Considering The Nodes Join/Leave Behavior in The Analysis of Chord Stabilization in The Heterogeneous Network

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Summary
Since each node in the heterogeneous network has a various device and connection capabilities, the hierarchical architecture is a suitable structured P2P architecture for this kind of network, where the more stable nodes (super nodes) acts as a gateway for other less stable nodes (normal nodes). While structured peer-to-peer (P2P) has benefits of its scalability and capability in performing a successful query lookup, its stability is suffered from the dynamics of networks that form the P2P overlay. The dynamics of network, called churn, is affected by the nodes joining and leaving continuously in the network. Previous works on the analysis of impact of churn in structured P2P have not yet distinguished the impacts of nodes join events and of nodes leave events. In this paper we investigate the effect of churn to the performance of Chord protocol by observing the different impact caused by nodes join events and nodes leave events. Distinguising the impacts of nodes join events and nodes leave events is an important point in maintaining the stability of Chord overlay that implement hierarchical architecture. In the previous approach, when a super node (which is a member of Chord ring) experiences a failure, the normal nodes should perform individual rejoin. From the experiments we found that the increasing of node join events lead to a significant increasing of the successful lookup latency and decreasing of successful lookup rate, even more significant than the impacts caused by nodes leave events. Regarding to these results, the individual rejoin, as commonly implemented in current Chord-based hierarchical P2P, will suffer the overlay stability. In addition, we also note that in order to hold the relative-stable performance, nodes leave events produce higher traffic load than nodes join events.

Keywords
Churn, hierarchical P2P, stability, heterogeneous network

1. Introduction

Peer-to-peer (P2P) network is a distributed system that has benefits in scalability and resources/services efficiency. In the context of resource efficiency, P2P network offer a concept of resources/services sharing, to reduce the services availability dependency to the central node (server) that leads to single node failure. The increasing of resources efficiency is reached by optimization of the capability of each participant node. Currently, P2P system has been implemented in Internet applications, but it is potential to implement P2P in an ubiquitous computing that has independencies and inter-entity collaboration characteristics.

One of the popular P2P implementation is data/file sharing applications. In an enterprise organization, it is common to use an integrated information that come from various database reside in servers owned by other institutions in different area. Some applications that suitable to implement P2P network are e-health services, traffic management system and food/commodity management system.

In a P2P network, the implemented resources/services query algorithm is dependent on the implemented overlay architecture. Two types of P2P architectures are unstructured and structured [1]. The unstructured architecture includes the centralized type like Napster [2], fully distributed (e.g. Gnutella [3]) and the hybrid architecture (Kazaa [4]). Although the unstructured P2P has benefits on simplicity and stability, the most common problem of the unstructured P2P is the high traffic load as the impact of its flooding search method.

The new generation of P2P is structured architecture, as implemented in CAN [5], Chord [6], Pastry [7], and Tapestry [8]. It was designed to address the efficiency and scalability problems in unstructured architecture. To maintain the structured overlay, the system retrieve the entry of a Hash table to lookup the querying services/resources. To distribute the index information of the shared objects/services to other peers, the system used a distributed hash table (DHT). However structured P2P is suffered from the dynamics of peers, which is a natural characteristic of heterogeneous network. This paper focused on Chord which has the best scalability in the structured P2P architecture with the maximum nodes to retrieve and hash table size are O(log n) for an overlay network build by n peers.

Chord implements consistent hashing to define an identifier of a node and the object key of the shared objects/services. The identifier of a node is obtained from the hash value of the node identifier (such as SHA-1) and the key identifier is obtained from the object identity (such as file's name). The identifier is ordered in a modulo 2^m ring size, for m-bit identifier. The key k is assigned to the first node that has the same value or follows the identifier k in the identifier space. This node is the successor node

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of key k, called successor(k). Suppose the identifiers are represented in a ring with the number of 0 to 2^m-1, then the successor(k) is the first node (succeed k) in the clockwise direction. Each node has a finger table (with maximum entry m) and a successor list. When a node sends a query, a receiving node performs a lookup in its finger table to find the suitable finger i entry. The query will be forwarded to the node s which is the successor of i that responsible to the queried object. Then node s sends the queried node address direct to the requester node, so the requester node is able to contact the owner of the queried

2. Nodes Join and Leave Mechanism

Fig 1. shows the steps when a node n joins the system at a position between p and s. It will contact the node s and tells s that currently s is its successor (Fig.1.a). Node s then updates its predecessor entry to point to new joining node n to replace the former node p (Fig.1.b). This mechanism will not give node p information about the node n as its new successor automatically. Each node in the Chord ring performs stabilization periodically by sending a message to its successor nodes (node also p sends a message to node s). The successor node responses by sending message contain the information of its current predecessor. By receiving this response, node p knew that the message contains identity of node n (not p), then p should replace its successor node to n. The last step in this stabilization mechanism is the node p sends a message to no n, telling that n now is its successor, then node n should point its predecessor pointer to p (Fig.1.c).

When a node leave the system according to the volunteer leaving or to any disconnection problem (node failure), the system does not perform any related stabilization mechanism. While in the voluntary one, the leaving node transfer its shared-object information first to its successor node before leaving, it does not happen in node failure event. The fundamental things in a P2P networks is the ability to maintain its overlay due to the occurrences of churn. Churn is a dynamic condition of P2P network when a node joins or leaving the system concurrently.

3. Churn Impacts Analysis

Some previous research in the interest area of impacts of churn to the P2P network performance were taking a view from the common DHT performance [9-11], and some were focused on Chord [12]. But to our best of knowledge, none of them explicitly distinguished between the impacts of churn affected by nodes join and those by nodes leave/failure.

This paper present an analysis of impacts of churn based on the nodes join and leave. To our opinion, this distinguished analysis is needed to identify the impacts clearly, since in the heterogeneous networks the connection capabilities of nodes are various. By understanding which event is more influence to the system, we can develop the algorithm addressing these problems effectively. In a hierarchical P2P architecture, the failure of a super node (gateway) has a domino effects to the normal nodes under its responsibility. Then it is important to develop an algorithm to handle these nodes in performing rejoin process to the system in a minimum cost.

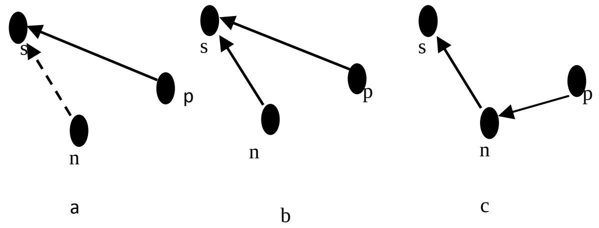

Fig. 1 Node joins mechanism

There are two factors that impact the system stability : internal and external factors. The internal factors are controllable factors, means that we can provide an optimal value to that kind of parameters when developing an algorithm to maintain the protocol performance. Two internal factors in Chord are the size of finger table and successor list. As the opposite, the occurrences of the external factors are based on users' behavior and are not fully controllable. These are common due to the dynamism of the heterogeneous networks, as the consequences of the node join/leave concurrently (churn). The only way to handle these events is performing anticipations to reduce the impacts to minimize the system performance degradation. Churn is an external factor that impact to Chord ring size and stabilization, as well as lookup latency. The lookup latency is a period of a requester node to get the response of the query lookup (notes : the path length/the amount of node to visit to perform lookup query follows O(log n)). The other external factors that impact the performance of the system are nodes join/leave and lookup query frequency in a unit time. The first term refers to churn rate and the second is lookup rate. The higher the both factors lead to the higher system workload.

4. Experiments and Analysis

4.1 Simulation Environtment

The experiment is performed using Peersim simulator [13], a specific software simulator for P2P networking [14]. The input parameter to be simulated is node join/leave frequency (churn rate) for each of three conditions : fixed

Chord ring-size, increased Chord ring-size, and decrease Chord ring-size. The nodes leaving have the same behavior with the nodes failure, which means that the leaving node does not provide any announcement nor information transfer to rest nodes in the system. All the experiments are applied on initial network size 5000 nodes. To obtained the results focuse on the impacts of churn rate in nodes join and leave events, we hold the the finger table size in the fixed value. This also consider that in Chord we can apply existing Hash function like SHA-1 that implement the 128-bit table entry. The output to be observed are the system performances which are consist of lookup latency and success rate ratio, as well as the network traffic loads which reflected in number of stabilization traffics per lookup query. The lookup latency is time consumed to perform a successful lookup query, while the success rate ratio is the ratio between the successful lookup query and total lookup query. The stabilization traffic load is amount of stabilize messages that must be sent to maintain the system stability during the successful lookup query. The main tasks of stabilize message is to update the finger table when a new node join as a new peer and also to fix the invalid successor list due to the node leaving events.

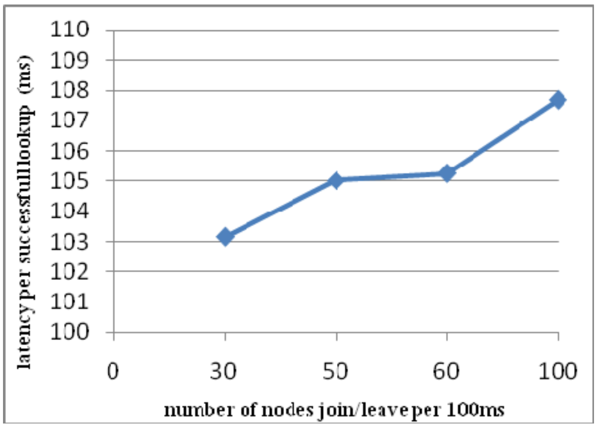

Fig. 1 The latency per successful lookup under various churn rate in fixed ring size

4.2 Result Analysis

For the basic experiment we first set the nodes leaving and joining the overlay concurrently in the same number. Since the leaving nodes are replaced by the same number of joining nodes then the ring size is remained the same. The system workload is raised up along with the increasing of the number of churn events (churn rate). This naturally will impact to the longer time needed to complete a lookup query (lookup latency) as shown in Fig.2. The domino effect is the system's performance degradation in completing a lookup query request (successful lookup rate). Fig.3 shows the performance of Chord in completing lookup query requests under various churn rate in a fixed ring size.

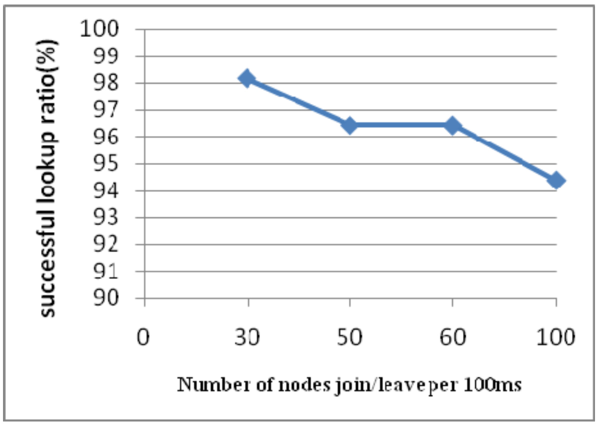

Fig. 2 The successful lookup ratio under various churn rate

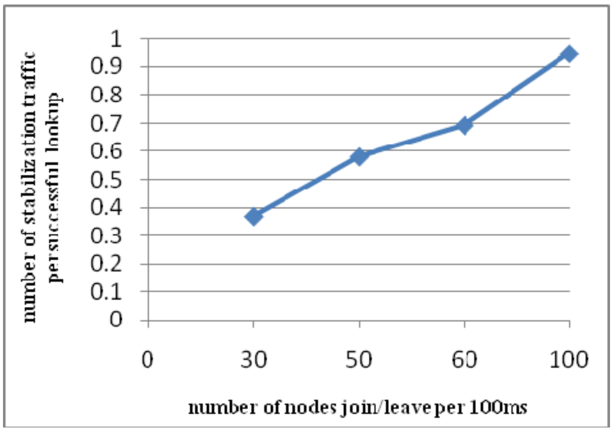

Fig. 3 The successful lookup ratio under various churn rate in a fixed ring size

This condition also produces the higher traffic load, due to the stabilization that must be performed to maintain the Chord ring structure by sending a probing message to ensure that the successor node is valid. When a query lookup is performed, and a wrong node's successor is found, then a stabilization mechanism must be performed first. Fig. 4 shows that the stabilization message that must be sent for each lookup query is increased as affected by the increasing of the amount of churn events.

Using formula (1) the calculation provides the correlation coefficient more than 0.99, means that the lookup latency has strong-positive correlation with traffic load [15].

$$Correl(X,Y)=\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \quad (1)$$

where: X is set of lookup latency and
Y is set of traffic stabilization.

As the aim of the research is to investigate the impacts of nodes join/leave events to the Chord performance, the following experiments are designed in a distinguished the two categories. The first category is the performance and traffic load caused by churn when there are only nodes join events and the second is those in a churn when there are only nodes leave events.

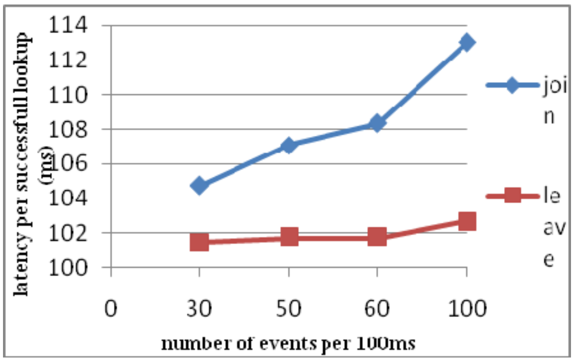

Fig. 4 The comparison of latency per successful lookup between node join events and nodes leave events

The increasing of churn leads to the more significant impacts to the nodes join condition than to the nodes leaving condition. In Fig. 5 we can see that the successful lookup latency achievement is relative stable in the node leaving events, while the contrast is in the node join events. The nodes join event is sensitive to the increasing of the nodes join rate. In our opinion this due to the longer steps that should be performed when a node joins to the ring, as described in Section 2. This condition suffers the system stability and lead to the performance degradation in its abilllity to complete the lookup query request succesfully (see Fig.6).

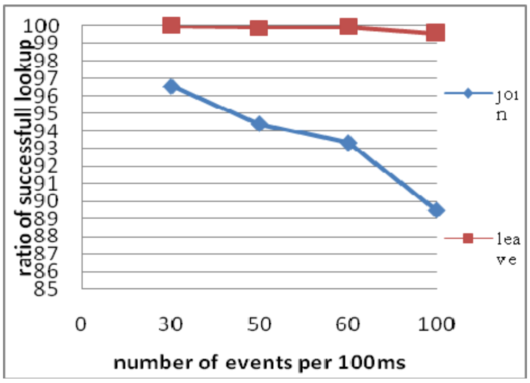

Fig. 5 The comparison of ratio of successful lookup between node join events and nodes leave events

The separate experiments of nodes join and leave events have investigated a more detailed behaviour in the context of traffic loads produced by both events. From Fig.7 we can see that the stable successful ratio in node leaving event is at a cost of higher stabilization effort it should be performed. The load traffics produced per lookup query in node leave event is increased significantly while the leave rate is increased. In other words, when a system has a condition that node leave events is higher than node join events, than the system should performed more effort to stabilize the overlay. To our opinion, this fact is a logical consequencies, since the nodes leave the overlay without any confirmation to the rest nodes. This condition caused the not uptodate of the finger table. Since to be able to perform a lookup query successfully the lookup process need a valid finger table, the the fix finger process should be performed first each time the invalid finger table entry is found. These effort are less in nodes join events, since each time a new node joins the Chord ring, the finger table and succesor list is updated.

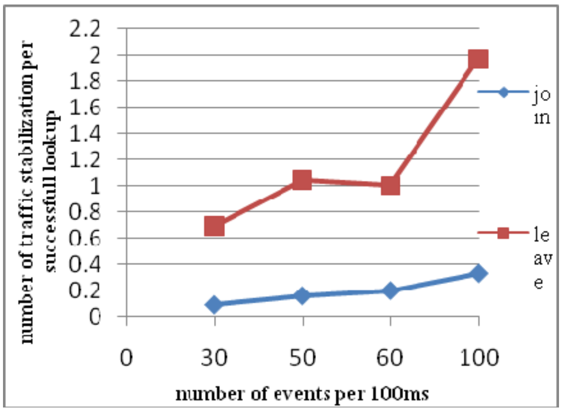

Fig. 6 The comparison of stabilization traffic load per successful lookup between node join events and nodes leave events

5. Conclusions and Future Works

From the experiments results we conclude that the performance of node join events in the increasing of churn rate is more sensitive than in the increasing of node leave events. To our opinion, this is an important point in developing hierarchical P2P protocol. The hierarchical P2P is suitable to the heterogeneous network which is the nodes capability are various. In this context, the super peer is a node that became a member of Chord ring due to the higher capability it has than the normal node has. Since the normal nodes involved to the system through the super peer node, then the failure of a superperer will lead the normal nodes to the unconnected from the system condition. For this reason, the way how the normal nodes perform rejoin mechanism is an important thing in to not suffering the performance of the network. If a large amount of disconnected normal nodes rejoin to the Chord ring individually, then the performance of the system will degrade significantly. The close agenda of our future research is developing a normal node rejoin mechanism that addresses these problems while keeping the message size and frequency in moderate level.

References

[1] J.Kangasharju, "*Peer-to-Peer Systems*", Handbook of Research on Ubiquitous Computing Technology for Real Time Enterprises pp.174-189, 2008

[2] http://www.napster.com

[3] http://www.gnutella.com

[4] http://www.kazaa.com

[5] S. Ratnasamy, P. Francis, M. Handley, R. Karp, and S. Schenker, "*A Scalable Content-Addressable Network*". Proceedings of the 2001 Conference on Applications, Technologies, Architectures, and Protocols For Computer Communications (SIGCOMM '01) pp. 161–172, 2001.

[6] I.Stoica, R.Morris, D.Liben-Nowel, D.Karger, M.F. Kaashoek, F. Dabek, H. Balakrishnan , " *Chord: A Scalable Peer-to-peer Lookup Service for Internet Applications*", Proceeding of SIGCOMM 2001, ACM Press 2001, pp. 149-160, 2001

[7] A. Rowstron and P. Druschel, "*Pastry: Scalable, decentralized object location, and routing for large-scale peer-to-peer systems*", Lecture Notes in Computer Science, 2218:329–350, 2001

[8] B. Y. Zhao, L. Huang, J. Stribling, S. Rhea, A. D. Joseph, and J. D. Kubiatowicz, "*Tapestry: A Resilient Global-scale Overlay for Service Deployment*," *IEEE Journal on Selected Areas in Communications*, vol. 22, no. 1, pp. 41–53, 2004.

[9] J. Li, J. Stribling, T. M. Gil, R. Moris, and M. F. Kaashoek, "*Comparing the Perfonnance of Distributed Hash Tables under Chum,*" Proceeding of The 3rd International Workshop on Peer-to-Peer Systems (IPTPS), San Diego, CA 2004

[10] D.Yang, Y.X.Zhang, H.K.Zhang, T.Y.Wu, and H.C.Chao, *"Multi-factors Oriented Study of P2P Churn"*, International Journal of Communication Systems, 2009

[11] Z.Liu, R.Yuan, Z.Li, H.Li, and G.Chen, "Survive Under High Churn in Structured P2P Systems: Evaluation and Strategy", LNCS 3994, pp. 404–411, Springer-Verlag Berlin Heidelberg, 2006.

[12] G.Kunzmann, A.Binzen, and R.Henjes, *"Analyzing and modifying chord's stabilization algorithm to handle high churn rate"*, Proceeding of The 6th Malaysia International Conference on Communications (MICC) in Conjunction with International Conference on Networks (ICON), Kuala Lumpur, Malaysia, 2005.

[13] http://peersim.sourceforge.net

[14] R.Bhardwa, A.K. Upadhyay, V.S. Dixit, " *An Overview on Tools for Peer to Peer Network Simulation*", International Journal of Computer Applications (0975 - 8887)Volume 1 – No. 19, 2010

[15] Aunuddin, "Statistika : Rancangan dan Analisis Data", ISBN979-493-115-2, IPBPres,2005,Bogor, pp.20.

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