The Design of Video Streaming Proxy in High-Speed Train

Ching-Lung Chang
Dep. of CSIE
National Yunlin University of Science & Technology
Taiwan, R.O.C.
chang@yuntech.edu.tw

Xan-Hua Hsieh
Dep. of CSIE
National Yunlin University of Science & Technology
Taiwan, R.O.C.
g9817705@yuntech.edu.tw

Wei-Ming Chen
Institute of CSIE
National Ilan University
Taiwan, R.O.C.
wmchen@niu.edu.tw

Abstract—**This paper considers the characteristic of high-speed train about precise timing information, such as arrival time, depending duration on station, traveling time and current location of train, to design a video proxy agent for VoD service in train. Based on the information of current active video flows, a burst pre-fetching scheme is developed when the high-speed train depends on station. The video data required by the passengers in near future is burst downloaded to the train proxy to release the bandwidth constrain in train traveling. The most of playback video data can be provided by the train proxy during the train moving. The proposed scheme increases the system performance and video playback quality. The simulation results reveal that the proposed scheme has better performance in term of byte hit rate and amount of missed deadline streams compared with other schemes.**

Index Terms—**high-speed train, video proxy, burst pre-fetch, video streaming, video on demand.**

I. Introduction

With the wide acceptance and development of the Internet, it is trend to integrate all of services into Internet. At the same time, the fast development of communication technology that are evolution from narrowband dial-up networks to current broadband networks, from wired network to wireless network. In the visible future, the communication will be converged to IP centric networks to come up to pervasive/ubiquitous network environments, users can be serviced with the Internet anytime and anywhere.

At the same time, high-speed train has become the one of major transportation for business users. The business users take one to two hours in the high-speed train. It is an important issue to provide Internet access service, especially video service in high-speed train for realizing ubiquitous network environments. Up to now, the access bandwidth in high-speed train is limited under current wireless technology.

An Internet access test project of TGV (Train à Grande Vitesse) in France was beginning in December 2007 [1]. There is 2Mbps usable bandwidth provided by TGV with satellite communication. The Shinkansen in Japan started to provide wireless connection in March 2009 [2]. Using leaky wave cables, there are 2Mbps downlink bandwidth and 1Mbps uplink bandwidth provided by Shinkansen. The ITRI [3] issues a WiMAX testing project in Taiwan High-Speed Rail (THSR) at April 2010. It provides 3Mbps downlink bandwidth and 2Mbps uplink bandwidth at 300km/h moving speed.

Nowadays, although the access bandwidth in high-speed train is enough to provide text-based Internet services, such as E-Mail and web page access, the playback quality of multimedia services is still difficult to be guaranteed in limited access bandwidth. The major target of this paper is to provide a video on demand (VoD) service in high-speed train under restricting access bandwidth condition. To considering the characteristics of high-speed train, such as precise arrival time, traveling time, depending duration on station, and the current location of the train, a train proxy cooperated with burst pre-fetching scheme is designed for VoD service to maximize the system capacity.

II. Related Works

Proxy server is broadly used to reduce the time of data transfer between client and server to improve the network utilization. When a client requests data from the server via proxy server, if proxy server has been cached the required data, the required data is directly provided by the proxy server. Otherwise, proxy server demands the data from the server and caches the responded data and forwards it to the client. Therefore, if we can increase the data hit rate in the proxy, the stress of server and network bandwidth requirements can be significantly reduced.

Recent years, with the rapid development of VoD service and digital video processing technology, the data type cached in proxy server has gradually changed from static data, i.e. text, picture, and Web page, to video streaming data. Due to the size of video data is huge; applying the proxy technique to video applications can effectively reduce the bandwidth requirements. At the same time, the size of commercial film is about several hundred mega bytes, which is difficult to download whole film to the proxy server. Thus, developing a good video caching algorithm is important for multimedia applications to provide better playback quality to reduce network bandwidth requirement.

In order to solve the high-latency and high error rate between video server and client, the prefix caching scheme [4] is proposed to pre-download few minutes of beginning video data to proxy. The method makes the client have continuous and smooth video playback even in an unstable external bandwidth environment. Based on capacity of the available bandwidth in client, a video staging algorithm is proposed by [5] which set a cut-off rate for a VBR (Variable Bit Rate) video. In this scheme, as long as the data rate is larger than a predetermined cut-off rate, the exceeded video data part will be pre-fetched to the video proxy to reduce the bandwidth requirement between server and proxy. A Generalized Interval Caching is proposed [6], which segments video files into several segments to maximize the streaming capacity of video proxy. Two selective caching schemes called SCQ and SCB, were proposed by [7] for QoS networks and best-effort networks to increase overall performance.

Different from the literatures which design video cache scheme in Internet network environment, in this paper, we uses video cache scheme to provide VoD service in high-speed train environment. In the following section, we describe our proposed scheme.

III. Burst Pre-fetch Scheme

A. Environment

In this work, we assume that the train has broadband access channel called broadband channel and narrow-band access channel called moving channel in the situation of train stopping and train moving, respectively. During the train stopping on station, a broadband wireless technique can be easily applied to provide broadband communication. On the other hand, when the train is in high-speed moving, with current wireless technique, it can only provide limited bandwidth to train for network access. Due to the operations of high-speed train are in high precision, we assume the system can get the train stopping time and next traveling time when train depends on station. Except for the timing information the system also understands the information of how many passengers are streaming which video and playback position. Based on the playback position, we can further derive the expected playback duration in next train traveling.

The working environment of the proposed proxy-based VoD service for high-speed train is illustrated in Fig. 1. As Fig. 1 depicts, there are train proxy and station proxy in train and in station, respectively. We assume that the train proxy has the information of current active video streams and the associated playback position before the train depending on the station. In the following, we describe the detail operations of proposed video cache scheme for VoD service.

Before the high-speed train depending on the station, the train proxy informs the playback position of active video streams to the station proxy via moving channel. Once the station proxy receives the active video stream information, it requests the required video data from the VoD servers located on different Internet location before the train depending on station. Thus, when the train depends on station, the required video data has been cached in station proxy. In this time, the train proxy applies burst pre-fetching scheme to burst download the required video data from station proxy to train proxy via broadband channel. Once the train moving to the next station, the required video data has been cached in train proxy and can be provided to the users. Thus, the loading of the moving channel can be significant reduced.

In this paper, we target on developing a burst pre-fetching scheme to increase system capacity and to reduce the moving channel load when the train depends on station.

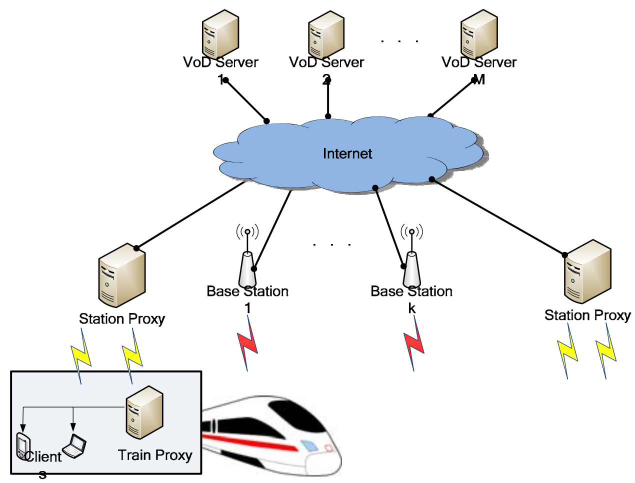

Fig. 1 The proposed architecture for VoD service in high-speed train

B. Burst Pre-fetch scheme

A burst pre-fetching scheme is developed between train proxy and station proxy, which uses priority-based scheduling scheme to download the video data required in the next train traveling from station proxy to train proxy, to release the bandwidth stress of moving channel. According to the playback position of video stream, each video is partitioned into multiple segments. Each segment is assigned a priority value. All of video segments are sorted with the priority value. The burst pre-fetching sequence is based on the sorted sequence. In the following, we describe how to decide the differentiate priority value for each video segment. First we define the parameters used in the burst pre-fetching scheme in Table I.

Table I Notation definition

Notation	Definition
V	The set of all active videos.
U	The set of all users.
U_i	The users who watches the video i. U_i is the subset of U.
P_j^i	The beginning playback position of video i for user j. $i \in V, j \in U$
T	The traveling time between two stations.
S_i	The set of segments belonging to video i. $S_i = \{s^i_1, s^i_2, \cdots, s^i_k\}$. The symbol s^i_k means the starting time of the k'th segment of video i.
w_k^i	Important value of s^i_k. (Higher value is more important.)
$b_{j,k}^i$	Boolean value 0/1. The value is 1 if the segment s^i_k is acquired in next train traveling by user j, otherwise is 0.

	$i \in V, j \in U$.

The relationship among the symbols of P^i_j, s^i_k, and w^i_k for video i is shown in Fig. 2. The length of P^i_j to P^i_j+T means the required playback video data during the next train traveling.

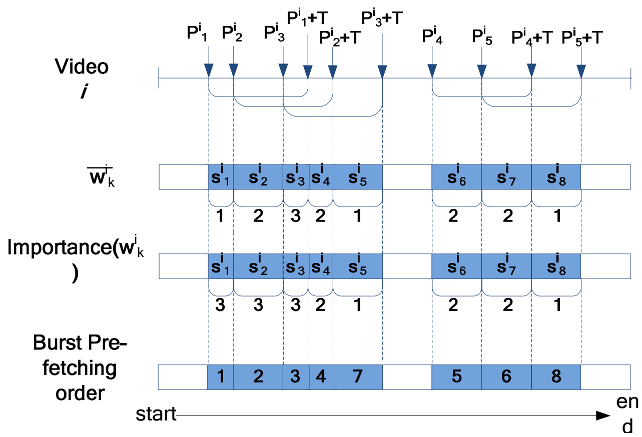

Fig. 2 The important value w^i_k and burst pre-fetching sequence of video segments

According to the required playback position, we partition the video i into multiple segments, represented as s^i_k. The important value w^i_k of video segment k belonging to video i is calculated as follow.

$$\overline{w^i_k} = \sum_{j \in U_i} b^i_{j,k} \qquad i \in V, k = 1, 2, 3, \cdots \tag{1}$$

The $\overline{w^i_k}$ stands for the number of users who will access the video segment s^i_k during the next train traveling. In the Fig. 2 depicts, the segment of s^i_3 has the most importance value, which has three users access this segment. When considers the continuous video playback in train traveling, the important value of video segments belong to the duration of P^i_j to P^i_j+T for user j are adjusted and decided the important value of video segment. The adjusted method is based on the Eq. (2),

$$w^i_k = \max \{ \overline{w^i_k}, j = k \text{ to } x \}, \tag{2}$$

where x is the last segment id in the playback duration from P^i_j to P^i_j+T for video i. Finally, we rank the important value w^i_k of all of videos in ascending order. This sorted order is the burst pre-fetching order from station proxy to train proxy. The order of segments with same important value is decided by the playback time. The former of playback time is prior to pre-fetch. Based on the derived pre-fetching order, the video segments are burst download from the station proxy to the train proxy. Figure 3 illustrate the algorithm of video segment partition and the associated important value assignment.

Input: $P^i_j \;\; i \in V, j \in U_i$

Output: L^i_k, s^i_k and $\overline{w^i_k}$ $\; i \in V, k = 1,2,3,...$

for i=1 to $|V|$
  /*segmentation*/
  P_i= the set of sorting sequence with P^i_j and P^i_j+T for all $i \in V, j \in U_i$;
  k=1;
  s = pop one element from P_i;
  $s^i_k = s$;
  while P_i is not empty
    s = pop one element from P_i;
    if ($s^i_k+T \le$ s)
      $L^i_k=T$;   //L^i_k: the length of segment s^i_k
      $s^i_{k+1}= s$;
    else
      $L^i_k= P^i_j - s^i_k$;
      $s^i_{k+1}= s$;
    end if
    k++;
  end while
  /*important value decision*/
  S_i= the set of sorting sequence with segment s^i_k for video i;
  for k=1 to $|S_i|$
    $\overline{w^i_k}$ =0;
    for j = 1 to $|P^i_j|$
      if($P^i_j \le s^i_k < P^i_j$+T)
        $\overline{w^i_k} = \overline{w^i_k} + 1$;
  end for
  P_i= the set of sorting sequence with playback position P^i_j;
  while P_i is not empty
    s = pop one element from P_i;
    for k=1 to $|S_i|$
      $w^i_k = \overline{w^i_k}$;
      if (s≤ s^i_k <s+T)
        for j = k to $|S_i|$
          if (s≤ s^i_j <s+T) and ($\overline{w^i_j} > \overline{w^i_k}$)
            $w^i_k = \overline{w^i_j}$;
  end while
end for

Fig. 3 The algorithm of video segment partition and the associated important value

IV. Simulation And Discussion

We compare the performance of the proposed burst pre-fetch scheme, in term of byte-hit ratio and the amount of fully support rate, with *maximal user first* and *proportional prefix size* approaches. The *maximal user first* denoted as maximal users in results, sorts the required video data according to the number of request users and fetches the entire video from station proxy to train proxy based on the sorted sequence. The *proportional prefix size* denoted as proportional is to allocate the available bandwidth to each video with proportion as Eq. (3) depicts.

$$pre\_fetch\ data\ of\ video\ i = depend\_time \times \frac{r_i \times T_t}{\sum_{k=1}^{M} r_k \times T_t}, \quad (3)$$

where the r_i is the average playback rate of video i. In the simulation, there are 100 distinct videos whose playback rates are 500kbps in average. The Zipf-like user request frequency distribution is applied in this paper. The access frequency of video i is calculated as Eq. (4).

$$f_i = \frac{1}{i^{\alpha} \cdot \sum_{k=1}^{M} \frac{1}{k^{\alpha}}} \quad (4)$$

where f_i is user access frequency of video i, M is number of videos and α is the Zipf factor ($0 \le \alpha \le 1$). Under the instance of 100 videos and 500 users, the distribution of the user access frequency against to the ranking of video segment in Zipf-like distribution with 0.8 α value is illustrated in Fig. 4. The associated parameters of high-speed railway are defined in Table II.

Table II Simulation Parameters

Moving channel bandwidth	2 Mbps
Broadband channel bandwidth	100 Mbps
depend Time	300 sec.
Traveling Time	1140 sec.
Number of users	100, 200, …, 1000
Watching location	Uniform distribution

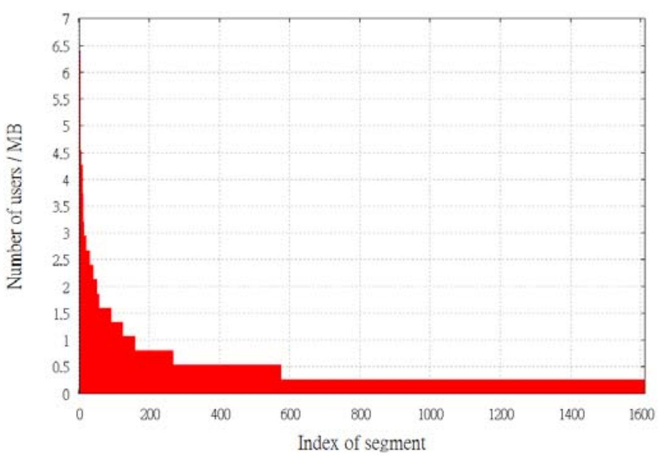

Fig. 4 usage rate per size of each segment

The term of byte-hit ratio (BHR) and full supporting rate are used to evaluate the proposed scheme. The definition of BHR is defined in Eq. (5).

$$BHR = \sum_{j \in U} \sum_{i \in V} \frac{C_j^i}{T_t \cdot \bar{r}_i} \quad (5)$$

where the $\bar{r}_i$ is the average playback rate of video i, C_j^i is the size of data which can be transferred by train proxy.

Figure 5 shows the results of BHR. Due to the proportional prefix scheme allocates the available bandwidth to each video in proportion, the factor of the video segment access frequency is not considered in this scheme. Thus the value of BHR with proportional scheme is decrease when the number of users is increase. As the Fig. 5 depicts, the proposed scheme has better BHR than other schemes in different number of users. The values of BHR in proposed scheme and in maximal users scheme are about 0.48 and 0.45 during 300 to 1000 users, respectively. Both schemes fetch the video data according to the number of access user to maximum the resource utilization. Under the limited bandwidth of broadband channel, there are 341 video segments can be pre-fetched to the train proxy in proposed scheme. In 500 request users, these pre-fetch segments can support 244 users under Zipf-like user access distribution. At the same condition, there are 7.53 videos can be pre-fetch to the train proxy in maximum user scheme, which can support 211 users.

Figure 6 shows the results of fully support rate. The fully support rate is a percentage of users who can be fully supported playback during train traveling. The definition of user who can be fully supported playback is the desired video of user can be smoothly playback during train traveling. Because the pre-fetch granularity of the proposed scheme is segment, the bandwidth resource can be used in more efficiency than maximal user scheme which pre-fetch unit is whole video. Thus, there are 26% performance improve in term of fully support rate in comparison with maximal user scheme under 800 access users.

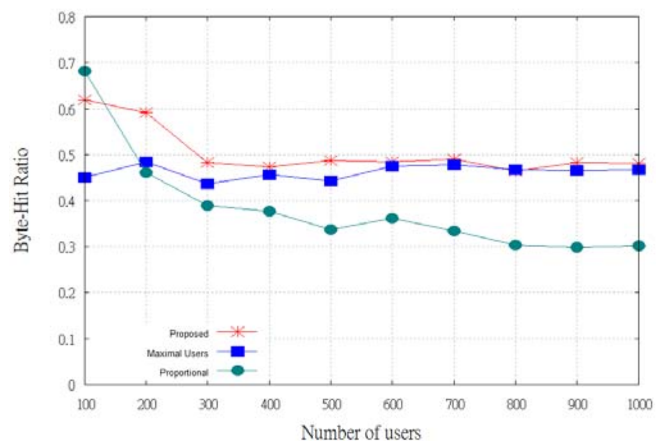

Fig. 5 Comparison of byte-hit ratio

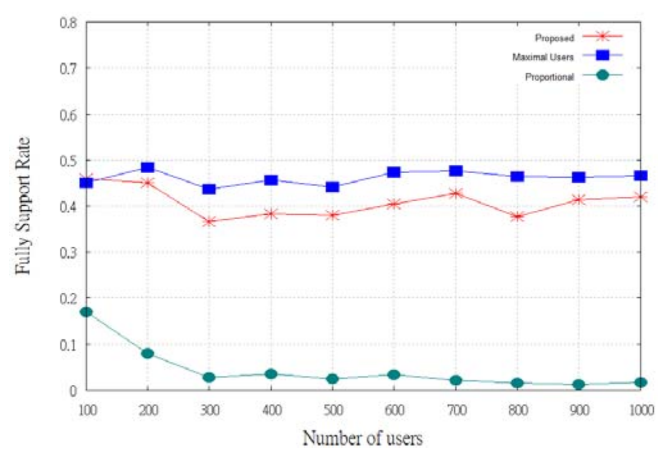

Fig. 6 Comparison of fully support rate

V. CONCLUSION

This paper proposed a pre-fetching scheme which bases on the video population and considers the characteristic of high-speed train in precise timing information, to provide VoD service in high-speed train environment. The simulation results reveal that the proposed scheme has better performance in term of BHR and full supporting rate than other schemes.

ACKNOWLEDGEMENT

This work is supported by the National Science Council, Taiwan, Republic of China, under grant number *NSC100-2218-E-224-012-MY3*.

REFERENCES

[1] D. Sanz, P. Pasquet, P. Mercier, B. Villeforceix, D. Duchange, "TGV Communicant Research Program": from research to industrialization of onboard broadband Internet services for high-speed trains," Proceedings of WCRR, 2008.

[2] G. Barbu, "E-TRAIN-Broadband Communication with moving trains. Technical Report - Technology state of the art," Paris:International Union of Railways, June 2010.

[3] C. H. Yeh, C. W. Chow, et al., "Theory and Technology for Standard WiMAX Over Fiber in High Speed Train Systems," Journal of Lightwave Technology, Vol. 28, No. 16,pp. 2327-2336, August 15, 2010

[4] S. Sen, J. Rexford, D. Towsley, "Proxy prefix caching for multimedia streams," Proceedings of IEEE Infocom. 99, 1999.

[5] Z. Zhang, Y. Wang, D.H.C. Du, "Video staging: A proxy-server-based approach to end-to-end video delivery over wide-area networks," IEEE/ACM Transactions on Networking, pp. 429–442, 2000

[6] A. Dan, D. Sitaram, "A generalized interval caching policy for mixed interactive and long video workloads," Proceedings of SPIE, pp. 344–351, 1996.

[7] Z. Miao, A. Ortega, "Scalable proxy caching of video under storage constraints," IEEE Journal of Selected Areas in Communications, pp. 1315–1327, 2002.

[8] "Taiwan High Speed Rail" http://www.thsrc.com.tw.