Prediction-Based Cache Adaptation for Named Data Networking

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Abstract. Much more handling devices (e.g., smartphone, or tablet) were used today, host to host communication cannot guarantee able to use effectively in backbone network anymore. To achieve better communication quality for peer-to-peer (P2P) and fairs used web resources, the name data network (NDN) architecture therefore is proposed. One of critical issues in this field is that how to increase the cache hit rate, but rarely discussed for wastage data, that is why this research focuses on integrate NDN and virtualized to predict the size of the storage space algorithm (SCA) and dynamic cache adjustment algorithm (DCA). Moreover, we also attempted to solve the problem of wasted space cache and let each router should be able to naturally environment and open the appropriate cache size, saving resources apply to needed elsewhere. Finally, the proposed method and other state-of-the-art method will be compared with the NDN architecture.

Keywords: Network transmission, name data network, network planning

1 Introduction

In today's society, the existence of Internet application services to every corner of the world, high speed internet [1] has become part of human life regardless of class, work or leisure, in order to bring people greater convenience, the message transfer mode in network need to innovate and research. When Internet communications technology continues to evolve, Internet problems are emerging, for example, when users search or share information, they used to use the name to describe a data not instead of using a bunch of pointless IP addresses to represent. To solve this problem and providing faster transmission service, Domain Name System (DNS) [2] had proposed, the method it used to do is the conversion between field names and IP [13], but when the popular information was searched, the router need repeated transmission of the same path, the more nodes, the more waste caused by data transmission. In response to the traditional host-to-host communication problems [3], US National Science Foundation made the naming data network (NDN) architecture, It's concept is that use of content as core foundation of binding cache, let popular data dispersed store in popular router in order to save wasted repeated transmission and Improve the overall efficiency and effectiveness of content delivery. In the pursuit of higher data transfer rates and quality, we also want to cache the problem space into consideration at same time, although there are many mechanisms to increase the cache hit rate but few studies on the use of cache space, this study will look to import the information in the next generation of name data network and combine with virtualization of the machine.

The rest of the paper is organized as follows. Section 2 introduces CCN / NDN architecture and Cloud Media Related research. Section 3 definition of the problem to be solved and the simulation presented in section 3. Finally, this chapter will summarize research contributions and for future work to do some simple narrative.

2 Background

2.1 CCN / NDN

NDN - By the National Science Foundation (NSF) put forward a new network architecture formerly known Content Centric Networking (CCN). Under CCN [6] architecture, each node caching mechanisms are independent of each other. Suppose there is information request that data transmitted by the A to B, route between A to B all will cache data. Today CCN now renamed named data network (NDN), In NDN [7] Architecture, each router will have two table, One is pending interest table (PIT) and the other is forwarding information base (FIB), when a user sends a request for routing information, PIT table will record the receiving end of the data sources, if the cache does not scratch this information, the information will be forwarded to other routes and forwards the information to join FIB Table.

CCN / NDN architecture completely disable the overall strategy for IP agreements and content as the core foundation with the routing architecture of the node cache content, allows the user to access content to the nearest node, we can achieve optimal path, resources and improve the overall efficiency and effectiveness of content delivery, the ultimate goal is to reach any-to-any communication. In the absence of IP protocol architecture implemented in the network infrastructure NDN, to ensure data connectivity

2.2 Cloud Media

Cloud media [8] concept originated in cloud computing [9], cloud media standards has not been a formal specification or make Gakken community, The main concept is dependent on cloud computing and the Internet, the messages can be automatically integrated classification and technical conditions cross processed through newspapers, television, Internet, mobile phones and other new and different forms of media and carrier, polymerization become the majority of the media-rich clusters, then build a centralized media content in this bundle without boundaries, carrier and carrier diversification application, Focus body style participation, all resources and information are integrated into a common platform, for users with different orientations were passing messages massed demand and analysis of information effectively to the user selected the most meaningful content and then combined into a new media development. Traditional media to the core features of User Centric, Content Leaded, technology & business Driven. Therefore, from traditional media towards cloud media must be more consideration and analysis of user behavior and habits in order to achieve compliance with three polymerization characteristics of cloud media, we will use these three characteristics together with CCN / NDN architecture to improve overall transmission efficiency.

2.3 Related Research

In the field of data transmission there are many scholars began to study, at present, research methods for caching mechanisms have many, in [10], CCN architecture proposed by the authors for each child node will cache all data by solving waste popular data transmission on the traditional point to point transmission infrastructure, in [11], the authors propose a concept of the central node, only the central node to communicate with each other and popular materials was stored, and reduce the number of road communication routes and increase cache hit rate, Although these studies are to effectively improve the cache hit rate but does not effectively use the space in the cache of the router, therefore, this paper proposes to improve the disadvantages while both go higher hit rate of resource utilization.

3 Problem Definition and Solutions

Due to the current router cache space mostly as a fixed value, based on each user's interest in different cache will cause unnecessary waste of space, for example, when the World Cup open play, live events became popular search target, this time we put the World Cup if the resource cache to professional services routers and pre-sentence needs to open up the size of the storage space, Professional Services Routers (PSR) is each user of the requirements of a data router, this approach can significantly reduce waste point transmission and data storage space, therefore, this study will make use of virtualization technology Hypervisor architecture, the infrastructure (such as CPU, memory, storage space, etc.) resources cloud media communications platform virtualization, in accordance with the individual service user's router to open the appropriate state cache storage space to avoid unnecessary waste, to be able to articulate the status of data acquisition and waste, we define the cache hit rate is the data requirements of all users of the service router, the following formula:

$$HR = \frac{(\sum_{i}^{S} D_i)}{N} \quad (1)$$

Be Where Di is the amount of each data was obtained, HR representative waste rate, N is the total number of data. For information on the extent of waste, we define cache waste rate is the actual data to predict the number and ratio of the total number of data together, using the following formula:

$$WR = \frac{\sum_{i}^{S}(F_i - T_i)}{F_i} \quad \textbf{(2)}$$

where Fi is the number of data pre-contracting, *Ti* is the number of actual data, if *Ti* is greater than *Fi*, on behalf of the *i-th* material waste was 0. In order to be able to follow instructions of our proposed method in detail, we have developed a common symbol table as shown in Table 1.

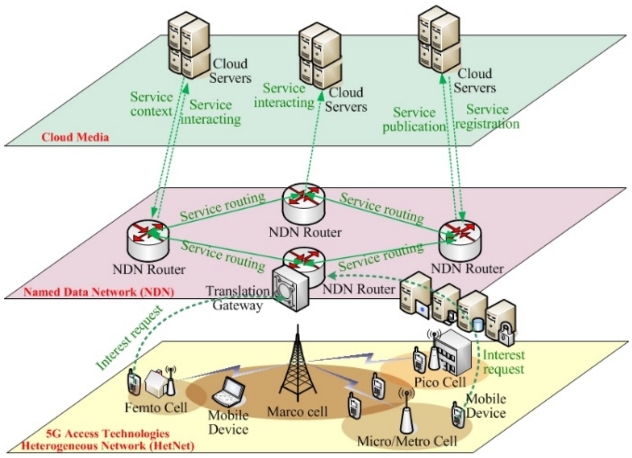

Fig. 1. Network architecture

Table 1. Important symbol table

Variable	Definition
WR	*Cache waste rate*
HR	*Cache hit rate*
N	*The total number of data*
n	*The number of routers*
$V=\{V_1, V_2, \dots, V_n\}$	*Collection of router* V_i
$N = \{N_{11}, N_{12}, \dots, N_{nn}\}$	*Users set the router* V_i *services*
$E = \{E_{12}, E_{13}, \dots, E_{n \dots m}\}$	*Collection of data transmission path*
CS	*Cache maximum capacity*
S	*Information on the general category*
ND	*Division normal function*
$DS = \{DS_1, DS_1, \dots, DS_n\}$	*The size of each data*

According to our definition of the network model, as long as we put every router to minimize wastage rate, the whole will be able to achieve the lowest overall environmental waste rate, so we have to solve the overall goal of minimizing wastage rate routing.

According to the above purpose, we established a linear programming model used in this study:

$Minimize \sum_{i=1}^{n} |WR|$

s.t

$$v_i \cap v_{i+1} = \emptyset$$
$$DS < CS$$
$$0 \le WR \le 1$$
$$0 \le HR \le 1$$

3.1 Network Model

1) Network architecture

In accordance with ILP, we will construct infrastructure between the cloud media and the Internet to pass the bridge, we use NDN characteristics, as a reference to the content of the request, with the transmission characteristics of the core of the cloud media information, the role of the intermediate layer to reduce the waste of network transmission resources.

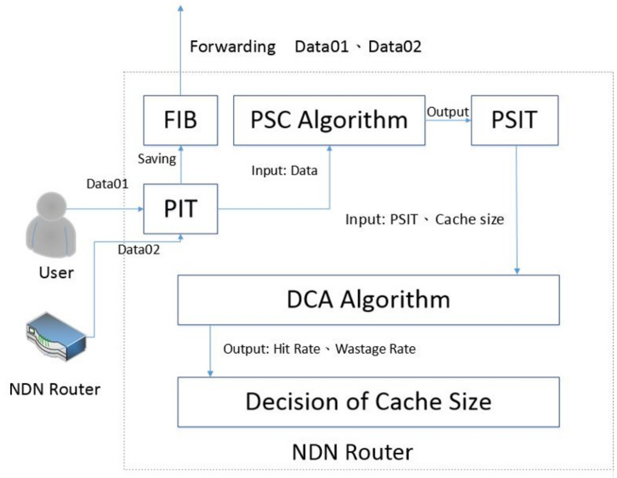

Fig. 2. NDN Router Architecture

In order to more clearly illustrate the research framework, we explained above diagram, when the user sends the information request, the router will be stored in the PIT in the request list, if the router does not cache data, PIT will forward the request to the other routers, at the same time the information will be forwarded data stored in FIB, we can use the information in the PIT, after the PSC algorithm calculates whether the user can filter for PRS services to the router to forward the request and the type of information requested in accordance with the number of occurrences from more to less sorted, you can get a list PSIT through PSC algorithms, we use DCA algorithm can calculate the cache hit rate and waste rate and then determine how much cache space can open the most effective use of resources.

2) Internet patterns

Our network patterns is expressed as $G = (V, N, E)$, $V = \{V_1, V_2, \ldots, V_n\}$ is a representative collection of routers in the network, $N = \{N_1, N_2, \ldots, N_n\}$ is a representative of each router service users, $E = \{E_{12}, E_{23}, \ldots, E_{n \ldots m}\}$ is a collection of representative data transmission path, In the network model:

$$v_i \cap v_{i+1} = \emptyset \quad (3)$$

$$E_x = |x| \quad (4)$$

x is the set of data transmission through the router through, for example, $x = \{1,2,3\}$ is the representative when the user sends the information request, information will first go through a router V_1 and then spread to router V_2 and finally back to the native side to obtain information router V_3, $|x| = 3$ is a representative sent the information request to obtain the information needed through several routers, to avoid waste caused by duplication of information cache, we define when each user to send information requests, only the PSR PSIT will cache data, In the above example, only router V_1 in PSIT will cache data, so there is no intersection between each router.

3.2 Ordered PSIT Mode

To predict data that each router was need cache, we will use historical data in pending interest table (PIT) , In accordance with the number of users interested in the kind of conduct in descending order, give the user the most commonly issued within a period of time the average interest lists with the message, further to the information added to this list, the judge can increase the cache hit rate by this method, then we have to reduce the amount of computation of the machine, we put the above list of independent, defined as the pending Species interest table (PSIT).

Assuming human usage information for queries belonging normal distribution, Figure 3, we can make use of historical data to get a normal distribution model based on this assumption and calculate the probability of each possible data by Poisson probability distribution, then we cache from high to low probability of occurrence and find effective cache size. The M in Fig.3 is the representation first cache area, the y-axis is probability of occurrence and the x-axis is data species. The data 0 is the most of probability of occurrence and the others is decreasing, we can follow this rule cache data that from 0 to 5 & -5, the following is the formula for a normal distribution [12]:

$$f(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}}\, exp(-\frac{(x-\mu)^2}{2\sigma^2}) \quad \textbf{(5)}$$

μ represents the expected value of the probability distribution, σ represents the standard deviation of the distribution of the probability, σ^2 represents the variance of the probability distribution, in response to different conditions in each region query data, you can always change these three variables to achieve a model of local conditions, we use historical information to identify PIT distribution model with this formula and then pre-sentence cache hit rate and waste rate.

$$f(x) = \frac{e^{-\lambda} \cdot \lambda^x}{x!}\ , x = 1,2,3, \cdots \quad \textbf{(6)}$$

Equation 6 is a probability distribution formula. λ is the average number of times an event occurs in specific interval. e is number of 2.71828. We can count the probability of data which chances appear more than once in router by this formula. The equation 7 is the corrected formula:

$$D_j(S_i) = 1 - \ e^{-\lambda}(1+\lambda) \quad (7)$$

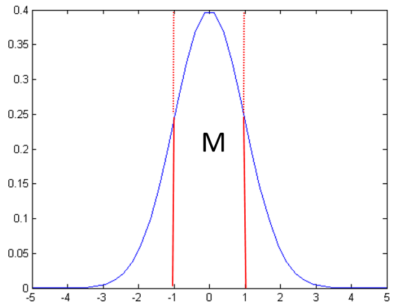

Fig. 3. Normal Distribution

The $D_j(S_i)$ is show that the S_i data appear probability next in the j router in the topology. This concept can extended to the whole network and count the probability which S_i is appeared in whole network. Please refer to Equation 8

3.3 Material Appearing Cycle Model

Our daily search for information in the process, there will be some differences, so we define each data has his information appeared cycle *T*, the information appears period was divided into two categories, we have the following examples:

On a regular basis: users will watch the program every Sunday, so the information appeared cycle for seven days, when we want to cache data, as long as Sunday to watch the program fixed cache, which in the six days you can put cache space utilization elsewhere.

On an irregular basis: When the World Cup open play, users will be viewing the live event, this type of irregular data cache, it must be time to immediately update the game and be cached by date.

To simplify the program, we put the information on a regular basis convergence model, we have the basis seven days a week, there are seven days a week, every day as long as we find the same information appears cycle data were PSIT sort, in accordance with the DCA algorithm can find daily adaptive cache information.

3.4 SCA and DCA Algorithm

In order to enhance the effective use of cache space and the overall transport network cache hit rate, two algorithms proposed in this study to resolve this problem, namely the PIT Sorting and classification algorithm (PSC) and Dynamic

Cache Adjustment Algorithm (DCA), first, we assume that the historical data sampling time interval is t, t by the user to decide, *T* is information appear cycle, *S (i)* is the *i-th* data, Then the router will first identify whether the object PSR services for our users, then the router will first identify whether the user object is PSR service for us, If the judgment result is YES, the information is included in PSIT, then the number of router statistics for each type of information that appears, as long as the information on *S(i)* species once, *c(i)* metering device to add 1, please refer to row 1 to row 5 in Table2. In accordance with the type of occurrences are sorted from more to less and built to PSIT table, please refer to row 2 to row 6 in Table 2.

Table 2. Sorting and classification algorithm (SCA)

```
Run the following at each node V
---------------------------------------------
Set N = Number of the data
Set S = Classify of the data
To recognize PSR user services
01    for (int j=1;j<=MAX(S);++j)
02      for(int j=1;j<=MAX(N); j ++)
03          if(S(i) == N(j))
04             c(i)=c(i)+1;
05    End
Order the PSIT from Max to Min
```

Then use PIT normal division of functions in anticipation of the formation time t, to 10% for PIT open units, please refer to row 1 to row 11 in Table 3. Then information appear cycle control PSIT and perform daily data cache, please refer to Table 3, line 5 predicate, again calculated Cache size corresponding hit rate please refer to row 14 to row 17 in Table3. And calculate wastage rate, please refer to row 18 to row 21 in Table 3. The following description of the operation of the algorithm of this study:

Table 3. Dynamic Cache Adjustment Algorithm (DCA)

```
SCA are continued
---------------------------------------------
Set  CS = The max of cache size
Set  ND = rand(N)   //ND ∈ Normal division
Set  size[] = Cache size form 10%~100%
Set  C=cache size dividing the number of segments
Set  DS =The data size of S
Set  T= Time period
01     for (int i=1;i<=C;i+)
02        Int g=1;
03       for (int j=1;j<=MAX(S);j++)
04          for(int h=1;h<=7;h++)
05             if (size [i] - DS(j)>0)&&T[j]=h
06               size [i]= size [i]-DS(j);
07               D(g)=S(i);
08               g=g++;
09               else if (s[i]-DS(j)<0)
10               break;
11             end
12            int Hit=0;
13            ND = rand(N);
14            for (int i=1;i<=g;++i)
15               for(int j=1;j<=N;++j)
16                  if(D(g)==ND(j))
17                     Hit=Hit++;
18               end
19             if (c(i) –Hit )>0)
20                 Wastage(i)
21                =(c(i)–Hit)/c(i)+ Wastage(i)
22             else if (c(i) –Hit>0)
23                 Wastage(i) =0;
24           end
25        end
26     end
Return Hit = Hit/(N× 7),Wastage;
```

4 Analog Parameter Setting and Results

4.1 Simulation Parameters Set

The main tool we use Matlab as this simulation, environment Construction in the total number of data for 1000, the number of routers is 10, the maximum cache capacity is 60G, each data built in size from 0.1 to 5G Random decision, please refer to Table 4.

Table 4. Simulation parameters Table

Name	Parameters
The total number of data	1000
The number of routers	10
Cache maximum capacity	60G
Data Size	0.1~5G
user	100
Data collection time	A week

Table 5. Bandwidth and delay in AT&T topology

Link Type	Delay		Bandwidth	
	Min	Max	Min	Max
Backbone-Backbone	5ms	10ms	40Mbps	100Mbps
Gateway-Backbone	5ms	10ms	10Mbps	40Mbps
Gateway-Gateway	5ms	10ms	10Mbps	40Mbps
Client-Gateway	10ms	70ms	1Mbps	3Mbps

Since virtually speed data transmission and the delay time are different. In order to more realistic environmental conditions, we refer to [12] the results of the data transmission bandwidth and delay time into consideration. Please refer to Table V. Figure 4 shows that the AT&T topology which is most simulation topology .The delay for client to gateway is 10ms and bandwidth is 1 Mbps to 3 Mbps, such as client1 to gateway1 that shown in Figure 4. Both of Gateway to Gateway and Gateway to Backbone router delay is 5ms to 10ms and the bandwidth is 10Mbps to 40Mbps, such as Gateway1 to Gateway2 and Gateway1 to backbone router1 in Figure 4. The delay for backbone router to backbone router is 5ms to 10ms and bandwidth is 40 Mbps to 100 Mbps, backbone router1 to backbone router2 that shown in Figure 4.

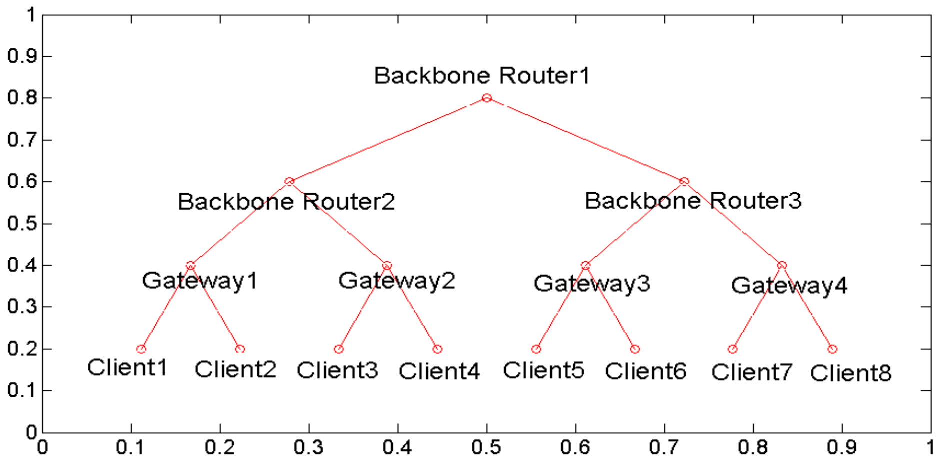

Fig. 4. AT&T Topology

In order to know SCA and DCA algorithm effect in different topology, we built two network topology. First is the regular situation that show Figure 5, each router service user was fixed and every layer router or user of topology was equal. The second topology is irregular situation that show Figure 6, each router service user was unfixed and branches is the same too.

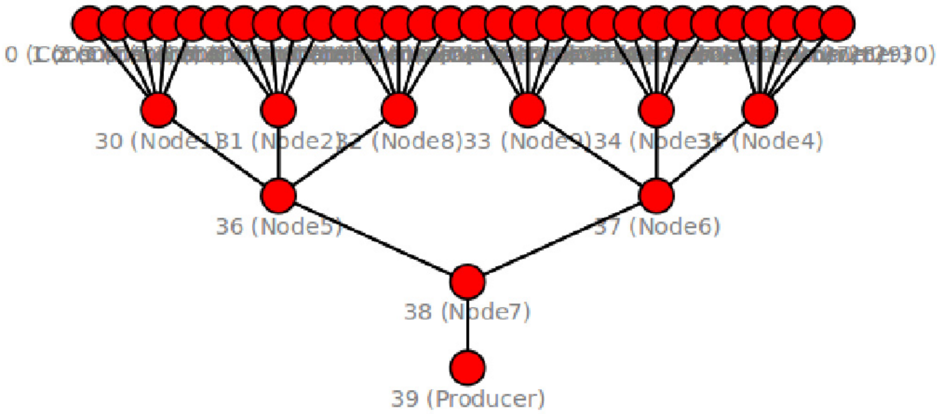

Fig. 5. Regular topology

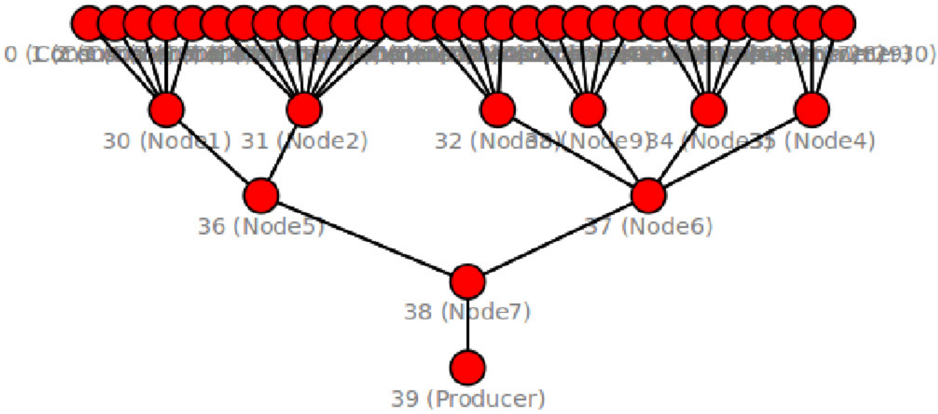

Fig. 6. Irregular topology

4.2 The Simulation Results

Figure 7 shows that the hit rate of CCN/NDN and DCA are changed since the cache size is changed. The blue line is CCN / NDN trend graph, red line is trend for DCA. In our framework, according to information appear cycle with distribution model that the most popular data were cache compare with CCN/NDN that cache all popular information, in the same Cache size, DCA's hit rate than the CCN / NDN higher, with the opening of the cache size increases, DCA's hit rate increases speed by first increased and then decline, because with different distribution curve data, cache space is open to some storage space can reach the highest hit rate. However, with the larger open space, cache space to store all the data close, so cache hit rate will be decreased.

Figure 8 shows that the wastage rate of CCN/NDN and DCA are changed since the cache size is changed. The blue line is CCN / NDN trend graph, red line is trend for DCA. We can find that the DCA wastage rate is lower than CCN/NDN in the same cache size, because of all popular data is cached by CCN/NDN but our mechanism is through information appear cycle and PSIT sorted, finally anticipation the most appear data, the difference is that the DCA can adaptation by self every date and release or cache size by anytime. We can find that the wastage rate was reduce then increase, because the more cache size the more information, but it have a transition when the data which appeared very low increase, the more unnecessary information in cache lead to wastage rate increase. We can also find that the CCN/NDN and DCA wastage rate was closed when cache size in 90%, because the information was almost cached by big cache size.

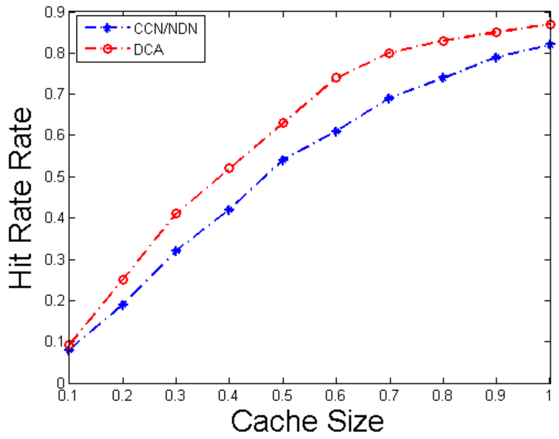

Fig. 7. Cache Size vs. Hit Rate

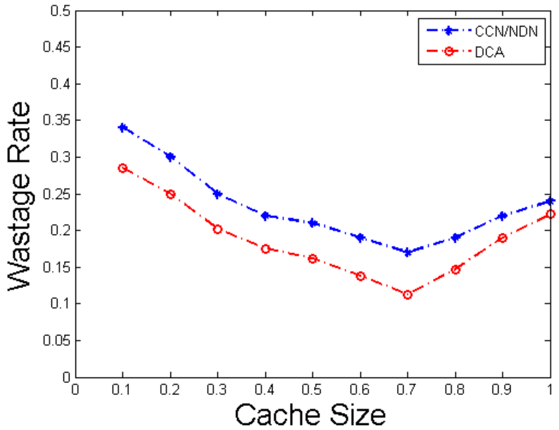

Fig. 8. Cache Size vs. Wastage Rate

Figure 9 shows that we can through our DCA algorithm in t units of time measurement 10 times the rate of time and a waste, the rad line hit rate is 0, the black line hit rate is 0.2, the green line hit rate is 0.4, the pink line hit cyan is 0.6, the rad line hit rate is 0.8, the blue line hit rate is 1, the normal division is changed after t=5. We can see that in accordance with our mechanism can effectively control the size wastage rate. The wastage rate was reduce in t=5 when hit rate increase from 0.2 to 0.8, because lower hit rate relatively speaking the cache size is smaller and information was cached is less. The wastage rate is increase when time from 0.8 to 1, because the results are not always predict the same with the actual, we assume that the hit rate 1 is the best value, but impossible to predict data which in accordance with the results of a normal distribution of historical data, so that will cause unnecessary waste of cache. We can see that the wastage rate is lower in time is 0.8.so that the most suitable hit rate setting is 0.8 in our environment.

Figure 10 shows that the router is opened cache size when hit rate is changed, our hit rate is 0.2,0.4,0.6,0.8 and 1, we can see that the more hit rate the more cache size open, it is lesser cache size gap from 0.2 to 0.4 because the popular data is concentrated in the forefront in PSIT, therefore, to improve the cache hit rate is relatively just need to increase the number of cache space, for ordering information compared to posterior segment, predict the results are less likely to occur, to improve the hit rate also needs more space to deposit additional information.

We simulate SCA and DCA algorithm in regular topology and irregular topology find that the data wastage rate which in regular topology is more stable with irregular topology. Because of that users in irregular topology is inequality. Base on the same cache size, wastage rate have two situation. First, the popular data is satisfy with the most user that was served with same router. The wastage rate in this situation is low. The second, the popular data is satisfy with the few user that was served with same router. The wastage rate in this situation is high.

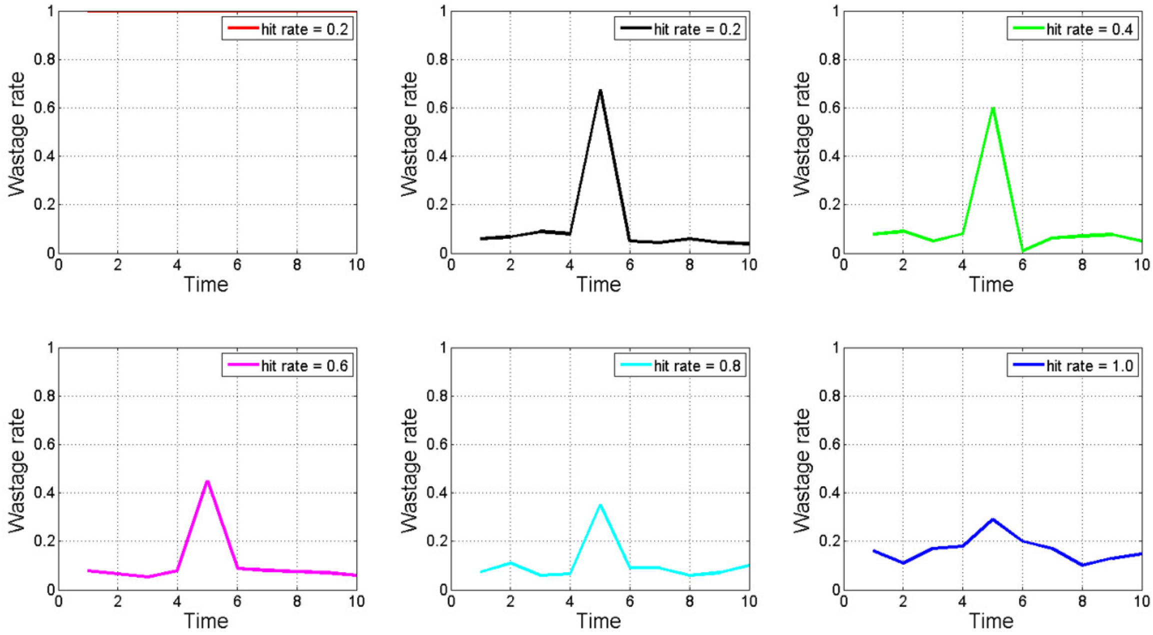

Fig. 9. Time vs. Wastage Rate

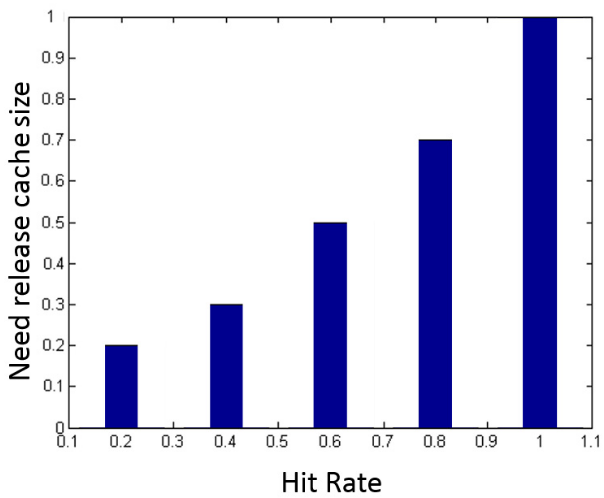

Fig. 10. Hit Rate vs. Need release cache size

5 Conclusions and Future Prospects

With the rapid development of Internet media, many scholars have begun to study the information under the naming data transmission network architecture model and put forward how to effectively increase hit rate, but in a same time, effectively use source is more impotent. Therefore, the most important contribution of this study is to propose a combination of the use of the concept of virtualize on NDN. To be effectively reduce wastage rate and useful in name data network, we propose CSA and DCA algorithms and predict how much cache size needs to open can reduce more wastage. Compared to the traditional hardware devices, resources can be effectively utilized to accomplish the task, in the future, I hope this study can be made out of the real and at a reasonable time complexity, come up with better anticipation mechanism for naming data network make a contribution.

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