Potential Energy Based Caching Decision Strategy for Content-Centric Network

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Abstract. A caching decision strategy based on potential energy is proposed to solve the problem of existing cache decision strategies in Content-Centric Network (CCN). The strategy applies the concept of "Potential Energy" to topology, and gives corresponding potential energy to the content and the nodes. It solves the redundancy caused by TERC through hierarchical caching. Finally, simulation results show that the strategy effectively improves the cache content diversity, reduces the cache content redundancy, thus reducing the user requests hop, raising the cache hit ratio compared with TERC and ProbC.

1. Introduction

It is urgent to propose a new network architecture because of the transformation of Internet's tasks and users' attention, which leads to the traditional network (IP-network) cannot meet the needs of The Time any more [1]. In view of this, the scholars at home and abroad have put forward many different network architecture [2], one of which named Information-Centric Network (ICN), an information-centric network architecture, has been widely recognized due to its good characteristics [3]. At the same time, the Content-Centric Network (CCN), a typical architecture of ICN, is considered as the most promising future network architecture.

Unlike IP-network, the identifier of content in CCN is its unique name, not IP-address, regarded as the index that instructs users to obtain content [4]. At the same time, the supply and demand of content can be decoupled in space-time due to the publish/subscribe mode. In addition, CCN router also has the function of storing and forwarding content [5], so that CCN is able to cache in its domain. And the request from users can be answered before it arrives source-server, while reducing the average request delay, the load on source-server is greatly reduced.

As an important part of CCN [6], the performance of domain-caching directly affects the overall performance of CCN. The buffer-space of CCN and each router is limited, therefore, choosing effective domain-caching decision strategy[7], placing content in suitable location, caching more diverse content in limited space, making more rational use of network resources, can increase the diversity of cached content, improve the cache hit ratio.
2. Related Work

In order to take full advantage of CCN [8], domain-caching decision strategy needs to meet the requirements as follows: (1) The content with high-visits should be cached to the edge of network, reducing request-delay, improving user experience; (2) Improve the multiplicity of content cached, reducing the redundant of the content, improving the cache hit ratio.

At present, there have been creative research achievements in domain-caching through the research of scholars at home and abroad [9]. TERC put forward by the literature [10], a default decision strategy, caches content to each router. So it causes huge redundancy and lower diversity, what’s more, TERC doesn’t take access-amount into consideration. ProbC [11] tries to cache content to the router closed to user to reduce request-delay. However, ProbC, as same as TERC, doesn’t take access-amount into consideration, increasing the competition of the edge of network. MPC, proposed in the literature [12] is to backup the content with high-popularity as much as possible, but MPC only cache the content with high- visits, therefore, the diversity is not ideal. In BCVC, proposed in literature [13], the content is cached to the router with the largest remaining buffer-space along the path, not considering the traffic, in addition, BCVC is not able to cache the content to the edge.

In view of the above problems, a caching decision strategy named PECDS is put forward in this paper, which applies "potential energy" in network topology and respectively gives corresponding potential energy to content and node. Matching the potential energy between content and node, so that the content can be cached hierarchically. This avoids the redundancy caused by TERC, improves the multiplicity, and can more rationally allocate resources, so that the utilization rate of resources is improved.

3. Potential Energy Based Caching Decision Strategy (PECDS)

3.1. Core Idea

PECDS adds a User Requests Information Table (URIT) on the basis of the original data structure (CS, PIT, FIB) of CCN. It is located in the each router which is the first hop from the user to record request information. It contains four fields, such as CN (Content Name), CPV (Content Page View) and CPE (Content Potential Energy) as well as RN (Router Number). Among them, CN is used to record the name of content requested; CPV records the number of request; CPE keeps a record of the potential energy level; the number of routers from the router to the content source server is recorded in RN. In addition, in order to be able to match the content and router, PECDS also modified the format of the Data package, adding the PE_C field to record the potential energy level of the content. Meanwhile, the PE_R field is added to each router to record the potential energy level of the router. Next, we will take the communication link shown in Figure 1 as an example to introduce the core idea.
between User and CRS. Among them, there are 8 contents stored in CRS, and the user have made requests for some of the contents, the name of the content requested and the request number are recorded in URIT shown in Figure 1(Ⅰ). Assuming that the traffic of C5 has reached the traffic threshold. Next, PECDS will divide the potential energy level of the content requested according to CPV as shown in Figure 1(Ⅰ). According to the formula (1), the content will be cached to a router that matches it. What Figure 1(Ⅱ) shows is the final state of the communication link, as we can see, C3 and C6 are respectively cached to R1 and R3; C5 and C8 are cached together in R2 because they are at the same level. Meanwhile, in order to avoid "cache pollution", the fields such as PE_C, CN and CPV as well as CPE will be emptied.

\[
I = \lceil \frac{N}{M} \rceil \tag{1}
\]

Among them, \(N\) represents the number of entries in URIT; \(M\) represents the number of routers on the communication link; \(I\) represents the number of levels cached in each router.

### 3.2. Algorithm Description

In order to make the implementation of PECDS easy to be understood, the pseudocodes of the initialization, the processing of Interest package and Data package are shown in Table 1, 2, 3.

| Table 1. The Pseudo-code of initialization |
|--------------------------------------------|
| **Pseudo-code I**                          |
| **initialization**                         |
| \(PE_C = NULL\)                           |
| \(PE_C = NULL\)                           |
| \(CPE = NULL\)                            |
| \(CPV = NULL\)                            |
| \(CN = NULL\)                             |
| \(RN\) is the number of router            |
| set \(PE_R\) (The potential energy of router) according to \(RN\) |
| **end**                                    |

| Table 2. The Pseudo-code of Interest package |
|----------------------------------------------|
| **Pseudo-code II**                          |
| **for each Interest**                       |
| User send Interest                         |
| URIT record the information of Interest, such as \(CN\), \(CPV\) |
| \(\textbf{if} \) Data in cache
| send Data & delete Interest                |
| \(\textbf{else if} \) Interest in PIT
| PIT records port                           |
| \(\textbf{else}
| PIT records Interest (name, port)
| transmit Interest according to FIB
| send Data                                 |
| **end if**                                 |
| **end for**                                |
Table 3. The Pseudo-code of Data package

| Pseudo-code III |
|----------------|
| for (CPV >= T) |
| set CPE according to RN & CPV |
| PE_C=CPE |
| for (each router) |
| if PE_C==PE_R |
| cache Data |
| PE_C=NULL |
| CPE=NULL |
| CPV=NULL |
| CN=NULL |
| end if |
| end for |

3.3. Potential Energy of Node

PECDS regards the user layer constituted by all users in the network topology as a “zero potential energy surface”, and each a "router plane" made up by all the routers those are same "vertical height" from “zero potential energy surface”. The “vertical height” refers the hops between user and router.

As described in physics, the potential energy of an object is determined by its own weight m, the local gravity acceleration g, and h-the vertical height from the ground. As we can see in Figure 2, each router has the same size to cache content, and each link with same material, so that the potential energy of each router only depends on its "vertical height" from user layer, and the potential energy of router will increase with the increase of the "vertical height”. As mentioned above, the potential energy of user is 0, therefore, the potential energy of R1 is 1, R2 is 2, and so on, the potential energy of RM is M, and CRS is M+1.

![Figure 2. The communication link](image)

4. Simulation Analysis

In order to evaluate the PECDS, we simulated TERC, ProbC and PECDS with a simulator named ccnSim, and compared them through Cache Hit Ratio(CHR), Cache Content Diversity(CCD) and Average Request Hop(ARH).

4.1. Simulation environment and parameter configuration

The topology is a six-layer tree as shown in Figure 3, in which there are 63 routers with the cache-space of the same size, and each one has the ability to rout and forward content at the same time. Each client is linked to leaf-node located at level 0, source-server, connected to the root-node located at level 5, has all backups of content which will be permanently stored. The simulation parameters are shown in Table 4.
Assuming there are 10000 content chunks in CRS, and the size of each one is 1MB, i.e., N=10000, S=1. The value of C is shown in Figure 4, and the value of M is 63 because of a six-layer tree topology. ProbC has a cache probability of 0.7, that is, p=0.7. The popularity of content has been modeled following a Zipf distribution with $\alpha =1$ [14]. In our experiments, LRU is adopted as the cache replacement strategy. T, an exclusive parameter of PECDS, means the threshold of content access, whose value should be set according to Zipf and the total number of requests from users, the value of T is 1280 due to each user send 1000 requests here.

4.2. Simulation Result Analysis

The simulation result just as shown in Figure 4, as it shows, we mainly compare the Cache Hit Ratio(CHR), the Cache Content Diversity(CCD) and the Average Request Hop(ARH) with the change of cache space. As shown in Figure 4(a), The Cache Hit Ratio(CHR) is increased with the cache space enlarge, we also see that, compared to TERC and ProbC, PECDS respectively increases by 60.1% and 17.5% when cache space is 2000MB. Figure 4(b) shows us that Cache Content Diversity(CCD) raises as the cache space expands, while it also tells us compared with TERC and ProbC, PECDS is obviously more advantageous. For example, compared to TERC and ProbC, PECDS respectively improves by 86.4% and 38.6% when cache space equals to 2000MB. What Figure 4(c) shows is the trend of the Average Request Hop(ARH) with cache space, it is very obvious that ARH shows a downward trend with cache space improves. However, compared with TERC and ProbC, PECDS respectively reduces by 1.16 hop and 0.6 hop. What it means that PECDS can cache more content in the router nodes, so that the load pressure on CRS is greatly reduced.
5. Conclusion

The domain-cache is the most important feature of CCN, and as an important component of domain-cache, the characteristic of cache decision strategy directly affects the performance of whole CCN. As default decision strategy, TERC causes a lot of duplicates and with long request-delay and low hit-ratio. PECDS, put forward in this paper, gives corresponding potential energy to content and node and realizes the hierarchical-cache. Simulation shows that compared with TERC and ProbC, PECDS is able to improve the cache hit ratio, reduce the duplicates among content cached and reduce the average request delay in a degree.

At future work, we will further optimize the matching mechanism, meanwhile, design and research cache replacement strategy matched with PECDS, and apply them in a topology to optimize to achieve optimal performance.

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