Locality Support for Mobile P2P Network

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ABSTRACT
Compared to Client/Server architecture, P2P architecture has the advantages of service availability, self-organization, and fault tolerance. However, the topology mismatching problem between logical P2P overlay network and underlying physical IP network has resulted in performance degradation of P2P network due to the randomly joining and leaving of peers, causing a large volume of redundant messages in the Internet. This situation is even more severe in wireless mobile P2P network. This study proposes a location-aware wireless mobile (LAWM) P2P architecture which adds the locality support for peers in order to alleviate the topology mismatching problem. LAWM employs a two-tier architecture where the upper tier is a Chord overlay network composed of super-peers, grouping nearby peers according to their location information, and the lower tier composed of clusters of peers, connecting to the physically closest super-peers. Simulation results show that the proposed LAWM architecture not only solves the topology mismatching problem but also significantly reduces the average neighbor's response time. Furthermore, the impact of the total number of peers, peer mobility ratio, and cluster size on performance is also demonstrated.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *network topology, network communications, wireless communication.*

General Terms
Performance, Design, Experimentation, Security

Keywords
P2P, topology mismatch, Chord, super-peer

1. INTRODUCTION
The advance on mobile communication infrastructure has extended the fixed Internet to wireless Internet, and the advanced computer manufacturing technology has created a new class of computing devices such as mobile phones, wireless Personal Digital Assistants (PDAs), smart phones, and UMPC (Ultra Mobile Personal Computer) in addition to now omnipresent laptops. A new computing paradigm called pervasive computing or ubiquitous computing has begun to surface offering a dynamic, active, spontaneous space where a spectrum of computers can freely communicate with each other and share resources. Through the seamless integration of heterogeneous network and computing devices, new functionality can be created, user productivity can be enhanced, human thought and activity with digital information can be augmented, and the overall daily tasks can be simplified [5].

Peer-to-Peer systems have gained tremendous attention of many researchers and companies alike through the widespread use of Napster and Gnutella [12]. Each node in a P2P system is presumed to have the equivalent functionality and is willing to share resources. Because of its ability to pool together and harness the large volume of resources, P2P systems' features include scalability, service availability, self-organization, fault tolerance, and load balancing. However, most P2P systems assume peers are using fixed Internet instead of wireless networks. Here we consider a mobile P2P network is an infrastructure designed to support mobile devices and wireless networks. That is, a mobile P2P architecture has to address the special characteristics of mobile environment such as high mobility, frequent connection and disconnection, and location-dependency of mobile devices.

A P2P network is an abstract, logical network called an overlay network which operates on top of a physical network. Because of the mechanism of a peer randomly joining and leaving a P2P network, topology mismatching problem occurs between a P2P overlay network and the underlying physical network. There are many types of P2P systems, and each of them has its own strength and weakness. In unstructured P2P systems like Gnutella and Freenet [3], there is no control of peers joining or leaving the system, and the search query is performed by flooding the network producing a huge amount of redundant messages and an inefficient network. Another source of inefficiency is due to the limited capabilities of some peers, assumed equal roles and responsibilities, in Gnutella system. As reported in August 2000, Gnutella network experienced degraded performance with slow response time and limited resource availability because of some dying peers [14]. In structured systems like Chord [12], CAN [10], or Pastry [11], the joining and leaving of peers are highly controlled, and the search query is performed by following a predetermined path from the source peer to the destination peer. However, structured P2P systems might suffer the same slow response time or limited availability of unstructured systems because of weak capabilities of some peers.

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Recently, the concept of super-peer networks has been proposed because a super-peer network combines the advantages of structured networks and unstructured P2P networks [14]. It has the potential of exploiting the efficiency of centralized search while maintaining the fault tolerance, self-organization, and service availability of distributed search. On the other hand, some researches have proposed adding the location information of peers to solve the topology mismatching problem [6, 7]. Therefore, this study proposes a location-aware wireless mobile (LAWM) P2P architecture which adds the locality support for peers in order to alleviate the topology mismatching problem. LAWM employs a two-tier architecture where the upper tier is a Chord overlay network consisting of super-peers, grouping nearby peers according to their location information, and the lower tier consisting of clusters of peers, connecting to the physically closest super-peers.

The goal of this study is to explore the locality feature of mobile peers and investigate the benefits of employing a super-peer overlay network. The contribution of this study can be stated as finding the answers of the following research questions:

1. Will the addition of locality support for mobile peers solve the topology mismatching problem?

2. What is the performance benefit of employing a two-tier super-peer/normal-peer P2P architecture compared to a single tier super-peer architecture such as Chord?

3. What is the effect of cluster size of peers and peer mobility ratio (percentage of peers in a cluster that moves to another location in a given time) on two-tier suepr-peer/normal-peer P2P architecture?

The rest of this paper is organized as follows. Section 2 discusses background and related works in detail. Section 3 presents the proposed LAWM P2P architecture, including design philosophy and system architecture. Section 4 evaluates the performance of the proposed system through the simulation and experiments on a developed prototype. Finally, Section 5 concludes this study and provides future research directions.

2. RELATED WORK

Many efforts have been devoted to design good search protocols to improve the search efficiency of locating a node with a particular data item. CAN, Chord, Pastry, and Tapestry [16] are such examples for supporting point queries, and any protocol of them can be used in the upper tier (super-peers) of the proposed two-tier architecture. Here, the Chord lookup protocol is adopted because of its simplicity and easy implementation.

Recent studies have begun to focus on using the location information of peers to solve the topology mismatching problem of P2P network. Liu [7] proposes the *Adaptive Connection Establishment (ACE)*. ACE is an algorithm which aims to build an overlay multicast tree among each source node and the peers within a certain diameter from the source peer. It also optimizes the neighbor connections that are not on the tree while retaining the search scope. ACE operates by building a minimum spanning tree for each peer together with its neighboring peers within a certain diameter according to its cost table. A cost table is constructed by each peer, which periodically probes its neighbors. Here, the cost stands for the network delay between any two peers.

Liu [8] further proposes *Location-aware Topology Matching (LTM)* technique which tries to build an efficient overlay by choosing physically closer nodes as logical neighbors and disconnecting nodes with slower connections. In LTM scheme, each peer floods a TTL2-detector message to all of its neighbors within two hops distance, and estimates the quality of connections with its neighbors periodically, based on the TTL2-detector message received. The connections to low quality neighbor peers are deleted from the system. The locality of both ACE and LTM are achieved by optimizing the P2P network repeatedly. Though ACE or LTM might alleviate the topology mismatching problem, they also incur extra messages overhead, and they do not exploit the heterogeneity of peers, assumed equal roles and responsibilities in a P2P network.

Xu [13] uses *landmarks*, the latency between each peer and multiple stable Internet servers, to determine the distance between peers. The measurement of landmarks is conducted in global P2P domain and it needs the support of additional landmarks. Thus, the search scope of P2P systems might be affected. Researchers in [15] build a locality-aware overlay, called mOverlay, by grouping peers into clusters using dynamic landmark technology. When a peer wants to join the mOverlay, it first randomly selects a group to join and then pings its neighbors to see whether its landmark ordering number is the same as that of its neighbors. If not, it switches to another group until it finds a group with the same landmark ordering number. The present study takes the similar approach as landmarks but it utilizes reliable location measurement technologies such as GPS, A-GPS, E-OTD, or UL-TOA [2] instead of landmarks to find the location of peers, and thus the inaccuracy and inefficiency of landmarks measurement can be avoided.

Ferreria [4] proposes a two-level P2P overlay architecture where the global overlay is composed of all peers in the P2P network and the local overlay is composed of peers with nearby IP networks according to their autonomous system number. Since each peer participates in both global overlay and local overlay, it must maintain two distributed hash tables. When a peer wants to perform a search query, it sends the query to the local overlay first, and then to the global overlay if the query is not answered in the local overlay. The problem with this approach is that each peer participates in two overlays and incurs heavy maintenance overhead. The two-tier P2P architecture proposed in this study is similar to that of Ferreria since it also consists of two overlays. However these two overlays are not overlapping. The upper overlay is actually a super-peer network which groups nearby normal-peers according to their location information, and the lower tier consists of clusters of normal-peers, connecting to the physically closest super-peers. The proposed approach takes advantages of the heterogeneity of peers since it distinguishes the capability of peers and allows the peers with better capabilities (CPU, memory, storage space, etc.) to act as super-peers to enhance searching performance. It also solves the topology mismatching problem since the peers' locations are obtained through reliable mobile location measurement technologies (GPS, A-GPS, E-TOD, etc.).

THE SYSTEM MODEL

2.1 Design Philosophy and Architecture

The proposed LAWM P2P architecture consists of two tiers. The upper tier peers are called super-peers and the lower tier peers are called normal-peers. The two-tier architecture combines the best features of centralized and distributed P2P networks to ensure the faster data lookup of centralized structure and the better load balancing and system stability of distributed structure. The upper tier forms a ring and uses Chord protocol for faster data lookup and thus reduces the maintenance overhead of heterogeneous networks. The lower tier forms a cluster that groups normal-peers based on their location information, and the cluster is attached to a physically nearby super-peer. Figure 1 shows the system architecture where the super-peer ring is composed of nodes 5, 17, 34 and 45. Four clusters 1, 2, 3, and 4 are attached to nodes 45, 5, 17, and 34 respectively.

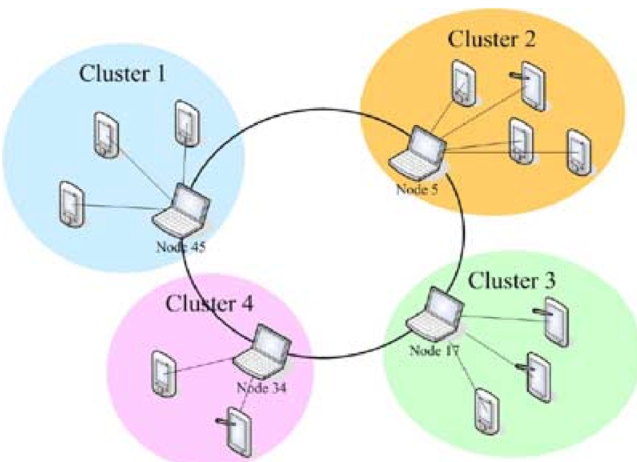

Figure 1. The system architecture overview

The differences between a mobile P2P network and a wired P2P network are the former's peers have higher mobility, and thus higher connection and disconnection rate of peers. To handle the mobility, each super-peer in LAWM needs to monitor the movement of normal-peers in addition to the finger table of Chord. When a super-peer dies, an election protocol such as majority protocol or quorum consensus protocol [1] is run to elect a normal-peer based on its capability to substitute the dying super-peer. For example, in Figure 1, if the super-peer 5 in cluster 2 for some reason does not respond to the queries from its peers within a certain period of time, the election protocol will be run to elect a normal-peer from cluster 1 to replace it. Because the upper tier uses the Chord protocol, each super-peer has to maintain a finger table. A super-peer also has to know the structure of its cluster and its cluster peers, and it has to maintain another table for its peers which we called Normal-Peer (NP) table, as shown in Table 1.

Table 1. The data structure of NP table

Item	Description
Nod	Node ordering number
IP	Node IP address
Port	Node's port number
isAlive	Is the node still alive? Value: T or F
Capability	Node's computing and storage power
id	Hashing value of a node's longitude and latitude position

2.2 Location Estimation Technique

This study uses Location Estimation Technique (LET) to support the locality of peers in LAWM P2P system. When a peer wants to join a P2P network, its location information (e.g. longitude of 2501.8887 and latitude of 12128.3807) is obtained through available location positioning technologies such as GPS, A-GPS, E-OTD, or UL-TOA. The peer's location information is then hashed to its node id. If the peer does not find any peer with the same hashed id, then it automatically becomes the super-peer and participates in the upper tier Chord ring regardless of its capability. However, if the peer finds a peer with the same id, then it becomes a member of that peer's cluster. A super-peer and its peers in the same cluster periodically communicate with each other and elect a peer with the best capability to be the super-peer.

The longitude/latitude values are hashed instead of the IP addresses because the former are more accurate than the latter. The hashing procedures are shown in Table 2. For example, a peer whose longitude value is 2501.8887 and latitude value is 12128.3807, then L = 2501, M = 12128, and P = 207048128. Figure 2 shows an example of the proposed two-tier mobile P2P network.

Table 2. Location estimation procedures

(a) Take the first 5 digits of longitude or latitude values.
(b) L = longitude value + 9000; M = latitude value + 18000
(c) Convert L and M to one dimensional value: P = L * 18000 + M
(d) node id = hash function (P)

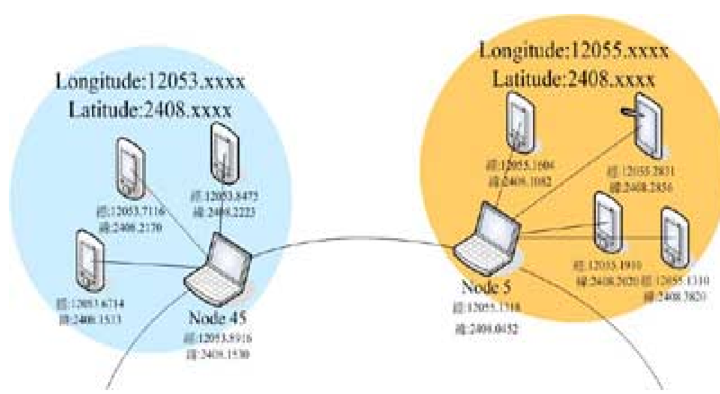

Figure 2. An example of the proposed mobile P2P network

2.3 Operations

The proposed LAWM two-tier architecture's upper tier is based on Chord. Therefore, node's operations such as joining, leaving, stabilizing, and searching are all the same as those of Chord. The differences between this study and Chord are briefly discussed below.

Joining and Leaving: If a peer is the first node of a P2P network, it will execute the *create* function and build a Chord ring. If a peer is not the first node, it will get a node id by hashing its longitude and latitude values. It then uses the id to find a super-peer with the same id; after that, it joins the super-peer's cluster. When a normal-peer wants to leave a cluster, it notifies its super-peer. The super peer will periodically update its NP table to detect its peers' abnormal disappearance. When a super-peer wants to leave a P2P system, it uses its NP table to find the normal-peer with the best capability to replace its role. When a super-peer disappears unexpectedly, the Chord ring can run *stabilize* function but the peers in the disappeared super-peer's cluster has to elect a new super-peer by themselves.

Searching: A normal-peer begins its search by sending a query to its super-peer which then tries to find a peer in its cluster with the response. If no peer in its cluster can answer the query, the super-peer runs the Chord protocol to find a peer with the response. Once a peer with the response is located, its information is forwarded to the querying peer.

Mobility: When a peer moves to another cluster, topology mismatching problem will occur. This study proposes a dynamic deployment mechanism to overcome this problem. The mechanism works as follows.

(a) A super peer communicates with its peers periodically.

(b) If a normal-peer leaves, the super-peer will update its NP table to reflect the fact that a normal-peer has left.

(c) The left normal-peer computes its new node id through hashing its longitude and latitude value and joins a super-peer with the same id.

(d) If a super-peer dies, leaves, or disappears abnormally, the normal-peers will find this out after a certain period of time (e.g. using timeout), and a new super-peer will be elected.

3. SIMULATION RESULTS AND DISCUSSIONS

The performance metrics used in the simulations are described first. Then, simulation settings are outlined. Finally, simulation results are shown and discussed.

3.1 Performance Metrics

The performance metrics are based on three parameters: average neighbor node's response time, peer mobility ratio, and cluster size. They are described briefly.

Average neighbor node's response time is used to measure the locality of a P2P system. In general, the better locality a P2P system has, the shorter response time it has. The response time is one of the most concerned criteria of P2P users. It is defined as the time period a source peer sends out a query till it receives the first response from any of its neighbors.

Peer mobility ratio is used to measure the effect of the mobility of peers has on the performance of a P2P network. A peer mobility ratio is defined as the ratio of peers, which have moved from one location to another location, to the total peers. That is, the percent of total peers that disconnect from the P2P network and then reconnect again after a certain period of time. The higher mobility ratio of peers is, the worse the performance a P2P network will be. However, if a P2P network supports locality, then its performance might be degraded gracefully instead of abruptly.

Cluster size is used to measure the effect of cluster size has on the performance of a P2P network. In a large P2P network, clusters help reduce the search time and can generate a better response time.

3.2 Settings

All simulations are run on an Intel PC with Pentium 2.8G CPU, 1G memory in Microsoft XP SP2 Professional operating system. The simulation software used is PlanetSim version 3.0 [9], which is written in Java, and is a simulation software for P2P network. PlanetSim consists of three layers: application layer, overlay layer, and network layer. All layers are customizable by developers. Currently, the Chord and Pastry overlay layers are supported in PlanetSim. This study extends the Chord overlay to support the proposed two-tier location aware mobile P2P architecture. The range of parameters is shown below:

Peer mobility ratio: 0% (static), 10%, 50%, and 90%.

Peer position: the longitude value and latitude value are within the range of Taiwan.

Peer total number: 100 to 1000, with the increment of 100.

Cluster size: 10, 50, and 100.

Simulation value: All values shown are the average of three runs of simulation.

Neighboring node: The definition is the same as that of Chord: a peer's neighboring node is its successor. A normal-peer's neighboring node is its super-peer and a super-peer's neighboring node is any peer of its cluster.

3.3 Results

The first simulation test is to see the effect of peer mobility ratio on a P2P network. Figure 3 shows the results of Chord and the proposed LAWM system. For 10% mobility ratio, LAWM outperforms Chord with or without locality support. For 50% mobility ratio, LAWM with locality support outperforms Chord. It is interesting to see that LAWM without locality support performs better than Chord when the total node number is below 500, above that Chord outperforms LAWM without locality support. This might be due to the fact that the bigger the mobility ratio, the LAWM without locality support will incur bigger overhead in tracing/finding its neighboring node and thus its *Average neighbor node's response time* is longer than that of Chord. When peer mobility ratio increases to 90%, LAWM with locality support still performs better than Chord which in turn performs better than LAWN without locality support.

The second simulation is designed to see the effect of a super-peer's cluster size and peers' mobility ratio on a P2P network. Figure 4 shows the simulation results. For 10% peer mobility ratio, LAWM with or without locality support outperforms Chord. For 50% peer mobility ratio, LAWM with locality support regardless of the cluster size outperforms Chord. However, the performance of LAWM without locality support is more interesting. Chord performs better than LAWM without locality support when the cluster size is 50 and 100, and the total node number is greater than 520, but Chord still performs worse than LAWM without locality support when the cluster size is 10 no matter what the total number of nodes is. For 90% peer mobility ratio, Chord still does not perform as good as LAWM with locality support regardless of what the cluster size is. However, it outperforms LAWM without locality support. From the results, it is obvious that clustering has a determined effect on the performance of a P2P system in addition to the locality support and peer's mobility ratio.

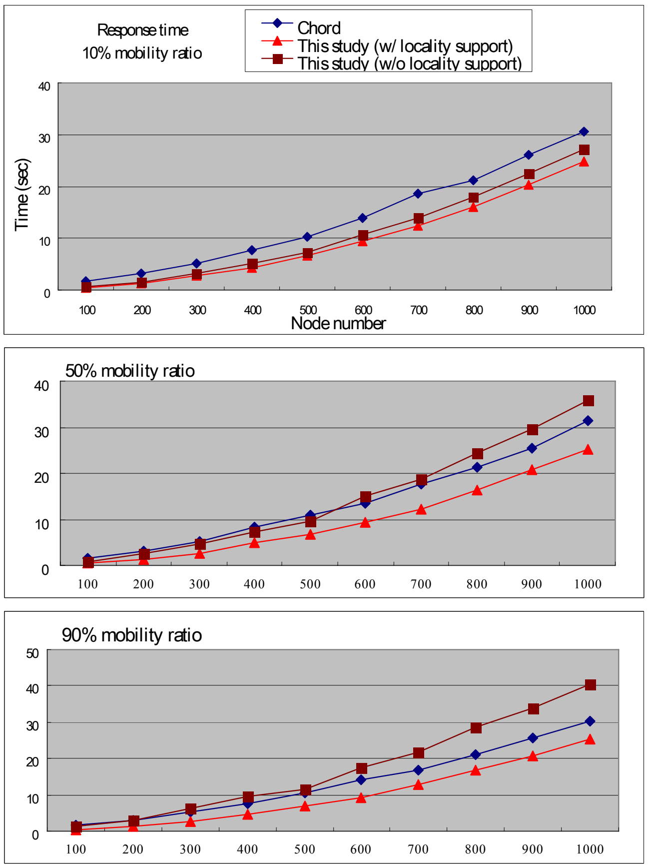

Figure 3. The effect of peer mobility ratio

4. CONCLUSION AND FUTURE WORK

This study proposes a two-tier location aware wireless mobile P2P architecture where the upper tier is a Chord overlay network consisting of super-peers, grouping nearby peers according to their location information, and the lower tier consists of clusters of peers, connecting to the physically closest super-peers. Simulation results show the effect of peer mobility ratio, the total number of nodes, and the cluster size on the performance of a P2P network. The locality support in LAWM can effectively overcome the topology mismatching problem caused by mobile peers' movement in a P2P network. Clustering support also helps to some degree on the average neighbor node's response time though it is not as effective as the locality support. The proposed LAWM outperforms Chord regardless of the cluster size and the peer

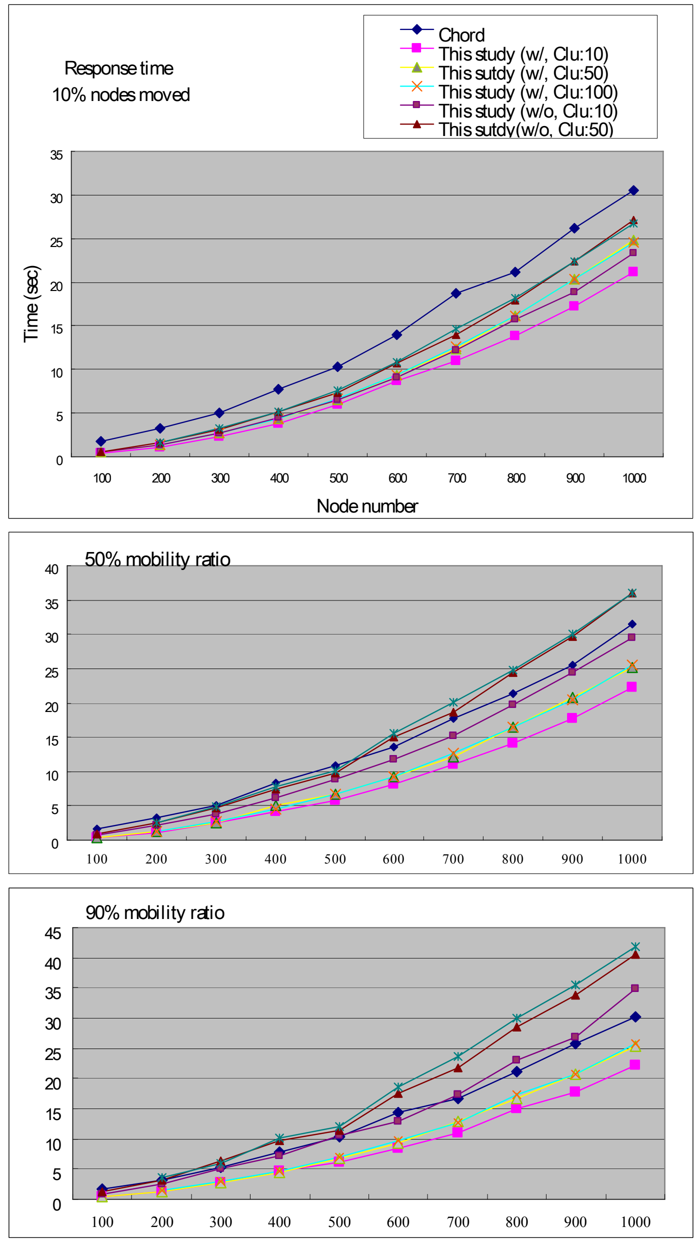

Figure 4. The effect of peer mobility ratio and cluster size

mobility ratio. However, Chord outperforms LAWM without locality support when the peer mobility ratio is greater than 50% and the total number of peers is greater than 500. Therefore, the addition of location information to an existing P2P network has the potential of greatly enhancing its query response time.

Limitations of this study include (a) it does not measure the search scope which is an indicator of the reachable range of a query in an information search space, and (b) it does not measure the traffic cost which has a determined effect on a system's scalability. These limitations are the future work that the current study is going to pursue in the near future.

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6. REFERENCES

[1] Agrawal, D. and Bernstein, A. J. A Non-blocking Quorum Consensus Protocol for Replicated Data. *IEEE Transactions on Parallel and Distributed Systems, 2*, 2 (1991), 171-179.

[2] Andersson, C. *GPRS and 3G Wireless Applications*. John Wiley & Sons, Inc., 2001.

[3] Clarke, I, Sandberg, O., Wiley, B., and Hong, T. W. Freenet: A Distributed Anonymous Information Storage and Retrieval System. *In Proceedings of the ICSI Workshop on Design Issues in Anomymity and Unobservability*, 2000, 44-66.

[4] Ferrera, R., Jagannathan, S., and Grama, A. Locality in Structured Peer-to-Peer Networks, *Journal of Parallel and Distributed Computing*, (2005), 257-273.

[5] Friday, A., Davies, N., Wallbank, N, Catterall, E., Pink, S. Supporting Service Discovery, Querying and Interaction in Ubiquitous Computing Environments. *ACM Baltzer Wireless Netw. (WINET): special issue: Pervasive Computing & Communication, 10,* 6 (2004), 631-641.

[6] Lin, C. H. *A Two-Tier Locality-Aware Peer-to-Peer Architecture*. Master thesis, National Tsing-Hua University, Taiwan, 2005.

[7] Liu, Y., Zhuang, Z., Xiao, L, and Ni, L. M. A Distributed Approach to Solving Overlay Mismatching Problem. In *Proceedings of the 24th International Conference on Distributed Computing Systems (ICDCS04)*, 2004, 132-139.

[8] Liu, Y, Xiao, L., Liu, X., Ni., L. M., and Zhang, X. Location Awareness in Unstructured Peer-to-Peer Systems. *IEEE Transactions on Parallel and Distributed Systems, 16*, 2 (2005), 163-174.

[9] PlanetSim, http://planet.urv.es/planetsim/, last accessed on March 1st, 2007.

[10] Ratnasamy, S., Francis, P., Handley, M, Karp, R., and Shenker S. A Scalable Content-Addressable Network. In *Proceedings of SIGCOMM*, 2001, 161-172.

[11] Rowstronl, A and Druschel, P. Pastry: Scalable, Decentralized Object Location and Routing for Large-scale Peer-to-Peer Systems. In *Proceedings of the 19th IFIP/ACM International Conference on Distributed Systems Platforms*, 2001, 329-350.

[12] Stoica, I. Chord: A Scalable Peer-To-Peer Lookup Protocol for Internet Applications. *IEEE/ACM Transactions on Networking, 11*, 1, 2003, 149-160.

[13] Xu, Z., Tang, C., and Zhang, Z. Building Topology-aware Overlays Using Global Soft-state. In *Proceedings of International Conference on Distributed Computing Systems (ICDCS)*, 2003, 500-508.

[14] Yang, B and Garcia-Molina, H. Designing a Super-Peer Network. In *Proceedings of the 19th International Conference on Data Engineering (ICDE 03)*, 2003, 49-60.

[15] Zhang, X. Y., Zhang Q., Zhang, Z. S., Song, G., and Zhu, W. A Construction of Locality-aware Overlay Network: mOverlay and its Performance. *IEEE Journal on Selected Areas in Communications, 22*, 1 (2004), 18-28.

[16] Zhao, B. Y., Kuibiatowicz, J. D., and Joseph, A. D. *Tapestry: An Infrastructures for Fault-Tolerant Wide-area Location and Routing*. Technical Report UCB/CSD-01-1141, University California, Berkeley, CA, 2001.