

Wireless Transmission of JPEG 2000 Compressed Video

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Abstract— In this paper, we propose a wireless transmission of JPEG 2000 compressed video. The proposed system employs the next generation wireless LAN system based on IEEE802.11ac specification. It reaches more than 33 meter propagation distance by using 80MHz of bandwidth on the 5GHz band. In this system, video data is compressed by JPEG 2000 with error resilience tools. These tools improve error performance against wireless channel, and enable very high throughput communication. Computer simulations are used to evaluate the bit error performance's influences to the video quality. Finally, we present RTL design results of the proposed wireless LAN system.

Keywords— Wireless LAN, JPEG 2000, 4K digital cinema, IEEE 802.11 TGac, RTL design

I. INTRODUCTION

Digital cinema is an application of digital technology for storage, distribution and projection of motion pictures [1]. This technology is also expected to be used in home theaters in the near future and promise much better image quality than high definition (HD) televisions. Similar to the motivations of Wireless HD (WiHD) [2], [3], wireless home digital interface (WHDI) [4] and other wireless transmission system for HD content, we are proposing a wireless transmission system for 4K digital cinema. To send raw video data of 4K digital cinema resolution however, the throughput needed for the wireless system should be more than 6Gbps. For this paper, we use JPEG 2000 coding to reduce the needed the throughput to about 1.2Gbps [5]. In line with the throughput demand of wireless communication, our desired application for instance, the IEEE802.11ac task group [6], [7], [8], [9] have been discussing the standard for very high throughput (VHT) wireless LAN (WLAN) system which has a throughput of at least 1Gbps [7]. Aside from being specified as the compression scheme of Digital Cinema, it also has several favorable properties not found in other compression schemes. JPEG 2000 coding localizes transmission errors by frame by frame processing. This prevents error in one frame to affect succeeding frames. Mpeg coding on the other hand needs at least 3 frames to implement the required motion coding. Mpeg

coding also has long latency as a result. The latency for JPEG 2000 is shorter than Mpeg coding.

Mobile wireless throughput is not constant but changing due to channel fading [10]. When the video is transmitted on this channel, we have to consider the throughput to change. When the video compressed by MPEG-2 or H.264 is transmitted, the rate control is needed [11], [12]. However, the rate control of MPEG 2 or H.264 needs very high complexity and has long latency. On the other hand, Motion JPEG 2000 can easily implement the rate control to have scalability. Therefore Motion JPEG 2000's rate control can be easier than MPEG 2's or H.264's.

This paper proposes a wireless transmission of JPEG 2000 compressed video. This paper is organized as follows. Section II outlines the proposed wireless transmission system for 4K digital cinema and shows the JPEG 2000 coding and the wireless transmission system in detail. Section III presents the image quality evaluation results caused by wireless transmission errors. In section IV, the proposed wireless LAN system implemented on the FPGA is discussed. Finally, section V presents the conclusions of this research and proposes the future work as well.

II. SYSTEM OUTLINE

The proposed wireless transmission system, which includes the transmitter and a receiver for 4K digital cinema is shown in Fig. 1. This system consists of following 3 parts. They are 1) Pre and post processing part, 2) JPEG 2000 coding part and 3) Wireless transmission part.

A. Pre/post processing part

Movie data from a video source such as a PC or a DVD player is divided into video, audio and control data. In the preprocessing part, if the video data is a compressed codestream, the codestream is decoded to generate uncompressed video data. Since the uncompressed video data is too large for sending over a wireless channel, it is compressed by JPEG 2000 coding. The encoded video is

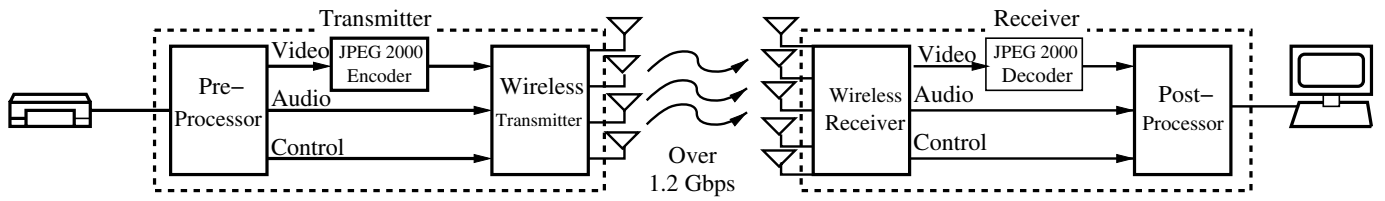


Figure 1. Proposed wireless transmission system for 4K digital cinema

TABLE 1. WIRELESS SYSTEM SIMULATION PARAMETER

MCS	Modulation	R	$N_{BPSC(i_{ss})}$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{SS}	Data rate[Mbps]		
									800 ns GII	400 ns GI	200 ns GI
1	64-QAM	2/3	6	228	8	5472	3648	4	912	1013	1073
2	64-QAM	3/4	6	228	8	5472	4104	4	1026	1140	1207
3	64-QAM	5/6	6	228	8	5472	4560	4	1140	1266	1341

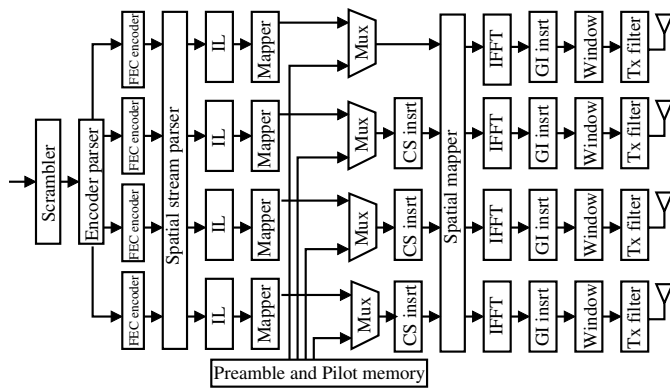


Figure 2. Transmitter

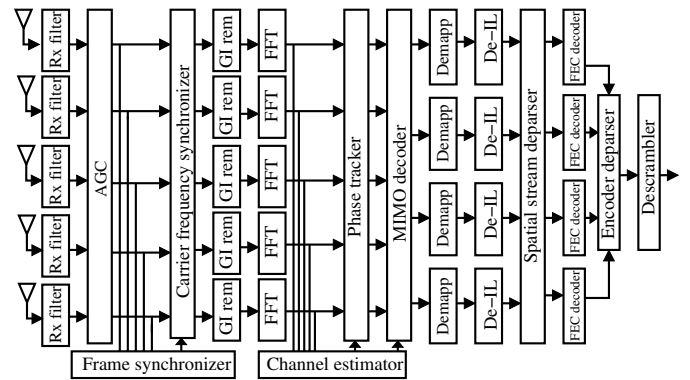


Figure 3. Receiver

transmitted by using a wireless transmission system with more than 1.2Gbps throughput. The wireless transmission part as earlier mentioned is based on IEEE802.11ac. The detail of proposed wireless transmission system for 4K digital cinema application is explained in the next section.

B. JPEG 2000 coding

The input image is decomposed into its sub-bands by a discrete wavelet transform (DWT) and then the wavelet coefficients of each sub-band are quantized. The quantized coefficients are coded by using the embedded block coding with optimized truncation (EBCOT) of the embedded bit stream algorithm [13]. In this algorithm, each sub-band is partitioned into rectangular blocks (e.g., 64 x 64) called “codeblocks,” which form the independent input to the coefficient bit modelling based on bit-plane and arithmetic coding. A layer divided structure is formed for scalability purpose of the bit stream while the output codestream are truncated so that they can achieve the target bit rate. Finally, headers are attached to create the JPEG 2000 codestream.

The JPEG 2000 has seven error resilience tools as mentioned in [5]. Note that the tools have no error correction capability. The image encryption in this system will employ JPSEC defined in JPEG 2000 standard as future work [14]. For the purposes of this paper all JPEG 2000 codestreams are assumed unencrypted.

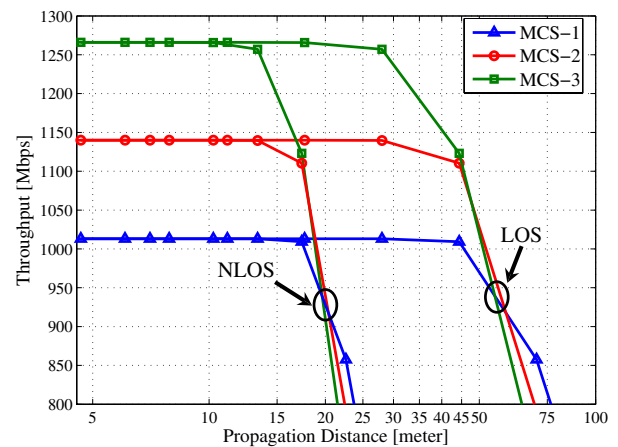


Figure 4. Propagation distance for LOS and NLOS

C. Wireless transmission system

The proposed wireless transmission system for 4K digital cinema is currently being developed as a next generation of WLAN system. The transmitter block diagram of the VHT system is shown in Figs. 2 and 3. 3 options of modulation coding scheme (MCS) which defines the parameters to calculate the data rate of this system are summarized in Table 1. In this paper, the system throughput is more than 1.2Gbps on the 5GHz band. The image binary input data is first

TABLE 2. WIRELESS SYSTEM SIMULATION PARAMETERS

Parameter	Value
MCS Index	3
System Throughput	1.266 [Gbps]
Frequency Carrier	5.2 [GHz]
Antenna Configuration	4 by 5
Bandwidth	80 [MHz]
Format Packet	VHT Greenfield Mode
FEC Encoder	BCC with soft Viterbi decoder
Spatial Mapping	Direct
MIMO Decoder	Linear MMSE
Guard Interval Length	400 [ns]
Channel	In-door channel model
SNR	32, 39, 42 [dB]

scrambled in order to have uniform distribution. This data is then encoded by using forward error correction (FEC) encoder. Examples are binary convolutional codes (BCC) and low density parity check (LDPC) codes. Both are used to enhance the performance of the system against noise. The coded data is then divided into four streams by the spatial stream parser. The interleaver (IL) as shown is used to mitigate errors due to the burst noise. After modulation, each stream is ready to be transmitted. The receiver synchronizes all signals and estimates the channel characteristics. After each stream is demodulated using the fast Fourier transform (FFT), a minimum mean square error (MMSE) multiple input multiple output (MIMO) decoder is used to cancel recover the transmitted signals. MMSE algorithm achieves a diversity order the number of $N_R - N_T + 1$, when $N_R > N_T$. N_T is antennas transmitting independent data streams. N_R is the number of antennas receiving independent data streams. After passing the received signals into the de-interleaver, receive signal errors are corrected by using the FEC decoder.

Finally, the de-scrambler descrambles the data and sends the binary-image output to a JPEG 2000 decoder. This system transfers stream data packet by packet to increase throughput. Fig. 4 shows throughput versus propagation distance of the proposed WLAN system in line-of-sight (LOS) and no LOS (NLOS) environment. MCS1- 3 refers to the modulation and coding scheme parameters used. Depending on these parameters, the reliability and raw throughput of the system can be changed. MCS1-3 have throughput of 1.013, 1.140, 1.266 Gbps respecting.

III. IN-DOOR CHANNEL SIMULATION

A. Simulation parameters

Table 2 lists the wireless system simulation parameters. On the other hand, Table 3 lists image simulation parameters. The frame size is 4096 x 1714 pixels while the total number of frame is 90 [15]. Also in the video sample used, the scene changes at frame number 36. When the frame size is 4096_1714 pixels, the throughput of the proposed system is 800Mbps for the video data. Table 4 lists the JPEG 2000 coding parameters. The simulation frame rate is 30 frames per second (fps) under an in-door channel model. Since 800Mbps

TABLE 3. IMAGE SIMULATION PARAMETERS

Parameter	Value	
ERT	with	without
Software	Kakadu version 6.0	
Target Bit Rate [bpp]	4.0	
Layer	10 Layers	No Layer

TABLE 4. JPEG 2000 CODING PARAMETER

Parameter	Value
Frame Size [pixel]	4096 x 1714
File Size [Mbyte]	20
Throughput [Mbps]	800
Frame Rate	30
MCS	MCS-3
Target PSNR [dB]	30

TABLE 5. BER OF SIMULATION

SNR [dB]	BER
32	8.6×10^{-4}
39	5.4×10^{-6}
43	3.2×10^{-8}

throughput is required, MCS-3 as mentioned in section II-C is used. We also verify H.264 coding compressed by Premium Pro CS4 [16]. The 4K image is divided into 4 images, each image is compressed in 200Mbps. We evaluate video quality using the peak signal to noise ratio (PSNR) and assume as a rule of thumb that the PSNR is 0dB when the image can not be decoded due to errors. The target PSNR of our simulation is more than 40dB. The specification of simulation can not be implemented on FPGA. Therefore, implementation of FPGA is downscale model.

B. Simulation results

Figs. 5 to 7 show the simulation results of 4096 x 1716 pixel video transmission. The simulations SNR are 32dB, 39dB and 43dB. The BER of each SNR is shown in Table 5. Fig. 8 and 9 show the PSNR comparison of the frame 58 at the SNR of 39dB.

In Fig. 5, we can see that the PSNR of almost all frames is below 30dB in the proposed system with, without ERT or H.264. This makes the received frames become unintelligible for a video content.

Fig. 6 shows the PSNR for BER of 5.4×10^{-6} which is achievable when SNR is 39dB. We can verify that even if the system is not equipped with ERT, the PSNRs of almost all frames are above 30dB and only 1 frame is below 30dB. These frames should be fine as a video content. However, there is still some noise as visible in Fig. 8. In contrast, when the ERT is used in the system, the PSNR of all frames are above 30dB. On the other hand, the PSNR of all frames compressed by H.264 is below 30dB. This makes the received frames become unintelligible for video content.

When the BER is less than 10^{-8} which is achievable when SNR is 43dB, we can transmit video with or without ERT as shown in Fig. 7. On the other hand, the PSNR of almost all of frames compressed by H.264 is below 40dB. This makes the received frames become unintelligible for video content.

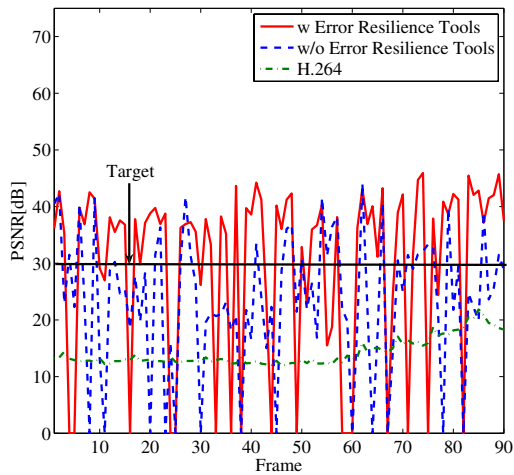


Figure 5. Quality of video transmission (4096 x 1714, CHB, SNR=32[dB])

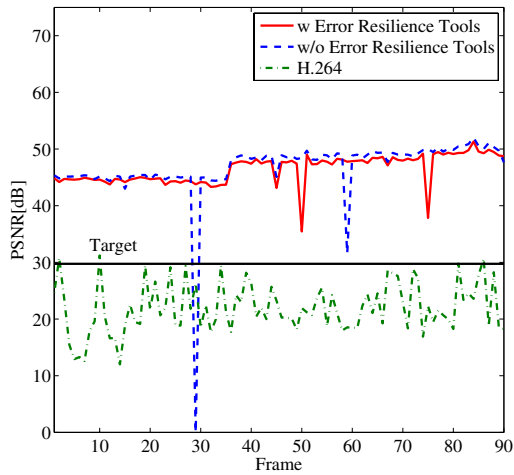


Figure 6. Quality of video transmission (4096 x 1714, CHB, SNR=39[dB])

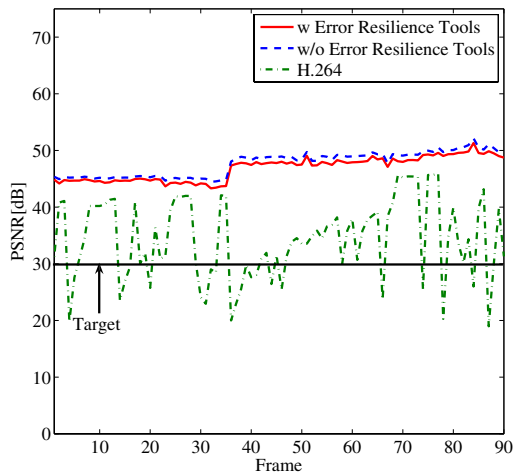


Figure 7. Quality of video transmission (4096 x 1714, CHB, SNR=43[dB])

TABLE 6. MIMO-OFDM BIT RATE

Bit rate [Mbps]		FFT point				
		64	128	256	512	1024
Bandwidth [MHz]	20	320	339	349	355	358
	40	608	676	715	737	748
	80	1040	1248	1387	1468	1513

TABLE 7. FPGA SYSTEM PARAMETERS

Parameter	Value
Baseband Bandwidth	40 MHz
Operating Clock	40 MHz
FFT points	256
Guard Interval points	1.6 us
Modulation	64-QAM
Coding rate	5/6
Data length (OFDM symbol)	32
Preamble length	44 us
Packet length	84 us

IV. FPGA IMPLEMENTATION

Fig. 10 shows the proposed wireless LAN system implemented on FPGA. Table 6 shows the theoretical throughput of proposed system. This specification is coding rate of 5/6, modulation of 64QAM and guard interval length of 200 ns. In order to reach the desired throughput of 1.2Gbps, we need to implement 80 MHz of bandwidth and more than 128 of FFT points as shown in table 6. However, even the latest FPGA can not handle this amount of throughput. For this reason, we decided to downscale the implementation to 40 MHz with the same number of FFT points. Other parameters for our FPGA implementation is shown in table 7. This reduces our target from 1.2Gbps to 600Mbps. The total number of gates for implementing the downscaled VHT wireless LAN is 166,613 LUTs using the Xilinx ISE. Table 8 shows the result of circuit size.

Both JPEG 2000 encoder and decoder part were done using Kakadu version 6.0 software while the wireless transmitter and receiver part are implemented on separate FPGAs. For this setup, the wireless system part consists only of the baseband components. The radio frequency (RF) module in this wireless system was not implemented. Instead, the transmitter and the receiver are directly connected in the FPGA development board. Due to FGPA limitations, the data rate in this wireless system is only about 430 Mbps. This is expected to achieve up to 800Mbps throughput after ASIC optimization and implementation.

V. CONCLUSION

In this paper, we have proposed a 4K digital cinema transmission over 1.2Gbps wireless LAN system. The proposed system uses the bandwidth of 80 MHz in 5 GHz band and aims to achieve the 1.2Gbps throughput. This wireless system is based on IEEE802.11ac. Computer simulation results show that at least 40 dB of PSNR for every frame assures good video quality. This can be obtained when the BER is less than 10^{-6} and when error resilience tools defined in JPEG 2000 were used. In addition, we are going

TABLE 8. FPGA CIRCUIT SIZE

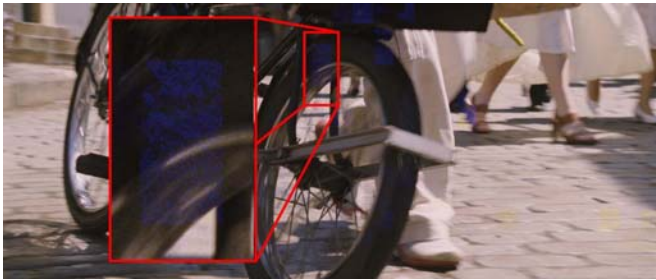
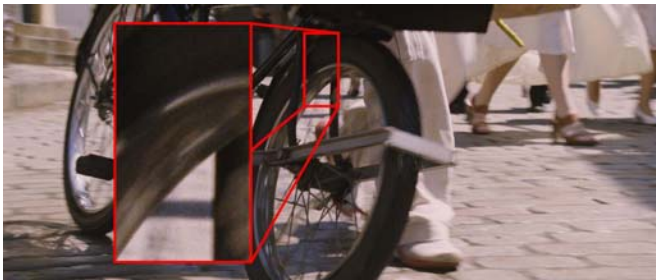
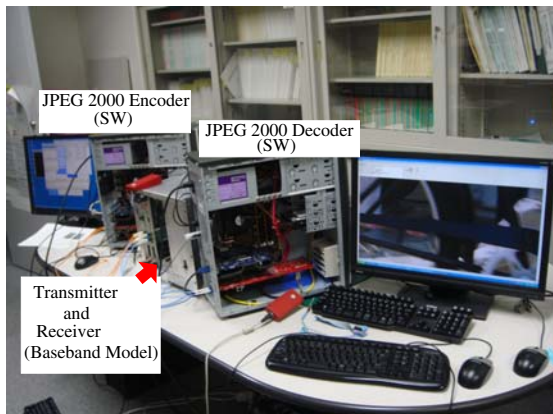
Block	TX			RX								
				FRONT-END			MIMO DEC. & CH EST.			REAR-END		
Device	Xilinx Virtex5 XC5VSX240T-2FF1738			Xilinx Virtex5 XC5VSX240T-2FF1738			Xilinx Virtex5 XC5VSX240T-2FF1738			Xilinx Virtex5 XC5VSX240T-2FF1738		
Resource Usage	Used	Available	Utilization	Used	Available	Utilization	Used	Available	Utilization	Used	Available	Utilization
Slice Registers	6,950	149,760	5%	4,688	149,760	3%	22,268	149,760	15%	10,441	149,760	7%
Slice LUTs	9,168	149,760	13%	15,445	149,760	10%	98,001	149,760	65%	33,999	149,760	23%
bonded IOBs	437	960	46%	224	960	23%	405	960	42%	348	960	36%
Block RAM/FIFO	26	516	5%	0	516	0%	66	516	13%	22	516	4%
DSP48Es	112	1,056	11%	128	1,056	12%	1,024	1,056	97%	24	1,056	2%

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**Figure 8.** Decode frame without ERT**Figure 9.** Decode frame with ERT**Figure 10.** Implemented wireless LAN system

through detailed evaluation and system optimization for ASSP(Application Specific Standard Produce) IP level implementation in our coming research work.