ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0012

Cooperative Caching Method based on Neighbor Node Content and Space

Chaowu Zhang*, Hui Wang

School of Information Engineering, Henan University of Science and Technology, LuoYang, Henan, 471000, China.

*Corresponding author's e-mail: 180318050219@stu.haust.edu.cn

Abstract

The caching system in the Named Data networking(NDN) is very important for achieving efficient content distribution. The size of the cache system in the NDN is very small compared to the amount of content in the network. Therefore, in order to improve network performance, only the allocation of cache resources can be fully utilized in order to make full use of the cache system resources. Aiming at the problem of high-frequency content replacement in NDN node cache, a collaborative utilization method based on neighbor node cache space is proposed. By caching the content replaced by the local node in the cache of the neighbor node, the collaborative utilization of the content and space between the local node and the neighbor node can be realized. When the local node receives the interest packet, the neighbor node can satisfy the content. Simulation experiments prove that compared with LCD, ProbCache and BetwCache, this method can make fuller use of cache space, improve cache hit rate, and reduce the number of routes and average request latency.

Keywords

Named Data Networking; Cache System; Neighbor Node; CSCS.

1. Introduction

Traditional TCP/IP network communication is based on end-to-end, and data exchange using endpoint addressing will inevitably have problems such as network paralysis and transmission congestion [1-3]. In order to solve these problems, domestic and foreign research institutions have put forward many excellent solutions to these problems in a "patch" manner, such as peer-to-peer network distribution technology, software-defined network, content distribution network, and overlay network application technology. The related protocols and technologies in these brand-new network types have achieved success in content distribution, ensuring fast and high-speed data transmission, and realizing network traffic control [4-5]. But it will make the network architecture gradually become bloated, increasing the redundancy of the network structure and uncontrollable factors in the network communication process. Therefore, the most fundamental solution to the scalability problem of the current TCP/IP network is to design a brand-new, brand-new future Internet network architecture that does not center on IP addresses [6-8].

In recent years, another "revolutionary" route has been proposed. During the research process, researchers found that nowadays users are no longer focusing on the location of the desired content on the network, but In recent years, a different kind of "revolutionary" route was put forward, the researchers found that users now in the process of research is no longer required content in the network location, but pay attention to the content itself, therefore, from the purpose of the communication network change direction, to systematically design a new science, reasonable new

ISSN: 2414-1895
DOI: 10.6919/ICJE.202106_7(6).0012

network architecture. Has come up with one of the most typical is centered on information network architecture, design and development of after a long time, Named Data Networking project stand out, become a can represent the new Internet architecture of ICN, has been widely recognized after it was put forward, has become the Internet architecture research hot spot [9]. Named Data Networking (NDN), as a new content-centered network architecture, is proposed to solve the existing problems in scalability, mobility, security, and other aspects of the current communication network. Its prominent features are a unique caching system, flexible routing strategy, and security mechanism based on data itself [10].

A unique caching system is the most important feature of NDN. How to effectively use the caching capabilities of core network nodes is the key to improving the efficient content distribution capabilities of NDN [11-12]. The efficient use of cache resources in the network depends on the design of caching strategies. Therefore, caching The formulation of strategies has become one of the key and difficult issues in ICN-related research work. The current cache system has similarities in user content preferences. Some repetitive or more popular content will be cached by most users, which will lead to excessive cache redundancy and insufficient use of cache resources. The current caching strategy is formulated to reduce cache redundancy by considering node cooperation, increase the difference of cached content on neighboring nodes, and improve cache efficiency [13].

The path cooperation strategy can only obtain the information of the nodes on the path, all nodes outside the path are ignored, and the cached content is only visible to the current path request, and its cooperation scope is small and the performance improvement is limited. In the global cooperation strategy, the global information of the network is decided by the centralized control node [14]. Its cache resources can be fully utilized, but the overhead is relatively high. In the neighbor cooperative caching strategy, the local node only caches the content that has not yet been stored in the neighbor node, and only shares the cached content without realizing the collaborative utilization of the cache space, and does not fully play the role of the cache system [15]. This paper focuses on the research on the caching strategy in NDN, and proposes a method named CSCS (content and cache space cooperating cache) to ensure that the cache system performance is improved while reducing cache redundancy [16-17].

2. Design of CSCS method

In the current collaborative caching scheme, the local node and the neighbor node only share the cached content, that is, the local node can forward the interest packet to the neighbor node according to the shared content cache information, and the collaborative utilization of the cache space is not realized. The local node only performs local replacement based on the value of the content to be cached, without considering the unified utilization of the neighbor node's cache space. After the local node receives the content and executes the replacement strategy, the received content will have two situations: abandon the replacement or succeed in the replacement and replace the low-value content. In these two cases, the uncached content or the replaced content will be directly discarded, and the cooperative use of neighbor cache space is not considered. Therefore, in order to improve the performance of the caching system and reduce the redundancy of the content in the caching system, a neighbor cooperative caching scheme is proposed. When the local node makes caching decisions, by considering the influence of neighbor nodes, the cache information of neighbor nodes is obtained, and the joint caching value of the content between nodes is obtained, and then the original content value is revised to realize the collaborative utilization of cache resources. It can improve the overall performance of the cache system while ensuring the reduction of cache redundancy.

2.1 Communication packet format and content value statistics table

In order to allow interest packets and data packets to carry the necessary information required by the local node and neighbor nodes in this strategy, the basic format of interest packets and data packets needs to be improved. The interest packet adds a timer based on the original content name, content selector, and the random number to determine whether the interest packet is still within the valid period. The neighbor node number is used to indicate the specific information of the neighbor node,

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0012

and the information flag is used to distinguish Duplicate information and invalid information. The node information and the content name information of the local phase query are added to the data packets of the corresponding neighbor nodes to meet the needs of the local node. details as follows:

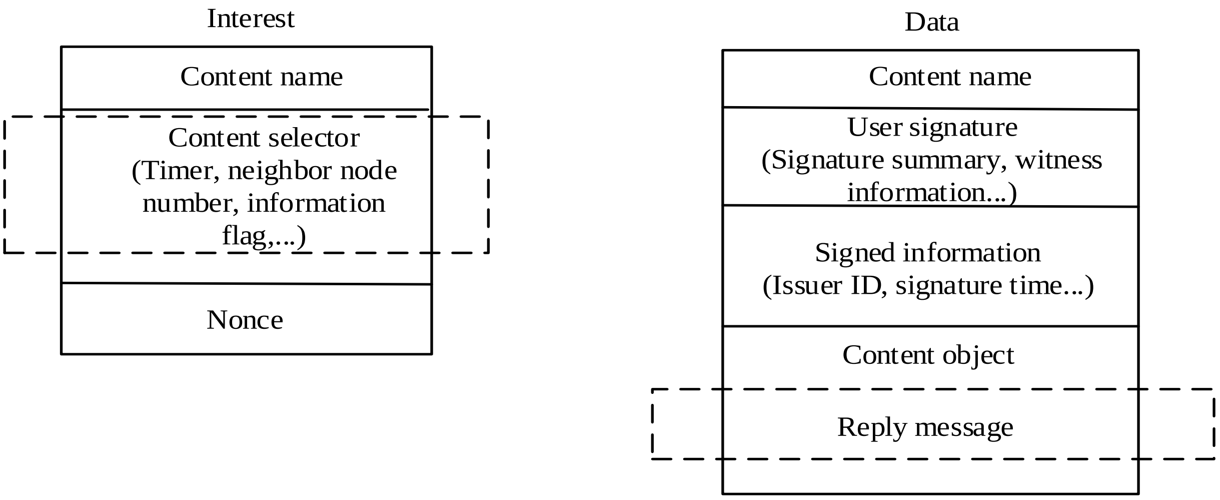

Fig. 1 Interest and data format modification

Table 1. Neighbor node content information table

Neighbor node	Content name	value
Node1	/Video/3	5.3
	/Video/6	2.9
	/Picture/3	6.4
	/Video/5	1.2
Node2	/Video/9	8.5
	/Picture/11	1.9
	/Video/15	11.2
…	…	…

2.2 Update the value of the content in the node

Since the local node may cooperate with other neighbor nodes for caching, that is, the local node caches the content replaced by other neighbor nodes or the content that cannot be cached. Subsequent neighbor node requests for this content will be forwarded to the local node, so it is necessary to consider neighbor cooperative caching. value. In addition, the nodes in the collaborative caching scheme may cache the same copy of the content in the neighbor node, which may cause multiple duplicate content copies in the neighbor node, so the duplicate value needs to be considered. Therefore, when considering the influence of neighbor nodes and the content in the nodes, the original local content value is corrected according to the joint cache value of the content between the nodes, and the neighbor cooperative cache value and the duplicate cache value are comprehensively considered.

2.3 Interest and data processing flow

The local node's packet processing flow is divided into a response flow to the received interest packet and a content replacement flow to the local node's packet processing flow is divided into a response flow to the received interest packet and a content replacement flow to the received data packet:

The specific processing flow of the local node's response to the interest packet is:

1) After receiving the interest packet, the local node first queries the local cache information table, if there is a corresponding internal, the content is directly returned to the request source, otherwise, step 2 is executed;

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0012

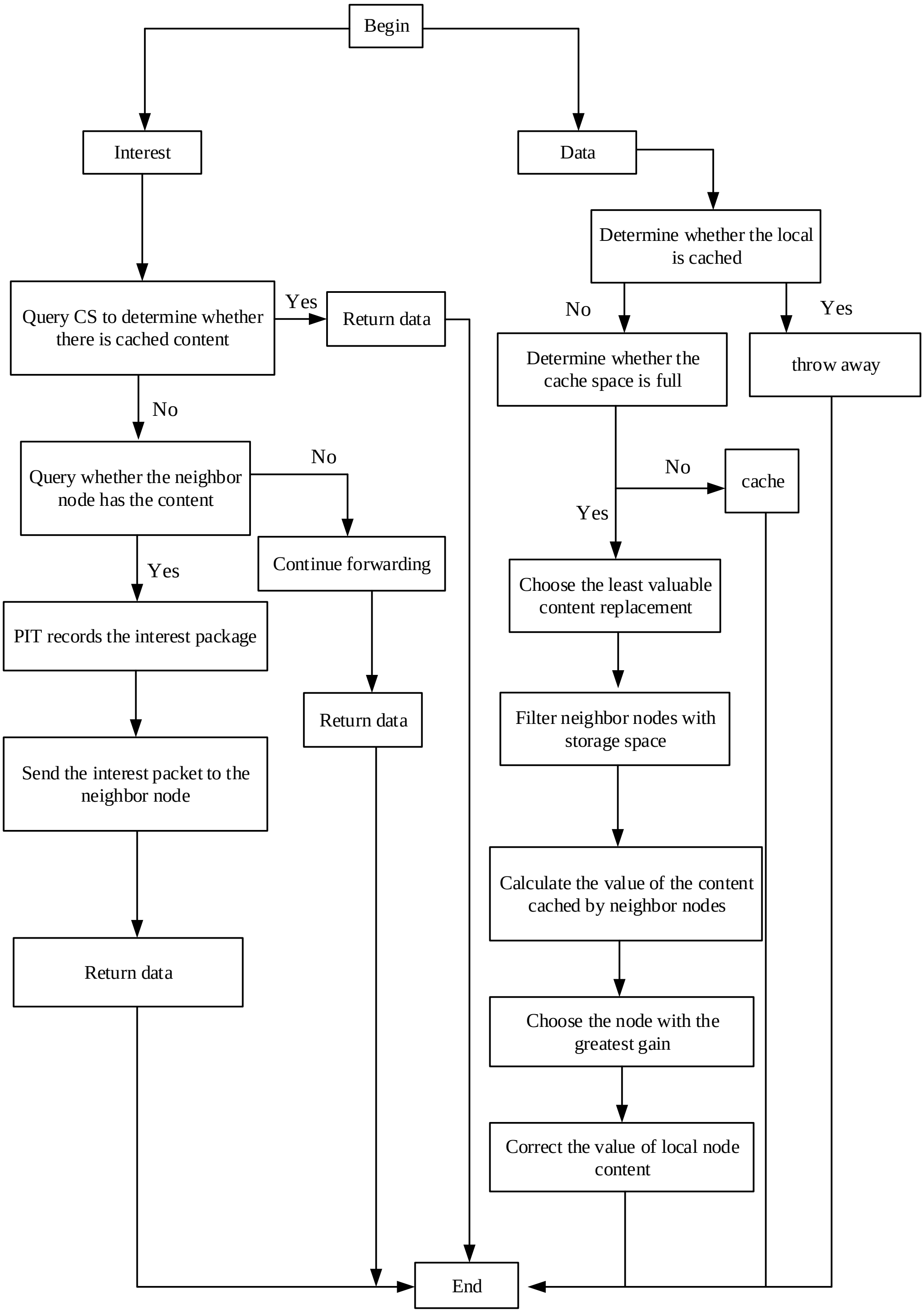

Fig. 2 The flow of CSCS method

2) The node queries the local neighbor content table to see if there is a corresponding record, if there is, it records the request

Record in the PIT table, and request the neighbor node to continue forwarding, if not, go to step 3;

3) The node records the request in the PIT table and continues to forward the request to the corresponding node according to the FIB.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0012

After the node receives the data packet, if the local cache space is insufficient, the locally replaced content or the content that cannot be cached needs to be directly discarded according to the NDN mechanism, and the neighbor cache space is not fully utilized. Therefore, this strategy considers the use of neighbor nodes' cache space for cooperative replacement. The specific processing flow is as follows:

1) After the local node receives the data packet, it first judges whether the local node has the content in the cache, and discards it if there is. If not, go to step 2.

2) Determine whether the buffer space is full. If it is not full, it will be cached. If it is full, go to step 3.

3) According to the local node value information, the content with the lowest value is selected for replacement. For the content to be replaced locally, you first need to query the neighbor content table and calculate the cache value of each neighbor node that has storage space to cache this content. The neighbor node with the largest gain is selected to forward the data packet received by the local node to the neighbor node.

4) After the neighbor node receives the data packet, it caches it in the node, and finally the local node revises its content value. So that when the next content is received, the lowest value content is replaced.

The flow chart of this strategy see Fig. 2:

3. Simulation Environment and Analysis of Experimental Results

This article uses the NS-3 based ndnSIM network simulator for experimental simulation. In a simulation scenario with a size of 200m*200m, the BRITE network topology generator is used to generate a suitable network structure to simulate the real network scenario. The number of scene nodes is 30, and the distribution law conforms to the Waxman model. Randomly select 3 nodes out of 30 nodes as producers, including 50 initial content objects. In the simulation process, 5 nodes except the data source node are randomly selected to generate corresponding interest packets at a time interval of 3s. The request probability of content objects in the communication network obeys the Zipf distribution. The other nodes are used as network routing nodes, but a client who can generate content requests is set up on each network routing node End program. The movement method of the content producer uses the SLAW model that integrates LATP, irregular waypoints, and personal walking models. This model can capture meaningful data in human movement and effectively reflect the characteristics of human movement. Use this model Let content providers simulate the way humans move after they move. The ratio of the number of mobile nodes to the total number of nodes in the network can be adjusted, and no other nodes except mobile nodes will move. In the simulation process, the buffer in the NDN intermediate router is empty as the initial state, and the simulation cycle is 50 times.

It can be seen from Fig. 3, Fig. 4 and Fig. 5, under different cache capacities, the average route hops, cache hit rate, and average request latency of the CSCS method are reduced compared with LCD, PaoCache, and BetwCache. The CSCS method can take into account the caching of neighbor nodes, and can cache the content as far as possible to routing nodes that are relatively close to the local node. The CSCS method can fully schedule the cache system in the network and will provide users with more efficient content services.

Fig. 6, Fig. 7, and Fig. 8 respectively show the changes in the cache hit ratio, average routing hop, and average request latency for the LCD strategy, the ProbCache strategy, the BetwCache strategy, and the CSCS method as the content quantity changes. As shown in the figures, as the number of content increases, the cache replacement ratio of a large amount of cached content is gradually increased. Therefore, the average request hops and average delay latencies of the caching decision strategy have increased gradually. Under different Zipf(α), compared with LCD, ProbCache, and BetwCache, the average routing hops, cache hit rate, and average request waiting time of the CSCS

ISSN: 2414-1895
DOI: 10.6919/ICJE.202106_7(6).0012

method are all reduced. The main reason is that the CSCS method reasonably utilizes the content and space of neighbor nodes, can balance the load pressure of nodes, and make it easier for users to obtain the required.

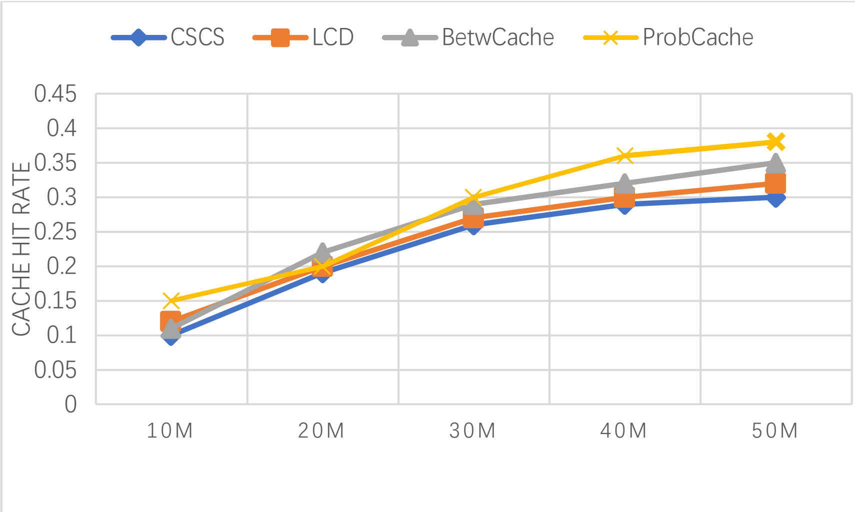

Fig. 3 Cache hit ratios with different node cache's capacities

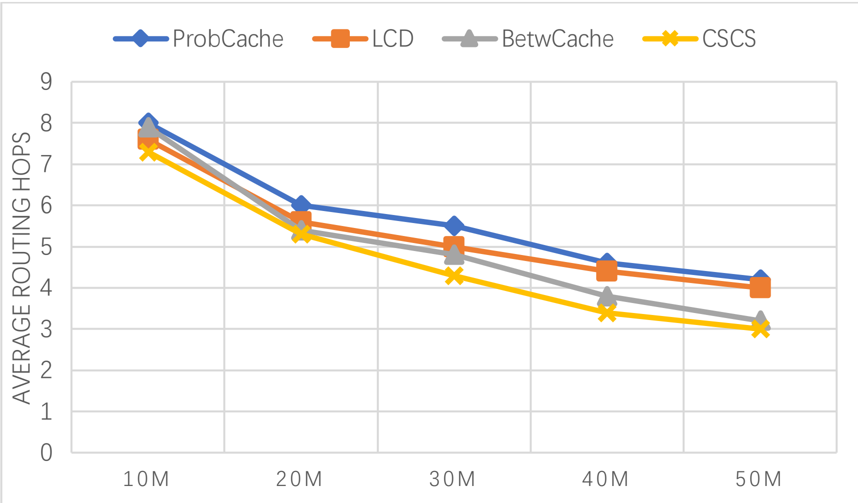

Fig. 4 Average routing hops with different node cache's capacities

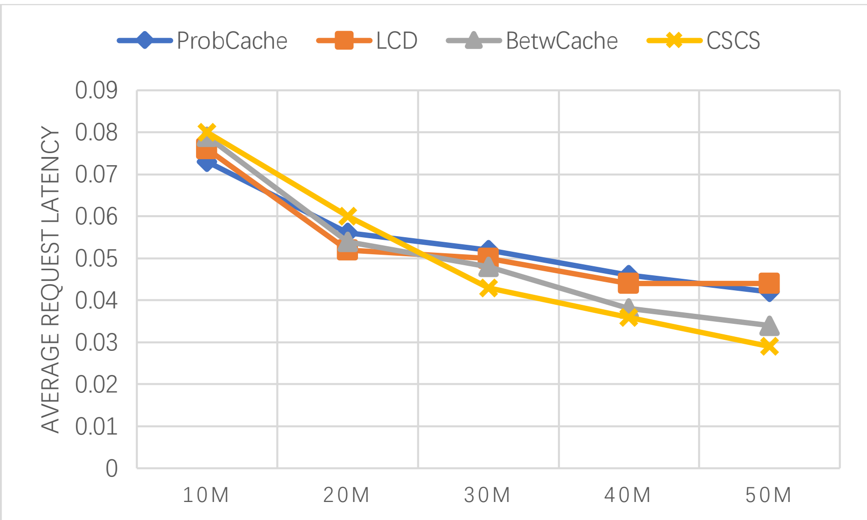

Fig. 5 Average request latencies with different node cache's capacities

ISSN: 2414-1895
DOI: 10.6919/ICJE.202106_7(6).0012

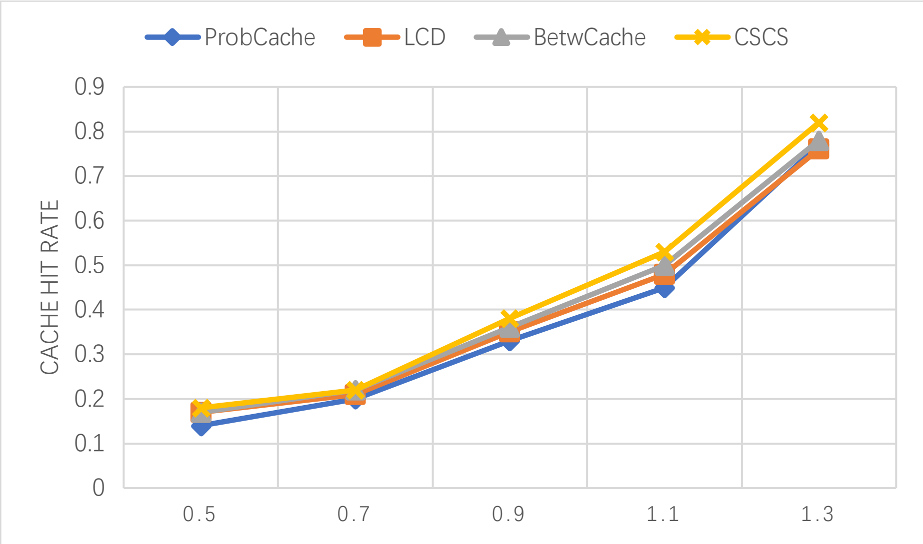

Fig. 6 Cache hit ratios with different zipf(α) parameters

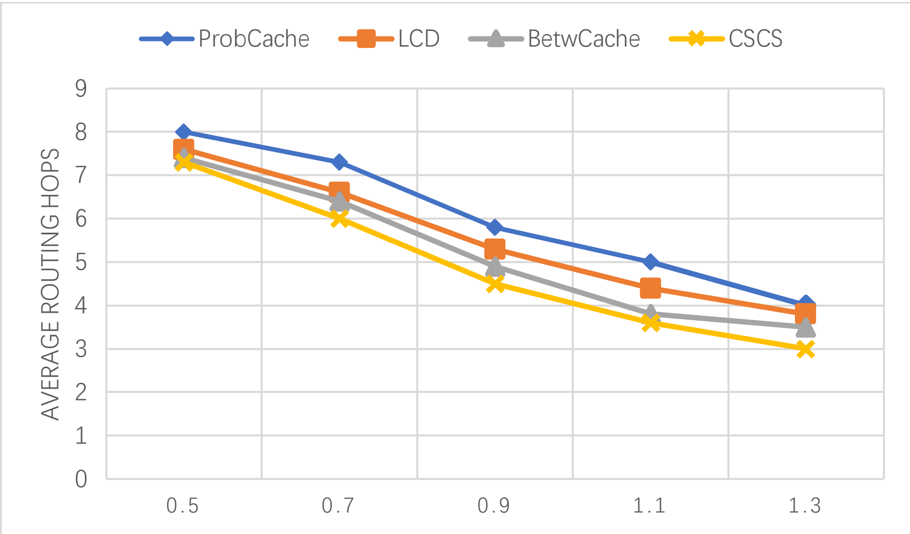

Fig. 7 Average routing hops with different zipf(α) parameters

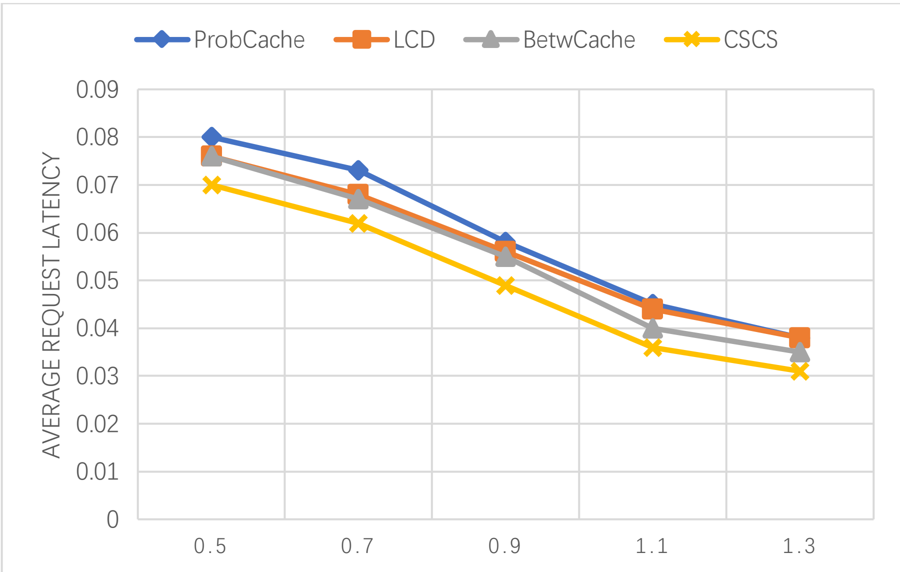

Fig. 8 Average request latencies with different zipf(α) parameters

ISSN: 2414-1895
DOI: 10.6919/ICJE.202106_7(6).0012

4. Conclusion

The use of the content object of the node caching approach is one of the most significant features of the CCN network. By caching the content object in the routing node, the user's content request can use a relatively recent copy of the content without having to go through multiple forwardings to find the source content server node Obtaining the content object can effectively reduce the propagation delay of the content in the network, and can also reduce a large amount of unnecessary network consumption in the network, and improve the overall service performance of the CCN network. The Named Data Networking can use the default "cache after passing" mechanism to cache content objects and improve network performance. However, all content objects are cached without distinction, and there are some shortcomings. Therefore, a CSCS method using the space of neighbor nodes is proposed to realize the coordinated use of space. The experimental results show that the cache space is fully utilized through cooperation. Compared with the traditional caching strategy, the user's content acquisition delay is effectively reduced. The cache hit rate is further improved, and the overall network cache performance and network performance are improved.

Acknowledgments

This article is one of the phased achievements of the key scientific research project (18A520007) of higher education institutions in Henan Province and Research on Heterogeneous Network Congestion Control Based on IPV6 (NGII20180107).

References

[1] Dai H, Lu J, Wang Y, et al. BFAST: High-Speed and Memory-Efficient Approach for NDN Forwarding Engine[J]. IEEE/ACM Transactions on Networking, 2017, PP(2):1-14.

[2] Zhang R, Liu J, Huang T, et al. Adaptive Compression Trie based Bloom Filter: Request Filter for NDN Content Store[J]. IEEE Access, 2017, PP(99):1-1.

[3] Wu H, Li J, Wang Y, et al. EMC: The Effective Multi-Path Caching Scheme for Named Data Networkinging[C]// International Conference on Computer Communications & Networks. IEEE, 2013.

[4] Shinohara R, Kamimoto T, Sato K, et al. Cache Control Method Mitigating Packet Concentration of Router Caused by Interest Flooding Attack[C]// 2016 IEEE Trustcom/BigDataSE/ISPA. IEEE, 2017.

[5] Hassan S, Din I U, Habbal A, et al. A popularity based caching strategy for the future Internet[C]// Itu Kaleidoscope: Icts for A Sustainable World. IEEE, 2016:1-8.

[6] Azgin A, Ravindran R, Wang G. A Scalable Mobility-Centric Architecture for Named Data Networkinging [C]// 23rd International Conference on Computer Communication and Networks (ICCCN). arXiv, 2014.

[7] Kong J, Rui L, Huang H, et al. Link congestion and lifetime based in-network caching scheme in Information Centric Networking[C]// 2017 International Conference on Computer, Information and Telecommunication Systems (CITS). 2017.

[8] Tseng Y F, Fan C, I, Wu C Y. FGAC-NDN: Fine-Grained Access Control for Named Data Networkings[J]. Network & Service Management IEEE Transactions on, 2019, 16(1):143-152.

[9] Aboud A , Touati H , Hnich B . Efficient forwarding strategy in a NDN-based internet of things[J]. Cluster Computing, 2018.

[10] Guo H, Wang X, Chang K , et al. Exploiting Path Diversity for Thwarting Pollution Attacks in Named Data Networkinging[J]. IEEE Transactions on Information Forensics & Security, 2016:1-1.

[11] Shannigrahi S , Papadopoulos C , Yeh E , et al. Named Data Networkinging in Climate Research and HEP Applications[J]. Journal of Physics Conference Series, 2015, 664(5):052033.

[12] Zheng, Y., X. Piao and K. Lei. Anchor-Chain: A Seamless Producer Mobility Support Scheme in NDN. 2017.

[13] Amadeo M, Molinaro A, Campolo C, et al. Transport lPPtver design for named data wireless networking[C]// IEEE INFOCOM 2014 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS). IEEE, 2014.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0012

[14] He L , Kaoru O , Mianxiong D . ECCN: Orchestration of Edge-Centric Computing and Content-Centric Networking in the 5G Radio Access Network[J]. IEEE Wireless Communications, 2018, 25(3):88-93.

[15] Yasuda Y, Nakamura R, Ohsaki H. A Probabilistic Interest Packet Aggregation for Content-Centric Networking[C]// 2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC). IEEE, 2018.

[16] Rehman R A, Ahmed S H, Kim B S. OEFS: On-demand Energy-based Forwarding Strategy for Named Data Wireless Ad Hoc Networks[J]. IEEE Access, 2017:1-1.

[17] Yao L , Fan Z , Deng J , et al. Detection and Defense of Cache Pollution Attacks Using Clustering in Named Data Networkings[J]. IEEE Transactions on Dependable and Secure Computing, 2018, PP:1-1.