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Efficient Peer Allocation Policy for Mobile P2P Network

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Abstract

In keeping with the development of wireless networking technology, P2P computing is moving towards the environment of P2P based networks among mobile devices. Particularly, media streaming services using P2P have become essential technology to increase users' utilization and enhance efficiency through being grafted onto other wireless networking technologies. However, resource utilization should be enhanced, given frequent churning and delay state caused by the characteristics of mobile devices; and overall system performance should be improved through continuous contribution. Hence, this paper proposes an efficient peer allocation mechanism, in which a newly joining peer selects a proper bandwidth and a parent node having much remaining download time. Mobile P2P streaming to which this proposed technique was applied shows system improvement through continuous connection.

Keywords: *P2P network, P2P service, Mobile P2P*

1. Introduction

These days, the time has come when mobile users can transmit and receive diverse data via various networks that provide rapid speed and high quality. Particularly, since these users tend to prefer media streaming services, attention has been paid to more efficient and stable services for networks and terminals. On the other hand, research on mobile P2P using mobile devices is under way thanks to the development of mobile devices and wireless communication. Thus, it is expected that mobile P2P technology will follow different patterns from the existing traditional file sharing [1]. Traditionally, the client-server system has been a major method for distributed computing. However, the concentration of services and information in the client-server system is apt to cause a bottleneck, and so reduced the potential of guaranteed stable services. Hence, the P2P architecture resolved such a problem by permitting equipotent computer behaviors on the network. Through this, in case of failure in network load balancing or network connection between nodes, it was made possible to provide more fail-proof networks using alternative paths [2]. Napster, a music file sharing program, showed promise in P2P computing [3]. At present, most P2P models are based on the wired communication method of static IP modes such as the Internet. However, P2P computing is gradually moving towards wireless networking environment between mobile devices according as wireless networking technology advances [4], and mobile P2P computing will provide new communication services such as location-based services and social computing, using LAN [5]. On the other hand, we should resolve the conventional problems of mobile computing such as the limitations of wireless communication

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(communication network, irregular bandwidth, frequent interruption, *etc.,*) and the problems of mobile device itself (CPU, keyboard, battery, memory, and display) [6]. In addition, P2P users' selfish propensity to only receiving desired data without sharing their own resources ('free-riding problem' [7]) causes the bottleneck between peers, which ultimately results in the performance degradation of the overall system. To correct the chronic problems of mobile P2P, differentiated peer selection techniques according to various peer conditions should be introduced [8].

2. Related Works

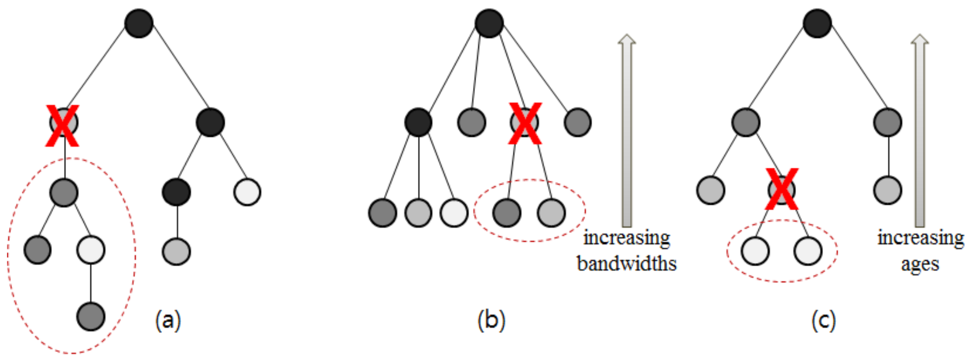
2.1. Peer Management for Mobile P2P Service Model

The mobile P2P service is joined by heterogeneous terminals via various access networks. Therefore, it needs to be managed to be an efficient service in consideration of the service areas and characteristics of peers. That is, in the case of mobile peers, they have restrictive features such as the bandwidths of various performances according to access networks, the playback time of media, the performance of buffers, network interfaces, software platforms, the reproduction of terminals, and the mobility of terminals. Methods for the enhancement of accuracy using the geographical features of GPS information, RTT and TTL have been suggested in order to detect the geographical locations of mobiles [9].

In addition, the join/leave of peers in the P2P system is called churning. Frequent churning causes the reduction of system performance, and adequate streaming quality can't be guaranteed [10]. Particularly, for the mobile P2P service, which is limited in resources and performance, this problem, proves to be a more sensitive factor. Therefore, the design of streaming system for a mobile P2P of excellent performance requires a strategy for reducing the churning rate and providing more robust and resilient topology. Also, the problem of batteries can be cited as a limitation in the physical resources of mobile terminals. A new node trying to join the P2P network may check the state-of-charge of a battery before determining a parent node. The overall energy can be saved by reducing request messages transmitted continually within the system as well as re-peering caused by battery exhaustion [11]. Recently, mobile system energy efficient apps, which stop or temporarily end background apps, are very popular for the extension of battery life. In this situation, if a user stops a P2P-related app, file sharing may temporarily fall into a delay state. Therefore, a separate strategy is needed to address problems caused by the insufficient resources of mobile devices and to exchange contents effectively. In addition, due to the characteristics of P2P users, the bottleneck between peers may be caused by selfish peers that are only interested in down-linking bandwidths, but are reluctant to share their own resources, and so the decline of the overall system performance is a problem that must be resolved.

2.2. Bandwidth-Ordered (BO) Tree and Time-Ordered (TO) Tree

Generally, in mobile P2P, the quality of a P2P network is lowered by the frequent join/leave of peers. Therefore, to provide effective media streaming services in the mobile P2P environment, the method for selecting a node in consideration of the stable topology configuration [12] and reliability is required. To construct a reliable tree in the dynamic environment of such nodes, the Depth optimizing algorithm and the Time optimizing algorithm were proposed. As the Depth optimizing algorithm, the minimum-depth algorithm and the high-bandwidth-first algorithm may be considered; the latter is also called Bandwidth-Ordered (BO) algorithm, for it allocates nodes for bandwidths [13]. Also, as for the Time optimizing algorithm, nodes are allocated in a tree according to their own features of time (age). Its representative algorithm is the longest-first algorithm. This is a method of allocating nodes to higher nodes according to the order of long duration of stay at a tree after joining the tree. It was thought that the longer a peer stays at and serves a P2P network, the more loyal the peer to the network is. The algorithm of allocating nodes in the order of time of staying at a tree includes the Time-Ordered (TO) algorithm [14].



(a) Random (b) Bandwidth-ordered (c) Time-ordered

※ *Darker colors represent older nodes. The dashed lines represent the regions affected by a node failure.*

Figure 1. Examples of the Three Types of Tree

Sequential construction according to the bandwidths of nodes for constructing a shorter tree depth in the dynamic situation of nodes is called the BO tree. It is constructed according to bandwidths, and so nodes having many bandwidths are located at the higher levels of the tree. In this construction, the tree comes to have a relatively shorter depth, and is affected less even in the dynamic situation of nodes. The method of constructing a dynamic tree for the BO tree is based on the order statistics [15] algorithm. Figure 1 shows the random method, the BO tree method, and the TO tree method for constructing a tree. In the case of the BO tree method, however, if the bandwidth is maintained too long or too large, bandwidth imbalance may be caused among nodes. In addition, in the case of a mobile device of large bandwidth and short stay time, it takes long recovery time whenever leave occurs among many children nodes. In the case of the TO tree, nodes are allocated at higher nodes in the order of long stay at a network. Therefore, in the existing wired networks that are rich in node resources, have high network reliability, and are stable, the TO tree can be an efficient method. It is, however, difficult to be applied to mobile networks having limited resources and great changes in the network due to the mobility of devices. Therefore, this paper proposes a method for constructing a system that considers the features of mobile devices themselves and can provide stable services despite the dynamic changes of peers that participate in the network.

3. The Structure of LRDT (Longest Remaining Download Time) System

3.1. Concept

The peer management policy for efficient streaming services on the mobile P2P network requires running the network operation policy differently from the existing wired Internet due to the limitation of resources owned by mobile peers. First, frequent join and leave may occur at a P2P group receiving services, due to the mobility characteristics of peers. Second, a mobile peer of the parent node is probable to leave the network if its desired streaming service is completed. Third, when a mobile peer becomes the parent node, it is difficult to expect stable service due to the limitation of bandwidth, memory or battery capacity. For these reasons, a peer's loyalty to the network service may decline significantly, compared to the wired system. Hence, the reallocation of peers on the P2P network may occur frequently, which can reduce the efficiency of the network. Figure 2 shows the comparison of the characteristics of peer reallocation between two mobile peer groups. In Figure A, when parent node 1 leaves the group, child node 2 searches first for a peer to be its parent node according to the reallocation policy (TO, BO) of the network. If k children nodes to be served under a parent node are { n_1, n_2, n_3 } and the network operation time for node n_i to search for a new parent node is $SNorg_i$, the total number of operations for node n_i to search for a new parent node is $totSG_i$ = $\sum_{i=1}^{i=k}(SNorg_i)$. Therefore, in the existing P2P networks, the more the children nodes to be served are, the longer the network operation time becomes. In contrast, let's see Figure B, which represents LRDT. Node 2 only has to join directly a higher parent node that has served parent node 1. If the network operation time for node n_i to search for a new parent node is $SNlrtf_i$, the same consistent node search time $SNlrtf_i$ is spent regardless of the number of children nodes. And $SNorg_i \leq SNlrtf_i$.

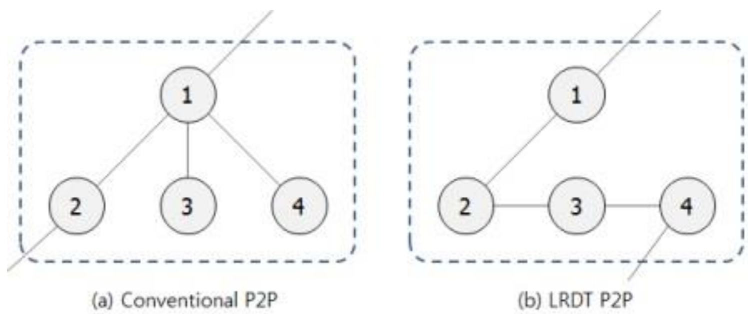


Figure 2. Compare the Two P2P Networks

3.2. LRDT Parent Node Selection

In the LRDT model, if there is multiple parent nodes capable of joining in case that a new node joins a method for processing it effectively is required.

The method proposed by this paper is that when a new node wants to join, it peers preferentially a node having the most bandwidths and remaining download time among the existing nodes that joined most recently, in order to maintain the existing topology and reduce the rate of churning. (Provided, that the present study assumes that the capacity of all the batteries are the same.) Figure 3 shows a list of candidate parent nodes (C_1, C_2, C_3) currently capable of peering if a new node requests joining.

Most mobile nodes that have downloaded all of their needed streaming files are probable to leave the relevant P2P group. Therefore, it may be said that the selection of a node having joined most recently among several candidate parent nodes is likely to permit long stream download through the relevant node. In addition, some mobile nodes may stop download for the reason of delay or break while downloading.

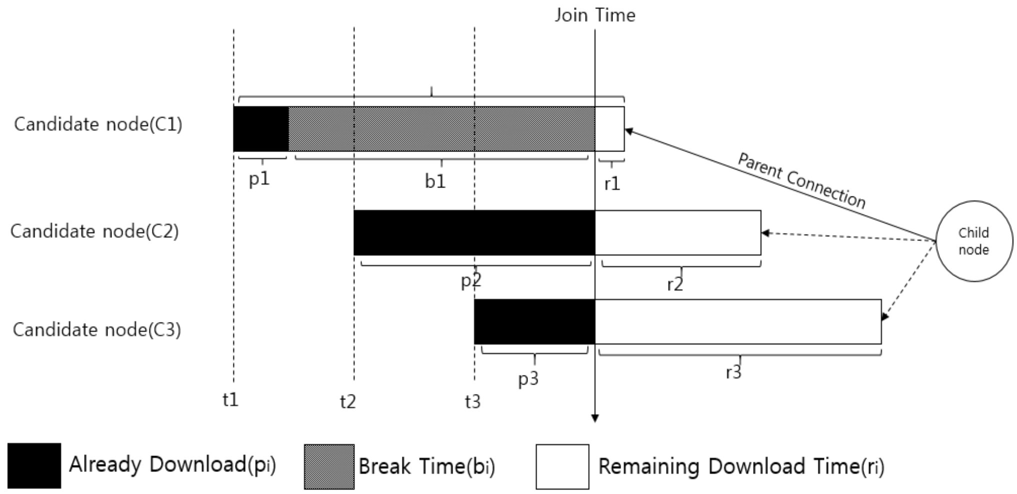


Figure 3. LRDT Parent Connection Method

In such a case, if the parent node is determined only by the time when candidate nodes joined the network, efficient service can't be provided. When selecting the parent node, the LRDT model considers download break time caused by various reasons as well as the initial joining time of candidate nodes.

Among candidate nodes in Figure 3, C_3 may be the parent node, for it joined most recently; however, the final result shows that C_1 became the parent node. Because C_1 has the delay time of b_1, and so it's remaining time for full downloading (R_1) is $R_1 = r_1 + b_1 > r_3$. As mentioned in 2.2, churning, which is caused by frequent join/leave, among considerations in the design of mobile P2P system, results in performance degradation, and consequently suitable streaming quality can't be guaranteed [10]. Therefore, a candidate node having a lot of streaming data to be downloaded should be selected to reduce churning. That is, a peer that has much download time left is probable to remain connected with the network for a long time in order to complete downloading.

3.3. LRDT System Model

Newly joining nodes start streaming service in earnest after a series of processes for exchanging buffer map information periodically through the P2P network agent so that they may select their optimum parent nodes. For this, the agent uses information on nodes including upload/download information, bandwidths, remaining download time, IP addresses and PID. As shown in Figure 4, a joining node requests resource allocation from the P2P network to which it belongs.

At this time the joining node delivered its required bandwidth $bW_{join}(t)$, and the resource allocation agent selects a node with a bandwidth suitable to the joining node's request and the longest remaining download time, maintaining the optimized resource allocation so as to get the most out of its shared down-link bandwidths.

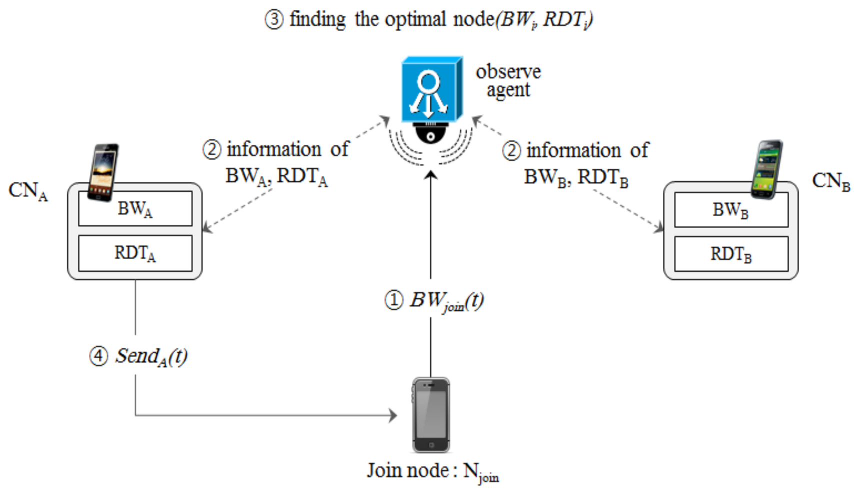


Figure 4. Proposed Model

Expression (1) represents the concept that the most suitable parent node CN_i is selected among candidate nodes and the description of the elements of the expression is shown in Table 1.

$$CN_i \in \{ \{ BW_{join}, for\ all\ i \} \cap \{ MAX(RDT_i)\ for\ all\ i \} \} \quad (1)$$

Table 1. Notation and Variable Definitions

Notation	Definition
N_{join}	a new node to join the network
CN_i	a candidate node to be chosen as a parent node
BW_{join}	required bandwidth of N_{join}
BW_i	available bandwidth of candidate nodes A and B
RDT_i	remaining download time of candidate nodes A and B
MAX_RDT_i	maximum remaining download time of candidate nodes A and B
$Send_i$	a bandwidth actually sent

Thus, the method for a joining node to select a parent node is as shown in Expression (2).

$$CN_i = \alpha \times BW_{join} + (1 - \alpha) \times MAX\_RDT_i \quad (2)$$

Provided, that α here is a weighted value for bandwidth and remaining time ($0 \le \alpha \le 1$).
Also, the algorithm for selecting a parent node is as follows:

Algorithm-1

Input : N_{join} Output : CN_i
  $TmpW_{join}$ ← *Retrieval_Candidate*(BW_i)
  BW_{join} ← *Choose value using* $TmpW_{join}$
  $TmpRDT_i$ ← *Retrieval_Candidate*(RDT_i)
  MAX_RDT_i ← *Choose value using* $TmpRDT_i$
  Calculate CN_i
End

4. Performance Evaluation of the Proposed Model

4.1. Simulation Environment

1,200 nodes, which vary in transmission cost and available bandwidth, were generated for the mobile P2P network environment. It was assumed that a mobile node leaves the relevant session a time for downloading a multimedia stream (600 seconds) after joining. The play time of one video was assumed to be 600 seconds.

4.2. Performance Evaluation

To investigate the effects of the proposed algorithm on video streaming, the existing Random, TO, and BO methods were evaluated as follows:

(1) Utilization of non-terminal nodes

In the existing TO tree structure and BO tree structure, a tree(m^{th} degree) generates a considerable number of terminal nodes. The terminal nodes only receive services from their parent nodes, but have no child node, and thus they can't propagate service any more.

After all, to improve the overall P2P network performance, it is important to enhance the utilization degree of terminal nodes.

The proposed LRDT system was configured in such a way that each node has a small degree, and so the number of non-terminal nodes in the tree was reduced and the number of nodes participating in streaming services was increased.

At this time, the depth of a tree increases as the degree is lowered. Due to the mobile characteristics, however, if the degree increases, several devices are connected to a node and such phenomena as the frequent join/leave problem, the limited resources problem, and network load caused by node reallocation occur.

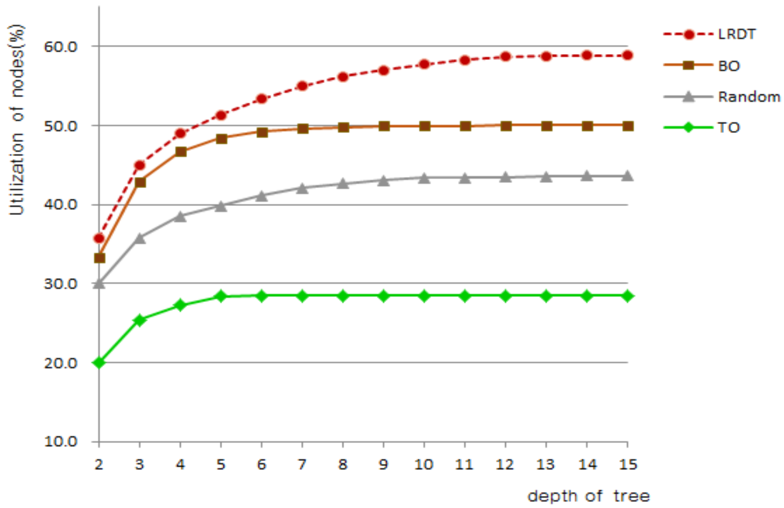


Figure 5. Utilization of Non-terminal Nodes

Figure 5 is a diagram showing the percentage of non-terminal nodes among overall nodes for the Random tree structure, the BO tree structure, and the LRDT tree structure.

For example, if the depth of tree is 5, the rate of non-terminal node utilization is shown to be 39.85% for the Random method, 48.39% for the BO tree, 24.93% for the TO tree, and 51.30% for the proposed LRDT method.

The experiment shows that the rate of non-terminal node utilization for the existing methods is 20.50% ~ 51.27% and that about 48% are nodes that only receive services; and thus a plan is needed for having nodes actively participate in the P2P network. In contrast, in the case of LRDT system, 36.50-58.86% becomes non-terminal nodes that perform uplink and downlink simultaneously, which enhances the efficiency of the overall system.

(2) The number of relocation with children nodes due to node leave

Figure 6 below shows the number of children nodes to be relocated for the existing Random tree, BO tree, and TO tree in case that any node leaves, with the maximum height of tree being 8.

The existing methods should relocate children nodes according to bandwidths and time sequence if their parent node leaves. In the proposed LRDT method, however, there are a small number of nodes that should be relocated, for the degree of a lower node is minimal. (In Figure 6, only 2-31 nodes are involved in relocation.)

Also, children nodes after the loss of a node can be relocated to a higher node as they are, with the concept of sub-tree, and so operation with search and relocation is easy and network overhead can be reduced.

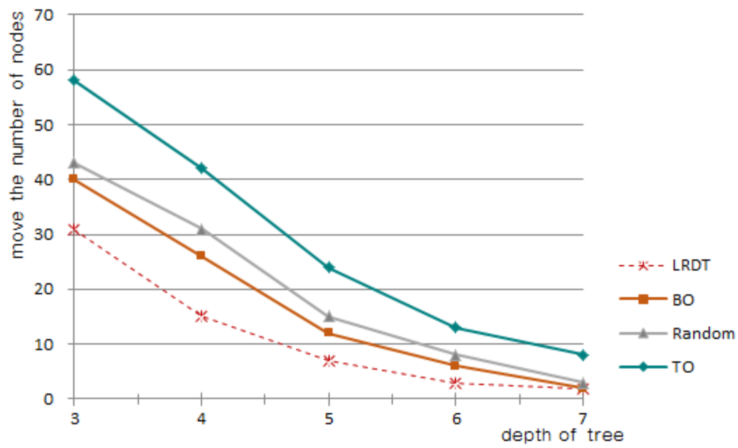


Figure 6. The Number of Relocation with Children Nodes Due to the Leave of a Parent Node

5. Conclusion

This paper proposed a peer selection method that enhances the overall system performance and takes into account a mechanism focusing on bandwidths and remaining download time, in order to improve mobile P2P networking and mobile streaming services. It was evaluated in comparison with the existing Random, TO, and Bo policies that P2P streaming performance can be enhanced through raising the maximum use rate of resources within the system by using major considerations in peer selection obtained from the investigated model and experiment. The experiment showed that the rate of node participation in P2P network improves up to more than 33.86%, compared with the existing methods. Also, in case that any node leaves, the evaluation of the number of relocation with remaining nodes showed that the number of relocation is relatively lowered, compared with the existing methods. Therefore, the proposed algorithm showed the results that it lowers dependence on media caching and efficiently activates connection between terminals. On the basis of highly functional mobile terminals and intelligent networks, users are demanding higher quality media services. Currently, research on diverse technologies for the stability of service quality and the minimization of cost accruing for it is under way. In the future design of service systems responding to the revitalization of mobile P2P streaming services, it is needed to carry out research on efficient mobile P2P network services by studying additional plans for resources optimization, the energy-saving effects in the system, differentiated user services, and the scheduling of lower video layers.

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