Cooperative Cloud Computing in Research and Academic Environment using Virtual Cloud

Sheheryar Malik[1], Fabrice Huet[1], Denis Caromel[2]
[1]Research Team OASIS
INRIA - Sophia Antipolis
Sophia Antipolis, France
[2]Polytech Nice Sophia
University of Nice Sophia Antipolis
Sophia Antipolis, France
sheheryar.malik@inria.fr, fabrice.huet@inria.fr, denis.caromel@inria.fr

***Abstract*—Cloud computing is becoming as a main choice computing paradigm for the enterprises. Use of cloud computing technologies is increasing by every passing day. It has great advantages of on-demand computing, scalability, proactive resource management, better application throughput, and enhanced security. Due to its openness and adaptability, it can be a good option for voluntary resource computing among non-profit organizations. In this paper, we present a model for cooperative cloud computing among research institutes and universities using Virtual Cloud concepts. The propose model of Cooperative Cloud Computing encompasses the concepts of cloud federation and volunteer computing and is based on our Virtual Cloud architecture. The cooperative cloud computing can be performed at a global scale among universities and research centers (institutes) located in different continents. In this model, institutes get benefited with a much higher computing power available through cloud federation.**

Index Terms– Cloud computing; Cooperative Computing; Cloud federation; Virtualization; Volunteer Computing

I. Introduction

Cloud computing is an emerging computing paradigm which offers on-demand computing services. It is an Internet-based computing, where the cloud vendor provides the services in form of software, hardware, resources, storage etc [1], [2]. By opting to the cloud computing, an organization no longer needs to host the technology infrastructure at its own premises. Only in a couple of years, cloud computing has acquired a lot of importance due to its convenience in terms of cost, variety of services, scalability, adaptability, and computational support to the devices with less computational power [3]. Though some people are worried about the security in the cloud. But in fact, the cloud is more secure than the proprietary infrastructure. As in the cloud computing, we outsource the computation, not the control [4].

There exist many cloud vendors and most of them offer their services against some monetary cost. Cloud computing has proved to be a cost benefited option for the enterprises, who wants to extend their clusters' capacity [5]. Some of the big cloud infrastructure/service providers are Amazon [6], Salesforce [7], Google App Engine [8], and Microsoft Azure [9]. The major users of these cloud providers are the enterprises. Some of the universities and research institutes also use these public cloud infrastructures, but they have to pay a high amount of money for that. Universities and research centers are not the money making entities as compare to the business enterprises. So their major concern in utilizing these cloud services is the monetary cost, which can be quite high, keeping in view their budget. On the other hand, in most of the cases, research centers and universities often require to have large technology infrastructure to fulfill their high computing demands. But limited funding and resources abstain them to actualize this. Even this problem is more prevalent in developing countries. These institutes can get the benefit of more computing power than they have, by cooperating computing on cloud infrastructure. This can be achieved first by creating cloud environment (virtualization) onto the technology infrastructure of these institutes (research centers, universities etc.) and then by federating these cloud infrastructures. We have already proposed the Virtual Cloud model [10] for the small enterprises. This model is quite applicable in the scenario given above with the little change in concepts.

To achieve the low cost cloud computing solution, we propose the Cooperative Cloud Computing (3C) model for the research centers and universities. This model is based on the Virtual Cloud model. This model is mainly aimed to provide a big pool of computational resources to the research centers and universities at virtually no additional cost. In this model, an institute acts as a Virtual Cloud vendor, who offers services to the users, rents the resources from some other institute(s) and also rents its own resources to some other institute(s). This renting is supposed to be free, however mutual agreements can be made between the cooperating institutes to charge some minimal service utilization fee. In this paper, we will use the terms "Principal Institute" and "Cooperating Institute". Principal institute is the primary cloud provider institute (universities and research centers) for which a user (researcher or student) is directly related. Generally a user submits his job to the principal institute. Cooperating

978-1-4673-4451-7/12/$31.00 ©2012 IEEE

institute is the other cloud provider's institute, which offers its resources to the principal institute and other cooperating institutes.

Research centers and universities across the globe can be benefited by the Virtual Cloud model by using it as a Cooperative Cloud Computing. Especially, if we apply this model at the global scale, then an institute in one continent can even fully utilize the complete cloud infrastructure of the institute(s) in other continent(s). Because a peak hour for an institute's load can be off-peak hour for the other institute's load. For example, the universities in the four continents, i.e. Australia (Australia), Asia (Pakistan), Europe(United Kingdom) and Americas(United States) have different time zones i.e. Australia (UTC+10), Pakistan (UTC+5), United Kingdom (UTC), United States (UTC-5). So they can use each other's cloud infrastructure at a high capacity.

The rest of the paper is structured as follows. Section 2 gives the overview of some related work. Then in section 3, we present our propose model. In section 4, we describe the architecture of Cooperative Cloud Computing. Then in Section 5, we describe the working mechanism of our model. We conclude in Section 6 and discuss the future research directions.

II. Related Work

The propose model of Cooperative Cloud Computing is based on cloud federation and volunteer computing concepts. Some work has been done onto these concepts. Some of the existing work related to the volunteer computing has been done in BOINC [11]. But it is not too much applicable to scenario we are focusing on.

The concept of cloud federation is given in the interconnection model of the Grid and Cloud like InterGrid and InterCloud. InterGrid [12], [13], [14] is the integration of different grids. In this model, there are multiple peer-to-peer multi-grid architectures, which are federated through P2P InterGrid Gateway. There is also a cloud computing test bed named Open Cirrus [15], which has federated data centers for open source systems and services research. Celesti et. al. have done some work in the area of cross-cloud federation [16], [17]. They have proposed a three phase model for cross-cloud federation. These three phases are discovery, match-making, and authentication. Keahey et. al. introduced the concept of Sky Computing [18], which is based on the concept to interconnect the different infrastructure as a service cloud. Bernstein et. el. have also proposed a model for the Intercloud architecture [19]. Condor [20] is a distributed environment, designed for the high throughput computing and CPU harvesting to use the CPU, when they are not in use. But it can also be used for small environments as well.

III. Proposed Model - Cooperative Cloud Computing

The proposed model of Cooperative Cloud Computing (3C) is specifically targeting the universities and research centers. In this model, these institutes share their resources with each other. To do so, they first virtualize their existing infrastructure to form a cloud environment. Then they use the Virtual Cloud model to do the federation across multiple institutes. Their resources are shared to provide volunteer computing. Virtual Cloud keeps track of the service utilization for each institute for services acquired and services provided. In this model, an institute acts as a cloud vendor, who rents the resources from some other institute and also rents its own resources to the other institutes. These resources are then used by, faculty, researchers, students and staff. The generic model of Cooperative Cloud Computing is given in Figure 1. The two stakeholders i.e. institutes and users are mentioned in the figure.

The concept of Cooperative Cloud Computing is engendered by keeping in view mainly the monetary benefits of the institutes. It is based on the following objectives:

- Reduce the monetary cost of technology infrastructure for the institutes.
- Provide a very large pool of software and hardware resources, which is not possible or very difficult to attain in normal circumstances.
- Create a cooperation for technology and information sharing, among different universities and research centers through cloud federation.

In Cooperative Cloud Computing, an institute does not need to have the complete in-house technology infrastructure. It borrows the computing resources from cooperating institutes. Whenever a service/resource is requested from a user, it is first meant to be served by the principal institute. If principal institute cannot provides the requested service then the request is forwarded to the cooperating institutes. Depending on the nature of the job, this request can be served by a single cooperating institute or by multiple including principal institute. The requested service can be for the hardware, software, processing, memory or storage resources.

Cooperative Cloud Computing provides the following benefits.

- Infrastructure is shared and each institute has more infrastructure available at disposal than their own.
- Software are shared, thus it is no longer needed to purchase the software separately for each institute.
- Administrative cost for the principal institute is less, as it has to only manage its own technology infrastructure.
- It needs less space, energy, and human resources to manage its own technology infrastructure.
- Monetary cost is saved by not purchasing the additionally required infrastructure and using the others infrastructure at free of cost.
- Energy is saved by using the existing infrastructure of other institutes instead of increasing own infrastructure. The new infrastructure consumes additional energy to perform operations.
- Researchers and students can execute their tasks from variety of devices and onto a variety of resources.
- A variety of technology infrastructure is available.

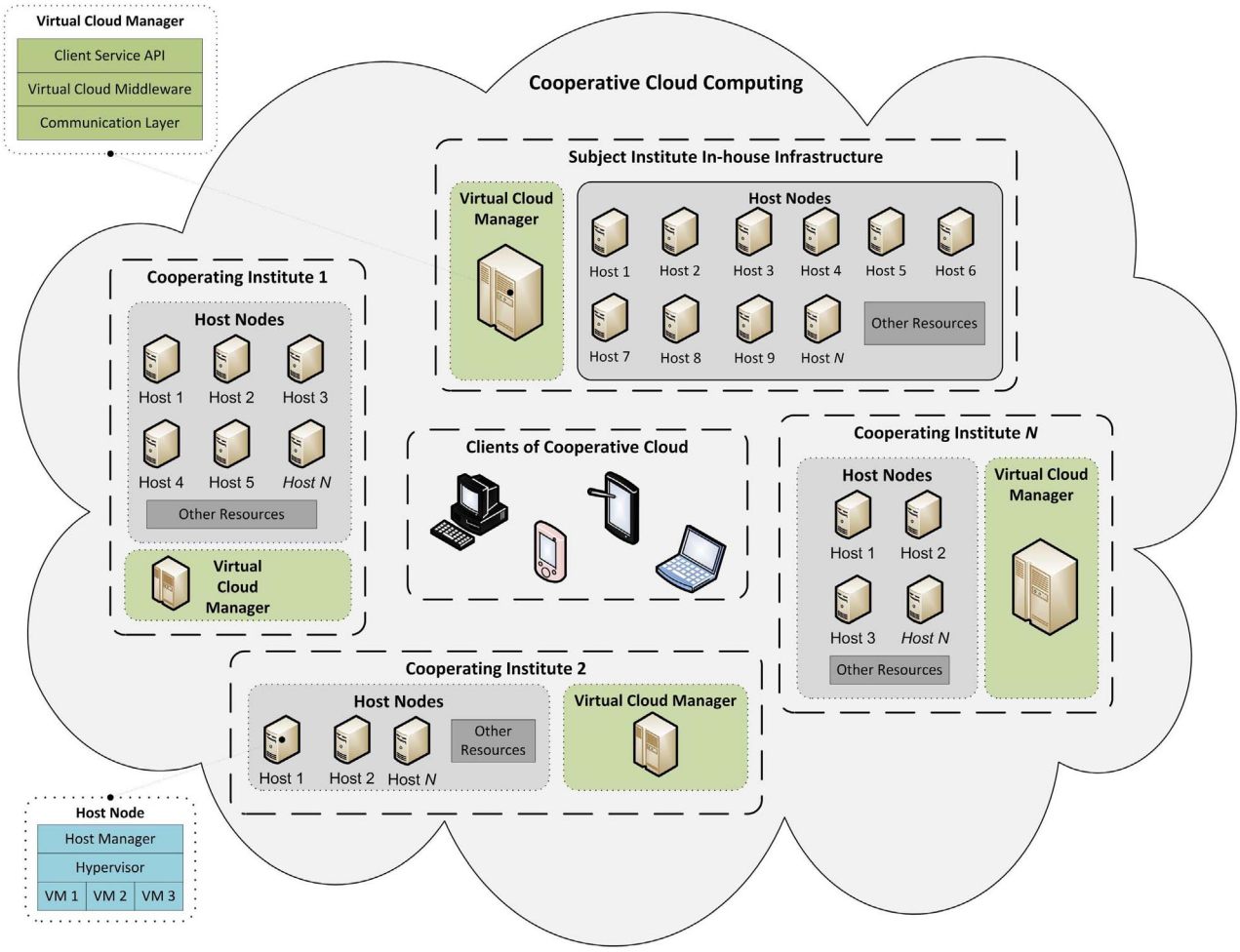

Fig. 1. Model of Cooperative Cloud Computing in Universities & Research Centers

- Experimental test bed is available for large scale experimentation.
- Real experimental test bed is available for the network experiments requiring large geographical locations.

IV. Cooperative Cloud Computing Architecture

The architecture of Cooperative Cloud Computing is based on Virtual Cloud and in general it is comprised of many Virtual Clouds, working in form of a federation. The core of the Cooperative Cloud Computing architecture is the Virtual Cloud implementation. Virtual Cloud is a client-server model, which is partitioned into two main components. One component is Virtual Cloud Manager (VCM) and the other is Host Manager (HM). Virtual Cloud Manager is a server type component, which is responsible for all the core functionalities of the Cooperative Cloud Computing including cloud federation. Host Manager is a component installed at each host machine. Generally, these host machines can be located in different labs of the universities or cluster.

A. Virtual Cloud Manager

Virtual cloud manager (VCM) is the core component of the each virtual cloud, which is responsible for all the major tasks in the cloud. It is a server type instance running at each institute's infrastructure. Virtual cloud manager consists of 3 layers i.e. Client Service API, Virtual Cloud Middleware and Communication Layer.

1) Client Service API: Client service API is an interface layer to the Virtual Cloud Middleware, which enables different clients to request the different types of services from Virtual Cloud Manager. It understands different types of messages and service requests.

2) Virtual Cloud Middleware: Virtual Cloud Middleware is the core part of the Virtual Cloud Manager. It has different components to deal with the different types of tasks. The functionality of these components is given below.

Distributor is the central point of the Virtual Cloud Middleware. It is responsible for task assignment and communication among all the components of the Virtual Cloud Middleware. It receives a request from a client through client service API and route it to the appropriate component responsible for the

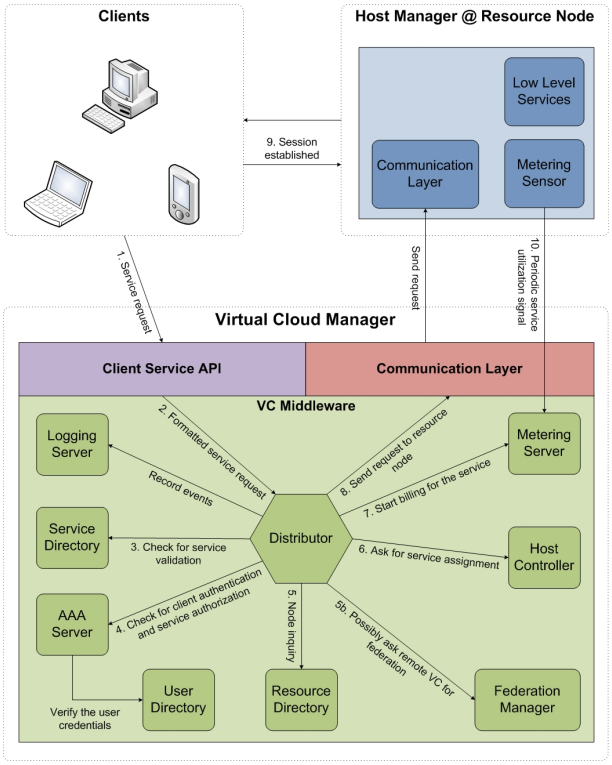

Fig. 2. Interaction model for Service Utilization within a single Virtual Cloud for Cooperative Cloud Computing [10]

desired task.

AAA Server is a module responsible for the Authentication, Authorization, and Auditing of the clients. Authentication is required to use the cloud service. A cloud user must be already registered with all of his credentials in the AAA server. Authorization checks that whether the user is authorized to use a particular service or not. Whenever a user requests for some cloud resource or service, the request is first passed to the AAA server to check for authorization. Auditing service checks for the user integrity control. It finds which variables are required for correctly identifying and relating all the actions of the user at a particular instant of time. It verifies the correct use of services and resources by the users.

Metering Service is an accounting service for both the users and hosts. Because Cooperative cloud is a volunteer and free of cost, so it only calculates the service utilization time for the users.

User/Client Directory is register for the users. It contains detail information about the users and their credentials.

Service Directory keeps the record of the available cloud services. It tells the user that what types of cloud services are available at a particular time.

Resource Directory keeps record of all the hosts and the information about their infrastructure resources. It also has a record of the federated resources from the other institutes' cloud infrastructure.

Host Controller is responsible for managing the hosts. It has a capability to perform certain node management tasks, including the node creation, termination, assignment/acquisition, release etc.

Logging Service is responsible for keeping record of all the events occurring in the VCM manager. In case of any discrepancy, one can verify the source of problem with its log record.

Federation Manager/Service is responsible for cross-cloud federation with other cooperating institutes' Virtual Cloud. It makes it possible to have the resources available voluntarily to other cooperating institutes. It has the record about all the institutes in its federation. It has two main tasks to do. The first is to periodically advertise its own shareable resources and services to the other cooperating institutes in its federation. The second task is to receive advertisements from the other cooperating institutes for their available resources. It records the details about the resources into the Resource Directory and details about the services in the Service Directory. Federation Manager uses the Instant Messaging and Presence Service (IMPS) protocol to advertise its resources. Federation Manager provides very high level of scalability to the Cooperative Cloud. If the desired resource is not available locally within the Principal Institute's Virtual Cloud then the federation manager requests its peer federation manager located on the remote Virtual Cloud of some other cooperating institute for the resources.

3) Communication Layer: Communication layer is responsible for communication with the users, hosts and with other VCM in case of cross-cloud federation. It is responsible to have a guaranteed communication between user & VCM, Host & VCM and VCM & VCM. It is capable to understand different communication protocols and technologies. It is able to communicate across firewalls and non-routed networks using SmartSockets [21].

B. Host Manager

Host manager is responsible for virtualization on the host machines and provision of services to the users. It creates a virtualized environment with the help of a hypervisor, to provide a set of cloud services. It has three components i.e. Metering Service Sensor, Communication Layer and Low Level Services.

1) Metering Service Sensor: It is responsible for the accounting of resource usage. In Cooperative Cloud Computing it only keep track of the usage of a particular resource/service. It constantly monitors the resource utilization and periodically sends the statistics to the Metering Service at VCM. Metering Service at VCM updates the time utilization information for the user on the basis of this information.

2) Communication Layer: Communication layer is responsible for communication with the users, Virtual Cloud Manager, and other hosts. It is responsible to have a guaranteed communication between users & Host, VCM & Host, and Host & Host. It is capable to understand different communication protocols and technologies. It is able to communicate across the firewalls and non-routed networks using SmartSockets.

3) Low Level Services: It is responsible for interaction with the external environment of the host manager. It works in conjunction with the hypervisor to create virtual machines. It also communicates with the virtual machines at the host node to provide the requested services.

V. Working Mechanism of Cooperative Cloud Computing

A. Cooperative Cloud Formation

Cooperative Cloud Computing model is based on Virtual Cloud architecture, encompassing the cloud federation and utility computing concepts. A Cooperative Cloud is comprised of many Virtual Clouds, working in form of a federation. In this model, all the participating institutes virtualize their technology infrastructure to create their own cloud and individually use the Virtual Cloud to perform federation and sharing of other institutes' cloud. In case of a service request from a user, the corresponding institute (principal) is responsible to first try to serve the request at its own cloud infrastructure. The request is forwarded to the cooperating institutes' cloud in the following cases; (1) the available resources are insufficient at a particular time at the principal institute then the resource request is forwarded to the cooperating clouds. In this case, the request can either be served partially by the principal institute cloud and partially by the cooperating institute or fully served by the cooperating institute. (2) the requested resource or service is not available at all at the principal institute, then the request is served by the other clouds in the federation. (3) it is explicitly stated in the request to serve it on other clouds for the experimentation purpose.

In Cooperative Cloud Computing, all the participating institutes create Virtual Cloud environment on their technology infrastructure. It is done by using hypervisors (Xen, VMWare etc.) and using ProActive Cloud middleware [22]. Virtual Cloud is responsible for federation with other Virtual Cloud. The institute (research center or university) installs and sets up its virtual cloud manager (VCM) on some very powerful machines. To provide cloud services to the users, it installs Host Manager on the host machines. These host machines can be located in the same cluster/lab or can be geographically far away to be in different cluster, lab or even city. Host machines also have hypervisor installed. Host manager works with the hypervisor to perform virtualization on the host machines.

B. Functional Methodology of Cooperative Cloud Computing

The functional methodology of Cooperative Cloud is based on Virtual Cloud mechanism and is given in Figure 2. User initiates service request at his/her principal institute's cloud by the means of web services. It requests the desired service from the principal institute's Virtual Cloud, where Virtual Cloud Manager is responsible for handling these requests. The request is passed through Client Service API, which allows the access from different types of client platforms and message formats. It then forwards the request to the Distributor, which is responsible for managing all the activities within cloud middleware. Distributor first checks the service validity. In this process, it checks with the service directory that whether the demanded service is within its domain and whether it can be provided at this time or not. Then it verifies the user's credentials and the service authorization by AAA Service. It checks for the authentication of user and authorization for particular service. Then it checks from the resource directory that where the resources for the particular service do exist. In case, if the Distributor manages to find a resource to perform the task, it asks the Host controller to assign a host node (expected to run/running the service) to the service. But if the Distributor cannot find an existing resource/host for the service, then it asks the Host Controller to first create/register a host node and then assign that host to the service. Host node creation and termination record is updated in the Resource Directory and host assignment and release is updated in Metering Service. At the time of service assignment, a unique service assignment ID (SaID) is generated, which shows that a particular client is using a particular service. If the distributor totally fails to find an existing resource or to create a new host or the user has explicitly mentioned to serve the request at the cooperating institute's Virtual Cloud, then it performs the cross-cloud federation. The distributor asks its federation manager to contact the remote federation manager for a service assignment.

Then Host Controller forwards the request to the communication layer, which sends the request with the service assignment ID to the host node. The request is passed through the communication layer at Host Manager, which understands different communication protocols and ensures a reliable communication.

Host node serves the required service to the user, on the basis of service request from the VCM. It creates a direct communication link with the user and uses the SaID for reference. Metering sensor periodically sends the service utilization signals to metering service at virtual cloud manager. When a client wants to finish the service utilization, it asks the VCM. Host controller at VCM requests the host node to terminate the service and it releases the node from the service. Then distributor updates the resource directory that the node has been released and also informs metering service to stop metering.

C. Cloud Federation in Cooperative Cloud Computing

Federation is one of the key feature of our model. Cooperative cloud uses the federation manager of Virtual Cloud to do the cloud federation. Figure 3 shows the cloud federation scenario in our model. In case of federation, the Distributor is responsible to request its federation service to ask its peer federation manager on cooperating institute's Virtual Cloud for the resources. Federation service sends a resource request to the Federation Manager of cooperating institute's virtual cloud manager. Cooperating institute's federation service asks the distributor (on that cooperating institute's Virtual Cloud) to request for the service. Cooperating institute's Virtual Cloud Manager assigns a host node to the service and informs the principal institute's Virtual Cloud Manager through federation

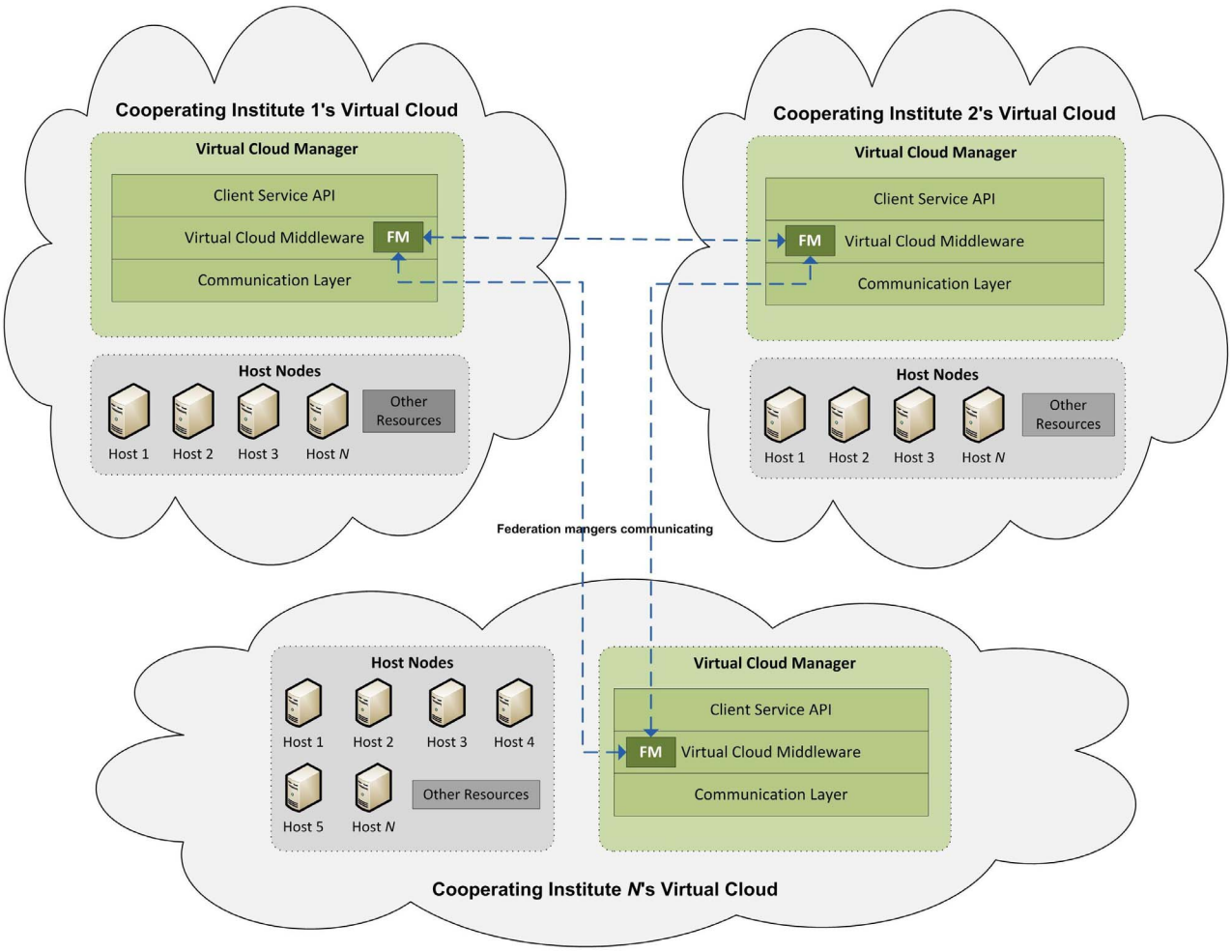

Fig. 3. Federation Scenario in Cooperative Cloud Computing Model

service about the service assignment. Then cooperating institutes VCM starts service utilization timer for the service usage in the name of principal institute's Virtual Cloud vendor. The Metering Sensor sends the usage information to the cooperating institute's VCM, which not only performs its own metering but also forwards it to the principal institute's VCM. Principal institute's VCM updates the usage information for the users in its metering database.

VI. Discussion and Conclusions

The proposed model revolves around the concept of volunteer computing through cloud federation. It aims to provide much higher computational power to an institute than it actually have at virtually no additional cost. It specifically targets the university and research centers, which normally require more technology infrastructure than they have. But they lack in having this infrastructure due to the limited finances. These institutes can be benefited by joining the cloud federation created on the basis of the proposed model. It implements the Virtual Cloud model. This model is based on volunteer computing concept, so its quality of service can be compromised sometimes. But it is at the gain of high savings in cost and availability of variety of cloud resources.

The proposed model is going to be implemented using Virtual Cloud implementation with existing virtualization technologies (like Xen). It will be available as an open source solution. Virtual Cloud is already in implementation phase and is building on existing *ProActive* cloud/grid middleware [22]. *ProActive* is an open source cloud/grid middleware, which enables the user to execute its tasks on a cluster or cloud infrastructure.

It is a highly applicable and cost efficient model, so we hope that more and more institutes across the globe can be benefited. We are also working on another framework, named Network Aware Cloud Scheduling (NACS) module [23]. It is a framework for network aware cloud computing. We had built a module, which assists the cloud scheduler in doing the scheduling decisions on the basis of certain network resource characteristics. As we are going to integrate NACS into Virtual Cloud, so the intelligence of NACS will also be available to the users of Cooperative Cloud Computing model.

There can be few more research issues associated with our proposed model. It contains most of the existing research issues for the traditional cloud and have some more raised due to the cloud federation. These issues are computing instance management, organization and distribution of memory pool, storage management and distribution, process and data migration among different hosts and to the host belonging to the other institutes.

REFERENCES

[1] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica, and M. Zaharia, "A view of cloud computing," *Communications of the ACM*, vol. 53, pp. 50–58, April 2010. [Online]. Available: http://doi.acm.org/10.1145/1721654.1721672

[2] M. Creeger, "Cloud computing: An overview," *ACM Queue*, vol. 7, June 2009.

[3] J. Hurwitz, R. Bloor, M. Kaufman, and F. Halper, *Cloud Computing for Dummies*. Wiley Publishing, Inc., 2009.

[4] R. Chow, P. Golle, M. Jakobsson, E. Shi, J. Staddon, R. Masuoka, and J. Molina, "Controlling data in the cloud: Outsourcing computation without outsourcing control," in *Proceedings of the 2009 ACM Workshop on Cloud Computing Security (CCSW '09)*, Nov. 2009, pp. 85–90.

[5] M. D. de Assuncao, A. di Costanzo, and R. Buyya, "Evaluating the cost-benefit of using cloud computing to extend the capacity of clusters," in *Proceedings of the 18th International Symposium on High Performance Distributed Computing (HPDC '09)*, Jun. 2009, pp. 141–150.

[6] "Amazon elastic compute cloud," http://aws.amazon.com/ec2/.

[7] "Salesforce's force.com cloud computing architecture," http://www.salesforce.com/platform/.

[8] "Google app engine," https://appengine.google.com/.

[9] "Windows azure platform," http://www.microsoft.com/windowsazure/.

[10] S. Malik and F. Huet, "Virtual cloud: Rent out the rented resources," in *Proceedings of the 6th IEEE International Conference for Internet Technology and Secured Transactions*, ser. ICITST 2011, December 2011, pp. 536–541.

[11] D. P. Anderson, "Boinc: A system for public-resource computing and storage," in *Proceedings of the 5th IEEE/ACM International Workshop on Grid Computing*, ser. Grid '04, November 2004.

[12] R. Buyya, R. Ranjan, and R. N. Calheiros, "Intercloud: Utility-oriented federation of cloud computing environments for scaling of application services," in *Proceedings of the 10th International Conference on Algorithms and Architectures for Parallel Processing (ICA3PP 2010)*, May 2010.

[13] M. Dias de Assunção, R. Buyya, and S. Venugopal, "Intergrid: A case for internetworking islands of grids," *Journal of Concurrency and Computation: Practice & Experience archive*, vol. 20, pp. 997–1024, Jun. 2008.

[14] M. D. de Assunção and R. Buyya, "Performance analysis of allocation policies for intergrid resource provisioning," *Information and Software Technology*, vol. 51, pp. 42–55, Jan. 2009.

[15] R. Campbell, I. Gupta, M. Heath, S. Y. Ko, M. Kozuch, M. Kunze, T. Kwan, K. Lai, H. Y. Lee, M. Lyons, D. Milojicic, D. O'Hallaron, and Y. C. Soh, "Open cirrustm cloud computing testbed: Federated data centers for open source systems and services research," in *Proceedings of the 2009 Conference on Hot Topics in Cloud Computing (HotCloud'09)*, Jun. 2009.

[16] A. Celesti, F. Tusa, M. Villari, and A. Puliafito, "How to enhance cloud architectures to enable cross-federation," in *Proceedings of the 2010 IEEE 3rd International Conference on Cloud Computing (CLOUD '10)*, Jul. 2010, pp. 337–345.

[17] A. Celesti, F. Tusa, M. Villari, and A. Pulafito, "Three-phase cross-cloud federation model: The cloud sso authentication," in *Proceedings of the 2010 Second International Conference on Advances in Future Internet*, Jul. 2010, pp. 94–101.

[18] K. Keahey, M. Tsugawa, A. Matsunaga, and J. Fortes, "Sky computing," *IEEE Journal of Internet Computing*, vol. 13, pp. 43–51, Sep. 2009.

[19] D. Bernstein, E. Ludvigson, K. Sankar, S. Diamond, and M. Morrow, "Blueprint for the intercloud protocols and formats for cloud computing interoperability," in *Proceedings of the 4th International Conference on Internet and Web Applications and Services (ICIW 2009)*, May 2009, pp. 328–336.

[20] D. Thain, T. Tannenbaum, and M. Livny, "Distributed computing in practice: The condor experience," *Concurrency and Computation: Practice and Experience*, vol. 17, pp. 323–356, April 2005 2005.

[21] J. Maassen and H. E. Bal, "Smartsockets: Solving the connectivity problems in grid computing," in *Proceedings of the 16th international Symposium on High Performance Distributed Computing (HPDC '07)*, Oct 2007, pp. 1–10.

[22] "Proactive parallel suite," http://proactive.inria.fr/.

[23] S. Malik, F. Huet, and D. Caromel, "Nacs: A framework for network aware cloud computing," in *Submitted in the 5th IEEE/ACM International Conference on Utility and Cloud Computing*, ser. UCC 2012, November 2012.