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The Spatial-Temporal Characteristic of Video Content and Its Impact on the Quality of Wireless Conduits

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***Abstract*—Applications are constantly being developed with a view to maximizing bandwidth usage. This is necessitated by the overwhelming popularity of an ever-increasing wave of bandwidth intensive multimedia services that are constantly deployed to meet end user demands. All contemporary information communication systems and networks are expected to maintain the quality of these applications with different Quality of Service (QoS) levels. QoS requirements are generally dependent on the parameters of network and application layers of the OSI model. At the application layer QoS depends on factors such as resolution, bit rate, frame rate, video type, audio codecs, etc. At the network layer, distortions such as delay, jitter, packet loss, etc. are introduced. This paper presents simulation results of modeling video streaming over wireless communications networks. Simulation showed that different video subject groups affect the perceived quality differently when transmitted over networks. We show conclusively that in a transmission network with a small error probabilities ($BER = 10^{-6}$, $BER = 10^{-5}$), the minimum bit rate (128 kbps) guarantees an acceptable video quality, corresponding to MOS > 3 for all types of frames. It is also shown through analysis that the efficiency of error correction methods is I strongly correlation with the spatial-temporal properties of the analyzed video sequences.**

***Index Terms*— video streaming, trace file, BER, PSNR, MPEG Codec**

I. Introduction

The growing popularity of multimedia applications brings with it the attendant necessity for optimizing the distribution of telecommunication network bandwidth. To a certain extent, the quality of video playback is dependent on application type. For example, in the playback of highly dynamic events such as sports and films, it is imperative to maintain a high video quality, while for relatively static events such as newscast and videoconference the accent would be more on the content. Contemporary telecommunication networks are required to support the quality of different applications with varying QoS levels [1]. The requirements on QoS are as a rule dependent on network and application layer parameters [2]. At the application level, QoS depends on such factors as bit rate, frame speed, types of video- and audio-codecs, etc. Some distortions such as delay, jitter, packet loss, etc are introduced at the network level. Normally, data transmission over wired networks with limitless bandwidth is characterized by a very low probability of bit error occurrence. However, due to the unpredictability of real-time transmission conditions, communication over a wireless network has certain peculiarities [3], [4], [5]. Wireless channels are characterized by independent and randomly distributed bit errors. It is for this reason that the White Gaussian Noise (WGN) model is used in the modeling and simulation of wireless channels. In this model, a bit in the video sequence is distorted (inverted) with a priori probability. [6] – [8] give detailed explanation of the effect of bit error on video quality during transmission. The effect of different types of video subjects on the quality of video playback (for example from static e.g. newscast to highly dynamic e.g. sporting events) as related to the parameters of network and application layers is however not usually considered in the literature. The main objective of this paper is to fill this glaring gap. To this end we present two questions that are very important in relation to the network and application layers:

Q1. What is the minimum bit rate value for all types of video subjects for transmission over telecommunication networks that will guarantee acceptable QoS ($\mathrm{PSNR} > 27dB$), which corresponds to a $\mathrm{MOS} > 3$ [9]?

Q2. What is the acceptable number of error bits for all types of video subjects, and what consequently is the limit (threshold) vis-a-vis playback quality under which viewer experience remains of acceptable quality?

Q3. How efficient are the methods adopted for error correction in this work?

II. Experiment

In order to answer these questions, video clips were grouped based on their inherent spatial and time redundancies [10]. Next, an experiment of video transmission over a wireless network under various transmission conditions was conducted and the threshold for high, medium and low quality were consequently determined.

A. Classification of video into subject groups (SG)

The process of grouping video streams into different subject groups makes it possible to examine members of a particular group in terms of their similar characteristics. This allows for priority control and consequently optimization of the bandwidth of a given video stream. An automatic classification of video subject will make it possible to forecast video quality with a priori probability. Defining

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such dynamics is of great interest for video coding, since the space-time characteristics of video signal defines the effectiveness of the coding procedure. In addition to quality measurement, it is possible to calculate the spatial and time features of the video (Fig. 1). As such, predicting video quality in relation to the dynamics of the subject based on the change in MOS becomes possible [11].

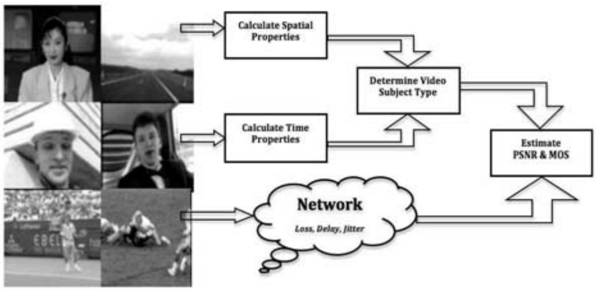

Fig. 1. Method of estimating video quality based on subject type

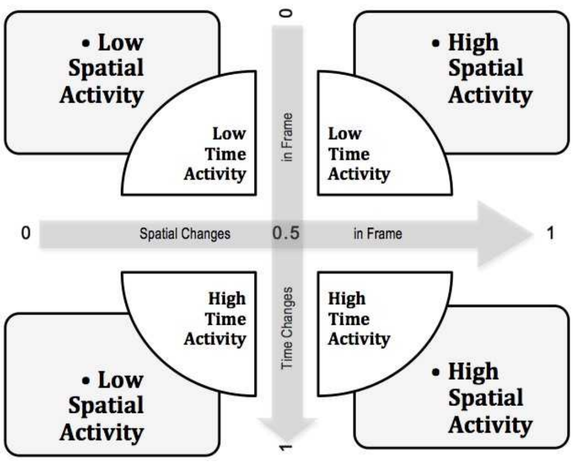

Fig. 2. Space-time diagram for video classification

The subject of each video clip may differ considerably from others depending on its dynamics (i.e. the spatial complexity and time activity of the image). In the space-time plan introduced in [9], each video clip (of limited duration and homogeneous content) may be presented in the Cartesian coordinate system, where the spatial characteristic is on horizontal axis, and the time characteristic is on the vertical axis (Fig. 2). In line with the approach depicted in Fig. 2, each video clip depending on the dynamics of its subject group may be classified into one of the following four categories, namely:

Low spatial-Low time activity (LSLT: Top left); High spatial-Low time activity (HSLT: Top Right); Low spatial-High time activity (LSHT: Bottom left) and High spatial-High time activity (HSHT: Bottom Right).

Suffice to note here that this classification will not be effective for video sequences that are of considerable duration, because of the inherent non-homogeneous nature of their content – a consequence of their length. Video clips are classified into different groups based on the spatial and time dynamics of change of picture elements (pixels) [11].

B. Calculation of time changes

Motion in a video clip is estimated using the Sum of Absolute Difference (SAD) indicator, which calculates the pixel-wise sum of absolute differences between two frames being compared. The formula for calcuating SAD is given in (1):

$$SAD_{n,m} = \sum_{i=1}^{N}\sum_{j=1}^{M}|B_n(i,j) - B_m(i,j)| \qquad (1)$$

where B_n , B_m are two NxM sized frames;
i, j are pixel coordinates.

C. Calculation of spatial changes

Spatial peculiarities are calculated at the edges of block segments, as well as through the contrast and brightness between current and previous frames. Brightness is calculated as the modal difference between the average brightness value of the previous and present frames using the formula in (2):

$$Br_n = \sum_{i=1}^{N}\sum_{j=1}^{M}\left|Br_{av(n)}(i,j) - B_{av(n-1)}(i,j)\right| \qquad (2)$$

where $Br_{av(n)}$ and $Br_{av(n\text{-}1)}$ – average brightness of nth frame with size NxM ; i and j – pixel coordinates.

Using equations (1) and (2), video sequences were grouped into three basic types of subjects [11] namely: 1) Static Subject Group (SSG) - which includes sequences with minimal observation area (e.g. face of a tele-presenter) on a static background (Fig. 3); 2) Pseudo Static Subject Group (PSSG), incorporating video sequences with continuous and homogeinic change in picture e.g. Movies (Fig. 4); and 3) Highly Dynamic Subject Group (HDSG) comprising of video sequences, where both local and global parts of the picture undergo abrupt and heterogeneous change e.g. sporting events (Fig. 5).
The subject classification adopted is based on the parameters described above. Due to the availability of a plethora of objective parameters, a statistical method was adopted for data analysis and subject classification. Each of subject type defined above is characterized by a unique set of statistical motion-related features.

D. Modeling of video streaming over a wireless network

Twelve standard test video clips of YUV format and resolution CIF (352×288) available in [12] and recommended in [13] by the ITU for carrying out test experiments were used as input test video sequences. The block diagram of the experimental setup is shown in Fig. 6. The input video sequence of YUV format is coded by an MPEG-2 codec with GOP type IBBPBBPBB. Each video was coded using a different bit rate (128, 384, 768, and 1,150 kb/s). Coding and decoding of the input video and modeling of a wireless network with random bit errors in its channel was achieved using the VCDemo software [14]. Simulation of video streaming over a wireless network was done in accordance with the OSI model on known layers: Application, Transport, Network, Data link and Physical.

Fig. 4. Examples of typical *pseudo static* video sequences: a) *Foreman*, b) *Flower*, c) *Highway*, d) *Bus*.

Fig. 3. Examples of typical *static* video sequences: a) *Akiyo*, b) *Hall* c) *Paris* d) *News*

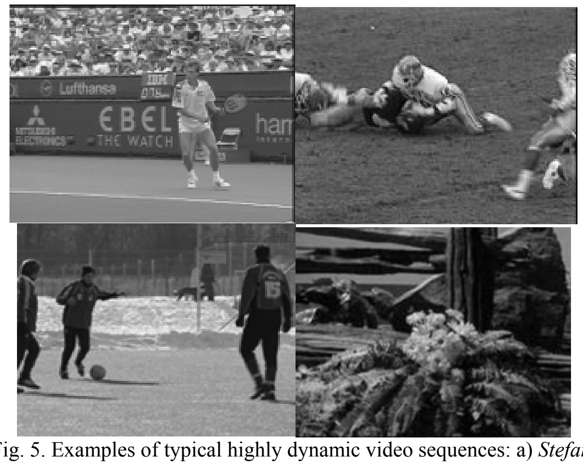

Fig. 5. Examples of typical highly dynamic video sequences: a) *Stefan*, b) *Football*, c) *Soccer*, d) *Tempete*.

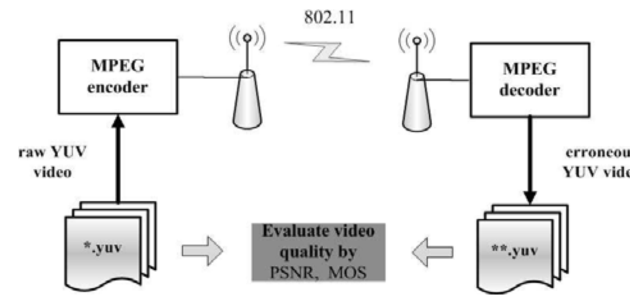

Fig. 6. Block diagram of experimental setup

Application layer: Coding, decoding and packetization of the video stream are done at the application layer of the OSI model. The video stream is divided into variable length packets of sizes up to 1,500 Bytes, with subsequent addition of a 12-Byte RTP heading. The addition of the RTP heading ensures that the MPEG bit stream is segmented in such a way that MPEG start codes are withheld in the beginning of data packets.
Transport layer: The UDP protocol is modeled at this layer, with the addition of heading and control sum (8 Bytes). A 20-Byte IP heading is subsequently added at the network layer.
Data Link layer: The modeling of IEEE 802.11 protocol is done at this layer. The channel bandwidth is set to 20 Mb/s.
Physical layer: Simulation of random bit error (WGN) in the channel with BER probability taken as equal to 10^{-4} and 10^{-3} is done at this layer.

Thus, changing of the parameters of transmitted video over wireless network was achieved both for the application layer (by changing the bit rate speed) and the network layer (by changing BER). The Peak Signal-to-Noise Ratio (PSNR) and Mean Opinion Score (MOS) were used as quality indicators [15]. Transmission of each video clip over the network was simulated 16 times with different settings.

III. Results and Discussion

A large quantity of experimental data was generated in the course of the experiment reported in section 2.0 above. Average values of PSNR from different BER for varying bit rate values are presented in Fig. 7. From Fig. 7, it is seen that by increasing the BER to 10^{-4} for different bit rates, the average PSNR remains practically the same. This indicates that the quality of transmitted video clip remains unchanged a pointer to the fact that the decoder is able to correct errors at this BER level. For BER=10^{-4}, a slight change in quality is observed only for HDSG video sequences. However, a decrease in the average value of PSNR is observed for practically all the video clips for $10^{-3} \geq \text{BER} \geq 10^{-4}$. The highest degradation of 10 dB is gotten for the Soccer video. In addition to the average values, it is necessary to estimate the distribution of PSNR value for each experiment, since the average value cannot adequately depict the change in quality that occurs for different modeling conditions. The histograms of PSNR value distribution for the video clips are shown in

TABLE 1. PARAMETERS USED IN SIMULATION

A	B	C	A	B	C	A	B	C	A	B	C
1	128	10^{-6}	5	384	10^{-6}	9	768	10^{-6}	13	1150	10^{-6}
2	128	10^{-5}	6	384	10^{-5}	10	768	10^{-5}	14	1150	10^{-5}
3	128	10^{-4}	7	384	10^{-4}	11	768	10^{-4}	15	1150	10^{-4}
4	128	10^{-3}	8	384	10^{-3}	12	768	10^{-3}	16	1150	10^{-3}

A – Experiment serial №; B – Bit rate in kb/s; C – BER.

Fig. 8 through Fig. 10 for all the 16 modeled cases. The numbers 1 to 16 on the right horizontal axis represents the serial number of the experiment with the corresponding parameters given in Table 1.

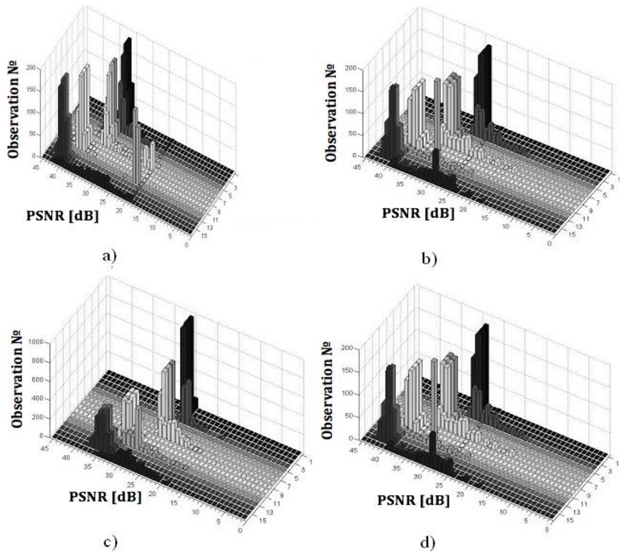

Fig. 8. PSNR distribution histograms for *SSG* video clips under various modeling conditions: a) *Akiyo*, b) *Hall* c) *Paris* d) *News*

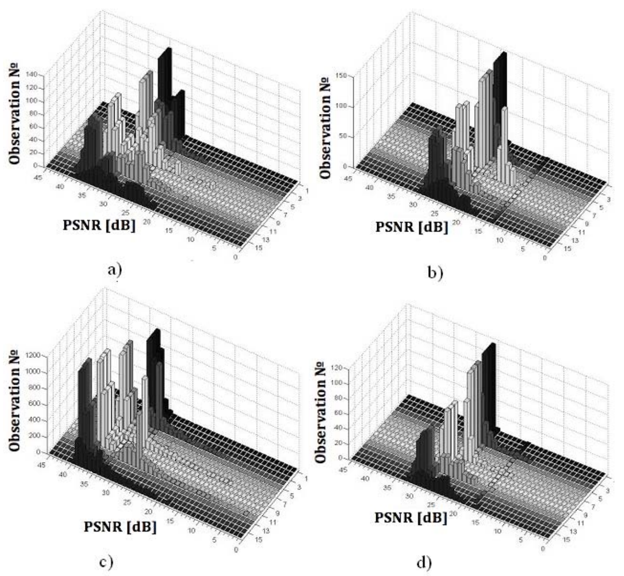

Fig. 9. PSNR distribution histograms for *PSSG* video clips under various modeling conditions: a) *Foreman*, b) *Flower*, c) *Highway*, d) *Bus*

We see from Fig. 8 through Fig. 10 that for BER values of $10^{-6}$and 10^{-5}, the distribution of quality indicator is practically identical and situated in the high PSNR region. For BER $= 10^{-4}$, the distribution of HDSG PSNR value is different when compared with those of other subject groups. In the case of BER $= 10^{-3}$ for different bit rate values, the distribution is spread out and tends toward the region of low PSNR values. This indicates degradation in the quality of transmitted video sequence. The presence of low PSNR value components in the distribution indicates the existence of frames with minimum acceptable quality. For example, the worst reception quality (PSNR $< 20\ dB$) is lowest for the SSG and higher for PSSG. The highest quantity is seen in HDSG.

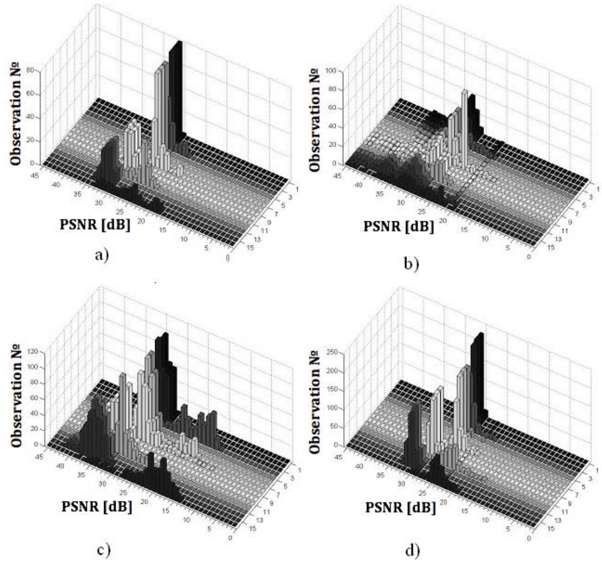

Fig. 10. PSNR distribution histograms for *HDSG* video clips under various modeling conditions: a) *Stefan*, b) *Football*, c) *Soccer*, d) *Tempete.*

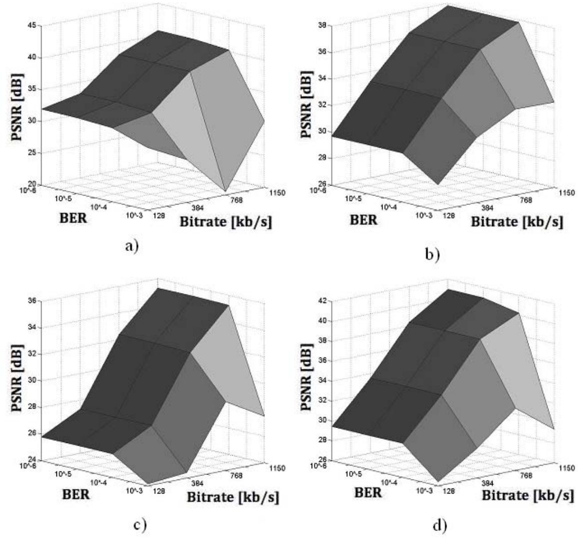

Fig. 11. Average PSNR value from *SSG* video clip Bit rate and BER values for various modeling conditions: a) *Akiyo*, b) *Hall* c) *Paris* d) *News*

We also note that an increase in the bit rate brings about a shift in PSNR towards its region of higher value. This is clearly observable for video sequences of the SSG type, where the difference between average PSNR values for 128 kb/s and 1,150 kb/s bit rates oscillates between 8 and 11 dB for BER $= 10^{-6}$, BER $= 10^{-5}$, and BER $= 10^{-4}$. For PSSG, this indicator comprises from 4 to 7 dB, and 4 to 6 dB for HDSG. We can infer from the foregone that an increase in the bit rate has most effect on SSG. The relationship between average PSNR value of video clips, Bit rate and BER is shown on Fig. 11 through Fig. 13. The general picture of changes in the average PSNR value while increasing bit rate and BER allows for drawing the following conclusions. For SSG, average value of PSNR for changes in bit rate from 128 kb/s to 1,150 kb/s has an upward increase from 32 dB to 41 dB (Akiyo) and from 30 dB to 38 dB (hall). It may be noted that increasing error level to BER $= 10^{-4}$ has no effect on quality. However, for BER $= 10^{-3}$ the quality of SSG video clips degrades considerably down to 27 dB.

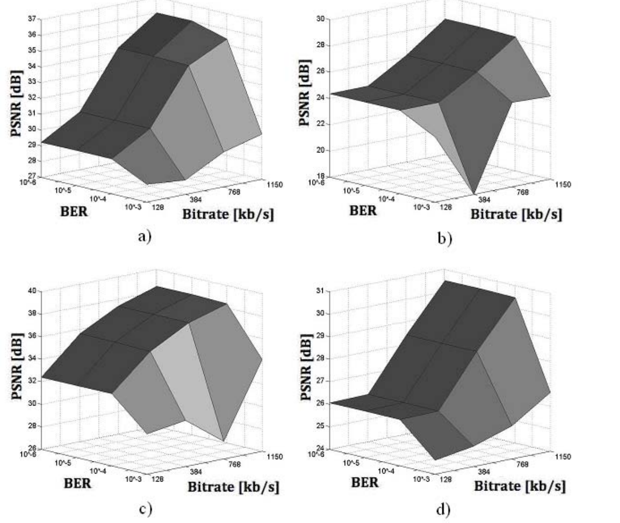

Fig. 12. Average PSNR value from *PSSG* video clip Bit rate and BER values for various modeling conditions: a) *Foreman*, b) *Flower*, c) *Highway*, d) *Bus*

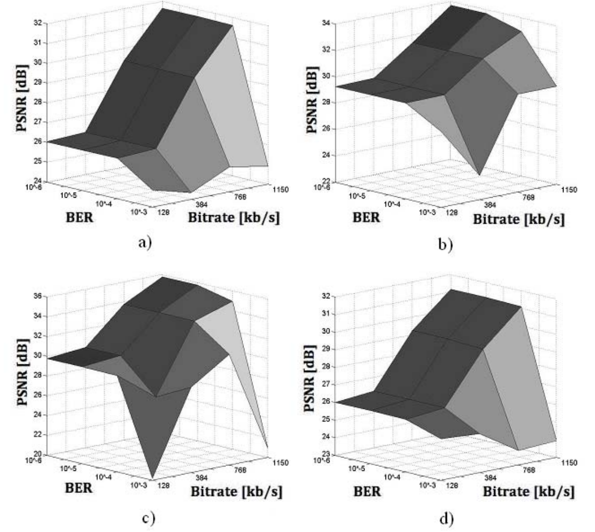

Fig. 13. Average PSNR value from video clip *HDSG* Bit rate and BER values for various modeling conditions: a) *Stefan*, b) *Football*, c) *Soccer*, d) *Tempete*.

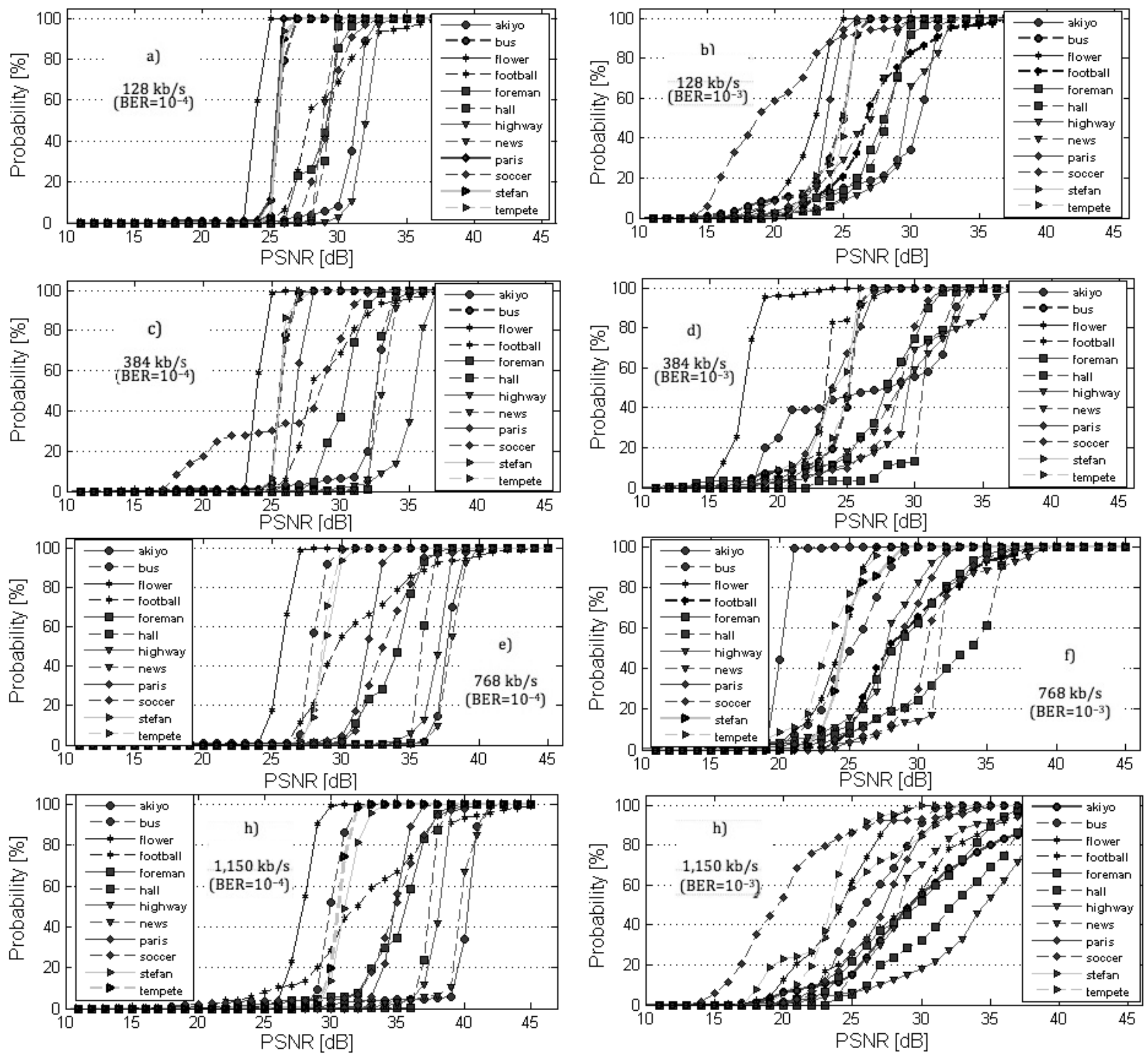

Fig. 14. Probability distribution of experimental data with different bit rates and BER: a) 128 kb/s (BER=10^{-4}); b) 128 kb/s (BER=10^{-3}); c) 384 kb/s (BER=10^{-4}); d) 384 kb/s (BER=10^{-3}); e) 768 kb/s (BER=10^{-4}); f) 768 kb/s (BER=10^{-3}); g) 1,150 kb/s (BER=10^{-4}); h) 1,150 kb/s (BER=10^{-3})

With an increase in bit rate from 128 kb/s to 1,150 kb/s, the average PSNR value for HDSG increases from 29 dB to 36 dB and from 32 dB to 38 dB for Forman and Highway respectively. It is obvious that an increase in error to BER=10^{-4} has practically no effect on signal quality for low bit rate values. For a bit rate of 1,150 kb/s, a slight degradation of 0.5 dB in quality is observed. It can be inferred that the decoder is incapable of reproducing the input video signal with moving elements under high bit rates and BER of 10^{-4}. With an increase in error to an error bit in every 1000 bits received (BER=10^{-3}), the quality of HDSG degrades to 28 dB for all bit rate values. For HDSG and with an increase in bit rate from 128 kb/s to 1,150 kb/s, the average PSNR value increases from 30 dB to 36 dB and from 29 dB to 34 dB for Soccer and Football respectively. A comparison with other subject groups reveals that a distinct degradation in quality is observable for $\mathrm{BER} = 10^{-4}$. This corroborates our earlier submission on the decoder's inability to reproduce the input picture with moving elements under high bit rate conditions given that $\mathrm{BER} = 10^{-4}$. With a further increase in $\mathrm{BER} = 10^{-3}$, average PSNR value decreases to 20 dB for bit rates of 128 and 1,150 kb/s.

The probability distribution of experimental data for different bit rate values is shown on Fig. 14a – 14h. The distribution values for $\mathrm{BER} = 10^{-6}, \mathrm{BER} = 10^{-5}$, $\mathrm{BER} = 10^{-4}$are almost identical and as such shall not be discussed. An interesting fact worth mentioning is the distribution of video clip data for different subject groups under low ($\mathrm{BER} = 10^{-4}$) and high ($\mathrm{BER} = 10^{-3}$) probability of error occurrence.

Probability distribution for 128 kb/s and BER=10^{-4} for twelve video clips lies in the region of 22 to 37 dB. The probability has an abrupt vertical rise for all videos, thus videos of different subject groups are practically identical. Probability distribution $\mathrm{BER} = 10^{-3}$for six video clips lies in the region of low PSNR with values from 13 to 37 dB. For HDSG we observe a high probability of poor quality occurrence (degradation by 10 dB).

Probability distribution for 384 kb/s, $\mathrm{BER} = 10^{-4}$for six videos lies in the region of 22 to 37 dB. And in similarity to previous bit rates, probability distribution for all videos has a vertical spiky character. For HDSG the distribution characteristic not unlike for 128 kb/s bit rate is less abrupt, indicating a high probability of poor quality occurrence.

Probability distribution for 768 kb/s, BER=10^{-4} for six videos lies in the region of 26 to 45 dB, which attests to a rise in the quality of all video clips. For almost all the videos, probability distribution has a vertical spiky character, showing constancy in quality.

For $\mathrm{BER} = 10^{-3}$the distribution has a slope shape, which indicates a high probability of occurrence of poor quality. The greatest change in quality is demonstrated by (akiyo) SSG video clip and (Football) HDSG video.

Probability distribution for 1,150 kb/s bit rate and $\mathrm{BER} = 10^{-4}$ for six videos lies in the region of 17 to 45 dB, which indicates a wide spread of quality. For SSG and PSSG, the distribution has a vertical spiky form in the region of high PSNR value. For PSSG and HDSG, the distribution is less abrupt, which indicates PSNR data heterogeneity tending towards low values. The probability distribution of all videos is of a slanting form, highly dispersed and lies in the region of 13 to 45 dB. The distribution has the most vertical form for HDSG, but lies in the low value region, which indicates the presence of a large number of poor quality frames.

IV. Analysis of Error Correction Methods

Errors occurring in the course of transmitting video signals over radio channels can result in loss of quality at the decoding stage, which is manifested as visible artifacts. It thus follows that such errors must be compensated for. For this purpose, both time and spatial correlation are done away with.

It is necessary to analyze both the video sequence and error characteristics in a bid to eliminate the error. This approach allows for qualitative error compensation. Knowledge of these characteristics is essential for choosing the right error compensation approach to adopt. The error compensation choice will depend on what was distorted during transmission – motion vector, prediction type or result.

It is important to know the amount of frames that were not distorted. If the error occurs in I frame, it will affect practically the whole sequence. It will lead to error propagation in all the frames up to the next block. If the error occurs in P frame, it will affect only part of the frames adjacent to the current frame. Correction of spatial errors is based on the strong correlation between video frames. Information for correction of error is gotten from frames adjacent to the distorted frame.

Each specific correction method is adopted for specific corresponding situation. The error correction methods are as a rule very simple. The following are the most widely adopted correction methods:

A. Copying

This is the simplest error correction method, in which the missing blocks from frame n are replaced with spatially corresponding blocks from frame n–1 according to equation (3).

$$F_n(i,j) = F_{n-1}(i,j) \tag{3}$$

B. Block Comparison

The best results in error correction can be achieved by using macro blocks $\mathrm{MB_D}$. Macro blocks are given top, bottom, right, and left boundaries given in equation (4):

$$[\hat{x},\hat{y}]_D = arg \min_{x,y\in A_D} \sum_{i,j\in MB_D} |F_{n-1}(x+i,y+j) - MB_D(i,j)| \tag{4}$$

where $\mathbf{A}_\mathrm{D}$ is a search region in the block $\mathrm{MB_D}$ for the best replacement for the missing macro block.

The final position of the best search result is defined as the average of the number of positions of all found blocks as given in equation (5):

$$\hat{x} = \frac{1}{M}\sum_D \hat{x}_D \ ; \ \hat{y} = \frac{1}{M}\sum_D \hat{y}_D \tag{5}$$

The appropriate macro block was found in the region with coordinates (x,y) out of the $\mathrm{F_{n-1}}$ possible options. It was subsequently used to replace the damaged block $\mathrm{F_n}$. In a bid to reduce the quantity of operations, only adjacent macro blocks are used for analysis.

C. *Remnant-free Decoding*

Remnant-free decoding is widely adopted in H.264 algorithms. It is possible to correct erroneous blocks in the presence of motion vectors, while there is an absence of remnants. Error correction will be particularly effective in the case where only a few number of pixels have been distorted.

D. *Elimination of Temporal Redundancy*

In the process of error correction, it is of imperative importance to exploit the knowledge of a presence of temporal correlation within video sequences. Estimation of motion vectors allows for the recovery of data lost during transmission over a wireless conduit.

E. *Averaging*

Each picture element $p(i,j)$ can be defined as an interpolation from the linear combination between the closest pixels. It should however, be noted that this method can only be adopted in cases where changes in brightness of the block is gradual; otherwise, visible artifacts will result.

F. *Remnant-free Decoding of I frames*

In the absence of a remnant, and given that the prediction is done correctly, the sequence becomes only decodable in cases with only a few distorted data blocks.

G. *Boundary Comparison*

Analysis of the effectiveness of error correction methods is done using the example of an *I* frame, containing information about luminance and two color components. For the comparison of different error correction algorithms, we consider the YUV color model since errors are easily hidden in luminance components.
With the aid of freely available software called *Joint Model* (JM 18.2) [15], we determine the Peak Signal-to-Noise ratio for the luminance component Y and the two color components U and V from equation (6):

$$PSNR_k^{(c)} = 10 \cdot log_{10} \frac{255^2}{MSE_k^{(C)}} \; [dB] \qquad (6)$$

Where parameter $\mathrm{MSE}_k^{(C)}$ characterizes the Mean Square Error in the luminance and color components. It is gotten from equation (7):

$$MSE_k^{(C)} = \frac{1}{M \cdot N} \sum_{i=1}^{N} \sum_{j=1}^{M} [\boldsymbol{F}(i,j) - \boldsymbol{F}_0(i,j)]^2 \qquad (7)$$

Where $N \times M$ is the size of the frame and $\mathbf{F_0}$ is the original (uncompressed and loss-free) frame of the color component c.
The software [15] also calculates the average value of the luminance and color signals for each frame separately using equation (8):

$$PSNR_{av}^{(c)} = \frac{1}{N_{fr}} \sum_{k=1}^{N_{fr}} PSNR_k^{(c)} \qquad (8)$$

Where N_{fr} is the serial number of the current frame.

Four different video sequences were analyzed in a bid to assess different methods of correcting errors occurring in communication channels, which result in loss of video packets during decoding, namely: Akiyo, Foreman, Football, and Video clip (Fig. 15).
We see from the graphs in Fig.15 that for static subject group (Akiyo video sequence), the best result is obtained by using the 'Remnant-free decoding' and 'Boundary comparison' methods. In this case, PSNR has a highest value of 40.9 dB. For pseudo dynamic subject groups (Foreman video sequence), good results are obtained using Remnant-free decoding with PSNR = 37.14 dB. For highly dynamic subject groups (Football and Video clip video sequences), appreciable results are gotten from the Remnant-free Decoding of I frames error correction method. In which case PSNR = 36 dB is achievable.

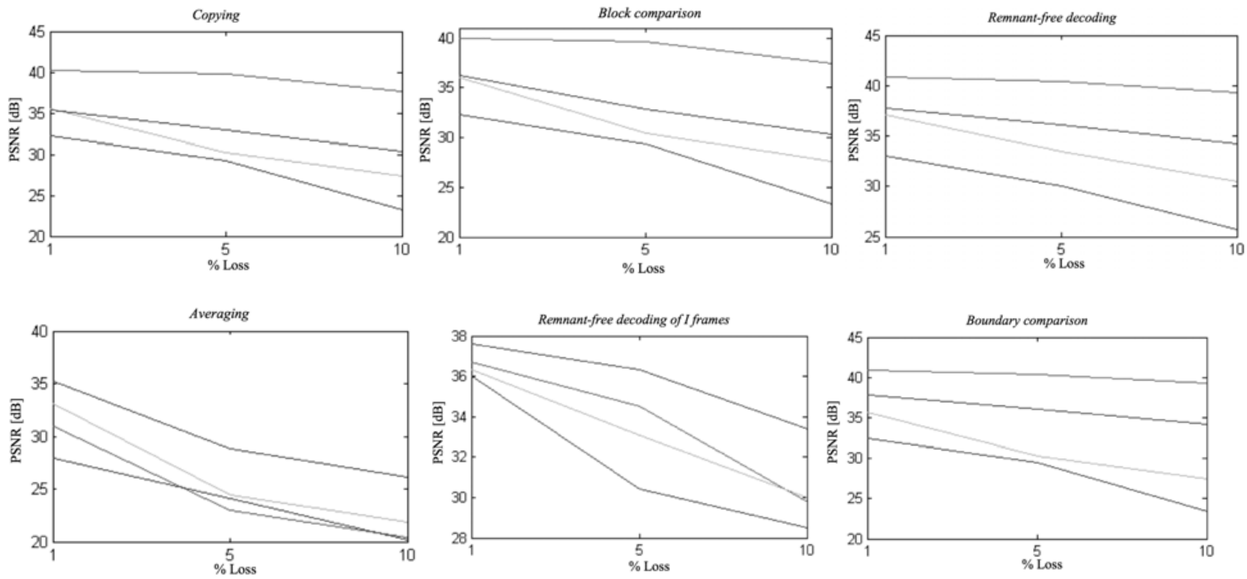

Fig. 15. Relationship between PSNR and percentage of lost packets for different error correction methods.

V. SUMMARY

Simulation showed that different video subject groups affect the perceived quality of video transmitted over wireless telecommunication network differently. Hence, a mere consideration of only the quality of transmitted (and subsequently decoded) video sequence at the application (i.e. bit rate) and network (i.e. BER) layers will not suffice, but another criterion of no mean importance must also be considered – i.e. the subject group category to which video sequence belongs. Increasing the bit rate value further affects the SSG mainly, while no appreciable improvement in quality is observed for video clips with moving elements (i.e. PSSG and HDSG). A low error level (BER=10^{-4}) does not affect the quality of decoding SSG video sequences, but it affects that of PSSG and is very pronounced for HDSG videos. This observation leads us to safely conclude that the decoder is only capable of effectively correcting small errors in static pictures. Increasing the error rate to BER=10^{-3} affects the decoding of video sequences of all the subject groups. The SSG and PSSG demonstrate satisfactory quality, while HDSG shows poor quality from a subjective assessment point of view.

VI. CONCLUSION

We have shown conclusively in this paper that in transmission conditions over any information communication network with low probability of error occurrence ($\mathrm{BER} = 10^{-6}$ and $\mathrm{BER} = 10^{-5}$), the minimum bit rate value of 128 kb/s provides acceptable video quality corresponding to an MOS > 3 for all types of video subject groups. This succinctly answers the first question (Q1) posed in the introduction to this paper.

The acceptable number of error bits, and consequently, the threshold from quality point of view, for which the viewer picture perception remains of acceptable quality for all types of video subject groups is $\mathrm{BER} = 10^{-4}$. This is the answer to the second question (Q2) raised at the onset of the paper.

The third question posed, as an objective of this work is to determine the level of efficiency of the methods adopted for error correction. From the results of the analysis of error correction methods obtained in section IV, we submit unequivocally that the methods adopted are extremely efficient, in that they allow for choosing the contextually right error compensation approach to adopt. The efficiency of analyzed error correction methods is strongly correlated with the spatial-temporal properties of the analyzed video sequences.

We have thus been able to achieve the objectives of this paper by proffering satisfactory answers to questions Q1, Q2, and Q3. By so doing we have fulfilled the aim of filling a gap identified in the literature vis-a-vis the impact of different video subject groups on the quality of decoded video transmitted over information communication wireless networks.

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