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A Fair Load-balancing Method in Hierarchical DHT-based P2P Network

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Abstract: A key-spliting-based approach is proposed for hierachical DHT P2P network to balance superlayer load. The identification space that super nodes charged are mapping into multi-dimension, the load of each dimension is counted and the fairness function is applied to balance the loading. The simulation results show that the method can balance the load among supernodes in proportion to their capacity for hierarchical DHT-Based P2P network and reduce the uneven probability of local super-layer throughput.

Key words: Load balancing, hierarchical P2P, chord, peer to peer

INTRODUCTION

Most of structed P2P network is based on DHT scheme, which provides efficient, scalable and self-organizing algorithms for data management and retrieval offer crucial advantages compared to unstructured P2P approaches (Saroiu *et al*., 2003). However, the performance of structed P2P overlay network is limitted by some factors. Firstly, computational capability of nodes in network is of great differences, for example storage space, bandwidth, CPU capability and so on. That is, DHT cannot be guaranteed in the appropriateness of nodes. Secondly, the stability of nodes is too unreliable and nodes can join or leave anytime in P2P network, which leads to higher maintenance cost (Krishnamurthy *et al*., 2008).

To resolve these problems, hierarchical P2P structure was proposed. For example, chord2 (Joung and Wang, 2007) utilize heterogeneity to build a maintenance infrastructure in DHTs to reduce the costs; Canon (Ganesan *et al*., 2004) assumes homogeneous structure for all clusters and provides a general technique for constructing hierarchically structured DHTs. HIERAS Xu *et al*. (2003) keeps scalability property of current DHT algorithms and improves system routing performance by the introduction of hierarchical structure.

While using hierarchy has great advantages, which include scalability, administrative autonomy, adaption to the underlying physical network and hierarchical access control, the load imbalance among supernodes become a crucial issue. The reasons which result in the load imbalance for the hierarchical DHT network are same to the structed networks and we can refer to Wei *et al*. (2009) for them. At thes same time, the higher the layer of the network, the more influential the nodes owns and so the higher its imbalance costs.

In this study, a key-spliting-based approch for balancing the superlayer load to the hierarchical DHT P2P network is proposed. The key space super nodes charged are spitted into several dimensions; the fairindexof the characterization overlay network bottleneck is introduced into the fair load undulation limiting function. Load of every dimension are monitored, when a dimension is over loading, the load will be diverted to a new node which is gave by fair load undulation limiting function. Analysis and simulation results show that while maintaining the advantages of hierarchical DHT, the load of nodes in superlayer will be balanced.

RELATED WORK

Hierarchical DHT networks: As aforementioned, nodes rarely have equal capabilities in practical network. The handheld, mobile phone, person computer and other devices can be used to participate in overlay network by system user, their processing power, storage capacity and access data rate are vary from each, which is difined as heterogeneity. Plenty of reasons are responsible for the come being of hierarchical DHT network, but the heterogeneity is the main one.

Three topological structures are shown in Fig. 1, which are referred to intra-group structure (Zoels *et al*., 2008). It is shown that the respective architectures include supernodes and common nodes and every supernode manages a group of common nodes. Fully-meshed and intra-group structures are similar to the C/S architecture, group node is connected to all other group nodes to the fully-meshed structure connects, but

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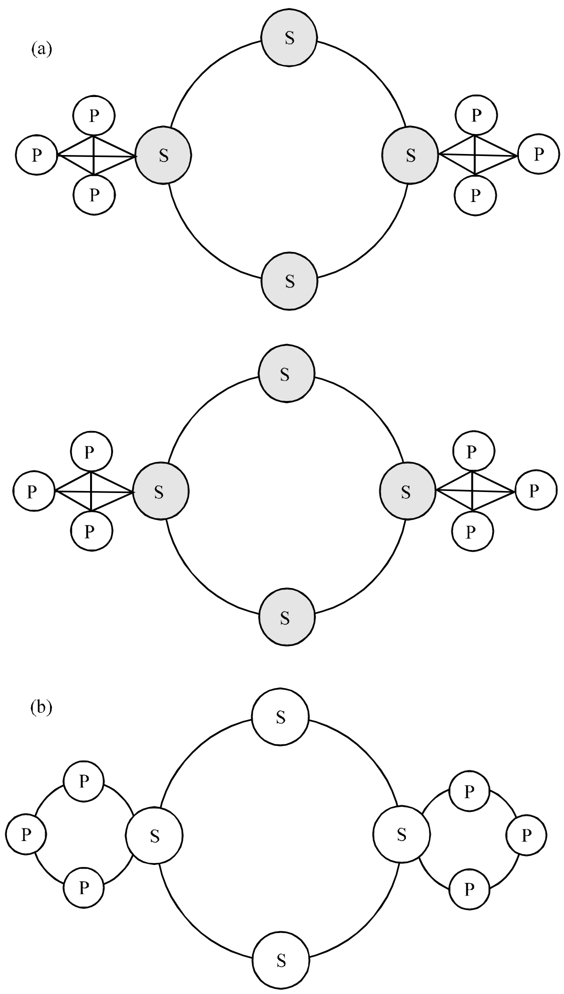

Fig. 1(a-b): Intra-group architectures, (a) Fully-meshed and single-connection structure and (b) DHT structure

to single-connection, group nodes are connected only to the group's supernode. On the contrast, the DHT intra-group structure applies a DHT (Chord in this case) to connect the nodes within each group and it can benefit from the advantages of DHTs in comparison to unstructured intra-group.

Another hierarchical DHT architecture is described as chord[2] which as previously mentioned. It suggests imposing a conduct layer over the regular DHT network (Fig. 2). In this design, high level rings can be assigned more critical tasks that demand high stability of structure. In comparison with the intra-group architectures, the full DHT hierarchical structure can cope with the problem of single failture of supernode in effect. In this study, our load balancing method involves only the full DHT hierarchical arichitecture. The super node layer and

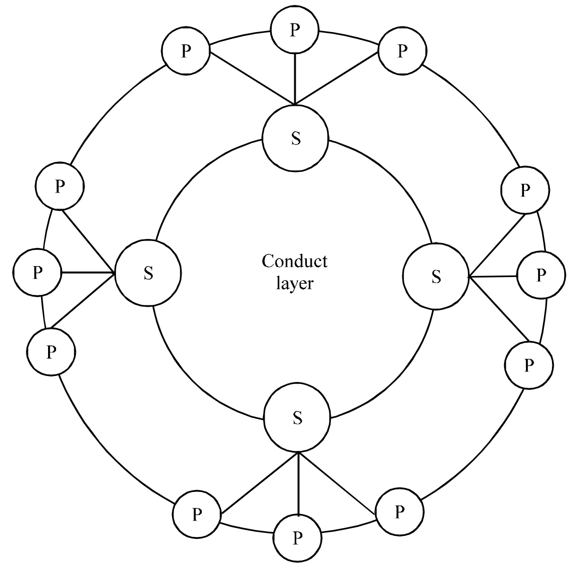

Fig. 2: Full DHT hierarchical architecture

common node layer of full DHT hierarchical architecture are all conducted by Chord protocol; such design main purpose is to maintain routing consistency and simplicity management of two layers. However, keywords of integrated space interval division and merge operation are restricted, thus the local load balance problem is critical to full DHT hierarchical P2P network.

Load balancing in full DHT hierarchical network: As mentioned above, the DHT mechanism has many advantages, but also showed some inadequacies which has not been solved and the heterogeneity of data distribution will cause the entire network load differences. In addition, because of the differences in network environment, different regional business throughout is undulate and frequency of access to resources is uneven, which result in the load imbalance of DHT P2P network.

To structured DHT network, according to reallocate hosted Hash space and keyword space, virtual server algorithm (Rao *et al*., 2003) can control the join and quit of network node and the load balancing of each node is achieved. In hierarchical P2P network, the number of super node layer control is the main ideas of its load balancing, so the above method is limited by the overlay network hierarchy. Zoels *et al*. (2007) proposes a Load balancing method for intra-group structures P2P network, its main idea is monitoring super node layer load and control of the common node of the join request; Zhang Yuxiang, etc. (Zhang and Zhang, 2010) proposes a novel load balancing algorithm, in which each super node,

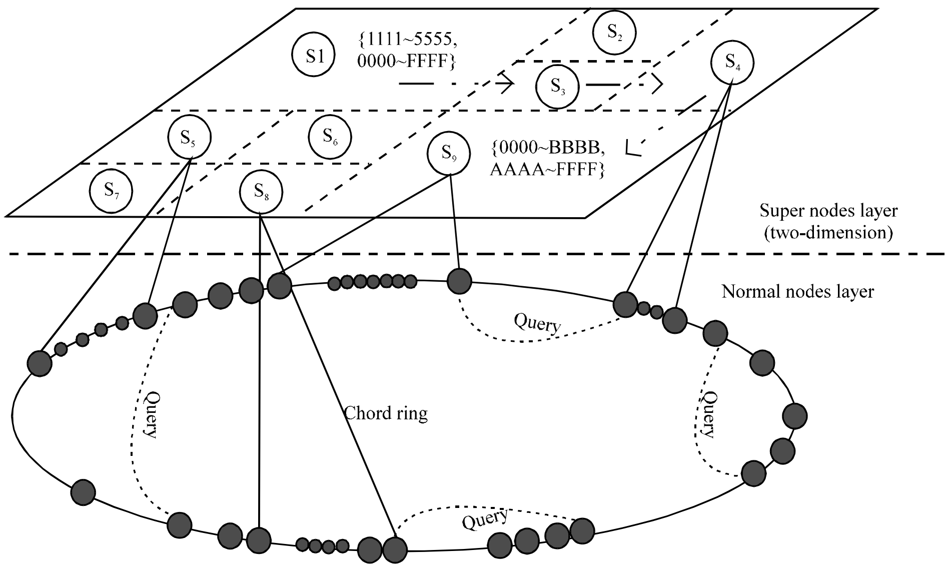

Fig. 3: Hierarchy P2P network based on two-dimensional CAN

besides being responsible for the Chord identifier interval from its predecessor to it , maintains the linear leaf node interval within which its leaf nodes fall. This method can balance the total load of super layer, but there is still a problem: it ignores the local load bottlenecks of the super node layer which can lead to system congestion and reduce the system throughput.

KEY WORDS SPACE

Super node management space: In the P2P network of hierarchical structure, the super layer and the common node layer mapped the load to the single dimensional space, but this could not fundamentally solve the problem of local characteristics of the load, so we introduced the concept of multi dimensional space into the super nodes' management of the common nodes. The nodes either in the super node layer or in the common node layer are organized in accordance with a single dimension Chord ring structure and the scale of its identifier space is determined by the Hash function. The management space of super nodes references the basic idea of extensible Content Addressable Network (CAN), divides it into the multi-dimensional space and it follow the independent mechanism for routing and data exchange. The specific topological structure is as shown in Fig. 3.

The simplest method to generate a multidimensional identifier from the plane of hash value is to allocate a fixed number of bits for the coordinates of each dimension. If the single dimension marking length is n, the spatial range is $[0, 2^n]$. The management of space is mapped for d dimensions, to the system having n_s super nodes, the average search path length is $O((d/4)(n_s 1/d))$. Each super node has a constant number of neighbours 2d.

Load of super node: Load generally refers to the number of data files the node stores and manages. But Stefan Zoels thought it should be more suitable to define it as the number of message nodes in the network system (especially heterogeneous network) send and receive. For nodes in the peer-to-peer network, there are two kinds of basic message load:

- When the file stored in the node is accessed, the destination node need to transmit a response message to the requesting user and this type of load is called a requesting message load
- In addition to send a response message, the node in the overlay network also need to send or forward routing and maintenance messages, this type of load is called routing message load

In general, the load of the response message and routing message to the nodes are mainly bandwidth consumption and the operation is basically the same, so this study will unified both for bandwidth load. At the same time, regardless the maintenance of whether the keyword query or data storage it needs the computational power of the node itself and the corresponding load is called computational load. Bandwidth load and computational load are abstracted for two types of resources of P2P network: Transmission resource and computing resource and we generally use the node Bandwidth Resource (BR) and node Computing Resource (CR) to represent. Load balancing is to constrain the resource distribution in network space, thereby enables the cyber source utilization rate reaches a maximum. As a whole, the individual effects of super nodes on the network or the system should be transparent and this is to say despite the load of a super node is constrained by two kinds of resources, the two can be uniformed. Therefore, the super node load this article tells refers to the carrying capacity of both the computing resources and transmission resource.

FAIR LOAD BALANCING METHOD

Load balancing algorithm: This algorithm calculates the consumption cost of the service resources by calculating the sum of resource consumption of the node (below uniformly called carrying cost), according to load balancing optimization of the P2P network, it used the node resource metric constraints: The service resource consumption rate of node N_j is f_B (N_j, B_t), in which B_t is a bearing resource demand constraint of the service request.

Set BR_j is the available resources of node N_j, the heuristic cost function of the node is:

$$C(N_j) = f_B(N_j, B_t) = B_t/BR_j \quad (1)$$

Due to the lack of ability for P2P network to know the global resource's distribution and the management operation of the super node layer is basically finished between the adjacent nodes, thus this study introducing regional consumption cost function of node N_j:

$$\text{Cost}(N_j) = \sum_{N_{ng} \in list(N_j)} C(N_{ng}) = \sum_{N_{ng} \in list(N_j)} \frac{B_t}{BR_{ng}} \quad (2)$$

This study introduced a weight constraint method for service resource utilization equity index, through the calculation of the fairness of the node's all neighbors' resource utilization to measure if there is fairness unbalanced load in the super node layer. Assuming the existence of sequences of X_1, X_2, ... , X_n, the fair index function f (x) to measure the sequence of equilibrium is defined as follows:

$$f(x) = \frac{(x_1 + x_2 + \ldots + x_n)^2}{n * (x_1^2 + \ldots . x_n^2)} = \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n * \sum_{i=1}^{n} x_i^2} \quad (3)$$

Take the node's area consumption cost function into the Eq. 3 and we get the node's regional load balancing fairness utility function:

$$f_B(N_j) = \left(\sum_{N_{ng} \in list(N_j)} \frac{B_t}{BR_{ng}}\right)^2 \Bigg/ n \bullet \sum_{N_{ng} \in list(N_j)} \left(\frac{B_t}{BR_{ng}}\right)^2 \quad (4)$$

The kernel methods of the fair load method based on the fair utility function are: Super node's overall load is statistical, if overloaded, the neighbor node's load fairness will be compared, in the situation of ensuring no overload choose fairness utility function of maximum value distribution, transfer part of the load to the neighbor node; otherwise, select the node which have the largest load capacity in the common nodes layer to join the super node layer and transfer its load. The detailed algorithm for nodes to join super layer is described as follows:

```
Algorithm: fair load balancing
Input: (Super Node Nj, Neighbors Node Table pList (*Nj)
  Ouput: The result of load balancing
  Begin Procedure
  coordinate = getHeaviestLoad(Nj);
  *cNode = getNode(pList(Nj),coordinate)£»
  *node = selectLightNode(*cNode,áLoad(Nj));
    if(*Node==NULL)
    nNode = getNorConductNode(Nj)£»
    transferLoad(nNode,Nj);
   else
    *cost = calculateCost(*node);
    transferLoad(*cost->largestNode,Nj);
     end if
   end Procedure
```

Network maintenance

Load transfer: According to partitioning demand of CAN space, load of node does not necessarily to split their management area half to the target node, it also can transfer the whole management region to the target node. If the load transfer is between the nodes of the super node layer, it will give priority to fairness index to decide to take the split transfer or transfer all; if there is a new node to join the super layer, in the premise of checking the load capacity of it, transfer the load according to the fair load-balancing algorithm.

Join and leaving of common node: Common node via bootstrap to join the network, first selected a start node, to establish a routing table of common node layer. Secondly, through the direct predecessor or successor in the route table to access super node layer network, became the leaf node responsible for the super node; super node will regularly test for the existence of the leaf node, if the node has withdrawn from the network, it would notify the relevant node updates the routing information.

Join and quit of super node: Node was selected to be the super node only in load imbalance situation and this has been mentioned in process 1; super node exit need to assign the node regional node it was responsible to other super nodes averagely in the same dimension. If the combined super node is overload or overloaded, it can be balanced by the algorithm proposed in this study.

PERFORMANCE ANALYSES

Configuration of experiments: Space identifier length of the network environment is used in this experiment is 10, the number of common nodes will be 1024, that is the number of nodes space reach saturation. Assume that the operation of the system was in a stable condition. The actual load and carrying capacity of the node are generated using the Pareto distribution and Zipf distribution (Zhu and Hu, 2005), which reflects the heterogeneity of the nodes. Carrying capacity $C_i = 1000/i^{\beta}$ ($\beta = 1.2$), the total carrying capacity of the network $C_T = \Sigma C_i$; the distribution of the actual load is corresponding to f_i = Pareto (α, θ) ($\alpha = 1.5$, $\theta = v(\alpha-1)/\alpha$), where, v = 0.3.0.05 p) C_T/n ($1 \le p \le 9$) is the mean value of the distribution. In order to guarantee the carrying capacity of the network nodes is higher than the actual load capacity, liner transformation is done to C_i, i.e., $C_i = C_i + \kappa$.Max $\{f_i|i<n\}$. The parameters used in this study to measure the load balancing performance including the smallest proportion of super nodes and the untilization of super node layer, which are got by comparing with the 2 Chord (Zhang and Zhang, 2010) system.

Smallest proportion of super nodes: During the simulation, while the load capacity of the nodes remains fixed, the actual load is variable. Figure 4 shows the comparison of the smallest proportion of the super nodes in the condition of Pareto load distribution. As shown in the figure, the method proposed can get better load balancing with the increasing of the load and the stability of the scale of the super node layer can be ensured. With the increasing of the total load, CAN space allocated according to fair load algorithm will be reasonable merged and the proportion of super nodes will be further reduced.

Utilization of super node layer: Figure 5 shows a comparison of super-node load capacity and actual load in case of the parameters v = 0.6, k = 5. The actual utilization of the nodes is 0.9002, 0.8980, 0.9013 and 0.8457 and the fairness function value is 0.9993, which indicated that the load get a more reasonable distribution. Figure 6 shows the average utilization of the super node layer, the CAN space add the nodes with higher capacity into the super node layer, therefore the average utilization of the method proposed in this study is between the two schemes of 2 Chord. As the nodes with higher carrying capacity added to the super layer, number of super nodes will reduce, thereby reducing the network cost of the precise queries and range queries.

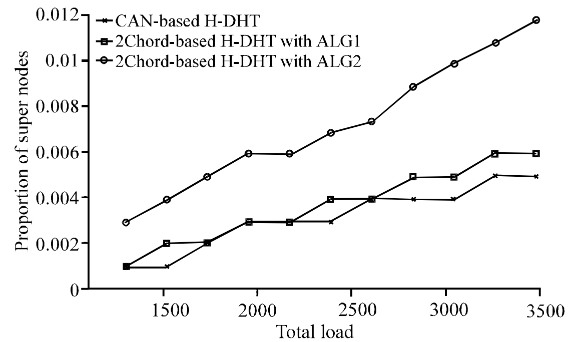

Fig. 4: Smallest proportion of super nodes

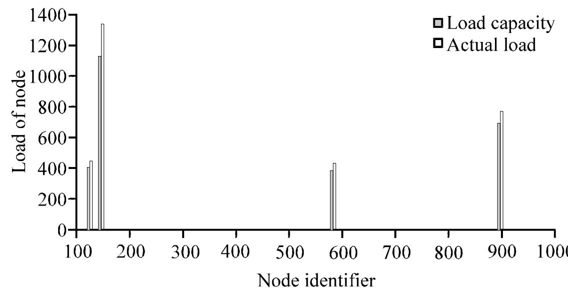

Fig. 5: Load and capacity of super nodes

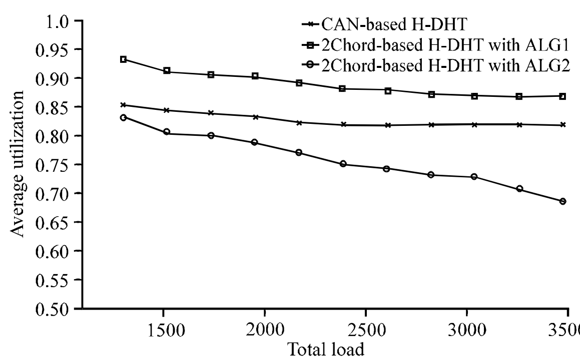

Fig. 6: Average utilization of super node layer

CONCLUSION

The performance of hierarchical P2P network depends largely on the supernode management and the load management is the most important. This study make the identity of the management multidimensional in using of the CAN space and add the fairness utility function to balance the load of super nodes. Simulation results show that this method reasonably adjust the load between the super nodes, effectively balances the load between the supernode and` improves the fairness of the load balancing on the basis of maintain the hierarchy of the P2P network. This method also reduces the probability of the unevenness of the super-layer local throughput.

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