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Replication of Query Messages in the Unstructured Overlays Peer-to-Peer Network

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Abstract—

Unstructured peer–to-peer (P2P) networks are attractive because they impose few constraints to the participating peers and have a low maintenance overhead. It provides high resilience and tolerance to the continuous arrival and departure of nodes. However the current P2P networks are mostly constricted by on-demand content discovery mechanism. The CoQUOS Approach has been suggested over publish-subscribe systems which can continuously notify the new data items, and a means for the peers to advertise contents. Another point that should be considered is churn which is the phenomenon of dynamic nature of entry and departure of peers in the P2P network. Thus the churn significantly affects the search mechanism in the P2P networks leading to question the effectiveness and reliability of P2P networks. In addition to the two novel techniques, namely cluster-resilient random walk algorithm for queries propagation and dynamic probability-based query registration scheme as suggested in CoQUOS approach, we suggest the message replication of query registrations present on a peer to one or more of its neighbouring peers. For this, a technique called Frequency Aware Search is suggested that defines a policy for partitioning the search space and a replication policy of keys. This paper elaborates the suggested algorithms through theoretical analysis and also reports the effectiveness proposed schemes through experimental evaluations.

Keywords— Peer-to-Peer networks, CoQUOS Approach, Random Walks, Churn, Message replication

1. INTRODUCTION

Unstructured peer-to-peer networks have been use for quite a long time for content sharing or file sharing by the participating nodes. Searching in these types of networks is very popular these days. Overlays networks form virtual topologies on top of an underlying network as the links in the overlay networks have no correspondence with links established in the underlying network. P2P networks are the best example of such overlays network.

In each of the P2P networks, a search mechanism needs to be defined so that resources need to be known to be of importance to be used by users. But the problem arises because of the dynamic nature of the P2P network which lacks central directory for resource location. Moreover current P2P content distribution systems suffer from limitations such as content discovery mechanism only when requested and have no provision for declarations of data items they own to other interested peers. Participating peers in the P2P network discover data by circulating queries which are received by other peers and respond back if it has any matching data. But the shortcoming is that these queries are not cached in the overlays network which results in the network to forget the query once it completed circulation. Besides these limitations P2P networks must also deal with the churn which is the instantaneous connectivity of the peers and intentionally or unintentionally departing from the network at any instance of time. The more the churn is prevailing in the network lesser will be the reliability of the network.

1.1 Paper Contributions

In a P2P network, data and other necessary resources are stored in a distributed fashion by the participating peers of the network which has to be of any interest to others. However to know whether the data is available or not and also to inform the interested peers that requested data is available, flooding of message seems to be an easy way out. But it results in unnecessary traffic in the network. In this paper we discuss about the CoQUOS approach for unstructured overlays network which not only implements the message forwarding without flooding to all the peers but also provides best-effort notification service for the registered queries from the peers about the discovery of the required data. The main advantage of this approach is that it doesn't enforce any topological constraints on the underlying network structure and doesn't require any complex index structures of routing mechanism. On top of these features, this paper deals with a search algorithm to improve the negative impacts of the churn by replicating the messages to the neighbouring peers. This algorithm is Frequency-Aware Search (FASE) which is basically a search space partitioning mechanism, combined with a replication policy. It also doesn't require the rigid network structure or any pre routing informations.

2. THE CoQUOS SYSTEM OVERVIEW

The CoQUOS system is a lightweight middleware that supports continuous queries and announcements/advertisements about discovery of data to the requesting peers in the unstructured overlays or simply saying P2P networks. The key features of this system include Cluster Resilient Random Walk (CRW) [3] for forwarding the messages to other peers in the network and a dynamic probability scheme for the registration of queries in the peers. Continuous query is the means of communication through which the peer registers its interest to the network. It can be represented as Q=(SID, Predicate, VTime), which is actually a tuple consisting of SourceID(SID) that identifies the requesting peer, a query predicate(Predicate) for matching condition of the query with the requested data and validity time(VTime) which is the lifetime of interest of the requesting peer.

2.1.1 Design

The CoQUOS system maintains each continuous query at one or more peers in the network. The main objective of this system is to achieve high notification success rate for the query individually for the peer as well as overall for the complete network. The figure below shows the design of the CoQUOS system.

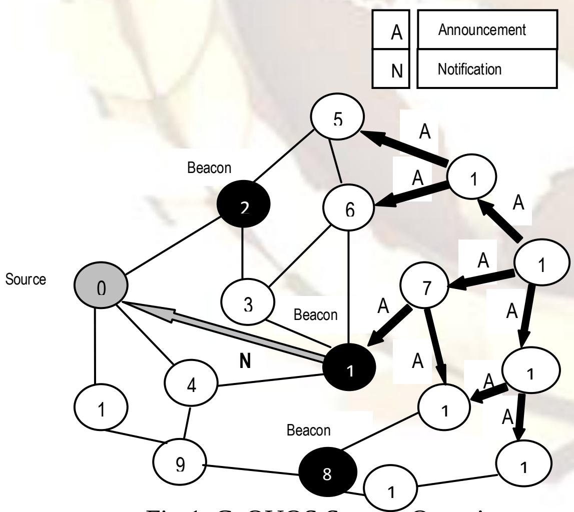

Fig.1. CoQUOS System Overview

If a continuous query Q_m is registered at a peer P_i, then P_i is called beacon node which implicitly takes the responsibility of notifying the source node of any matching data items that it might discover through incoming peer advertisements and checks with the registered query if anything matches to provide notification to the requesting node about the availability of the data. In the figure the peers shown in black i.e. {P_2, P_8, P_{11}} are the beacon nodes and P_0 is the requesting peer which may receive multiple notifications. The Beacon nodes should be selected in such a manner that they are distributed in every major region of the network such that every other peer in the network can reach them in a very small number of hops and they should not be located very close to each other.

2.2 Cluster Resilient Random Walk

In P2P networks Random Walk message propagation are more popular than flooding. In this approach a peer receives and forwards the message to another neighbouring peer at random if its Time-To-Live (TTL) is not expired. Since this message forwarding is done only one at a time so it reduces the message traffic in the network in comparison to the flooding. However with the networks with high degree of clustering of nodes, there is a greater chance the message gets trapped within the cluster and its TTL gets expired before it come outs of the cluster. To overcome this drawback, CoQUOS system suggests a technique called Cluster Resilient Random Walk (CRW). This technique considers the concept of two peers being in the same cluster if they have the large number of common neighbours. So CRW forwards messages to those nodes which have less neighbours in common by calculating the probability of nodes being not in the same cluster. Thus a peer has to compute the overlap between its neighbours list and those of each of its neighbours, and make message forwarding decisions.

Let NbrList(P_j) denote the list of neighbours of P_j and P_k,P_{k+1},P_{k+2}...,P_{k+l} denote the neighbours of the node P_j. UniqueNbrs(P_{k+1},P_j) denote the set of neighbouring peers of P_{k+1} that are not the neighbours of P_j. Suppose the node P_j receives a query message from a neighbouring peer P_k. The probability[3] of a neighbour P_{k+1} receiving the message in the next hop can be calculated as

$$\text{FwdProbability}(P_{k+1}) = \frac{\left(\frac{\text{UniqueNbrs}\ (P_{k+1},P_j)}{\text{NbrsList}\ (P_{k+1})}\right)^{\lambda}}{\left(\frac{\text{UniqueNbrs}\ (P_l,P_j)}{\text{NbrList}\ (P_l)}\right)^{\lambda}}$$

The propagation of query in CRW starts with source peer creating a query message initializing its TTL to a default value. Each peer along the query's path forward the message to one of their neighbours according to their FwdProbability values. The TTL is then decremented at each hop until it becomes zero. The Fig. 2. [3] given below illustrates CRW message forwarding in a single step. The query message is at the node p_4 and λ which controls the extent of the bias is set to 2. The numbers on the edges indicate the probabilities of forwarding the query along that link. It has been observed that CRW is better than normal random walks and flooding techniques in forwarding messages to various regions of the P2P overlays.

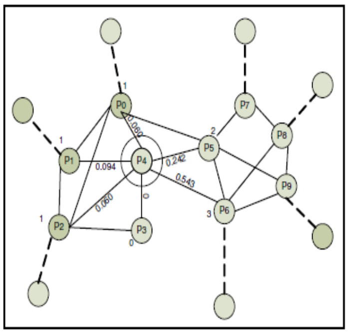

Fig. 2. Illustration of Cluster Resilient Random Walk

2.3 Dynamic Query Registration

This technique is based on the dynamic probability of the peers to decide the registration of queries on their own will. The registration probability of a query varies as the query traverses along its path depending on whether the query has been registered or not at the nodes it visited in the recent past. Thus if it has been registered at the node in the recent past the probability of getting registered in the next hop will be low and vice versa.

The registration probability [3] value of each message Q_m is denoted as ($R_p(Q_m)$). This value is set to an initial value when a peer issues a query. If a peer registers this query, then it resets the value of $R_p(Q_m)$ to the default initial value, before forwarding to its neighbours. However if the peer choose not to register the query then it increments $R_p(Q_m)$ by a pre-specified amount and forwards to the neighbour. That means the $R_p(Q_m)$ value keeps on incrementing until it gets registered wherein there will be sudden fall of point to the initial value. This technique helps in controlling the number of beacon nodes where such query registration is done.

3. NETWORK OVERLAY CHURN

The very dynamic nature of P2P networks means that there will be number of nodes that will be entering and leaving the network at will. This means besides the resource location, P2P networks must also cope with the intermittent connectivity of the peers in the network to ensure the reliability of the overall network and data transfer. If this **churn** is not handled well it can impact the success of continuous queries and announcements as well. When a node leaves the system properly, its responsibilities are well taken care by the neighbouring peers, but when it happens abruptly, all the query registrations are lost thus it will hamper the notification success rates of the respective queries and the matching announcements will be dropped. In order to resolve this problem one solution is the replication of queries on one or more of its neighbours. For this, the technique called Frequency- Aware Search (FASE) algorithm can be implemented which is basically a search protocol over unstructured network which works well by replication of queries with CRW technique.

4. FREQUENCY AWARE SEARCH

This technique defines a policy for dividing the search space in the network and a key replication policy.

The term frequency [6] is defined to be any element of a finite and discrete set Φ. We define functions f_N: $N \rightarrow \Phi$ and f_K: $K \rightarrow \Phi$ mapping respectively the set of nodes (N) and keys (K) in frequencies. A pointer is a tuple defined as follows:

Pointer: <Key,URL>

In a pointer, a key identifies the item and an URL is an unique node address where the query will be replicated. FASE improves search results by having nodes to forward random walks preferably to nodes in the same frequency of the search key. This algorithm assumes that majority of nodes in the overlay have a constant degree.

4.1. Pointer Replication

In order to reduce the impact of churn and properly facilitate item location, nodes replicate pointers using replication messages which carry one or more pointers with keys of the same frequency. For the message M_R let $f_K(M_R)$ be the frequency of the keys being carried. These replication messages carry a counter that defines the maximum number of replicas of each pointer to be stored. Every peer that decides to store pointer decrements the replica counter and when the counter becomes 0 the message is discarded. Replication messages are forwarded to those neighbours who have not been visited previously. Since the replication message is preferably forwarded to nodes labelled with the same frequency of the item, only one pointer is stored for the whole path that contains number of nodes. This leads to the efficiency in storing the pointer. The main purpose of this replication method is to make items well available for searches at any point.

The pointer replication process is illustrated in the Fig. 3 given below.

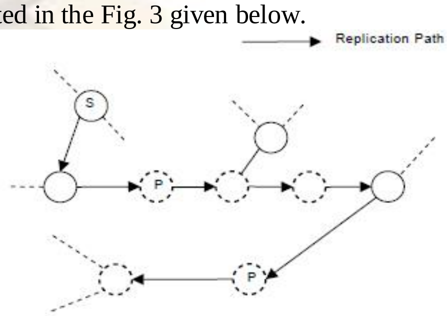

Fig.3. Pointer Replication [6]

The above figure shows the path of a replication message M_R starting at node S. The dotted circles are the nodes in the same frequency of the message. Here node S forwards message to a random neighbour as it has no neighbour in M_R frequency, $f_K(M_R)$ and thus the neighbour in the following hop with $f_N(n) = f_K(M_R)$ will store a pointer. The figure shows that a replication message is always forwarded to unvisited nodes of the same frequency. The nodes labelled with P store the pointer carried by M_R. These pointers are stored once per path and the forwarding of M_R is stopped once the replica counter reaches 0 or when all the neighbours of the current node have been visited before by M_R.

5. EXPERIMENTAL EVALUATION

This section shows the experimental results of the simulation of FASE algorithm with CRW technique. For this we have simulated a network consisting of 1000 nodes. The simulation created 100 unique data items, from a group of data items in excess of 4000, each advertised by a distinct node selected at random to the beacon nodes. For evaluation of the algorithm, queries are performed for items that are present in the network and are selected uniformly at random.

We measured the difference in the Notification Success Rates (NSR) of overlay network with and without the application of FASE algorithm with CRW. The Fig.4. and Fig.5. shows the NSRs of the two approaches for which the registration probability value is set to 0.3.

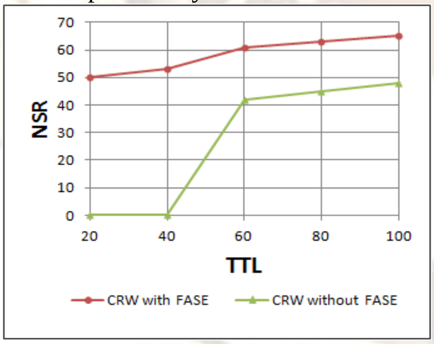

Fig.4. Comparison of minimum NSR of CRW with and without use of FASE

In this experiment, the minimum NSRs of CRW were set to different values with the use of FASE and without FASE and the results show that there is significant benefit in the NSR with the use of FASE yielding reasonable NSR even at relatively low initial TTL values.

We also checked the effectiveness of the CRW with and without using FASE to evaluate the effect of churn. The Fig.5. shows the results of the experiment.

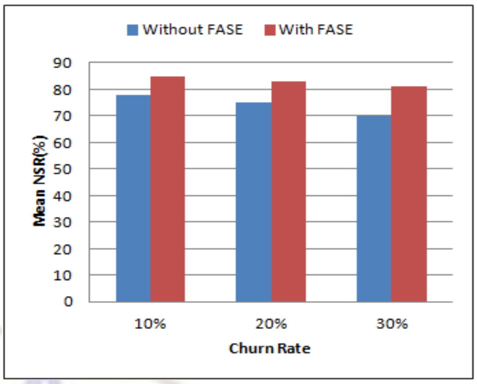

Fig.5. Effectiveness of FASE to tackle churn

The mean NSRs which were measured when the churn rate is set to 10%, 20% and 30% show that NSRs are high when using FASE than without using it.

6. CONCLUSION

Maintaining the network reliability and data resources available in a P2P network is a challenge provided its dynamic nature i.e. churns. Although there may not be any perfect solution to tackle this problem but the presented Frequency-Aware Search algorithm helps to reliably search the data item in the unstructured overlays networks to very good extent. Like CoQUOS approach FASE doesn't enforce any restriction on the network structure or topology. Our evalution shows that with the use of FASE, we can achieve high NSRs even on increasing the churn rate. The results suggest that, the replication policy like FASW helps to increase the availability of searched items.

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