Opportunistic Quality Adaptation for Scalable Video Streaming in Information Centric Networks

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Abstract

In these modern days, video streaming is the major portion of Internet traffic. To cope with the increasing demand Information Centric Networking (ICN) architecture has been proposed. Layered video, encoded with Scalable Video Coding (SVC), are envisioned to be very beneficial in CCN. In this paper we propose a mechanism for video quality selection that opportunistically request additional enhancement layers of SVC to fully utilize advantages of CCN routers' content caching. We enable the routers to take decision of discard the forwarding of outdated optional enhancement layers of the video in order to reduce unnecessary traffic inside the Network.

1. Introduction

Internet traffic will be consisted of 75% video traffic by 2018 [1]. Current IP based network architecture is not well suited to meet the increasing demand because it is location specific. To meet the rapidly increasing users' demand for bandwidth intensive applications, Information Centric Networking (ICN) [2] has been introduced which changes the current IP based network from "Where" to "What".

Content Centric Networking (CCN) [3] is one of the most promising architecture of ICN. In CCN users generate Interest message whenever they need some content. CCN router when received the Interest provide the Data packet if the requested content is cached in Content Store (CS). If CS don't have a copy of the requested data it forwards the Interest on the faces that potentially can reach to the content provider with the help of Forward Information Base (FIB). CCN keep track of the unresolved Interest using Pending Interest Table (PIT). PIT is used to aggregate the similar Interest and forward only one request in order to reduce duplicate traffic inside the network. On reception of Interest, content provider reply with the Data packet, which is sent on the reverse path of the Interest. CCN routers on the path cache a copy of the content in order to provide it to the similar request in near future.

On the other hand Scalable Video Coding (SVC) [4] encodes the video in layers to provide scalability to the users according to their devices capabilities and/or available link speed and their budget. In SVC the video is encoded into one mandatory base layer and several optional enhancement layers. There is

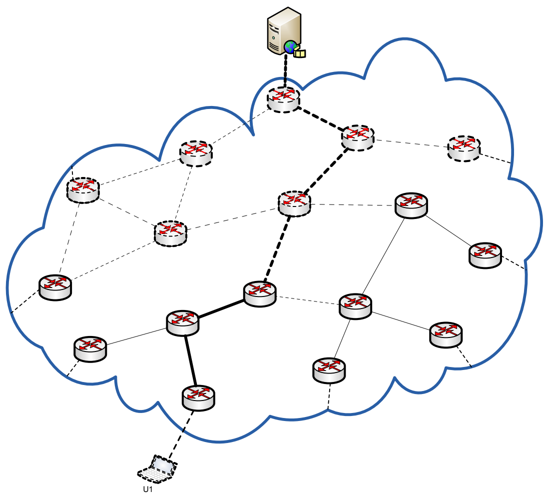

Figure 1: System Architecture

strong dependency between the layers. All the lower layers must be present in order to decode the higher layer. SVC encoder decides to request the number of layers on the basis of network condition and/or device capabilities.

In this paper we propose an opportunistic approach to request the higher layer of the video in order to fully utilize the content caching capability of the CCN routers. If the opportunistically requested layer of the video is present in a CCN router's cache, the user can get it within the playback time and can get higher quality video. Our SVC decoder drops the enhancement layers that are not downloaded in time to avoid video stalling. We enable the CCN routers to discard the outdated opportunistic Data packet in order to eliminate the useless data traveling inside the network.

2. System Architecture and Assumptions

Our proposed scheme can be applied to arbitrary CCN topology i.e., mesh topology as shown in figure 1. There are two kind of nodes edge nodes, which are connected to servers and users, and intermediate nodes. We call CCN router as Content Router (CR).

To implement the proposed mechanism in CCN we need to add a flag, named op (opportunistic), to Interest message and add a marker to PIT. The flag will carry a 1 bit value indicating the requested packet is normal or opportunistic and marker in PIT also points out the forwarded Interest's state.

3. Problem Formulation and Motivation for the Proposed Mechanism

Video streaming is a delay sensitive application. If the user wait for to download all the requested layers of the video, then in case the available bandwidth is not enough or the requested content is not present in CR cache, the video will either stop playing video and wait for the download of all the layers or, to avoid video from stalling, additional enhancement layers are dropped. The first case is not acceptable as video is delay sensitive and users don't have patience to stay tune for watching a video that stops and play again and again. In the latter case the user will feel happy because watching lower quality video without stop and play is better than frequently stalling video. However, the 2nd case, i.e., dropping the layers that are unable to be downloaded in time, will waste valuable network bandwidth because enhancement layers are downloaded but being delayed they are not been used for decoding the video.

In this paper, we present a mechanism that will protect the network from passing the outdated Data chunks and will also enable the user to request the higher quality layer opportunistically in order to take benefit if the higher layer can be get from a CR cache.

4. Video Layers selections

In our proposal, we measure download bandwidth with the following formula like in [5]:

$$W_i = {ChunkSize_i}/{t_i} \quad ---- (1)$$

Where W_i is bandwidth for ith chunk and t_i is the time required to download the chunk. $Q = \{q_1, q_2, q_3, ..., q_n\}$ represents quality of a video where q_1 is the lowest quality (base layer only) and q_n is the highest quality (all available layers of a video). Quality for the ith chunk is selected according to the following formula:

Algorithm 2: Opportunistic video retrieval mechanism

Rate Selection by User:
  IF ($W_{i-1} = 0$) then {for first chunk only}
    Request (q_1)
  ELSE
    Request ($\min\{y \mid \forall y \in Q : y > W_i\},\ i > 1$)
  EndIF

At each router for opportunistic layer only:
Calculate Delivery Time for requested Data according to eq(3)
  If ($DT(v_i^{op}) > UT(v_i^{op})$) then
    Mark opportunistic marker in PIT = 1
    Put expiration time (according to eq(4))
  ELSE
    Drop the Interest
  EndIF

$$r_i^{op} = \begin{cases} q_1, & i = 1 \\ \min\{y \mid \forall y \in Q : y > W_i\}, & i > 1 \end{cases} \quad --- (2)$$

Our algorithm start to request q_1 for the first chunk of the video. For the subsequent chunks the quality is selected on the basis of previous chunks bandwidth. Let suppose $Q = \{100Kbps, 150Kbps, 200Kbps, 250Kbps\}$ and $W_{i-1} = 180$ then according to eq (2) for next chunk, r_i^{op}, selected will be 200kbps. We assume if we remove one layer from the quality selected according to eq (2) the bitrate will come below the bandwidth of last downloaded chunk. In our proposal the last layer is always marked as opportunistic (i.e., in Interest op=1), similarly the router also put 1 in PIT for this opportunistic packet.

5. Video Retrieval Mechanism

In our proposed system, user always declare the last layer of video as the opportunistic layer and append playout delay (the last time layer can be used in video decoding, we call it Useful Time *(UT)*) with this packet. Every CR, on reception of opportunistic layer Interest, calculate expected time for delivering the requested Data, we call it Delivery Time (*DT*) according to the following formula:

$$DT(v_i^{op}) = \left\{ \frac{2(t_i^c - t_i^s)}{s_i^I} \right\} * s_i^D + \beta \quad ---- (3)$$

Where v_i^{op} is the opportunistic layer of video i, t_i^c and t_i^s are current and starting times respectively, s_i^I and s_i^D are Interest and Data packets sizes respectively. β is used for the packet preparation delay. At any CR if the

Table 1: Comparison of Proposed Mechanism with SLA

	Cache	Not Cache	Cache	Cache	Cache	Not Cache	Cache	Cache
Quality Selection (SLA)	300	500	300	500	700	1024	300	500
Quality Selection (Our Proposal)	300	700	500	700	1024	1024	500	700
Useful Bandwidth (SLA)	300	300	300	500	700	300	300	500
Useful Bandwidth (Our Proposal)	300	300	500	700	1024	300	500	700
PSNR (SLA)	20	20	20	25	30	20	20	25
PSNR (Our)	20	20	25	30	35	20	25	30
Bandwidth Wastage (SLA)	0	200	0	0	0	700	0	0
Bandwidth Wastage (Our)	0	0	0	0	0	0	0	0

$DT(v_i^{op})$ is more than $UT(v_i^{op})$ will discard the Interest packet. Similarly each router while putting entry for opportunistic layer in PIT put a timer, Remaining Useful Time (RUT),

$$RUT(v_i^{op}) = UT(v_i^{op}) - DT(v_i^{op}) \quad ---- (4)$$

If the timer is expired before the arrival of corresponding Data the PIT entry is deleted and hence, if the Data packet is arrived this CR, It will discard it because of having no PIT entry for it. The SVC client will request next chunk if the video in buffer is low, without waiting for the download of additional enhancement layers.

6. Numerical Results

In this section we present a numerical analysis of over proposed mechanism. We compare our proposed mechanism with SLA [5] in a specific scenario. The scenario we selected is that there is a user who request a video that have 8 segments. We are taking assumptions that, segment 1, 3, 4, 5, 7 and 8 are cached inside the service provider's CCN core while segment 1 and 6 are not cached. For simplicity we assume that if a segment is cache inside the providers CCN domain it can always deliver any requested quality to the user. However, if the segment is not cached, then only base layer (300Kpbs) can be delivered in time. We also assume that the quality (PSNR) of 300Kbps is 20db, 500Kbps is 25db, 700Kbps is 30db and 1Mbps is 35db. The results are shown in table 1.

Figure 2 shows decoded video quality of the selected video in our proposed mechanism and SLA. We can see that our proposed mechanism outperform the SLA in the proposed scenario. On average our proposed mechanism give PSNR of 25.6db while SLA gives 22.5db.

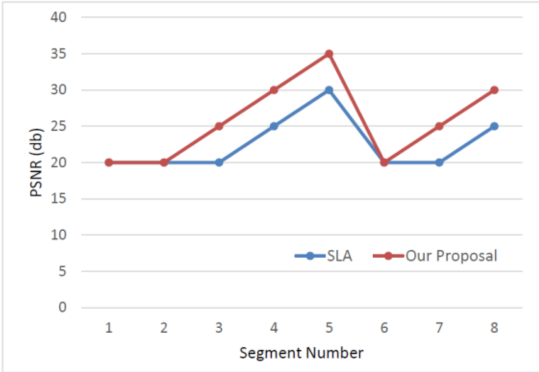

Figure 2: Downloaded Video Quality Comparison for Proposed Mechanism and SLA

7. Conclusion and Future Work

In this paper we presented a mechanism for video quality selection that opportunistically request additional enhancement layer of SVC in order to fully utilize advantages of caching in CCN routers. We also suggested a mechanism how routers can make decision to stop forwarding outdated chunks. Thus the network valuable bandwidth wastage is reduced.

In future we intend to extend our idea and to perform more analysis of the proposal to make it more solid.

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