Adaptive Bandwidth Allocation Strategy under Cloud Platform

Hong Li Chen and Shan Guo Lv
Software School, East China Jiaotong University, Nanchang, China
E-mail: chl@ecjtu.jx.cn

Keywords: cloud computing; cloud bandwidth allocation; cloud collaboration synergy

Received: July 16, 2015

With the rapid development of cloud-computing technologies, more and more Internet applications appear with cloud platform. In this paper, cloud computing is introduced. Renting cloud platform which provides computing, storage, bandwidth resources can improve the performance of file sharing systems. The hybrid file sharing system combines P2P mode and cloud serving mode. This system provides both peer-assisted acceleration and cloud-assisted acceleration to download processes. Cloud bandwidth is scalable in the cloud-assisted file sharing system. In order to save cost while meeting QoS requirement, author conducts measurement and analysis on the QQ offline downloading system to find key factors which impact the cloud bandwidth consumption of download process. An adaptive cloud bandwidth rental and allocation strategy is proposed. The experimental results show that the system with this strategy not only ensures the quality of service but also slashed cloud bandwidth consumption.

Povzetek: Predlagana je izboljšava računalništva v oblaku.

1 Introduction

With the rapid development of cloud-computing technologies, more and more Internet applications appear with cloud platform. As popular services with a large amount of users, P2P (peer-to-peer) file distribution systems are also evoluting toward cloud, and then turning into the cloud-assisted file sharing systems. Cloud computing is dynamic and extensible. It usually provides the virtual computing model of resources through the internet. Its major features are capable of rapid deployment of resources or access to services, scalability on-demand and use. It provides service through the internet.

In order to enhance the quality of file sharing and save system cost, we study on real system to solve these questions. Network measurement is considered to be one of the important means to understand the internet and its applications. It is also often used to find problems in network applications and provides the basis for system optimization. P2P file-sharing system which is the most popular web application has become the main source of Internet traffic. P2P file-sharing system has attracted many scholars to start measurement researching. Some researchers found that there are two obvious flaws in this system. One is the availability of file resources can not be guaranteed, the other is the huge download speed difference of users [1]. On the one hand, the availability of documents can not be guaranteed because there are no central servers saved the actual contents of the file in P2P file-sharing system. File data is completely provided by the user. But user may be online or offline, the dynamic behavior can not guarantee to provide a complete copy of all documents at any time. Therefore system can not guarantee the availability of documents. On the other hand, there are two factors for the difference of users download speed. One is the difference between supply and demand in different files, the other is the difference of connectivity between different network nodes. User may even suffer from extremely low download speed. Studies have shown that node connectivity between each other is very good in the situation of campus network environment, but every day there will be a large number of download task stop or restart due to access not any file data in P2P file sharing system. Therefore the most fundamental reason leading to above two defects is that P2P file sharing system service model, rather than the node network connectivity. In order to compensate for the lack of pure P2P model, some scholars have put forward the hybrid file-sharing publishing system, this hybrid system combines the CDN (content distribution network) and P2P system [2,3]. In this hybrid system some popular shared files will be uploaded to the CDN server, users can download the popular file data from the server. But there is almost no effect on the improvement of non-popular file download experience.

With the improvement of cloud technology and cloud infrastructure, renting cloud platform provides computing, storage, bandwidth resources. It can improve the performance of P2P file sharing and distribution system. People apply the idea to practice, forming a cloud-assisted P2P file sharing application. For example, QQ offline download is also known as cloud download [4], which provides a support for the appointment file download service. After receiving the user's download request, the system takes over the user's download task through renting computing resources from the cloud platform. User does not need to online wait after user submits a download request. The renting computing resources serve as download machines to finish the task.

The download file will be uploaded to the storage space rented from a cloud platform [5-7]. This storage space is called cache cloud. The system immediately notifies the user can download the booking documents in the next period of time (e.g. seven days).

At present the measurement research of the cloud assist P2P file sharing system is lacking. In this paper, using QQ cyclones offline download system for measuring object, we research the file availability, user's download experience and system cost. First the offline download system architecture and working principle are introduced. Second, through the actual measurement we analyze the characteristics of the offline download system, understand how to solve the defects of the file availability and user download speed in the cloud assist service mode and analyze the load of the offline download system and cloud bandwidth consumption. Finally, an adaptive cloud bandwidth rental and allocation strategy is proposed. The strategy is applicable to the cloud assist P2P file sharing system. It can maximize the synergy between the node acceleration and cloud acceleration and guarantee the quality of service and save the cloud bandwidth cost.

The rest of this paper is organized into five sections. In Section 2, the offline download system architecture and working principle are introduced. In Section 3, we measure the actual system and analyze the effectiveness of cloud collaboration service model. An adaptive cloud bandwidth rental and allocation strategy is proposed in section 4, discuss how to guarantee the quality of service and save the cloud bandwidth cost. Experiments and discussions are detailed in Section 5. This paper is concluded in section 6.

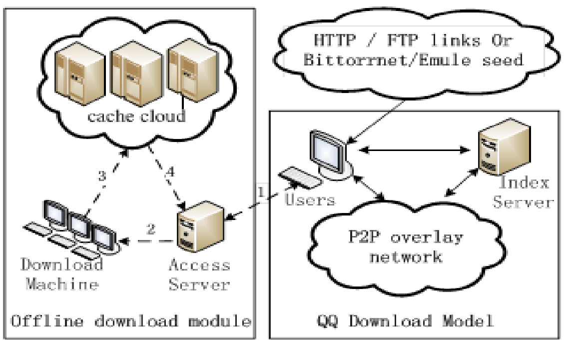

Figure 1: Offline Download System Architecture.

2 Offline download system architecture and operating principle

In order to improve the service quality of the existing cloud –assisted file sharing application system, we collected the actual operational data of QQ offline download system for 60 days. In this section, we first describe the offline download system architecture. Then describe its working principle.

2.1 System architecture

QQ offline download service is built based on the original QQ Tornado download acceleration system architecture. In the original QQ cyclone system, the source that users download can be ordinary HTTP/FTP links and Bittoirent/eMule. After the client has obtained the Hash of content about the target download file, it will communicate with QQ index server to get other online nodes information. These online nodes are sharing user's target file. Therefore, in the process of the download we can simultaneously acquire data from the source and QQ P2P networks. In Figure 1, the right part is the architecture of the conventional QQ download system. The left part is the new modules.

QQ offline download system is composed of the following components.

(1) Caching cloud: The general term lease from the cloud platform to store and upload bandwidth resources. Cache cloud is composed of many cloud storage servers which are distributed in different network locations. Cache cloud is used to cache the files which users appoint offline download, and accelerate the retrieve user's files process.

(2) Access server: It holds the information of all files currently stored in the caching cloud. Such as the file original source link, content Hash, file size and so on. In addition, if the file that user requests to download is not yet stored in the caching cloud, the access server will send the relevant information of the target file to download machine and assign download machine to take over the download task.

(3) Download machine: Download machine is composed of a large number of virtual machines. The physical location of the virtual machine may be distributed in a number of different areas. According the information received from the access server, download machine plays online download node to help users downloading the target file, and upload the successful download files to the caching cloud.

2.2 Operating principle

When users use offline download, the download process can be divided into two steps: add tasks and retrieve files.

(1) Add task: When the user requests a file offline download, QQ client will send the file information including content Hash and source link to access server of offline download system. It is shown as the arrow 1 in Figure 1. If the target file is not stored in the cache cloud, the access server will send the received file information to download machines, and assign one of the virtual machines to take over the user's download task. It's shown as the arrow 2 in Figure 1. The download progress will be informed the client in real time. In this case, users do not need to wait for download process online. After the file is completely downloaded, download machine will upload the file to caching cloud. It's shown as the arrow 3 in Figure 1. Then the caching cloud will generate a URL for the received file and send

information to the access server. It’s shown as the arrow 4 in Figure 1. Access server will store cache cloud URL, file Hash and file size in the database. As long as the requested file already stored in the cache cloud, the client will receive the URL that access server sends. The user is informed immediately that file retrieval operation can be carried out at any time within a certain period of validity. The process of add a task completes. Of course, if the user initiate offline download request, the target file already stored in the caching cloud, then the process of adding task complete immediately. Access server can immediately notify user to start high speed retrieve the file.

(2) Retrieve file: In the offline download application, users download the request file to a local machine. The process is called retrieve file. In this process, the data may come from a source link of the file, the QQ node that is sharing the file and a cloud that has been stored the file. It is shown as the broken line arrows in Figure 1. The primary task of the cache cloud URL is to ensure availability of the files. In addition, the initial system design, it provides consistent upload speed limit for each retrieved file.

3 Offline download system measurement and analysis

By actual measurement, we expect to get the following features of the offline download system: cloud service model can help solve the defects of original P2P file-sharing file system; in the user file retrieve process we monitor cloud data transfer rate, system load and the corresponding cloud bandwidth consumption; find the major factors which affect the bandwidth consumption of cloud in the file retrieval process. According to the above measurement target, we set the data information obtained. First the measurement data set is described. Subsequently, display and analyze the measurement results.

3.1 Measurement methods and data set description

According to the measurement target, we need obtain the following data.

(1) The requested file has been stored in the cache cloud. There is at least one complete copy in the system. Therefore, the proportion of the request reflects the ability of guaranteeing file availability. We can get the proportion from the requests stored in access server.

(2) Study the effect of cloud assist in improving the download speed, we need to compare the offline download file retrieval process and the data transfer rate of ordinary QQ download process. The duration and the amount of total download data are required in each acquisition process.

(3) The proportion of various types of data transfer rates in the file retrieval process, we need to get statistical task duration, the amount of data download from cache cloud, P2P networks and the source link respectively.

(4) Get the start time and the stop time of each file retrieval process. From the two times we can calculate the number of concurrent tasks in the system at any time. It reflects the system load. According to each file download speed from cache cloud, we can approximately get the cloud bandwidth consumption of offline download system at any moment.

(5) In each file retrieval process we extract the identity of the download target file, the download user ID and the identity of the user's network connection type. It can help us to reveal whether the different users have different download experience when they retrieval different documents.

The above data, the total amount of offline download request and the amount of request completed immediately can be obtained from offline download access server, the rest information needs to extract from the user QQ client records.

3.2 The effectiveness of cloud collaboration service model

On the basis of measurement results, we analyze the cloud collaboration service model. Whether the existing cloud collaboration service model can solve the availability of documents and users download speed in P2P file sharing system.

(1) Availability of download file

We have a statistics of the users’ retrieval files through offline download. The amount of their respective downloads is rare. In all the offline download files, more than 50% of the resources are only downloaded once within the 10-day period. 91.7% of the average daily downloads is less than one time, while the proportion of documents more than 10 times only is 0.44% in the average daily downloads. These results indicate that the files which user requests by offline download service are almost non-popular documents. The file retrieval process can start, namely, the target file already stored in the cache cloud, and the cache cloud can provide high-speed upload for users. Therefore, file availability is guaranteed. The resource of user request have stored cache cloud, user can get the best download experience, but the resource is not stored cache cloud, user need to wait the download machine to finish the download task. The proportion of cache cloud files is bigger, the user download experience better. During the measurement period of two months, we found that the proportion every day is more than 94%. This results show that users can immediately begin high-speed download after users send a offline download request. So cloud assist offline download service is good to guarantee the availability of download files.

(2) Download speed

Download speed is generally considered the most important performance indicators in the file sharing system. Now we analyze the measurement results of the data transfer rate in the process of offline download files retrieving. Compared offline download process with general QQ download process, the average download speed can evaluate the effectiveness of improving download speed of cloud collaboration.

The traditional QQ download system mainly depends on the node accessibility to accelerate the download process. For the user, offline download system provides the cloud collaboration and synergy auxiliary node acceleration services. Cloud acts as a significant role in assisting acceleration mode, but in the process of offline download file retrieval download speed obtained from QQ P2P network is very limited, with an average of only 28 KB/S. Node auxiliary acceleration effect on offline download file retrieval process is not as good as on traditional QQ download task. This maybe that most offline download requests are unpopular files, also maybe that the stable data transmission rate provided by cache cloud seizes the user download bandwidth.

Cloud Collaboration offline download service significantly improves the performance of P2P file sharing system. The system leases computing resources from cloud platform to act as download machines which take over the download tasks. The system rents large capacity cloud storage resources to store user request download files. It greatly improves the usability of the unpopular file. The system also rents the cloud bandwidth to provide cloud collaboration acceleration for user file retrieval. The model can ensure the user high-speed downloads. Even if the request download file is unpopular, it can not accelerate from a P2P network, but it can still get very high download speeds. With the rapid expansion of the user group, file retrieval process over reliance on cloud acceleration method is bound to the offline download system brings a huge cloud bandwidth consumption.

(3) Offline download system load

Actual measurements reflect the bandwidth consumption and the load condition in the cloud offline download system. Figure 2 (a) depicts the number of concurrent tasks and the corresponding cache cloud bandwidth consumption in the offline download system during the first 4 weeks of the measurement cycle. It shows that the consumption of cloud bandwidth in the offline download system changes as the parallel number of the file retrieval process. Bandwidth consumption reaches a peak value of 18Gbps. Through the characterization of system load changes in a single day, we can observe more clear cache cloud bandwidth consumption and the relationship of system parallel tasks. Figure 2 (b) depicts the system load and upload bandwidth evolution of cache cloud in a single day. The figure shows the number of running tasks in the system is relatively less from 5:00 to 7:00 in the morning. In this period of time the cache cloud bandwidth consumption remained at the lowest level of the day. From 8:00 to 13:00 in the morning file retrieval process running in the

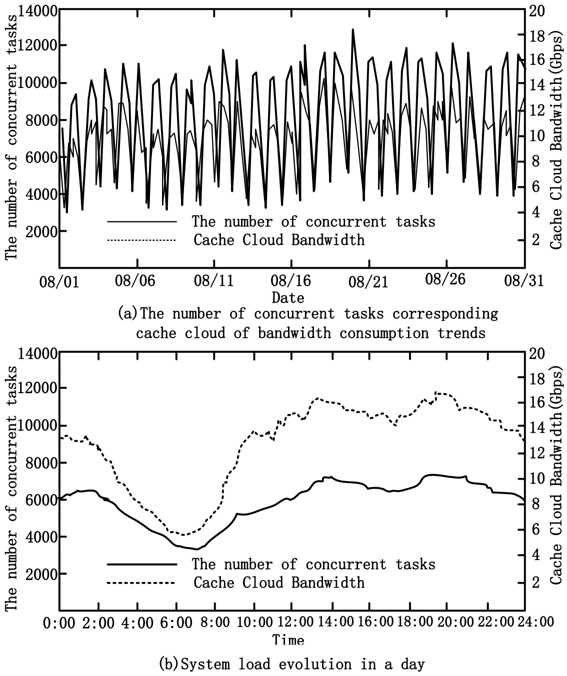

Figure 2: QQ offline download system cache cloud bandwidth consumption trend.

offline download system steady growth. Upload bandwidth consumption of cache cloud will also rise. Both reached a peak in the vicinity of 20:00 in the day. In the case of node assisted download acceleration, it still shows strong positive correlation between cache cloud bandwidth consumption and the number of parallel tasks. This will cause a great deal of system operation cost. It is essential to reasonable cache cloud bandwidth allocation strategy.

4 Cache cloud bandwidth strategy

If the potential of the node acceleration mode can be fully played out, we can not only ensure the user download speed but also reduce the data transmission speed which is provided for file retrieval process by cache cloud. This can reduce the system cloud bandwidth consumption, save the operating cost of the system. Therefore, this section an adaptive cache cloud strategy is proposed. It applies to the mixed model of cloud collaboration and P2P file sharing system. The strategies maximize the synergistic effect on node Auxiliary Acceleration and cloud assist acceleration. This can guarantee the quality of service and save the bandwidth overhead of cloud.

The following is the design idea of the adaptive cache cloud bandwidth strategy. We first get the download speed of the file retrieval process obtained from P2P networks, calculate cloud acceleration rate with QoS indicators in each file retrieval process, and then get cache cloud bandwidth rented from cloud platform.

Assuming at time t there are N(t) files are in offline download file retrieval process， these files can be expressed as $I=\{1,2,\ldots,N(t)\}$, any file $i\in I$,useful information extracted from the index server are summarized as follows: $D(i,t)$ is the number of users downloading the file i at time t ; $D_{NAT}(i,t)$ is the number of NAT users downloading the file i at time t ; $D_d(i,t)$ is the number of directly connected users downloading files i at time t ; $S_{NAT}(i,t)$ is the number of NAT users as a seed file i at time t ; $S_d(i,\text{t})$ is the number of directly connected users as a seed file i at time t ; $D_{NAT}^{o}(i,t)$ is the number of NAT users using offline download to retrieve files i at time t ; $D_d^{o}(i,t)$ is the number of directly connected users using offline download to retrieve files i at time t .

NAT Users upload bandwidth is expressed as u_{NAT} , directly connected users upload bandwidth is expressed as u_d . P2P connections can only be initiated by the NAT user itself, initiated by an external node connection requests will be masked the NAT [8]. For the file i , all users can provide at time t available upload bandwidth, which is calculated as (1) shown below:

$$U_{NAT}(i,t)=u_{NAT}\times D_{NAT}(i,t) \qquad (1)$$

All directly connected users who is sharing file i can provide at time t available upload bandwidth, which is calculated as (2) shown below:

$$U_d(i,t)=u_d\times[D_d(i,t)+S_d(i,t)] \qquad (2)$$

NAT users who are Downloading file i can obtain the upper limit of the average speed of P2P, the upper limit is calculated as (3) shown below:

$$\begin{aligned} r_{P2P,d}(i,t)&=\frac{U_d(i,t)}{D(i,t)}+\frac{U_{NAT}(i,t)}{D_d(i,t)} \\ &=\frac{u_d[D_d(i,t)+S_d(i,t)]}{D_d(i,t)+D_{NAT}(i,t)}+\frac{u_{NAT}D_{NAT}(i,t)}{D_d(i,t)} \end{aligned} \qquad (3)$$

Collaboration in the cloud service model, cloud bandwidth leased in accordance with the cycle, the system can adjust the amount of bandwidth leased before the arrival of each lease period. in every lease cycle (assuming each lease period length T) within a cloud platform provides a fixed maximum upload bandwidth offline download system, adaptive caching cloud strategy we propose is that the bandwidth of the decision before the arrival of each lease period Cloud Bandwidth the amount of rent and hire cycles in the cloud cache bandwidth reallocation necessary. Strategies are as follows:

Assuming a cloud bandwidth leasing period beginning from the time t , cache cloud provide bandwidth for offline download file retrieval process of file i ,the bandwidth is calculated as (4) shown below:

$$J_{req}(i,t)=K_{NAT}(i,t)[R_{thres}(t)-r_{P2P,NAT}(i,t)]\times D_{NAT}^{o}(i,t)+K_d(i,t)[R_{thres}(t)-r_{P2P,d}(i,t)]D_d^{o}(i,t)$$

(4)

$R_{thres}(t)$ represents cache cloud provide acceleration threshold value at time t , $K_{NAT}(i,t)$ represents NAT users cloud acceleration switch, the values is calculated as (5) shown below:

$$K_{NAT}(i,t)=\begin{cases}1 & r_{P2P,NAT}(i,t)<R_{thres}(t)\\ 0 & r_{P2P,NAT}(i,t)\geq R_{thres}(t)\end{cases} \qquad (5)$$

$K_d(i,t)$ represents directly connected users cloud acceleration switch, the values is calculated as (6) shown below:

$$K_d(i,t)=\begin{cases}1 & r_{P2P,d}(i,t)<R_{thres}(t)\\ 0 & r_{P2P,d}(i,t)\geq R_{thres}(t)\end{cases} \qquad (6)$$

At time t, all running the file retrieval process of the total demand for bandwidth cache cloud, the total demand is calculated as (7) shown below:

$$J_{total}(t)=\sum_{i=1}^{N(t)}J_{req}(i,t) \qquad (7)$$

Therefore, from time t to $t+T$ within the cloud bandwidth rental period, system leased from the cloud platform cache cloud bandwidth $B=J_{total}(t)$.

If the lease period, no other file $j\notin I$ retrieval process is started, for any file $i\in I$, cache cloud provides a total bandwidth of all the file retrieval process within the renting cycle always $J_{req}(i,t)$.

If at time $t'\in(t,t+T)$, start the file retrieval process of file $j\notin I$, then the system cache cloud reallocation of bandwidth leased. first, the update the file retrieval process is in the collection of all the files, the updated collection is $I=\{1,2,\ldots,N(t')\}$, then obtains the number of users corresponding to each file $i\in I$ and the user type information of network connection, according to the equation (4) calculate the cache bandwidth $J_{req}(i,t')$ it needs to provide the cloud, Finally, calculate all the tasks needed to retrieve the cache files total cloud bandwidth $J_{total}(t)$.

If $J_{total}(t')\leq B$, the system first assigned to the file i size of $J_{req}(i,t')$ cache cloud Bandwidth, the remaining part of the cache cloud of bandwidth $B-J_{total}(t')$ will be allocated equally to each the file retrieval process is running.

If $J_{total}(t')>B$, to be fair, caching cloud assign cache cloud bandwidth to all the file retrieval processes of the files i .the bandwidth is $B\times J_{req}(i,t')/J_{total}(t')$.

In the lease cycle, whenever the file retrieval process of a new file start, more than the bandwidth of the cache cloud rented allocation strategy executed once. Rent amount until the next cycle before the next arrival of renting, adaptive bandwidth strategy according to formula (7) obtained in one period are adjusted cloud cache bandwidth.

Considering the system dynamic, the cloud bandwidth strategy can adaptively adjust the amount of leased cloud bandwidth and the accelerate efforts to process each file download. This strategy not only considers the influence of file polularity, but also provides the same service for different file download process.

5 The experimental results

Through simulation of the actual system operational data, analysis of the feasibility of bandwidth adaptive caching cloud strategy and cloud saving system bandwidth overhead effects. In order to save the system cloud bandwidth overhead, we calculate the theoretical maximum rate of P2P in the file retrieval process. Then the acceleration ability of P2P network to the file retrieval process is evaluated. We improve the node assisted acceleration as far as possible. After the P2P rate in offline download file retrieval process, the bandwidth strategy will decide whether to provide cloud acceleration according to the threshold rate. The sum of cloud acceleration rate provided to all file retrieve process aiming at one file is cache cloud bandwidth applied for this file. The cache bandwidth sum of cloud which is assigned to all being downloaded files is system rented cloud bandwidth in the next cycle.

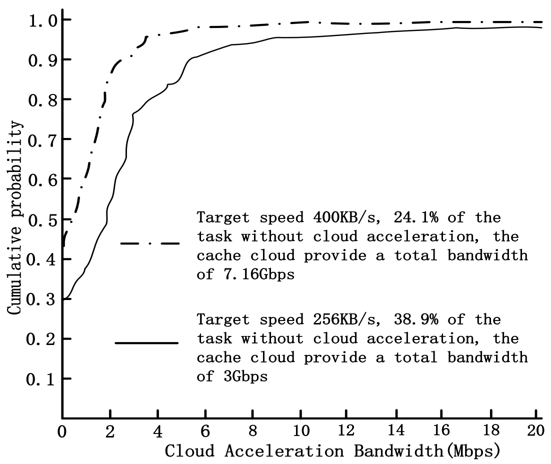

Figure 3: Cumulative probability distribution of the accelerate bandwidth that allocate each files by the cache cloud bandwidth strategy at idle time.

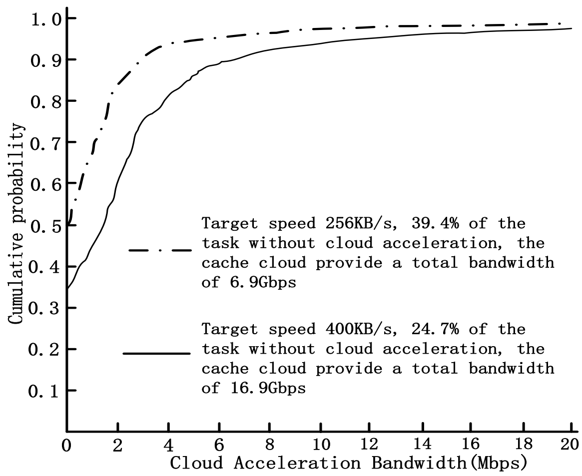

Figure 4: Cumulative probability distribution of the accelerate bandwidth that allocate each files by the cache cloud bandwidth strategy at peak hours.

In the idle period (6:00) and peak hours (20:00), after the implementation of the strategy of cloud bandwidth allocation, the distribution of the accumulated probability of the cache bandwidth provided to each file is as Figure 3 and 4. From Figure 3, when the threshold speed is set to 256KB / S, over 46% of 1,686 files being downloaded can't get accelerate bandwidth provided by the cache cloud. Most files which need cache cloud to provide acceleration bandwidth required bandwidth not high. When the threshold rate was 256KB/S, the gain-bandwidth cloud acceleration values greater than 4Mbps file only about 5 percent of the total file was being requested. When the threshold rate is 400 KB/S, the ratio of the value is only about 23%. In addition, even if the threshold value is set to be as high as 400 KB/S, as many as 30% of the file does not need to get acceleration bandwidth from the cache cloud. Finally, in the two different rates, only a very small amount of files need to get the acceleration bandwidth over 20 Mbps from the cache cloud.

In the hot time, the online node is the most and the ability to accelerate the process of file retrieval is more powerful, so the long tail of cache cloud acceleration bandwidth distribution is obvious. Figure 4 shows that the threshold rate is 256KB/S, over 50% of 2,742 files being downloaded do not need accelerate bandwidth provided by the cache cloud. When the threshold rate is 400 KB/S, the ratio is still more than 30%. The two values are higher than the corresponding value at 6:00. This indicates that the offline download file retrieval process may be obtained a greater intensity of node assisted acceleration from the P2P network. As the same as the idle period, most of the downloaded file does not need to consume too much bandwidth of cloud cache during the hot time. While the number of concurrent offline download files is even greater, there are still only a very small number of files to need a larger acceleration bandwidth by cache cloud.

Analysis of the results of the strategy implementation, the strategy has the ability to significantly relieve the pressure on the cache cloud bandwidth in the condition of ensuring the user download experience

Conclusion

With the development of cloud technology and cloud infrastructure improvement, the cloud platform provide computing, storage and bandwidth resources. Cloud assist service model hire a large number of cloud storage space to cache user appointment downloaded file. The system can guarantee download speed of the appointment documents through renting cloud bandwidth. The system can adjust the rental amount of cloud bandwidth every cycle. We propose a cloud bandwidth rental and allocation strategy. Based on the actual operational data, we simulate the adaptive cache cloud bandwidth strategy implementation process. The strategies maximize the synergistic effect on node auxiliary acceleration and cloud assist acceleration. This can guarantee the quality of service and save the bandwidth overhead of cloud.

References

[1] Johan Pouwelse, Pawel Garbacki,Dick Epema, Henk Sips. The Bittorrent P2P File-Sharing System [J]. Measurements and Analysis Lecture Notes in Computer Science, 2005， Vol.36 (40), pp: 205-216.

[2] [2] Yin H., Liu X., Zhan T., et al. Design and deployment of a hybrid CDN-P2P system for live video streaming experiences with Live Sky[C]. In Proceedings of ACM Multimedia (MM), 2009.

[3] Xu D,Kulkami S., Rosenberg C, Chai H.. Analysis of a CDN-P2P hybrid architecture for cost-effective streaming media distribution [J]. Multimedia Systems, 2006.

[4] Huang Y., Li Z., Liu G., et al. CloudDownload: Using Cloud Utilities to Achieve High-quality Content Distribution for Unpopular Videos[C]. Proceedings of ACM Multimedia (MM'11), 2011.

[5] Ao N.X., Xu Y.Y.,Chen C.J. et al. Offline Downloading: A Non-Traditional Cloud-Accelerated and Peer-Assisted Content Distribution Service[C]. Proceeding of 2012 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC， 12).

[6] Qiu X.J, Li H.X., Wu C. Cost-Minimizing Dynamic Migration of Content Distribution Services into Hybrid Clouds[C]. Proceedings of the 31st IEEE International conference on computers and communications (ICC'12), 2012.

[7] Li X, Yang Y. Trusted Data Acquisition Mechanism for Cloud Resource Scheduling Based on Distributed Agents [J]. China Communications, 2011, Vol.8 (6), pp: 108-116.

[8] Liu Y., Pan J. The impact of NAT on BitTorrent-like P2P systems[C]. Proceeding of 9th IEEE Peer-to-Peer Computing (P2P'09), 2009.

[9] Jin Li, Xinyi Huang, Jingwei Li, Xiaofeng Chen, Yang Xiang. Securely Outsourcing Attribute-based Encryption with Checkability. IEEE Transactions on Parallel and Distributed Systems, vol. 25(8), pp: 2201-2210, 2014.

[10] Jin Li, Xiaofeng Chen, Mingqiang Li, Jingwei Li, Patrick Lee, Wenjing Lou. Secure Deduplication with Efficient and Reliable Convergent Key Management. IEEE Transactions on Parallel and Distributed Systems, vol. 25(6), pp: 1615-1625, 2014.