Cache Management and Interest Forwarding for Scalable Video Streaming in ICN Enabled Mobile Access Networks

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Abstract

Information Centric Networking (ICN) is envisioned to be the future Internet architecture and mobile access network like Long Term Evolution (LTE) i.e., 4G and 5G will be the major access networks. In this paper, we present a cache management and request forwarding schemes for Scalable Video Streaming (SVS) in Information Centric Networking (ICN) enabled mobile access networks. SVS video is consisted a mandatory baselayer and multiple optional enhancement layers. Baselayer, which is enough to decode the video with the lowest quality, is needed by every user that want to watch the video while enhancement layers are used to improve the video quality. Only a subset of users download enhance layers of the video. Therefore, caching the baselayer nearer to the users will increase their Quality of Experience.

1. Introduction

Future of Internet is envisioned to be Information specific rather than location, i.e., "what" rather than "where". One of the leading information specific architecture (NDN or CCN) is presented by Van Jacobson et al. [1]. Caching the content is one of the most important feature of Content Centric Networking (CCN) node.

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 needs.

In this paper, we propose cache management and Interest forwarding schemes in LTE network, Network architecture is shown in Fig. 1. According to our proposed scheme, the most important part of the video i.e. BL is store in the nearest place to the users i.e., evolved NodeB (eNB) and the ELs up in the network. We also propose a cooperative Interest forwarding scheme, according to which, directly connected eNBs share information of popular video contents in its Content Store (CS) with each other.

2. Motivation for the Proposed Scheme

SVS provide video from a single encoded file to different users according to their budget and device capabilities. Figure 2 is showing an example of delivering one video to 3 different users over the Internet. Let's suppose smart phone is using 3G laptop is using WiFi 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.

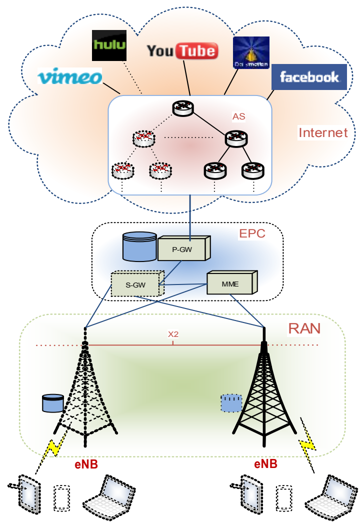

Figure 1: System Architecture for the proposed scheme

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 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

Our proposed scheme can be applied to a typical LTE network like given in Fig. 1. Mobile Users Equipment (UEs)

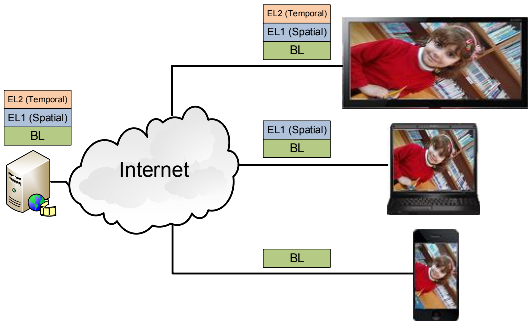

Figure 2: Layered video delivery over Internet

are connected to Base Station (BS) i.e., eNB. All eNBs are connected with the Evolved Packet Core (EPC). EPC is consisted of Serving Gateway (S-GW), PDN Gateway (P-GW) and Mobility Management Entity (MME). EPC is connected to the internet. In the Internet, there are different Autonomous Systems (ASs) which are eventually connected to different content providers like, Youtube, dailymotion etc in case of video contents. eNBs are connected with each other usually via X2 interface as shown in Fig. 1. Here, we are assuming eNBs can communicate with each other without involving the EPC.

Users generate requests (Interests) for their desire data chunk. We assume that the users request the whole video content by generating sequential Interest packets. One Interest is generated for one video segment, which is carried by one Data packet. In other words, one video segment is equal to one data chunk.

4. Proposed Scheme

In this section we discuss our proposed cache management scheme. As we discussed in Section 2, Baselayer is the part of the video that is needed each and every user that is interested to watch the video. Here we present our proposed cache decision and cooperative Interest forwarding scheme in this section, which treats baselayer of the video differentiatedly.

4.1. Cache Decision

We introduce a new field to the PIT for making the cache decision, we call this new field as CM (Cache Marker). CM contains either "0" or "1". CM value 1 means cache and 0 means do not cache.

When an Interest reaches to eNB, it extracts the layer information from it. For SVS, as been suggested in [3], the Interest name is modified by adding layer ID information after the segment number in Interest packet like (e.g. stream/segments/%00%01/layer1). If the Interest is for requesting the BL then, the CM filed in the eNB is marked as 1 otherwise it is marked as 0. For the corresponding Data packet, if the CM is 1, then consider caching the Data considering LRU as the cache replacement policy, otherwise

Algorithm 1: Interest Forwarding

On Interest Arrival:

If The Interest is for BL **then**
    Check CS
    If the requested content is found **then**
        Update CH: CH = CH +1
        If CH = β **then**
            Send update to neighbor eNBs
            Reply with the Data and discard Interest
        else
            Reply with the Data and discard Interest
        end if
    else
        Search the content in NCS
        If entry for the requested content is found **then**
            Forward the Interest to corresponding eNB
        else
            Put 1 in CM and forward the Interest to EPC
        end if
    end if
else
    Forward the Interest to EPC
end if

just pass it to the users. If LRU selects a popular content (we discuss popularity later in this section) to be replaced then the directly connected eNBs are informed so they remain updated.

To measure the local popularity of the content, we propose a new field to the CS of eNB. We call this CH (Cache Hits). If CH for a content reaches to a threshold β in an eNB, it informs it directly connect eNBs (which are connected via X2 interface) about this content. eNBs store this information in a table which we call NCS (Neighbors Content Sores). NCS is similar to the CS but instead of Data chunk it stores the face information that leads to the eNB that contains this chunk physically. Cache decision process is presented in algorithm 2 in detail. Cache decision for the ELs is done in the EPC and ASs in the internet according to [4].

4.2. Cooperative Interest Forwarding

Information of the popular contents in the neighboring eNBs are stored in NCR of each eNB. When an Interest reaches to an eNB, first it extracts the layer information from it. If the Interest is requesting baselayer of a video, first it checks it CS to find the content there. If the requested content is found there it reply with the Data and discards the Interest. If the requested chunk is not found in the CS next it checks NCS. If an entry for the requested chunk is present there, the Interest is forwarded to the corresponding eNB via the face listed in NCR for the requested chunk. If no entry is found

Algorithm 2: Cache Decision

On Reception of Data Packet:

If CM is 1 in PIT **then**

Cache the content with probability 1, replace according to LRU, when cache is full

If CH = β for the replacing content **then**

Send update to the neighbor eNBs

Forward the Data to the requesting UE(s)

else

Forward the Data to the requesting UE(s)

end if

else

Forward the Data to the requesting UE(s)

end if

found in NCR for the requested content, then the Interest is forwarded to the server via EPC. Interest forwarding mechanism is presented in algorithm 1 in detail.

5. Evaluation

In this section we present analysis and results discussion of our proposed system.

5.1. Cache Hit Rate Approximation

The hit rate for cache that follows Least Recently Used (LRU) cache replacement policy can be accurately approximated by the Che approximation [5]. Following Che approximation, we can find the hit rate $h(C)$ for each layer of the video by the following formula;

$$h(C)_l = \sum_1^C q_i^l (1 - e^{-q_i^l t_C}) \qquad (1)$$

Where C is the cache size, q_i^l is the popularity of layer l of the content i, and t_C is the cache characteristic time. Cache characteristic time can be defined as the time required to receive requests for C distinct items. The characteristic time i.e., t_C should satisfy the following

$$C = \sum_i (1 - e^{-q_i^l t_C}) \qquad (2)$$

5.2. Numerical Results

We implemented eq. 1 and eq. 2 in matlab to approximate cache hit for our proposed cache management scheme. The results are shown in Fig. 3. Graph is showing 4 lines for different ratio of requests for BL and ELs. Since we only consider caching BL at eNB therefore cache hit rate for our proposed scheme will be like 100% Interests are coming for BLs i.e., like red line in the graph. No other proposal can reach to our proposal in regards of cache hit rate as it is impossible that all the users only request the BLs. The other 3 lines are showing the upper bound of cache hit rate for any proposal for different ratio of BL and ELs demand. We can see that our proposal can't be beaten with any ratio of demand.

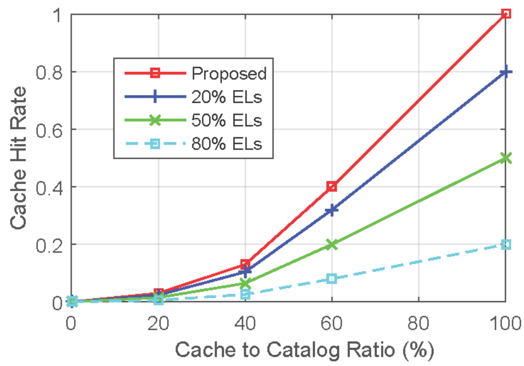

Figure 3: Cache Hit Rate for Different Ratio of Lyers

6. Acknowledgement

This research was one of KOREN projects supported by National Information Society Agency (15-951-00-001).

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7. Conclusion and Future Work

In this paper, we presented a cache management scheme for scalable video streaming in a mobile access network i.e., LTE eNB. We derived motivation that base layer is the most important layer of a video which is needed by all the users who want to watch a video regardless of the network condition they have and the their device capabilities. We proposed and presented the mechanism for caching the baselayer of the SVS in eNB. We also propose cooperation for Interest forwarding between eNBs for the popular contents. Our numerical results show that theoretically, we can achieve up to 100% cache hit rate for the BL of the content at eNB if the cache size reaches to the size of the baselayer in all the catalogs. We intend to extend our proposal in future and analyze the proposal through intense simulations as well as in real environment.

8. References

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