subsequently reduce the cost of power.

Among the advantages of this connected architecture, the data center broker will be able to detect the crash of one of the DCs and quickly restart the VMs impacted on another DC, which guarantees the resources necessary for the VMs, Host and VM resources and reduce the downtime of VMs.

5. CONCLUSION

In this paper we have proposed an architecture that aims to reduce energy consumption while optimizing the execution time of different services. This architecture is based on the use and parameterization of an open source cloud broker, integrating energy constraints. These constraints must allow the placement and the movement of the virtual machines by integrating the energy point of view. We have developed a DMS module that will be implemented at this cloud broker, it will have the role to choose the services that have an optimal QOS with the different suppliers. This architecture will be used by the regional observatory of health of Morocco. To guarantee the confidentiality, integrity and management of access to health data, it is envisaged to implement an authentication system that will enhance the security of the various users. This will be the focus of our future work

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