Caching and Forwarding Layered Video in ICN Enabled Cellular Networks with Base-Station Assistance and D2D Communication

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Abstract

Users demand for watching high-quality video on the move is increasing day-by-day. Despite of achieving high bandwidth in the fourth and fifth generation of cellular networks, the bandwidth is not sufficient for meeting video-on-demand requests. Device-to-device communication is a way to achieve more spectral efficiency by frequency re-use. On the other hand, Information centric networking is introduced to optimize the Internet structure to handle the future user's demand. In this paper, we are introducing caching and forwarding the H.264/SVC encoded layered video in information centric networking enabled cellular network. In our proposal, base-station (either small-cell base-station of macro base-station) plays a vital role in managing the device-to-device communication and caching and forwarding decisions for the video content.

1. Introduction

Users demand for video content is very rapidly increasing. According to cisco video traffic will grow 3-fold from 2015 to 2020 [1]. On the other hand, mobile video traffic will grow 11-fold from 2015 to 2020 [1].

After LTE-Advance, further improving the spectral efficiency will be very limited because, this fourth-generation cellular system uses MIMO-OFDM with highly efficient codes. Another possibility of increasing the area spectral efficiency is to decrease the transmit power in order to increase the spectrum reuse. However, in this case more Base-Stations (BSs) will be needed to cover the area. Installing new BSs will cause huge infrastructural development cost. Device-to-device (D2D) communication is envisioned to increase the spectrum reuse without any investment in infrastructural development.

Hardware technology and the memory department has achieved high improvement over the recent fast. Therefore, the modern Internet routers are very powerful. To take full advantage of it, Van Jacobson et al. has introduced a new architecture for future Internet, which they call Named Data Networking (NDN) or Content Centric Networking (CCN) [2]. CCN is Information specific rather than location, i.e., “what” rather than “where”. Reusing the content for near future demands is one of the most important feature of Content Centric Networking (CCN) node. Furthermore, forwarding the user requests intelligently is another important aspect of the CCN.

Video streaming on the other hand is always been a challenging issue for the network engineers to deal with it because of its large size and dynamic nature. Scalable Video Streaming (SVS) [2] provide video to users with different requirements from a single file. SVS achieves scalability via layering. Video is encoded in a mandatory Base Layer (BL) and several optional Enhancement Layers (ELs). Users are provided as many layers as they need.

In this paper, we propose cache management and Interest forwarding schemes in which, important parts of the popular videos are stored in the users' devices and a D2D communication is established whenever possible. Base-stations, either Macro Base-Station (MBS) or Small-cell Base-Station (SBS), plays the vital role in cache decision and D2D communication establishment.

2. Motivation for the Proposed Scheme

SVS provide video from a single encoded file to different users according to their budget and device capabilities. Let suppose there are three users (a desktop, a laptop and a cell-phone) are connected to internet.

Let's suppose smart phone is using 3G laptop is using Wi-Fi and desktop is using wire connection to access the Internet. Here we can see that, user with smart phone will need lower quality video because of its device specification and network capacity. So it is provided with base layer only.

User with the laptop can afford higher quality video because of higher specifications device and better connection, so it is provided an additional EL (i.e., EL1) along with BL. The desktop user is provided highest quality (BL with 2 ELs) because of high end device and high speed link. Here important thing to notice is that BL is needed by all the users

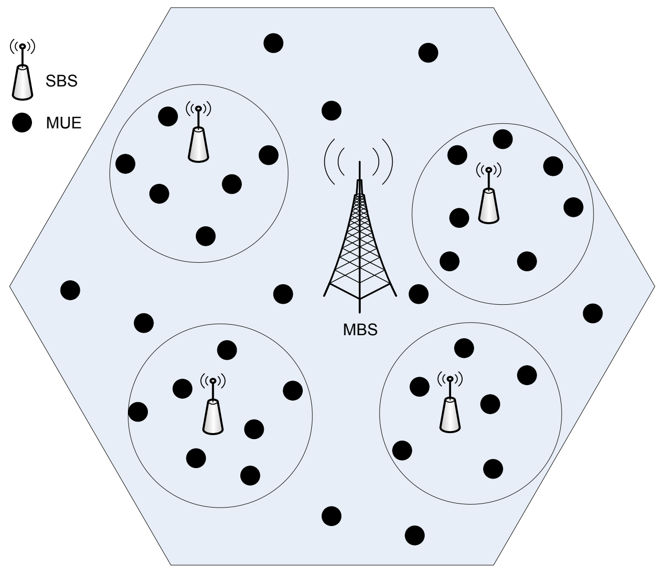

Figure 1: System Architecture for the proposed scheme

and EL1 by lesser users and EL2 by more lesser users. We use this hierarchal popularity of the video layers as the baseline guidance for proposing the cache decision policy in this paper which we present in the next session.

3. System Architecture and Assumptions

System Architecture for our proposed cache management and Interest forwarding in 5G cellular network is shown in figure 1. In an area, there is one Macro Base-Station (MBS) and several Small-cell Base-Stations (SBSs). Users i.e., Mobile Users Equipment (MUEs) that are in the transmission rage of an SBS are connected to it and the remaining users are served by the MBS directly. All the devices in the system are CCN enabled i.e., they generate and forward the packets in the form of Interest and Data packets. Interest packet is carrying hierarchal name of the required data in which the last part is carrying the layered information of the H.264/SVC encoded video Interest name packet e.g., stream/segments/%00%01/layer1. If the last component (layer1 in the above example) is not mentioned in an Interest, it by default will mean the user is requesting BL.

We assume that the SBSs are covering a small area and MUEs connected to the same SBS can form D2D link using Bluetooth, Wi-Fi direct or millimeter-wave communication (if they are in line of sight). SBS maintain a Content Store like table that we call LCC (List of Cached Content). For our proposed mechanism, the content server provides caching weight for each content, which is discussed in section 4, CCN nodes maintain this value in the CS and append it with the Data packet at the time of delivery.

4. Popularity of video

We define popularity of a video content i as the number of request for content i as compared to total requests. This popularity of the video contents is mathematically modeled using Zipf Law. According to Zipf popularity distribution, each content is assigned a rank and the contents are placed in descendent order i.e., the most popular is ranked one so on. For our model, according to Zipf law, frequency of content i with rank k_i is represented by the following formula.

$$R_i = f_i(k_i;\alpha, M) = \frac{1/k_i^{\alpha}}{\sum_{m=1}^{M} 1/m^{\alpha}} \qquad (1)$$

Where, α is the value of exponent that shows skewness of the Zipf distribution. M is the total number of video contents.

5. Content delivery mechanism

User generate Interest packet and send it to the BS they are connected with (MBS or SBS). In case of SBS, the SBS searches the content in LCC, if found then the requesting MUE is provided the list of MUEs that possess the requested content. The requesting MUE establish a D2D connection with one of the provided MUEs for pursuing the content.

If the requested content is not present in the cache of any other MUE, the SBS provide the content from its own cache or forward the Interest according to conventional CCN in order to retrieve the requested content. BSs and other routers in the network follow [3] for caching the layered video contents.

5.1. Cache Decision

BS maintain records of all the MUEs cached content in LLC. BS assists MUEs in cache decision. In case the LCC search is failed and the BS has to provide the requested content from its own CS or other place, it calculates the cache weight of the requested content according to the following formula:

$$C_w^i = \frac{R_i}{L_i} \qquad (2)$$

Where, C_w^i is the caching cost of the content. R_i is the rank of content according to Zipf distribution and L_i is the layer of requested content. BS appends this C_w^i with the Data packet.

MUE take caching decision according to the following formula:

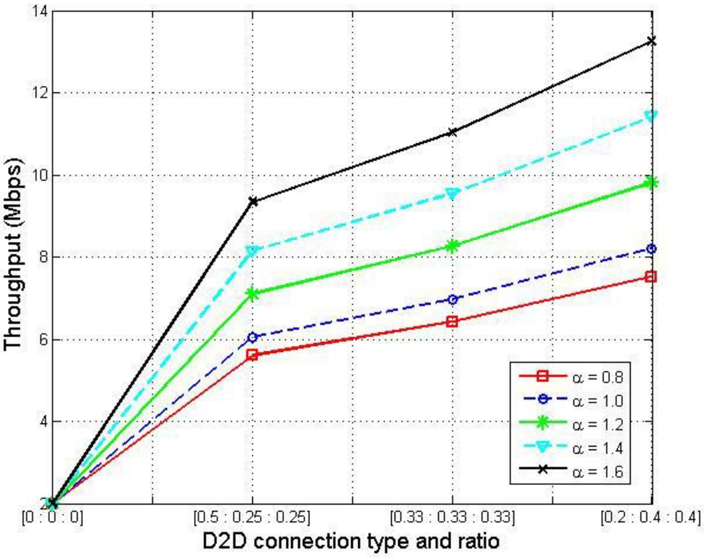

Figure 2: Throughput at different popularity and D2D communication scenario

$$\Pr(ch) = \begin{cases} 1, & if\ C_w^i \geq C_w^{LRU} \\ 0, & otherwise \end{cases} \quad (3)$$

Where C_w^{LRU} is cache weight of the last content in MUE's cache according to LRU cache replacement policy. According to eq (3) user will cache the content if the cache weight of the incoming content is more-than or equal-to the cache weight of the LRU content.

6. Evaluation

In this section we are presenting a simple evaluation of our proposed system. We are taking a scenario where there is one MBS and 10 SBSs on average there are 8 MUEs connected to each SBS. The MUE that are not in the transmission range of any SBS are served by the MBS directly. For D2D communication the MUE prefer millimeter wave communication if line of sight is available, otherwise chose Wi-Fi or Bluetooth depending on availability. For D2D communication we are considering lowest link capacity, to be exact, millimeter wave is 100 Mbps [4], Wi-Fi is 11 Mbps and Bluetooth is 4 Mbps in our analysis. We have random selection of the D2D link and availability of the requested content is based on Zipf distribution. Based on the above we have performed analysis using Matlab. The results of our analysis is given in Figure 2. In the figure x-axis is showing different ratio of millimeter, Wi-Fi direct and Bluetooth communication. The label [0 : 0 : 0] on the x-axis represents no D2D communication. Y axis is showing average throughput for all the MUEs in the system. We can see that for higher α, per-user throughput is higher because the users cache fewer popular contents and hence opportunity of more D2D communication. Moreover, communication via millimeter-wave yields higher throughput and vice versa.

7. Conclusion and Future Work

In this paper, we present caching and forwarding schemes for layered video streaming in 5G network with D2D communication. In our proposed scheme the caching decisions are taken on the basis of video popularity and SVC encoded video's layer information. In future, we aim to evaluate our proposed idea both mathematically and through simulations with practical scenarios and more parameters.

8. Acknowledgement

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