ARTICLE IN PRESS

Journal of Network and Computer Applications (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

GBC-based caching function group selection algorithm for SINET

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ARTICLE INFO

Keywords:
SINET
CCN
Cache
Group Betweenness Centrality

ABSTRACT

The emerging future network designs such as Smart Identifier Network (SINET) and Information-Centric Networking (ICN) can provide efficient content delivery via its in-path caching. However, it is not an optimal way to cache contents at all intermediate routers for that current technology is not yet ready to support an Internet scale deployment. Most of the existing works select cache location based on the important of single node rather than that of entire cache group, which may result in inefficient problem caused by reduplicative impertinences. In this work, we study the intelligent cache location selection algorithm with an objective to maximize cache delivery performance while minimize the number of caching nodes. We first investigate the recent work in term of content location selection schemes, and formulate this problem as finding the prominent group with the highest Group Betweenness Centrality (GBC). We then propose a GBC-based in-path caching function group selection algorithm to select the caching nodes in SINET. We evaluate the performance of proposed algorithm through simulations and compare it with others. The final results show that GBC-based algorithm can provide better performance in term of average hop of content delivery. Using our finding, the network operators could deploy cache easily.

1. Introduction

The booming of heterogeneous devices, systems and networks technologies is changing the Internet service pattern. According to Cisco visual networking report, the video services have already occupied almost a half of today's traffic, and more specifically mobile video traffic has occupied about 55% of total mobile data traffic in 2015. In this context, the mobile rich multimedia content retrieval become a dominated application (Pu et al., 2016), which results in the Internet paradigm has gradually shifted from resource sharing to content dissemination and retrieval, and Internet has evolved from a network connecting pairs of end-hosts to a substrate for information dissemination. As a result, the traditional end-point centric model seems to no longer cater current communication demands (Katsaros et al., 2011). In the meanwhile, the unprecedented challenges such as security, mobility and energy consumption are emerging along with this paradigm shifting, and several projects have been launched aiming to design a clean slate future network architecture. Our previous research (Zhang et al., 2016) has found out that the root causes of these challenges in the current Internet is the triple bindings which refer to the resource/location binding (r/l binding), user/network binding (u/n binding) and control/data binding (c/d binding). Most of future network architecture designs focus on one of triple bindings. For example, Information Centric Networking (ICN) (Ahlgren et al., 2011) aim to decouple the r/l binding by replacing the location routing by contents routing, and Locator Identifier Separation Protocol (LISP) separates the node's identifier and routing locators, and Software Defined Network (SDN) separates the control plane and data plane by introducing the controller and forwarder.

To decouple the triple bindings, our previous work has proposed a future network architecture named Smart Identifier Network (SINET), aiming to set up a collaborative architecture. Different to the current Internet, SINET defines a "three layers and two domains" reference model as shown in Fig. 1. Three layers are in charge of network services, network functions and network components, respectively. More specifically, the smart pervasive service layer deals with the service naming, registration and management. The dynamic resource adaption layer manages and organizes different network function groups to support mobility, security, in-path caching and energy saving. Each function group is a set of network nodes or components which are selected by combining the upper layer requirement and lower layer capability. The collaborative network layer consists of various network nodes such as routers, host, sensors, and carries out the specific task such as routing, caching, mobility.

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http://dx.doi.org/10.1016/j.jnca.2016.12.004
Received 1 August 2016; Received in revised form 20 November 2016; Accepted 2 December 2016
1084-8045/

Please cite this article as: Guan, J., Journal of Network and Computer Applications (2016), http://dx.doi.org/10.1016/j.jnca.2016.12.004

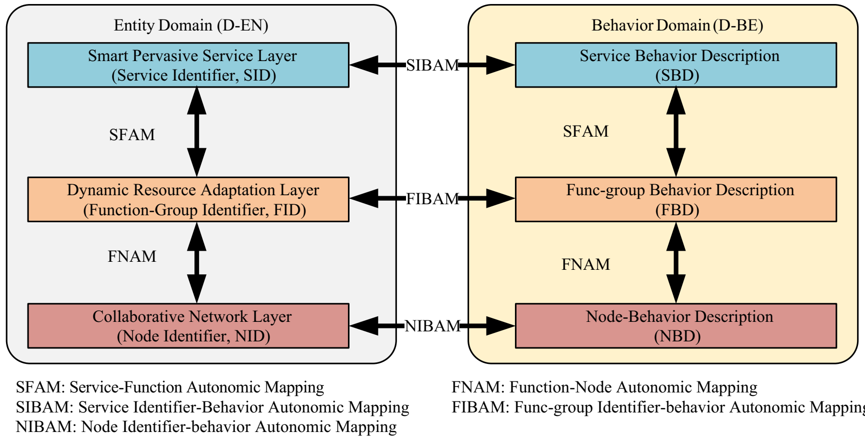

Fig. 1. SINET reference model and key mechanism.

One import function of SINET is to set up the in-path caching function group for the upper layer services based on the combination of network nodes. The in-path caching function group selects a set of suitable nodes based on the FNAM mechanism to provide the caching service, which can improve the resource utilization and reduce the energy consumption.

The caching mechanisms have been studied in Web service, Content Distribution Network (CDN) and Content-Centric Networking (CCN). The web cache services are used to reduce load on access links and shorten the selected content accessing time to acquire better performance (Che et al., 2001; Podlipnig and Osz, 2003). However, the end-to-end design pattern of the current Internet is inefficient to provide these contents delivery services. Different to traditional web cache, CCN caches the very small data chunks (typically packet-size) instead of caching full objects, which can be identified by users (called data chunks). Each router in network will cache the data chunk and sends back to users once an interest packet hits the cache (Jacobson et al., 2009). However, it is not optimal to cache the chunks at all intermediate routers in CCN (Li et al., 2012) for that it may introduce large additional deployment cost. In addition, the recent research (Perino and Varvello, 2011) shows that today's technology is not yet ready to support an Internet scale deployment of CCN at a CDN and ISP scale. So, the caching routers will be deployed in selected locations of Internet and cache the heterogeneous contents (Wang et al., 2016). The same problem is also existing in SINET. However, how to map the in-path caching function group into the network nodes is an open issue. Our previous work has studied the content selection problem (Guan et al., 2016) and location selection problem (Guan et al., 2012). Our previous work has found that Betweenness Centrality has the better performance than others, and it can be used as a metric to select the cache locations. This work considers the impact of single node, and chooses the cache group based on the rank of nodes. However, the set of high rank node cannot insure highest performance for that there may be lots of reduplicative impertinences.

This paper aims to seek this gap, and figures out the impacts of single node metric and group metric. More specifically, we consider the importance of the entire group, and adopt Group Betweenness Centrality (GBC) to further improve the cache importance. We introduce this algorithm into the in-path caching function group decision for SINET, and highlight how it works to select the network nodes. We show its performance under different simulation scenarios including the social network such as Zachary's Karate Club (ZKC) (Data file from) network, inter-AS network such as Barabási-Albert (BA) network and scale-free network.

To summarize, the key contributions of this paper are: (1) study in-path caching function group deployment problem during the transition period, and formulate this problem as finding the prominent group; (2) propose a GBC-based algorithm to select the network nodes, which can maximize the caching delivery performance while minimize the number of participated caching nodes; (3) evaluate the average hop of content delivery under different network topologies and compare it with others schemes. The rest of this paper is organized as follows. Section 2 investigates the related work of caching mechanisms. Section 3 describes the proposed solution. Section 4 evaluates the performance under different scenarios. Finally, Section 5 concludes this paper.

2. Related work

The cache locations selection schemes are generally derived from the work of CDN (Chen et al., 2008; Zhang and Tatipamula, 2011; Yang et al., 2011) and web services (Krishnan et al., 2000). The caches can be placed on the edges such as proxy or insides of networks, which can be reduced to the well-known *p-median problem* that is also similar to the *facility location problem* (FLP). However, it is a NP-hard problem and difficult to solve. Most researches are focused on better approximation algorithms (Dohan et al., 2015), while only few topologies such as trees, line and ring, can get the optimal solution in polynomial time. Lots of work are based on the results of tree, and extend it to multiple identical servers (Wang and Ding, 2014) and combine it with other algorithms such as knapsack algorithm.

Different to CDN or Web caching which are based on the current network architecture, the CCN caching works at network layer directly with transparent, ubiquitous and fine-grained features (Zhang et al., 2013). The existing location selection schemes in CCN/NDN mainly depend on node importance (Guan et al., 2012; Rossi and Rossini, 2012; Wang et al., 2013; Xu et al., 2014; Cui et al., 2013), node capability (Mishra and Dave, 2015; Xu et al., 2015) and node attribution (Sourlas et al., 2015).

Rossi and Rossini (2012) adopted the graph-related centrality metrics (e.g., betweenness, closeness, stress) to proportionally allocate content store across the CCN networks, and got that the simple metric such as degree centrality only get the limited gain under different topologies. The following research of Guan et al. (2012) compared the performance of different network centralities and found that betweenness centrality has better performance compared with other centralities. These results show that the metric based on single node cannot largely benefit the overall performance, and it should consider other factors. After that, Wang et al. (2016, 2013) comprehensive considered the factors of topology, network size, content characteristic and replacement strategies, and proposed an optimal solution for cache allocation under the given total storage budget. This algorithm divides the cache location problem into the cache location in shortest path tree and the knapsack problem. And one of their results shows that the cache should be heterogeneous especially for the larger network.