Locality-Aware Chord Networks Based on Cloud-Assistance

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***Abstract*—Peer-to-Peer (P2P) technologies have been widely applied in various network applications, such as BitTorrent, P2Plive, Skype, etc. Improving the performance of P2P networks has always been a topic of interest. The key to improving P2P networks is to solve the consistency problem, which states that the overlay network topology is not congruent to the physical network topology. The overlay network is a logical network topology built on existing physical networks. If overlay networks are constructed according to the location of peers, the consistency problem could be solved. In this paper, locality-aware Chord P2P networks based on cloud-assistance are proposed. A cloud database of mapping IP addresses onto geographical positions is built to completely manage the locality information of peers. Four new schemes of identification (ID) assignments associated with geographical positions of peers have been designed to construct the rings of Chord networks. The arrangement of peers on a ring is close to their physical positions. As a result, unnecessary searching routing can be reduced. Besides, a new download method which can select the nearest nodes to get resources has also been designed. The simulation experiments show the searching and downloading performance of our proposed locality-aware Chord networks can be improved.**

Keywords-P2P Networks; Cloud; Overlay Networks; Chord Networks.

I. INTRODUCTION

The ways of sharing resources are diverse, from traditional client-server model to peer-to-peer (P2P) and cloud-based models. Recently, P2P and cloud-based models have appeared in more and more network applications. Compared to P2P networks, cloud services can provide more scalable storage and computing power. However, for a successful cloud-based resource sharing, enough network bandwidth between user nodes and cloud systems is necessary. Besides, the use of P2P networks might be more convenient than cloud services because peers can join P2P networks without any authentication. Therefore, there still exist many popular P2P network applications, such as BitTorrent-like P2P systems [1], PPLive [2], and PPStream [3].

Two basic operations of P2P networks are searching and downloading processes. Peers need to search the desired resource by overlay network [4] to find which peer owns the resource and then download it directly. The overlay network is a logical network topology built on existing physical networks by logically connecting all of joining peers. In general, the edge of the overlay network is set up by a Transmission Control Protocol (TCP) connection. A long-latency delay may exist at the edges of the overlay network because the overlay network topology is not congruent to the physical network topology.

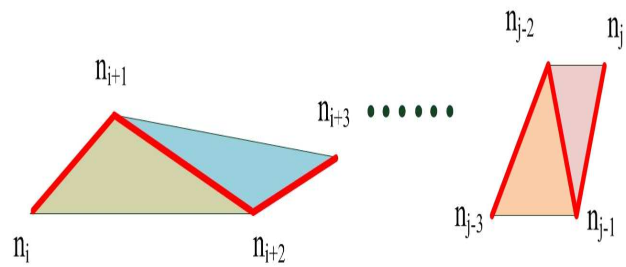

Figure 1. Triangle searching path.

Well-known peer-to-peer systems for file sharing are proposed in Napster [5] and Guntella [6]. The directory of the shared files is managed by a centralized server in Napster. The system scalability and single-point failure problem exist in the Napster system due to the centralized management. Guntella P2P system is also suffering from scalability problems because the message for locating a resource needs to be flooding over the overlay network. The more nodes in the system, the more flooding traffic could occur. To overcome the scalability problems, some structured P2P based on Distributed Hash Tables (DHT), such as Chord [7], CAN [8], and Tapestry [9], have been proposed. Each joining peer and the shared resource are given an unique identifier (ID) respectively generated by the same DHT hash function. The overlay networks are constructed as a tree or ring network topology by the IDs of peers. The information of the shared resources, such as the IP addresses of the owners, are distributed over the joining peers in load balance. In a DHT-based P2P system, a searching query message can be forwarded to its destination within $\bigcirc(logN)$ hops on overlay networks, where N is the number of nodes in the P2P system.

Although the DHT-based P2P systems have the advantage of scalability, the locality information of joining peers is not considered in construction of overlay networks. The consistency problem still exists and unnecessary triangle routing in physical networks could occur during the searching process. In a DHT-based P2P system, a searching query message is forwarded to the next peer until the owner(s) of resource is(are) found. There must exist a searching routing path for each resource query. An example is shown in Figure 1. On the routing path $(n_i, n_{i+1}, n_{i+2}, \cdots, n_j)$, the distance (n_i, n_{i+1}) should not be longer than the distance (n_i, n_{i+2}) in physical networks. It is obvious that the distance (n_{j-3}, n_{j-2}) is longer than the distance (n_{j-3}, n_{j-1}). We refer to this kind of unnecessary routing as triangle routing. The more triangle routing events occur in resource searching, the more delays and network bandwidth is wasted.

In the literature, many related works [10]-[14] attempted to solve the consistency problem by building topology-aware overlay networks with the assistance of locality information of peers, such as Autonomous System (AS), or Internet Service Provider (ISP) peers belong to. The improvement of these works is limited due to lack of precise locality information of nodes. In [14], a packet loss module installed on routers is given the ability to recognize P2P traffic and find out the AS and ISP to which packets belong. When the source and destination IP addresses of P2P packets are not at the same AS or ISP, the packet loss module will drop them with a predetermined probability. This way, peers have a high probability to get resources from their nearby peers and data traffic across different ISPs (or ASs) could be reduced.

Cloud-assisted P2P network applications in [15]-[17] have been proposed in the literature. They focus on some specific P2P applications but the fundamental problems of P2P networks are not further discussed. In [15], cloud services are applied to improve the transmission quality of P2P streaming. In [16], a reliable P2P-based service-oriented architecture is proposed by cloud-assistance. To provide successful resource reservation, the cloud system maintains the capabilities of peers, such as computing power, storage space, and network bandwidth. Resource reservations can be successful by several redundant resources from selected peers. In [17], the cloud system is used to handle spikes in the query of a popular resource. The queries of peers will automatically be transferred to the cloud system to seek popular resources when the load of peers is over the predefined threshold.

The P2P consistency problem can be efficiently improved if the locality information of all joining peers is known. A simple way of managing locality information is by having centralized dedicated servers, but the single point of failure, overloading, and scalability problems can not be avoided. One of the best solution is to migrate locality information of joining nodes from traditional servers to a cloud system with scalable storage and computing power. To completely manage locality information of joining nodes, a free database GeoLiteCity [18] is adopted for mapping IP addresses onto geographical positions. When peers join the system, geographical positions of peers are mapped by a query of GeoLiteCity and saved in another database.

In this paper, we focus on improving the Chord P2P networks based on cloud-assistance. In the original Chord system, a logical ring network topology is constructed in increasing order of IDs of peers in a clockwise direction. A peer can find its predecessor and successor to join the ring of Chord networks according to its ID number generated by a hash function. In fact, the logical position of a peer on the ring depends on its ID number without any concern of its locality information. As a result, the consistency problem can not be controlled. In our proposed locality-aware Chord networks, we have designed new strategies of ID assignments according to geographical positions to have an arrangement of peers on a ring approximately close in their physical positions.

The rest of the paper is organized as follows. The proposed system model based on cloud-assistance is described in the next Section. The locality-aware Chord networks with new schemes of ID assignments are given in Section III. The performance of resource searching and downloading in our proposed Chord networks is evaluated by simulations in Section IV. Finally, some concluding remarks and future work are given in Section V.

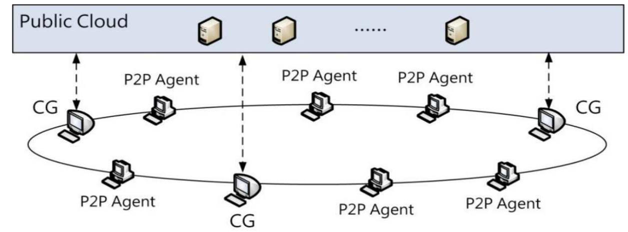

Figure 2. Chord networks with cloud-assistance.

II. System Model based on Cloud Computing

The proposed locality-aware Chord networks are designed on the basis of our previous work. In [19], we have implemented a locality-aware unstructured P2P network using a cloud-assisted platform. A free database GeoLiteCity is built on Hadoop [20] cloud system for mapping IP addresses onto geographical positions referred to as locality information of peers. On that platform, two kinds of peers are implemented, namely P2P agent and Cloud Gateway (CG) node. The CG node with more computing power and network bandwidth can be the interface between peers and the cloud system. A P2P agent, which is a general peer, can request the CG node to upload its IP address to the cloud system. The geographical position of a peer can be gained by a query of GeoLiteCity using its IP address and then maintained in the cloud system.

In this paper, we focus on improving Chord networks based on the cloud-assisted platform. The system architecture of the proposed locality-aware Chord networks is shown in Figure 2.

Due to the maintenance of geographical positions of all peers, peer can select the nearest resource owner instead of random selection from searching result to download. This is because the nearest resource owner can be found by computing and sorting the physical distance between the requesting peer and owners of resource in our cloud-assisted platform.

Besides, the bidirectional searching algorithm proposed in [21] is adopted in our proposed Chord networks. According to the ID of a resource, a peer can search the owners of a resource in clockwise or anti-clockwise direction on Chord networks from finger tables [21] maintained by peers. The logical hop count of searching path can be reduced on average.

III. Locality-Aware Chord Networks

Considering the locality information of peers, four schemes of ID assignments of peers in the proposed locality-aware Chord networks are designed as follows.

A. *Longitude Positioning with ID Exchange*

The simplest way of arranging peers on a ring is to map peers onto the equator, which is a natural ring on earth. According to the longitude degrees of peers, peers can be projected onto the equator to form a clockwise ring from East to West longitude. Figure 3 shows an example of a Chord network constructed by four peers and three default CG nodes on the equator.

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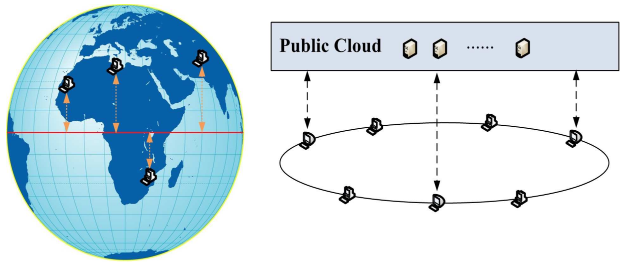

Figure 3. Longitude positioning Chord networks.

Figure 4. ID assignment of global positioning hash.

In our proposed cloud-assisted platform, the geographical positions of all peers are maintained in the cloud system. The ring of Chord networks can be constructed by the order of longitude degrees of peers. Since the original IDs of peers are generated by a hash function, the increasing order of IDs of peers might not be consistent with it of longitude degrees of peers. However, the consistency problem can be solved by exchanging IDs of peers.

Now, we describe the scheme of Longitude Positioning with ID Exchange (LPIDE) as follows. When a new joining peer is coming to the system, the predecessor and successor of the peer on a ring onto the equator can be easily computed by the cloud system. Simultaneously, the increasing order of IDs in the Chord network can be also verified. Once the increasing order of IDs is violated, the cloud system will inform the related peers to exchange IDs for solving the consistency problem. Two peers can exchange their IDs by exchanging their predecessors, successors, and finger tables in constant time.

B. Global Positioning Hash

The scheme of longitude positioning with ID exchange can not distinguish peers with the same longitude degrees. As a result, these peers could be neighbors on a ring mapping on the equator whereas some distance may exist among them. In addition, exchanging IDs of peers may often incur extra overhead.

To improve the lack described as above, a new scheme referred to as Global Positioning Hash (GPH) is proposed. It provides a new ID assignment of peers according to the geographical positions of peers such that the arrangement of peers on a ring approximately close in their physical positions.

The new ID of a peer is composed of two parts as shown in Figure 4. The second part (i.e., low significant bits) is generated by a hash function of IP address, which is the same as in the original Chord networks. The second part makes the ID of peers unique, even peers have the same geographical positions. The first part (i.e., most significant bits), denoted by ID(Global Position), is defined by the function of geographical position including longitude and latitude degrees, as shown in equation(1).

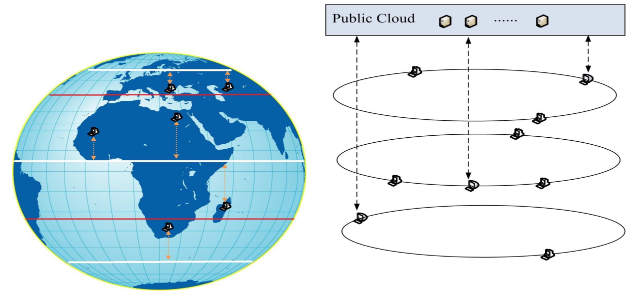

Figure 5. Triple rings Chord networks.

$$ID(Global\ Position) = \lceil (a+180)*200+(b+90) \rceil \quad (1)$$

where a is longitude degrees and b is latitude degrees.

The first part of the ID decides the order of peers on the ring of Chord networks. The idea of equation (1) is to map geographical positions of peers onto a first quadrant in two-dimension plane, and then execute a linear transformation by sum of the scaled longitude degrees and latitude degrees. This makes sure ID(Global Position) is a positive and an unique integer. The equation (1) reflects relative locations of peers. According to the IDs generated by the GPH scheme, the arrangement of peers on a ring could be approximately close in their physical positions. Unnecessary triangle routing of resource searching could be reduced.

C. Triple rings with Chord

Peers could be from anywhere in the world. The searching performance may suffer in Chord networks with a single ring due to the distribution of peers in physical location. The scheme of Triple Rings with Chord (TRC) is designed to distribute load from a single ring to the three rings of Chord networks.

Peers join one of the three rings in Chord networks according to their location. Considering most of Earth's land is located on Northern Hemisphere, the three rings are planed as shown in Figure 5. The first ring is formed by the peers at above (or equal to) $23.5°N$, the second ring is constructed by the peers at between $23.5°N$ and $23.5°S$, and the peers at under (or equal to) $23.5°S$ can join the third ring.

Each joining peer can upload its IP address to the cloud system by a random CG node to find which ring it has to be joining. In this scheme, each ring is constructed in the same way as it is in the original Chord networks. To improve the searching performance, the way of publishing a new resource is adapted. When a new resource is published on one of the three rings, it would be published on the other two rings by the assistance of a random CG node.

D. Triple rings with global positioning hash

The scheme of Triple Rings with Global Positioning Hash (TRGPH) is a hybrid scheme of TRC and GPH schemes. Peers can join one of the three rings according to their physical locations but each of ring is constructed by the scheme of global positioning hash.

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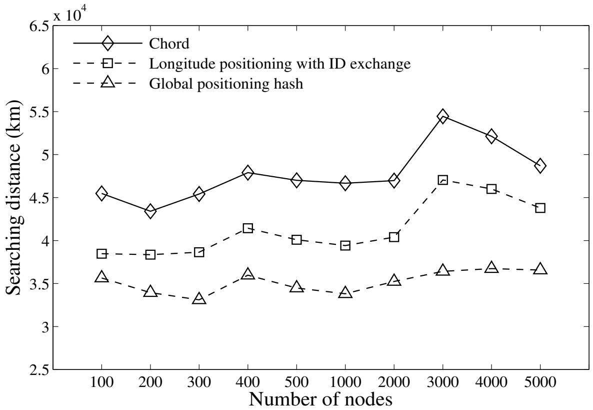

Figure 6. Searching distance for the two proposed schemes.

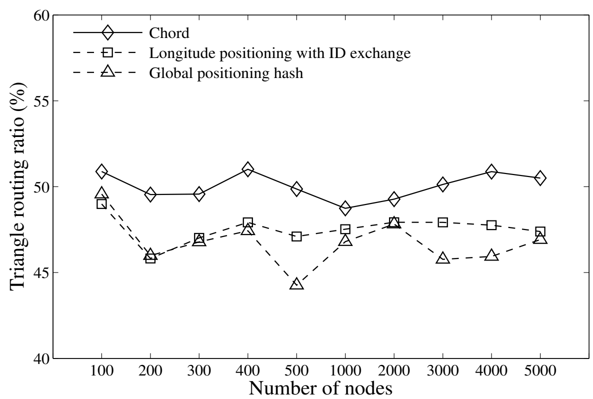

Figure 7. Ratio of triangle routing.

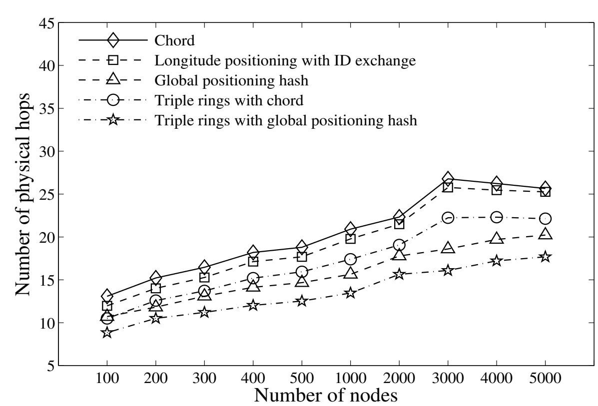

Figure 8. Physical hops of searching cost for all of proposed schemes.

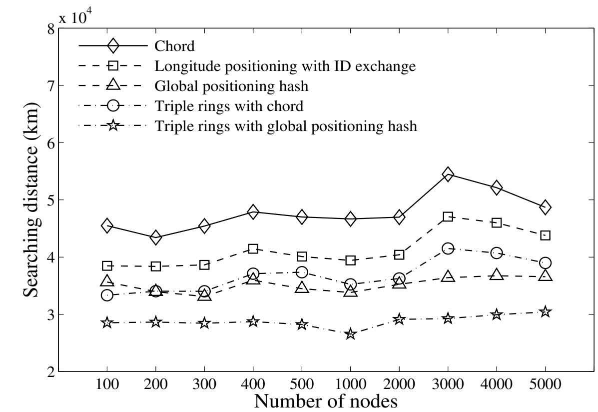

Figure 9. Searching distance for all of proposed schemes.

IV. PERFORMANCE EVALUATION

In this section, simulations are performed to study the performance of our proposed locality-aware Chord networks.

A. Simulation Environment

To simulate Internet topology, the topology generator IGen [22] is used to generate random graphs mapped onto real Earth and modeled by Waxman [23]. Nodes are only distributed on Earth's land and the distance between two connected peers is defined by their geographical distance. The simulation programs are written in Java language.

In the system initialization, there are eight kinds of file resources to be shared and each of them is owned by three different random peers in the system. Peers may join or leave the P2P system in our experiment. The times of peers joining the P2P system form a Poisson process. The mean time of a peer joining the system is 10 minutes. The lifetimes of peers in the P2P system form an exponential distribution. The mean lifetime of peers is two hours. For each data point in our experiment, 10 random graphs are generated and 5000 queries for requesting a random resource from eight kinds of files are performed in each graph. The times of queries from random peers in the P2P system form a Poisson process. The mean time of a query happened is twenty minutes.

B. Simulation Results

The performance of Chord networks can be evaluated by the cost of resource searching and downloading.

During the searching process, a query message is forwarded on a logical ring network to find out where the owner(s) of a resource is(are), and then the response message including searching result will be returned. Due to the consistency problem, long distance and more than one routers may exist between two neighboring peers. In our simulation, the physical distance and number of routers that the query and response messages are traveling during the searching process are referred to as the searching distance and physical hops, respectively.

Figure 6 shows the average searching distance in our first two proposed schemes for different number of nodes in the networks. Compared to the original Chord system, the searching distance of our proposed two schemes are shorter than that of the original Chord system. This is because the locality information is considered, and then unnecessary searching routes could be reduced.

The ratio of triangle routing is calculated to evaluate how congruent the overlay network is with and physical network topology. For each query message, every three contiguous peers along its routing path, the triangle routing event is verified and statistically counted to compute the ratio of triangle routing. Figure 7 shows the GPH scheme has lower ratio of

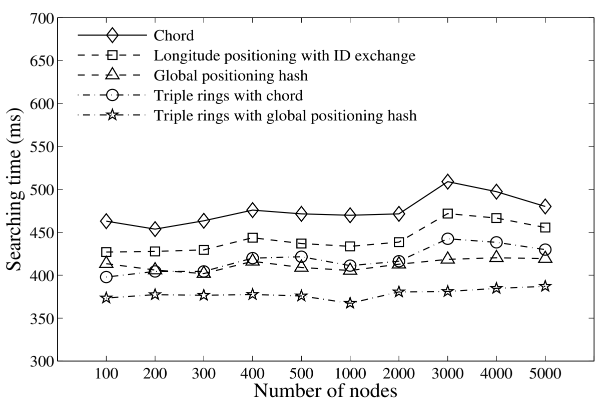

Figure 10. Searching time for all of proposed schemes.

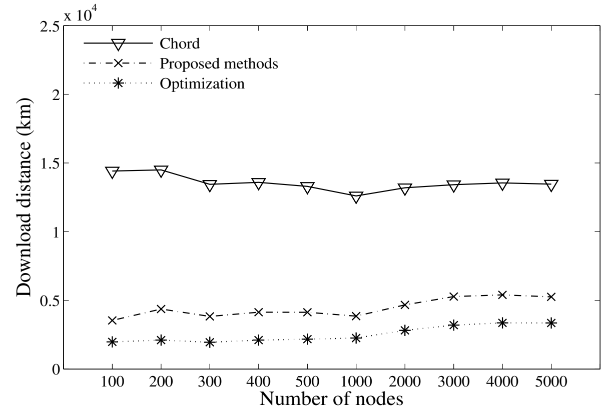

Figure 12. Download distance for the proposed methods.

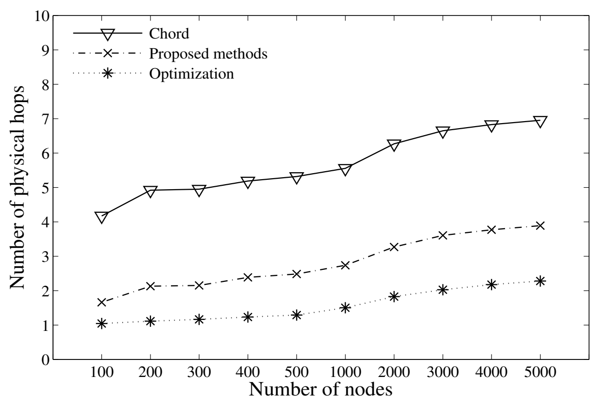

Figure 11. Physical hops of download cost.

triangle routing than the other two schemes in most situations. This phenomenon also verifies that the searching distance for GPH scheme is shorter than that of LPIDE scheme. It is worth noting that the ratio of triangle routing for global positioning hash is still larger than 45%.

Considering the distribution of peers, triple rings are designed in our proposed Chord networks. Figure 8 and Figure 9 show the average number of physical hops and distance respectively for all of the proposed schemes in different number of nodes. From these two figures, we can observe that the performance of GPH scheme is still better than that of TRC scheme. Since the way of constructing logical rings in TRC scheme is still the same as it in the original Chord system, the improvement of consistency problem is limited. These two figures also show the performance of TRGPH scheme is better than that of the others. This is because load can be distributed into different rings and simultaneously the order of peers on logical rings is decided by their geographical positions.

The time necessary for the searching process can be defined as the propagation delay plus the queuing delay when the transmission time of messages is ignored. The propagation delay can be computed by the searching distance divided by the signal speed, $2 * 10^8\ km/s$. In our simulation, the queuing delay of messages elapsed at the routers on the Internet is modeled by an exponential distribution and the mean time is $240\ ms$. Figure 10 shows the average searching time for all of the proposed methods in different number of nodes. The simulation results are similar with those measured by the metrics of physical hops and distance. The average searching time for TRGPH is less than $120\ ms$ compared to the original Chord system when the number of nodes is 3000 in the networks. In summary, the performance of TRGPH scheme is better than the others.

From Figures 6, 8, 9 and 10, we can observe the performance increases to its worse maximum at 3000 nodes and then it decreases. This phenomenon is the effect of number of on-line peers and the distribution of peers locations in network topology. Before the end of simulation, almost all of nodes are on-line when the number of nodes in the networks is less than 3000, while more peers are off-line when number of nodes in the networks is starting from 3000 to 5000. Peers need to take more cost to find their required resources when the number of off-line peers suddenly increases. From the Figure 8, we can see that the difference of physical hops between 2000 nodes and 3000 nodes is more than 4 but the difference of physical hops for 3000 to 5000 nodes is less than 1 for the original Chord system. The minor difference for the later is due to the distribution of peers locations in network topology.

From the searching result, a peer could directly get the resource from the owners without the help of overlay networks. The cost of downloading can be defined as the physical hop count, or distance between the requesting peer to the resource owner. In our proposed Chord networks, peer can find the resource owner which is the nearest physical distance from it by cloud-assisted platform. In our simulation, the cost of downloading is evaluated by selecting the nearest peer to get a resource instead of randomly selecting from the searching result.

Peers can find the nearest resource owner by cloud assistance whenever the ways of ID assignment are adopted in our proposed schemes. In our simulation, the performance of downloading is the same for all of the proposed methods except the original Chord system. It is worth noting that the nearest resource owner is defined by the minimum geographical distance between the requesting peer and the resource owner instead of the shortest path between them in the networks. The performance value measured by such a peer with shortest path from the requesting peer is viewed as the optimal value in our simulation.

Figure 11, Figure 12, and Figure 13 show the physical hops,

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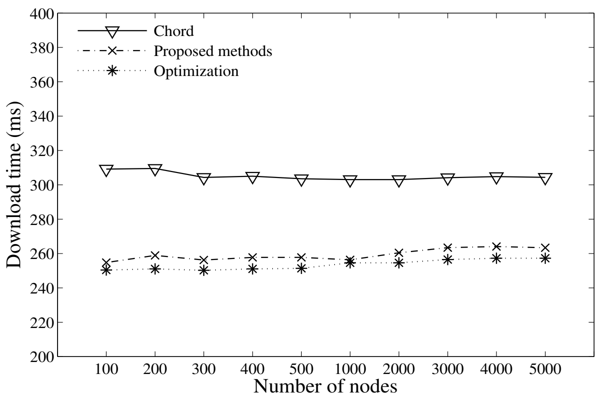

Figure 13. Download time for the proposed methods.

distances, and download time respectively for our proposed methods and the original Chord system compared to the optimal solution in different number of nodes in the networks. From these figures, we can see that the performance of our proposed methods is close to the optimal solution and better than the original Chord system.

V. Conclusions and Future Work

In this paper, locality-aware Chord P2P networks based on cloud-assistance are proposed. Four new schemes of ID assignments associated with geographical positions of peers have been designed. The arrangement of peers on the rings constructed by our proposed methods is approximately close in their physical positions. The ratio of unnecessary triangle routing in the searching process can be reduced. In addition, a new download method which can select the nearest nodes to get resources has also been designed. The simulation experiments show the TRGPH scheme has better performance than the others.

The ID assignments of our proposed schemes only consider the physical locations of peers but the free database GeoLiteCity could not provide precise enough physical locations of peers. In the future, the other IP-geolocation mapping schemes, such as in [25]-[26], will be considered to design the schemes of ID assignments to improve the performance. In addition, the real life networks from the data sets [27] will be adopted in our simulation experiments to compare the performance affected by network topologies and distribution of peers locations.

Acknowledgment

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