Delivering Scalable Video Streaming in ICN Enabled Long Term Evolution Networks

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***Abstract*—Information Centric Networking (ICN) is envisioned to be the future Internet architecture and mobile access network e.g., Long Term Evolution (LTE), and 5G will be the major access networks. In this paper, we present a cache management and cooperative request forwarding schemes for Scalable Video Streaming (SVS) in Information Centric Networking (ICN) enabled mobile access networks. H.264/SVC encoded video is consisted a mandatory baselayer and multiple optional enhancement layers. Baselayer, which is enough to decode the video, though with the lowest quality, is needed by every user who want to watch the video while enhancement layers are used to improve the video quality. Only a subset of users download enhancement layers of the video. Therefore, caching the baselayer nearer to the users will increase their Quality of Experience. Furthermore, we introduce cooperative request forwarding for the baselayer of video to take more benefits from cache of neighboring base stations. We have intensively simulated our proposed schemes by extending chunk level simulator ccnsim which is developed over Omnet++. Our experimental results show that, cache hit rate can be improved significantly by adopting our proposed caching and Interest forwarding schemes.**

***Index Terms*—ICN, Scalable Video Streaming, Cooperative Interest forwarding, Scalability, LTE.**

I. Introduction

Current Internet structure which is end-to-end communication between users and content server(s) is not suitable to fulfill the future demands because it does not fully utilize the enriched resources of modern networking nodes i.e., routers. To take full benefits from the advanced routers, concept of Information Centric Networking (ICN) [1] is introduced.

Content Centric Networking (CCN) [2] is one of the premium instance of ICN on which we are focusing in this paper. Among many features of CCN the most attractive is the ability of content distribution by further utilization of in-network data storage and computational resources. CCN users, send Interest packet that contains name of the Data chunk in order to get the requested Data. Every CCN router on the way, checks it Content Store (CS) to find the requested Data chunk. If found, it reply with the Data chunk and discard the Interest. Otherwise, the Interest is forwarded towards the content provider if the path is founded in Forward Information Base (FIB). The Interest is flooded if no path is found in the FIB. Information of the unresolved Interests is saved in Pending Interest Table (PIT) in order to aggregate the similar Interests.

On the other hand, according to [3], Internet video was 59% in 2014 which will increase to 77% in 2019. Scalable Video Coding (SVC) based adaptive video streaming [4], which we call Scalable Video Streaming (SVS) in this paper, is envisioned to be very beneficial in CCN [5], [6]. SVC encodes video in layers, consisted of a mandatory Base Layer (BL) and several optional Enhancement Layers (ELs). Users are provided as many layers as they can afford according to the network condition and/or device capabilities.

In SVC based adaptive video streaming there is strong dependency between the layers. In order to use higher layer(s) all the lower layers must be present. Users' requests as many layers of the video as much they can afford according to their Internet connectivity and/or their device capabilities.

In this paper, we present detailed mechanism of caching the mandatory BL in eNB and cooperation between eNBs in Interest forwarding for the content that having high local popularity. According to our proposal, eNBs maintain a CS like table (which we call Neighbors Content Store (NCS)) that contains the details of popular contents cache in the neighboring eNBs. With the help of NCS, eNB forwards requests for the popular contents to its neighboring eNB that have the requested contents instead of content providers. We have intensively simulated the proposed mechanism by extending ccnsim simulator [7] which is build over OMNet++. Our simulation results show significant improvement in cache hit rate and delay in delivering SVC encoded video to the users in CCN enabled LTE networks.

II. Motivation for the Proposed Scheme

H.264/SVC encoded video is a good choice for video delivery in CCN [6] as it can provide video from a single encoded file to different users according to their budget and device capabilities. Fig. 1 is showing an example of delivering one video to three different users over the Internet. In the example cell phone requests only base layer (BL) of the video due to its low speed Internet connectivity (3G) and low device specifications. Laptop requests BL with one enhancement layer (EL) of the video as it has better Internet connectivity (WiFi) and better device specifications. The desktop requests BL with two ELs as it has high speed Internet connectivity (wired connection) and high specification device. Here, we can see

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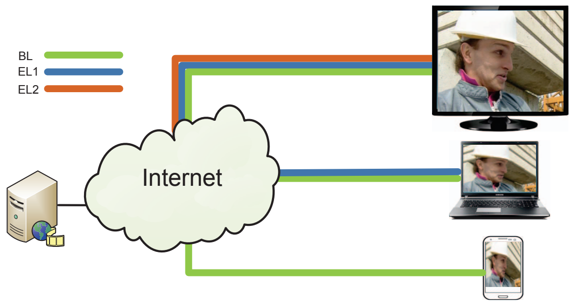

Fig. 1: H.264/SVC encoded video delivery to various devices with different device capabilities/bandwidth

that BL is requested by all the users while ELs are requested by a subset of the users. This phenomenon encourages us to cache BL at the nearest location to the users.

III. Proposed Schemes

In this section we discuss our proposed cache management and cooperative Interest forwarding schemes. As we discussed in section II, baselayer is the part of a video that is needed by each and every user who is interested to watch the video. Therefore, we treat baselayer of the video differentiatedly.

A. System Architecture and Assumptions

Our proposed scheme can be applied to a typical LTE network like given in Fig. 2. Mobile User Equipments (UEs) 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. Content providers e.g., Youtube, dailymotion, hulu etc., (in case of video contents) are connected to EPC via Internet. eNBs are connected with each other usually via X2 interface as shown in Fig. 2. Here, we are assuming eNBs can communicate with each other without involving the EPC. 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. To make our proposal very focused, in this paper, we assume, users generate Interest for Scalable video streaming contents only. However, this assumption is not very strict, it can be omitted very easily.

We introduce a new field to 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. To measure local popularity of the content, we propose a new field to the CS of eNB. We call this new field as CH (Cache Hits). Detailed discussion of the CM and CH is given in section III.

If CH for a content reaches to a threshold β in an eNB, it informs 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

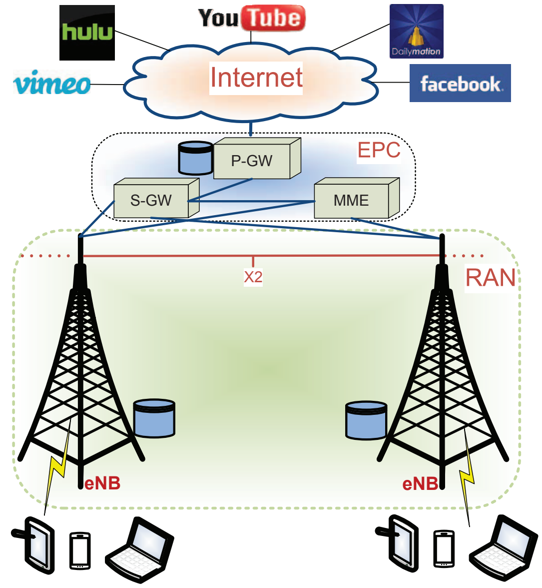

Fig. 2: System Diagram

chunk physically. Purpose of introducing this new NCS is to take full benefits from cache of neighboring eNBs. To keep the complexity under control, NCS is assigned a predefined limited size. After reaching to the limit, NCS uses Least Recently Used (LRU) policy for replacing old entry with the new one.

B. Cooperative Interest Forwarding

When an Interest reaches to an eNB, first it extracts the layer information from it. If the Interest is not for the BL, it is forwarded to EPC after making a PIT entry for it and putting "0" in the CM. In case the Interest is requesting BL of a video, first eNB searches it in CS to find the requested content. If the requested content is found, it replies with the Data, increment "CH" of the chunk in CS by 1 and discards the Interest. If CH value is equal to β, eNB send an NCS update message (NCS-A) to all directly connected eNBs as a result of which all the directly connected eNBs make an entry in their NCS. If the requested chunk is not found in the CS next it searches NCS. If an entry for the requested chunk is found, the Interest is forwarded to the corresponding eNB via the face listed in NCS for the requested chunk after making a PIT entry with setting CM value as 0. If no entry is found in NCS, the Interest is forwarded to the server via EPC after making a PIT entry with setting CM value as 1. Interest forwarding mechanism is presented in algorithm 1 in detail.

Upon receiving Interest via X2 interface, the neighbor eNB checks its CS to find the requested content, if found, replies with the Data, increment "CH" of the chunk in CS by 1 and discards the Interest. In case the requested Data chunk is not present in the CS, the neighbor eNB forward the Interest towards the EPC like ordinary Interest putting 1 in the CM field of PIT to consider the corresponding Data for caching.

Algorithm 1 Cooperative Interest Forwarding

```
On Interest Arrival:
Extract layer information from the Interest
if the Interest is for BL then
    Search CS for the requested chunk
    if the requested content is found then
        Update CH: CH = CH + 1
        if CH = β then
            Send NCS − A 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 chunk is found then
            Forward the Interest to corresponding eNB
        else
            Forward Interest to EPC & put "1" in CM of PIT
        end if
    end if
else
    Forward the Interest to EPC
end if
```

C. Cache Decision Policy

By receiving a Data packet, eNB first checks the CM field in PIT, if it contains 0 for the corresponding Data, the chunk is forwarded to the requesting UE without considering it for caching. If CM field contains 1 for the corresponding entry in PIT, the Data packet is cached in CS. If cache is full, eNB will use LRU for cache replacement. If LRU selects a popular content (i.e., for which the Cache Hits (CH) are greater than or equal to threshold β) to be replaced then the directly connected eNBs are informed, via a NCS removing message (NCS-R), so they keep their NCS updated. On reception of NCS-R, the neighbor eNBs search the content in their NCS, if found deletes it otherwise ignores the message. Cache decision process is presented in algorithm 2 in detail. Cache decision for the ELs is done in the EPC and Autonomous Systems (ASs) in the Internet according to [8] or any other cache decision scheme.

IV. Performance Evaluation

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

A. Simulation Setup

We have evaluated our proposed cache management and request forwarding mechanism by modifying chunk-level simulator, ccnsim [9] that is developed over Omnet++. Source code of the simulator is available at [7]. All links in the network have the same capacity. Table I shows the parameter used in the experiments. Clients generate Interests in a random manner governed by zipf distribution with different parameter

Algorithm 2 Cache Decision Policy

```
On Reception of Data Packet:
if CM is 1 in PIT then
    Cache the content with probability 1
    if (CH ≥ β for the replacing content) then
        Send NCS − R message to the neighbor eNBs
    else
        Forward the Data to the requesting UE(s)
    end if
else
    Forward the Data to the requesting UE(s)
end if
```

TABLE I: Parameters used in the experiments

Parameters	Values
num; repositories	1
replicas	1
num; clients groups	$1 \sim 4$
λ	$10 \sim 20$
max no; layers in a video	4 (1 BL, 3 ELs)
α	$0.8, 1, 1.2, 1.4$
Total videos	$10,000$
Chunks per video	20
Cache decision schemes	lcd, lce, ProbCache
Replacement policy	LRU
Cache size	$0\% \sim 100\%$

(α) ranging from 0.8 to 1.4. There are total 10 thousand videos in the server. Each video is consisted of 4 layers i.e., 1 BL and 3 ELs. Users request either only BL or BL and 1 EL or BL and 2 ELs or BL and 3 ELs on random basis. We assume that the size of all the layers is equal as well as all the videos are of the same size. There are total 20 chunks in one content i.e., 5 chunks for each layer. Each chunk represents one segment of video.

B. Simulation Results

In this section we discuss results of our simulation in detail. We focus on the cache hit parameter which is measured with the following formula:

$$CacheHit = \frac{CacheHit}{CacheHit + CacheMiss} \tag{1}$$

Cache hit reflects transit traffic from the domain. High cache hit means better QoE by the users, as they get the contents from the cache which is definitely quicker than getting the contents from other place like server.

1) Impact of Varying Users Demand for Different BL and ELs: To show the significance of our proposed cache decision policy, we have done comparison of different Baselayer and Enhancement-layers demand rate. The results are shown in Fig. 3. The experiments are performed with 4 different users' demand patterns. Firstly, all the users are requesting only BLs of the videos. Secondly, demand for BL of the video is 75% of all the requests from all the users while the remaining 25% of the requests are for the ELs. Thirdly, users generate 50% of the Interests for BLs and 50% for the ELs. Fourthly, users demand for BL of the video is 25% while 75% of the requests are for ELs. The last demand pattern is very pessimistic, because

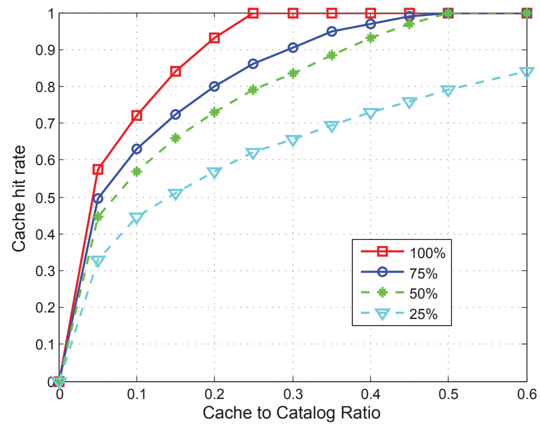

Fig. 3: Comparison of different demand rate for BL

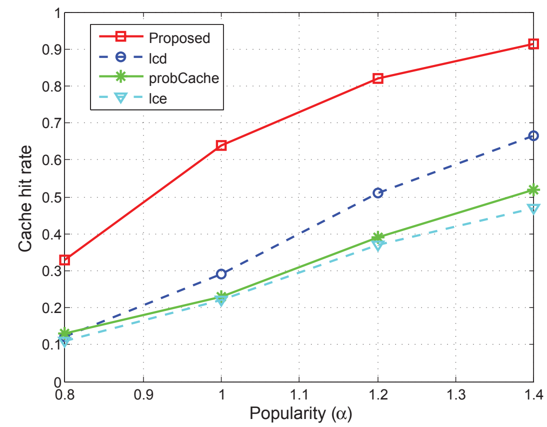

Fig. 4: Cache hit rate for different caching schemes

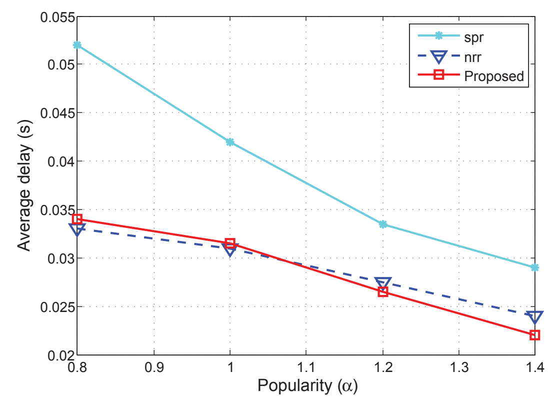

Fig. 5: Delay performance of different Interest forwarding schemes

majority the users in cellular network many not have such high signal quality that they are able to request the highest quality of video. In Fig. 3, we can see that for higher BL demand (which is the baseline of our motivation for this paper) the cache hit rate is very high. The cache hit rate is decreasing as the demand for the BL is decreasing.

Fore the following two subsections we have taken simulation scenario of 4 BSs connected to each other via X2 link.

2) Comparison with Different Cache Decision Schemes: Fig. 4 is showing the cache hit rate performance of our proposed scheme as compare to other cache decision schemes. All the compared schemes use Shortest Path Routing (spr) [9] for Interest forwarding except our proposed which uses Interest forwarding scheme presented in section III-B. Here, we can see that our proposed mechanism out performs all other related cache decision schemes in the literature.

3) Comparison with Different Interest Forwarding Schemes: Fig. 5 is showing the delay performance of our proposed scheme as compare to other Interest forwarding schemes. Here, cache decision scheme is Leave Copy Everywhere (LCE) for all proposals except our proposed one for which we used our proposed cache decision scheme presented in section III-C along with our cooperative Interest forwarding scheme presented in section III-B. Here, we can see that the spr is the worst performer because it do not exploit cache of other BSs and always forward the Interest to the content server if the cache hit fails at the first BS. The nrr [9] broadcasts Interest in all the 4 BSs to find the requested content and thus exploit the entire network to find the requested content. Our proposed Interest forwarding scheme outperform nrr due to our efficient cache decision scheme and NCS.

V. Conclusion

In this paper, we presented a cache management scheme for scalable video streaming in a mobile access network i.e., LTE's eNB. Our proposed mechanism caches baselayer (the most important part of SVC-encoded video) in eNBs. We also proposed cooperation for Interest forwarding between eNBs for the popular contents. Simulation results show that our proposed mechanism outperforms other similar cache decision and Interest forwarding schemes. For our future work, we aim to implement our idea in real environment and evaluate the proposal with other parameters like received video quality etc.

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