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Letian Rong
University of Wollongong

I. Burnett
University of Wollongong, ianb@uow.edu.au

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Improved Dynamic Multimedia Resource Adaptation-based Peer-to-Peer System through Locality-based Clustering and Service

Letian Rong, Ian Burnett
TITR[1]
University of Wollongong
Wollongong, Australia

***Abstract*—A dynamic P2P architecture based on MPEG-21 was proposed in our previous work to support resource adaptation/personalization according to the surrounding usage environment and user preferences. In this paper, we improve the proposed system through two separate but related modifications. Firstly, peers are clustered according to registered geographic location information. Secondly, based on that registered location information, a locality-based service is introduced which allows users to search services according to their geographic locations. The service complements the proposed P2P architecture by encouraging service providers to increase the uptime of their devices and hence provide the spare computer power for active adaptation of resources for low-end peers. Simulation results show that the proposed approach reduces download time and network delays while increasing resource availability and download speed in the network.**

I. INTRODUCTION

P2P networking has become a significant area of research in recent years as well as seeing substantial consumer uptake. However, as computing devices become more diverse, it is important that P2P systems provide resource sharing suitable for a ubiquitous computing environment. In particular, resources should be dynamically adapted to suit the usage environment of requesting peers. A super peer-based architecture was proposed in our previous work [1] to facilitate dynamic resource adaptation in a P2P environment.

In the proposed system, peers are grouped into clusters based on similarity of their shared contents and super peers are nominated to be in charge of one or more clusters. On joining the network, a peer must submit information about its shared resources and its related usage environment attributes to the responsible super peer(s). Super peers then use the registered information to adapt search results and resources to the request peers.

However, an important missing aspect in the current architecture is that it does not locate copies of a resource based on their locality attributes; this is not scalable in a large P2P network as long network delays could occur between peers [9].

Locality-aware overlay P2P systems are the topic of various active research projects [5, 7, 8] which aim at providing a means of locating copies of objects in the local area quickly if they exist, before directing the query down more expensive wide area links. However, those projects are designed for pure unstructured P2P systems which mainly focus on the aspect of minimizing the cost of routing in locating objects. In contrast, our proposed architecture is a super-peer based P2P system and therefore the locality-aware features should be designed by taking advantage of the existing structure.

Another aspect that we consider is that it is always likely that some peers would be idling in the network and super peers could utilize their spare computer power to adapt resources for low-end peers. The challenge with this approach is to create the incentives for high-end peers to leave their machines idling on the network for significant periods.

In this paper, we address these two separate aspects of improvements through the deployment of a locality-based clustering approach and a locality-based service model and demonstrate how they are related and complementary aspects of an improved architecture.

II. LOCALITY-BASED CLUSTERING AND SERVICE

A. *Locality-based clustering approach*

In other related P2P work, network topology, IP or autonomous system (AS) path length, or RTT (i.e., round trip time) are used as the distance metrics to cluster peers to reduce network delays [5] or to determine optimal path between the sender and receiver [3]. However, these approaches have several disadvantages:

1. It is unrealistic to obtain lower level network topology information in a global P2P network as the network could consist of thousands of private networks.
2. It generates additional overheads in the network to obtain accurate measurement of metrics such as RTT [2].
3. The dynamic property (i.e., join/leave the network at any time) of peers in a global P2P environment makes it difficult to perform network tests on each peer (e.g., hop counts via route tracing).

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4. Tracking the past history of each node also has no value if nodes are never seen or used again.

In contrast, it is shown in [4] that static properties such as physical distance are actually more accurate than most dynamic metrics mentioned above as a measurement of network delays, with the exception of RTT. Also physical distance could be calculated based on the geographic locations of peers and the location attribute is a metric that can be obtained through either manual user entry or retrieval from the consuming device; this eliminates the need to use complex algorithms or create extra network overheads to obtain the data. Furthermore, in our proposed architecture the super peers are used to stored peer related information and the architecture could be easily modified to allow geographic location information to be stored and provided. These useful facets created the motivation behind using geographic location as the metric to cluster peers.

With locality-based clustering, the network is clustered into a number of locality clusters, with each governed by a locality super peer. The maximum size of the locality clusters is predefined during the initialization of the network. Once a locality cluster reaches its maximum size, its locality super peer nominates a peer as the new locality super peer based on stored peer related information and splits the cluster in half based on the geographic locations of the peers (e.g., split a cluster into east and west side). When new peers join the network, they must register with a corresponding locality super peer based on their geographic locations and submit related peer information (i.e., terminal capabilities) to it. Peers could also register with category super peers (i.e., super peers which govern one particular type of content) based on their shared contents.

B. *Improved resource request based on idling peer power facilitation*

Based on the idea of utilizing idling peer power to adapt resources for low-end peers, as well as the introduction of locality clusters in the architecture, we modified the resource request steps accordingly as follows:

When a peer requests a resource, the request is forwarded to the locality super peer, which retrieves the peer IDs of all the peers in the cluster and forwards the ID list, together with the request, to the corresponding category super peer (note: we assume that each locality cluster is defined at reasonable size and therefore the peer ID list would not be too large). In addition, the locality super searches its cluster for high-end peers who are idling and have the ability to perform adaptations that are related to the request and forwards the idling peer list to the category super peer.

The category super peer then selects the peer sender who is capable of sending the requested resource based on the stored information of shared contents and their hosting peers, as well as information received from the locality super peer. Next, the category super peer uses the idling peer list to determine if there are potential idling peers who have higher terminal capabilities than the peer sender (i.e., processing power) in terms of adapting the resource. If a potential adaptation peer is found from the list, the super peer would request the peer sender to transfer the resource to the adaptation peer, who adapts the resource before sending it to the request peer; otherwise the peer sender simply adapts and sends the resource by itself.

If no results are found in the locality, then the search is expanded into the nearest locality clusters until either a result is found or a predefined search boundary is reached (i.e., 5 locality clusters).

C. *Locality-based service and its linkage of the two improvements*

It is shown in [6] that 30% of the computer users in the US claim that they have a home-based business and 30% of them claim that they have 3 or more computers. This data indicates that there is a large potential market for people to promote their services on the P2P network. It also indicates that these peers would most likely be powerful computing devices (i.e., servers and desktop PCs) connected to the P2P network for long periods of time (i.e., 24 hrs).

Based on these findings, we modified the existing P2P architecture by allowing not only resources, but services to be dynamically adapted and shared in the network. The adaptation of services uses the same adaptation approach as proposed in [1]. This modification, in conjunction with the proposed locality-based clustering approach, creates a new service model: locality-based service. The locality-based service takes advantage of the fact that every peer is required to register its geographic location with a locality super peer in the locality-based clustering approach to enable searching of services based on their locations. It allows people to promote their services to a local community or search for services within certain distances, through a P2P network. For example, a user arrives in a new area and would like to search for a hotel to stay over in the nearby area. A graphic illustration of the locality-based service is shown in Fig. 1.

The main motivation behinds the proposed locality-based service is that it benefits the idea of utilizing idling peer power to adapt resources through creating the incentives for some peers on the network to increase the uptime of their machines, e.g., business oriented peers would want to continuously promote their services. This is a practical scenario as business users trade idle computer power to promote their services.

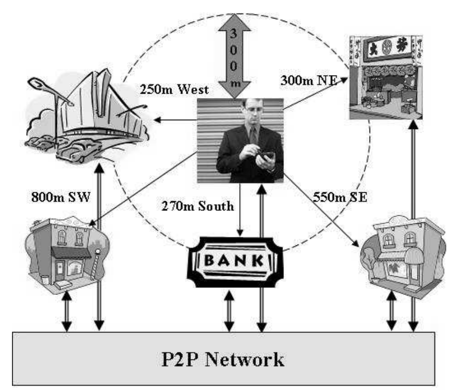

Figure 1. An example of the locality-based service in a P2P environment

III. SIMULATION

A simulation was created previously in our work to evaluate the performance of the proposed dynamic resource adapting architecture and the details of the simulation can be found at [1]. We added code to the simulation based on the proposed improvements to evaluate their performances. Furthermore, several major improvements have been made to the simulation to create a more realistic P2P simulation environment. The improvements include allowing a predefined number of randomly generated/selected peers with resources are allowed to join/leave the network at random intervals. Also, the popularities of old resources gradually decrease through the simulation.

TABLE I. SIMULATION SETTINGS

Total no. of peers	2000
No. of super peers (including locality super peers)	40
No. of locality super peers	20
No. of provider peers	160
No. of freeloaders	1800
No. of unique resources (initially during startup)	500
Resource size	10-200 Mbs
Percentage of total resources owned by freeloaders	30%
Percentage of total resources owned by provider peers/super peers	70%
Zipf skew factor	0.271
No. of new peers joined the network while running	500
No. of peers left the network while running	500
Total no. of requests	10000

The following comparisons are made between the performance of the proposed locality-based approach, the previously proposed dynamic resource adapting architecture and traditional P2P systems where resources are simply downloaded and consumed by peers without any adaptations. We assume that with the locality-based approach, 10% of total peers are capable of performing adaptations for other peers when they are idling. Simulation settings in Table 1 were used to obtain the results and we have also simulated other peer compositions which have shown similar trend in the results.

We use average download time as a performance metric to compare the three systems. Previously, the resource adapting architecture had a much higher average download time initially (in comparison to traditional systems), due to the factor that extra time was spent adapting/down-scaling resources to appropriate sizes. The approach in this paper closes this initial gap by utilizing the computer power of high-end peers to adapt resources for the low-end peers in the network; it also reduces the overall download time throughout the simulation as shown in Fig. 2. In addition, the decrease in download time contributes to the increase of download speed which is particularly evident for low-end peers as shown in Fig. 3.

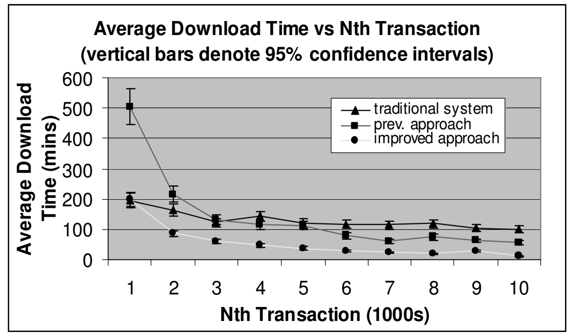

Figure 2. Average download time of different approaches

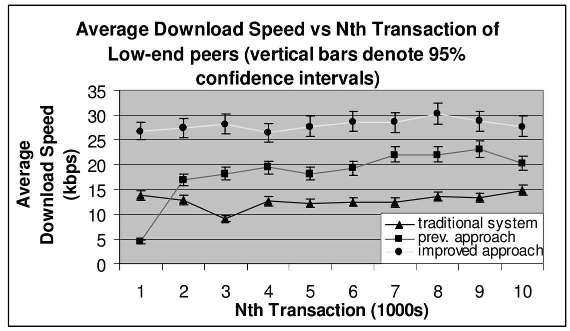

Figure 3. Average download speed of low-end peers of different approaches

In addition, average network delay is measured as a metric to compare the locality-based approach which finds resources based on their locality attributes) and a standard approach which returns the first available copy of a requested resource. In Fig 4, it shows that the network delays of the locality-based approach gradually drop as more copies of resources are created/adapted on the network and therefore increases the chance of finding resources closer to the request peers; whereas the standard approach shows a horizontal trend in the delays.

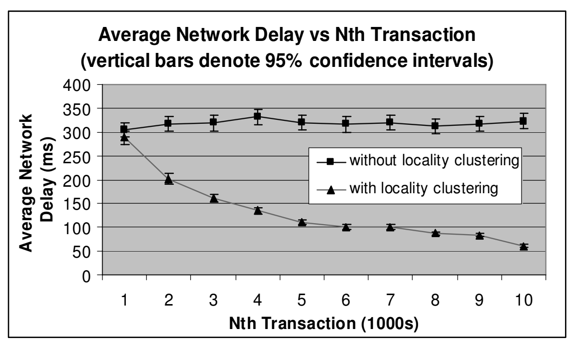

Figure 4. Average network delay of different approaches

The number of resources on the network was also periodically recorded. We found that the improved approach has, on average 10% more resources than the existing dynamic adaptation approach as every time an adaptation task is forwarded to an idling peer, one additional copy of the original resource is created during the process (i.e., original copy transferred to the idling peer to be adapted). This increase of resources further increases the average download speed as less congregated downloads would occur in the network.

IV. CONCLUSION

In this paper, we improve the performance of our previously proposed dynamic resource adapting P2P system through a locality-based clustering approach and a locality-based service type which are closely related. Simulation results have shown that with the utilization of the computer power of a small percentage of idling peers to adapt resources in the network (i.e., 10%). The average download time is significantly reduced while the average download speed is noticeably improved. In addition, the average network delay is reduced as the clustering approach locates resources which are nearby to the request peers.

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