Adaptive Channel Allocation Methods for Distributed MPEG Player System over a Cellular Radio Network

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Abstract

The growing importance of mobile networks has stimulated active research into how multimedia information can be distributed over a slow and reliable network. In this paper, we propose a multi-channel approach for transmitting video frames over a GSM network. A number of strategies are proposed for channel allocation so that sufficient bandwidth can be provided to satisfy the timing requirements of the video frames. Their performance evaluated using simulation.

1 Introduction

In recent years, a lot of work has been devoted to the study and design of distributed MPEG video player systems [1]. To support an acceptable quality of service (QoS) in video playback to clients through a network, the transmission rate of video frames from the video server to the clients must be high and predictable [2]. Various techniques such as buffering, data streaming and pre-fetching, have been proposed to minimise the impact of the unpredictable network performance on the system performance. However, recent advances in mobile communication technologies have made the design of distributed MPEG video player systems over a mobile network more feasible [3,4,5,6]. This can lead to novel mobile multimedia applications such as tele-medicine in ambulance, real-time traffic navigation systems and mobile news services.

Owing to the intrinsic limitations of a mobile network, the design of an efficient and cost-effective mobile MPEG player system poses many challenging problems. Low bandwidth is one of the main concerns. For example, the bandwidth supported by a radio cellular network is in the range of 9.6 to 33.3 kps. This is much lower than the bandwidth provided by a typical LAN which is on the order of 100 Mps. Even though it is assumed that the sizes of the video frames are small, it is still difficult to support a high quality video playback over a cellular radio network.

In this paper, we use a multi-channel approach to overcome the low bandwidth of cellular radio networks. We concentrate on the channel allocation problem in a GSM radio cellular network [7] for transmitting MPEG video frames, since we assume that the bottleneck resource of the system is the mobile network instead of other components such as decompression, video frame retrieval and video display. Several strategies are proposed for channel allocation so that sufficient bandwidth can be provided to satisfy the timing requirements of the video frames. GSM is chosen as an example because of its popularity, particularly in Hong Kong. Since multiple channels are used, a synchronisation scheme between the different channels is also proposed.

2 Channel Allocation Procedure

To support real-time video playback over a cellular radio network, we have to solve the following three practical problems:

(1) The number of channels and time slots to be allocated to serve a video request;
(2) which channels and time slots to be allocated to serve a video request; and
(3) the way to synchronise the data of a frame of a group of frames when multiple channels are used concurrently for their transmission.

To maximise channel utilisation, we adopt a dynamic approach to allocate the channels and time slots to serve a video request. The channel allocation algorithm is invoked whenever a video frame arrives. To reduce the overhead, we may invoke the procedure for transmitting a group of frames instead of each frame. The number of channels and time slots to be allocated for transmitting a video frame can be calculated based on the actual bit rate of a time slot calculated earlier. A more difficult issue, however, is the synchronisation of the data when multiple channels are used to transmit a frame.

To determine which channels and time slots are assigned to transmit a frame without violating the synchronisation problem, several algorithms are proposed: the channel grouping algorithm, video channel allocation algorithm, audio allocation algorithm, frame transmission and drop strategy. The channel grouping algorithm is first applied to assemble channels with similar status to form a channel resource map. Then the video channel allocation algorithm is employed for assigning appropriate time lots to serve the video request based on their status. Three video allocation methods, minimum channel, maximum channel and adaptive channel allocation method, are proposed. Audio channel allocation method is used to assign time slots to serve the ordinary users. Finally, frame transmission and drop strategy is applied to optimise the system performance.

2.1 Channel Grouping Algorithm

The grouping algorithm consists of two procedures: Get_channel_status and Group_Aggregation. The first procedure is used to identify similar status channels which mean that the channels have the same idle time slots at the same time. The second procedure is to group the similar status channels together so that when the allocation algorithm is invoked, the algorithm can determine which channels and time slots should be allocated.

```
Grouping Algorithm
  Get_channel_status
     If status equal
```

```
    Assign the same group number
  Else
    Assign a new group number
Group_Aggregation
    Aggregate two groups containing maximum
    concurrent time slot number
  Endif
```

Get_Channel_Status basically contains three operations. They are binary to decimal operation, grouping operation and count idle timeslot operation. To obtain the channel status, a binary to decimal (B/D) operation is employed on the channel resources map for each channel. By grouping the channels with the same decimal number, similar status channel can be brought together. They are used as input to the Group_Aggregation process which combines groups for more flexible channel allocation.

2.2 Video Channel Allocation Algorithms

In this section we propose three different algorithms for video channel allocation. They are (1) minimum channel, maximum time slot allocation, (2) maximum channel, minimum time slot allocation, and (3) adaptive channel allocation.

(1) Minimum Channel, Maximum Time Slot Allocation

This method is summarized by the following pseudo-code:

Calculate the required number of channels

$$\left(= \frac{request\ timeslot\ no.}{max.\ no.\ of\ timeslot\ can\ be\ used / user / channel} = A \right)$$

Calculate the required number of time slots per channel

$(= max.\ no.\ of\ timeslot\ can\ be\ used / user / channel = B)$

```
Get_Channel_Status;
Group_Aggregation;
For each entry in the common time slots matrix i, j
    If  the no. of common time slots >= A
      Set the entry to be True
      For all the True entries
          Select the one with the greatest number of time slots
      Endfor
          Select the group(s) corresponding to the select entry
          For those channels which are belonged selected group(s)
              set the appropriate location(s) of channel resources
                  map to zero
              holds the time slots for a time depending on
                  the number of group of frame transmit at a time
              reset the appropriate time slot(s) in the channel
                  resources map to one again
        Endfor
        Return
    Else
        drop the frame(s)
    Endif
Endfor
```

(2) Maximum Channel, Minimum Time Slot Allocation

Calculate the required no. of channel =
no. of concurrent channels in a handset

Calculate the required no. of time slot per channel

$$\left(= \frac{request\ timeslot\ no}{max.\ no.\ of\ concurrent\ channel\ that\ client\ handset\ can\ supprot} = D \right)$$

```
Get_Channel_Status;
Group_Aggregation;
result = 0
for x = 1 to total group number
    If ( total no. of ch. of the joined group x >= C,
       where the concurrent timeslot no. is specified by D)
       allocation pass
       result = 1
       set the appropriate location(s) of channel resources map to zero
          hold resources for a time depending on number of group
              of frame transmit at a time
          set the appropriate location(s) of channel resources
              map to one again
       exit (x for loop)
       If ( result = 0 )
           allocation fail
```

(3) Adaptive Channel Allocation

Calculate channel no. and time slot no. combination fulfilling the requested time slot no.

```
Get_Channel_Status
Group_Aggregation
result = 0
for y = 1 to maximum number of parallel channel
Choose the combination with least wastage of
    timeslot (channel no. = E and timeslot no. = F)
for x = 1 to total group number
      If  ( total no. of ch. of the joined group x >= E,
         where the concurrent timeslot no is specified by F)
        allocation pass
        result = 1
        set the appropriate location(s) of channel
            resources map to zero
           hold resources for a time depending on number
               of group of frame transmit at a time
           set the appropriate location(s) of channel
            resources map to one again
           exit
  If ( result = 0 )
        allocation fail
          Take drop frame statistic
```

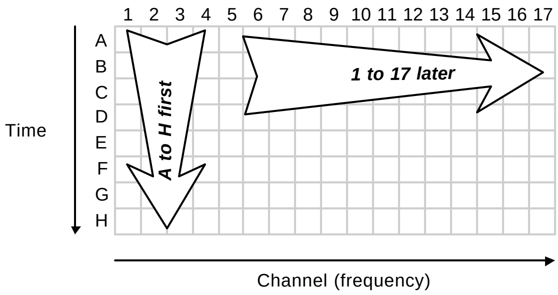
2.3 Frame Allocation and Discard Strategy

To reduce overhead in performing the channel allocation procedure, we may perform the procedure for a group of video frames instead of each video frame. However, the grouping of video frames has to confirm to the characteristics of the MPEG video file. Taking MPEG-1 video as an example, if the frame pattern is IBB PBB PBB PBB, the possible numbers of frames to be transmitted are 1, 2, 3, 4, 6 or 12. Of course, if the number of frames in a group is larger, it will be more difficult to find the suitable channels and time slots to transmit the frames as it will require more time slots. The trade-off is smaller overhead for performing the channel allocation procedure.

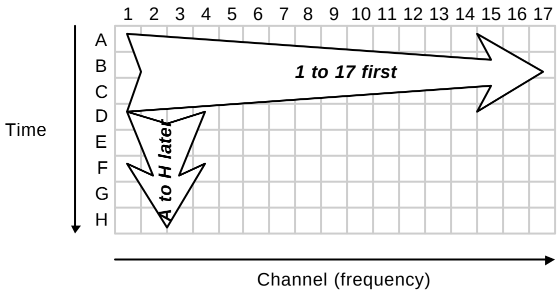
The frame discard strategy is based on the MPEG file format. When an I-frame has to be dropped due to no suitable time slot for its transmission, the following P-frames and B-frames should also be dropped. Similarly, if a P-frame has to be dropped, the following B-frames should be dropped as well. Discarding frames although will affect the QoS of the playback, it can save the channel bandwidth for other frame transmission if it is being dropped before it is being sent. Since I-frames are the most important frames, we have designed the following algorithm for discard the frames in which we try to allocate the I-frames first if there are not sufficient number of time slots and suitable channels. In our strategy, we try to avoid discarding I-frames. Conversely, if the rejected frame group contains no I-frame, the current transmitting frame group will be dropped and the following group will be transmitted at the next request. This situation will be continued until the arrival of the next I-frame.

2.4 Channel Allocation for Ordinary Users

The channels in a GSM network will also receive voice data transmission requests. Actually, the number of voice data transmission requests should be much greater in number than the video transmission requests as most of the users will use the GSM network for voice communication. In this paper, we have designed two audio channel allocation algorithms, to be performed when the system receives a voice data transmission request. We call the two methods time slots first (TS) and channel first (CH) respectively. In the TS method, all the time slots in a channel will be searched before switching to the next channel. This is shown in Figure 1(a). In the CH method (illustrated in Fig. 1(b)), channels with the same time slot number will be searched before changing to the next channel. The performance of these methods is related to the video channel allocation scheme.



(a)



(b)

Figure 1. Audio channel allocation. (a) TS method; (b) CH method

3 Performance Study

3.1 Simulation Model

The mobile system model used in our simulation is shown in Figure 2. It consists of a video server and a number of mobile clients, some of which are voice clients and others are video users. The video server contains a video player frequency channel selector and a video buffer.

Within a pre-set simulation time limit, the mobile clients will generate requests. To serve a request from a voice user, the system needs only one time slot for certain period of time. If the required time slot is not available, the voice request will be rejected. When the system receives a video request, the channel allocation procedure will be invoked. It will get the first frame or (a group of frames) of the requesting video file. Then, the system will determine how many time slots are required and which time slots will be assigned to transmit the first frame or a group of frames by performing the grouping algorithm and channel allocation algorithm. The video request is served when all the video frames of the video file have been transmitted to the client or have been dropped. After the completion of a video request or a voice request, the mobile client will generate the next request after a think time.

In the simulation, we implement the following frame discard strategy. If the required time slot cannot be allocated for a video frame, the request will be refused, and the frame or the group frames will be dropped. Furthermore, if it is an I-frame, the following frames will also be dropped until the next I-frame. If it is a P-frame, the following B-frames will be dropped until the next P-frame or I-frame. The procedure is repeated until all the frames in the requesting video file have been transmitted or dropped.

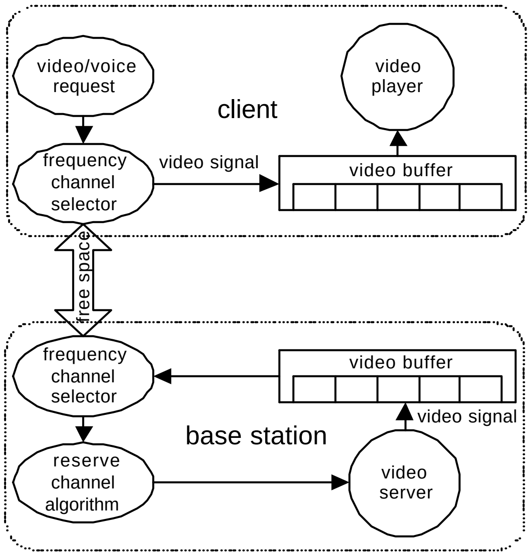


Figure 2. Model of the Adaptive Channel Allocation System

3.2 Results and Discussion

Various audio allocation methods are employed to examine the channel resource utilisation for the three video allocation approaches. It can be observed in Figure 3 that the minimum channel allocation method consistently gives a better channel resource allocation than the adaptive channel allocation method and also the maximum channel allocation method when TS is used. Maximum utilisation occurs when group frame size equal to 3 for minimum channel allocation method. In Figure 4, it can be seen that the adaptive channel allocation method consistently produces much higher channel utilisation than other two methods when CH is used. This may be because the CH audio allocation method produces a less efficient more channel resource allocation than the TS method. The reason for better channel utilisation of minimum channel allocation and adaptive channel allocation is that they request more timeslots than other methods during the simulation period.

In Figure 5, it can be observed that the maximum channel allocation method regularly provides a higher I frame drop rate than the other two methods. Also, the I frame drop rate comes to 100% when group frame size is equal to 12. This implies the channel allocation system cannot support relatively large timeslot requirements. In Figure 6, it can be seen that the minimum channel allocation method constantly produces a higher frame drop rate than the other two methods. Furthermore, as in Figure 5, the I frame drop rate of the three methods increases to 100% when group frame size equals 12. (The drop rates of P-frames and B-frames of the algorithms are similar to that shown in Figure 5 and Figure 6.)

5 Conclusions

In this paper, we address some of the issues involved in transmitting multimedia traffic over a low speed cellular network. Using the GSM network as an example, we adopt a multi-channel approach in order to provide reasonable delivery service for bandwidth intensive traffic such as video. We proposed a grouping mechanism to reduce overhead in channel allocation, as well as a number of video and audio allocations. Frame drop strategies are also proposed since given the low overall network capacity, it is not always possible to allocate sufficient channels for video traffic. The effectiveness and trade-off using these methods are studied using simulation experiments.

References

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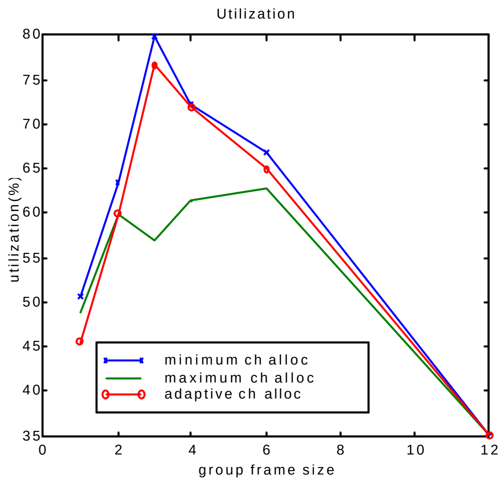

Figure 3: Impact of group size with TS algorithm

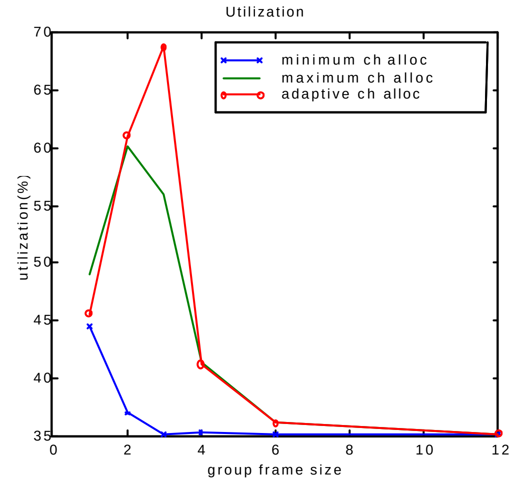

Figure 4: Impact of group size with TS algorithm

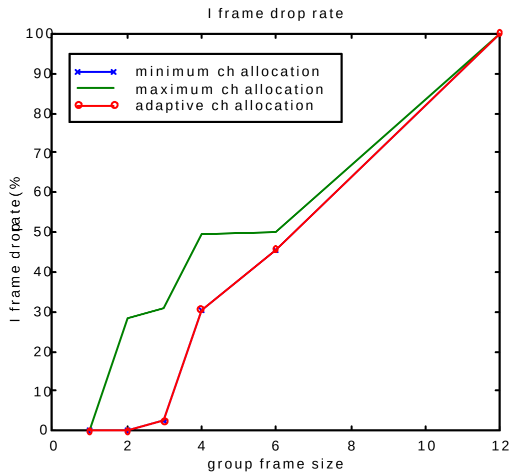

Figure 5: Impact of group size on I frame drop rate with TS

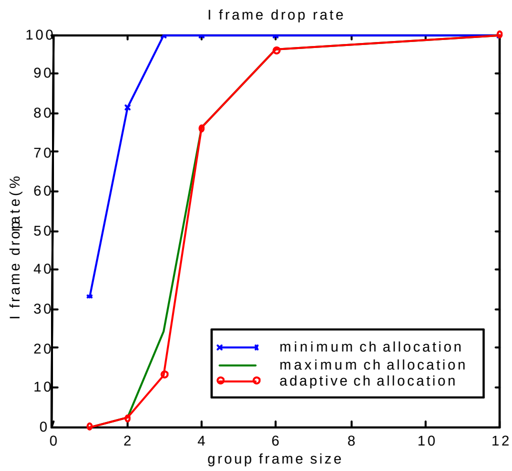

Figure 6: Impact of group size on I frame drop rate with CH