Adaptive Video Streaming in Mobile Network and Social Video Sharing using Clouds

H. D. Gadade[1], Sachin S. Dhingra[2], Sachin S. Mandhan[3]
[1] Assistant Professor, Computer Department, Govt. College of Engg. Jalgaon, Maharashtra, India
[2]Student, Computer Department, Govt. College of Engg. Jalgaon, Maharashtra, India
[3]Student, Computer Department, Govt. College of Engg. Jalgaon, Maharashtra, India

Abstract - In this generation of wireless networks, Internet service providers (ISPs) are expected to offer services through several wireless technologies (e.g., WLAN, 3G, Wi-Fi, and WiMAX). Thus, mobile computers equipped with multiple interfaces will be able to maintain simultaneous connections with different networks and increase their data communication rates by aggregating the bandwidth available at these networks. To guarantee quality-of-service (QoS) for these applications, this paper proposes a dynamic QoS negotiation scheme that allows users to dynamically negotiate the service levels required for their traffic and to reach them through one or more wireless interfaces [3]. While demands on video traffic over mobile networks have been souring, the wireless link capacity cannot keep up with the traffic demand. The gap between the traffic demand and the link capacity, along with time-varying link conditions, results in poor service quality of video streaming over mobile networks such as long buffering time and intermittent disruption. The private agents in the clouds can effectively provide the adaptive streaming, and perform video sharing (i.e., prefetching) based on the social network analysis.

Keywords:Scalable Video Coding, Adaptive Video Streaming, Mobile Networks, Social Video Sharing, Cloud Computing, mobile video streaming, packet scheduling, wireless networks.

1. INTRODUCTION

Over the past decade, increasingly more traffic is accounted by video streaming and downloading. In particular, video streaming services over mobile networks have become prevalent over the past few years [1]. While the video streaming is not so challenging in wired networks, mobile networks have been suffering from video traffic transmissions over scarce bandwidth of wireless links. Despite network operators' desperate efforts to enhance the wireless link bandwidth (e.g., 3G and LTE), soaring video traffic demands from mobile users are rapidly overwhelming the wireless link capacity.

While receiving video streaming traffic via 3G/4G mobile networks, mobile users often suffer from long buffering time and intermittent disruptions due to the limited bandwidth and link condition fluctuation caused by multi-path fading and user mobility [2] [3]. Thus, it is crucial to improve the service quality of mobile video streaming while using the networking and computing resources efficiently [5] [6].

2. CLOUD COMPUTING

With the rapid development of processing and storage technologies and the success of the Internet, computing resources have become cheaper, more powerful and more ubiquitously available than ever before. This technological trend has enabled the realization of a new computing model called cloud computing, in which resources (e.g., CPU and storage) are provided as general utilities that can be leased and released by users through the Internet in an on-demand fashion. In a cloud computing environment, the traditional role of service provider is divided into two: the infrastructure providerswho manage cloud platforms and lease resources according to a usage-based pricing model, and service providers, who rent resources from one or many infrastructure providers to serve the end users. Cloud computing provides severalfeatures shown as below.

- No up-front investment: Cloud computing uses a pay-asyou-go pricing model. It simply rents resources from the cloud accordingto its own needs and pay for the usage.
- Lowering operating cost: Resources in a cloud environmentcan be rapidly allocated and de-allocated on demand which provides huge savings.
- Highly scalable: Infrastructure providers pool largeamount of resources from data centers and make them easilyaccessible.
- Easy access: Services hosted in the cloud are generally web based.
- Reducing business risks and maintenance expenses: By outsourcing the service infrastructure to the clouds, a service provider shifts its business risks (such as hardware failures) to infrastructure providers.

Cloud services are popular because they can reduce the cost and complexity of owning and operating computers and networks. Since cloud users do not have to invest in information technology infrastructure, purchase hardware, or buy software licences, the benefits are low up-front costs, rapid return on investment, rapid deployment, customization, flexible use, and solutions that can make use of new innovations [12].

3. TWO ASPECTS TO IMPROVE THE SERVICE QUALITY OF MOBILE VIDEO STREAMING

3.1. Scalability:

Mobile video streaming services should support a wide spectrum of mobile devices; they have different video resolutions, different computing powers, different wireless links (like 3G and LTE) and so on. Also, the available link capacity of a mobile device may vary over time and space depending on its signal strength, other users traffic in the same cell, and link condition variation. Storing multiple versions (with different bit rates) of the same video content may incur high overhead in terms of storage and communication. To address this issue, the Scalable Video Coding (SVC) technique (Annex G extension) of the H.264 AVC video compression standard [7] [8] defines a base layer (BL) with multiple enhance layers (ELs). These substreams can be encoded by exploiting three scalability features: (i) spatial scalability by layering image resolution (screen pixels), (ii) temporal scalability by layering the frame rate, and (iii) quality scalability by layering the image compression. By the SVC, a video can be decoded/played at the lowest quality if only the BL is delivered. However, the more ELs can be delivered, the better quality of the video stream is achieved.

3.2.Adaptability:

Traditional video streaming techniques designed by considering relatively stable traffic links between servers and users, perform poorly in mobile environments [2]. Thus the fluctuating wireless link status should be properly dealt with to provide ‘tolerable” video streaming services. To address this issue, we have to adjust the video bit rate adapting to the currently time-varying available link bandwidth of each mobile user. Such adaptive streaming techniques can effectively reduce packet losses and bandwidth waste [2].

4. AMES-CLOUD FRAMEWORK

As shown in Figure 1, the whole video storing and streaming system in the cloud is called the Video Cloud (VC).

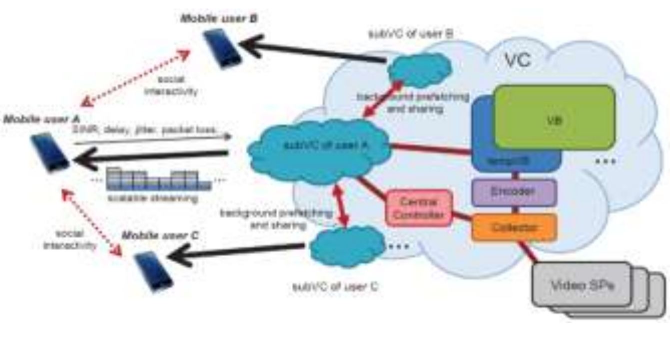

Figure 1.An illustration of the AMES-Cloud framework

In the VC, there is a large-scale video base (VB), which stores the most of the popular video clips for the video service providers (VSPs). A temporal video base (tempVB)is used to cache new candidate for the popular videos, while tempVB counts theaccess frequency of each video. The VC keeps running a collector to seek videos which are already popular in VSPs, and will re-encode the collected videos into SVC format and store into tempVB first. By this 2-tier storage, the AMES-Cloud can keep serving most ofpopular videos eternally. Note that management work will be handled by the controller in the VC.

5. AMOV: ADAPTIVE MOBILE VIDEO STREAMING

5.1. Scalable Video Coding

The Scalable Video Coding extension (SVC) of the H.264/MPEG-4 Advanced Video Coding (AVC) standard (H.264/AVC) is the latest amendment for this successful specification. SVC allows partial transmission and decoding of a bit stream. The resulting (decoded) video has lower temporal or spatial resolution or reduced fidelity while retaining a reconstruction quality that is close to that achieved using the existing single-layer H.264/AVC design with the same quantity of data as in the partial bit stream. SVC provides network- friendly scalability at a bit stream level with a moderate increase in decoder complexity relative to singlelayer H.264/AVC. Furthermore, it provides the functionality of lossless rewriting of fidelity-scalable SVC bit streams to single-layer H.264/AVC bit streams. The SVC extension of H.264/AVC is suitable for video conferencing as well as for mobile to high-definition broadcast and professional editing applications[4].

5.2. Types OfScalability InSVC

There are three main types of scalability in SVC. The first type provides a spatial enhancement layer which allows the stream to be decoded in several resolutions. Switching between spatial layers can be done only at some specific points in the stream called the Instantaneous Decoder Refresh (IDR) frames. Typically this is at the beginning of each Group of Picture (GoP).

The temporal enhancement layers are encoded using hierarchical B frames. Finally, the SNR enhancement layers is simply spatial enhancement layers but with the same resolutions as the base layer for inter-layer prediction.

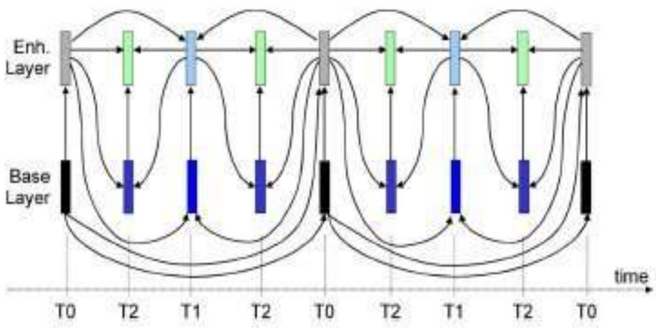

Figure 2.An example GoP structure of a SVC stream

Figure 2 shows an example of an SVC stream with 1 spatial layer, 3 temporal layers and one SNR enhancement layer. The intraframe and inter-frame prediction dependenciesfor decoding are shown with arrows. For more detailedinformation on the SVC [13].

5.3.Adaptability WithMonitoring On Link Quality

We design the mobile client and the subVC with the structure as shown in Figure 3. The link quality monitor at mobile client keeps tracking on metrics including signal strength, packet round-trip-time (RTT), jitter and packet loss with a certain duty cycle. And the client will periodically report to the subVC. Hereby we define the cycle period for the reporting as the "time window", denoted by *Twin*, Note that the video is also split by temporal segmentation by interval *Twin*.

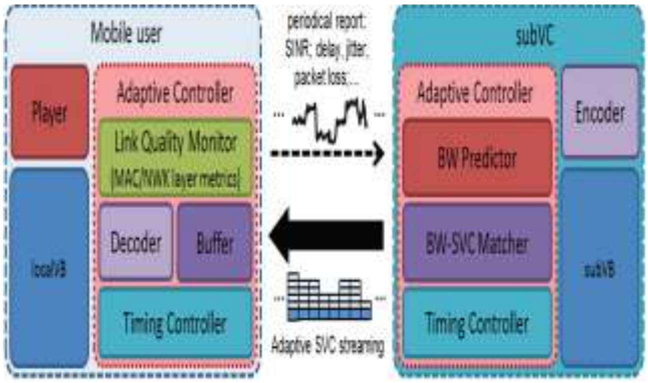

Figure 3.Functional structure of the client and the subVC.

Once the subVC gets the information of the link quality, it will perform a calculation and predict the potential bandwidth in the next time window. Note that we will use "predicted bandwidth" and "predicted goodput" interchangeably in following parts.

Suppose sequence number of current time window is *i*, the predicted bandwidth can be estimated by:

$$BW^{estimate}_{i+1} = BW^{practical}_{i} \cdot [\alpha \cdot f(p_i, p_{i-1})$$

$$+ \beta \cdot g(RTT_i, RTT_{i-1}) + \gamma \cdot h(SINR_i, SINR_{i-1})]$$

where, $\alpha + \beta + \gamma = 1$ indicating the importance of each factor, *p* is for packet loss rate, *RTT* is for RTT, *SINR* is for the signal to interference and noise ratio, and *f*(), *g*(), *h*() are three functions reflecting the value change of each factor compared with that of last time window [9].

6. ESOV:EFFICIENT SOCIAL VIDEO SHARING

6.1. Social Content Sharing

In SNSs, users subscribe to known friends, famous people, and particular interested content publishers as well; also there are various types of social activities among users in SNSs, such as direct message and public posting. For spreading videos in SNSs, one can post a video in the public, and his/her subscribers can quickly see it; one can also directly recommend a video to specified friend(s); furthermore one can periodically get noticed by subscribed content publisher for new or popular videos [1].

Instead, a user can click to see without any buffering delay as the beginning part or even the whole video is already prefetched at the localVB. The amount of prefetched segments is mainly determined by the strength of the social activities. And the prefetching from VC to subVC only refers to the "linking" action, so there is only file locating and linking operations with tiny delays; the prefetching from subVC to localVB also depends on the strength of the social activities, but will also consider the wireless link status [10].

Algorithm 1 Matching Algorithm between BW and Segments.

$i = 0$

$BW_0 = R_{BL}$

Transmit BL_0

Monitor $BW_0^{practical}$

repeat

  Sleep for T_{win}

  Obtain p_i, $RT\,T_i$, $SIN\,R_i$ etc., from client's report

  Predict $BW_i^{estimate}{}_{+1}$ (or $BW_i^{estimate}{}_{+1} = BW_i^{practical}$)

  k=0

  BW_{EL}=0

  repeat

    k++

    if$k >= j$ break

    $BW_{EL} = BW_{EL} + R_{EL}k$

  until$BW_{EL} >= BW_i^{estimate}{}_{+1} R_{BL}$

  Transmit BL_{i+1} and $EL^1{}_{i+1}$, $EL^2{}_{i+1}$,...,$EL^k{}_{i+1}{}^1$

  Monitor $BW_i^{practical}{}_{+1}$

  i++

until All video segments are transmitted

6.2.Prefetching Levels

Different strengths of the social activities indicate different levels of probability that a video will be soon watched by therecipient. Correspondingly we also define three prefetching levels regarding the social activities of mobile users:

- "Parts": Because the videos that published by subscriptions may be watched by the subscribers with a not high probability, we propose to only push a part of BL and ELs segments, for example, the first 10% segments.

- "All": The video shared by the direct recommendations will be watched with a high probability, so we propose to prefetch the BL and all ELs, in order to let the recipient(s) directlywatch the video with a good quality, without any buffering.
- "Little": The public sharing has a weak connectivity among users, so the probability that a user's friends (followers) watch the video that the user has watched or shared is low. We propose to only prefetch the BL segment of the first time window in the beginning to those who have seen his/her activity in the stream.

The prefetching happens among subVBs and the VB, also more importantly, will be performed from the subVB to localVB of the mobile device depending on the link quality. If a mobile user is covered by Wi-Fi access, due to Wi-Fi's capable link and low price (or mostly for free), subVC can push as much as possible in most cases.

Table 1.Social activities and background pushing strategies

	Direct recommendation	Subscription	Public sharing
V →subVB	All	Parts	Little
subV→BlocVB (via Wi-Fi)	All	Parts	Little
subVB→locVB (via 3G/4G)	Parts	Little	None

However if it is with a 3G/4G connection, which charges a lot and suffers limited bandwidth, we propose to downgrade the prefetching level to save energy and cost as listed in Table. 1, but users can still benefit from the prefetching effectively. Note that some energy prediction methods can be deployed in order to actively decide whether current battery status is suitable for "parts" or "little" [11]. If a user, A, gets the direct recommendation of a video from another user, B, A'ssubVC will immediately prefetch the video either from B's subVB, or from the VB (or tempVB) at the level of "all", if A is with Wi-Fi access. However if user A is connected to 3G/4G link, we will selectively prefetch a part of the video segment to A's local storage at the level of "parts". Note that the subscribed videos will be not prefetched when user A is at 3G/4G connection, as it is downgraded from "little" to none.

7. PERFORMANCE ANALYSIS

The performance of video cloud is better than the previously used techniques. We consider the comparison of AMES Cloud and TFRC to our proposed method Video Cloud. The working of the AMES and VC are more equal and most of the extra loaded components which are found in AMES are reduced.

Vagents carry out most of thepreprocessing of the video streaming sharing in media. Vagents also prefetch the requested video by the user fromTempVB or VB for providing better services. TRFC does not provide any dedicated method to improved the service tothe user, it tells how the transfer medium could be monitored and bandwidth level could be negotiated so as the datatransfer can beachieved very efficiently. The over comparison of the services provided based on bandwidth andbuffer time is considered [15].

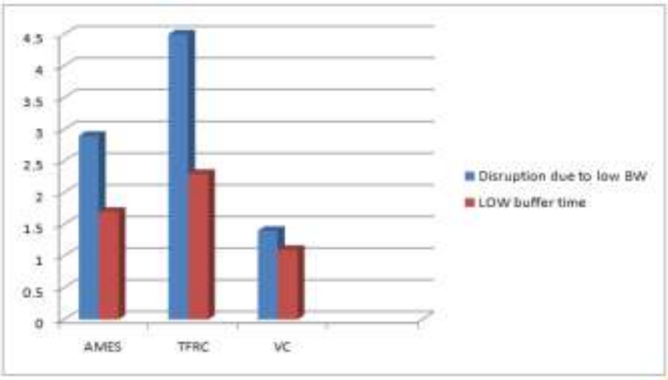

Figure 4.Comparison of performance

Figure 4 show the graph of VC provides better result than AMES the disruption due to low and varying bandwidth.

8. VIDEO STORAGE AND STREAMING FLOW BY AMOV AND EMOS

The two parts, AMoV and EMoS, in AMES-Cloud framework have tight connections and will together service the video streaming and sharing: they both rely on the cloud computing platform and are carried out by the private agencies of users; while prefetching in EMoS, the AMoV will still monitor and improve the transmission considering the link status; with a certain amount of prefetched segments by EMoS, AMoV can offer better video quality. With the efforts of AMoV and EMoS, we illustrate the flow chart of how a video will be streamed in Figure 5.

Once a mobile user starts to watch a video by a link, the localVB will first be checked whether there is any prefetched segments of the video so that it can directly start. If there is none or just some parts, the client will report a corresponding VMap to its subVC. if the subVC has prefetched parts in subVB, the subVC will initiate the segment transmission. But if there is also none in the subVB, the tempVB and VB in the center VC will be checked. For a non-existing video in AMES-Cloud, the collector in VC will immediately fetch it from external video providers via the link; after re-encoding the video into SVC format, taking a bit longer delay, the subVC will transfer to the mobile user.

Also in AMES-Cloud, if a video is shared among the subVCs at a certain frequency threshold (e.g., 10 times per day), it will be uploaded to the tempVB of the VC; and if it is further shared at a much higher frequency (e.g., 100 times per day), it will be stored with a longer lifetime in the VB. In such a manner, which is quite similar to the leveled CPU cache, the subVB and VB can always store fresh and popular videos in order to increase the probability of re-usage.

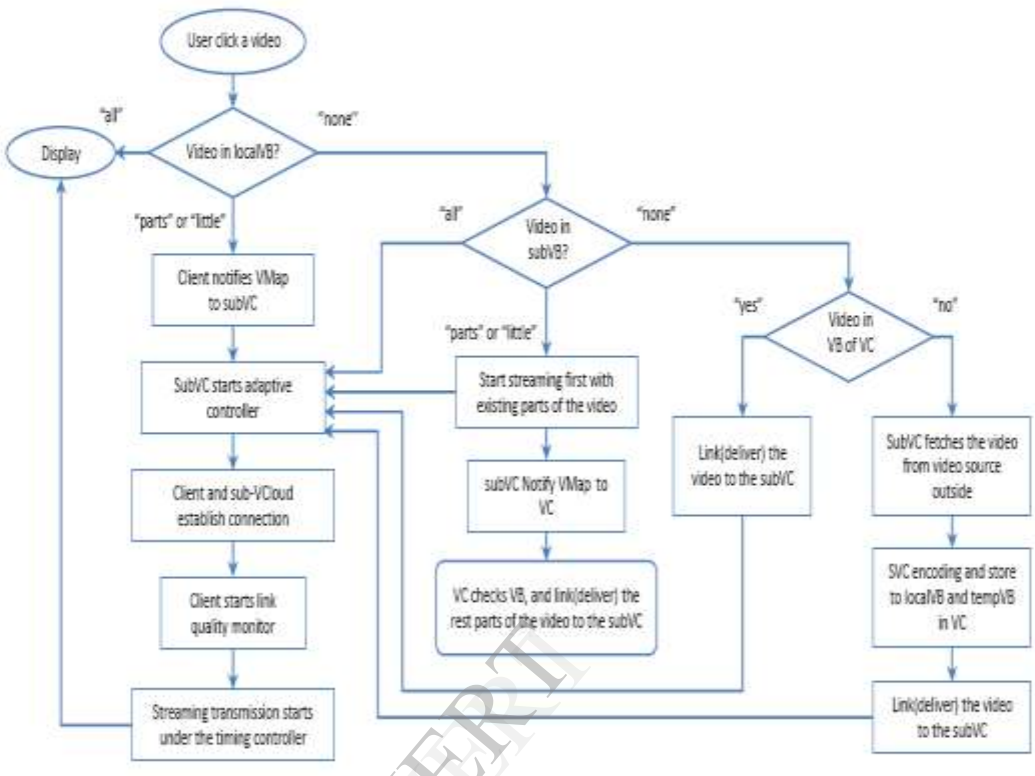

Figure 5.Working flow of video streaming in the subVC and VC of AMES-Cloud framework.

9. CONCLUSIONS

In this paper, we discussed our proposal of an adaptive mobile video streaming and sharing framework, calledAMES-Cloud, which efficiently stores videos in the clouds (VC), and utilizes cloud computing to construct privateagent (subVC) for each mobile user to try to offer "non-terminating" video streaming adapting to the fluctuation of link quality based on the Scalable Video Coding technique. Also AMES-Cloud can further seek to provide "nonbuffering"experience of video streaming by background pushing functions among the VB, subVBs and localVBof mobile users. We evaluated the AMES-Cloud by prototype implementation and shows that the cloud computingtechnique brings significant improvement on the adaptivity of the mobile streaming.

Video streaming in mobilenetworks can greatly benefit from using the adaptation capabilityof the SVC codec in conjunction with TFRC. The bit rate of thestream can be dynamically adapted to the changing channelconditions which greatly improves all performance indicatorssuch as interruption time, loss rate, delay and buffer requirements.This also implies that more users could be admitted to the cell andit would still be able to guarantee certain service qualities.

The focus of this paper is to verify how cloud computing can improve the transmission adaptability and prefetchingfor mobile users.

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