Efficient P2P Service Control Overlay Construction to Support IP Telephony Services Over ad-hoc Networks

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Abstract

Wireless ad-hoc networks is the key technology for community networks and rural regions that lack an established networking infrastructure. On the applications front, IP Telephony is also a killer application among the various multimedia services. It is therefore natural that wireless ad-hoc networks are expected to provide IP Telephony services. In this paper, we define strategies for constructing a P2P service control overlay to support IP Telephony services in wireless ad-hoc networks with no mobility, and validate the efficiency of our approach via simulations. This service control overlay provides a critical component to the deployment of various session-based multimedia applications in wireless ad-hoc networks.

1. Introduction

The dynamic topology and scarce wireless link capacity in wireless ad-hoc networks demands an efficient service architecture that fits the characteristics of these networks for supporting multimedia and advanced services. Despite the extensive research on routing and lower layer protocols, however, there has not been enough efforts devoted to the service architecture for these network architecture.

Among the various multimedia services, IP telephony is emerging to be the killer application for these networks.The most important part of an IP telephony service architecture is the *service control system* which is responsible for the localization of clients, processing of queries and routing them to the correct destinations. Therefore, to provide IP telephony services, the first step is to establish a scalable, dynamic and reliable service control system.

Traditionally, IP telephony systems follow the client/server model (e.g. H323 and SIP). The clients register with certain servers, which are responsible for handling the queries pertaining to these clients and routing the requests to the desired destinations. The client/server model is very inefficient for wireless ad-hoc networks for the following reasons. Firstly, this model requires the configuration of servers and proxies which contradicts with the sought after auto-configuration feature of ad-hoc networks. Secondly, such a centralized model does not fit the dynamic and changing topology of these networks. On the other hand, P2P IP telephony systems have emerged in the Internet, like Skype and P2P SIP. In these models, which are called *structured multi-layer P2P overlays*, a certain number of nodes form a P2P overlay by using *distributed indexing* to provide the required service to all the nodes [5]. These nodes are typically called *Super Nodes*. Almost all of P2P overlays suffer from inefficient routing of the queries. Therefore they can not be deployed directly in ad-hoc networks with scarce bandwidth and limited energy resources.

There are some researches to deploy P2P DHT based service overlay in ad hoc networks [6][4][2][1]. The major contribution of all of these works is benefiting from network layer information to optimize the route between overlay neighbors which may be physically very far. From the best of our knowledge the importance of the selection of Super Nodes that forms the service overlay in wireless ad-hoc networks is not evaluated.

In this paper, we define new strategies for selection of the Super Nodes in overlay network.Then, via simulation, we evaluate how the propose strategies can speed up query processing and lead to shorter session establishment time.

2. Proposed Overlay Construction Strategy

Followings are the general characters of our strategy for overlay construction.

Two Kinds of Nodes: We assume the existence of Ordinary Nodes (ON) and Super Nodes (SN). Super Nodes partici-

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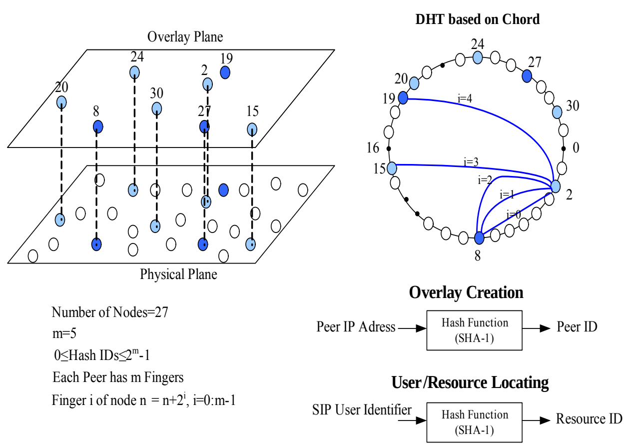

Figure 1. Overlay based on CHORD

pate in forming the Overlay Networks and they process and route the service queries.

Bootstrap Super Nodes: We assume the existence of some bootstrap super nodes to guarantee a minimum of service in the initial phase.

Clustering: The network is divided into the clusters according to the proximity of the nodes. Each cluster is managed by a *Cluster Head* (CH). A cluster head is always a Super Node (but not vice versa). In the bootstrap phase, all the bootstrap super nodes become a cluster head.

Location Information: Existence of a free range location estimation system [3]is a complementary assumption that we consider.

The overlay system is constructed based on CHORD technology. In Chord with N Super Node, every Super Node keeps maximum the link to $log(N)$ neighbors. Figure 1, shows the creation of a super node finger in Chord. Due to the routing cost in wireless technologies, our strategy is to select, as much as possible, the fingers which are physically near to the Super Node. The distance between a Super Node and its fingers can directly affect the response and consequently the session establishment time. To have the finger i with minimum possible distance, we have modified the finger selection process as in Algorithm 1.

All the peers (users), are identified by a contact-ID which may be a SIP URI in the form like user-name@domain-name.

In order to localize the peers, the overlay system should store the binding between contact-ID and the node IP address. On the other hand, in order to establish a call, a peer sends a query indicating the destination contact-ID (SIP URI) to find its IP address. In our approach, the query first arrives at the cluster head, if the destination resides in the same cluster, the cluster head returns the requested IP address to the caller and the process is finished. If not, the

Algorithm 1 Modification of CHORD

for i=1:log N **do**
  $h = i;$
  A: $List = \{SN_j | ID_{SN} + 2^h \leq ID_{SN_j} < ID_{SN} + 2^{h+1}\}$
  if List $\neq \oslash$ **then**
    $finger = SN_k \, | distance(SN_k, SN)$
    $= Min\{distance(SN_j, SN), \forall SN_j \in List\}$
  else
    $h = i + 1$
    goto A
  end if
  $finger_i = finger$
end for

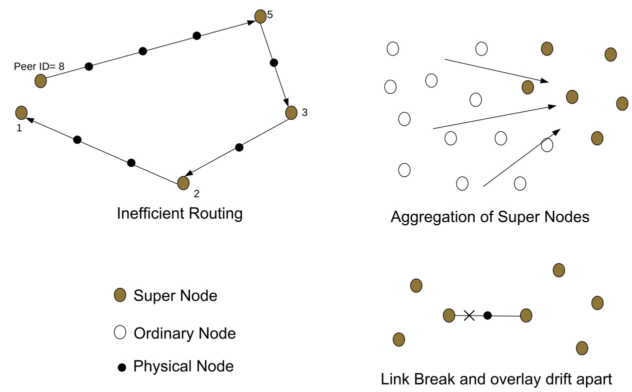

Figure 2. Undesirable Scenarios

cluster head starts the lookup process in the DHT overlay. The destination contact-ID will be hashed to obtain the key. Then the request will be sent to the finger with the nearest peer-ID to this obtained key. This process continues until the query arrives at a super node to which this key is assigned. The overlay network should grow up according to the increase in the number of service requests.

Selecting the Super Nodes based on the nodes capabilities only and without considering their locations, their relative distance to other Super Nodes and their accessibility lead to some undesirable scenarios as depicted in Figure 2. In this work, we investigate how the definition of good selection policies with careful consideration of the location information of the Super Nodes can improve the performance of overlay system. We admit new Super Nodes in our service overlay system mainly based on three admission strategies:

- The number of members in a cluster controlled by a Super Node.
- Responsiveness of the overlay network: Mean Lookup Delay and Maximum Lookup Delay.

- High density of member IDs in a domain of overlay ID space.

3. Simulation Model and Results

We consider a 50x50 grid (2500 physical node) as our test-bed to create the physical network. The horizontal and vertical separation between adjacent nodes is 20 meters. Moreover, the wireless range of each node is also considered 20 meters. These nodes don't necessarily participate in overlay.

Moreover, three strategies of overlay construction are considered for the simulation:
1) *Pure DHT*: The overlay is constructed based on Chord rules.
2) *Intelligent DHT*: We apply Algorithm 1 for finger selection.
3) *Intelligent DHT+Clustering*
We have defined 5 criteria such as *Mean Hop-Count*, *Maximum Hop-Count*, *Responsiveness Delay*, *mean finger hop-count* and *Query Failure* to compare the performance of these three strategies. However, because of space limitation only the simulation results for mean-hop an max-hop count are presented here. We define *Hop-Count* the number of *physical* hops in the route of a query that are traversed before query arrive in destination.

As Figure 3 shows, regarding the *mean hop-count*, Intelligent DHT+Clustering has shortened the query route for $\%38$ in comparison to the pure DHT. In addition, even without using clustering, Intelligent DHT improves significantly the mean query hop counts for $\%22$. Similar improvements are also obtained for maximum hop-count (Figure 4).

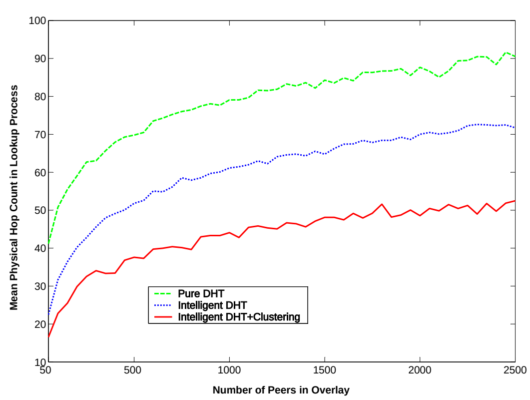

Figure 3. Mean Hop Number

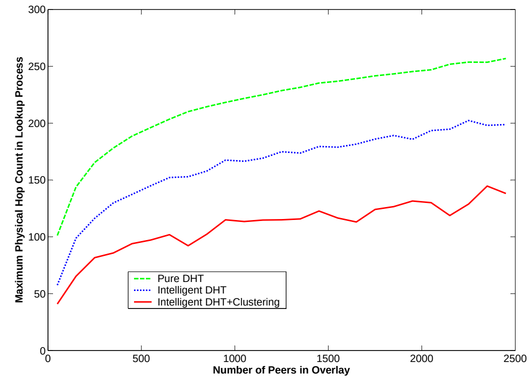

Figure 4. Maximum Hop Number

4. Conclusions

In this paper we have presented new strategies for construction of service control overlay in order to support P2P IP-Telephony Services in wireless ad-hoc networks. The main contribution of the paper was defining the strategies for selecting the super nodes which participate in DHT overlay construction. For this selection, we consider the arrangement of Super Nodes in the overlay, their physical locations and their relative distances. We have modified CHORD to add some proximity intelligence in order to set finger table. We demonstrated through simulations how our strategies can improve the performance criteria including query-hop-counts .

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