Distributed Service Discovery Architecture: A Bottom-Up Approach with Application Oriented Networking

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Abstract— **Peer-to-Peer service discovery is the norms of today's Service Oriented Architecture. Efficiency and scalability of these systems are adversely affected by the type of distributed architecture, the query routing mechanism and the effective usage of underlying network topology. Traditional query routing mechanisms in distributed P2P systems function purely at the overlay layer by isolating itself from the underlying IP layer that degrades the performance due to large amount of inter-ISP traffic and unbalanced utilization of underlay network links. In this paper we address this problem by proposing novel distributed service discovery architecture, which enhances underlay awareness without the involvement of the overlay peers. Our design starts from the underlay layer, which is built on top of Application Oriented Networking (AON) backbone that exploits message level routing. This feature is further leveraged in the overlay layer with industry based classification of published services, which complements the process of message level routing. We present the conceptual design of our framework and analyze its effectiveness. We argue that both performance and scalability of the system are drastically improved by moving down the overlay query routing mechanism to the IP layer.**

***Keywords-Web services; service discovery; AON; P2P; multicasting; clustering; SOA*.**

I. INTRODUCTION

In Service Oriented Architecture (SOA) the complexity of service composition increases proportionately with the increase in number of services. Efficient service discovery is one of the key aspects in automating the service composition process. Initially, SOA started with centralized service discovery. As more and more services are made available both from within and outside organizations, the centralized service discovery proved to be unsuccessful in terms of scalability and single point of failure [1], which paved the way for distributed approach.

Many approaches have been proposed earlier for the distributed service discovery which has its roots from Peer-to-Peer (P2P) file sharing systems. Amongst various P2P approaches, only few are suitable to be implemented in the service discovery domain, as their target is file sharing applications, where file download efficiency is one of the major concerns. However this is not the case for the service discovery where other constrains such as range queries, service cost and multiple matches are taken into account. The current P2P systems have been mainly classified into three categories; unstructured, structured and hybrid. The main shortcoming of the unstructured systems is their scalability, whereas the structured systems are prone to complex administration and poor performances in dynamic environment [2]. On the other hand hybrid systems are focused towards key mapping mechanisms which are inclined towards the tightly controlled structured approach. In this paper our focus is towards unstructured systems which are widely deployed due to their flexibility with dynamic entry and exit options for the peers.

Currently, most of the query routing mechanisms are implemented in the overlay layer which result in IP-oblivious query forwarding. This leads to three major problems. First, it heavily increases the inter-ISP network traffic [3], which is expensive for the service providers. Second, the network links are not loaded in a balanced manner which ends up with poor performance and thirdly it introduces interlayer communication overhead. To alleviate these problems several contributions have been made in making the peers underlay aware while choosing their neighbors. However, these solutions just provide the network knowledge to the peers in the overlay and let the peers decide on their own [4]. Letting the peers aware of network related parameters may lead to privacy and security issues both for the peers and the ISPs.

To this end, our contribution in this paper focuses on enhancing underlay awareness without involving the overlay peers; and to implement IP layer multicasting with message

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level intelligence. We argue that the performance can be drastically improved if the search mechanism is moved down to the underlay layer and seamlessly integrated with the Internet protocol (IP) layer.

We also argue that our architecture enhances the following characteristics of distributed service discovery, which are lacking in the current systems,

1. Non-involvement of peers in the locality aware query forwarding that results in improved efficiency.
2. Increased peer privacy.
3. Increased response time with the elimination of interlayer communication overhead.

The rest of the paper is organized as follows. Section 2 discusses the related work, Section 3 demonstrates our design and analyzes the performance and Section 4 concludes the paper with future work.

II. Related Work

Various approaches have been proposed and investigated towards improving the network layer awareness in query routing mechanisms.

TOPLUS [5] organizes peers into group of IP addresses and uses longest prefix match to determine the target node to forward the query. Here the peers use an API in the application layer to find the neighbor to forward the query. Their scope is not moving the routing decision functionality to the IP layer.

PIPPON [6] is closer to our effort in trying to match the overlay with the underlying network. The clustering mechanism in the overlay layer of PIPPON is based on network membership and proximity (latency). However, the similarity of the services provided is not taken into consideration in the cluster formation. Moreover, it ends up in a highly structured system with high administrative overhead.

The contribution made in [7] is a technique called *biased neighbor selection*. This technique works by selecting a certain number of neighboring peers within the same ISP and the remaining from different ISPs. This helps in reducing the inter-ISP traffic. This approach is well suited for file sharing systems like BitTorrent. However, the neighbors still functions at the overlay layer.

In [3], authors have discussed the problem space for the Application Layer Traffic Optimization (ALTO) working group, which is initiated by IETF. This approach allows the peer to choose the best target peer for file downloading by querying the ALTO service which has static topological information from the ISP. Here the ALTO service is provided as a complementary service to an existing DHT or a tracker service. The problem space here is the final downloading of the file and not the query search mechanism itself.

A framework that is used for conveying network layer information to the P2P applications has been proposed by P4P [4]. Peers make use of *iTrackers* and *appTrackers* to obtain the network information. The network information is used for the overlay query routing mechanism. However, the scope of the work is not in moving the query routing to the network layer which is the focus of our contribution.

Plethora [8] proposes a locality enhanced overlay network for semi-static peer to peer system. It is designed to have a two-level overlay that comprises a global overlay spanning all nodes in the network, and a local overlay that is specific to the autonomous system (AS). This is highly structured and is not suitable for highly dynamic environments.

There has been substantial contribution made in clustering as well. One such recent contribution is [9]. Our contribution contrasts with this and all others in making network provider based clustering, which aids in reduction of number of super registries that needs to be handled by Application Oriented Networking (AON) multicasting.

Deploying message level intelligence in network layer multicasting and dealing with QoS requirements in the service discovery domain are discussed in [10-12]. In [13], authors have initiated the discussion of employing AON in the service discovery but have not given a concrete implementation model, which is where our contribution fits in. The increasing trends in deployment of AON in other areas of SOA are provided in [14].

III. Architecture and Design

A. Design goals

The following goals are considered in our design.

1. **Enhanced Security:** To enhance the security of the discovery system, network aware query routing is delegated to the underlying layer and is kept transparent to the overlay layer.
2. **Reduced inter-ISP traffic:** Another design focus is to let the query forwarding traffic enter the ISP domain only if it hosts the targeted service registry.
3. **Minimized overlay process overhead:** To eliminate the involvement of intermediate registries (peers) in query processing.
4. **Interoperability:** To integrate seamlessly with non-AON routers, if encountered, along the path of query forwarding.

To implement these goals a conceptual framework has been designed as shown in Figure 1. In layer 2 AON is employed for carrying query messages to the targeted peers with the help of message level intelligence. As redundant query forwarding in the underlay is minimized by AON with message level multicasting, the performance gain is very close to the IP level multicasting [15]. AS-based clustering and service classifications are implemented at layer 3, which leverages the message level multicasting by AON.

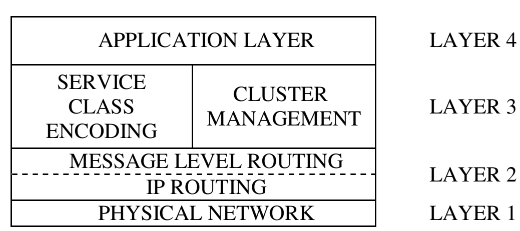

Figure 1. Layers of P2P service discovery.

B. Registry Clustering

Our approach in clustering is with respect to AS so as to reduce the inter-ISP traffic. A super registry (SR) is elected in each AS as shown in Figure 2 which demonstrates the connectivity of SRs to the underlying physical network. The SRs are responsible for accepting queries for the whole AS.

The services published in the registries are classified in accordance with Global Industry Classification Standard (GICS) [16]. Our architecture uses these coding for the implementation of AON routing at the underlying layer. A sample of GICS industry classification is shown in Table 1.

This AS-based SR approach leverages the following characteristics of our system.

1. Enables the AON router in layer 2 to learn the query forwarding interface(s) that are specific to particular class of services.
2. Improves the scalability and dynamism of the system as new registries can enter and exit the cluster with minimal overhead.
3. AON routes learned by the routers are restricted to SRs which minimize the routing entries.

We also propose to use crawling technique [17] to update the entries in the super registries so that queries forwarded within the AS could be minimized as well.

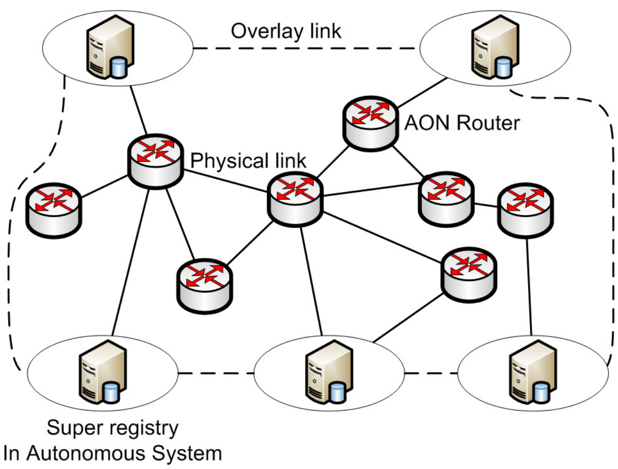

Figure 2. Autonomous system based clustering of service registries.

TABLE 1. SAMPLE INDUSTRY TYPES AND THEIR CODES

Industries	Class codes
Air Freight & Logistics	20301010
Airlines	20302010
Hotels, Resorts & Cruise	25301020
Leisure Facilities	25301030
Restaurants	25301040

C. AON Implementation

AON routers are capable of taking routing decisions based on application level messages [13]. We find this feature fits quite nicely into the distributed service discovery. Any query generated from an AS needs to be forwarded to the super registry in the AS which has an interface for classifying the query into one or more of its service classes. Then the message is constructed by encapsulating the query and its class and forwarded to the neighbors in the overlay routing table. Our packet structure in the IP layer is designed to record the interface(s) of the intermediate routers through which a particular router has received its query and reply, along with the intended source and destination IP addresses. The AON router uses this feature to inspect and update these fields and its AON specific routing table which is used for query multicast.

Possible scenarios that could be encountered during query forwarding are depicted in Table 2.

TABLE 2. SCENARIOS ENCOUNTERED IN QUERY FORWARDING

Router	Packet	Remark
AON	AON	Routing based on message level intelligence
AON	Non-AON	Classical routing based on IP header
Non-AON	AON	Classical routing based on IP header
Non-AON	Non-AON	Classical routing based on IP header

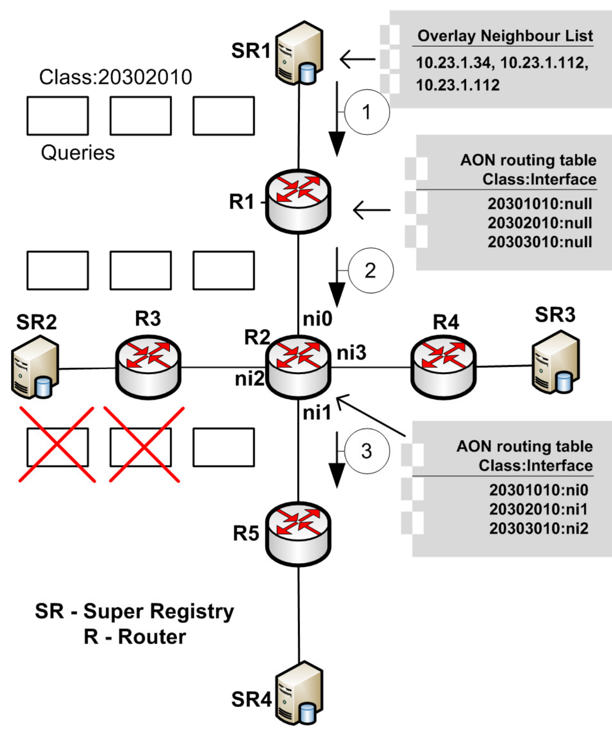

Figure 3. Sample scenario – Query forwarding.

D. Query forwarding

Figure 3 depicts an illustrative scenario of four ASs each with its own super registries connected via AON and non-AON routers. A query forwarded from an AS is received by the border routers of ASs, in this case router R1. Router R1 uses classical routing either if it is a non-AON router or an AON router in bootstrapping state. During the bootstrapping process the AON router would not have learned the service-classification specific routing and hence uses the IP header for the classical routing. Figure 3 demonstrates a sample query

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forwarding from SR1 to SR2, SR3 and SR4 as per its overlay routing table (neighbor list). However, AON-router R2 inspects the query and finds that this query could be answered by SR4 alone as per its AON routing table. Hence it forwards the query via ni1 and drops the other queries intended for SR2 and SR3, which are connected via ni2 and ni3, respectively.

E. Analysis

In a pure overlay-based routing, for instance, Gnutella like systems, considering the worst case scenario (Flooding), query from SR1 to SR2, SR3 and SR4 would generate traffic along the paths SR1→SR2, SR1→SR3, SR1→SR4, SR2→SR4 and SR3→SR4 each having four physical links from the source to the destination. However, if AON routing is employed the traffic generated is just along the path SR1→SR4. This clearly illustrates that ineffective query propagation could be effectively limited by AON to improve the efficiency of search mechanism. The same can be visualized in terms of inter-ISP traffic as well. In our illustration the only inter-ISP traffic is from the source to the AS in which the target SR resides. Performance can also be improved in case of other query forwarding heuristics like random or probabilistic selection of neighbors which is summarized in Table 3.

TABLE 3. PERFORMANCE ANALYSIS FOR THE GIVEN SCENARIO

Query propagation method	No. of peers involved	No. of paths involved
Flooding (select all 3 neighbors)	4 (SR1,SR2, SR3,SR4)	5 (SR1→SR2, SR1→SR3, SR2→SR4, SR3→SR4, SR1→SR4)
Random/Probabilistic(selects 2/3 neighbors)	3 (SR1, SR2, SR4)	3 (SR1→SR2, SR1→SR4, SR2→SR4)
AON based	2 (SR1, SR4)	1 (SR1→SR4)

F. Current issues

1. **Security issues:** It is possible that routers could be compromised and mislead query forwarding which could result in performance degradation. In our design the system functions even if some routers along the path are non-AON-routers. In the event of an attack the ISP could detect it and switch the respective router(s) to classical routing until the attack is neutralized.
2. **Router performance:** There could be overhead in the router which processes the AON packets and in maintaining the second routing able. However, we argue that with tremendous increase in processing power and memory capacity of current routers, this issue can be resolved.
3. **Involvement of ISPs:** It needs to be studied that how ISPs could be encouraged to provide AON service. The reduction of cost due to reduced inter-ISP traffic could be the incentive.
4. **File sharing and downloading:** Our focus in this paper has been in resource discovery process. Its applicability in file sharing and downloading such as BitTorrent like systems need to be studied.

IV. CONCLUSION AND FUTURE WORK

We have introduced underlay-aware distributed service discovery architecture with message level intelligence and analyzed its effectiveness in terms of privacy and security of peers in the overlay, efficient query forwarding, scalability and performance. Currently a mathematical model for a full scale system is being developed. The system is also being modeled using J-Sim, a Java based network modeling and simulation tool. In future, we are planning to simulate the system with real case studies and compare its performance with relevant literatures as in [5-7].

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