Distribute the Video Frame Pixels over the Streaming Video Sequence as Sub-Frames

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Abstract—**Real-time video streaming over wireless channel has become an important issue due to the limited bandwidth that is unable to handle the flow of information of the video frames. The characteristics of wireless networks in terms of the available bandwidth, frame delay, and frame losses cannot be known in advance. As the effect of that, the user may notice a frozen picture in the mobile screen. In this work, we propose a technique to prevent freezing frames in the mobile devices based on spatial and temporal locality for the video stream, by splitting the video frame into four sub-frames and combining them with another sub-frames from different sequence positions in the streaming video. In case of frames losses, there is still a possibility that one fourth (one sub-frame) of the frame will be received by the mobile device. The received sub-frames will be reconstructed based on the surrounding pixels. The rate adaptation mechanism will be also highlighted in this work, by skipping sub-frames from the video frames. We show that the server can skip up to 75% of the frame's pixels and the receiving pixels (sub-frames) can be reconstructed to acceptable quality in the mobile device.**

Keywords-streaming video; wireless network; frame splitting; sub-frame crossing; rate adaptation.

I. INTRODUCTION

Nowadays mobile cellular networks provide different type of services and freedoms to the mobile users anywhere and at any time while the mobile users on the move. Streaming services become an important application to the mobile user, while streaming video is the classical technique for achieving smooth playback of video directly over the network without downloading the entire file before playing the video [1][5][14].

The unpredictable nature of wireless networks in terms of bandwidth, and loss variation, remains one of the most significant challenges in video communications [9]. In this context, video streaming needs to implement an adaptive techniques in terms of transmission rates in order to cope with the erroneous and time variant conditions of the wireless network [9][10].

Bandwidth is one of the most critical resources in wireless networks, and thus, the available bandwidth of wireless networks should be managed in an efficient manner [7]. Therefore, the transmission rate of the streaming video should be maintained according to the networks bandwidth [2][6][11].

Network adaptation refers to how many network resources (e.g., bandwidth) a video stream should utilize for video content, resulting in designing an adaptive streaming mechanism for video transmission [15]. To stream video, it is desirable to adjust the transmission rate according to the perceived congestion level in wireless networks, to maintain the suitable loss level and fairly shared bandwidth with other connections. Furthermore, it is favorable for the streaming video to be aware of the transmission level in order to obtain good streaming quality by appropriate error protection.

In this paper, we proposed a sub-frame crossing technique based on frames splitting. The video frame will be split into four sub-frames, and combine the sub-frame with another sub-frame from different sequence position and from different spatial data in the streaming video. The crossing frames in the streaming video will carry pixels from four different frames that belong to four different positions and will transmit over a single wireless channel. In case of sequence of frames losses or frames corruption from the streaming video, the losses of the sub-frames will be distributed on the streaming video and there is still a possibility that one of the fourth sub-frames will be received by the mobile device, while the missing sub-frames from the frames will be reconstructed based on the surrounding pixels.

The remainder of this paper is organised as follows. Section II provides background and related work. Section III explain the proposed of streaming the video as sub-frames crossing. The rate adaption mechanism is presented in Section IV. The results are discussed in Section V, while the conclusion is presented in Section VI.

II. BACKGROUND AND RELATED WORK

Various techniques are proposed by many researchers for video frame slicing and reconstruction. The proposed techniques are based on H.264/AVC standard tools[20], where the Flexible Macroblock Ordering (FMO) slicing type dispersed to split the video frames and streaming them over the networks, while adaptive the slices is needed to send the highest priority information.

Huang [13] proposed a scheme for Adaptive Region of Interest (AROI) extraction and adaptation by integrating the visual attention model in the human visual system. The scheme are applied to the Region of Interest (ROI) based on video coding for adaptation and delivery, by embedding the anchor point of focusing Macroblock (MB) in each key frame and motion vectors in other frames in the coded video stream or the sequence parameter set in the Scalable Video Coding (SVC). The error resilience tool FMO can be used to define certain of ROI in SVC, while the slice groups can be used to constitute a number of columns covering the frame by some elaborated tiled partitions in order to meet the mobile terminals with different resolutions.

Wang and Tu [16] introduce an adapter FMO type, which classifies the MBs into important and unimportant slices. The important slice involves the details of the frames which represent the important contents. The complexity of MB content and texture change which are used to judge the importance of the MB. The unimportant MBs are divided into two slices based on edge match rule, which contributes to the error concealment in the decoder. The important slice is protected than the unimportant slice in the receiver so that the subjective quality of the reconstruction frame will be improved greatly. The proposed of adapter FMO scheme is to increase the error resilience of the encoded video stream and contribute to the error concealment realization in the decoder. The adapter FMO strategy is suitable technique for the video transmission over low bandwidth.

Aziz et al. [3] present a technique to overcome the freezing frames problem on the mobile device and providing a smooth video playback over a wireless network. The frames in the streaming video will be splitted into four sub-frames on the server side and transmitted over Multiple-Input Multiple-Output (MIMO) by using the Multiple Descriptions Coding (MDC) technique. Where an initial delay time had been set between different channels to avoid the interruption on the sub-frames that are belong to the same frame. In case of the sub-frames that belonging to any subsequence are lost during the transmission, a reconstruction mechanism will be applied in the mobile device to recreate the missing pixels that are belongs to the missing sub-frames based on the average of the neighbouring pixels.

To overcome the transmission of each frame over MIMO and to increases the ability to handle long losses during the transmission over unreliable network. A splitting technique is proposed to deal with the sub-frames as equally important, by splitting the frames into sub-frames and cross them with another sub-frame from different sequence position.

The initial idea is been proposed in [4], where the frames been splitted into two sub-frames, where one sub-frame contains the even pixels and another contains the odd pixels. The combination of the sub-frame with another sub-frame from different sequences positions within the same transmission rate. The combined sub-frames will be streamed over a single wireless channel. In case of the frame being lost the available sub-frame in the mobile device will be reconstruct based on the surrounding pixels, while the maximum frames sequence lost that can be tolerated is half second.

The work has been extended to tolerate a maximum frame sequence lost up to six seconds (in worst cases), while the adaption mechanism allow us to stream up to one fourth (skipping three sub-frames) of the video frames to the mobile device according to the proposed technique. The reconstruction to the sub-frames in the video sequence will be measured by the Structural Similarity (SSIM) index.

III. THE PROPOSED TECHNIQUE

Mobile video streaming is characterized by low resolutions and low bit rates. The bit rates are limited by the capacity of UMTS radio bearer and the restricted processing power of the mobile terminals. The commonly used resolution is Quarter Common Intermediate Format (QCIF, 176 x 144 pixels) for mobile phones [8].

Mobile real time applications like video streaming suffer from high loss rates over the wireless networks [12] and the effect of that the mobile users may notice some sudden stop during the playing video, the picture is momentarily frozen. The frozen pictures could occur if a sequence of video frames is lost.

Distribute the frame’s pixels as sub-frames over the streaming video is considered in this work by splitting each frame into four sub-frames [3], where each sub-frame contains one fourth of the main frame pixels, as shown in Figure 1. The crossing technique will be applied after splitting the frames as sub-frames and it will be crossed with other sub-frames that are from different frame sequence position.

During the interactive mode where the mobile clients request the connection to the video server, the server will start streaming the frames based on the frames splitting and frames crossing technique, as shown in Figure 2, 3 and 4, respectively.

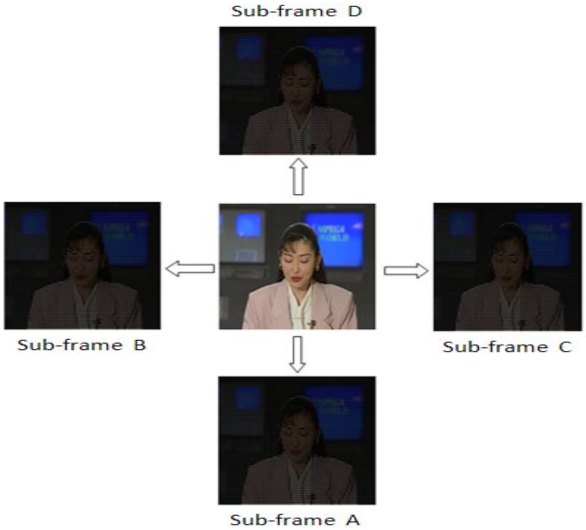


Figure 1. Snapshot of Akiyo frame splitting.

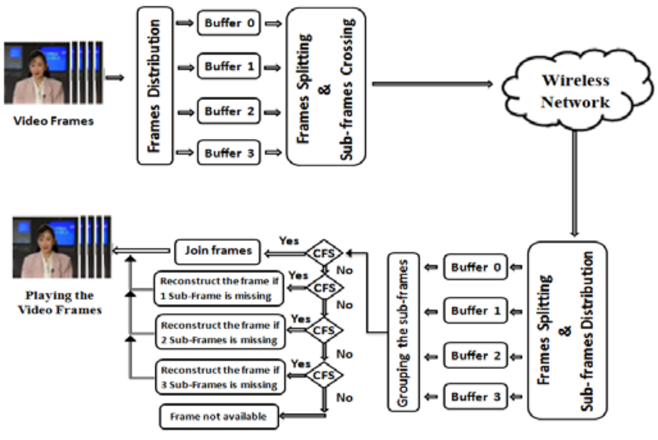


Figure 2. Streaming video as sub-frame crossing over wireless network.

Each video frame is splitted into **s** sub-frames, where **s = 0,…S-1**, where **s** is four sub-frames (**A**, **B**, **C**, **D**), as shown in Figures 1 and 3(a), respectively.

Each sub-frame contains different pixels information which make it possible to implement the frames crossing technique among the frames groups to created the new frames crossing (**FC**).

The sequence of the video frames will be grouped in the streaming server according to the transmission rate per second as a frames group (**FG**), as shown in Figure 3(a), where **g** is the index of the frames group, **g** = **0,…, G-1**.

To implement the frames crossing technique between different frames in different group where **i** is the index of the frames group crossing (**FGC**) where **i** = **0,…, S-1**, where the sub-frames **s** of group **g** of the **FGC i** is obtained as

$$FGC_i\,(g,s) = sF(G.\,((s + i) \bmod S\,) + g\,,\, s), \tag{1}$$

and are illustrated in Figures 3 and 4, respectively.

Crossing the sub-frames among the frames groups is required **s** buffers to queue the **FG**s, where the buffer size is equal to the frames rate, as shown in Figure 2. As an example, the first frames group **FG0** will be queued in buffer 0, and the second **FG1** will be queued in buffer 1, the third **FG2** will queued in buffer 2, and the fourth **FG3** will be queued in buffer 3. During the process of each buffer the next arrival group of frames, which is the fifth **FG4**, will be queued in buffer 0 and so on.

The transmission rate are considered in this work is 30 frames per second, where the frames group (**FG**) size will be 30 frames, during the arrival of the streaming video; the first 30 frames (**FG0**) will be splitted into four sub-frames, as shown in Figure 1 and 3(a). The same technique will be applied to the arrival of the second 30 frames (**FG1**) and so on.

When the first frame from the fourth group (**FG3**) of 30 frames arrived, the frames will be splitted into four sub-frames and the crossing technique will be applied immediately to distribute the frames pixels among the four groups in the streaming video, as shown in Figure 3.

$$\begin{array}{llcccc}
 & & A & B & C & D \\
 & 0 & sF_{0,0} & sF_{0,1} & sF_{0,2} & sF_{0,3} \\
 & 1 & sF_{1,0} & sF_{1,1} & sF_{1,2} & sF_{1,3} \\
FG0 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & g & sF_{g,0} & sF_{g,1} & sF_{g,2} & sF_{g,3} \\
 & g+1 & sF_{g+1,0} & sF_{g+1,1} & sF_{g+1,2} & sF_{g+1,3} \\
 & g+2 & sF_{g+2,0} & sF_{g+2,1} & sF_{g+2,2} & sF_{g+2,3} \\
FG1 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & 2g & sF_{2g,0} & sF_{2g,1} & sF_{2g,2} & sF_{2g,3} \\
 & 2g+1 & sF_{2g+1,0} & sF_{2g+1,1} & sF_{2g+1,2} & sF_{2g+1,3} \\
 & 2g+2 & sF_{2g+2,0} & sF_{2g+2,1} & sF_{2g+2,2} & sF_{2g+2,3} \\
FG2 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & 3g & sF_{3g,0} & sF_{3g,1} & sF_{3g,2} & sF_{3g,3} \\
 & 3g+1 & sF_{3g+1,0} & sF_{3g+1,1} & sF_{3g+1,2} & sF_{3g+1,3} \\
 & 3g+2 & sF_{3g+2,0} & sF_{3g+2,1} & sF_{3g+2,2} & sF_{3g+2,3} \\
FG3 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & 4g & sF_{4g,0} & sF_{4g,1} & sF_{4g,2} & sF_{4g,3} \\
 & 4g+1 & sF_{4g+1,0} & sF_{4g+1,1} & sF_{4g+1,2} & sF_{4g+1,3} \\
 & 4g+2 & sF_{4g+2,0} & sF_{4g+2,1} & sF_{4g+2,2} & sF_{4g+2,3} \\
FG4 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & 5g & sF_{5g,0} & sF_{5g,1} & sF_{5g,2} & sF_{5g,3} \\
 & 5g+1 & sF_{5g+1,0} & sF_{5g+1,1} & sF_{5g+1,2} & sF_{5g+1,3} \\
 & 5g+2 & sF_{5g+2,0} & sF_{5g+2,1} & sF_{5g+2,2} & sF_{5g+2,3} \\
FGg-1 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & g-1 & sF_{g-1,0} & sF_{g-1,1} & sF_{g-1,2} & sF_{g-1,3}
\end{array}$$

a. The sub-frames that are related to the original frame sequence.

$$\begin{array}{llcccc}
 & & A & B & C & D \\
 & FC0 & sF_{0,0} & sF_{g+1,1} & sF_{2g+1,2} & sF_{3g+1,3} \\
 & FC1 & sF_{1,0} & sF_{g+2,1} & sF_{2g+2,2} & sF_{3g+2,3} \\
FGC0 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & FCG-1 & sF_{G-1,0} & sF_{2G-1,1} & sF_{3G-1,2} & sF_{4G-1,3}
\end{array}$$

b. The crossing frames position for FGC1.

$$\begin{array}{llcccc}
 & & A & B & C & D \\
 & FCg+0 & sF_{g+1,0} & sF_{2g+1,1} & sF_{3g+1,2} & sF_{0,3} \\
 & FCg+1 & sF_{g+2,0} & sF_{2g+2,1} & sF_{3g+2,2} & sF_{1,3} \\
FGC1 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & FC2G-1 & sF_{2G-1,0} & sF_{3G-1,1} & sF_{4G-1,2} & sF_{G-1,3}
\end{array}$$

c. The crossing frames position for FGC2.

$$\begin{array}{llcccc}
 & & A & B & C & D \\
 & FC2g+0 & sF_{2g+1,0} & sF_{3g+1,1} & sF_{0,2} & sF_{g+1,3} \\
 & FC2g+1 & sF_{2g+2,0} & sF_{3g+2,1} & sF_{1,2} & sF_{g+2,3} \\
FGC2 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & FC3G-1 & sF_{3G-1,0} & sF_{4G-1,1} & sF_{G-1,2} & sF_{2G-1,3}
\end{array}$$

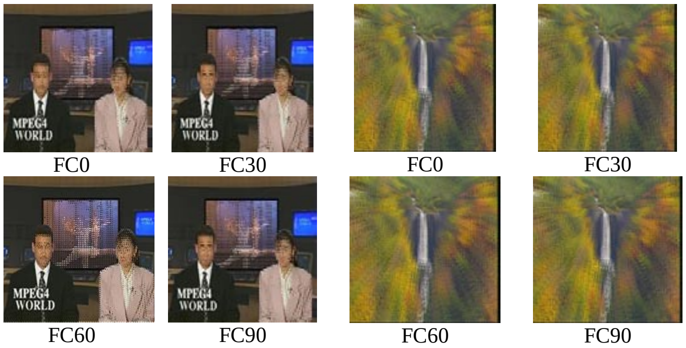
d. The crossing frames position for FGC3.

$$\begin{array}{llcccc}
 & & A & B & C & D \\
 & FC3g+0 & sF_{3g+1,0} & sF_{0,1} & sF_{g+1,2} & sF_{2g+1,3} \\
 & FC3g+1 & sF_{3g+2,0} & sF_{1,1} & sF_{g+2,2} & sF_{2g+2,3} \\
FGC3 & : & : & : & : & : \\
 & : & : & : & : & : \\
 & FC4G-1 & sF_{4G-1,0} & sF_{G-1,1} & sF_{2G-1,2} & sF_{3G-1,3}
\end{array}$$

e. The crossing frames position for FGC4.

Figure 3. The position of the sub-frames in the video sequence.

a. Akiyo b. Foreman



c. News d. Waterfall

Figure 4. Snapshot for the Sub-frame crossing.

The crossing technique is implemented based on the frames crossing; where the frames crossing (**FC**) contains four different sub-frames from different **FG**s that belong to the same group. As an example, the first frame crossing **FC0** will contains the sub-frame **A** from frame number 0, sub-frame **B** from frame number 30, sub-frame **C** from frame number 60, and sub-frame **D** from frame number 90, while the second **FC1** will contains the sub-frame **A** from frame number 1, sub-frame **B** from the frame number 31, sub-frame **C** from frame number 61, and sub-frame **D** from frame number 91. In another way, the streaming video will be based on the sub-frames crossing and it will be transmitted as;

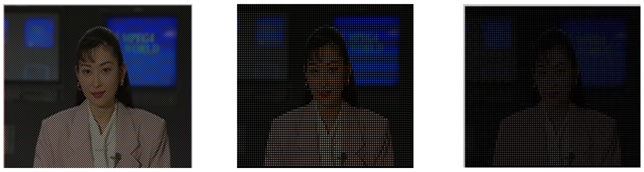
FC0(A0,B30,C60,D90),**FC1**(A1,B31,C61,D91),…, **FC30**(A30,B60,C90,D120),**FC31**(A31,B61,C91,D1),…, **FC60**(A60,B90,C120,D30),**FC61**(A61,B91,C1,D31),..., **FC90**(A90,B120,C30,D60),**FC91**(A91,B1,C31,D61),…, **FC120**(A120,B30,C60,D90),.., and so on, as shown in Figures 3 and 4 respectively.

The cost for implementing the proposed technique will be 3 seconds as an initial delay time, where the delay time is the time to queue **FG0**, **FG1**, **FG2**, for splitting and waiting for the fourth **FG3**, the time of the first frame from **FG3** arrived it will be split and combine them with another frames from **FG0**, **FG1**, **FG2** based on the proposed technique been described early. In this case we manage to distribute the frames pixels from different frame numbers and from different frames positions in the streaming video.

The crossing technique will be applied to all the frames in the video streaming sequence and it will be transmitted over a single channel. The reason behind that, if there is lost or dropped of sequence of frames from the streaming video and under different networks condition. The effect will be on at least one fourth of the sub-frames from the four different sub-frames that are in different positions.

The quality of the video will be affected and it will be distributed on the streaming video frames.

After each frame has been received by the mobile device, a splitting frame technique will be applied. The sub-frames will be held in different buffers and according to the order they been splitted at the server side, as shown in Figure 2. The sub-frames will be distributed to the relevant buffers and the combination of the sub-frames that are related to the same frame and according to their sequence positions based on switching between buffers to create the original frames sequences for the streaming video.



a. One sub-frame is missing b. Two sub-frames is missing c. Three sub-frames is missing

d. Reconstruct one missing sub-frame e. Reconstruct two missing sub-frames f. Reconstruct three missing sub-frames

Figure 5. Akiyo snapshots of the missing and the reconstruction to the sub-frames.

The check frame sequence (CFS) procedures will take place in the mobile device, to check the availability of the sub-frames. The CFS and the reconstruction mechanism are used to identify the missing sub-frames and to reconstruct the missing pixels from the frames by considering the following checking procedures [3], and as shown in Figure 5;

- The first CFS will check whether all the sub-frames that are related to the same original frame are available. If the four related sub-frames are available, then a joining mechanism will be applied to return the frame to it is original shape.
- The second CFS will check if at least three sub-frames are available. If one sub-frame is missing, then the average of the neighbouring pixels will be calculated to replace the missing frame pixels.

- The third CFS will check if at least two sub-frames are available. If two sub-frames are missing, then the average of the neighbouring pixels will be calculated to replace the missing sub-frame pixels.
- The fourth CFS will check if at least one sub-frame is available. If three sub-frames are missing, then the average of the neighbouring pixels will be calculated twice, the first time to find the half of the frame and the second time to return the full frame to it is normal shape.

IV. RATE ADAPTION

Rate adaptation for streaming video is regarded as it necessary mechanism to handle the network conditions, and the fluctuations of the network bandwidth.

The adaption rate for the sub-frames crossing technique should be considered carefully to avoid skipping the sub-frames that belonging to the same frame and with the consideration of the available bandwidth and network interruption to the streaming video. The adaption rate can be implemented by not considering the combination of the four sub-frames and transmitting either three or two or one sub-frame to the mobile device and according to the following adjustments cases:

- 25% adjustment, the streaming server will skip only one sub-frame from the video frames sequence, as shown in Figure 5 (a).
- 50% adjustment, the streaming server will skip two sub-frames from the video frames sequence, as shown in Figure 5 (b).
- 75% adjustment, the streaming server will skip three sub-frames from the video frames sequence, as shown in Figure 5 (c).

The rate adaptation mechanism is needed to adjust the transmission rate based on the congestion level. The server will adjust the transmission rate by skipping the sub-frames that are not related to each other and the skipping rate limits shouldn't cross 75% from the frames pixels to avoid discard to the sub-frames that are related to the same video frame. The receiving sub-frames will be reconstruct to it is original frames, as shown in Figure 5.

V. RESULTS AND DISCUSSIONS

In the normal situation, when the streaming video is transmitted over a single channel, the mobile device will start receiving the video frames and it will be held in the buffers until the mount of frames rate are arrived to start playing the video. While real time video streaming suffers from high loss rates over wireless networks [17], the result of that, the users may notice a sudden stop during the video playing. The picture is momentarily frozen, followed by a jump from one scene to a totally different one.

The proposed technique is based on sub-frames crossing for the video test sequences Akiyo, Foreman, News, and Waterfall, as it is a well known professional test sequences [19], with a transmission rate of 30 frames per second.

The quality to the reconstructed sub-frames is expressed in terms of the Structural Similarity (SSIM) Index [18]. The SSIM index will measure the reconstructed video frames to the reference frames, as shown in Figures 6, 7, and 8 respectively.

Considering the same losing frame sequence in [3], where the number of frames are lost are 20 frames as light lost rate from the streaming video, then the affect of losing frames will be distributed on the streaming sequence and the affect will be on 80 frames, as these frames will loss one sub-frame. As an example, if the frame losses is started from frame 121 to 140, then the effect of losing one sub-frame will affect the frames sequence from 121 - 140, 151 - 170, 181 - 200, and from 211 - 230, as the losses of these frames are fall in the same crossing group. The frames that lost the sub-frame it will be reconstructed and therefore, the quality level of the frames will be affected.

If the numbers of frames are lost are 40 frames as medium lost rate from the streaming video, then the affect of losing frames will be distributed on the streaming sequence and the affect will be on 120 frames, as some frames will lose one sub-frame while others will lose two sub-frames. As an example, if the loss of frames starts from frame 121 to 160 then the effect of losing one sub-frame from 131-150, 161-180, 191-210, 221-240. While the following frames sequence will lose two sub-frames will affect the frames 121-130, 151-160, 181- 190, 211-220. Therefore, the quality level of the video will be distributed on the video sequence after been reconstructed as some video frames loss one sub-frame and others will loss two sub-frames.

If the numbers of frames are lost are 60 frames as high lost rate from the streaming video, then the effect of losing frames will be distributed on the streaming sequence and the effect will be on 120 frames. As an example, if the falls of frame losses are started from frame 121 to 180, then the affect of losing sub-frames will affect the frames from 121 to 240 as all the effected frames will loss two sub-frames. The receiving sub-frames will be reconstructed in the mobile devices to return the missing pixels for each frame and played in the mobile screen with less quality than the original frames.

The losses duration can be handle in this technique is up to six seconds, as shown in Figure 3. If the losses occur in the **FGC1**, **FGC2**, **FGC3**, **FGC4**, **FGC5**, and **FGC6**, the mobile device will received the following sequence of one sub-frame from 0 until 239, as these sub-frames are received by **FGC0** and **FGC7**.

The adaption rate is also considered in this paper, where the server can skip either one, or two, or three sub-frames, where the quality level of the video will be affected according to the adaption rate, as shown in Figure 8. Skipping three sub-frames shows low quality than skipping two or one sub-frame. The Waterfall video shows better results as the pixels of the video frames have similar data where the reconstruction mechanism didn't been effected that much, while the News video is been effected highly by the reconstructions mechanism as it is quite motion video and it can be seen clearly in Figure 6.

Original frame

The reconstruction for one sub-frame missing

SSIM : 0.955

Original frame

The reconstruction for one sub-frame missing

SSIM : 0.948

The reconstruction for two sub-frames missing

SSIM : 0.929

The reconstruction for three sub-frames missing

SSIM : 0.911

The reconstruction for two sub-frames missing

SSIM : 0.941

The reconstruction for three sub-frames missing

SSIM : 0.907

a. Akiyo

b. Foreman

Original frame

The reconstruction for one sub-frame missing

SSIM : 0.939

Original frame

The reconstruction for one sub-frame missing

SSIM : 0.982

The reconstruction for two sub-frames missing

SSIM : 0.923

The reconstruction for three sub-frames missing

SSIM : 0.874

The reconstruction for two sub-frames missing

SSIM : 0.972

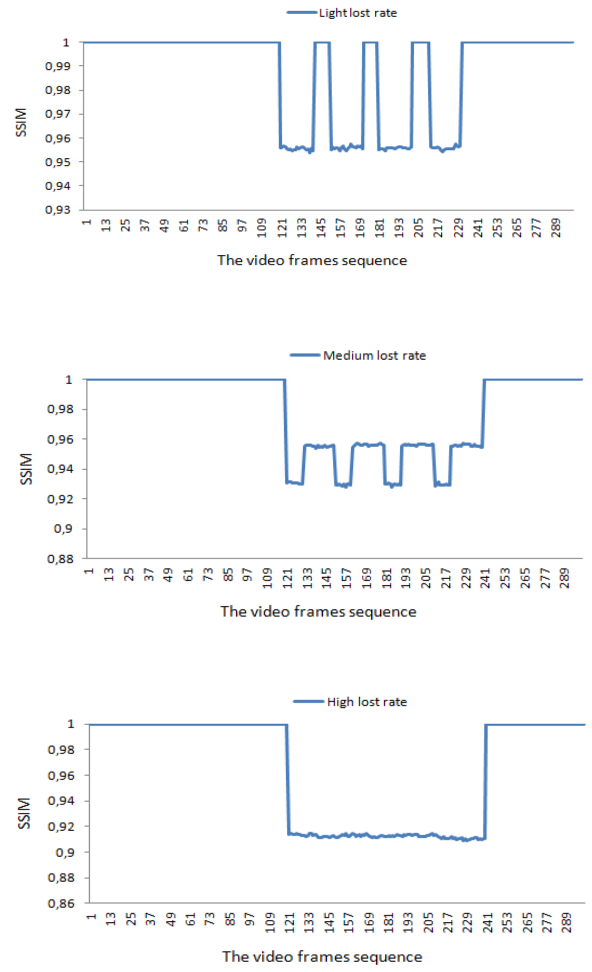
The reconstruction for three sub-frames missing

SSIM : 0.945

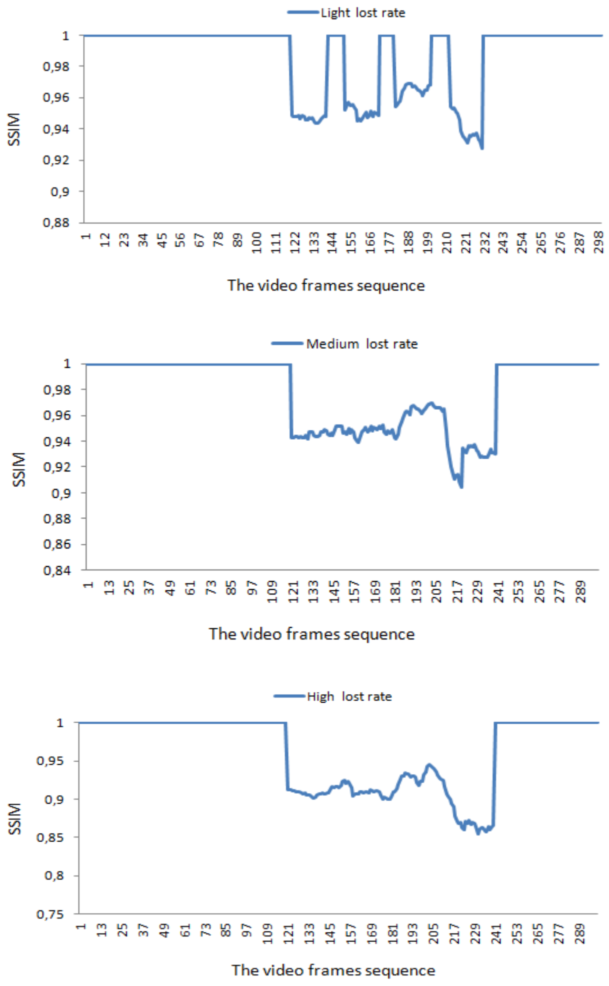
c. News

d. Waterfall

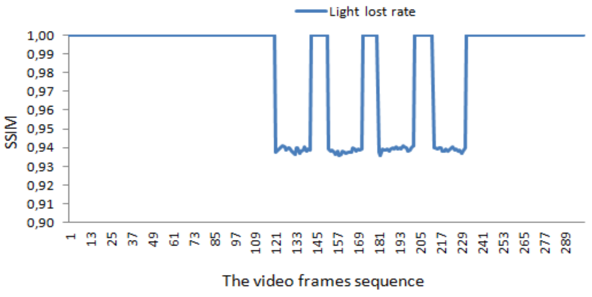
Figure 6. The SSIM for the frame number 140.

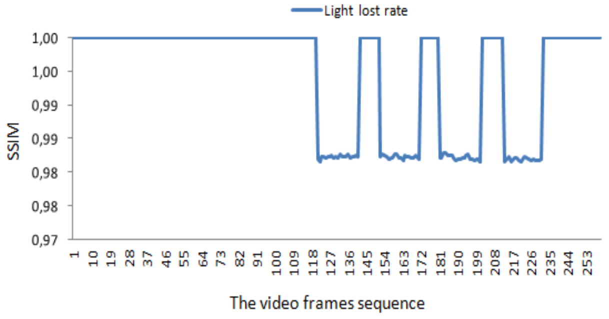


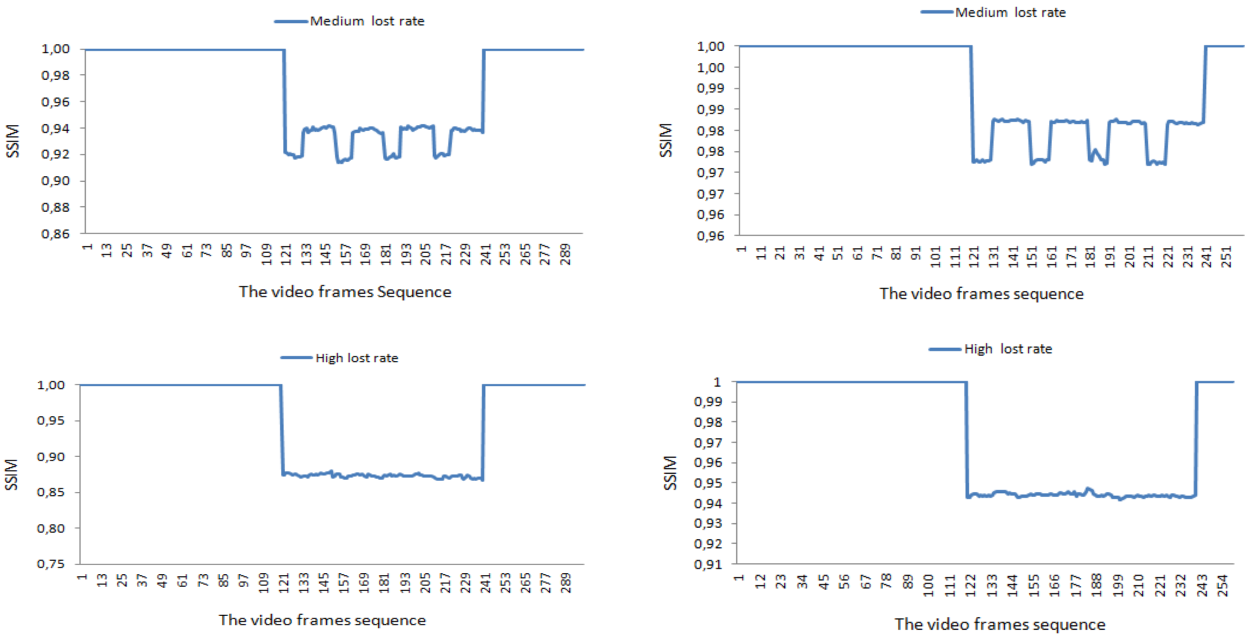
a. Akiyo



b. Foreman



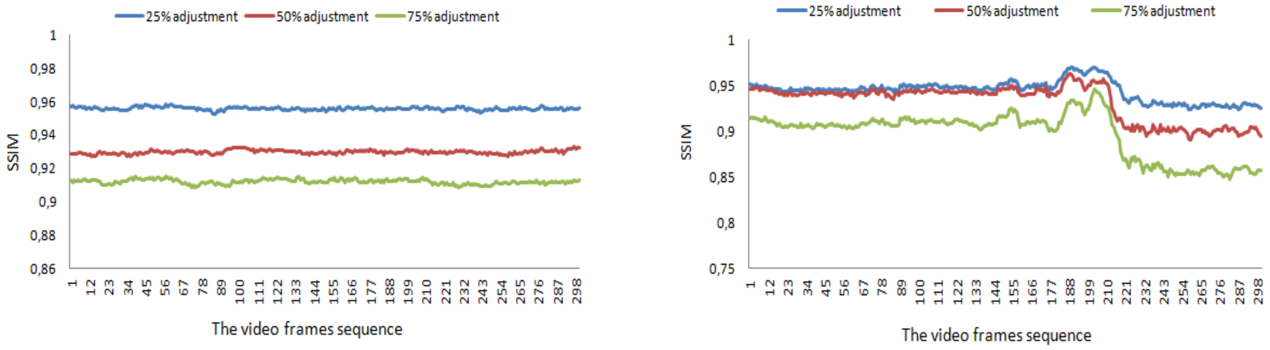




c. News

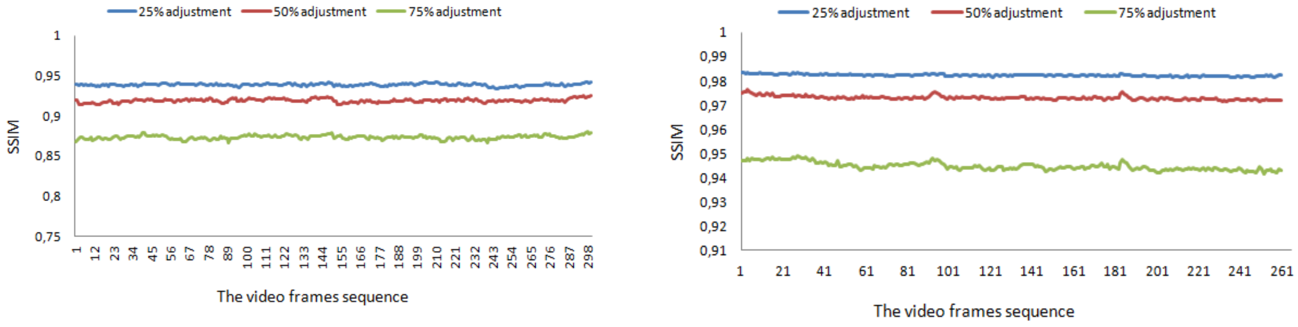
d. Waterfall

Figure 7. The SSIM for video frames after the lost been distributed and reconstructed to the sub-frames.



a. Akiyo

b. Foreman



c. News

d. Waterfall

Figure 8. The SSIM for the reconstruction sub-frames for the adaption rate to the video frames sequence.

VI. CONCLUSION

In this paper, we proposed a sub-frames crossing technique to distribute the pixels as sub-frames in different positions in the sequence of the streaming video by combining it with other sub-frames from different positions. The idea behind that is to eliminate the losses of the complete single frame and allow at least one fourth of the frame (one sub-frame) to be received by the mobile device. The receiving sub-frames will reconstruct based on the neighboring pixels to replace the missing pixels.

From the results, it is shown that our proposed technique provides a promising direction for eliminating the frozen picture in the mobile screen, that been caused by missing frames from the streaming sequence. Adjusting the number of frames according to the bandwidth changes is highly needed to reduce the amount of data to be transmitted to the mobile device in a congested network.

However, the quality of the played video is degraded and it depends on the number of frames that are lost or skipped. The numbers of buffers are needed will be equivalent to the number of crossing group, while the initial delay time it needed to implement the crossing technique.

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REFERENCES

[1] G. Bai and C. Williamson, “The Effects of Mobility on Wireless Media Streaming Performance,” Proc. of the Wireless Networks and Emerging Technologies (WNET 04), July 2004, pp. 596-601.

[2] G.-R. Kwon, S.-H., Park, J.-W. Kim, and S.-J. Ko, “Real-Time R-D Optimized Frame-Skipping Transcoder for Low Bit Rate Video Transmission,” Proc. of the 6th IEEE International Conference on Computer and Information Technology (CIT 06), Sept. 2006, pp. 177-177,doi: 10.1109/CIT.2006.158.

[3] H. M. Aziz, M. Fiedler, H. Grahn, and L. Lundberg, “Streaming Video as Space – Divided Sub-Frames over Wireless Networks,” Proc. of the 3rd Joint IFIP Wireless and Mobile Networking Conference (WMNC 10), Oct. 2010, pp.1-6, doi: 10.1109/WMNC.2010.5678760.

[4] H. M. Aziz, H. Grahn, and L. Lundberg, “Sub-Frame Crossing for Streaming Video over Wireless Network,” Proc. of the 7th International Conference on Wireless On-demand Network Systems and Services (WONS 10), Feb. 2010, pp. 53 – 56, doi: 10.1109/WONS.2010.5437132.

[5] H. Zhu, H. Wang, I. Chlamtac, and B. Chen, “Bandwidth Scalable Source-Channel Coding for Streaming Video over Wireless Access Networks,” Proc. of Wireless Networking Symposium (WNCG 03), Oct. 2003.

[6] H. Luo, M.-L., Shyu, and S.-C. Chen, “An End-to-End Video Transmission Framework with Efficient Bandwidth Utilization,” Proc. of the IEEE International Conference on Multimedia and Expo (ICME 04), June 2004, pp. 623-626, doi: 10.1109/ICME.2004.1394269.

[7] J.-Y. Chang and H.-L. Chen, “Dynamic-Grouping Bandwidth Reservation Scheme for Multimedia Wireless Networks,” IEEE Journal on Selected area in Communications, vol. 21, Dec. 2003, pp. 1566-1574**,** doi**:** 10.1109/JSAC.2003.814863.

[8] M. Ries, O. Nemethova, and M. Rupp, “Performance Evaluation of Mobile Video Quality Estimators,” Proc. of the European Signal Processing Conference (EUSIPCO 07), Sept. 2007, pp. 159-163.

[9] P. Antoniou, V. Vassiliou, and A. Pitsillides, “ADIVIS: A Novel Adaptive Algorithm for Video Streaming over the Internet,” Proc. of the 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC’07), Dec. 2007, doi: 10.1109/PIMRC.2007.4394583.

[10] R. Weber, M. Guerra, S. Sawhney, L. Golovanvsky, and M. Kang, “Measurement and Analysis of Video Streaming Performance in Live UMTS Networks,” Proc. of the 13th International Symposium on Wireless Personal Multimedia Communications (WPMC 06), Sept. 2006, pp. 1-5.

[11] S. Cen, C. Pu, and R. Staehli, “A Distributed Real-time MPEG Video Audio Player”, Proc. of the 5th International Workshop on Network and Operating System Support of Digital Audio and Video, LNCS, 1995, pp. 142-153, doi: 10.1007/BFb0019263.

[12] T. Nguyen, P. Mehra, and A. Zakhor, “Path Diversity and Bandwidth Allocation for Multimedia Streaming,” Proc. of the International Conference on Multimedia and Expo (ICME 03), July 2003, pp. 1-4.

[13] T.Y. Huang, “Region of Interest Extraction and Adaptation in Scalable Video Coding,” Proc. of the 7th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD 10), Aug. 2010, pp. 2320-2323, doi: 10.1109/FSKD.2010.5569822.

[14] X. Cao, G. Bai, and C. Williamson, “Media Streaming Performance in a Portable Wireless Classroom Network,” Proc. of IASTED European Workshop on Internet Multimedia Systems and Applications (EuroIMSA´05), Feb. 2005, pp. 246-252.

[15] X. Zhu and B. Girod, “Video Streaming over Wireless Networks,” Proc. of the European Signal Processing Conference (EUSIPCO 07), Sept. 2007, pp: 1462-1466.

[16] X. Wang and X. Tu, “Adaptive FMO Strategy for Video Transcoding,” Proc. of the International Conference on Communications, Circuits and Systems (ICCCAS 09), July 2009, pp. 540 – 544, doi: 10.1109/ICCCAS.2009.5250462.

[17] Y. Wang, A. R. Reibman, and S. Lin, “Multiple Description Coding for Video Delivery,” Proc. of the IEEE Journal, vol. 93, Dec. 2004 pp. 57-70, doi: 10.1109/JPROC.2004.839618.

[18] Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, “Image Quality Assessment: From Error Visibility to Structural Similarity,” IEEE Transactions on Image Processing, vol. 13, April 2004, pp. 600-612, doi: 10.1109/TIP.2003.819861.

[19] http://trace.eas.asu.edu/yuv/index.html (visited, 1/11/2011)

[20] H. Schwarz, D. Marpe, and T. Wiegand, “Overview of the Scalable Video Coding Extension of the H.264/AVC Standard,” Proc. of the IEEE Transactions on Circuits and Systems for Video Technology, vol. 17, Sept. 2007, pp.1103-1120, doi: 10.1109/TCSVT.2007.905532.