Popularity Biased Hybrid Search in P2P Systems

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Abstract

Hybrid search, which combines the flooding and DHT techniques, has been employed for efficient content-locating in Peer-to-Peer (P2P) systems. Choosing a flooding or a DHT subjects to the population of desired data. However, existing studies summarizes the popularity only based on local information, or does not take into account the dynamic factor of P2P systems. Thus, the users suffer from long search latency when performing hybrid search due to inaccurate estimations of the resource popularity. In this paper, we propose a popularity biased hybrid search method in systems. Our model allows the P2P systems dynamically detect the content popularity, and accurately make a decision of search methods. In this way, our work effectively reduces the query traffic cost and response time. The result our trace-driven simulations report shows that our model outperforms existing approaches in search efficiency.

Keywords: ***Peer-to-Peer, Hybrid search, Dynamic rate***

1. Introduction

Peer-to-peer model has been widely deployed in Internet applications such as file sharing, distributed directory service, web cache and storage [4, 6-8, 11-15, 17, 18]. According to the search algorithms, P2P models fall in two categories: structured [1, 2] and unstructured. In structured models, the P2P overlay is tightly controlled and the files are deterministically placed at certain locations based on distributed hash functions that make the queries easier to answer. In unstructured P2P systems， there is no any precise control over the network topology and the file placement. To find a file, a node queries its neighbors with a flooding-based technique. Past experience shows that flooding is an efficient, simple solution for finding copies of popular files[9], but has poor latency and result quality for queries that look for rare items, and may loss some matches that actually exist in the network due to the partial coverage problem of flooding.

To improve search quality and efficiency for both popular and rare items in P2P system, hybrid P2P that combines the unstructured P2P model with DHT-based search in structured models has been introduced since 2004 [9, 10]. In hybrid P2P, queries are addressed in a hybrid manner: popular items are found via native flooding while rare items are located via DHT-based algorithm. Though the recent works [9, 10, 19] shows that hybrid model can significantly improve search quality and efficiency for both popular and rare items in decentralized P2P system, however, they do not consider the dynamic nature of P2Ps where peers frequently join and leave. This drawback would incur extra traffic costs and long search latency in hybrid P2P systems. In this paper, we propose a **P**opularity **B**iased hybrid **S**earch for Hybrid P2P (PBS) to improve the hybrid search under dynamic environments. PBS employs a dynamic detecting mechanism to report the dynamic rate of P2P systems. Upon the results, PBS guides/adjusts the search decision-making. Our analysis and simulation results show that PBS outperforms existing approaches in terms of both traffic cost and response time.

The rest of this paper is organized as follows: We present the related work for hybrid search Section 2. In Section 3, we discuss the dynamic issue in current hybrid P2Ps. We describe our approach in Section 4. We also present our simulation result in Section 5 and conclude our work in Section 6.

2. Related Work

Many efforts have been made to improve search quality and efficiency in P2P systems, such as DHT-based, flooding-based, caching-based, topology optimization, and hybrid search. An overview of DHT-based search approaches can be found in [5]. In this

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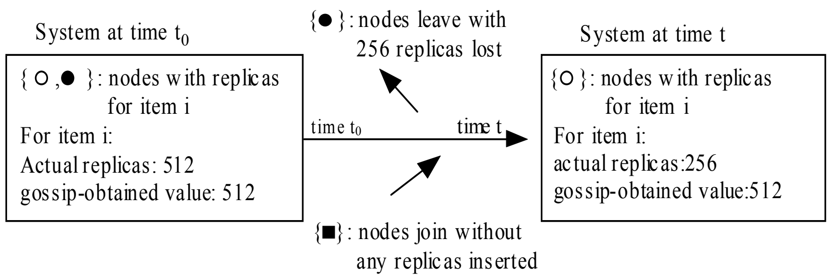

Figure 1. Dynamic impact on item popularity

type of searching scheme, nodes organize in a deterministic and distributed manner based on DHT table. All files are inserted into certain nodes and found by specifying their unique keys. To forward lookup messages, each node needs to maintain a routing table based on the DHT overlay.

Flooding-based approaches are widely deployed in practical decentralized and unstructured P2P networks such as the Gnutella-like P2P systems. In this search scheme, peers are connected in an ad-hoc fashion, and search is flooding-based.

Having observed that the Gnutella-like P2P is effective for locating highly popular items but less efficient for finding rare data, B. T.Loo et al proposed SimpleHybrid, a hybrid search infrastructure combing flooding and the DHT-based [9, 10]. SimpleHybrid first employs flooding for desired item. If no matching results return, the item is indicated as a rare one and the query is reissued via DHT-based search.

To improve search efficiency, GAB [19] makes search decision based on global statistics of document popularity. GAB outperforms SimpleHybrid by using a gossip algorithm to collect popularity information of desired items. However, its gossip-obtained based popularity statistics do not accurately reflect real situation due to the dynamic joining and leaving characteristics of peers. This inaccuracy leads to unnecessary flooding or inappropriate document publishing in DHT.

3. Dynamic impact on hybrid search

In hybrid P2P systems, efficiency and Quality of Service (QoS) mainly depend on the correctness of making search decision. The most recent work GAB [19] proposes a novel solution to this issue. When a node receives a document title it has not indexed before, it tosses a coin up to k times and counts the number of heads before the first tail appears. It then gossips the values for all titles with the other nodes to compute the maximum value. More widely a document is replicated, larger expected maximum value the document would have. Upon a query, the node computes the popularity of desired item and compares it to a flooding-DHT threshold to determine the search method.

Our observations show that GAB is effective when peers have long enough uptimes, such as in an ultrapeer/leaf mode. In most P2P systems, however, not all "normal" hosts have as long expected uptimes as ultrapeers and they leave or join the network randomly. Study in [3] shows that in Gnutella about half of the peers participating in the system are replaced within one hour. Under a dynamic environment, as shown in Fig 1, GAB popularity does not well reflect the network snapshot.

Obviously, GAB works well when the replicas statistics of the items remain unchangeable or increasing. However, there is an actual decreasing in item replicas because of node departure. Indeed, under the dynamic environment, GAB statistics is not accurate.

Motivated by above observations, we propose PBS, a dynamic biased hybrid search approach. In this design, item popularity is based on historical statistics on item replicas as well as replicas dynamics information. Therefore, the PBS' estimation of item popularity is more accurate than GAB-like protocols.

4. Dynamics adaptive hybrid design

In PBS, we still use GAB's gossip algorithm to obtain approximate global statistics of item replicas. For the dynamic information, we designate a set of *smart nodes* acting as some sensors and use the collected results to adjust the gossip-obtained popularity values to make them close to the network snapshot. The design of PBS details as follows.

4.1 Smart nodes and lazy nodes

In our model, we classify P2P nodes into two types: *smart* node and *lazy* node. Smart nodes act as popularity dynamic sensors in the system, while lazy nodes are monitored by smart node. Each *smart* node needs to maintain some extra information such as SmartNodes List, monitoring nodes set, global replica dynamic rate β_g, and local replica dynamic rate β_l, while a lazy node only maintains β_g and the sensor node ID it belongs to. SmartNodes List preserves the information of a number of other smart nodes. A smart node updates its SmartNodes List via PONG messages among other smart nodes. Each smart node includes all its monitoring nodes into its monitoring nodes set.

4.2 Smart node generation

One challenging issue in our model is the determination of smart nodes number. Too many smart nodes may overlap their functions and incur unnecessary overhead. On the other hand, too few smart nodes might lead to an inaccurate estimation of dynamic rates because of uncompleted coverage. The proper ratio of smart nodes should be decided by some important factors such as the system size, nodes' computational capability, nodes' connectivity, expected sensing accuracy, and traffic overhead, etc. In practice, we summarize a smart node ratio from experience value and refine it by practical experiments. Once this ratio is decided, we use this ratio as a probability to assign a node as a smart node when it joins the system. Each fresh node obtains a host list from the bootstrapping node, it calculates a probability approximately equal to the smart node ratio to determine whether it becomes a smart node.

4.3 Sensing dynamic change

The detection of dynamic change of P2P systems comprises two phases: locally sensing and globally aggregating. All smart nodes co-operate to report the dynamic factor of P2P systems.

Periodically, a smart node detects the replica changes within its monitoring region and computes its local replicas dynamic rate β_l. To guarantee the accuracy of local sensing results, each smart node remains the information of leaving nodes in its host list until it ultimately loses the trace of leaving nodes. When performing detection, a smart node retrieves the replica change of items from laze nodes it monitors. The replica change of each item is given by: $\beta_l = (\Omega - \Delta) / \Psi$, where Ω denotes the amount of replica of a given item emerging in the region, Δ denotes the amount of those replica brought away by leaving nodes, and Ψ denotes the replica amount till last sensing time.

In the aggregating phase, some smart nodes act as collectors to collect local β_l. If a smart nodes has the smallest IP address in one SmartNodeList, it automatically becomes a collector. Collectors gather local β_l from other smart nodes in its SmartNode List, aggregate received values and update a global replicas dynamic rate β_g, and deliver it to all smart nodes in its SmartNode List. Those smart nodes will forward this value to their monitoring nodes

4.4 Usage of dynamic factor

In our design, there are two situations needing to adjust the item popularity:

- **When publishing a query**

Each time when a node receives a query for item i, it would compute the popularity of item i before making a search decision. Suppose that the popularity for item i is $p_i(t_0)$ with timestamp t_0 at time t, it would adjust $p_i(t_0)$ into $p_i(t)$ by

$$p_i(t) \leftarrow p_i(t_0) \cdot \gamma = p_i(t_0)[1 + \beta_g(t - t_0)]$$

If p_i(t) is exceeded to the threshold T_f, the query would be flooded. Otherwise, the query would be published into DHT.

- **When gossiping the item popularity with other nodes.**

During Gossip process, if a node has known v_i, the replica statistics for item i with timestamp t_1 at time t, on receiving a gossip message from node j, within which the gossip replicas statistics for item i is v_{ij} with timestamp t_2, it updates v_i by

$$v_i = \gamma_1 v_i \forall \gamma_2 v_{ij} = v_i[1+\beta_g(t-t_1)] \forall v_{ij}[1+\beta_g(t-t_2)]$$

5. Simulation Results

We have evaluated our motivation through trace-driven simulations. The Ion P2P Snapshots[16] used in our simulations include snapshots of a hybrid Gnutella system ranging from 2004 to 2005.

We firstly determine the smart node ratio. For any given P2P topology, the sensing accuracy increases when enlarging the x/n ratio. We also find the ratio would decrease when the size of the system increases while the computing accuracy of popularity can still be guaranteed. Figure 2 depicts this trend with different computing accuracy. Indeed, as we have expected, the larger the P2P network size is, the less smart nodes are needed.

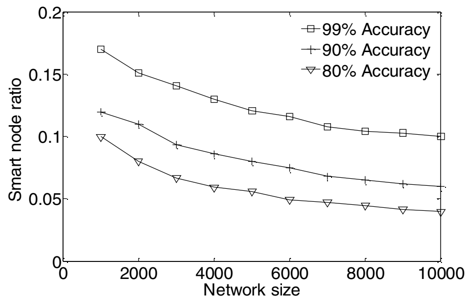

Figure 2. Smart nodes ration VS network size

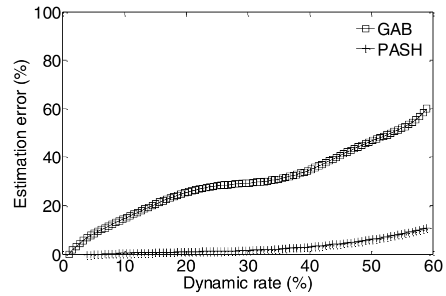

Figure 3. Popularity accuracy VS dynamic rate

After employing proper smart nodes, we have made use of them to compute the popularity for requested item. Here we compare our design with GAB in the estimating accuracy of flooding-DHT threshold. We define the estimation error ε by $\varepsilon = (E - P) / P$, where the E is estimation value and P is the exact popularity value of a resource. Figure 3 has showed that our design outperforms the GAB estimation accuracy of resource popularity in a dynamic P2P system.

6. Conclusions

Compared to flooding or DHT-based search, hybrid search model is more effective in decentralized P2P networks. However, the search efficiency calls for more focuses and works on dynamic features of P2P networks. In this paper, we propose PBS, an efficient and accurate search model for hybrid search in P2P systems. By dynamically detecting the P2P overlay change and hereby refining the estimation of the content popularity, our work outperforms existing hybrid search approaches in P2P networks.

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