

Research Article

Variable Content Characteristic and Variable Network Coding for Wireless Digital Video Broadcasting Application

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Abstract

Digital video broadcasting network facilitates distribution of real time video and video on demand services to global end users. This network has significant limitations stemming from scarced network resources to meet users popular demand of improved received quality. This research, presents a thorough investigation of variable content characteristic and application of variable network coding on digital video quality performance over wireless channel to enhance received video quality performance. In the proposed scheme, variable channel coding-rate is deployed to provide significant received quality performance gain by intelligently avoiding waste of limited network resources related to the fixed resource allocation necessary to guarantee acceptable quality performance. In order to assess the performance of the proposed scheme, experimental set up consisting of H.264 reference software for source coding, motion rate classifier and simulated wireless channel consisting of various channel coding and modulation schemes were adopted for this study. The test video samples were classified into high and low motion rate videos. In contrast, investigation of extension from fixed channel coding scheme to the application of variable channel coding-rate and modulation schemes in response to variable content motion-rate is analyzed over error free and poor channel conditions. The quality performance of received video quality over various wireless channel conditions is measured using standard objective algorithm, Peak-Signal-to-Noise-Ratio (PSNR). For the Soccer test video sample representing high motion rate videos, the 16QAM;1/2, the lower channel coding rate recorded the highest received video quality performance with PSNR value of 37.95dB compared to PSNR values of 33.29dB for 64QAM;1/2, and 24.40dB for the 64QAM;2/3 modulation and channel coding technique. Whereas, Akiyo test video sample representing low motion rate videos recorded significant quality performance of 51.19dB, 50.97dB and 39.93dB for 16QAM;1/2, 64QAM;1/2 and 64QAM;2/3 channel coding and modulation schemes, respectively.

Keywords

Coding, Content Characteristic, Video Broadcasting, Error Concealment, Error Protection, Network

1. Introduction

Digital video communication include video on demand, real time video applications like live video broadcasting and video calls. Conventionally, video content requires more bitrates for true representation, and as well are sensitive to

network challenges such as poor wireless channel conditions. The encoded video bitstream are susceptible to channel errors and limited network resources. These factors including transmit energy affect quality performance of wireless com-

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munication as in the case of Unmanned Aerial Vehicle (UAV) for essential services and real-time surveillance environmental monitoring [1]. Sustaining good communication link is challenging due channel errors and limited network resources. Various network distribution mechanisms to improve video quality performance have been presented in the literature. Optimum power allocation-based channel conditions, where satellite network resources are adapted based on scintillation effects from atmospheric conditions has been discussed [2-4]. Specifically, streaming of video content over wireless networks has increasingly become the popular mean of communication. In contrast to the conventional audio traffic, video distribution requires more network resources to meet acceptable quality of services in terms of delay variation and packet losses due to channel errors. Video packet loss affects quality performance of received video contents [5-8]. This implies that there is a need to devise an intelligent system to enhance quality of video services, considering a typical digital video broadcasting application, to deliver video services to mobile users over wireless networks to facilitate unlimited access to multimedia services at anytime, any location with any receiving device. Compressed video bitstream is susceptible to channel errors which result in quality degradation of the reconstructed video. The degree of received video quality performance depends on a number of factors such as the level of distortion, source quantization errors due to lossy compression, error concealment algorithms, power constraints and limited bandwidth. Provision of satisfying wireless video services require development of efficient end-to-end model for improved services. Error protection and recovery techniques can be classified into two main groups, pre-processing and post-processing techniques. Post-processing technique includes Error Concealment (EC) utilizes the reconstructed frames to conceal the errors. Pre-processing mechanism such as Error Resilient (ER) technique improves the robustness of media stream by encoding media stream with additional bits called parity bits for error control (channel coding) and Automatic Retransmission reQuest (ARQ), retransmission of the corrupted video data upon negative acknowledgement [9-11] request from a receiver when it detects corrupted video data. For sensitive video application with zero delay tolerance, e.g. high motion sequences including soccer, football and athletic events, delays caused by re-transmission of loss video packets during error correction is always annoying, with poor jerky visual quality. This retransmission process often results in excess traffic load and poor throughput management. In contrast to retransmission scheme, application of Forward Error Correction (FEC) for real time application, lowers Bit Error Rate (BER) for low overheads in terms of parity bits. FEC mechanism improves end-to-end reliability of the transmitted video bitstream such that if part of the transmitted bitstream is corrupted the codes can facilitate error detection and correction process to mitigate impact of errors and sustain acceptable received video quality. However, during video transmission, there are some video packets among the bitstreams that

do not require that much protection, due less complexity in reconstruction process of the loss video packets. This common for video with low motion rate or less active scene in the video production. It is not effective network resources management [12, 13] approach to apply high degree of protection to such less significant video bitstreams in a constrained network since it incurred more overheads in terms of redundancy bits. Thus, efficient video transmission mechanism is required to guaranteed acceptable received wireless video quality performance in a constrained wireless network.

In response to meeting end user's quality performance expectation for digital wireless video broadcasting applications, some advanced techniques have been discussed in the literature including dynamic end-to-end quality of service support for video application, where video packets are scheduled considering the available network resources and quality expectation [14]. Other methods of effective wireless video communication include media motion-based resource distribution for mobile video networking, where Signal to Noise ratio (SNR) level of bitstreams are regulated based on media content [15]. In contrast to the existing technique, where Signal to Noise Ratio (SNR) levels are adapted based on the content characteristics, this research work adopts innovative approach to improve the average video quality performance by intelligently adapting channel coding scheme based on motion-rate of video bitstreams. The concept focus on mitigating video packet losses by adaptively transmitting the video bitstream with high motion-rate using low channel coding-rate and good error correction capability. This concept facilitate recovery of the loss video packets due to channel errors. The video quality performance is further enhanced using error concealment method for prediction and reconstruction of loss video packets.

The results obtained from the experiment demonstrate that application of lower channel coding-rate with good error detection and correction functionalities to high motion-rate video bitstream can sustain good quality performance over poor channel conditions compare to application of higher channel coding-rate with low error detection and correction capability. The scheme exploits robustness of dynamic channel coding to improve the quality of video services. The video quality is measured with the standard Peak-to-Signal-Ratio (PSNR) algorithm [16-18]. It is essential to analyze the quality performance received under different channel conditions, though studies have investigated video communication system for particular applications, there is a lack of comprehensive assessment of efficient system with consideration of dynamic video content characteristics and variable channel coding scheme. This study attempts to fill the gap through detailed analysis of the proposed scheme, variable content motion-rate and variable channel coding-rate for wireless video broadcasting application. The next section of this paper discusses system modelling follow by detail description of the proposed variable content motion-rate variable channel coding-rate approach. Section III delves into

materials and methods, while presentation and discussion of results is captured in Section IV. The conclusion and future research work are presented in Section V.

2. System Modeling

2.1. Variable Content Characteristic

Variable content characteristic in this context represents measurement of motion displacement including temporal and spatial resolutions in video sequence. Motion of video bitstream is modelled by;

$$\varphi_i = \sum_{i=0}^{L-1} \frac{MAL_i}{T} \times R \quad (1)$$

where L depicts the number of frames in the video segment, R represents the spatial resolution, T depicts frame rate, φ_i presents motion-rate and MAL_i represents the motion displacement across the video frame. The video bitstreams are classified into two categories, High Motion (HM) priority and Low Motion (LM) priority [19], based on the intensity of motion displacement, of the video bitstreams:

$$\varphi_i = \begin{cases} HM, & \text{if } \varphi_i > y \\ LM, & \text{if } \varphi_i \leq y \end{cases} \quad (2)$$

where y is the threshold based on the framework for measurement of motion intensity of video [20]. Figure 1, presents motion displacement of selected sample video sequences deployed during research investigation.

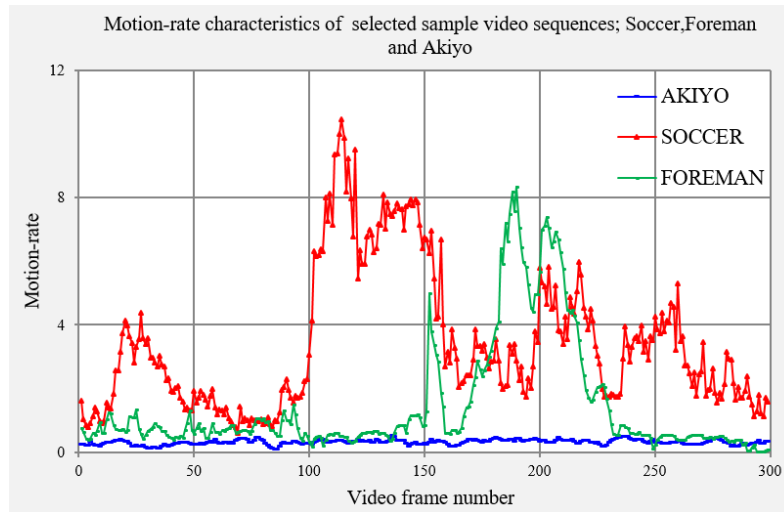


Figure 1. Motion displacement of selected sample video; Soccer, Foreman and Akiyo.

2.2. Network Coding

Wireless video service is susceptible to channel errors, which affects the quality of video services. Thus, the reliability of transmitted video bitstreams is necessary to guaranteed acceptable received quality to users. Network coding is usually applied in wireless system to improve fidelity of the transmitted video bitstreams and enhance its received quality. In channel coding process, controlled redundancy is inserted into video bitstream to facilitate detection and correction errors induced by the channel. The parity (redundancy) is added to bitstream for error detection and correction processes at the receiver. Though, error detection and correction capability of variable channel coding is limited by the block-size and delay constraints. Reed-Solomon code RS (z, x) are used to generate z blocks of encoded bitstream from the packetized video block x to generate parity block [21]. The parity data facilitate smooth reconstruction of corrupted video packets

and enhances the received quality performance. The code rate λ is given by x/z , thus, the lower the coding rate λ , the higher probability of error detection and correction for improved received video quality performance. However, the conventional coding approach may not be efficient enough since the technique does not adjust to variable error protection requirements for variable video motion-rate and prevailing network conditions. The insensitivity of the conventional channel coding technique to response to the variation of error protection requirements across video bitstream wastes network resources and in many cases results in insufficient error protection to satisfy the error correction level in high motion-rate video bitstream.

2.3. Variable Content Characteristic and Variable Network Coding System

Some practical mechanisms to reducing impact of channel errors on video bitstreams include increase in Sig-

nal-to-Noise-Ratio (SNR), interleaving, randomization. However, excessive large increment in transmit power to meet acceptable target bit error rate pose complexity with possible threat of interference to nearby users. Alternatively, interference-reduced technique to improving robustness of video bitstream includes maintaining reasonable SNR and varying channel coding-rate. In contrast to the adaptive forward error correction protocol for end-to-end transport of real time traffic based on state of network condition [22], the methodology adopted in the system may not facilitate efficient usage of the limited network resources because the dynamic motion-rate of video bitstream is not harnessed. Due to variation of motion level across video bitstream, it will be more efficient to adopt unequal error protection approach, in terms of adaptive channel coding scheme to provide the needed adequate protection to the different segment of video bitstream based on the variation of motion-rate for enhanced received quality performance while making good usage of the limited network resources. In an attempt to address this prevailing challenge, Variable Content Motion-Rate and Variable Channel Coding-Rate is proposed. Thus, this research investigates performance of variable content motion-rate variable channel coding-rate scheme for improved wireless video communication, in preference to conventional fixed

channel coding-rate without consideration of variable content motion-rate and prevailing network conditions. The concept involves application of robust channel coding technique to significant video packets with high motion (HM) characterization while considering the network conditions. Video content is classified into high motion-rate (HM) and low motion rate (LM). Motion-rate, defines the level of motion characterization of video sequence, is also studied in the course of this research. Motion-rate of video bitstream is harnessed in implementation of suitable channel coding-rate for different types of video packets. Higher code rate is characterized with low error correction capability. Lower code rate presents more additional bits for better error correction capability. Thus, high motion-rate video packet which is more susceptible to the impact of channel errors is encoded with suitable lower code rate. When channel condition is characterized with high bit error rate (BER), more errors occur, thus, the application of lower channel coding-rate in such poor channel scenario is required to improve recovery of transmitted video bitstream. When the channel condition improves, the use of higher channel coding-rate is applied to avoid waste of network resources. Figure 2 shows the proposed system architecture.

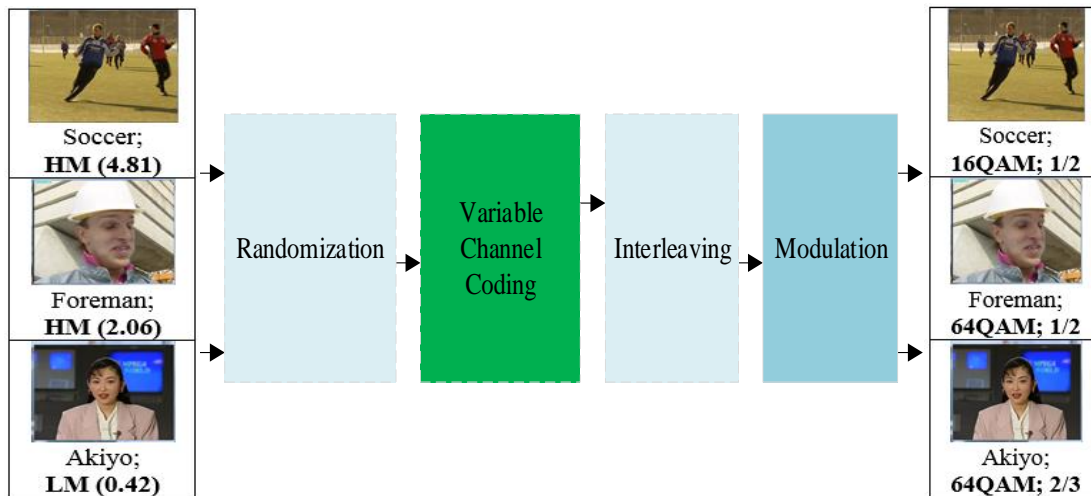


Figure 2. Variable Content Characteristic and Variable Network Coding System Architecture.

Three major steps involve in the process include randomization, variable channel coding and interleaving. The video content bitstream is randomized prior to transmission to enhance protection by avoiding long sequences of consecutive ones or consecutive zeros. Variable content motion-rate and variable channel coding-rate is an innovative error mitigation technique involve in encoding of video bitstream with variable parity bits data to facilitate error detection and correction process for improved received video quality performance.

3. Materials and Methods

Experimental configuration to validate the efficacy of the proposed technique consist of three stage processes including source encoding, channel coding and received video quality assessment. H.264/Advanced Video Coding reference software [23] was deployed for source encoding and decoding processes. Standard sample test video sequences, Soccer, Football, Crew, Akiyo, news, Hall, Sean, Weather and Container test video samples were deployed in the source encod-

ing process. The test video samples in common intermediate format, were encoded at 30fps using group of picture size of 8 and video packet size of 512bytes for wireless network application. Content Adaptive Binary Arithmetic Coding (CABAC) scheme was deployed, with a macroblock size of 16×16 pixels and a total number of 300 frame length for all test video samples. The video packets were encapsulated in advanced video coding real time protocol for improved error concealment over wireless channel. Classification of motion-rate, include analysis of video samples using optical flow algorithm to measure the motion-rate. The videos motion-rates were grouped into High Motion-rate (HM) and Low Motion-rate (LM) according to the motion displacement in the video sequence. The proposed system architecture is based on wireless network architecture, where channel coding performance is evaluated. The model exploits advantage of flexible Orthogonal Frequency Division Multiple Access Time Division Duplexing (OFDMA-TDD) configuration [24-29] with capability of adapting channel resources among subcarriers independently. In the proposed scheme, additional adaptation parameter, motion-rate of the video bitstream is considered. Each video bitstream is assigned a subset of the subcarriers based on the content motion rate and prevailing channel conditions. The three common channel coding and modulation schemes deployed in wireless communication system, 6QAM;1/2, 64QAM;1/2 and 64QAM;2/3, were deployed in the experiment to demonstrate the efficacy of the proposed technique under different channel conditions. The compressed video bitstreams were transmitted while adapting the channel coding-rate based on the motion-rate of the video bitstreams. The video quality performance of the propose scheme was measured using Peak Signal-to-Noise Ratio (PSNR) objective metric. The higher value of PSNR indicates better received video quality performance.

4. Results and Discussion

This section presents the results obtained at various test scenarios ranging from motion-rate test results of the sample test video sequences to video quality performance of video bitstreams transmitted at various channel conditions using variable channel coding scheme. The motion-rate test results obtained from the optical flow algorithm, shows that the motion-rate of Soccer, Football, Foreman, and Crew test video samples were characterized with high motion (HM) indicating high dynamic motion displacement in the test video samples. Whereas, the motion-rate of Akiyo, News, Sean and Weather test video samples were classified as low motion-rate (LM), indicating relatively average low motion scenarios in the test video sequences. The experimental analysis shows that there is variation of video quality performance at different channel coding schemes across the tested video samples. The video quality performance of Soccer test sample under error free channel condition and different test scenarios is presented in Figure 3. From the soccer test results, it is observed that many

video packets get corrupted due to channel errors. This video packet corruption is obvious at frame numbers, 10th, 45th, 50th, 80th, 148th, 198th, 225th and 275th frames while using 64QAM;2/3 scheme. Whereas, few packets get corrupted at frame numbers, 46th, 98th, 149th, 252th and 270th frames, while using relatively improved lower channel coding rate, 64QAM;1/2. In contrast to the high number of video packet corrupted while using higher channel coding scheme, negligible number of video packets get damaged at frame number 96th and 252th, while using lower channel coding scheme, 16QAM;1/2. Statistically, the average video quality performance measured with PSNR (dB) software is 37.95dB when 16QAM;1/2 channel coding scheme, 33.29dB for 64QAM;1/2 channel coding, and 24.30dB for 64QAM; 2/3 channel coding scheme. Figure 3, presents video quality performance of Soccer test video sample under different test scenarios.

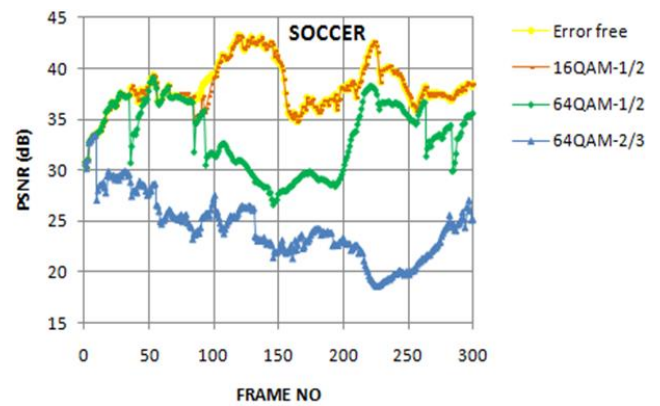


Figure 3. Quality performance of Soccer test video sample.

From figure 3, it is obvious that error free channel condition test scenario outperformance others, indicating a situation where there was no loss of video packets due to channel errors. It also observed that the average received video quality performance improves significantly when the video bitstream was transmitted using lower channel coding scheme, 16QAM;1/2, in contrast to the quality performance when higher channel coding schemes, 64QAM;1/2 and 64QAM;2/3. Thus, transmission of sensitive video bitstreams using higher channel coding-rate are not favored in this analysis because of high probability of errors associated with the scheme. Although, higher channel coding scheme could offer spectral efficiency under free error channel condition. It has also been observed the higher the number of channel errors in terms of number of video packets getting corrupted, the lower the average received video quality performance, as seen in the cases of higher channel coding scheme. Figure 4, presents video quality performance of Football test video sample under different test scenarios.

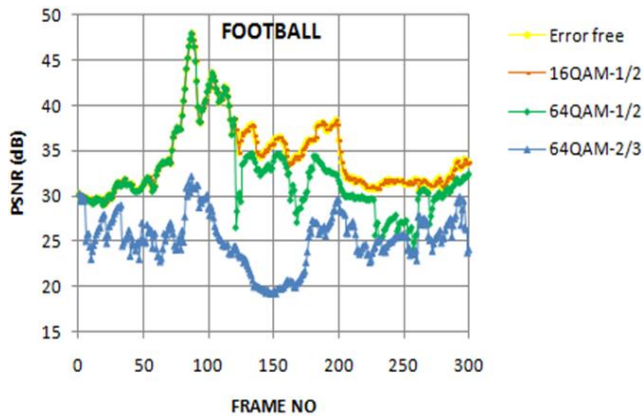


Figure 4. Quality performance of Football test video sample.

From the result presentation in Figure 4, there is a clear disparity in terms of video quality performance results with respect to the different channel coding schemes deployed. It is observed that with Football test video sample, the average video quality performance for 16QAM;1/2 channel coding scheme leads with 34.25dB follow with 32.37dB for 64QAM;1/2 and 25.15dB for 64QAM;2/3 channel coding schemes respectively. This result indicates that thorough study should be carried out to guide in the adaptation of channel coding-rate for improved video quality performance. Furthermore, as depicted in Figure 4, good video quality can be achieved using lower channel coding-rate compared to higher coding scheme under error prone wireless channel. Figure 5, presents results for Foreman test video sample.

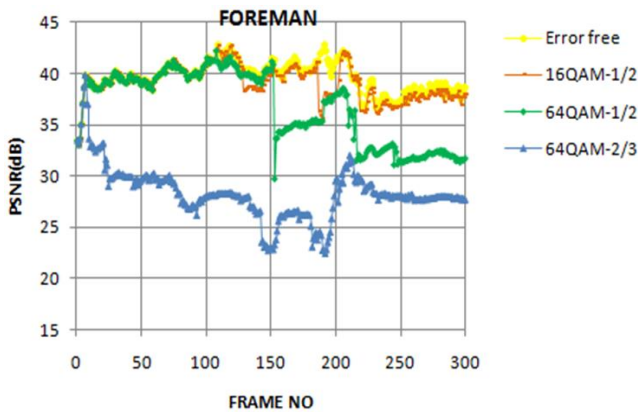


Figure 5. Quality performance of Foreman test video sample.

Figure 5, presents result for Foreman test video sample. The results analysis shows a similar pattern with leading received average video quality performance of 39.06dB for 16QAM;1/2, follow by 36.73dB for 64QAM;1/2 and 28.26dB for 64QAM;2/3 channel coding scheme. Observably, there are deep quality (PSNR) fluctuations at frame numbers 150th and 190th, while using 64QAM;2/3 channel coding scheme. This indicates loss of video packets due to channel errors, which could not be recovered with higher channel coding rate, but

rather recovered while using lower channel coding rate of 64QAM;1/2. Analysis from Foreman test video sample, further shows a strong relationship between the video quality performance and channel coding-rate. Figure 6, presents quality performance of Crew test video sample.

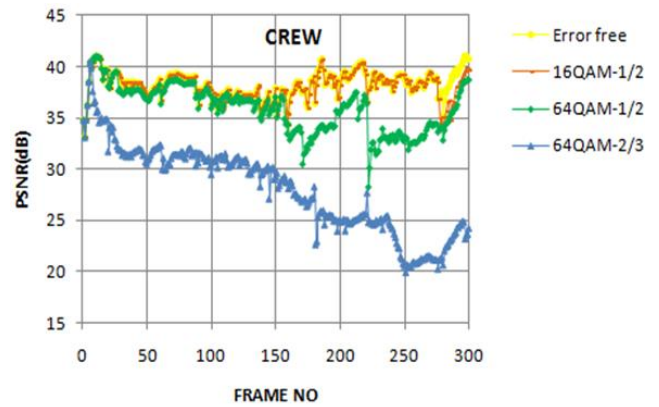


Figure 6. Quality performance of Crew test video sample.

For Crew test video sample result presented in Figure 6, the average received video quality performance for 64QAM;1/2 and 64QAM;2/3 test scenarios are 34.89dB and 28.06dB respectively. There is also a substantial quality enhancement, of 38.09dB when using 16QAM;1/2 channel coding scheme. The quality improves significantly in comparison with the higher 64QAM;1/2 and 64QAM;2/3 coding schemes, as shown in Figure 6. Based on the analysis, the result demonstrates that the lower coding scheme has more error detection and correction capabilities than higher channel coding schemes. This strong characteristic of lower channel coding scheme facilitates significant number of error detection and correction functionalities to further improves video overall video quality services over error prone wireless network. Figure 7, quality performance of News test video sample.

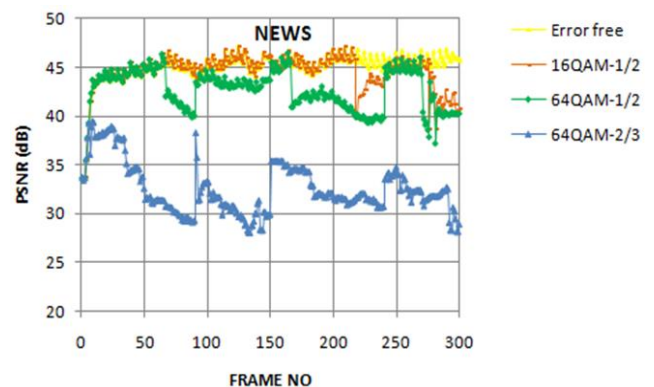


Figure 7. Quality performance of News test video sample.

Figure 7, presents the test results for News sample averaged

across encoded 300 frames of the test video sequence at three distinct network coding schemes; 44.18dB for 16QAM;1/2, 42.65dB for 64QAM;1/2 and 32.52dB for 64QAM;2/3 respectively. The variability of received quality performance is influenced by channel condition and channel coding scheme as depicted in Figure 7. The result indicates that, even under similar channel characteristic, impact of random channel errors in form of random packet losses, adversely affects overall received video quality performance, highlighting the impact of channel errors on digital video communication. This video packet losses are obvious as seen on frames, 90th, 140th, 240th and 282th of News test sample (Figure 7). The lower coding is advantageous under poor channel condition while the higher coding has advantage where higher data throughput is prioritized over improved received video quality performance. Figure 8, presents quality performance for Hall test video sample.

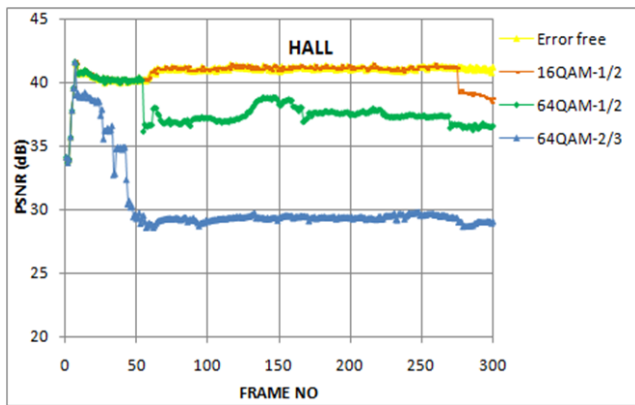


Figure 8. Quality performance of Hall test video sample.

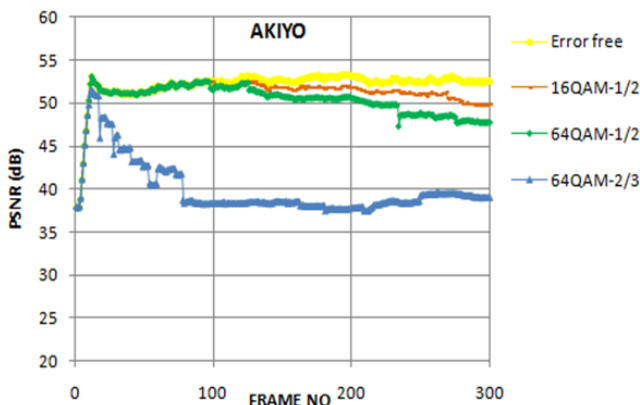


Figure 9. Quality performance of Akiyo test video sample.

Figure 8, shows quality performance result for Hall test sample with PSNR value of 40.69dB for 16QAM;1/2, 37.82dB for 64QAM;1/2 and 30.42dB for 64QAM;2/3 test

scenarios. Comparatively, the performance of Hall test sample under 64QAM;1/2 and 64QAM;2/3 channel coding schemes, show significant quality improvement of 7.2 dB (PSNR) for the Hall video test sequence. The quality gain is a result of enhanced error recovery strategy associated with lower channel coding technique. Figure 9, presents quality performance for Akiyo test video sample.

Similar pattern of quality performance is observed in Akiyo test video sample result, where the lower coding scheme outperforms the higher channel coding technique, as presented in Figure 9. Observably, there are few video packets drops between the 10th and 70th frames while using higher coding-rate of 64QAM;2/3, compared to using 64QAM;1/2 and 16QAM;1/2 where the video packets are sustained. The 16QAM;1/2 sustained 51.19dB, 64QAM;1/2 produced 50.97dB and 64QAM;2/3 maintained 39.93dB video quality performance. Figure 10, shows quality performance of Sean test video sample.

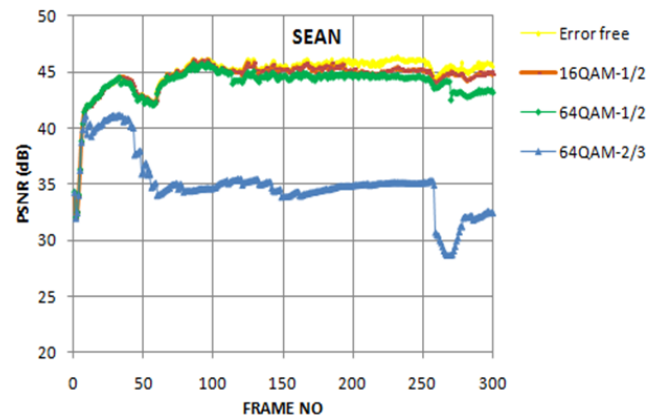












Figure 10. Quality performance of Sean test video sample.

From Figure 10, representing Sean test sample, peak average quality output of 44.51dB for 16QAM;1/2, was observed, followed by 43.94dB by 64QAM;1/2 and 35.06dB for 64QAM;2/3 system. It is also noted that more video packets get affected by channel errors as seen around frames number 11th, 20th, 51th, 53th, 150th, 250th and 256th, while using 64QAM;2/3, compared to few video packets loss while using 64QAM;1/2. The high rate of video packet loss further affects the average received video quality performance.. Notably, the lower coding scheme, 16QAM;1/2, sustain better video quality because of the robustness and good error detection and correction capability of the channel coding scheme. Table 1, shows comparative visual presentation of some test video frames under different channel coding schemes.

Table 1. Comparative visual presentation of some test video frames under different channel coding schemes.

Test Video Sample	16QAM;1/2	64QAM;2/3
Football		
Soccer		
Crew		
Foreman		
Hall		

Test Video Sample	16QAM;1/2	64QAM;2/3
Akiyo		

5. Conclusion and Future Research

5.1. Conclusion

The study provides a comprehensive analysis of video contents and variable network coding for digital video broadcasting application, focusing on received video quality enhancement in limited wireless network environment. Variable Network coding scheme is deployed to provide significant received quality performance gain by intelligently avoiding waste of network resources related to the fixed resource allocation necessary to guarantee acceptable quality performance. In contrast, investigation of extension from fixed channel coding scheme to the application of variable channel coding scheme while paying attention sensitive video content is analyzed over different channel conditions. Comparatively, the received video quality performance improves significantly on low channel coding scheme, compared to the results obtained on application of higher channel coding scheme. The results demonstrate effectiveness of lower channel coding scheme, capable of mitigating impact of channel errors on received video quality performance. The proposed scheme is essential to improving quality of wireless video broadcasting application.

5.2. Future Research

Future research concentrates on more advanced models that can incorporate adaptive channel coding and modulation techniques to enhance wireless video communication, and as well satisfy video viewers' quality of experience by focusing on individual video users' quality preferences.

Abbreviations

PSNR	Peak-Signal-to-Noise Ratio
UAV	Unmanned Aerial Vehicle
EC	Error Concealment
ER	Error Resilient
ARQ	Automatic Retransmission reQuest

FEC	Forward Error Correction
BER	Bit Error Rate
SNR	Signal to Noise Ratio
H.264/AVC	H.264/Advanced Video Coding
CABAC	Content Adaptive Binary Arithmetic Coding
OFDMA-TDD	Orthogonal Frequency Division Multiple Access Time Division Duplexing

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Author Contributions

Ubong Ukommi is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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