# Adaptive Server Bandwidth Allocation for Multi-channel P2P Live Streaming

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**Abstract.** With the growing popularity of P2P live streaming, more and more channels have been set up, however, this poses new challenges to P2P technology, such as stronger dynamic characteristic, high switching delay. In this paper, we focus on the server, which can allocate different bandwidth to meet the needs of each type of peers, especially the switching peers. On a close study of the basic tradeoff between the switching peers' and overall performance, we propose new peers first strategy and adaptive bandwidth allocation, and get a satisfactory result. Our results show that the full and rational utilization of server bandwidth is of great help for improving the performance of multi-channel P2P live streaming.

**Keywords:** P2P live streaming, multi-channel, new peers first, adaptive bandwidth allocation.

## 1 Introduction

During recent years, many researches on P2P and P2P live streaming have done, and won a tremendous success, such as data-driven/mesh-based P2P streaming protocol [1], GridMedia [2], iGridMedia [3], and Ration [4]. More and more practical P2P live streaming systems have put to use, and the largest supportable number of online people has also surpass the million mark, e.g., PPLive [5].

As P2P live streaming has got an extensive application and rapid development, it has entered the multi-channel era. However, this poses new challenges. As we know, the cooperation and coordination between peers is a huge advantage of P2P network, but this is inevitably impacted by the separation of different channels. High switching delay is another problem in multi-channel. On the other hand, the peer scheduling in P2P network, which is the focus of the past P2P research, doesn't go very far towards solving these problems.

Aim at the above-mentioned problems, we refocus on the server. We recognize that there are various peers in each channel. Then, we can provide QoS guarantee for different peers, through the server scheduling algorithm. In this paper, we mainly discuss the channel churn in multi-channel. A new-peers-first strategy, which prioritizes direct access of new peers to the server, has been implemented and evaluated. We reduce the switching delay by about 50%. But the basic tradeoff between the switching peers' and overall performance need be considered. Then we propose adaptive bandwidth allocation strategy.The whole study is based on pull-push protocol [2] and Ration algorithm [4].

S. Boll et al. (Eds.): MMM 2010, LNCS 5916, pp. 719–724, 2010.

The remainder of this paper is organized as follows. In Section 2, we implement and evaluate two server connecting strategies. In Section 3, we hash over new peers first strategy and adaptive bandwidth allocation strategy. The simulation results are given in Section 4. In section 5, we conclude this paper.

## 2 Performance Analysis of Server Connecting Strategy

### 2.1 The Role of the Server

As we know, there are dedicated streaming servers as the video source data providers in the P2P live streaming, which are different from the normal peers. Because the streaming media transmissions consume a lot of network bandwidth resource, the servers are indispensable. In the multi-channel system, the server is in response to the request peer, offers large amounts of streaming media data to the peer in each channel. We should change the role of the server, from passive response to active control. Through the analysis of known server bandwidth allocation, we reallocate server bandwidth to the peers with the different requirements, in order to utilize the limited bandwidth more rationally.

### 2.2 Server Connecting Strategy

The first factor to be considered is the server connecting strategy, which decides what kinds of peer can be connected to the server. Normally, the neighbor search of a node is random, so the connecting between two nodes doesn't need to be controlled. But the server is particular, the choice of its neighbors can affect the performance of the entire network. So the connecting between the server and the peers is not random, but complies with some rules.

iGridMedia [3] propose **rescue connection** to guarantee data transfer delay. In this strategy, once an absent packet is about to pass the deadline, the peer will directly request this packet from the server through the rescue connection established between the peer and the server. So video can play with the guarantee-delay. Another strategy is opposite, which limits the number of peers connected to the server. These peers are called first-level peers, because the server provides data to them directly. In this strategy, the video source data are sent to the first-level peers at first, and then spread to the entire network through the cooperation and coordination between peers.

Here, we define term *Peer Resource Index (PRI)*. It is defined as the ratio of the total peer upload capacity $\sum_{i=1}^{n} u_i$ to the minimum bandwidth resource demand (i.e, streaming rate $r$ times the viewer number $n$), that is., PRI $=\sum u_i/nr$. Other performance indexes are as follows: **the peer quality**——the ratio of filling buffer, **the channel quality**——the quality sum of all peers in the channel, **the channel delay**——the average transfer delay of all packets in the channel.

The comparison of these two strategies is given below. Fig. 1 and Fig. 2 show that the rescue connection reduces the data transfer delay effectively, but the first-level peers structure is more helpful to improve quality. When PRI is 1.4, the difference becomes smaller. We can discuss the reasons in detail. The rescue connection is equivalent to allocating most of the bandwidth to send the rescue

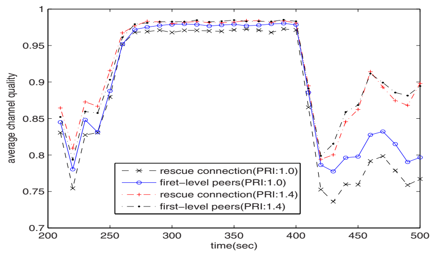


**Fig. 1.** Average channel quality with respect to PRI and server connecting strategy

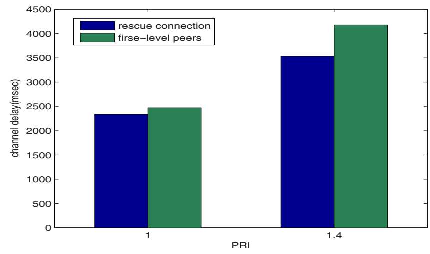


**Fig. 2.** Channel delay with respect to PRI and server connecting strategy

data, but not the newest data, especially when the bandwidth is tight. And the data from other peers is limited, so the peer quality sharply declines. On the other hand, the video data transmission needs to go through first-level peers, so the transfer delay is increased in the first-level peers' structure.

To sum up, we can know the effect of server bandwidth allocation. Especially when the bandwidth is tight, we can't ensure all performances to be good enough. Therefor, active control of server bandwidth allocation is important to adapt for the heterogeneous and dynamic characteristic of actual network.

## 3 Adaptive Server Bandwidth Allocation for Peer Diversity

Through the above analysis, we realize the importance of server bandwidth allocation. So we should continue to discuss how to allocate bandwidth to the peers connected to the server. In traditional P2P network, there are no differences between the peers for the server. But in fact, there are various peers in each channel, such as the switching peers. In this section, we will discuss how to control server bandwidth allocation to reduce the switching delay.

### 3.1 New Peers First Strategy

At first, let's analyze what should be done for the switching peer. Once a peer begins to switch channel, it should be disconnected from the original neighbor and take some time to find new neighbor in the new channel. Then, the switching peer receives data from its neighbor, but won't play video until the buffer count is more than a given ratio (such as 80%) of the total size of its playback buffer. So the search of the new neighbor and the rebuffering lead to the high switching delay. With respect to these two causes, we note the specificity of first-level peers. The first-level peers receive data from the server, and are easy to connect to the server. In other words, it solves these two problems. Based on this, we propose *new peers first strategy*——select the switching peers to be first-level peers.

The advantage of new peers first strategy is obvious. But it leads to new problem: the other peers have to reduce the data request to the server. Moreover, in P2P network, the impact of a peer is not isolated, but will be passed on to the neighbors and spread to the entire network finally. In other words, if the ratio of the switching peers in first-level peers is reduced, the overall performance will increase, however, the switching peers' performance will decline. The priority is so crucial that we should set it carefully. At section 4, we will show the evaluation results of new peers first strategy with different priorities.

### 3.2 Adaptive Bandwidth Allocation

As previously analyzed, new peers first strategy impacts the overall performance, and the adjustment of the priority should reach a compromise between new peers' and overall performance. Now, the question boils down to how calculate the ratio of the switching peers in first-level peers to meet the switching peers' needs as much as possible with ensuring the other peers' performance.

Ration [4] derives the relationship among streaming quality $q$, server bandwidth usage $s$, and the number of peers $n$ in each channel $c$ as follows:

$$q^c = \gamma^c (s^c)^{\alpha^c} (n^c)^{\beta^c}. \tag{1}$$

where $\gamma$,$\alpha$,$\beta$ can be estimated with least squares algorithms by using historical data, and the result indicates that $0<\alpha<1$ and $-1<\beta<0$.

We can also apply this formula to the switching peers. Let $q_n$ be the switching peers' quality, $n_n$ be the number of the switching peers' quality, $s_n$ be the server bandwidth allocated to the switching peers, $q_o$,$n_o$,$s_o$ be for the other peers. Through the training of historical data, we can get $\gamma_n$,$\alpha_n$,$\beta_n$,$\gamma_o$,$\alpha_o$,$\beta_o$. Our aim is to obtain the maximum of the switching peers' quality, with guaranteeing the other peers' quality. Such an objective can be formally represented as follows:

$$max\{q_n\} = max\{\gamma_n (s_n)^{\alpha_n} (n_n)^{\beta_n}\} = max\{\gamma_n (U * r_n)^{\alpha_n} (n_n)^{\beta_n}\}. \tag{2}$$

subject to

$$U = s_n + s_o = U * r_n + s_o, 0 \le s_n \le B_n, 0 \le s_o \le B_o, q_o \ge Q.$$

where the objective function $B = (\gamma n^{\beta})^{-\frac{1}{\alpha}}$ denoting the maximal server capacity requirement, that achieves $q$=1. As given value, U is the total server bandwidth, Q is the minimum of the other peers' quality what we should guarantee.

To solve this problem, we notice $\alpha>0$, so $q$ and $s$ are positively correlated. Besides, $n$ can be got from the regular reporting. In other words, if we want to maximize $q_n$, we should increase $r_n$. We can calculate the extremes of $r_n$ in three aspects, and take the minimum of them to guarantee the other peers' quality. Then ,our complete strategy is summarized in Table 1.

This adjustment isn't always carried out, but is triggered by some conditions. In practice, we receive the peers' information report regularly. Unless the quality of the switching peers or the other peers is reduced by more than 10%, we won't adjust the ratio. Because (1) is an empirical formula, the accuracy is limited. Therefore, the ratio do not need to change within some errors. This strategy can balance new peers' and overall performance well, through the server bandwidth rational allocation to the two types of peers. The simulation results will also be present at section 4.

**Table 1.** Adaptive Bandwidth Allocation Strategy

| |
|---|
| 1 Collect the historical data with peer heartbeat messages, then we can predict $n_n$ and $n_o$ with ARIMA(0,2,1) model, and estimate $\gamma_n$,$\alpha_n$,$\beta_n$, $\gamma_o$,$\alpha_o$,$\beta_o$ as mentioned above [4]. |
| 2 Calculate the minimum of $s_o$:$s_{omin} = (\frac{Q}{\gamma_o n_o^{\beta_o}})^{1/\alpha_o}$.Then $r_1 = 1 - s_{omin}/U$. |
| 3 Calculate the maximum of $s_n$:$s_{nmax} = (\frac{1}{\gamma_n n_n^{\beta_n}})^{1/\alpha_n}$.Then $r_2 = s_{nmax}/U$. |
| 4 Calculate the maximum of the ratio of the switching peer in first-level peers.Then $r_3 = n_n/n_f$,where $n_f$ is the number of first-level peers. |
| 5 Calculate $r_n$ as $r_n = min\{r_1, r_2, r_3\}$. |

## 4 Experimental Evaluations

Based on an implemented event-driven packet-level simulator coded in C++ and the multi-channel alteration, we implement the above strategies, conduct a series of simulations in this section.[1] The basic parameters of the simulation network are as follows: The default streaming rate is set to 500kbps, PRI is set to 1. The default neighbor count is 15, the default request window size is 20 seconds, the buffer size is 35 seconds, the simulation time is 500s, the channel number is 3, the peers' number of each channel is 300, so the server bandwidth is about 450Mbps. We set node-to-node latency matrix and the peers' bandwidth distribution according to the actual Internet. And for each point in the figures, we average the results by repeating 10 runs with different random seeds.

Fig. 3 shows that the rise speed of the switching peers' quality has a marked increase——about 50%, by new peers first strategy. But, as mentioned above, the other peers' quality is reduced. Because the switching peers account for only 10%, the decline is limited. We will do further testing in the following.

In Fig. 4 and Fig. 5, we raise the ratio of the switching peers in the network. The results show that the overall performances are reduced by new peers first

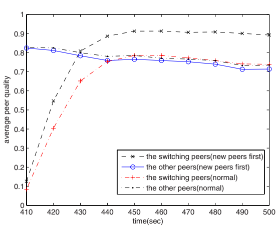


**Fig. 3.** Average peer quality with respect to the peers' type and whether to use new peers first strategy

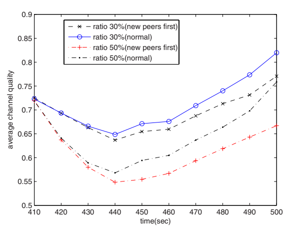


**Fig. 4.** Average channel quality with respect to the ratio of the switching peers in the network and whether to use new peers first strategy

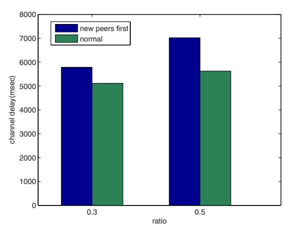


**Fig. 5.** Channel delay with respect to the ratio of the switching peers in the network and whether to use new peers first strategy

[1] The simulator is available online for free downloading at `http://media.cs.tsinghua.edu.cn/~zhangm`

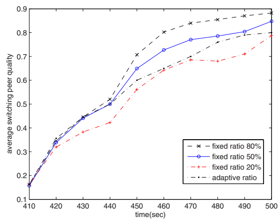


**Fig. 6.** Average switching peer quality with respect to the ratio of the switching peers in first-level peers

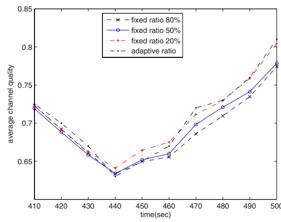


**Fig. 7.** Average channel quality with respect to the ratio of the switching peers in first-level peers

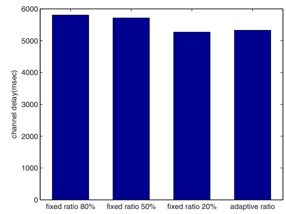


**Fig. 8.** Channel delay with respect to the ratio of the switching peers in first-level peers

strategy. Besides, the larger the ratio is, the more obvious the decline is. So we can't use new peers first strategy directly to guarantee the overall performances.

Fig. 6 , Fig. 7 and Fig. 8 indicate the ratio of the switching peers in first-level peers is a key factor.It has a positive correlation with the switching peers' performance, but negatively related to overall performance. So we can know the advantage of adaptive bandwidth allocation: without affecting overall performance, adaptive bandwidth allocation can maximize the switching peers' performance.

## 5 Conclusion and Future Work

In this paper, new peers first strategy and adaptive bandwidth allocation strategy are proposed to reduce the high switching delay. And the work of this paper can guide us to allocate the server bandwidth more fully and rationally. For future work, we can record the users' behavior to adjust adaptive bandwidth allocation strategy to adapt to the characteristics of the actual Internet.

**Acknowledgments.** This work was supported by NSFC under Grant No. 60503063 and No.60833009, and 863 program under Grant No.2009AA01Z328.

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