A Dominating-set-based and Popularity-driven Caching Scheme in Edge CCN

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***Abstract*—In this paper, we try to design a collaborative caching scheme in an edge Content Centric Networking (CCN). Specifically, we first decompose the arbitrary network into clusters based on dominating set. Then, we place the content heterogeneously within each cluster based on the content popularity results and resort to a dynamic request routing. Simulation results show that the proposed outperforms the existing caching mechanisms in CCN.**

Keywords—CCN; in-network caching; popularity; dominating set

I. INTRODUCTION

The content-centric networking(CCN) is a significant future Internet architecture that is better suited to the increasing demand for highly efficient content distribution [1]. In-network caching is a key part and its function is critically related to the overall performance or even the viability of CCN [2]. Specially, in-network caching exhibits fundamental differences from the traditional overlay caching approaches and poses new challenges. Firstly, replicas of contents in CCN may lay in any cache-equipped nodes covering the whole Internet scale, which are arranged as an *arbitrary graph topology* rather than a hierarchical topology. Such arbitrary topology without explicit affiliation among nodes makes it difficult to realize the collaborative caching.

Secondly, we argue that the *line-speed requirement renders prohibitive the employ of complex collaborative content placement schemes.* Therefore, the collaborative caching scheme with sophisticate optimization method in [2] is too complex to be used in CCN. While the collaborative caching scheme [3] with lower complexity is more suitable to CCN, which mainly prefers to cache diverse contents according to the content popularity in an lightweight coordination manner. However, these schemes lack a simple correct popularity statistic method in CCN due to its **filtering effect** and **request aggregation** mechanism. The former means that only the cache missing requests are forwarded up to higher level nodes, and the latter means that an intermediate CCN node may receive many requests for the same object but send out only a request. H. Wu et al. [4] present a method to get the content popularity; however, it works with high cache redundancy and can only apply in the hierarchical topology.

Finally, caching in the intermediate routers of in-network caching increases the *content availability*. In order to fully realize this merit, *it is crucial to make the temporary cached content to be visible in its vicinity*. Thus, dynamic request routing, except request forwarding according to the FIB, is necessary in CCN, collaborated with caching scheme. Our previous work SAC [5] propose a caching scheme, combining the content placement with dynamic request routing, but without the proper content popularity information support.

In this paper, we are concerned about low complexity content placement scheme, combined with dynamic request routing, according to the popularity statistic results, in *edge CCN arbitrary caching network*. Therefore, we propose a Dominating-set-based and Popularity-driven Caching scheme (DPC) with the goal to reduce the egress traffic as well as caching redundancy.The DPC itself can also apply to a large scope network without limitation.

II. CACHING MECHANISM

Our proposed DPC scheme consists of four main stages, including network decomposition, the popularity statistic, collaborative content placement and dynamic request routing.

Network Decomposition. In this paper, we use dominating set (DS) to distinguish caching nodes and then decompose the network into clusters to realize collaborative content placement in CCN arbitrary topology [6]. An arbitrary topology of CCN can be represented by an undirected graph $G=(V, E)$. A DS of G is a subset $V^{'}\in V$, such that each node in $V-V^{'}$ is adjacent to some node in $V^{'}$. A connected dominating set (CDS) C of G is a dominating set which induces a connected subgraph of G. Nodes in the CDS are termed as *dominating nodes* (cluster head), and the remainder nodes are termed as *non-dominating nodes* (cluster member). We use these dominating nodes to decompose the arbitrary network topology into several clusters. Each cluster includes one dominating node and its mastered non-dominating nodes.

The Popularity Statistic. In our proposal, all the access routers collect every object's request rate periodically and record corresponding information in a local vector called Request Vector (RV) [4]. The intermediate cluster head node sums up all the request rates belonging to the same content in RV sent from its cluster members and all its subordinate clusters. Then the cluster head nodes go on to spread the accumulated RV towards the gateways hop by hop along the Forwarding Path. In the end, the gateways get popularity information of the whole edge CCN network.

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The Collaborative Content Placement. The cluster head node at the gateway first ranks the accumulated *RV* in a descending order in term of the number of request rates. Then, it fetches the records in turn from the top of *RV* and a corresponding item is marked so that the replica will be cached as soon as it passes the cluster. In the end, the marked content items are removed from the *RV* and the latest *RV* is sent downstream to the child clusters. As for the intra-cluster content placement, the cluster head will select itself or one of its cluster member nodes randomly till the caching space of the whole cluster is full. Therefore, this online collaborative content placement scheme can cache content heterogeneously from the gateways downwards access routers cluster by cluster according to their popularity. If a return content arrives and it is marked, then cache the content in the cluster and record it to the *CachedTable*. The *CachedTable* keeps its entry in a form of (*Content Identifier; Node*), so it can be used to direct the following requests.

Dynamic Request Routing. The *CachedTable* maintained by the cluster head makes the cached content to be visible in the cluster. To maximize the cache utility, the key idea is to route the unsatisfied requests in descendant clusters firstly to the cluster head, instead of the default route according to FIB.

An example of content request rates at each access router is given in Tab. I. In each column, $O = \{O_1, O_2, \ldots, O_N\}$ denotes a set of cacheable content objects and *#R* stands for the number of each access router. As illustrated in Fig. 1, we can see that the cluster at the gateway caches the most popular contents, then its descendant clusters cache the next popular contents, and so on. Therefore the DPC can increase the content diversity and reduce the egress traffic.

TABLE I. THE REQUEST RATE AT EACH ACCESS ROUTER.

#R	O_1	O_2	O_3	O_4	O_5	O_6
8	53	28	16	13	10	6
9	45	30	17	12	8	5
10	49	25	20	16	13	10
11	34	20	16	10	9	7
12	31	40	23	11	8	4
13	57	22	20	18	10	10

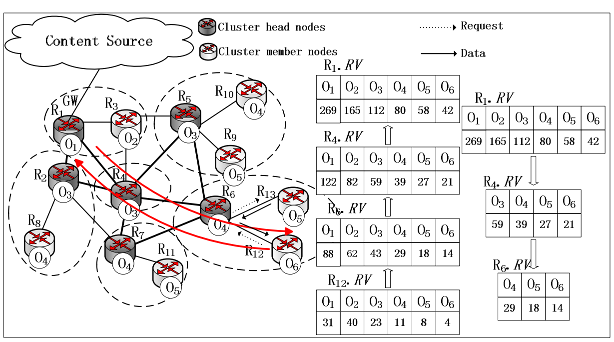

Fig. 1. An example of cache placement process in DPC.

III. EXPERIMENTAL EVALUATION

In order to evaluate the performance of DPC, we develop our simulation environment in Java, a simulation platform for CCN in-network caching. We consider two simulation scenarios, one is a simple topology as shown in Fig. 1, the other is a real edge AT&T network topology covering 156 nodes and 392 edges. We compare the performance of DPC against: i) the default caching strategy in CCN, called LCE. ii) our previous caching strategy based on the dominating-set [6], termed as CollaCache. iii) the EMC approach in [4].

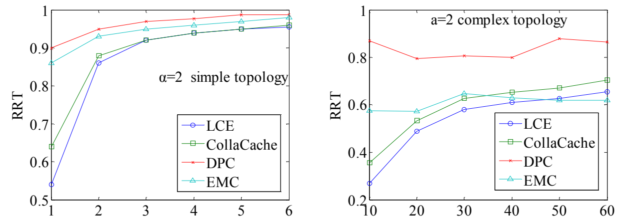

Fig. 2. RRT vs. Cache Size.

The Fig. 2 depicts the average *Ratio of Reduced Traffic* (*RRT*) curves as a function of cache size when popularity skewness factor α=2. The *RRT* is defined as the ratio of the number of requests served by the whole edge caching network to the total number of requests sent by users. We can see that DPC improves the *RRT* over the other schemes no matter in the simple or in the complex topology scenario.

IV. CONCLUSION

In this paper, we have proposed a collaborative caching scheme called DCP to achieve the specific objective of minimizing the network egress traffic in CCN networks. Extensive experimental results demonstrate that DPC significantly improves the caching performance in term of reducing the network egress traffic with reasonably light overhead.

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