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Towards a novel cache replacement strategy for Named Data Networking based on Software Defined Networking☆,☆☆

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ABSTRACT

The Information Centric Networking (ICN) approach proposes to rebuild the Internet communication model and to focus entirely on the data content. Although the Named Data Networking (NDN) architecture is considered as one of the most credible ICN architectures, it does not have an effective cache replacement system. Software Defined Networking (SDN) is an architecture where the control plan is completely decoupled from the data plane. In fact, with the steady growth of existing network infrastructures, we take advantage of the SDN to enhance the caching in the NDN architecture.

In this paper, we introduce a Named Data Networking Cache replacement approach based on SDN, that we called NC-SDN. Thus, our proposal relies on data popularity calculation performed by the switches to define a cache replacement strategy. Through experimental tests, we evaluated the performance of our solution, and we compared it to the NDN equipped with different cache replacement policy.

1. Introduction

In recent years, the amount of traffic that Internet users produce on a daily basis has been exponentially increasing mainly due to the success of video streaming services, such as Netflix and YouTube [1]. However, the Internet protocol stack was not designed for this traffic, but it was rather conceived as a means of communication between two remote hosts. Therefore, this new use scenario requires the new techniques to ensure effective distribution of content through the Internet. Among these methods, the Information Centric Networking (ICN) approach [2] was proposed to solve the problems of the current Internet architecture by putting the content at the core of its communication model. On account of this vision, some features, such as: data cache management, mobility management, naming, forwarding and security, become fundamental elements in the ICN model.

The use of the cache becomes a vital component to deliver data, especially in Web traffic, Peer-to-Peer applications and Content Delivery Network (CDN) [3]. In the ICNs, this service, noted in-network caching, was not deeply dealt with by the first solutions [2]. Indeed, some recent studies have shown that cache replacement management has a significant impact on ICN performance [4]. Based on these studies, several researchers become aware of the importance of proposing new techniques in order to improve ICN replacement management [5].

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Named Data Networking (NDN) [6] is one of the first ICN architectures. Though it is widely adopted in many studies and by the industrial communities, its actual architecture does not propose a performed cache replacement policy. Currently, NDN uses a set of techniques, such as Least Frequently Used (LFU) [7] and Least Recently Used (LRU) [7]. These methods are incapable of providing expected results for NDN architecture. Therefore, it is necessary to propose a new replacement mechanism for NDN architecture in order to improve its performances.

Thus, Software Defined Networking (SDN) [8] was proposed to transform the backbones of the traditional networks into a rich service delivery platform. By decoupling control plans and network data, the SDN-based architecture isolates the underlying infrastructure from the applications using it. This isolation improves the NDN network's management, scalability and dynamism.

Because the actual NDN architecture does not have a performed cache replacement policy, more attention must be paid to the NDN caching strategy. To optimize cache resources management and speed cache recovery, we proposed, in this paper, a new cache strategy managed by SDN controllers and switches. Thus, our proposal relies on data popularity calculation performed by the switches to define a cache replacement strategy. Indeed, Named Data Networking Cache replacement approach based on Software Defined Networking (NC-SDN) stores only the most popular content instead of caching the requested content to each traversed node. Therefore, we implemented this proposal under a new architecture based on the combination of NDN and SDN.

In this work, our intention is to benefit from the SDN architecture to enhance the management performances of caches in the NDN network. For this reason, we introduced a cache replacement strategy relying on data popularity driven by the SDN architecture. Our solution, called NC-SDN, is a clean-slate approach. The experimental results show that NC-SDN allows reducing the bandwidth consumption and improving the offered services.

By applying our approach, we benefited from the advantage of SDN networks to enhance the forwarding and caching processes in the NDN networks. Our forwarding SDN-based strategy improvement was studied in [9]. In this article, we will propose an improvement of the cache replacement management based on SDN.

The remainder of the paper is organized as follows: we start with Section 2 by providing an overview of the ICN. In Section 3, we present the SDN concept. Afterwards, we illustrate the related work in Section 4. In Section 5, we describe our approach. The obtained results of our simulation experiments are shown in Section 6. Finally, Section 7 concludes the paper and presents future work.

2. Information Centric Networking

The Internet was created in the 70's to exchange information or allow people to communicate with each other. At that time, the uses of the internet were relatively too limited and simple. The users were restricted to looking for information on websites, chatting with friends through instant messaging softwares, sending / receiving emails, downloading files from FTP servers, etc. Thus, communications in the networks were carried out based on an end-to-end model by establishing communication tunnels from one terminal point to another. In this model, the TCP / IP protocols were perfectly adapted to these uses.

However, recently the Internet has become more and more popular and increasingly used in various domains. Thus, terminals are no longer desktop or laptop computers. Nowadays, many devices, such as smart phones, tablets and video game terminals, have been developed, and network infrastructures are no longer limited to xDSL or fiber optics. Indeed, Wi-Fi, mobile 4G / 5G, WSN and satellites have widely become deployed. It has become more and more complex for the structure of TCP / IP and the transport layer to manage this plurality of environment. Thus, several layers and services have been added in order to satisfy these needs [10].

To overcome the afore-mentioned disadvantages, researchers considered a new Internet solution, that is well adapted to current Internet uses. These reflections have resulted in a new network paradigm called ICN [2]. This innovative network paradigm is designed to change the Internet, which is currently based on the location of servers with well-defined addresses, into an architecture based on the names of the objects. In an ICN network, the basic elements of the network are the data contents. In fact, these contents are attributed with specific names, rather than the machines (e.g. servers, routers) identified with their IP addresses. All network functions, such as routing and security, are also based on the names of the contents. ICN is able to cache and secure content in networks. Due to these merits, ICN networks are more efficient in delivering content to users with better quality as well as improving the network capacities management of network providers. The main functions integrated in ICN are mentioned below:

Caches in networks: ICN networks are mainly characterized by their ability to cache content directly in the nodes of the network. Each piece of content can be cached in the network nodes on the delivery path of the content, so that subsequent requests can be fulfilled more quickly and directly by the caches of the ICN nodes. Moreover, lost packets can also be recovered faster by direct retransmissions from the nearest caches.

Multicast: In the case of multiple requests from different users for the same content, only the first request is sent to a potential source, while the other ones are recorded and put on hold in the ICN node. Once data return from the source, they will be transmitted to each requestor via the interface on which the request was received. Accordingly, ICN can natively perform multicast to optimize content delivery.