Volume 2, Issue 8, August 2012 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Mechanism to Provide Incentives in Peer-to-Peer Overlay Networks

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Abstract*— Peer-to-Peer networks are widely used to share and locate distinctive resources across the Internet. To explore this, new deployment strategies are emerging. Recently, the cloud computing has added more possibilities to it. Particularly, some applications like VoIP were proposing the creation of overlays for the localization of services based on equivalent servants (e.g., voice relays). This paper focuses on services provided by equivalent servants and models and analyzes the performance of structured overlays when used to provide such services. We demonstrate that the architecture- EQUATOR chosen for the P2P network has a enormous impact on the overall performance of the service. In particular, with the support of some analytical and simulation results, we show that how a structured network based on epidemic dissemination and built over a scale-free overlay topology is an effective solution to deploy in this context. One of the possible issue is the definition of mechanisms for encouraging users to enter the EQUATOR overlay and share some of their resources. Existing solutions [2], [3], [4] can be adapted to operate in the EQUATOR scenario and a mechanism is defined to provide incentives in the EQUATOR overlay.

Keywords*— Equivalent servants, overlay networks, structured networks, scale-free topology, incentives.

I. INTRODUCTION

In the past few years, the resource sharing services across the internet focused on storage available in the cloud. As cloud computing becoming popular two groups can be identified, they are users and servants. A servant can provide a particular service while a user asks for that service. The servants are composed of millions of processing platforms across the Internet. The users actually do not worry about which servant is processing their service. Here, there might be number of service providers and locating such equivalent servants is an important task, which explores the possibilities of locating equivalent servants over peer-to-peer networks.

In this context, a new set of services are emerging, where each servant is potentially able to satisfy users' requests. In fact, many operations alloted to the cloud (especially by thin clients) often require "limited" resources in terms of bandwidth, storage or CPU cycles, and therefore can be easily handled by any of the many peers participating in the service-oriented overlays. We can say that those services are based on multiple, equivalent servants. Existing works lack in providing enough support to these emerging distributed systems. In fact, most of them focus on the development of a system supporting specific requests, ranging from a distinctive specific file to a set of resources characterized by well-defined parameters. While these systems can also support the localization of equivalent servants, they are not optimized for this purpose because of the different requirements they comply with, more rigorous in terms of resource constraints, but simpler in terms of timely response.

This paper focuses on services provided by equivalent servants and models and analyses the performance of structured overlays when used to provide such services. We demonstrate that the architecture- EQUATOR chosen for the P2P network [1] has a enormous impact on the overall performance of the service. In particular, with the support of some analytical and simulation results, we show that how a structured network based on epidemic dissemination and built over a scale-free overlay topology is an effective solution to deploy in this context.

II. RELATED WORK

During the last few years, *structured* and *unstructured* P2P solutions have started to be adopted as building blocks for the definition of more complete P2P systems able to provide arbitrarily complex distributed services. For example, [5] and [6] are two similar unstructured architectures for the provision of Grid-like services. On the structured side, some examples of these architectures have been presented in [7]–[10]. All these proposals address a problem that is distinct from the scenario we have, where users are interested in locating one of the many available servants. Even more important, the users do not investigate the effects of the overlay topology on the performance of this type of resource lookup in order to determine the best overlay technology for the given service.

The equivalence of servants is considered to propose a scheme for CPU cycle sharing over an unstructured P2P network. Here, we have to consider the unbalanced node degree distribution, which may result in real overlay networks, as a possible hurdle to the lookup effectiveness of the system and, consequently, they propose mechanisms to overcome these limitations. In this paper, we show instead how an unbalanced node degree distribution if properly exploited, ensures high lookup performance. Peer-to-peer SIP (P2PSIP [11]) proposes to use a DHT to support lookups of relay nodes among all the participating equivalent peers, which can be done by randomly choosing a target node and then moving over the DHT to reach this target. The previous work[20] shows the idea of a service based on equivalent servants, but it limits its application to a distributed connectivity service in a SIP infrastructure.

This paper focuses on services based on equivalent servants and brings various assistance to the existing work on this topic.

1) We compared the possible overlay architectures to support our class of services and we showed, through extensive analytical and simulation studies, that an unstructured overlay based on a scale-free topology is an interesting solution in this context. Furthermore, we show the corresponding penalty in case a DHT architecture is chosen, as proposed in [11].

2) We proposed a overlay construction algorithm which (*a*) is suitable for implementation in real networks, (b) supports a standard service, and (*c*) approximates an ideal well-known scale-free overlay construction model.

3) We analysed various network scenarios by varying the servant characteristics (e.g., their lifetime), which provides an imminent of the possible performance of different services in our context.

III. OVERLAY ARCHITECTURE

In Structured Overlays first we have to investigate the possibility to deploy a structured overlay based on a general DHT, as it has been proposed in [11] for the P2PSIP architecture. Since in our scenario all peers provide the same functionality (i.e., we have only one resource provided by many nodes), the number of copies predominates over the number of unique services and therefore the ability of DHTs to locate the specific resource is of little help. Therefore,[11] proposes to use the DHT in a more intelligent way: the queries are performed by randomly selecting a target key and then moving in the overlay to reach this target.

An efficient unstructured overlay is differentiated by high lookup performance and small amount of traffic required to maintain the overlay. The above two parameters were influenced by the topology and the operating principles (e.g., nodes spread information) of the overlay.

A. Pure Peer-to-peer Networks

In pure peer-to-peer networks, Peers act as equals, merging the roles of clients and server. There is no central server managing the network and there is no central router.

B. Epidemic dissemination algorithm

One of the interesting lookup solution that avoids the harmful traffic overhead generated by flooding-based queries is the adoption of a service lookup based on *random walks*[12] encompassing a bounded number of nodes. In this technique, the service request is forwarded at each node, to a peer randomly selected among its neighbours. If the encountered peer is available or knows an available servant, the procedure terminates. The knowledge of peers can be improved through proper advertisement messages containing the node itself and/or other participating peers, thus implementing a so called *epidemic dissemination algorithm*.

In a scale free network, the node degree distribution follows a power-law:

$$Pow(n) = cn^{-£}$$

Where *Pow(n)* is the probability that a node has connections and *c* is a normalization factor. Hence, only few nodes (*hubs*) have a high degree, i.e., are aware of the existence of a large number of participating peers. The idea is that directing random walks towards hubs means looking for the service where there is a great knowledge of servants. This guarantees high lookup performance with respect to an overlay based on a balanced degree distribution (e.g., a random graph or a regular topology) where service requests are randomly distributed among peers.

C. Scale-free topology construction

The scale-free topology also guarantees a good efficiency of epidemic dissemination algorithms as exhibits a small average path length. In essence, a large number of advertisement messages reach the hubs even with a small dissemination depth (the number of hops encompassed by advertisement messages before elapsing) and a small out-degree (the number of peers to which a node directs advertisement messages). Another interesting feature of scale-free networks is that they can scale to an arbitrarily large network size without modifying the node degree distribution, which continues to follow the same law. This ensures that new hubs are automatically created when the network size increases, therefore maintaining the above described properties. In essence, scale-free networks potentially combine the advantages of centralized indexing (where a single entity directly handles all possible servants and consequently offers the best performance) and totally distributed solutions (which can scale to an arbitrary large number of participating servants and users).

One of the most popular mechanisms to construct a scale-free network is Barabasi-Albert model [13]. This is an ideal network formation algorithm that requires a global knowledge of the existing nodes. Clearly, this is not feasible in a real network. Hence, while this section shows the effectiveness of a scale-free solution, that's way we use an overlay construction algorithm based on a limited network knowledge which approximates the Barabasi-Albert model.

IV. PEER-TO-PEER EQUIVALENT SERVENTS

The equivalence of servants is considered in; propose a scheme for CPU cycle sharing over an unstructured P2P network. They consider the unbalanced node degree distribution, which may result in real overlay networks, as a possible obstacle to the lookup effectiveness of the system and, consequently, they propose mechanisms to overcome these limitations.

V. STRUCTURED DHT BASED P2P OVERLAYS

Structured – Structured Overlay network topology is tightly controlled and the content are placed not at random peers but at specified locations that will make subsequent queries more efficient. It uses Distributed Hash Table (DHT) as a substrate, where data object (or value) location information is placed deterministically, at the peers with identifiers corresponding to the data object's unique *key*.

Examples – CAN, Chord, Tapestry, Pastry.

In a DHT, Data objects are assigned unique identifiers called *keys*, chosen from the same identifier space. The *Keys* are mapped by the overlay network protocol to a unique live peer in the overlay network. The P2P overlay supports the scalable storage and retrieval of {key, value} pairs on the overlay network, and each peer maintains a small routing table consisting of its "neighbouring" peers' Node IDs and IP addresses.

Unstructured - This system composed of peers joining the network with some loose rules, without any prior knowledge of the topology and the network uses flooding or random walks as the mechanism to send queries across the overlay with a limited scope. When a peer receives the flood query, it sends a list of all the content matching the query to the originating peer. Examples – Free Net, Gnutella, KaZaA, Bit Torrent.

VI. PEER JOIN/LEAVE

In the network, each file has a hash and a descriptor. Client sends keyword query to its group leader then Group leader(super peer) responds with matches (For each match: metadata, hash, IP address). If group leader forwards query to other group leaders, they respond with matches. Client then selects files for downloading, HTTP requests using hash as identifier sent to peers holding desired file.

VII. DHT EQUIVALENT SERVANTS

DHT (Distributed Hash Table) introduce an additional feature to this querying mechanism: during the lookup process, any node encountered along the path is checked for availability and can be selected as a servant for the querying user. Notice that this operating mode makes the approach independent of the adopted DHT. In fact, only the overlay topology (which is a regular graph in existing DHTs) is of interest in our context. In other words, we adopt the topology of a generic DHT, with a fixed number of neighbours for each node, but we use a different routing mechanism.

The idea of using a DHT for our scenario of equivalent servants is especially interesting in case a DHT has to be implemented anyway for some other services.

VIII. DHT EQUATOR SIMULATION EQUIVALENT SERVANTS

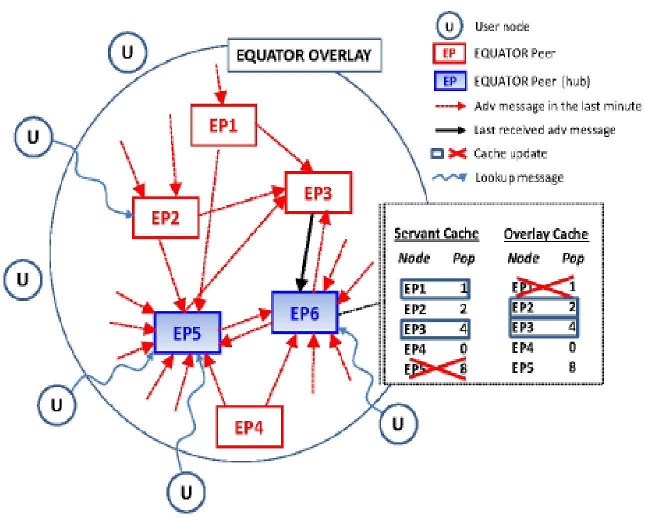

Fig-1: EQUATOR Architecture

In EQUATOR, we prefer a more flexible approach that relies on multiple Bootstrap reachable through appropriate DNS records thus guaranteeing redundancy and load balancing. Bootstrap servers globally store information about n_0 participating peers; when a peer joins the overlay. It adds the proposed Equivalent servant locator (EQUATOR) architecture shown in *Fig-1*, which overcomes the issues related to the deployment of a scale-free topology for service location in a real network, mainly due to the static nature of the ideal scale-free construction algorithm and the lack of a global knowledge of the participating peers. Simulation results confirmed the effectiveness of EQUATOR, showing how it offers good lookup performance in conjunction with low message overhead and high resiliency to node churn and failures.

EQUATOR is an unstructured overlay based on the Barabasi-Albert model, which adopts a set of construction and operating rules that are suitable for real networks. An Epidemic dissemination algorithm is used to spread the network knowledge among the participating peers. An EQUATOR Bootstrap service is required in order to provide the knowledge about the existing overlay for newly joined peers. We need to calculate the popularity of nodes. The popularity of a node is used both in the overlay construction and in the overlay maintenance and is propagated in the advertisement messages. Each peer must have overlay knowledge and advertisement messages information. Each node in the overlay maintains two different node caches: a Servant Cache and an overlay cache. Cache update process is done in order to maintain the updated information in all peers.

IX. INCENTIVE MANAGEMENT ALGORITHM

Incentive Management algorithm is used to provide incentives in peer-to-peer overlay networks. The algorithm works as follows:

```
Step 1 :  Start
Step 2 :  when a peer joins  the Network
          2.1. if new peer then
         Add new record with Incentive←0
         2.2. end if.
         2.3. if existing peer then
                 Do nothing.
         2.4. end if.
Step 3: when a peer sharing the file successfully
         3.1. for  specified no of files  repeat the       loop.
             3.1.1. if  first time then
                 Incentive ← incentive+1.
                 3.1.2. end if.
         3.2. Else
                 Do nothing.
Step  4 : when a peer leaves the Network
         4.1. If  Updating incentives pending then
                 Update the incentive value
         4.2. end if.
         4.3. Else Close the peer
  Step 5:  Stop.
```

In order to calculate incentives we can use the following scheme[14]:

Peer **i** is paid a price $\mathbf{P_i}$ per file shared, where $\mathbf{P_i}$ is given by,

$$\mathbf{P_i = \Theta_{-i} / \Theta}$$

Where $\mathbf{\Theta_{-i} = \Sigma_{j \neq i} \theta_j}$ and $\boldsymbol{\theta}$ is Payoff parameter.

X. RESULTS

In this section we presents some simulation results on the EQUATOR architecture. We first validate our overlay construction algorithm, in which we show to result in a scale-free topology. We also show how EQUATOR is comparable to the ideal Barabasi-Albert network in terms of lookup performance.

Performance Comparisons for Lookup

To evaluate the effectiveness of the EQUATOR overlay network when providing lookup services, we consider the 1-hop average blocking probability. i.e., the probability that a user does not find an available servant when $D_l = 1$, where D_l is defined as the maximum depth of a service lookup. Coherently with the assumptions of a Lookup performance model, we consider a lookup hop to be exhausted when that node (that node receives a service request) and all the servants it knows have been asked for the service.

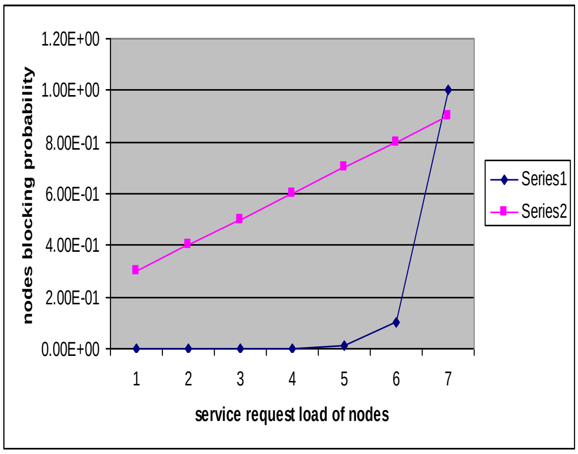

Fig -2: Average Blocking Probability of nodes

Series 1: Barabasi-Albert model N=5

Series 2: 10000 nodes EQUATOR Overlay

We use as a reference the lookup performance calculated over a Barabasi-Albert network where lookup procedures start only at nodes whose in-degree is greater than a given value *N*. We consider values for *N* ranging from 2 to 6 a good trade-off between lookup performance and lookup load distribution among nodes. *Fig. 2* shows how EQUATOR and this ideal network achieve comparable results. In particular, EQUATOR behaves similar to a Barabasi-Albert overlay where *N*=5. Given the limited size of caches in EQUATOR, this result is obtained thanks to the policies adopted in advertising peers and in handling such caches. These tend to favour the selection of popular nodes, thus approximating the behaviour of a Barabasi-Albert network where *N* assumes values reasonably greater than 1. This is confirmed by the cumulative distribution of the average percentage of lookup messages per minute received by nodes when $D_l = 1$ Although about 45% of participating peers are target of lookups from users, about 9% of nodes handle 99% of service requests, with a consequent high lookup performance.

For the purpose of completeness, *Fig- 2* also considers the lookup performance of EQUATOR when nodes select their neighbours randomly among peers in the overlay cache and users start lookup procedures from a node selected randomly among peers they know. These mechanisms follow the behaviour of existing hierarchical overlays (e.g., KaZaA), where super nodes are sparsely and randomly connected and ordinary nodes (the users in our case) do not implement any degree-driven selection of the super nodes to contact during searches [15]. The figure shows the better performance of EQUATOR with respect of this randomized overlay, thus confirming the effectiveness of our scale-free approach.

XI. CONCLUSION

This paper focuses on service-oriented overlays where users are interested to locate any of the many available overlay peers in the shortest time, i.e., the offered service is based on equivalent servants. Existing solutions, either structured or unstructured, can support these services but are not optimized for this purpose, which however is growing in importance due to the spread of many applications which need these specific features (e.g., a proxy node to anonymize a communication). This paper compares structured and unstructured overlays, demonstrating through analytical and simulation results how an unstructured solution relying on a scale-free topology is an effective option to deploy for offering services based on equivalent servants. On the basis of this result, we proposed the EQUivalent servAnt locaTOR (EQUATOR) architecture, which overcomes the issues related to the deployment of a scale-free topology for service location in a real network, mainly due to the static nature of the ideal scale-free construction algorithm and the lack of a global knowledge of the participating peers. Simulation results confirmed the effectiveness of EQUATOR, showing how it offers good lookup performance in conjunction with low message overhead and high resiliency to node churn and failures. Some possible future works are introduced in Section IV-F and are related to some complementary issues ranging from the proximity-aware selection of servants to the introduction of proper incentives to encourage nodes to join the EQUATOR overlay and offer their resources.

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