A Leading Routing Mechanism for Neighbor Content Store

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Abstract. It is very easy for the nodes in Named Data Networking to ignore the neighbor nodes. To solve this issue, this paper proposes a leading routing mechanism for neighbor content store. Firstly, through building the interest clusters, the nodes are partitioned to different reigns to announce the information of content store. Secondly, the packets and the fast routing tables are designed. Finally, the best path is chosen to send the interest packets. The theoretical analysis and the simulation results show that this mechanism adequately uses the neighbor content and effectively decreases the average network delay. The server load is reduced by 30%.

Keywords: NDN · Content routing · Interest cluster · Neighbor content store

1 Introduction

With the rapid development of Internet technology and applications, and the rapid growth of Internet users, the way of the address of traditional IP network representing both the node location information and the identity information confuses the boundaries of the location and identification?, the limitations in the support of content distribution business become increasingly apparent. To solve this problem, in recent years, an innovative proposal of separating the hosts and contents in the network layer causes widespread concern. Content-centric networks become an important model and a developing trend of the future network.

NDN (Named Data Networking) proposes a new network architecture---- Named Data Network, using hierarchical data name instead of the IP address for data transfer, so that the data itself becomes a core element of the Internet architecture[1-2]. The architecture adopts the way of "Interest packets" to complete the multipoint access and distribution of contents in the form of announcement; "Data packets" along the reverse path of the interest packets passing the content to the requester achieve a balanced flow based on jump, try to reside the higher heat service content in the form of caching on the path to the node, and arrive at requesters in the shortest transmission path as much as possible.

Named Data Network directly based on the name of the routing and forwarding method can effectively solve the problems of exhaustion, mobility and extensibility in the IP network address space. NDN network router is responsible for name prefix announcement, spread by routing protocol in a network, and each router receiving the notice sets

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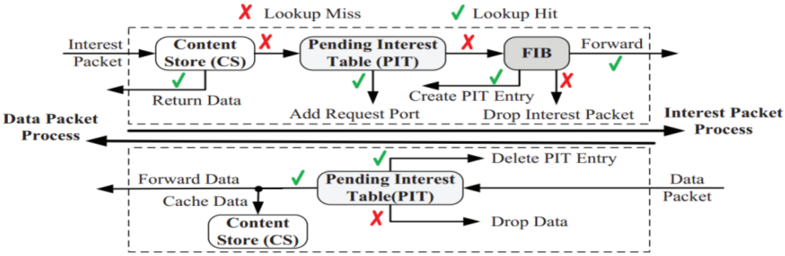

Fig. 1. NDN model of the network routing and forwarding

up its own FIB (Forwarding Information Base). When there are multiple Interest package requesting for the same data at the same time, the router will only forward the package firstly received and store these requests in the PIT (the Pending Interest Table).When the packets are sendedback, the router will find matching entries in the PIT, and forward packets to the interface according to the items shown in the list of interfaces. After that, the router will remove the corresponding PIT entries, and cache in the CS (Content Store).The CS is the router's buffer memory, using a buffer replacement strategy.

Named Data Network adopts the content-based routing method: node interest packets are directly forwarded to the source content server, and detect whether the nodes along the requesting path cache the requested content in the process of forwarding to achieve the goal of the shortest time of return data. Although compared with IP network, content-based routing method of the named data network improves the efficiency of the return packets, but such path-caching way cannot make full use of the neighboring cache which is not in the path. As shown in figure 2, the routing nodes around users store the corresponding data, but cannot make full use of them, which leads to the long path in the access of data.

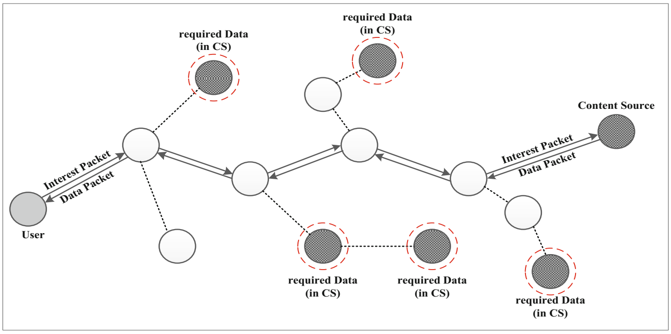

Fig. 2. The content retrieval process diagram in Named Data Network

As for the routing nodes' cache utilization problems in Named Data Network, related research has made certain progress and results. Shanbhag S 's team put forward a kind of SoCCeR service routing method, which turns the content routing problem into the service selection problem, and achieves to make full use of the nodes along the cache, while it still doesn't consider the cache content in neighboring nodes [5]. Literature [3] compares two different routing methods, and puts forward a hybrid routing method, namely establishing the routing to source server content and detecting the content copies of the node cache, but its starting point is to reduce the number of route entries and network costs. Literature [6] applys the routing based on potential energy to network content and designs the CATT routing cache perception target identification method. CATT method, however, before the request through the potential energy routing adopts the method of randomly forwarding. As a result, routing performance depends on the random initial value, and may lead to a longer path delay. Literature [7] proposes to establish the neighbor cache table's NCE routing strategy by detecting the neighbor nodes' cache content, so as to make full use of the neighbor node resources. But considering the large number of the contents in NDN, the detection method has difficulties in implementation, which would lead to the increase of the average response time of the contents' request. Literature [8] has carried on the qualitative analysis for the necessity and feasibility of the announcement of node copies. Although proposing to aggregate routing tables with the bloom filter, it still lacks the quantitative analysis and the concrete implementation for the routing mechanism. In addition, the above studies do not consider the update of node cache content according to the dynamic update of the heat and the differences between different content caches.

With the reference of the idea to create shortcut links in unstructured P2P networks in literature [9] and [10], this paper proposes a cache-oriented neighborhood for fast content routing (FCR), solving the problem of the construction of the neighboring routing cache in the Named Data Network. The structure of this paper is as follows: In Section 2 we mainly discuss the definition of FCR and explain the related concepts. In Section 3 we make a systematic analysis for the cost of cache notice between the content nodes and determine the notice way between adjacent nodes cache. In Section 4 we discuss the FCR mechanism based on nodes' interest clusters in detail. In Section 5 we provide some simulation experiments based on this mechanism and previous methods, compare the experiment results, and validate the feasibility and effectiveness of the mechanism.

2 Fast Content Routing

Content source server path is the shortest path for the user S to send interest packets to the source server D, during the process, the along nodes' set is $S = \{N_a, N_b, \ldots, N_m\}$, the response hop is H1.

2.1 Fast Content Path

Define the shortest path between the user node S and the required content of recent neighboring cache node N ($N \notin S$) as the FCP (Fast Content Path) for user S. During the process, the forwarding nodes are $S_{FCP} = \{N_A, N_B, \ldots, N_M\}$, the response hop is H2.

Among them, the routing node N as the closest cache node for user S must make $H_2 \leq H_1$. Otherwise, the fact that content source is the latest cache is inconsistent with definitions. If user S has FCP (Fast Content Path), then $S_{FCP} \cap S \neq \varnothing$.

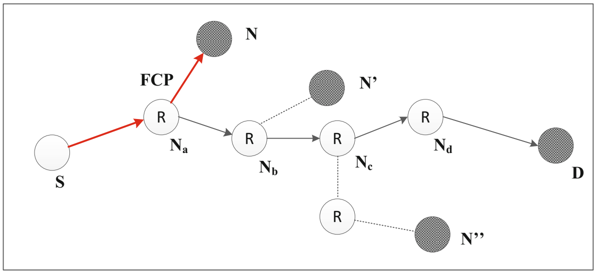

Fig. 3. Fast Content Path of the request nodes

Proof: Using the reduction to absurdity. Assume $S_{FCP} \bigcap S = \varnothing$, the routing node in the access network is N0.As the content source path must exist in the network, now we have $N_0 \in S$ and $N_0 \notin S_{FCP}$.And then the access point N0 for S disconnects with routing node N, resulting the non-exist of FCP, which has a contradiction with the above known. Thus, the hypothesis doesn't succeed.

According to the principle that FCP at least has an intersection point with the server path. In search of the construction of FCP, only by $S = \{N_a, N_b, \ldots, N_m\}$ to achieve the stored content in other neighbor node N with its corresponding content C, and compute the corresponding routing.

2.2 The Cache Notification and Cost Analysis

The distribution of cache around nodes can mainly be obtained from two ways, namely detection and active notification. Although the detection can locate the specific content accurately, its two-way generating traffic makes the network costs too expensive, which leads the difficulty of mass deployment. Compared with detection, active notification method is one-way traffic. With the notice in a reasonable control range, the mass distribution of its own cache items can make the network costs to a minimum.

As assumption, the network topology is represented as $G = \{V, E\}$, V is the set of nodes, E is the collection of links. The number of nodes in the network is |V|. The size of notice packet is B, the average link rate is m. The cache of nodes always updates according to the heat of the content in NDN, the interval is T. In the network G, change at least |V| times and require N (N >= $\log_m^{|V|}$, N is an integer) notices, only by this can send the updates of content cache to the whole nodes in the network. The cost of traffic is:

$$
\begin{aligned}
C &= (m + m^2 + \ldots + m^N) \cdot B \cdot |V| \\
&> m^N \cdot B \cdot |V| \\
&\geq |V|^2 \cdot B
\end{aligned}
$$

As the update time of the cache of the content node is just a few seconds, the cost of a time unit is $C/T \geq |V|^2 \cdot B/T$.

In order to reduce the cost of notice for the cached content, the proposed principle of the heuristic fast content routing announcement mechanism in this paper mainly contains two aspects:

A. Set reasonable notice scale for neighboring cache content |V|
The Internet has the feature of the small world, which visit in close distance has the similarity to the cache of content [11]. Due to the same cluster nodes probably interested in the same class content, we propose to build the interest cluster based on interest correlation standard. Therefore, the notice of nodes cache is tedious and unnecessary in the network, which raises the utilization ratio of announcement content by narrowing the notice in the interest cluster. Based on this deduction, this paper proposes a heuristic fast content routing announcement mechanism to overcome the huge traffic cost brought by the flooding notice method.
B. Choose the higher heat content to prolong the interval of notice time T
The routing lookup in NDN network starts with the frequently updates of the node contents' cache, which is dynamic and volatile. The frequently change of the cache items in the nodes has no significance for FCR. However, it may be cause the routing oscillation. Therefore, this paper proposes to notice only the higher heat node cache, which the steady part of the node resides data. Due of the frequently changing of the cache information not noticing outwards, it not only prolongs the advertisement interval, but also ensures the stability of the network node cache contents.
C. Design the unique notification message structure in order to reduce the size of the notification message B

3 Leading Fast Content Routing Mechanism

The proposed heuristic neighboring cache notification mechanism based on node cache heat and the similarity of demand will be divided into certain interest network node clusters. Cluster nodes only notice the higher heat content cache in the internal, and those do not belong to the same cluster don't notice the cache. The construction of fast content routing can be roughly divided into three steps: cluster building, caching notices and fast route setup. After the completion of the fast routing tables, if received content request, the node would perform corresponding forwarding operations according to the sequential look-up of content store tables, pending interest tables, fast routing tables and forwarding information base.

3.1 The Construction of the Interest Node Cluster

In NDN, given the content request nodes as i and j, the interest content set is $C_{\text{interest}}(i)$, $C_{\text{interest}}(j)$ .Their common interest set is $P_C = C_{\text{interest}}(i) \bigcap C_{\text{interest}}(j)$.

If node I requests certain content Mc times in the latest interval T, the IRC(Interest Relevancy Coefficient) is defined as:

$$\theta(i,j)=\frac{\sum_{C\in P_C}[M_{C,i}^2+M_{C,j}^2-M_{C,j}M_{C,i}]}{T(\sum M_{C,i}M_{C,j}+d)}\quad (d \text{ is positive number})$$

Mc,i and Mc,j respectively represent the request number in the last interval T of node i and j .The closer Mc,i and Mc,j, the more important influence on $\theta(i,j)$.This shows that node i and node j have a larger IRC. Oppositely, the IRC is smaller. Since Mc,i and Mc,j may be 0,so the positive number d $\neq$ 0.

3.2 The Selection of Core Nodes

The construction of an interest node cluster is not disorderly. Selecting the highest IRC Node (Leader Node) to build the interest cluster can increase the interests. Define the relevancy radio of node i, $\eta_i=\sum_{j\in Neighbor(i)}\theta(i,j)$, η_i is the standard of the Leader Node, which is the sum of IRC of the neighbor nodes. The higher relevancy the leader nodes have, the larger interest the cluster will get.

Among interest clusters, the relevancy η_i is the priority for selecting nodes. The interest nodes notice the neighbor nodes. In order to reduce the traffic redundancy in the selection of leader nodes, the larger η_i the node have, the shorter time they will wait. When the nodes receive the larger priority notice, they would not notice their own η_i, yet only notice the larger priority node messages.

3.3 Define the Scope of the Interest Cluster

In order to reflect the advantage of a neighboring node to improve the efficiency of the fast route, the scope of request nodes of the cluster in named data network should not be too big ($H_2 \le H_1$).Literature [7] has carried on the detailed research on the content network range announcement, pointing out that the average delay of network cluster at the scope of 2 just decrease by 3% than the scope of 1. As for the cache capable content network, most content requests can be satisfied within the scope of 1~2 (i.e. 3 jump range). Taking into account the superposition of two-way transmission delay, we will limit the scope of this paper notices set to 6-hop, namely Scope = 6, based on the literature [7]. The scope of the notice will be discussed through simulation experiments in later chapters.

3.4 Interest Cluster Construction Algorithm

According to that the interest correlation cluster building should consider caching content and its heat, the interest cluster can only notice some steady state cached data. The build process is as follows:

Table 1. Nodes Interest Cluster Construction Algorithm

Step1:	node N_i calculate η_i according to the current contents of the cache table and heat, and create announce packet P_i for N_i.
Step2:	After the waiting time T, the packet P_i is advertised to neighboring nodes, set the scope Scope and notice Hop values need to be forwarded to all interfaces.
Step3:	Within the time T, compare the received packets with information and notice the packet with a larger priority value out.
Step4:	In a cluster, the nodes with the best value of η_i will be set to the leader, it sends a confirmation message within a cluster, complete the Cluster.
Step5:	When all the contents of the cache node reaches a certain level or after a time interval T, re-content announcements.

4 Leading Neighboring Cache Notices

4.1 The Design of Notice Message

In order to achieve the neighboring cache of contents notice, the design of heuristic cache notification message in network is as follows:

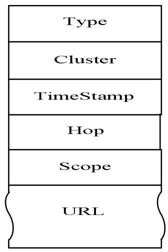

Fig. 4. Message format of heuristic neighboring cache notices

In the chart, Type format represents the type of message, the Cluster format records the number of the present cluster. TimeStamp format is used to record the sending time of messages, which can distinguish the latest version of notice message. Hop format is used to record the hops between the notice node and the present node, which can be used to represent the routing costs of notice to calculate the fast routing.

URL and Scope respectively are the name of required notice content (the naming mechanism in the NDN is in the form of a URL) and notice scope (hops). Hop would add one and the scope minus one when notice one hop with the end of 0 of the Scope. The neighbor nodes determine to continue notice according that whether the scope is 0. If scope is 0, the notice would stop.

4.2 The Choose of Notice Content

In order to avoid the notice message explosion caused by the frequent replacement of notification messages in the node cache, the notice content only choose the relatively stable (i.e. high heat value) content. Firstly the node cache sort the content by adopted caching strategies, select the top x % of the high heat copies to notice. If LRU strategy is used in such nodes, then they will notice the newly pumped cache queue x % to neighbor nodes, which is as follows:

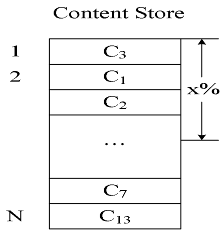

Fig. 5. The list of the heat nodes cache

Excessively frequent update may cause the miss of routing content items, any item of the current notice copy deleted by a node will trigger a new cache announcement, and the node will sent the information of the first node of x % cache in the current time sequence to all nodes within the cluster.

4.3 Leading Neighboring Cache Notice Algorithm

The node will be in separate to each cluster after the construction of the node cluster. The construction of fast routing can be divided into two stages: heuristic cache notice building and content delivery stage. Fast route construction mainly notices the content and builds the FCT (Fast Content Table). First of all, the cache nodes in the cluster make initialization before the announcement: node i sets the cluster number of itself, the content timestamp TSnew and the scope of its own announcement, and then forwards to all interfaces according to the first x % cache content items based on the heat contents. Set the result of neighboring node j before receiving announcement: <NameC, Face, TSold, Hopold>. The timestamp TSold = 0 when there is no record for content C. It will implement such algorithm when node j receive the announcement of node i.

Table 2. Heuristic Neighboring Cache Notice Algorithm

Step1:	Nodes i and nodes j to determine whether the same cluster; If yes, proceed to step 2, otherwise discard the notice packet and jump to step 5.
Step2:	Determine if the contents of the current received notification packets are up to date. If $TS_{new} < TS_{old}$, the notification message is stale information and discards the packet, step 5; otherwise, proceed to Step 3.
Step3:	if $TS_{new} \geq TS_{old}$,the content of the notice is the latest entries; Receive notification packets and calculate the value of the received message Hop as routing consideration: $Hop_{new} \leftarrow Hop_0 + Hop(i, j)$ .if $Hop_{new} \geq Hop_{old}$, description routing costs are too high, dropped packets, perform step 5; otherwise, proceed to Step 4;
Step4:	Query convenient routing table FCT, update the URL corresponding entries,Fill Hop_{new} in the forwarding table routing consideration domain, and then decide whether to forward the contents of this notice forwarded to the next node depending on the size Scope value;
Step5:	The end of the notice

After the completion of the fast routing tables, nodes compare the current routing cost and server path cost in the FIB after receiving the interest request. If fast routing cost is smaller, then process the items in the fast routing table and create one item of FIB. Namely, nodes perform corresponding forwarding operations according to the sequential look-up of the content store table, FCT and FIB.

The forwarding process of the interest packets are as follows:

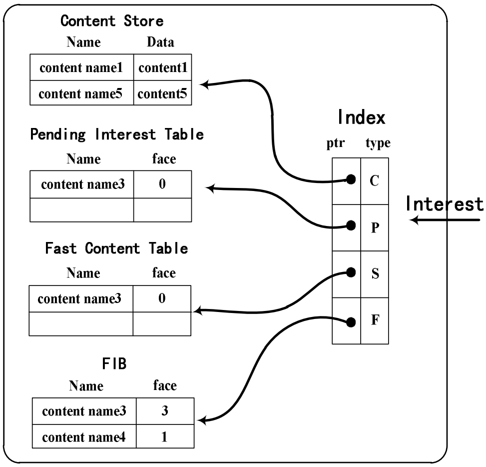

Fig. 6. The interest packets forwarding process in node

4.4 Fast Content Routing Algorithm

Node j would record contents name, arriving interfaces, and the price of this cache content after receiving the notification about the content C of its neighbor node i. Then it would implement the fast content routing algorithm.

Table 3. Fast Content Routing Algorithm

Step1:	Contrast Hop of this convenient route and the costof the forwarding information table to the content source server, if convenient route Hop is small, easy to create the entry in the routing table; otherwise delete the contents of the route entry corresponding convenient route.
Step2:	When there are several convenient route to the same content when forwarding interface Select the minimum cost of the interface as the next hop.

The format of FCT (Fast Content Table) built by the above algorithm is as follows:

Content Name	Face	Hop
/example.com/a	1	1
/example.com/b	2	3
/example.com/c	3	2

5 The Simulation Experiment and Result Analysis

These parts simulate an operation process topology in NDN network and its related performance using the C+ + and Matlab. The experimental environment is 4 GHZ Intel core 2 double processor PC with Windows 7 operating system. Firstly, build routing nodes based on the characteristics of named data network, then use the GT - ITM topology generation tool to generate a plane random network topology with 30 routing nodes, where the probability of any two routing nodes directly connected path is 0.3. Next, randomly select a node from the edge nodes as the server node of the network node of the whole content publishing and service, whose capacity is enough to store all the content objects. The rest of the nodes as ordinary routing nodes is directly connected with users, whose cache capacity of the content is B (assuming the same content object size, B represents the node number). In order to facilitate analysis, delay between adjacent nodes is set to 10ms.

For the convenience of measurement, set the content in the source server content object number N = 2000, assuming that the URL routing items are equal [13], which is set to 128 KB. Object content popularity follows Zipf-Mandelbrot distribution [3,4], namely the content popularity of the Kth object is: Pk=H-1(σ, q, N)/(q +k)σ. σ is the shape parameter, q is the mobility parameter, σ=0.4, q=10. H(σ, q, N) is normalized correlation coefficient. Content routing nodes directly connect with the user host, who send interest packets (data request packets) to the associated content of the nodes. In the simulation of users' sending packets, we use the Poisson arrival features to satisfy the process [20] ($\lambda=4$) to arrive at each router node randomly. The simulation topology is shown as follows. The circle point represents router, the line represents link, the bandwidth is 100Mbps.

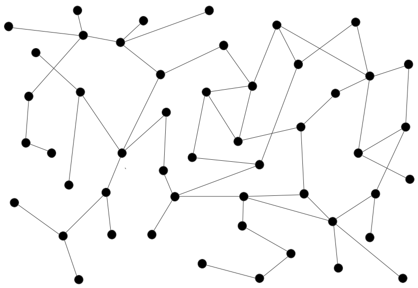

Fig. 7. The simulation topology

In order to effectively evaluate the experiment effect, this section simulates for the fast routing mechanism, and compares several previous methods of simulation at the same time. First one is the basic Content Routing mechanism of NDN network, regardless of the adjacent nodes cache, which directly forwards the request packet to the content source server [6], notes for SCR (Simple Content Routing). Next, it is the NCE strategy proposed by literature [7].The proposition of Literature [14] is the notice cached copy routing which is noted for ACC. When neighboring cache node content is missing in these three methods, it would directly forward the request packets to the content source. Finally, this section shows the simulation of the proposed heuristic fast content mechanism based on the interest nodes and FCR.

In order to validate the performance of the heuristic neighboring fast content mechanism, we choose the average delay of user requests and the content source server load as the standard to make comparison. The source server load is defined as the request packet number received during the simulation process.

5.1 Best Interest Cluster Scope

Figure 8 shows the influence on average delay and notice cost of different range announcement in the cluster building. According to the above simulation of the percentage of content announcement, take notice content to 60%. As the cluster radius increased, fast routing delay decreases. Heuristic notification message number also increases along with the cluster scope. From the figure, there happens the delay rotary phenomenon, which mainly caused by the large announcement scope, resulting that gradually close to the content source routing path length leads to the path delay picking up when the scope of interest cluster is more than 6 hops. Considering the impact on the performance and cost, the best range of cluster is 5.

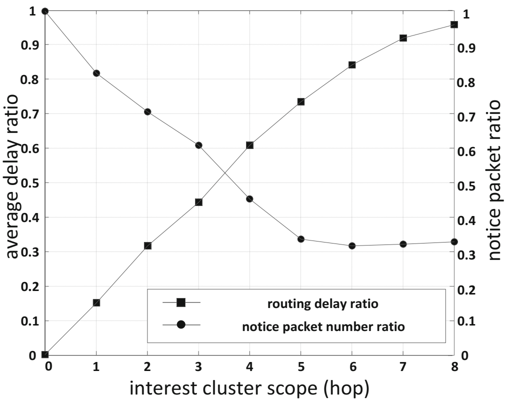

Fig. 8. The influence on time delay and the notification message number of interest cluster scope

5.2 The Proportion of Content Caching Announcement

Set the cache capacity B = 60, the total number of requests Nq = 2000.Set the proportion of content caching announcement x % as variables on the shortcut route delay performance simulation, the result is shown in figure 9. Gradually with the increase of circular ratio, time delay performance improves, but after the proportion is more than 80%, the average delay increased because the dynamic contents of the cache are part of the content of the frequent replacement notice to go out, causing the node forwarding the request to the removed content. As a result, it causes the missing of cache and increases the delay to get content from other nodes. In addition, with the expanding of notice range, this phenomenon of the increasing delay is more obvious.

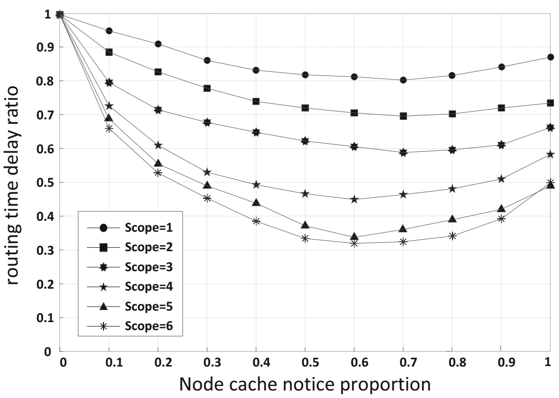

Fig. 9. The impact of the announcement ratio of cache content on performance

5.3 The Average Time Delay of the User Requests

The simulation process produced 2000 content requests. Define the single request delay as delay for a node from the content request to receive the requested data, then the simulation results of the average delay of the request contents is as shown in figure 10.

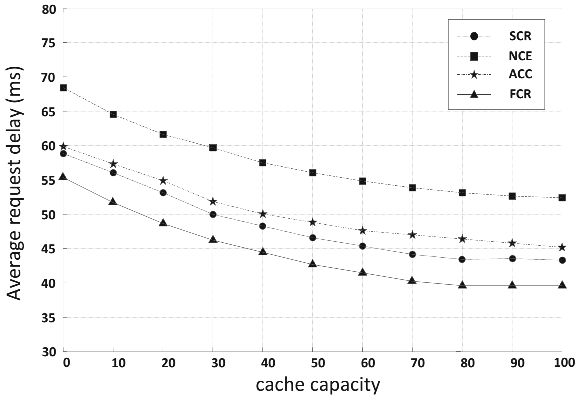

Fig. 10. The average time delay of the user requests

Seen from figure 10, the basic content routing in NDN has the largest time delay regardless of the copy in node. The methods of NCE and ACC both establish a copy of the neighbor node routing table, but they don't consider the differences in the heat of the neighbor node and the hit probability. The missing content situation is serious, which need to get from other resources, causing the increasing request delay. By contrast, the fast routing considers the update and delete of the cache node content. Once the cache content of announcement is replaced, then nodes update notification, and improve the hit probability of the request, which contributes to the minimum average request time delay.

5.4 Content Source Server Load

B= 60 cache capacity, content requests Nq = 2000. With the number of receiving interest in content server as norm, the performance of the server load simulation results as shown in figure 11. White represents the total number of request packets in the network, black for the number of received request packets for server.

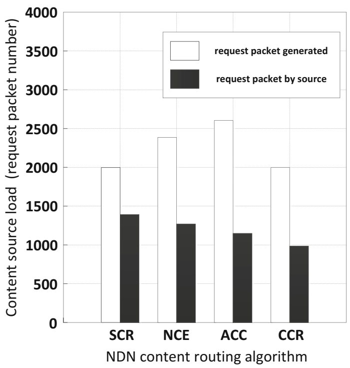

Fig. 11. Content source server load

From figure 11, the original NDN network routing way only routes the request to the determined server in the case that the total number of content requests is 2000, and thus it will not generate additional request packet. Lack of content, the ACE and NCE both have reroute request, which generate additional request packets. FCR will update notification timely to neighboring interest nodes within a cluster, so there is no reroute phenomenon. On the number of the received request packet for server, SCR is the most, because it only uses part of the forward path cache while the ACE, NCE and fast routing use the contents of the cache node resources, which effectively reduces the load of content server. Relative to the SCR, fast routing reduces about 30% on the server load.

6 Conclusion

The routing method improves the efficiency of the return packets through directly facing to the source server in the named data network, but cannot make full use of the neighboring cache content along the path. To solve this problem, this paper proposes the heuristic FCR (fast content routing) mechanism based on neighboring cache in interest clusters. Based on the small world feature of the Internet, we design heuristic announcement mechanism of cache contents in view of the different similarity between neighboring nodes in small community, and finally design the unique notification message structure and the reasonable notification scope to achieve fast content routing mechanism. Theoretical analysis and experimental results show that the method effectively reduces the average delay of the user request and the load of the source content server. Due to the frequently update of the content node, such fast content routing mechanism would lead to the expansion of the node routing table items. So how to aggregate and compress routing table items in the forward information base is the key point of further research and exploration.

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References

1. Carofiglio, G., Gallo, M., Muscariello, L.: Bandwidth and Storage Sharing Performance in Information Centric Networking[C]. In: Proceedings of ACM SIGCOMM ICN Workshop, 26–31(2011)
2. Tsilopoulos, C., Xylomenos, G.: Supporting Diverse Traffic Types in Information Centric Networks . In: Proceedings of ACM SIGCOMM ICN Workshop, 13–18(2011)
3. Chiocchetti, Raffaele, Rossi, Dario, Carofiglio, Giovanna, et al.: Exploit the Known or Explore the Unknown? Hamlet-Like Doubts in ICN[C]. Proceedings of ACM SIGCOMM ICN Workshop, Helsinki, Finland (2012)
4. Zhang Li-xia, Jacobson V, Tsudik Gene, et al. Named Data Networking (NDN) Project [R/OL]. http://named-data.org (2013)
5. Shanbhag, S., Schwan, N., Rimac, I., et al.: SoCCeR: services over content-centric routing. ACM SIGCOMM Workshop on Information-Centric Networking, Toronto, Canada (2011)
6. Eum, S., Nakauchi, K., Murata, M., et al.: CATT: Potential Based Routing with Content Caching for ICN. ACM SIGCOMM Workshop on Information-Centric Networking, Helsinki, Finland (2012)
7. Ye, R.: M. Xu, Neighbor Cache Explore Routing Strategy in NDN, Journal of Frontiers of Computer. Science and Technology **6**, 593–601 (2012)
8. Wang, Y., Lee, K.: Advertising cached contents in the control plane: Necessity and feasibility. In IEEE INFOCOM, NOMEN Workshop (2012)
9. Sripanidkulchai, K, Maggs, B, Zhang, H.: Efficient Content Location Using Interest-Based Locality in Peer-to-Peer Systems. In: Proceedings of IEEE INFOCOM (2003)
10. Pireddo, L., Nascimento, M.A.: Taxonomy-Based Routing Indices for Peer-to-Peer Networks. In: Proceedings of the Workshop on Peer-to-Peer Information Retrieval, 27th International Annual ACM SIGIR Conference (2004)
11. Mcpherson, M., Lovin, L., Cook, J.: Birds of a feather: Homophily in social networks. In Annual Review of Sociology (2001)
12. Zhang, Y., Zhao, J., Cao, G., et al.: On Interest Locality in Content-Based Routing for Large-scale MANETs(2009)
13. Masinter, L., Berners-Lee, T., Fielding, R.T.: Uniform resource identifier (URI): Generic syntax (2005)
14. Wang, Y, Lee, K., Venkataraman, B., et al. Advertising cached contents in the control plane: Necessity and feasibility[C]//Computer Communications Workshops (INFOCOM WKSHPS), 2012 IEEE Conference on.(2012)