Hypothesis 1: Given a resource identifier Ir, the routing in the virtual peer pp', which is closer to the destination virtual peer pp in the clockwise direction at the identifier ring than the other virtual peer pp'', takes equal or less number of messages to reach pp than the routing in a peer pp''. We formalize the hypothesis as follows:

Let PATH (pp', pp, Ir) be the routing path from p' to p and PATH (pp'', pp, Ir) be the routing path from pp'' to pp. Let Distance (pp', pp, Ir) be the number of hops of PATH(pp', pp, Ir) and Distance(pp'', pp, Ir) be the number of hops of PATH(pp'', pp, Ir).

If pp' is closer to pp than pp'' is close to pp in the clockwise direction, we have
Distance (pp', pp, Ir) <= Distance (pp'', pp, Ir)

The hypothesis is correct if pp' and pp'' are virtual peers that reside in the same physical node pp* since our routing algorithm will search routing tables and successor sets in pp* to find the same or closer next peer so that Distance (pp', pp, Ir) <= Distance (pp'', pp, Ir).

Table 2: Lookup Operation

0 Lookup (resource_category, resource_group, resource_object_name, resource_properties) {
1 // Generate the resource identifier based on the resource group
2 // and resource object name
3 Ir= GenerateResourceIdentifier (resource_category, resource_group,
4 resource_object_name);
5 (Ip', p') = **Routing (Ir, Ip, p)**;
6 (Ip'', p'') = (Ip, p);
7 // Find the node that stores the information about the resource object.
8 While ((Ip', p') != (Ip, p)) {
9 Forward the lookup requests to node p'
10 Continue the lookup operation in node p'
11 (Ip",p") = (Ip', p');
12 (Ip', p') = **Routing (Ir, Ip', p')**;
13 }
14 Now the node p' is the node that stores the information about the resource object.
15 Query the resource database in the node p' to return the records that satisfies resource properties including both functional properties and non-functional properties.
16 }

5. Conclusion

Structured peer-to-peer systems are popular solutions for large scale distributed computing and query processing. We implement a scalable peer-to-peer based directory service called PeerDS, which is built on an improved distributed hashed table protocol. PeerDS supports both pull-based queries and push-based update multicasts to address dynamism, heterogeneity, complexity and scalability of information.

Heterogeneity among peers calls for peer virtualization to maintain a simple, yet powerful peer-to-peer overlay network. Nevertheless, peer virtualization generates a huge number of virtual peers and causes the unnecessary communication overhead in the routing process. In this paper, we propose a new peer-to-peer routing algorithm that reduces the number of hops of message forwarding and improves the performance of routing.

We study the new and previous algorithms from the analytical perspective and through simulations. It shows that the average number of hops per query is improved by 15% to 25% in our algorithm. The load balancing scheme is based on multiple factors which could be optimized on cost, proximity, reputation and other factors. This scheme eliminates the need to periodically maintain metadata for load balancing. And it does not need a central pool available to maintain load information of overloaded peers and lightweight peers.

$$E = \sum_{p=1}^{P} \sum_{k=1}^{K} (\delta_{pk}^{o})^2 \quad (1)$$

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