A Hierarchical Caching Framework for 5G Cellular Networks

Latif U. Khan, Umer Majeed, Choong Seon Hong
Department of Computer Science and Engineering, Kyung Hee University, Yongin, 446-701 Korea
Email: {latif, umermajeed, cshong}@khu.ac.kr

Abstract

Recent years have witnessed an increase in number of users accessing video contents from a remote cloud via a base station (BS). Accessing video contents from the remote cloud experience significant delays that are undesirable. On the other hand, it is predicted that the users repeatedly request mostly similar video contents. Therefore, motivated by these facts it is necessary to effectively cache the video contents. In this paper, we present a hierarchical software defined networking-based framework for caching in heterogeneous cellular networks. The proposed framework use cache placement at both the BS and SDN-based core network. Furthermore, a hybrid control plane is adapted to enable scalability and reduce delay.

1. Introduction:

Recently, a rapid rise in a number of video content requests with strict latency constraints for different smart applications has been observed in cellular networks. To enable these smart applications with strict latency constraints, use of high bandwidth communication links is necessary. However, there exist significant bandwidth limitations. Therefore, it is necessary to consider other ways to improve users quality of service (QoS). On the other hand, according to statistics, a significant portion of the video traffic is transmitted repeatedly in the network [1]. This motivated us to temporarily store the frequently requested contents at the different locations in a network to provide simultaneous contents access with low latency and reducing core network traffic.

According to CISCO, 507.9 ZB data will be generated by the Internet of Things (IoT) based smart devices in 2019 [2]. Such devices data will put significant limitations on network performance. Numerous promising techniques, such as heterogeneous networks, millimeter wave communication, and massive input massive output have been used in literature for improving performance. Apart from that, within a heterogeneous network caching can be used to further improve performance by temporarily storing the contents at different locations in a network to avoid repeated transmission [3]. Storage of contents near the end user devices improves the latency as well as reduce the backhaul traffic.

On the other hand, user mobility and randomness in content popularity poses significant limitations on caching design [4]. Moreover, cache capacity is also limited that must be used effectively to enable massive content delivery for future mobile networks. In [5], hierarchical collaborative caching has been proposed in cellular networks. Other than this, [4] discusses the hierarchical caching in 5G networks. An architecture is proposed that focus on mobility-aware caching in a hierarchical fashion. Smart cars are used as collaborative caching agents that share their contents with BSs.

Software Defined Networking (SDN) and Network Function Virtualization (NFV) are considered as key enablers of 5G networks [6]. Therefore, in this paper, we consider the SDN based cellular network. Working of SDN is based on decoupling of the control plane from

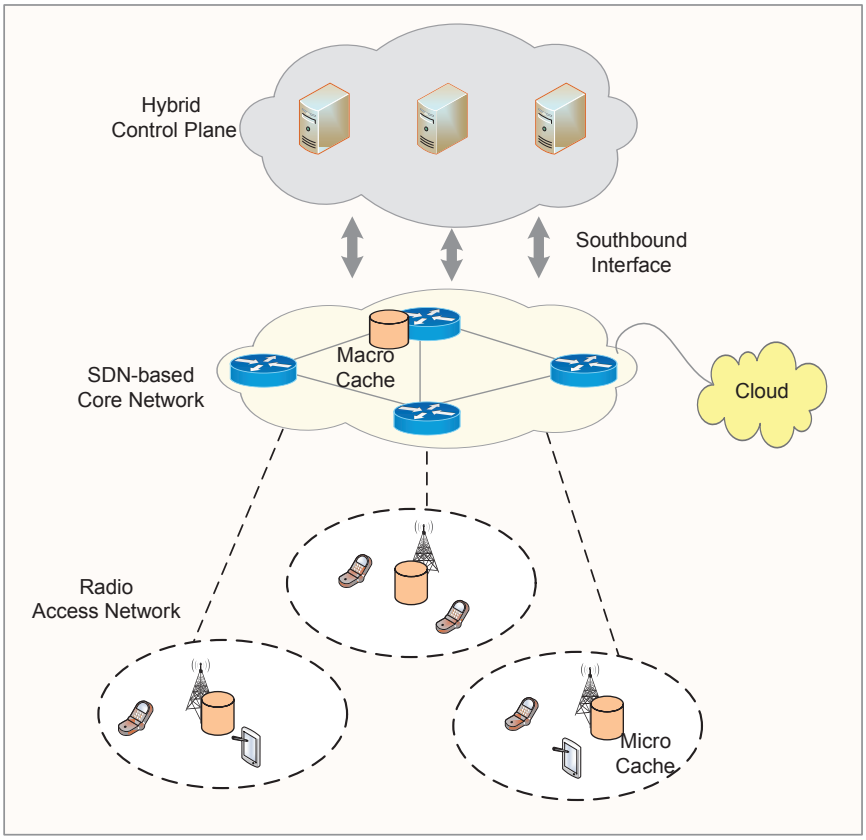

Fig 1: Proposed SDN-based Framework

the data plane. Traditional SDN was based on usage of a single logically centralized controller. However, usage of a single logical centralized controller suffers from the issues of scalability with an increase in network size. In this paper, we propose an SDN-based hierarchical framework for cellular networks. Furthermore, we consider hybrid SDN control plane to enable scalable operation.

2. Proposed Framework

Consider figure 1, which shows a proposed SDN-enabled hierarchical framework. The proposed SDN-based framework consists of layered architecture, such as data plane, control plane, and applications plane. In this paper, we adopted a hybrid control plane due to its feature of higher scalability than centralized control plane. Conventional design of centralized control plane performs all the control functions and suffers from scalability issues when the network size grows that is expected in the foreseeable future [7]-[9]. Therefore, in this paper, we adopted a hybrid control plane. We used two levels of controllers, such as a global controller and local controller. The local controller is intended to control caching at a single BS while global controller controls several local controllers in addition to core network caches.

We consider two types of caches such as micro cache and macro cache. The micro cache is placed at a BS, while the macro cache is placed at the SDN-based core network to perform caching for several BSs. Moreover, the capacity of the macro cache is more than a micro cache. Although the macro caches are positioned at the core network; however, still they play significant role serving the video contents requests. The micro cache has limited capacity and does not have the ability to store all the contents. Moreover, cache popularity is also time varying. Therefore, to cope with these

challenges, we use macro caches at the core network. The macro cache avoids duplicate transmission from the remote cloud. On the other hand, storing the cached content at the BS using micro caches has the significance of content delivery with low latency.

On top of the control plane, we can build an application plane. Numerous applications of the application plane can be used to instruct the control plane. The application plane communicates with the control plane using the northbound interface. The proposed framework has the ability to incorporate new functionalities easily by instructing the control plane using the northbound interface. Mainly, caching management functions can be divided into two types, such as local and global. Local management functions for controlling micro caches can be performed by the local controllers, whereas global cache management functions for controlling macro caches can be performed using global controllers. This trend of adapting hierarchical distribution of caching functions reduces the latency, which is expected if we use the only a centralized controller to enabled hierarchical caching.

3. Conclusion and Future Prospects

In this paper, we proposed a hierarchical SDN-based framework for 5G cellular networks. We adopted a two-level caching strategy to enable effective caching. Furthermore, we considered hybrid SDN control plane to enable scalability because of the significant requirement in 5G networks.

As future work, it is recommended to formulate hierarchical caching in 5G networks as an optimization problem. Furthermore, some novel techniques based on artificial intelligence must be used for the solution of the caching problem.

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*Dr. CS Hong is the corresponding author

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