Transmission optimisation technology based on edge-network

Baoqi Jiang and Yaozong Zhao

Personal Cloud Department,
Baidu Online Network Technology Company,
Shangdi Street, Beijing, China
Email: baoqi-j@163.com
Email: yaozongzhao@gmail.com

Chaoqun Hong

Xiamen University of Technology,
Tianma Road, Xiamen,
Fujian, China
Email: cqhong@xmut.edu.cn

Weipeng Wu*, Hongchao Zhang, Shuai Guo,
Ruifeng Li and Haihao Tang

Personal Cloud Department,
Baidu Online Network Technology Company,
Shangdi Street, Beijing, China
Email: weipengw0306@163.com
Email: comtjz@163.com
Email: shuaidai25@126.com
Email: wind-gofly@163.com
Email: haihaot@gmail.com
*Corresponding author

Abstract: With the development of network infrastructure, user data has shown an exponential growth. Improving the transmission quality of user network is essential for the current requirements, however, user network environment is generally quite complicated and there exists all kinds of problems, consequently, the traditional central server architecture cannot solve these issues out because it cannot support the high throughput in the network. According to these drawbacks, in this paper, we propose a new architecture, which is made of the edge nodes as points of presence (POP). This architecture improves significantly the user experience including connection and transmission by using network detection, data encryption, and smart access point selection. In particular, this improvement becomes more obvious to the user who experiences the slow network speed in network disk. Furthermore, this technology can be applied on services that require low latency and high throughput.

Keywords: edge points; network detection; transmission encryption; POP acceleration.

Reference to this paper should be made as follows: Jiang, B., Zhao, Y., Hong, C., Wu, W., Zhang, H., Guo, S., Li, R. and Tang, H. (2022) 'Transmission optimisation technology based on edge-network', *Int. J. Web Science*, Vol. 3, No. 3, pp.249–264.

Biographical notes: Baoqi Jiang was employed by Baidu Inc. from 2008. He is an architect in the direction of network disk network technology, covering bandwidth cost, user transmission experience, etc.

Yaozong Zhao was employed by Baidu Inc. He is an architect in the direction of network disk network technology, covering bandwidth cost, user transmission experience, etc.

Chaoqun Hong received his PhD degree from Zhejiang University, Zhejiang, China, in 2011. He is currently a Professor in the School of Computer and Information Engineering, Xiamen University of Technology, Xiamen, China. His research interests include high-performance computing, image processing, computer vision, and pattern recognition. He has authored or co-authored more than 40 scientific articles.

Weipeng Wu graduated from Loughborough University, and joined Baidu Inc. from 2020. He is charge of CV and related projects in Netdisk of Baidu.

Hongchao Zhang was employed by Baidu Inc. from 2008. He is an architect in the direction of network disk network technology, covering bandwidth cost, user transmission experience, etc.

Shuai Guo was employed by Baidu Inc. from 2008. He is an architect in the direction of network disk network technology, covering bandwidth cost, user transmission experience, etc.

Ruifeng Li has employed by Baidu Inc. for several years. He is the manager of Netdisk in Baidu. He is responsible for risk control and team growth and so on.

Haihao Tang has been working on infrastructure since 2012. He has participated in many large-scale projects and obtained lots of achievements.

1 Introduction

At present, considerable progress has been made in the corresponding research on internet, internet of things (IoT) and big data, so the amount of data on the internet has shown explosive growth (Atzori et al., 2010; Chao et al., 2021). It is expected that by 2025, the amount of data generated every day in the world will reach the 100 exabytes level, and it will grow at an annual growth rate of 30% (Heater, 2016). An efficient network transmission is the important foundation of the network performance (Pallis and Vakali, 2006; Vakali and Pallis, 2003; Molina Moreno et al., 2006). There are lots of factors that affect the transmission speed of users, including the performance of the user's local equipment, the network quality of home access point, the network quality of internet service provider (ISP) access point and data centre export quality and so on.

Generally, the performance of the user's local equipment and the network quality of the home access point are uncontrollable factors and even the transmission speed quality of the data centre can be optimised directly. Additionally, the ISPs also bring some difficulties to hinder the improvement of link performance. However, the current biggest problem is the transmission performance of the link from the home access point to the data centre. From the current works or papers about this issue, Dropbox, AWS (Palumbo et al., 2021), Azure and other companies have conducted many experiments on it and optimised the performance of the network links from different aspects. Particularly, Dropbox takes measures of creating around 20 points of presence (POPs) to accelerate the network, which decreases dramatically network latency and throughput when the distance is far between the data centre and the clients (Mathis et al., 1996; Khan et al., 2021). Although this infrastructure is applying well on the multiple countries in the world, it is still not suitable to the complicated links in China, because Dropbox needs to build POP network and dedicated transmission line by own and the few POP points, which cannot solve the transmission problems in our complicated scene (Cardellini et al., 2003; Nande et al., 2021; Song and Montenegro-Marin, 2021). Consequently, in this paper, we proposed a series of measures to solve this problem. The main approach is that using the third-party recruiting edge nodes as the POP point acceleration technology to improve the transmission performance (Nande et al., 2021) of the user network. Compared with those self-built POP points in the industry, the third-party recruitment of POP points faced some challenges such as data security and transmission performance, but it also has the advantages of more extensive nodes and low cost. Hence, in this paper, we proposed a novel method that can use the open construction of POP networks to increase the range of access points and solve data security issues through security encryption mechanisms, then the users who experienced a slow transmission speed reduced around 27.6% through using the POP-based network scheduling strategies.

The remainder of this paper is organised as follows, in Section 2, the details of the POP acceleration technology is introduced. In Section 3, some related applications are described. In Section 4, the experiments have conducted on the designed infrastructure. Lastly, this paper is concluded in Section 5.

2 POP acceleration technology

2.1 Connection issue

In the process of establishing a connection between the network disk client and the network disk source station server, data usually needs to span multiple networks to reach the network disk program server, and the network delay usually takes about 50 milliseconds. As shown in Figure 1, a telecom user who is from Guangdong Shantou needs to experience 14 hops to reach the network disk telecommunications access point to access the network disk (pan.baidu.com), which takes 43 ms. Each row of records in the chart means that the sent data has to be forwarded by a relay device. Generally, the more hops, the worse the access speed. If more than 30 hops, it may mean that the destination is unreachable. When a network disk client connects to the network disk service, if there is an abnormality in the route transfer process, such as downtime or slow forwarding, this will affect the network connection between the client and the server, such as abnormal connection disconnection problems, slow opening or slow downloading.

When the network disk client fails to connect or downloads slowly (Khan et al., 2021), if it is observed that the intermediate link device is abnormal, then the routing strategy will be adjusted and then skip the abnormal part, finally, it will connect to the network disk server by detour, which can be solved to a certain extent download problem for network disk users. However, the equipment in the middle of the link is uncontrollable, and the routing transfer algorithm is also uncertain, it is not feasible to adjust the routing link by the intermediate equipment. Therefore, we deployed the network disk on the ISP's line close to the network disk client through using the self-built or purchased POP access points. When the client downloads abnormally, it can connect to the nearest POP point and pass the current POP point. Assuming that when the link between Shantou Telecom and Guangzhou Telecom is congested in Figure 2, Shantou Netdisk users may experience connection failures or slow downloads. At this time, the POP nodes on other links are issued to the Netdisk client such as Zhongshan Telecom's POP, then bypasses the congested link and starts from Shantou through Zhongshan to Guangzhou Telecom, thus the user can experience at low cost the normal operation of the network disk.

According to Figure 2, compared with the original link, the introduction of the POP relay service has increased the route jump and the handling of the relay service, in addition, the abnormal link can be successfully bypassed, thus it provides a feasible solution for users to improve the slow speed of download.

2.2 General infrastructure

The whole system in Figure 3 can be divided into POP management, data centre, key management, edge points and client SDK:

- *POP management:* In POP management, it is in charge of managing online the edge points, including recording the unique identification, IP, ISP, regions, online status and so on. Aside from this, it is also responsible for selecting a certain number of high-quality edge nodes from ISP, regions and other factors when requesting the edge nodes.
- *Data centre:* The data centre service is mainly responsible for authenticating the edge nodes of request data to prevent forged requests, which is implemented by encrypting the returned data in real-time when the edge node requests data.
- *Key management:* The key management service uses mainly symmetric encryption to generate the keys for those files that need to be accelerated, and each file has its own key, and they will be cached according to the unique identification of files and key mapping. Additionally, the generated keys that have not been used for a long time will be deleted.
- *Edge nodes:* The edge nodes are located in the edge network and are close to the server of the client network. In order to avoid invalid requests, authenticating the client requests will be processed. The edge nodes forward the received client requests to the data centre, and then send the encrypted data returned by the data centre to the client.

- *Client SDK node management:* The client SDK node management module is responsible for requesting the edge nodes from the node management server and recording and monitoring the network quality of each edge node during it is running. The edge node optimisation module selects the most optimal edge node for acceleration based on some factors such as the time-consuming of the edge node RRT, ISP, the region, and the history of network quality. The connection scheduling module is responsible for concurrent connection quantity control, data distribution and monitoring connection quality and so on when the use of the edge nodes. The data decryption module is in charge of decrypting the encrypted data obtained from the edge nodes. The key management module is responsible for the key requests and storage.

2.3 Data security and encryption implementation

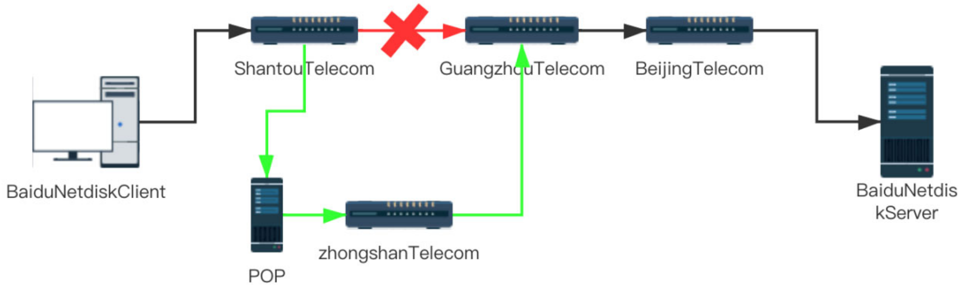
The POP points have lots of recruiting nodes, which are low in controllability, hence, when user data is posted to one of the nodes, a complete nodes security scheme is required to ensure that the user data is not leaked. In order to address these security problems, we proposed some methods as follow:

- The POP miner does not have login information, so a reliable API without user login information is supposed to be provided to the clients.
- The original data should be encrypted on the server before posting them to the POP, because POP miners only store the encrypted data without keys.
- The clients should be compatible with the encrypted data and non-encrypted data downloaded from the pop miner.
- The basic key needs to be encrypted to prevent the leakage of the basic key database.
- The master key and basic key should have invalidation and rotation mechanism.

Figure 1 This image shows a detailed connection information from an user to another server (see online version for colours)

S/N	IP Address	location	time
1	202.104.242.1	Telecom， Shantou City, Guangdong Province	0ms
2	125.91.2.157	Telecom， Shantou City, Guangdong Province	0ms
3	125.91.2.33	Telecom， Shantou City, Guangdong Province	0ms
4	125.91.1.85	Telecom， Shantou City, Guangdong Province	0ms
5	183.59.14.253	Telecom， Guangzhou City, Guangdong Province	6ms
6	59.36.104.81	Telecom， Dongguan City, Guangdong Province	6ms
7	202.97.22.170	China Telecom Network	51ms
8	--	Unknown address	0ms
9	--	Unknown address	0ms
10	220.187.17.150	Telecom， Beijing， Beijing	43ms
11	--	Unknown address	0ms
12	--	Unknown address	0ms
13	--	Unknown address	0ms
14	220.181.111.91	Baidu Access Point， Telecom， Beijing	43ms

Figure 2 Links example: show a link how to reach the destination from the client (see online version for colours)



Notes: Compared with the original link, the introduction of the POP relay service has increased the route jump and the handling of the relay service, in addition, the abnormal link can be successfully bypassed, thus it provides a feasible solution for users to improve the slow speed of download.

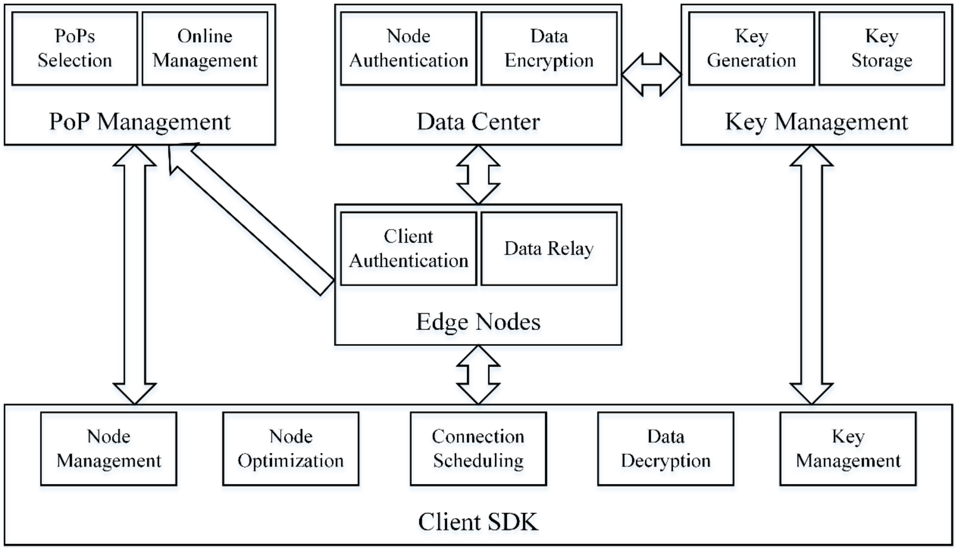
2.3.1 Encryption procedure

- The key management service is responsible for generating and storing the key. The key generation includes the key generation algorithm of the files and the key storage includes the basic key of file, encryption algorithm, the parameters of encryption algorithm and the slice size of encryption.
- The data encryption service is used to provide a download link, which means that it provides a separate API to obtain the encrypted data by doing stream encryption with those key parameters obtained from the key service to the original files.
- The POP miners obtain the encrypted data according to the download link produced from above.
- After the POP miners receive the encrypted data, the encrypted data will be parsed through the key parameters obtained from step 1.

2.3.2 Key management

- The data encryption service can obtain the basic key from the key management service. And the basic key is not stored on disk.
- The key management service authenticates the basic BNS authority of the data encryption service.
- The key service uses the master key to encrypt the basic key and store it in the key database. The key database needs to store the basic key, encryption algorithm, encryption algorithm parameters, encryption slice size, basic key expiration time and master key ID for each file. Additionally, the master key is not stored in the key service.

Figure 3 The POP edge nodes accelerating system architecture



Notes: The primary modules include POP management, data centre, key management, edge nodes, client SDK.

2.3.3 Authentication

- The POP miner will bring local information such as the MAC address to register by using the server interface after initialising.
- The server generates a public-private key pair and store the local information of the miner by using the POP miner ID. Besides, the POP miner ID is generated by the Md5 of the public key and the private key is used by the miners to identity authentication.
- The POP miners trust the server root certificate when compiling.
- The signature verification will be done when the key data is interacting between mining machine and mining machine, mining machine and user, mining machine and server.

2.3.4 Basic key

The basic key is randomly generated for each file and the expiration time is fixed, then the basic key will be encrypted by using the master key before adding to the database. The ID of the master key is stored in the key database along with the basic key, which facilitates the realisation of master key invalidation and rotation.

2.3.5 The encryption algorithm

The symmetric-key algorithm is considered because of the same file length before and after encryption. In addition, the encryption algorithm and its parameters will be added to the database with the basic key. There are lots of AES encryption modes, including ECB, CBC, CFB, CTR, GCM, etc. Among these modes, ECB and CBC need to be filled according to the length of the encrypted packet. However, the file length is not supposed to be modified so that it needs to be pre-filled to an integer multiple of the packet length and then padding is disabled. In addition, the ECB mode is not adopted, considering that the ciphertext obtained after the ECB encrypts the same content is always the same. On the contrary, other encryption modes convert the block encryption to stream encryption and the file length is always the same before and after encryption.

2.3.6 Segment encryption

When users are requesting data from the POP miners, the data centre obtains the encrypted key from the key management service and then slice the original file according to a fixed length. In order to be compatible with the existing P2P system, the maximum slice is 16 KB, and then it is encrypted in the unit of slice. Besides, the slice size is stored in the key database with the basic key.

Figure 4 The encrypted data structure, it shows that how the data is encrypted through basic key (see online version for colours)

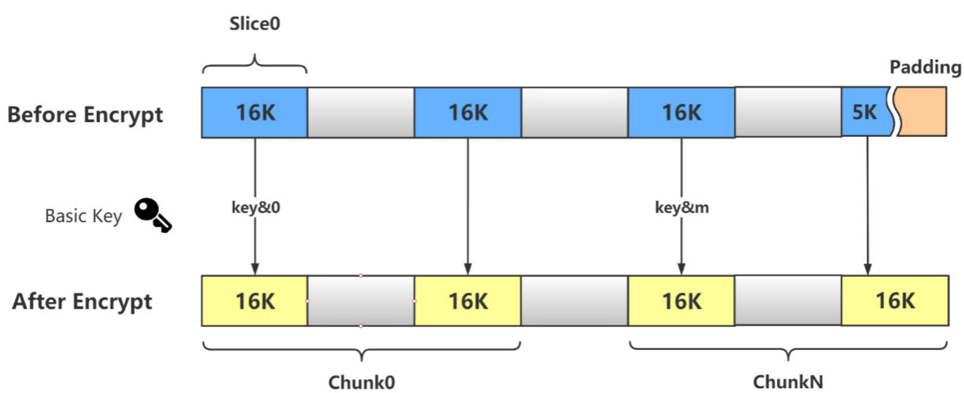
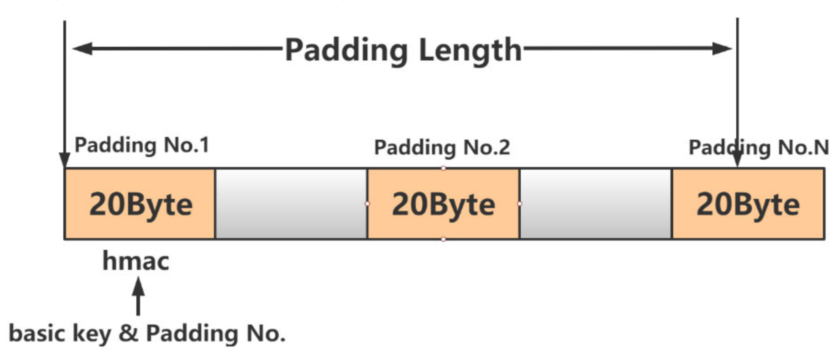


Figure 5 The 20 bytes length that needs to be filled and it will be encrypted by using basic key and padding number, lastly, the required length will be cut from the encrypted data (see online version for colours)



In order to prevent a large area of the same content from causing the same encryption result to cause content leakage, the number of slices relative to the entire file is used to add salt, that is, the encryption key of each slice is the base key and the number of the slice, and the end is less than the slice size of the slice. Partially use the following filling rules to fill up a slice size, as shown in Figures 4 and 5, the key generation rule with 16 KB as the slice size.

3 Experiment

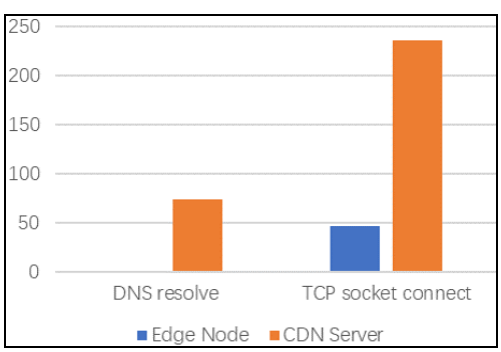
3.1 Network strategy

Transfer efficiency is very crucial target to prove the performance of this system, because all the clients will transfer data through the POP service. If the forwarding efficiency is low, the clients still experience the low download speed when they are using Baidu NetDisk service. Therefore, we take some measures to solve this issue for improving the experience of the users. Firstly, all the message interactions during the transfer process are completed in the memory, which can be implemented by using the zero-copy method. Secondly, the POP service uses the connection pool method to keep the connection with the clients and reduce the time-consuming hands. Besides, in order to save time for DNS resolution, the clients use IP address to connect directly to the POP service for the connection between the clients and the POP service. Also, the POP service has made a variety of adaptations and supported the transmission protocols of HTTP/HTTPS, HTTP2, UTP and KCP in the intermediate forwarding protocol. When the clients use HTTP/HTTPS to connect to the POP service, the TCP start-up needs to go through a slow-start mode. The initial congestion window after the handshake is generally 1–3 messages (in the kernel before Linux 3.0, the default is 3), in this paper, the value will be adjusted to 10. Regardless of packet loss, the time required to send data of size is directly related to RTT, the formula will be shown as follows:

$$Time = RT \times \log_2\left(\frac{size}{MTU \times IW}\right) \tag{1}$$

In the POP service, the initial size of the window is modified to 24, in the case of MSS = 1,460, the RTT is observed by sending different requests in Table 2.

Figure 6 The network time consuming (see online version for colours)



Notes: Edge nodes do not need DNS resolve, and the TCP socker connect time is reduced by five times.

From Table 2, with the increasing of the request size in some specific scenes such as cookie, SSL, the POP service can finish the request and send operations at a faster speed. In addition, for those idle connections, the POP service will turn off the slow-start mode in resuming transmission.

Table 1 The statisfication of speed-up effect

Request size	*Cwnd = 3*	*Cwnd = 10*	*Cwnd = 24*
<4 K	0	0	0
<10 K	1	0	0
<20 K	2	1	0
<64 K	3	2	1

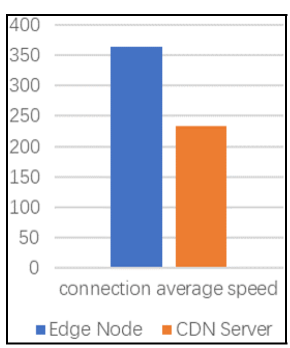
Notes: This table compare the RTT in different request size and Cwnd. When the value of Cwnd is equal to 24 and the request size is less than 64 K, the RTT is around 0–1.

In Figures 6, 7 and 8, Through the data forwarding evaluation in the unit of 512 KB, the single connection forwarding P90 time is basically maintained at about 600 ms. For network disk client can reach the maximum bandwidth capacity by establishing multiple connections.

3.2 *Scheduling strategies*

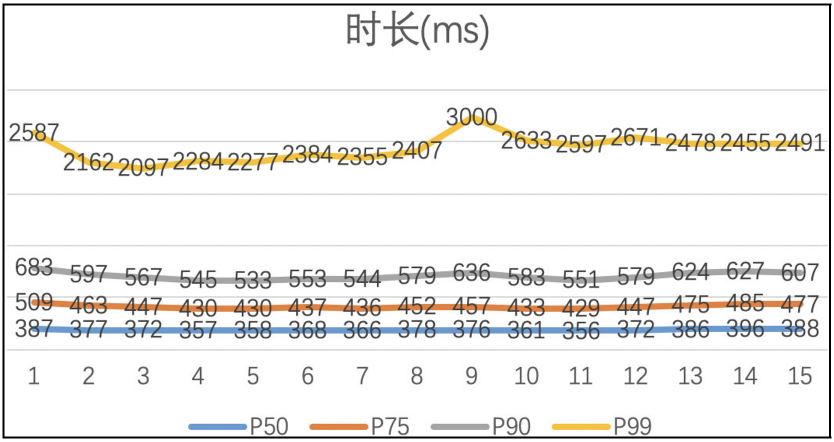
Because there is no absolute guarantee that abnormal links can be bypassed through a POP node, a particular selection of POP nodes is required in order for a network disk client to successfully bypass abnormal links through POP relay. The selected POP point not only needs to allow the disk client to connect properly, but also needs to ensure that the link from the POP point to the disk server is normal. This paper introduces the scheduling optimisation logic of PoP nodes to assign optimal access POP to clients. The basic idea is to collect all kinds of PoP node information that will affect the link between users and disk services, and to determine an optimal user – PoP – disk service path through the summary and integration of this information, so as to provide high-quality to forwarding capabilities for clients.

Figure 7 The average connection speed of the edge node and CND server (see online version for colours)



Notes: When the CDN occurs the download speed, the edge node will provide quicker speed for user.

Figure 8 The connection speed (see online version for colours)



Notes: When the CDN occurs the download speed, the edge node will provide quicker speed for user.

Nodes running POP programs detect link delay and download bandwidth of the network disk service at regular intervals to get information about the connectivity, delay, bandwidth speed of each link from themselves to the network disk service. When the network detection result is obtained, the POP program will be packaged and sent to the POP dispatch management service along with the running state (CPU, memory, network traffic, etc.) information.

In the service process of the PoP program, the service situation for the client is also collected. When each client downloads via PoP relay, PoP packages the client's IP address, version, and data round-trip throughput to the PoP Scheduling Management Service.

In POP management service, POP service information of one operator in the same region will be aggregated and sorted, and the PoP nodes in the range will be sorted and arranged to get the general details of the different levels of PoP nodes arriving at the network disk service link. Clients are also aggregated according to the geographic operator, and then connected with the geographic operator collection of the PoP node to get the link level from the client to the region level of the PoP node.

Another scheduling strategy here is to schedule according to the physical distance of the PoP node from the client. However, the set of POPs provided by distance does not necessarily guarantee that clients can connect to these POPs properly, because there is no historical proof, and the dispatching factor above is the presence of connection information for PoP nodes, so POP geographic operators below link quality can be excluded from dispatching based on the client's geographic operator.

If a client cannot connect to a POP node at a time or is still downloading slowly using POP, the client can request it again, and the manager adjusts it to the last selection in the hope that the new POP will improve user downloads.

Table 2 shows the connectivity rate of network disk clients with three access modes, namely, selecting the preferred node access through PoP dispatching system, near node access, and random node access. Comparison of average connection speed and slow repair (from less than 1 MB to more than 1.2 MB) shows that selecting the preferred node has a significant impact on improving the performance of disk clients at slow speeds.

Table 2 The figure shows the connectivity rate of network disk clients with three access modes, namely, selecting the preferred node access through PoP dispatching system, near node access, and random node access

None	*Preferential selection*	*Nearby selection*	*Random selection*
Connectivity rate	95%	83%	60%
Avg. speed	850 KB/s	780 KB/s	730 KB/s
Fix at slow speed	28%	25%	12%

In order to the unusual link can be bypassed when the POP service is forwarding, the POP needs to choose the best link and the chosen POPs not only keep the normal connection with the client of NetDisk, but also guarantee that the number of links from the POP points to the NetDisk server is in normal quantity. In order to finish scheduling strategy, the POP points will be assigned to each client, which is to collect the information from the POP service. Lastly, the POP can be judged whether the forwarding capabilities is provided for the clients.

In the POP service, link delay detection and download bandwidth detection are performed to the network disk service program at regular intervals to obtain information such as link connectivity and download bandwidth speed. After the network detection result is obtained, the POP service will be packaged and sent to the network disk POP management service along with the operating status (CPU, memory, network traffic, RTT, etc.) information. In the POP management service, the POP service information of one operator in the same region is aggregated and sorted, and the network disk service reaches the link state level at the regional operator level.

For the network disk client, the link status of the POP service cannot be detected from time to time or in the background. Therefore, when assigning POP information to the client, the client's regional operator and the POP information of the above management program will be integrated and analysed and a POP set that is superior in distance and link status will be selected as the result.

Although it provides a better set of POPs by distance, it does not necessarily guarantee that the client can connect to these POPs normally. Consequently, when the client cannot connect to the POP or the download speed is still slow while using POP, the client can request and manage again, the designed program will be adjusted according to the last selection conditions, in the hope that the new POP can improve user downloads.

3.3 The performance of the encryption algorithm

In order to show the performance of the encryption and decryption algorithm on our machine, we choose Intel(R) Core(TM) i5-8250U CPU @ 1.6 GHz 1.80 GHz with Win 10 profession version, 8 GB memory and x64 architecture in Table 3, then we design an experience to test our system's bottlenecks. From Table 4, we used NetDisk client to download and repeat 1,000 times to decrypt and encrypt different numbers of files with 16 KB. According to the different numbers of files (4,589, 1,896, 2,969, 1,217 and 2,628), we conduct five tests to statistic the time-consuming, encryption speed limit and decryption speed limit. After doing these experiments, under repeating the encryption or decryption operations, the decryption speed limit on the client is around 61 MB/s, and because the process is streaming decryption, when the download speed of the client from the pop is lower than 61 MB/s, the decryption speed will not affect the download speed. Except for the last 16 KB at the tail, according to the formula time = size / speed, it will take 0.26 ms more to download a file. Similarly, the encryption operation on the server is the same as the decryption operation, the only difference is that the time-consuming is mainly the first encryption fragment, which takes 0.26 ms. Overall, when the download speed is lower than 61 MB, the overall time-consuming impact is 0.52 ms. Our proposed pop acceleration technology is mainly aimed at slow users, so this encryption and decryption operations have little impact.

3.4 Simulation environment

Use the existing equipment resources to build a simulation environment and verify it through system operation. The process of environment construction and program deployment is as follows,

1 Build a server to provide key management functions, and deploy key generation and key storage programs. The server provides an interface for clients and data centres to query keys.

2 Deploy the edge node authentication program and data stream encryption program in the data centre server. When the edge node requests data, authenticate the edge node, and use the key for real-time encryption when spitting data to the edge node.

3 Build the edge node management server, deploy the edge node online management and edge node optimisation program. The management server provides an interface for the client to query the edge node, and provides an interface for reporting activity and information to the edge node.

4 Edge nodes deploy data transfer programs and client authentication programs on edge nodes by recruiting a number of network edge devices, such as routers, edge hosts, home devices, etc.

5 The client selects mobile devices such as PC host, Android and iOS, and deploys relevant programs on the device for node selection, connection management, data decryption and key management. The client program downloads data from CDN. When the download speed is lower than a certain threshold (1 MB), it triggers to speed up through edge nodes.

Table 3 This table show the experimental environment

System	*Processor*	*Memory*	*System type*
Windows 10 Pro.	Intel(R) Core(TM) i5-8250U CPU @ 1.6 GHz 1.80 GHz	8 GB	x64

Table 4 This table statistics the multiple experiments and time-consuming and speed limit about the encryption

No.	*Repeat download and decrypt files (16 K)*	*Time-consuming*	*Speed limit*
Test1	4,589	1,201.28 s	61.12 MB/s
Test2	1,896	509.67 s	59.52 MB/s
Test3	2,969	777.51 s	61.09 MB/s
Test4	1,217	300.152	64.87 MB/s
Test5	2,628	689.55 s	60.98 MB/s
Avg.	2,659.8	695.632 s	61.17 MB/s

3.5 The whole system test

In order to verify the feasibility and effectiveness of the edge node speed-up system, we designed a set of evaluation methods. When downloading through original download channels such as CDN, P2P, etc. and once the speed is less than a certain value, we call it the slow threshold which is considered that the current poor network quality may cause the slow speed. After that, the speed is increased by the edge node. If the download speed exceeds the slow threshold after the speed is increased, and the download speed through the edge node exceeds half of the slow threshold, it is considered that the speed has been increased by the edge node. The speed-up effect is measured by using the edge node speed-up success rate under slow speed conditions.

3.5.1 The calculation of speed-up success rate

A high speed-up rate represents that the client can experience the smooth network and access speed. The success rate can be calculated as follows:

$$R = S/(S+F) \tag{2}$$

where T is the slow threshold, S is the number in which the final total download speed is greater than T and the download speed through the edge node is greater than $T/2$, in other word, the effective number of using the edge node to increase the speed after the slow speed occurs. F is the number in which the final total download speed is less than T, in other word, F represents that the node's numbers that the speed is still slow after the edge node is used to speed up. R is the speed-up success rate of edge nodes under slow speed conditions. Furthermore, the edge node speed-up system has been applied to the NetDisk and performed a great performance on it when the slow threshold T is set to 1 M. From Table 5, it can be seen that when the original download network is abnormal and causes the slow speed, the speed-up effect can be achieved through the edge node, which effectively solves the problem of the user's slow download speed.

Table 5 *S*: the effective number of using the edge node to increase the speed after the slow speed occurs, *F*: the nodes numbers that the speed is still slow after the edge node is used to speed up and *R*: the speed-up success rate of edge nodes under slow speed conditions

S	*F*	*R*
35,972	94,543	27.6%

Notes: This table shows that the edge nodes can improve efficiently the download speed when the user network raises exception and leads slow download speed.

Table 6 The results of edge node requests

The nums of edge nodes	*The request success rate*	*The avg. nums of the returned edge nodes*
60,000	99.35%	20

Notes: This table shows that this system can prove the high request success rate and return the enough edge nodes while requesting.

3.5.2 The reliability of the edge nodes accelerate system

The edge node acceleration system should have high reliability. On the one hand, it ensures that any download node can successfully request the edge node for use in acceleration, on the other hand, each request needs to return a sufficient number of edge nodes to prevent some edge nodes with bad performance from failing. In addition, these edge nodes can be optimised and the download can be converged to the edge node with the best quality to improve the speed-up effect.

After extensive deployment of edge nodes for full coverage of regions and operators, and efficient scheduling of the edge node management system, this system can guarantee a high request success rate and a sufficient number of edge acceleration nodes.

3.5.3 The network quality of the edge nodes

The edge node network has certain advantages compared to the original CDN network. First, the edge node directly connects through the IP and port to prevent the connection failure caused by the DNS resolution failure, and it can also avoid the time-consuming DNS resolution. Secondly, because the edge node is close to the download node and the edge node has optimised the connection, the time to test the TCP socket connection of the edge node under the same network environment is 57.4% lower than that of the CDN.

In addition, in the actual application of our product, when the CDN download is slow, the edge node will start to speed up. At this time, the edge node and the CDN are downloaded at the same time. The average connection speed of the edge node under the current same network environment is higher than that of the CDN connection and the speed is increased by around 55.8%.

4 Conclusions

The POP network architecture of edge nodes based on open recruitment can be widely used in network disk data download and online video services that require high data throughput and delay. In this paper, we have described lots of experiments from different key factors to prove our proposed architecture that is effective. Additionally, a wider range of nearby access points provides higher network fault tolerance, greatly improves the network transmission experience of slow users, and can also be used as an external cloud service capability for commercial exploration in the future.

Acknowledgements

This work was partly supported in part by the National Natural Science Foundation of China (No. 62173285).

Contribution details

All authors have the same contributions.

References

Atzori, L., Iera, A. and Morabito, G. (2010) 'The internet of things: a survey', *Comput. Netw.*, Vol. 54, No. 15, pp.2787–2805.

Cardellini, V., Colajanni, M. and Yu, P.S. (2003) 'Request redirection algorithms for distributed web systems', *IEEE Trans. Parallel Distr. Syst.*, Vol. 14, No. 3, pp.355–368.

Chao, H-C., Wu, H-T. and Tseng, F-H. (2021) 'AIS meets IoT: a network security mechanism of sustainable marine resource based on edge computing', *Sustainability*, Vol. 13, No. 6, p.3048.

Heater, B. (2016) *Lenovo Shows off a Pair of Intel-Powered Smart Shoes*, June [online] https://techcrunch.com/2016/06/09/lenovosmart-shoes/.

Khan, S., Ul Haq, S.U. and Khan, A. (2021) 'Bringing innovative load balancing to NGINX', *International Journal of Research in Engineering, Science and Management*, Vol. 4, No. 3, pp.121–126.

Mathis, M. et al. (1996) 'TCP selective acknowledgment options', *RFC*, Vol. 118.

Molina Moreno, B., Palau Salvador, C.E., Esteve Domingo, M., Alonso Peña, I. and Ruiz Extremera, V. (2006) 'On content delivery network implementation', Vol. 29, No. 12, pp.2396–2412, DOI: 10.1016/j.comcom.2006.02.016 [online] https://dropbox.tech/infrastructure/dropboxtraffic-infrastructure-edge-network.

Nande, A. et al. (2021) 'Dynamics of COVID-19 under social distancing measures are driven by transmission network structure', *PLoS Computational Biology*, Vol. 17, No. 2, p.e1008684.

Pallis, G. and Vakali, A. (2006) 'Insight and perspectives for content delivery networks', *Communication of the ACM*, January, Vol. 49, No. 1, pp.101–106, ACM Press, NY, USA.

Palumbo, F. et al. (2021) 'Characterization and analysis of cloud-to-user latency: the case of Azure and AWS', *Computer Networks*, Vol. 184, No. 3, p.107693.

Song, H. and Montenegro-Marin, C.E. (2021) 'Secure prediction and assessment of sports injuries using deep learning based convolutional neural network', *Journal of Ambient Intelligence and Humanized Computing*, Vol. 12, No. 3, pp.3399–3410.

Vakali, A. and Pallis, G. (2003) 'Content delivery networks: status and trends', *IEEE Internet Computing, IEEE Computer Society*, November–December, pp.68–74.