Hybrid Cloud System and Software Agent: Towards Hybrid Cloud Intelligent Agent System

AMIR MOHAMED TALIB[1] and FAHAD OMAR ALOMARY[2]
Information Technology Department
College of Computer and Information Sciences
Al-Imam Muhammad Ibn Saud Islamic University
RIYADH, KINGDOM OF SAUDI ARABIA (KSA)
ganawa53@yahoo.com[1] and fahd.alomary@gmail.com[2]

Abstract: - Clouds are used through a service-oriented interface that implements the "as-a-service" paradigm to offer cloud services on de mand. The adaptation of cloud users and clouds services and application needs required large-scale infrastructures for high-performance computing, since this could be provided only by cloud computing. This paper discusses the cloud computing models, services and architectures. Specifically, discusses the differences and potential synergies between hybrid cloud computing models and Multi Agent Systems (MASs). The main contribution of this paper is to highlight the challenges of using intelligent software agent in high performance complex hybrid cloud computing models. The convergence of interests between MASs that need reliable distributed infrastructures and cloud computing systems that need intelligent software with flexible, dynamic and autonomous behavior can result in new systems and applications.

Key-Words: - Cloud Computing, Hybrid Cloud Computing, Software Agent and Multi Agent Systems

1 Introduction

Cloud computing provide elastic services, high performance and scalable cloud data storage to a large and everyday increasing number of cloud users [1]. Cloud computing enlarged the arena of distributed computing systems by providing advanced Internet services that complement and complete functionalities of distributed computing provided by the Web, Grid computing and peer-to-peer networks. In fact, Cloud computing systems provide large-scale infrastructures for high-performance computing that are dynamically adapt to cloud user and cloud application needs [2].

A hybrid cloud that is typical combination and integration cloud service utilizing both private and public clouds to perform distinct functions within the same organization. In fact, Cloud Computing has become a p opular topic in the research community because of its ability to transform computer software, platforms, and infrastructure as a service. Multi Agent System (MAS) represent another distributed computing paradigm based on multiple interacting agents that are capable of intelligent behavior and asked cooperation, interaction and negotiation. MASs are often used to solve problems by using a d ecentralized approach where several agents contribute to the solution by cooperating one each other. One key feature of software agents is the intelligence that can be embodied into them according to some collective artificial intelligence approach that needs cooperation among several agents that can run on a parallel or distributed computer to achieve the needed high performance for solving large complex problems keeping execution time low [3].

Although several differences exist between cloud computing and MASs, they are two distributed computing models, therefore several common problems can be identified and several benefits can be obtained by the integrated use of cloud computing systems and multi-agents. The research activities in the area of hybrid cloud computing are mainly focused on the efficient use of the hybrid computing infrastructure, hybrid service delivery and hybrid cloud data storage. On the contrary, research activities in the area of software agents are more focused on the intelligent aspects of agents and on their use for developing complex applications.

Despite these differences between cloud computing and software agents, cloud computing and MASs share several common issues and research topics in both areas have several overlaps that need to be investigated. In particular, cloud computing can offer a very powerful, reliable, predictable and scalable computing infrastructure for the execution

of MASs implementing complex agent-based applications such when modeling and simulation of complex systems must be provided. On the other side, software agents can be used as b asic components for implementing intelligence in cloud computing systems making them more adaptive, flexible, and autonomic in resource management, service provisioning and in running large-scale applications.
The main objectives of this paper are:

- ✓ To discusses the cloud computing models, services and architectures. Specifically, discusses the differences and potential synergies between hybrid cloud computing models and MASs.
- ✓ To highlight the challenges of using intelligent software agent in high performance complex hybrid cloud computing models.
- ✓ To convergence of interests between MASs that need reliable distributed infrastructures and cloud computing systems that need intelligent software with flexible, dynamic and autonomous behavior can result in new systems and applications.
- ✓ To compare our proposed system to other existing systems such as Licas system and Pingmesh system in term of servers utilized, services offered, design and implementation considerations and types of rules gained.
- ✓

2 State of the Art

About seven years ago, when the first cloud infrastructure has been deployed by Amazon, the online bookseller company that took the decision to start a new business selling computing resources to companies and private users, the only deployment model was the Public cloud one. It is a pay-per-use IaaS cloud infrastructure that is owned by an organization selling cloud services to the general public or to enterprises. Thus, it is public because it can be rent by anyone for developing and/or running any kind of applications. To use Amazon services, users must provide a credit card account and can spend from few cents to thousands or millions of dollars depending on the number of used resources and the usage time.
The literature also differentiates cloud computing offerings by scope. In private clouds; services are provided exclusively to trusted users via a si ngle-tenant operating environment. Essentially, an organization's data centre delivers cloud computing services to clients who may or may not be in the premises [2]. Public clouds are the opposite: services are offered to individuals and organizations who want to retain elasticity and accountability without absorbing the full costs of in-house infrastructures [2]. Public cloud users are by default treated as untrustworthy. There are also hybrid clouds combining both private and public cloud service offerings [4].
In the scientific literature, two different kinds of software agent approaches used in cloud computing security can be found: intelligent agent approaches and MAS approaches.
The review results of software agent used to ensure the security of hybrid cloud using the empirical and comparative analysis are shown in section 10.

3 Cloud Computing

Since the Cloud computing paradigm has been conceived several definitions have been given. Some of them focus on de mand dynamic provisioning of processing and storage resources, others emphasize the service-oriented interface and the exploitation of virtualization techniques. The National Institute of Standards and Technology (NIST) have given a co mplete reference definition [4]. NIST defined Clouds as follows: "*Cloud computing is a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*"
Cloud computing describes applications that are extended to be accessible through the Internet. Anyone with a suitable Internet connection and a standard browser can access a c loud application. Cloud computing consists of multiple cloud computing service providers. In terms of software and hardware, a cloud system is composed of many types of computers, storage devices, communications equipment, and software systems running on such devices. Cloud computing is a term used to describe both a platform and type of application. A cloud computing platform dynamically provisions, configures, reconfigures, and de provisions servers as needed. Servers in the cloud can be physical machines or virtual machines [5, 6].
The key characteristics of Clouds are: On-demand self service, ubiquitous network access, location independent resource pooling, rapid elasticity, and pay per use.
Currently there are five types of cloud computing deployment models namely public cloud, private cloud, hybrid cloud, community cloud and

combination cloud. C loud computing deployment models summarized as follows [5]:

- **Public Cloud:** Public cloud describes cloud computing in the traditional main stream sense, where resources are based on self-service basis over the Internet, via web applications or web services. In public cloud, numerous cloud users can share the computing resources provided by a single service provider. Cloud users can quickly access these resources and only pay for the operating resources.
- **Private Cloud:** Private cloud is a term to describe computing architecture that provides hosted services to a limited number of people behind a firewall. In the private cloud, computing resources are used and controlled by a private enterprise. It's generally deployed in the enterprise's data center and managed by internal personnel or service provider. The main advantage of this model is that the security, compliance, and quality of service are under the control of the enterprises.
- **Hybrid Cloud:** A third type can be hybrid cloud that is typical combination of public and private cloud. It enables the enterprise to running state-steady workload in the private cloud, and asking the public cloud for intensive computing resources when peak workload occurs, then return if no longer needed. In most countries, we are going to see lot of investment in the Hybrid Clouds in the next decade, for the simple reason, that lot of companies are skeptical about the Cloud's Security and they prefer that the critical data be managed by themselves and the non-critical data by the external provider.
- **Community Cloud:** The cloud infrastructure of community cloud is shared by several organizations and supports a specific community that has communal concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party, and may exist on premise or off premise.
- **Combination Cloud:** Two clouds that have been joined together are more correctly called a " combined cloud". A combined cloud environment consisting of multiple internal and/or external providers "will be typical for most enterprises". By integrating multiple cloud services users may be able to ease the transition to public cloud services while avoiding issues.

The architecture of cloud computing are broadly divided into six delivery models which are Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS), Communication-as-a- Service (CaaS), Data Storage-as-a-Service (DaaS) and Hardware-as-a-Service (HaaS). Cloud Computing delivery models are summarized as follows:

- **Infrastructure-as-a-Service (IaaS):** IaaS products deliver a full computer infrastructure via the Internet. Infrastructure as a S ervice is a p articular cloud layer where the Cloud computing vendor's resources are only shared with contracted clients at a pay-per-use fee. This can minimizes cost in computing hardware such as servers, networking devices, and processing power.
- **Platform-as-a-Service (PaaS):** The concept of PaaS cloud layer is like IaaS but it provides an additional level of "rented" functionality. Clients using PaaS services transfer even more costs from capital investment to operational expenses, but must acknowledge the additional constraints and possibly some degree of lock-in posed by the additional functionality layers.
- **Software-as-a-Service (SaaS):** SaaS also operates on the virtualized and pay-per-use costing model whereby software applications are leased out to contracted organizations by specialized SaaS vendors. It is accessed remotely using a web browser via the Internet. The software has limited functionality and its core pack can be expanded and contracted allowing of easy customization which user needs to pay. SaaS providers may host the software in their own data centers or they also may use IaaS providers. The availability of IaaS services is a key enabler of the SaaS model. Software as a service applications are accessed using web browsers over the Internet therefore web browser security is vitally important. Different methods of securing SaaS applications need to be considered by information security officers.
- **Communication-as-a-Service (CaaS):** As the need for a guaranteed quality of service (QoS) for network communication grows for cloud systems, communication becomes a vital component of the cloud infrastructure. Consequently, cloud systems

are obliged to provide some communication capability that is service oriented, configurable, schedulable, predictable, and reliable. Towards this goal, the concept of CaaS emerged to support such requirements, as w ell as network security, dynamic provisioning of virtual overlays for traffic isolation or dedicated bandwidth, guaranteed message delay, communication encryption, and network monitoring.

- **Data Storage-as-a-Service (DaaS):** The main infrastructure resource is data storage, which allows users to store their data at remote disks and access them anytime from any place. This service is commonly known as *D*ata-Storage as a S ervice (DaaS), and it facilitates cloud applications to scale beyond their limited servers. Data storage systems are expected to meet several rigorous requirements for maintaining users' data and information, including high availability, reliability, performance, replication, and data consistency; but because of the conflicting nature of these requirements, no one system implements all of them together.
- **Hardware-as-a-Service (HaaS):** The bottom layer of the cloud stack in our proposed ontology is the actual physical hardware and switches that form the backbone of the cloud. In this regard, users of this layer of the cloud are normally big enterprises with huge IT requirements in need of subleasing HaaS.

4 Hybrid Clouds

In its simplistic definition, a hybrid cloud is a combination of both public and private clouds as shown in Figure 1. In practice, an enterprise could implement hybrid cloud hosting to host their e-commerce website within a private cloud, where it is secure and scalable, but their brochure site in a public cloud, where it is more cost effective (and security is less of a co ncern). If we apply the definition from the National Institute of Standards and Technology (NIST), "a hybrid cloud is a combination of public and private clouds bound together by either standardized or proprietary technology that enables data and application portability." It could be a combination of a private cloud inside an organization with one or more public cloud providers or a private cloud hosted on third-party premises with one or more public cloud providers.

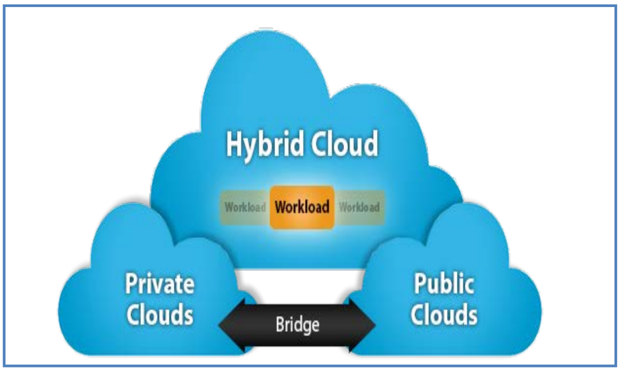

Fig.1. Hybrid Cloud Architecture

A hybrid cloud is an integrated cloud service utilizing both private and public clouds to perform distinct functions within the same organization. All cloud computing services should offer certain efficiencies to differing degrees but public cloud services are likely to be more cost efficient and scalable than private clouds. Therefore, an organization can maximize their efficiencies by employing public cloud services for all non-sensitive operations, only relying on a private cloud where they require it and ensuring that all of their platforms are seamlessly integrated.

Hybrid cloud models can be implemented in a number of ways:

- Separate cloud providers team up to provide both private and public services as an integrated service
- Individual cloud providers offer a complete hybrid package
- Organizations who manage their private clouds themselves sign up to a public cloud service which they then integrate into their infrastructure

Clouds technology has matured, opening up ne w possibilities for more elastic private, public and hybrid models. Organizations now see the hybrid clouds as an enhanced way to get value from cloud computing by leveraging the sometimes complementary benefit offered by private and public clouds agility, cost efficiencies and high availability of services.

There are many different scenarios for employing hybrid clouds but we will list out some of the most prominent ones:

- o Using the private cloud for mission-critical applications and pushing the non-critical ones to public clouds. For example, a company might use a public cloud for test and development while using a private cloud inside the organization for production deployment. Another example would be using public clouds for external facing applications while using a private cloud for internal applications.

- Cloud bursting, a dynamic deployment of an application running on a private cloud into public clouds to meet an unexpected demand, such as a retail company's need to meet increasing traffic associated with holiday shopping.
- Another example is non-destructive Disaster Recovery (DR) testing. Organizations can test if their production environment is DR ready by tapping the public clouds and without any disruption.

A hybrid cloud configuration, can offer its cloud users the following features:

- ***Scalability:*** whilst private clouds do offer a certain level of scalability depending on their configurations (whether they are hosted internally or externally for example), public cloud services will offer scalability with fewer boundaries because resource is pulled from the larger cloud infrastructure. By moving as many non-sensitive functions as possible to the public cloud it allows an organization to benefit from public cloud scalability whilst reducing the demands on a private cloud.
- ***Cost efficiencies:*** again public clouds are likely to offer more significant economies of scale (such as centralized management), and so greater cost efficiencies, than private clouds. Hybrid clouds therefore allow organizations to access these savings for as many business functions as possible whilst still keeping sensitive operations secure.
- ***Security:*** the private cloud element of the hybrid cloud model not only provides the security where it is needed for sensitive operations but can also satisfy regulatory requirements for data handling and storage where it is applicable
- ***Flexibility:*** the availability of both secure resource and scalable cost effective public resource can provide organizations with more opportunities to explore different operational avenues

Several companies set up large hybrid cloud facilities and built programming environments where developers can program applications as hybrid cloud software services. Just to mention some example: Expedient, Microsoft Hybrid Cloud, Fujitsu Hybrid Cloud Services (FHCS), HP Hybrid Cloud Management, IBM's Hybrid Cloud Options, Amazon Web Services (AWS) Hybrid Cloud, Rackspace Hybrid Cloud, EMC Hybrid Cloud and VMware vCloud Hybrid Service. On the other side, the research community developed open source software that can be deployed and configured on hybrid cloud. Examples of these systems are Eucalyptus, Apache CloudStack, Red Hat: The Open Hybrid Cloud, PlatFora: BI IS BS, Best Sysadmin Certs Hybrid Cloud, Wireless For All Hybrid Cloud and Tweet Of The Week Hybrid Cloud.

5 Software Agent

Multi Agent Systems (MASs) are techniques in the artificial intelligence area focusing on the system where several agents communicate with each other. MAS is defined as "a loosely coupled network of problem-solver entities that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity" [7].

Agents typically include a set of features. The main features of agents include the following [8]:

- ***Autonomy*****:** agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state.
- ***Social ability*****:** agents interact with other agents (and possibly humans) via some kind of ACL.
- ***Reactivity*****:** agents perceive their environment and respond in a timely fashion to changes occurring therein.
- ***Pro-activeness*****:** in addition to acting in response to their environment, agents are able to exhibit goal-directed behavior by taking the initiative. The strong notion of agency is an extension of the weaker notion, and advocates additional humanistic, mental properties such as belief, desire, and intention.
- ***Communication and Cooperation:*** the capacity to interact and communicate with other agents (in multiple agent systems), to exchange information, receive instructions and give responses and cooperate to fulfill their own goals.
- ***Negotiation*****:** the capability to carry out organized conversations to achieve a degree of cooperation with other agents.
- ***Learning*****:** the ability to improve performance and decision making over time when interacting with the external environment.

MAS consist of a number of agents interacting with each other, usually through exchanging messages across a network. The agents in such a system must be able to interact in order to achieve their design objectives, through cooperating, negotiating and coordinating with other agents. The agents may exhibit selfish or benevolent behavior. Selfish agents ask for help from other agents if they are overloaded and never offer help. Benevolent agents always provide help to other agents because they consider system benefit is the priority. For example, agents serving normal cloud users for CSP service are always ready to help other agents to complete their tasks [9, 10]. The study of MAS focuses on systems in which many intelligent agents interact with each other. The agents are considered to be autonomous entities, such as software programs or robots. Their interactions can be either cooperative or selfish. That is, the agents can share a common goal, or they can pursue their own interests [11].

In the past years several agent programming environments supporting specific agent architectures and providing libraries of interaction protocols like Jason, 3APL, JACK, Claim, SyMPA, JADE, Cougaar, Jadex, and ZEUS have been developed. Moreover, software engineering methodologies like Gaia, MaSE [12], Tropos [13], Prometheus [14] and AUML have been designed to analyze and design agent-based systems. Efforts have been done to standardize some features or facilities of agent systems, such as has been done with FIPA and KQML for inter-agent communication. These environments, toolkits and methodologies are enabling technologies for implementing MAS applications on traditional computing systems. However they can be more interesting if they will be available of distributed computing infrastructures like Grid, Cloud or P2P networks for supporting the development of large-scale MAS applications achieving high performance and scalability. However, despite the potential common space where agent technology and Cloud computing infrastructures can be effectively used to produce innovative models, techniques, systems and applications, till today only a few research activities that make use of both these technologies are performed. In the literature a very limited number of papers can be found on agents and cloud integration [15-18].

6 Software Agent Using Hybrid Cloud

The section discusses the principle that agent flexibility, intelligence, pro-activity, and autonomy can be used in hybrid clouds to produce new advanced hybrid clouds solutions and services that offer new functionalities and intelligent services that today are not yet available in current hybrid clouds computing infrastructures.

Hybrid clouds is a novel technology that has been designed and implemented in the last year, mainly due to industry that was looking to a large-scale scalable computing infrastructure for implementing and selling service-oriented commercial solutions. Whereas much of the current effort on hybrid clouds was devoted to the production of hybrid clouds and technologies for supporting virtualization and data centers, little attention has been devoted to introduce innovative methods for cloud users and developers to discover, request, assemble and use hybrid clouds resources. Autonomous and flexible agents and MASs are suitable tools for negotiating cloud user access, automating the resource and service discovery, and composition, trading, and harnessing of hybrid clouds resources. A new discipline, called agent-based hybrid clouds must be set for providing agent-based solutions founded on the design and development of software agents for improving hybrid clouds resources and service management and discovery, SLA negotiation, and service composition. Autonomous agents can make hybrid clouds smarter in the interaction with cloud users and more efficient in allocating processing and storage to applications. In large-scale data centers, agents can search, filter, query and update the massive volumes of data that are stored. We can envision a scenario where hybrid clouds agents working on our and operating systems behalf, to provide intelligent data access services, monitoring services, processor-to-application assignment strategies, and energy-efficient use of hybrid clouds. Research activities must be carried out to implement effective agent-based solutions for hybrid clouds. This work should be done towards the three different “as-a-Service” delivery classes. In IaaS infrastructures, agents can be used to help the intelligent provisioning of basic resources to cloud user applications, whereas in PaaS infrastructures, agent can play a role in the efficient deployment and execution of programming environments that developers use for application implementation. Finally, in SaaS hybrid cloud infrastructures, agents can be programmed to optimize the use of applications provided as services and the management of the underlying hardware/software infrastructure taking care of its efficient utilization and, at the same time, for maintaining the declared QoS. In Hybrid clouds, there also is the need to design and implement techniques and methodologies that adapt to the dynamic behaviors of hybrid cloud computing environments. Autonomic techniques may help providers and cloud users to reach this goal. MASs that are able to handle with changing configurations, heterogeneity, and volatility, can provide a promising approach for addressing this requirement. Last but not least, security and trust are two very critical issues in hybrid clouds as data and software are stored, accessed and run on machines that are not owned or directly managed by owners of data and software. Agent-based models and algorithms for trust and security in hybrid clouds could be very useful. In summary, if agent-based solutions will be introduced in the software infrastructure of hybrid clouds we will have:

- Intelligent and flexible Hybrid cloud services,
- Autonomous and pro-active services,
- Autonomic Hybrid clouds.

7 Hybrid Cloud Using Software Agent

The section discusses is centered on the idea that hybrid clouds can offer an ideal platform where run MASs, simulations and applications because of its large amount of processing and storage resources that can be dynamically configured to run large-scale MAS-based software at unprecedented scale.

Complex agent-based applications or large-scale simulations based on M ASs often require high-performance computing systems and large data storage devices. Therefore, hybrid clouds can offer an ideal platform where to run MAS-based systems simulations and applications because of its large amount of processing and memory resources that can be dynamically configured for executing large agent-based software at unprecedented scale. Agent-based applications can rely on hy brid clouds to access and use vast amounts of processors and data. So this approach would allow offloading the compute intensive agents to the appropriate subsets of processes and storage elements in a h ybrid clouds. The entire MAS application can run on a hybrid clouds or only the most compute intensive part of it can be hosted in the hybrid clouds, whereas the light part can run on a local server or simply on t he client PC. In this way agents can become more efficient and, at the same time, lighter and smarter. This can be obtained because, by using powerful hybrid cloud facilities, software agents can improve their intelligence and accurateness by running more sophisticated algorithms. In fact, the amount of storage and processing power of a hybrid cloud enabled MAS is larger than in other computing environments, making it more powerful. Hybrid cloud-enabled agents can couple agents and large-scale dynamic distributed computing platforms bringing big new opportunities to the agent computing area and expanding agent's knowledge beyond the possibilities offered by traditional computing platforms. Virtualization mechanisms offered by hybrid cloud can be exploited for efficient composition of parallel machines where to execute large scale concurrent agents with real-time constraints or needing high performance for achieving results in reasonable time. Agents implemented in hybrid clouds can adapt to available virtual machines by using the basic properties of agents such as autonomy, pro-activity, negotiation and learning. Since hybrid clouds are elastic, they can expand and shrink based on demand of cloud users or applications. This property is very useful for the scalable execution of MAS applications and simulation that are able to adapt to the available resources. In summary, agent can find in Hybrid cloud computing infrastructures the appropriate platform where to run and access large data. This opportunity must be exploited for implementing efficient MASs and, from a more general point of view, for advancing the way to design and implement a n ew generation of large-scale software agents.

8 Hybrid Cloud Implementation

Currently, there is no widely accepted standard for an agents and hybrid clouds integration. Hence, it is not possible to seamlessly integrate different cloud providers (private and public clouds) into one single infrastructure (hybrid clouds). In this section we will briefly review what the desired features of a hybrid cloud implementation are.

8.1 Design and Implementation Considerations

The particular nature of hybrid clouds demands additional and specific functionalities that software engineers have to consider while designing software systems supporting the execution of applications in hybrid and dynamic environments. These features, together with some guidelines on how to implement them, are presented in the following:

- ***Support for Heterogeneity:*** Hybrid clouds are produced by heterogeneous resources such as clusters, public or private virtual infrastructures, and workstations. In particular, for what concerns a v irtual machine manager, it must be possible to integrate additional cloud service providers (mostly IaaS providers) without major changes to the entire system design and codebase. Hence, the specific code related to a particular cloud resource provider should be kept isolated behind interfaces and within pluggable components.

- ***Support for Dynamic and Open Systems***: Hybrid clouds change their composition and topology over time. They form as a result of dynamic conditions such as peak demands or specific Service Level Agreements attached to the applications currently in execution. An open and extensible architecture that allows easily plugging new components and rapidly integrating new features is of a great value in this case. Specific enterprise architectural patterns can be considered while designing such software systems. In particular, inversion of control and, more precisely, dependency injection5 in component-based systems is really helpful.
- ***Support for Basic VM Operation Management:*** Hybrid clouds integrate virtual infrastructures with existing physical systems. Virtual infrastructures are produced by virtual instances. Hence, software frameworks that support hypervisor-based execution should implement a minimum set of operations. They include requesting a virtual instance, controlling its status, terminating its execution, and keeping track of all the instances that have been requested.
- ***Support for Flexible Scheduling Policies:*** The heterogeneity of resources that constitute a hybrid infrastructure naturally demands for flexible scheduling policies. Public and private resources can be differently utilized, and the workload should be dynamically partitioned into different streams according to their security and QoS requirements. There is then the need of being able to transparently change scheduling policies over time with a minimum impact on the existing infrastructure and almost now downtimes. Configurable scheduling policies are then an important feature.
- ***Support for Workload Monitoring:*** Workload monitoring becomes even more important in the case of hybrid clouds where a subset of resources is leased and resources can be dismissed if they are no longer necessary. Workload monitoring is an important feature for any distributed middleware, in the case of hybrid clouds, it is necessary to integrate this feature with scheduling policies that either directly or indirectly governs the management of virtual instances and their leases.

9 Hybrid Cloud Intelligent Agent System: Empirical and Comparative Analysis Results

Empirical studies are now being undertaken more frequently, as a means of examining a broad range of phenomenon in computer field. A systematic literature review presented in [5-11] is followed in this research work to conduct the review. A systematic literature review endeavour to provide a comprehensive review of current literature relevant to a specified research questions.

The review process is analysed based on three following questions:

Question 1: What is the mechanism used for data collection?

Question 2: What approaches have been introduced to ensure data security in hybrid cloud computing?

Question 3: How the approaches have been validated?

The final review result of ensuring the data security of hybrid cloud using MASs and intelligent agents approaches is shown in table 1. The sources used for this review include IEEE Xplorer, science direct, Scopus, Google scholar, ACM digital library, and ISI journals. The research focuses on the year's 2010 to 2016. The keywords used for search are Cloud computing, cloud security, hybrid cloud security, hybrid data security. A year wise result representation, frequency of papers with respect to sources and keywords of searching is shown in Figure 2.

Table 1. Mechanism wise result

Question 1	**Year**	**No of papers**	**Sources**	**Keywords**
What is the mechanism used for data collection?	2010	1	IEEE xplorer, science direct, Scopus, Google scholar, ACM, and ISI journals.	Cloud computing, cloud security, hybrid cloud security, hybrid data security
	2011	3		
	2012	4		
	2013	6		
	2014	2		
	2015	2		
	2016	4		
Total		22		

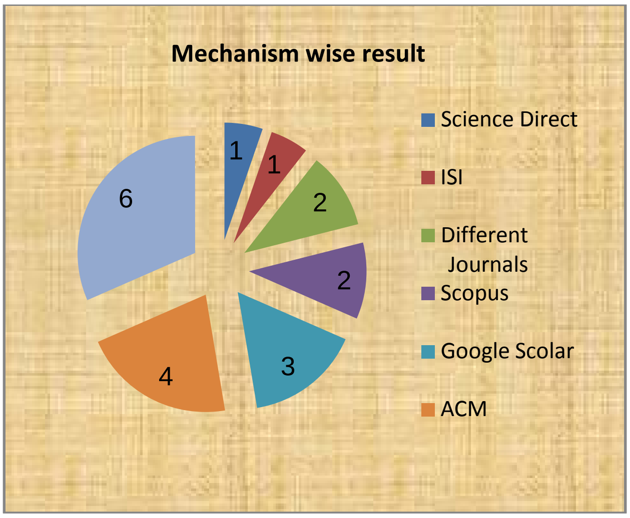

Figure 2. Type of mechanism

The result of review (Figure 3) show the proposed software agent approaches for the data security in cloud computing. These results are categorized into: (1) MASs approaches and (2) intelligent agents approaches. The result of these approaches have been introduced to ensure data security in hybrid cloud computing is shown in Table 2.

Table 2. Approaches wise result

Question 2	Approaches	No of papers
What approaches have been introduced to ensure data security in hybrid cloud computing?	MAS	16
	Intelligent Agent	6
Total		22

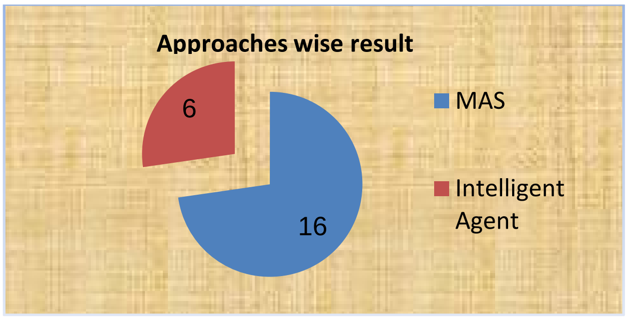

Figure 3. Type of software agent approaches

Figure 4 illustrated the result of review regarding the procedures adopted for validation as mentioned in Table 3. The categories of types of validation are: (1) Experiment, where an experiment is carried out to validate the results; (2) Meta analysis is used to validate the results; (3) Comparative analysis, where the results of proposed scheme is compared to other schemes to validate the results; (4) Test bed is used to validate the proposed approach; (5) Performance analysis, where the performance of proposed approach is analyzed by different methods; (6) Statistical analysis, where the results are analyzed by using some statistical technique; (7) Some of the proposed approaches have not performed any validation.

Table 3. Validation wise result

Question 3	Validation	No of papers
How the approaches have been validated?	Experiment	3
	Meta Analysis	1
	Comparative Analysis	8
	Test Bed	2
	No Validation	3
	Performance Analysis	3
	Statistical Analysis	2
Total		22

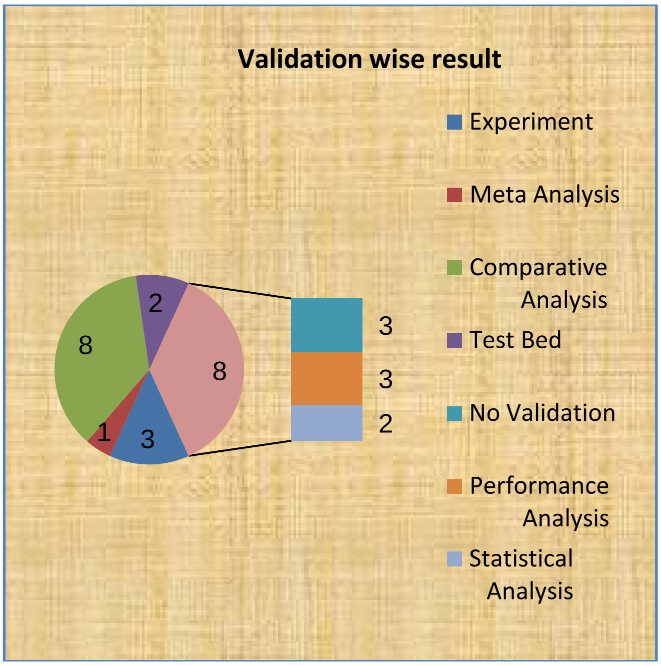

Figure 4. Type of validation

10 Comparative analysis

Comparative analysis as the form of validation is employed in 18% of the selected studies in which results of proposed scheme is compared to other schemes to validate the results.

In [19] the lightweight internet-based communication for autonomic services (licas) system is an open source framework for building Peer to Peer (P2P) service-based networks, similar to what you would do on a platform for Software Oriented Architecture (SOA) / Micro-services / Cloud. The framework comes with a server for running the services on, mechanisms for adding services to the server, mechanisms for linking services with each other, and mechanisms for allowing the services to communicate with each other. The lightweight architecture and adaptive capabilities through AI and text processing add something new that is not available in other systems. The free All-in-One GUI provides a basic operating environment, with some default services. Compared to our system, Pingmesh presented the design and implementation of for data center network latency measurement and analysis. Pingmesh is always-on and it provides network latency data by all the servers and for all the servers. Pingmesh has been running in Microsoft data centers for more than four years. It helps us answer if a service issue is caused by the network or not, define and track network SLA at both macro and micro levels, and it has become to be an indispensable service for network troubleshooting. Due to its loosely coupled design, Pingmesh turned out to be easily extensible. Many new features have been added while the architecture of Pingmesh is still the same. By studying the Pingmesh latency data and learning from the latency patterns via visualization and data mining, we are able to continuously improve the quality of our network, e.g., by automatically fixing packet black-holes and detecting switch silent random packet drops.

Cloud meet agent [20] proposes two main approaches for integrating agents and cloud systems. The first is based on the principle that agent flexibility, intelligence, pro-activity, and autonomy can help cloud computing platforms offer solutions, functionalities, and intelligent services that aren't available in current cloud infrastructures. The second approach centers on the idea that cloud infrastructures can offer an ideal platform on which to run multi-agent-based systems, simulations, and applications owing to its vast processing and storage resources that users can dynamically configure to run MAS-based software at unprecedented scale. Compared to our system, their respective research communities should exploit commonalities and differences among these models to integrate the use of technologies that are based on them. For example, researchers and developers can develop decentralized applications based on MASs on grid systems or P2P networks. Similarly, applications based on sensor networks can employ distributed intelligence techniques by means of an MAS with learning and pro-activity features.

Despite the differences, Cloud computing and MASs share several common issues and research topics in both areas have several overlaps that need to be investigated. In particular, Cloud computing can offer a very powerful, reliable, predictable and scalable computing infrastructure for the execution of MASs implementing complex agent-based applications such when modeling and simulation of complex systems must be provided. On the other side, software agents can be used as basic components for implementing intelligence in cloud computing systems making them more adaptive, flexible, and autonomic in resource management, service provisioning and in running large-scale applications. For these reasons, the work [21] investigates research work in the two areas and point out potential synergies that deserve to be analyzed. The paper discusses cloud computing models and architectures, their use in parallel and distributed applications, and examines analogies, differences and potential synergies between Cloud computing and multi-agent systems. Analysis is led having in mind the goal of implementing high-performance complex systems and intelligent applications by using both cloud computing systems and software agents. Compared to our work, agents can search, filter, query, and update the massive volumes of information housed in large-scale data centers. We might envision a scenario in which cloud agents working on behalf of users and their operating systems provide intelligent data access and monitoring services, carry out processor-to-application assignment strategies, and help cloud computing infrastructures to be used in an energy-efficient manner.

11 Conclusion

Admittedly, the integration of two cloud models would give numerous benefits to the cloud users, enabling them to embrace the advantages of cloud computing in terms of more computing resources, easier programming model, and more efficiency on application execution at lower expense and lower administration overhead. The marriage between clouds, hybrid clouds and software agents can be convenient for all parties. We discussed in the paper how this can be done and which scientific areas and issues must be involved to carry out research work that will produce intelligent hybrid cloud services and high-performance MASs on hybrid clouds. The

convergence of interests between MASs that need reliable distributed infrastructures and hybrid clouds that need intelligent software with dynamic, flexible, and autonomous behavior will result in new systems and applications. Both research communities must be aware of this opportunity and should put in place the joint research activities needed to reach that goal.
A literature review of the works in the area of hybrid cloud computing data security is conducted and the results of review are presented in this paper. The results show that the majority of approaches are based on MAS approaches (82%) out of which (18%) intelligent agent approaches are used.

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