MULTI-RING STRUCTURED OVERLAY NETWORK FOR THE INTER-CLOUD COMPUTING ENVIRONMENT

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Abstract: Although the Inter-Cloud environment enables new possibilities for several data-intensive e-Sciences applications, some challenging issues such as dynamic change of computing resources and management complexity of large-scale overlay network remain. The structured peer-to-peer overlay network approach is hereby adapted onto the Inter-Cloud environment to manage the consistency of the global information among clouds and enhance the churn resistance. We propose a multi-ring structured overlay network for the Inter-Cloud environment, in which nodes are organized into one sub-ring and all sub-rings are then composed to form a large single ring structured network. The global information is managed within the sub-ring so that the cost and the complexity for managing the global information can be reduced significantly. We evaluate the efficiency of our proposed methodology by using overlay network simulator and compare the results with other existing overlay networks. Moreover, several scenarios are further analyzed to show the effectiveness in real-world cases. The results indicate that, with our approach, the management cost for global information is reduced while the stability of the overlay network under churn can be maintained. The average reachability of network under churn is more than 89.2% which is better than other structured networks and by considering locality of node, the number of the distant messages also decreases by 58.4% with respect to the overall messages.

1 INTRODUCTION

The Inter-Cloud environment, which is a federated cloud environment where many clouds including both public and private clouds are connected together, is a possible platform for many e-Science applications, since such environment can provide much larger amounts of computational power and storage resources. Such an environment brings different cloud flavors and internal cloud resources so that users are required to select computing resources on demand in order to suite for particular application workloads while considering budget, urgency, and cost of computation, data movement and consumption, etc. Therefore, computing resources in this kind of environment may vary dynamically, since users try to optimize the computing resources according to the demands of users and, as a result, the resources may join and leave to the Inter-Cloud environment frequently. The problem is that how can the environment maintain the consistency of global information such as availability of overall resources and running applications in a highly dynamically changing cloud environment, while keeping high availability of the global information and minimizing resource consumption. Furthermore, automatic resource management is also a crucial research topic for these large-scale and dynamic systems.

Our goal is to reduce cost and complexity for managing the global information among clouds and automate the system so that it can adjust itself adaptively under churn situation when computing nodes enter or leave to a federated cloud

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environment at once. To that end, the structured peer-to-peer overlay network approach is hereby adapted onto the Inter-Cloud environment to manage the consistency of the global information among clouds and enhance the resistance to a large churn. We propose a multi-ring structured overlay network for the Inter-Cloud environment, in which nodes are organized into one sub-ring and all sub-rings are then composed to form a large single ring structured network. The locality of nodes is considered when a node decides to join into the sub-ring so that the number of distant messages which are the messages generated by the distant nodes can be decreased. The global information is managed within the sub-ring so that the cost and the complexity for managing the global information can be reduced significantly. Note that the cost for managing the global information in our approach is a number of messages used for requesting and updating data.

To evaluate the effectiveness of our proposed technique, we analyze the stability of our network and the efficiency of our technique in managing the global information across the Inter-Cloud. We implemented the overlay network simulator to analyze reachability of the network, consistency and availability of the global information. The results are compared with other existing overlay networks such as ring structured network, tree structured network and unstructured network. We also applied several scenarios to show the effectiveness of our algorithm in real-world cases, for example, the scenario when a large group of nodes decide to leave network at once when they are not in-use. The results indicate that, with our approach, the management cost for global information is reduced while the stability of the overlay network under churn can be maintained. The reachability of network under churn is 8.2% better than ring structured network and 23.1% better than tree structured network by average. The number of distant messages also decreases by 58.4% with respect to the overall messages when considering node locality.

2 RELATED WORK

Overlay network is a logical network that is built on top of another network such as physical network or IP network. Overlay network has been widely used in distributed system especially the peer-to-peer network. Overlay network can be categorized into either unstructured network or structured network. The unstructured network has minimal constraints on the network topology and content distribution, so it is suitable in highly dynamic and often ad-hoc peer-to-peer environments. Most of popular peer-to-peer applications nowadays operate on unstructured networks, e.g., Gnutella (http://www.gnutella.com/) and Freenet (http://free netproject.org/). In these networks, peers connect to other peers in an ad-hoc fashion. The location of the resources is not controlled by a single centralized entity in the system and there are no guarantees of query solution. CLON (Matos et al, 2009) is the example of the unstructured overlay network for cloud environment. The authors aim to approximate the structure of the physical network, while ensuring the connectivity properties desirable to ensure reliable dissemination of the gossip-based protocol. The algorithm is based on SCAMP (Ganesh et al, 2003) but also considered the locality of joining node so that the number of messages traversing the long-distant links can be significantly reduced.

On the other hand, the structured network has a strict control on an underlying network structure, a content publication strategy and query routing. While the structured network is suitable for fast, low cost resource lookup mechanism, it has a high management cost for maintaining the topology of the network. The examples of these networks are Chord (Stoica et al, 2001), CAN (Ratnasamy et al, 2001), and Tapesty (Zhao et al, 2001). All these networks utilize the distributed hash table (DHT) for fast and accurate resource lookup but have different network topologies. In the case of cloud environment, the network tends to be more reliable than peer-to-peer network because nodes in the cloud environment are usually part of the large data-center which has rich network utility, so churn is unlikely to occur frequently. For that reason, the structured network is more suitable for cloud environment

Other interesting overlay network that related to our proposed technique is ChordSPSA (Merz et al, 2009). ChordSPSA is a Chord-enhanced self-organizing super-peer overlay which is designed to suit the communication requirements of a peer-to-peer desktop grid system. This overlay network combines favourable properties of Chord rings and fully meshed super-peer networks. The result from the simulation shows that the algorithm can reduce average message hop count in half compared to pure Chord. Unfortunately, this algorithm is not designed for cloud environment, so applied this algorithm onto cloud may reduce the efficiency of algorithm.

There are also several works which focus on the federated cloud. Aneka-Federation (Ranjan et al, 2009) is a decentralized and distributed system that combines enterprise Clouds, overlay networking, and structured peer-to-peer techniques to create scalable wide-area networking of compute nodes for high-throughput computing. The system components are self-organized based on a structured peer-to-peer routing methodology and thus make the system more flexible, efficient, and scalable. However, the authors do not focus on overlay algorithm but rather explain the detail of each component in the system instead.

3 BACKGROUND ON INTER-CLOUD

3.1 Motivation behind Inter-Cloud

Although the cloud computing already has provide a lot of capability for flexible, by demand computing resources, it limited by some drawback which leads to an emerging of the Inter-Cloud. First, one set of cloud services is not going to be able to serve all the needs of a customer and the geographical location of cloud may limit ability of service to meet user QoS because of high data transfer cost. Moreover, user may want to use multiple clouds for different applications to match business needs and allocate different elements of an application to different environments, whether internal or external and may also want to move an application to meet requirements at different stages in its life-cycle, whether move between public clouds or move back to the data-center.

To overcome such limitation of cloud, the Inter-Cloud environment is developed to bring different cloud flavours and internal cloud resources so that users are required to select computing resources on demand in order to suite for particular application workloads while considering budget, urgency, and cost of data movement and consumption, etc. Such environment is a possible platform for many e-Science applications. Nowadays, there are several projects which already implemented the Inter-Cloud such as CloudSwitch (http://www.cloudswitch.com/), and Cisco/EMC Inter-Cloud project (http://cloudven tures.sys-con.com/). Examples of projects which built for the Inter-Cloud environment are IETF's Locator/ID Separation Protocol (http://tool s.ietf.org/wg/lisp/), DMTF's Open Virtualization Format (http:// www.dmtf.org/standards/ovf/) and Google Code (http://code.google.com/).

3.2 Challenges

Despite the potential of the Inter-Cloud environment mentioned earlier, we also summarize some challenging issues which it is still remained.

- How to manage the large-scale highly dynamically changing environment which may consists of millions nodes.
- How can the environment maintain the consistency of global information such as availability of overall resources and running applications in this environment, while keeping high availability of the global information and minimizing resource consumption.

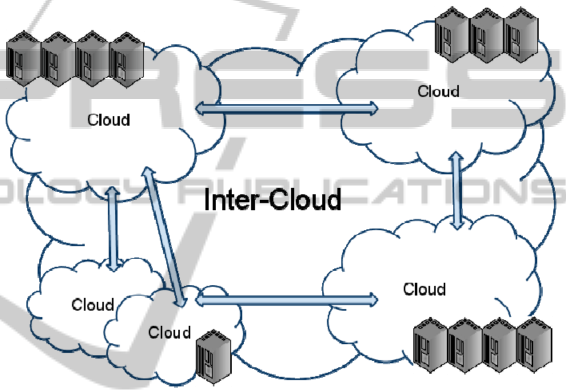

Figure 1: Inter-Cloud Environment.

For example, in a data-intensive distributed software framework like Hadoop (White, 2009), the job can be effectively scheduled and allocated to the most suitable node. As the result, the traffic cost to move the job data can be reduced efficiently. In Hadoop system, a JobTracker knows which node contains the desired resources and a location of nearly machines by using heartbeat mechanism to monitor TaskTracker and using a distributed filesystem such as HDFS (Borthakur, 2007) to share the job files. In case of the Inter-Cloud environment where multiple, different clouds are connected together, some clouds may not provide the data of node in the distributed filesystem and TaskTracker may be located in a different cloud. Thus, due to lagging the sufficient information, it is impossible for Job Tracker to effectively schedule the jobs across the dynamically changing clouds.

3.3 Requirement

To cope with the mentioned challenges, the system should be able to meet these requirements.

- The system should be automated, de-centralized, load-balanced, self-organized and should also have a low maintenance cost to be able to deal with dynamic changing of resources and for scalability
- Node locality should be concerned because of high cost of distant messages in wide-area network.
- The system should be able to maintain consistency of the global information, so sending or broadcasting messages should have minimal cost

Moreover, there is the difference that needs to be considered when designing the overlay for the Inter-Cloud. The Inter-Cloud environments have more reliable network connection than normal large-scale peer-to-peer network. Churn in this environment occurs when computing nodes has not been utilized and leave the network. In contrast, in peer-to-peer network, churn might occurs because network failures or user shutdown the system. So the structured overlay network approach is more suitable for the Inter-Cloud environment.

4 MULTI-RING STRUCTURED NETWORK

4.1 Overview

When considering all the requirements mentioned earlier, the structured peer-to-peer overlay network approach is hereby adapted onto the Inter-Cloud environment to manage the consistency of the global information among clouds and enhance the churn resistance. Moreover, structured peer-to-peer overlay network approach is known for its de-centralized and self-organized manner which will benefit the scalability of our network. We proposed a new multi-ring structured overlay network. Basically, our network is a composition of ring structured network as can be recognized as the group of ring network, called sub-ring, connected together to form a large single ring structured network as depicted in Figure 2. The blue circle represents a peer and the pink circle represents a super-peer. The function of peer and super-peer will be described in later section. Note that the reason for adopting the ring geometry is because of its simplicity, flexibility and resilience, especially when compared to other structured networks likes Pastry, CAN, Tapestry (Gunmadi et al, 2004). The main features of our network are:

- The load of the global information management is divided among sub-ring and managed within the sub-ring which leads to less management cost and complexity
- User can choose area size when gathering the resource information, and thus eliminate dispensable messages
- By considering node locality when new node joins the system, the number of the distant messages can be decreased
- The ring structured overlay requires relatively low cost to maintain the topology (Gunmadi et al, 2004) which make it more scalable and more resistance to churn

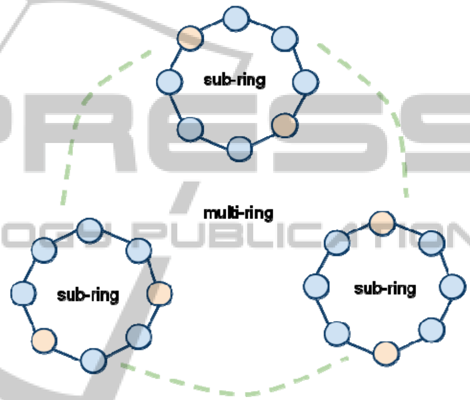

Figure 2: The multi-ring structured network.

To make our approach easier to understand, let take a look back to the Hadoop example mentioned in previous section. In case of our approach, super-peer can function as a Job Tracker and keep track of all the TaskTracker in the sub-ring. Super-peer can also contact and ask information from JobTracker in other sub-rings to schedule most suitable resources for specific jobs. In this way, not only the global information, such as resources location, can be managed efficiently across the clouds, the work load of the JobTracker can also be lighten and shared between sub-rings. Note that our sub-ring does not necessary represent one cloud, the sub-ring rather represents group of nodes that is located within the same geographical area. One cloud can be a subset of a sub-ring or can be divided into multiple sub-rings depending on the size of cloud.

4.2 Building the Overlay

The overlay network starts from a single node, other nodes will join the system later to form the overlay network. When a node wants to join the system, it has to contact one of member of the system. That member forwards the request to a super-peer which locates within the same sub-ring. Sequentially, the super-peer forwards this request to another super-peer in a sub-ring which a geographically location is closest to the joining node. The details of node's locality will be discussed later. Finally, the node joins in that sub-ring. The sub-ring will be divided into two sub-rings if member of that sub-ring exceeds a threshold. The node which already established itself in the sub-ring will get a local view from peer in the same sub-ring. A local view consists of a joining point and super-peers location. It also has to deal with a replica which will be explained later.

If node wants to leave the system, it has to inform super-peers and adjacent peers in sub-ring before leaving the system. The node is given two choices of leaving pattern which are:

- If node temporary leaves the system, temporary link between leaving node's neighbours is created to bypass the node. In this case, links and replicas are kept in unavailable state so that when the node rejoins the system, the node can join at the point where it leaves and get its replicas back from its neighbours.
- If node permanently leaves the system, links and replications will be erased. Sub-ring is merged if number of node in sub-ring is less than threshold. Node has to do the join process all over again if it wants to rejoin the system. When considering all the requirements mentioned earlier, the structured peer-to-peer overlay network approach is hereby adapted onto the Inter-Cloud environment to manage the consistency of the global information among clouds and enhance the churn resistance. Moreover, structured peer-to-peer

Node in the Inter-Cloud environment may locate in different cloud which may be as far as different continent. The cost for sending message between these two nodes is very high considering delay. The communication between these two nodes is likely to occur frequently if these nodes are neighbours or are within the same sub-ring. In our approach, we consider node's locality before let the node joins into the sub-ring and thus, the distant message can be reduced. There are many approaches to compare the locality of node (Matos et al, 2009), (Balbosa et al, 2004). In case of our network, we use message's delay time between nodes to measure their locality. If the delay is less than threshold, we assume that these two nodes located within the same locality.

4.3 Choosing Super-peers

We adopt the super-peer approach in our overlay network to manage the global information. In our multi-ring network, each sub-ring consists of multiple peers and super-peers. Normal peer can only contact with peers within same sub-ring, whereas super-peer can contact with super-peers in adjacent sub-rings.

Super-peer manages all shared-information within the sub-ring by providing or gathering data when needed. More details on how super-peer managing the global information will be discuss later in next section. Super-peer also functions as a hub for peers to connect to adjacent sub-ring. Number of super-peer in sub-ring is a portion of number of all peers in sub-ring (Mers et al, 2008)

In our algorithm, super-peer is randomly chosen and so it can be any node in the system, a computing node or a front-end node. But in the nature of the Inter-Cloud, super-peer's duty should be assigned to front-end node of the cloud because super-peer has to function as a hub to connect the sub-ring with other sub-rings. Before leaving the system, super-peer has to promote one peer to act as super-peer and send all the sub-ring information to that promoted peer.

4.4 Managing Global Information

In the Inter-Cloud environment where there is a wide variety of accessible computing resources and services for user, the available of global information is very essential for the system to efficiently utilize all the resources. Maintaining the consistency of global information such as availability of overall resources and running applications in a highly dynamically changing cloud environment, while keeping high availability of the global information and minimizing resource consumption is very challenging task.

The simplest way to make global information available to all nodes in the system is to have every node maintain information of all the system but the cost for managing the information will be unacceptable. In the Inter-Cloud scenario, nodes tend to be aggregated in sub-nets inside a data-center or in multiple data-centers, which are connected by costlier, long-distant links. We take advantage from this nature of the Inter-Cloud and divide our systems into multiple sub-rings. Each sub-ring represents a group of nodes which aggregated in sub-nets inside a data-center or within the same local area. In our approach, the cost of managing the information is distributed to each sub-ring and the information is managed within the sub-ring. As the result of this, the cost and the complexity for managing the global information can be reduced significantly.

Furthermore, to enhance the availability of the global information, we apply the replica strategy to our overlay network. Each peer has to make a replica of its resource information and send the replica to adjacent peers and also every super-peer in the sub-ring. Replica is proactively updated from replica's owner for data consistency which means that each peer has to inform adjacent peers and super-peers if there is any update in the resource information.

Whenever a peer needs the information, the peer sends request to super-peer within the same sub-ring. If aggregated global information is needed, super-peer will broadcast the request to super-peers located in another sub-rings. Generally user likely to requests the global information to obtain resource information of overall system. But in some scenarios, a job may limit by geographically location of the data and thus the resource locate faraway may not be able to meet user's QoS because of costlier, long-distant links. For example, user in Japan may want to use only resources which located within Japan or Southeast Asia because of a high data transfer cost. In this case, user can choose to get the information within the sub-ring or adjacent sub-rings only since our sub-ring already represents the approximation of the geographical location of node.

4.5 Dealing with Fault Tolerant

Our overlay network adopts heartbeat mechanism to detect node failure. Each node in the sub-ring sends heartbeat message to its neighbour periodically to monitor the existence of its neighbour. Recovery process is initiated when any failure is detected. First, a failed node is treated as a temporary leaved node and a time out counter is set. If the time out is reached, the failed node will be treated as a permanent leaved node and all of its temporary data will be deleted from the system. This algorithm provides a possibility for a node to re-join the system smoothly with less cost if the node fails unexpectedly.

5 EVAULATION

To evaluate the effectiveness of our proposed technique, we evaluate the reachability of the network, the consistency and the availability of the global information. We implemented the overlay network simulator using C# which the details is listed in Table 1. Note that in our simulation, a number of super-peers per sub-ring are fixed. We compared the results with other existing overlay networks such as ring structured network, tree structured network and unstructured network. The reason that we also compare the results with the unstructured network is to analyze the pros and cons of our decision to choose the structured overlay. In the first part, we investigate the stability of network by observing a percentage of reachable nodes when the network facing churn. Next we investigate the consistency and the availability of the global information when the churn rate is varied and the information is updated frequently.

To analyze data manage cost, we evaluate the cost of updating the information and requesting the information. Finally, we investigate the percentage of distant message which node received during a period of time to see how our technique can utilize the locality of nodes.

Table 1: Simulation Details.

Type of Overlay	Multi-ring, Ring Tree, Unstructured
System Size	1000 node
Churn Rate	10-80% per hour
Sub-ring Size	100, 200, 400 node
Number of super-peer per sub-ring	1,3,5,10 node per sub-ring

5.1 Stability of Network

The stability of overlay network is very important especially the large scale dynamically changing network likes the Inter-Cloud environment. The overlay should be able to repair itself when facing churn to maintain the topology and the reachability of the network. We investigate the stability of network by observing a percentage of reachable nodes when the network facing churn. In this simulation, we set churn rate at 10% per hour which means only half a day, all the nodes will be almost replaced with new nodes. Although in the real cloud environment, normally the churn rate may not be as high as our simulation, we want to simulate the worst case scenario to evaluate effectiveness of our approach.

Figure 3 shows the result from our simulation. We compared our multi-ring structured network with ring structured network, tree structured network and unstructured network. The graph indicated that our network can maintain the reachability as good as the unstructured network but far better than ring and tree structured network. The reachability is 8.2% better than ring structured network and 23.1% better than tree structured network by average. Note that the unstructured network does not have any constraint on network topology so it has more resistance to churn and better reachablity than those structured networks. However, when considering a cost for broadcasting messages which is essential for managing the global information, the unstructured network is not suitable approach since the messages will be flooded over the network.

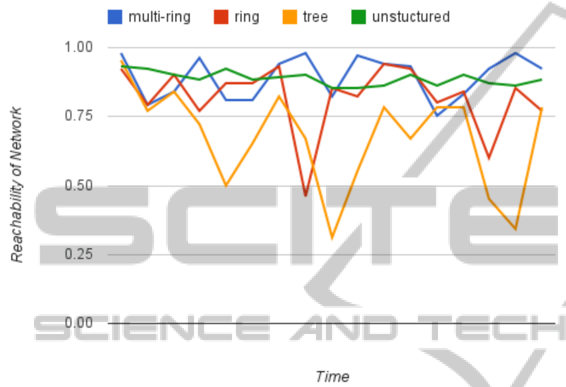

Figure 3: Reachability of Network.

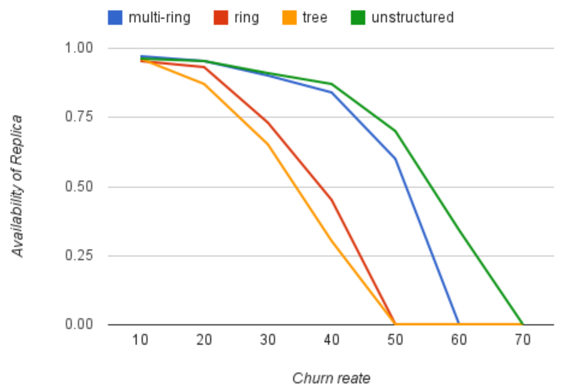

Figure 4: Availability of replicas.

5.2 Availability of Global Information

In this section, we investigate the effective of our approach on the availability of the global information. According to our approach mentioned earlier in Section 4, the information of each node such as available resources or running tasks is replicated to neighbour nodes and to super-peers. Therefore, the number of super-peer is a key factor of the availability of global information since the number of neighbour node is fixed at two.

In our first experiment, we set a number of peers to 1000, a number of super -peer per sub-ring to 3 and also set the same total number of replica to other overlay networks for the fair comparison. Note that for other overlay networks, we randomly choose the nodes which are responsible for keeping the replicas. The result from Figure 4 is matched with the result from the previous section which indicates that our technique can maintain the availability of replicas better than other structured network.

Next, we vary the number of super-peer in our approach to further analyze the effect of replicas on both the availability and consistency of the data under churn.

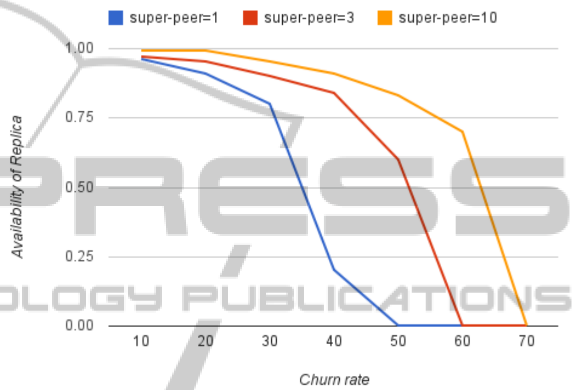

Figure 5: Effect of super-peer on availability of replicas.

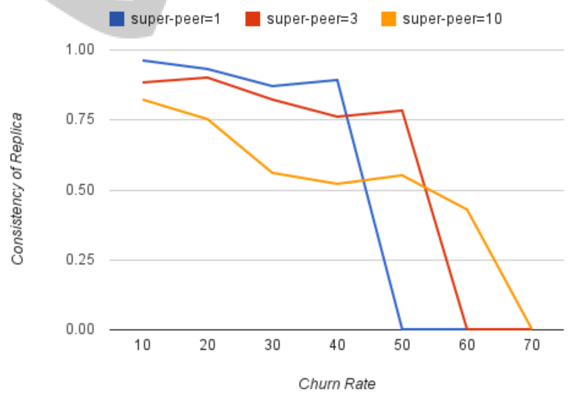

Figure 6: Effect of super-peer on consistency of replicas.

Figure 5 shows that as number of super peer increases, the availability of global resources can be properly maintained at higher churn rate. However, as in Figure 6, the consistency of global resources is reduced when number of super peer increases since it requires higher cost to keep the information updated. The availability of global information is likely to be a trade-off with a consistency.

5.3 Data Management Cost

Data management cost is a cost for requesting or updating the information. In case of requesting the data, the request message is forwarded to super-peer and then to another sub-rings. We measure hop-count that is needed for the node to get the request information, while in case of updating the data, node needs to send the update of its information to entire information replica. We also measure hop-count which is needed for the all replica to be updated. We set the number of super-peers per sub-ring to 3 and the sub-ring size to 100. Note that for other overlay networks, we randomly choose the nodes which are responsible for keeping the replicas as done in the previous experiment.

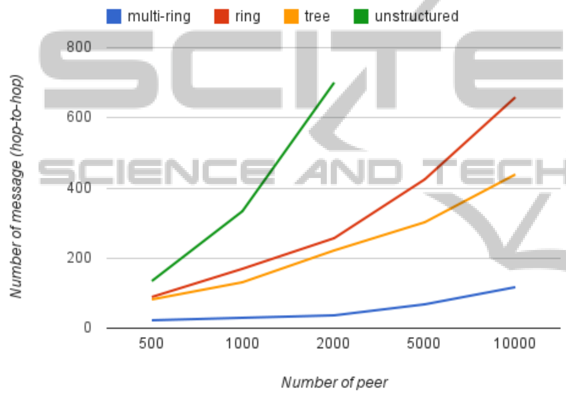

Figure 7: Request cost.

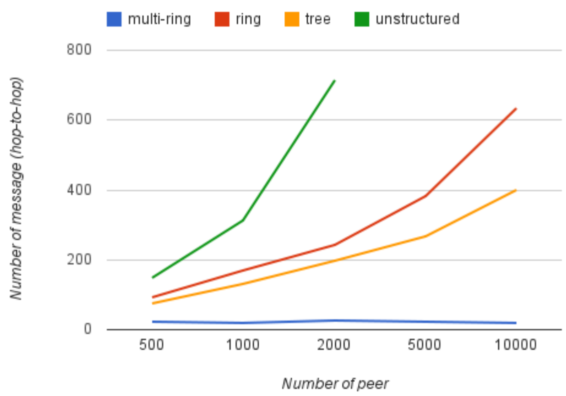

Figure 8: Update cost.

Figure 7 and Figure 8 shows that our sub-ring approach can reduce number of message's hop-count significantly in both request and update case compared to other overlay network, especially the unstructured network which cost is very high because the messages are flooded over the entire network. These results also show that by dividing the network into multiple sub-rings, the entire global management can also be distributed into each sub-ring effectively.

5.4 Effect of Locality

This section, we evaluate the effect of using node locality by measuring the percentage of distant message which node received during a period of time to see how efficient our technique can utilize the locality of nodes. The distant message is defined as a message which a delay time is more than our threshold. If the percentage of distant messages decreases, the average message delay also decreases. We set a number of super-peers per sub-ring to 3, a number of peers to 1000 and a sub-ring size to 100.

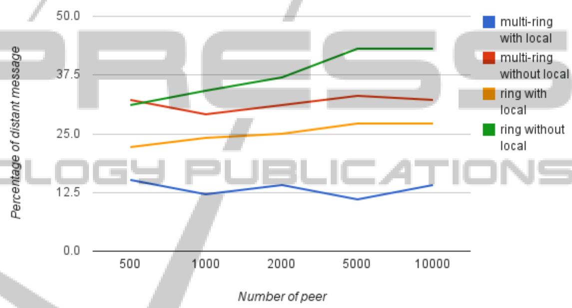

Figure 9: Percentage of Distant messages.

The result from Figure 9 shows that our approach can reduced the percentage of distant message by 47.2% compared to the ring structured network and by 58.4% compared to the multi-ring structured network without considering node locality. This result indicates that both node locality and sub-ring approach contribute to the reduction of a number of distant messages.

5.5 Summary

The results from our simulation experiments indicated that, with our approach, the management cost for global information is reduced while the stability of the overlay network under different churns can be maintained significantly compared to other structured networks. In case of the unstructured network, although the stability of network and availability of replica is better than our approach, the managing cost for the global information is unacceptable since the messages are flooded over the entire network.

6 SCENARIO STUDY

In this section, we simulate the scenario which could happen in the real Inter-Cloud environment situation. Since the Inter-Cloud environment provides lots of computing resources on demand. User tends to optimize the computing resources according to their demands; as a result, the resources may join and leave to the Inter-Cloud environment frequently. However, the scenario is not as same as a normal churn in the peer-to-peer network where resources randomly and uniformly leave the network. In case of the Inter-Cloud network, a group of resources in the same area such as within the same data-center tends to leaves the network together when they are not in-use. The churn in this scenario is still large as in the peer-to-peer but not uniform. We call this type of churn, *an area churn*.

The simulation is set as a group of adjacent nodes periodically leave of system together. We also vary the group size to further investigate its effect when the group size exceeds the sub-ring size. We evaluate the reachability of the network and the availability of the information to show a capability of our technique facing these scenarios. We set a number of peers to 1000, a number of super-peers per sub-ring to 3, the sub-ring size to 100. Note that for other overlay networks, we randomly choose the nodes which are responsible for keeping the replicas as done in the previous experiment.

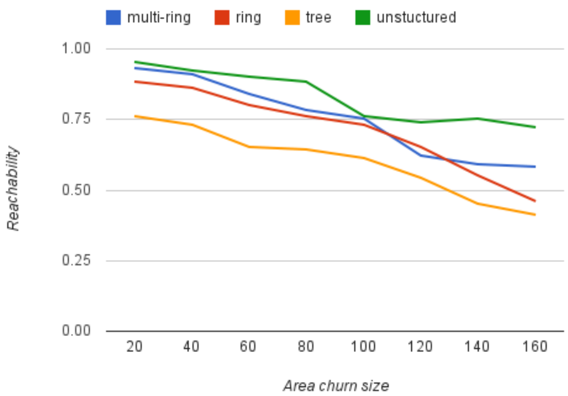

Figure 10: Reachability of network under area churn.

The result from Figure 10 shows that our approach can effectively maintain reachability of the network compared to other structured overlay networks. While the result from Figure 11 shows that our approach can also maintain the availability of the replicas even when facing area churn situation. More than 79% of replicas are available when area churn size is 160 nodes, which is larger than the size of the sub-ring.

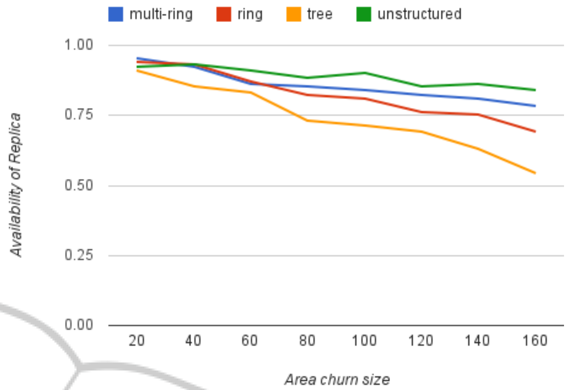

Figure 11: Availability of replica under area churn.

7 CONCLUSIONS

In this paper, we presented the multi-ring structured overlay network for the Inter-Cloud computing environment. The structured peer-to-peer overlay network approach is hereby adapted onto the Inter-Cloud environment to manage the consistency of the global information among clouds and enhance the churn resistance. We evaluated the efficiency of our proposed methodology by using overlay network simulator with several scenarios are further analyzed to show the effectiveness in real-world cases. The results indicated that, with our approach, the management cost for global information is reduced while the stability of the overlay network under different churns can be maintained. The average reachability of network under churn is more than 89.2% which is better than other structured networks and by considering locality of node, the number of the distant messages also decreases by 58.4% with respect to the overall messages.

8 FUTURE WORK

We plan to do more detailed simulations, with more comparisons and scenarios. In the next step, we intend to implement our technique onto real cloud environments such as Windows Azure and Amazon EC2. We're also interested in exploring the possibility to collaborate our system with the super-computer system. The different nature of the cloud environment and the super-computer will bring more challenges to our approach.

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