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Content Retrieval Method in Cooperation with CDN and Breadcrumbs Scoping on Domain

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Abstract: These days, in addition to host-to-host communication, Information-Centric Network (ICN) has emerged to reflect current content-centric network usage. The authors aim to establish the feature of ICN on conventional IP network to achieve feasible and efficient architecture. Specifically, we have proposed to operate Content Delivery Network (CDN) and Breadcrumbs (BC) frameworks coordinately on IP network. In this paper, furthermore, we propose to apply BC-Scoping on domain, which is a limited and selective BC framework as for network domain, to the cooperation with CDN.

1. Introduction

The current Internet architecture is based on host-centric communication model which was suitable for the Internet usage in several decades ago. Nowadays, most users are interested only in acquired contents themselves, and where to communicate is not important for them. This discrepancy between users and the Internet architecture causes various problems. In this context, Information-Centric Network (ICN) [1] has emerged as a future network architecture. ICN aims to reflect current content-centric network usage into network architecture. However, the clean slate approach of ICN, in which all the contents are processed by their names, has scalability problems because naming the contents in the network takes much overhead.

Therefore, the authors aim to establish the feature of ICN on IP network to achieve feasible and efficient architecture. To achieve this, we have proposed a cooperation method [2] between Content Delivery Network (CDN) [3] [4] and Breadcrumbs (BC) [5]. In this paper, furthermore, we propose to apply BC-Scoping on domain [6], which is a limited and selective BC framework as for network domain, to the cooperation with CDN.

2. Related works

Although there are some ICN approaches [7] [8], ICN is still immature and has scalability problems. In Named Data Networking (NDN) approach [7], each Content Router (CR), which corresponds to conventional router, needs to keep contents' names and their directions to forward them for routing. Thus, each CR must have huge amount of routing information because there are enormous contents in the Internet. Data Oriented Network Architecture (DONA) approach [8] forms hierarchical routing structure. Content providers register the contents' names and locations at Resolution Handler (RH), which corresponds to conventional router. These registrations are sent up to high level RHs, and hence, top level RH needs to have tremendous routing information. ICN has serious scalability problem as its routing is based on contents' names. To avoid this problem, we focus on Breadcrumbs [5] and CDN [3] [4] as content-centric methods; the former can be established easily on conventional IP network because of its simple mechanism, and the latter is actually working on the IP network.

In the proposed method, we create cache on not core routers but only user-edges such as edge-router, Optical Network Unit (ONU), Set Top Box (STB), and requiring user's PC for easy implementation. There are some researches in which router's cache is also utilized. In [9], each router has a cache of contents. Users' queries are sent through not shortest paths but bypassed paths where many caches exit. As a result, some users can obtain contents from nearer caches than the server. However, replicating cache in a router requires much memory capacity and very fast read/write operation of the memory in routers.

In [10] [11], users can obtain the contents from various proxy servers. Each proxy server coordinately communicates where the contents are, and users' queries are guided to one of the proxy servers.

2.1 Breadcrumbs

BC [5] is guidance information to route queries, which are sent from users to obtain intended contents, to the target contents stored at caches. BC entry consists of 5 items: ContentID, UpHop, DownHop, DownloadTime, and RequestTime. When a content is downloaded, a BC entry to the content is created at each router on the download path. This series of BC entries is called BC trail. After that, when a query encounters a node with a BC entry for the requested content, the query is routed by the BC trail. Specifically, at each router which forms the BC trail, the query is forwarded to DownHop node until it reaches a user-edge's cache. From the cache, the content is sent to the requesting user via a shortest path by IP routing. There is another option that traces the reverse BC trail but it tends to take longer hops. This BC method can be implemented on the conventional IP network with only small change of current system [12] [13] because of its passive and simple approach. A behavior of BC method is illustrated in Fig. 1. In this figure, when a content is downloaded from the server to user A, a BC entry corresponding to the content is created at each router on the content download path and a BC trail is formed among the routers. After that, user B sends a query to obtain the same content. Here, the query is routed to user A by the BC trail after it encountered the router with the corresponding BC entry. Thus, we can reduce server load by utilizing users' caches.

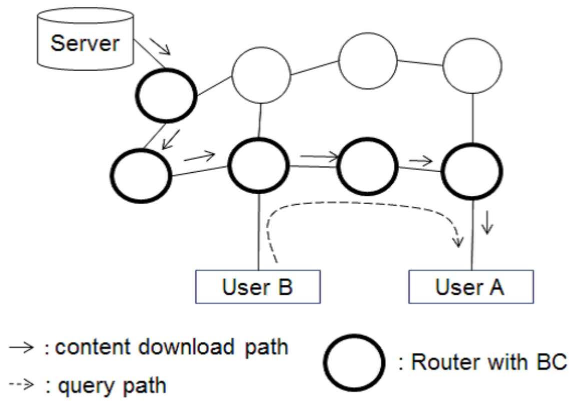

Figure 1. Behavior of BC method

2.2 CDN

CDN [3] [4] addresses a problem about how popular contents should be made widely available. In particular, CDN is expected to deal with flash crowds. It is difficult to predict flash crowds because it is caused by sudden event such as news about natural disaster. To address this problem, in CDN, replica servers called surrogate servers are placed dispersedly in the network, and contents are replicated on surrogate servers. Users' queries are redirected to one of the surrogate servers according to some selection rules, and the contents are delivered to the users from them. A behavior of CDN is illustrated in Fig. 2. First, a user sends a name resolution request to DNS. This request is finally redirected to the DNS operated by a CDN administrator (1). Next, the DNS selects the best surrogate server for the user according to some selection policies, and sends the server's IP address to the user (2). The selection policies generally take into account the surrogate servers' loads and the distances between the user and the surrogate servers. Then, the user requests a content to the selected surrogate server (3). Finally, the surrogate server sends the content to the user (4). Users can obtain requesting contents without concerning the locations. However, operating CDN takes some cost to place and manage surrogate servers and contents. As a result, using CDN also costs to some degree.

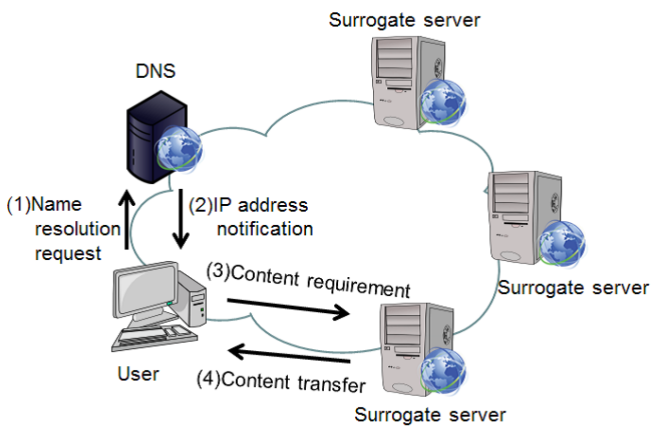

Figure 2. Behavior of CDN

3. Proposed method

In the authors' cooperative control between CDN and BC frameworks, we transfer queries so that as many as possible queries are guided by BC.

In most of CDN services, DNS selects the best surrogate server for each requesting user based on the distances and the server loads. Here, the proposed control introduces BC hit rate (R_{BChit}) that is calculated per surrogate server and content, based on the following formula,

$$R_{BChit} = C_{BC}/C_{all}. \quad (1)$$

Where, C_{BC} is the number of the queries handled by BC and C_{all} is the number of all the generated queries which are sent to a surrogate server. To calculate BC hit rate, we need to count these two numbers. DNS counts C_{all} when it sends an IP address to a user. Users need to report C_{BC} if we try to obtain it directly. However, to suppress users' loads, surrogate servers periodically report the number of queries handled by them (C_s) to DNS. Then, DNS calculates C_{BC} as follows,

$$C_{BC} = C_{all} - C_s. \quad (2)$$

When a user sends a query to obtain the corresponding content, DNS selects the surrogate server with the highest BC hit rate among the N_S designated surrogate choices as the destination of the query. Specifically, top N_S surrogate servers as for the smaller distances to a user are selected as the surrogate choices for the user. The distance between a user and a surrogate can be calculated by measuring the packet delay. By delivering contents from specific user caches holding the target contents, the workloads on surrogate servers can be decreased. As a result, CDN administrator can cut the implementation cost for surrogate servers. Moreover, contents provider can cut the cost to deliver their contents because the charge for using CDN is demanded based on the amount of access. Consequently, users can have some benefit from this, e.g. improvement of content providing service like less charge for the service.

In this method, however, we transfer users' queries, which are originally supposed to be handled by surrogate servers, to user-edges. Thus, user-edges experience extra burden. In particular, if a user-edge has a popular content's cache, many queries concentrate on the user-edge. To prevent this problem, we set upload limit to which user-edges offer their cached contents simultaneously. The user-edges do not respond to queries while they are simultaneously uploading content flows equal to the upload limit. In this case, the queries are redirected to surrogate servers which are the original destinations of them. Additionally, these queries do not follow BC anymore to prevent the situation that they are forwarded to other busy user-edges and rejected again, and that, as a result, the number of hops becomes large.

In this cooperative control, we apply BC-Scoping on domain [6] to suppress too long BC trail. The BC-Scoping limits the distribution scope of guidance information according to network domain.

4. Performance evaluation

4.1 Simulation scenario

We implemented a simulator in a hierarchical topology, shown in Fig. 3, with two level domains: high level and low level domain. Each of the routers in the high level domain is connected to one low level domain respectively. There are ten routers in the high level domain. Hence, there are ten low level domains. All the low level domains have 500 users and 5 original servers per domain, and half of the ten low level domains have one surrogate server per domain.

Unlike original BC method [5], we assume that contents are cached only in user-edges except for surrogate servers, and routers have only BC entries to save their computational cost. Note that we use BC+ method [14] instead of original BC method to solve a routing loop problem that queries are transferred within specific routers forever. We assume that the distances between each user and surrogate servers are computed in advance. The distances are used to select top N_S surrogate servers in the proposed method.

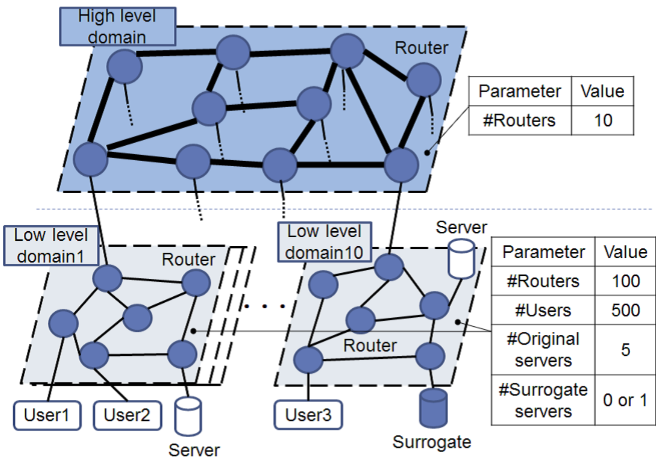

Figure 3. Topology

4.2 Results

We evaluate the proposed method described in Section 3, by comparing the following systems:

- Legacy CDN+IP
  CDN with conventional IP routing.
- Proposed CDN+BC (N_S)
  Users select a surrogate server with as high BC hit rate as possible. We vary surrogate choices (N_S) from one to five.
- Proposed CDN+BC-Scoping (N_S)
  Poposed method with BC-Scoping. We vary surrogate choices (N_S) from one to five.
- Simple coexisting approach of CDN and BC
  Each user always selects the nearest surrogate server and does not consider BC hit rate. This system corresponds to CDN+BC (1) and CDN+BC-Scoping (1).

Figure 4 shows the ratio of queries handled by a surrogate server to all generated queries. In the proposed CDN+BC and CDN+BC-Scoping, each number on the horizontal axis represents the setting of N_S. In legacy CDN+IP, all queries are transferred to a surrogate server. Surrogate utilization ratio, therefore, equals one. In the proposed CDN+BC and CDN+BC-Scoping, some queries are guided by BC; then contents are delivered from user-side caches, and thus, surrogate utilization ratio decreases. In particular, surrogate utilization ratio is small in CDN+BC, because in this method, BC trail is longer than CDN+BC-Scoping method. As a result, more queries encounter the BC trail, and surrogate utilization ratio becomes small.

Figure 5 and 6 represent average hop counts of query and content, respectively. In the proposed CDN+BC-Scoping, query hop count becomes large compared with legacy CDN+IP while content hop count becomes small. This is because queries are not always transferred based on minimum hop route by BC-based routing. Each query is first routed to a surrogate server, and then, it may be guided by BC, and finally, reaches a user-side cache holding the target content. On the other hand, content hop counts are relatively small because content packets are transferred based on minimum hop route. In comparison with CDN+BC-Scoping, both query and data hop counts are large in CDN+BC, because BC trail is longer than CDN+BC-Scoping method.

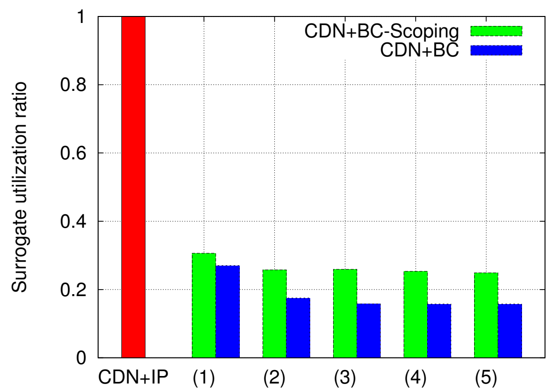

Figure 4. Surrogate utilization ratio

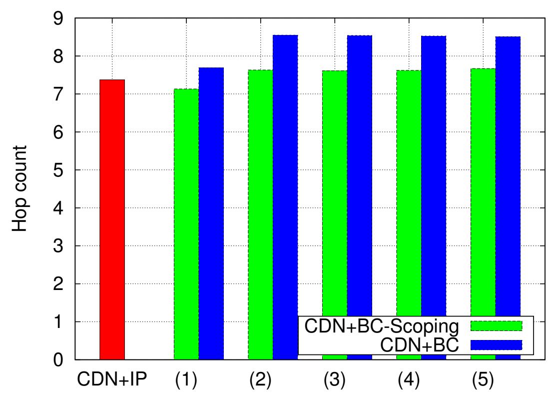

Figure 5. Query hop

5. Conclusion

In this paper, we presented a cooperation between CDN and BC-Scoping method on domain coordinately. In most

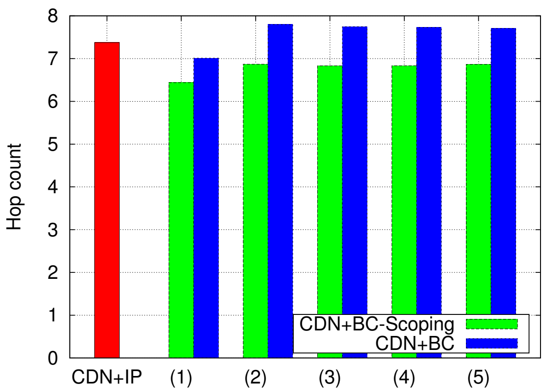

Figure 6. Data hop

CDN, DNS chooses optimal surrogate server for a requesting user based on the surrogate server workload and the distance between the user and the surrogate server. In our approach, we also consider BC hit rate to choose surrogate server. Thus, there is more chances that users obtain the content from another user. Simulation results demonstrated that combining CDN with the BC-Scoping method resulted in reduction of CDN utilization. We are planning to introduce BC-Scoping on popularity which can suppress the amount of BC entry by creating only popular contents' BC.

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