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WHDI vs. Wireless HD: 5 GHz based Wireless HDMI its Impacts and Challenges

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ABSTRACT
The nature of wireless video requires a solution which can adapt to changing environmental conditions and support very high data rates. This puts unique requirements on the wireless connection. It must maintain highly-reliable links, provide robustness toward packet errors and interference, deliver visually lossless compression and ensure system performance and cost effectiveness through a low-latency solution. In this paper we compare 5GHz wireless HDMI with 60GHz wireless HD. We propose UWB solution of wireless HDMI in which JPEG2000 and AES 128 encryption-decryption are key techniques to solve the raised technical problems. Initial performance evaluation shows that our approach can achieve high quality video streaming performance.

Keywords
HDMI, UWB (ultra wide band), JPEG2000, AES 128 encryption-decryption

1. INTRODUCTION

Various wireless technologies have been widely used indaily lives as cable replacement because of the convenient mobility support, fast and simple system setup, flexible network configuration change, reduced cost and etc. Another obvious trend in the consumer electronics (CE) industry is to support high-quality audio and high definition video in different CE devices such as HDTV, laptop, personal mediaplayer (PMP), set-top box (STB) and game console. There have been a lot of research works on wireless transmission of video streams since video has very challenging quality of service (QoS) requirements in terms of delay, jitter, robustness etc. By default before entering the wireless transmitter module a video stream is compressed by a video encoding mechanism specified in the standards of MPEG2, MPEG4, H.264, JPEG2000 and etc. [1]. After compression the video bit rate can be dramatically reduced. Several standard specifications such as High-Definition Multimedia Interface (HDMI), Digital Video Interface (DVI)and Display Port define interfaces for uncompressed HD transmission between devices through cables (wired links).These interfaces support 1 to several Gbps bandwidth capacity which cannot be provided by most wireless technologies. UWB integrated with JPEG2000 solve the raised technical problems. The Federal Communications Commission (FCC) agreed to allocate 7500 MHz spectrum in the 3.1-10.6 GHz band for unlicensed use for UWB devices [4] and limited the UWB Effective Isotropic Radiated Power (EIRP) to 41.3dBm/MHz [2]. The high level block diagram of the proposed system is shown in Fig.1. In the following sections we deal with the technology review followed by comparison with 60GHz wireless HD and UWB WHDI solution.

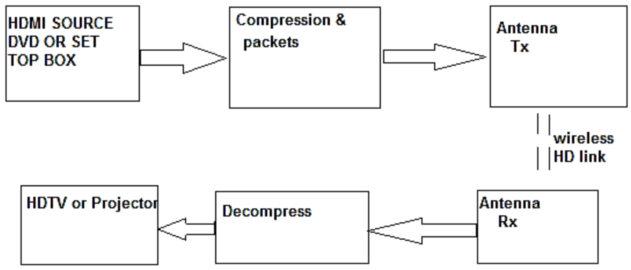

Fig. 1: high level proposed model of UWB based wireless HDMI

2. TECHNOLOGY REVIEW

Currently there are 3 types of wireless HDMI technologies:

2.1 Wi-Fi based technology [9]:

This is the same wireless technology applied to home computer networking. The original 802.11b standard only allows a max rate of 11 Mbps, which is not even adequate for the compressed 1080i (19 Mbps) signal. 802.11g standard was introduced to the market, with a max data rate of 54 Mbps. This is adequate for compressed HD, but still far short of the uncompressed HD data. Mostrecently, the new 802.11n, being drafted by the IEEE, holds the promise of a 540 Mbps data rate. Though a substantial gain, it’s still not wide enough for uncompressed HD.As you may know, the process of sending compressedvideo through a network is called streaming. HDTV streaming, with its extremely highdata rate, could dramatically slow down the network for other services that share the same channel, like email or web browsing.

2.2UWB based technology [9]:

UWB stands for ultra-wide band. It’s a new spectrum the FCC has allocated for high-speed communication (2002). The carrier frequency for this approach is from 3 to 10 GHz. The maximum error-correction encoded data rate is 675 Mbps, still far below the requirements of uncompressed HD signal. Even with compression, the maximum signal format this technology supports stops at 1080i. In theory, there is not enough bandwidth to send1080p signal via UWB but if lossless compression is integrated with UWB it is possible. One thing for certain, any lossy compression applied will unmistakably result in picture degradation.

2.3 Wireless HD [9]:

This technology is most likely to be ready 5 to 10 years from now. Sony, Panasonic, NEC, Samsung, LG and others formed an alliance to develop this technology using a 60 GHz band which is not yet approved by the FCC. With a carrier frequency that high, HD signal can easily be delivered uncompressed. As one could expect, however, there are a lot hurdles to overcome. First, the FCC approval and then the semiconductors (which are already very hot at 5GHz) are among them. A major technology break-through will be required to make the 60GHz chips a viable solution.

In addition to compression due to limited bandwidth, there are other challenges that wireless technology is facing:

a) Distance limitation: In wireless transmission, the higher the data rate the shorter the distance. Currently, most of the wireless for HDTV transmission is for indoor usage only and may not be far-reaching enough for projectors in large home theater configuration or for conference rooms, as examples [9].

b) Multi-path stability: The wireless signals can arrive at the receivers via direct (straight) path and/or multiple reflection paths, which is called multi-path. Because of the timing (phase) difference from multi-path signals, the combined signal at the receiver antenna can be destructive enough that the receiver will not decode correctly at a given moment [9].

c) Security: It may not be a big issue for home TV viewing; but it's absolutely critical for abusiness or government applications. Wireless signal is in the open air, so everyone inrange can receive it. To date, every data encryption system devised has been cracked [9].

d) Redundant usage of frequencies: In theory, you can have unlimited bandwidth in a given space with wires. In the wireless world, you can only have one set of bandwidth in a given space, say from 0 to 20 GHz, because it's shared by all the transmitters in the open air luckily.This could still be a real problem in high density livingplaces like apartments [9].

e) Link reliability: Link reliability well in excess of 99% is required for wireless video. This compares to 90% link reliability for data networks [4].

f) Low packet error rate: High-definition video content requires exceptionally low packet error rates of 10-8 for the wireless link to deliver hours of flawless video. Wireless data networks typically achieve a packet error rate of 5% to 8%. Additionally, when occasional errors occur, the compression scheme must be one which does not propagate errors through multiple frames [4].

g) Robust to interference: The home environment has numerous forms of RF interference. The preserve perfect video quality, the wireless link must avoid or cancel interference (both in-band and out-of-band) and continuously provide a perfect video signal [4].

i) Low latency: Total latency is a function of both the wireless link and the video compression timeline [4].

3. COMPARISON OF WHDI WITH 60GHZ WIRELESS HD& TECHNICAL CHALLENGES

Wireless HD and WHDI TV were compared and tests were performed to evaluate the wireless link stability. Test conditions were ideal for wireless HD. Wireless HD link becomes very unstable when any obstacles come in between the line of sight. It is easy to see that data rate drops significantly. And that the system compensates for this reduction by dropping pixels. In fact, the transmission rate in these conditions allows for transfer of only 25% of the pixels. The resulted artifacts are very annoying to eye. Short range Line-of-Sight (LOS) is only possible. Wireless propagation in 60GHz range is very poor due to energy absorption by oxygen molecules in order to achieve short-range NLOS, many antennas are used with high directivity, and hence chip size is increased.

It is very challenging to meet the strict Quality of Service (QoS) requirements from uncompressed video streaming applications since 60GHz wireless signals can be easily blocked by human body and other obstacles, but usually cannot block a 5GHz wireless channel [2].

60GHz signals have penetratingwalls and floors, leaving it as a short-distance solution rather than one for the whole home. In contrast, the WHDI approach also adds control protocols so that a DVD player downstairs can be controlled directly while watching the output up stairs.

60GHz is one of the resonant frequencies of water. That doesn't sound like a good thing, and because of the poor propagation it has to be transmitted at a higher power of all the wireless technologies, 5GHz is probably the safest. It's much lower power than 60GHz or cellular phones.

3.1 Technical challenges

Compared to compressed video transmission over wireless channel, uncompressed HD video over 60GHz has different technical challenges to affect the system performance.

3.1.1 Limitation of in-chip buffer size

In compressed video transmission system, usually multiple compressed video frames are buffered at the receiver toovercome the channel bandwidth fluctuation, absolve the transmission jitter and help to do error concealment. Buffering at the receiver is a proper solution for compressed video since the total required buffer size in a wireless chip is still small to store multiple compressed video frames. However, for uncompressed HD video, it may be difficult for the wireless receiver chip to buffer even one single video frame. For example, for 1080p video format, each frame has active picture information of 1920 rows and 1080 lines, and each pixel has 24 bits, then each video frame has about 6 Mbytes. Due to the size and cost constricts of millimeter wave wireless chip, usually the receiver can only buffer part of a video frame. This means the commonly used error concealment scheme by copying the information from previous video frame to recover the current frame is not applicable to millimeter wave wireless. In addition, it is also difficult to handle the channel bandwidth fluctuation and transmission jitter issues due to limited buffer sizes [5].

3.1.2 Sensitivity of millimeter wave wireless channel

At 60GHz there is much more free space loss than at 2 or 5GHz since free space loss increases quadratically with frequency [2]. In principle, this higher free space loss can be compensated by the use of antennas with more pattern directivity while maintaining small antenna dimensions. When such antennas are used, however, an obstacle like a human body can easily cause a substantial drop of received power and block the channel for several seconds. Some mechanisms such as dynamic beam-searching can be used to relieve this blocking effect and reduce the blocking time. However, for uncompressed video streaming applications, due to very limited buffer size compared to the very high data rate, the reduced blocking time still degrade the video quality greatly [5].

3.1.3 Long video format switching time at video input and Playback modules

The modulation and coding scheme (MCS) for an ongoing transmission needs to be dynamically adjusted according to the variable channel conditions. It means at the MAC SAP interface the available network bandwidth is dynamically changed too. And the video stream needs to switch its format to adapt to the available network bandwidth. For example, a video stream format can be switched from 1080p to 1080i to halve the data rate. Unfortunately, most HDTVs or other display devices take long time to switch from one format to another format, usually 4 to 6 seconds. And during the switching procedure video stream cannot be displayed on the screen. Long format switching time at the HDTV and otherdisplay devices cannot meet the user's continuous streaming and playback requirements. How to support stable uncompressed video streaming with variable channel conditions is a big challenging for millimeter Wave system design [2][5].

4. UWB WIRELESS HDMI SOLUTION

Recently Ultra-Wideband (UWB) systems were proposed to standardize high bandwidth wireless communication systems, particularly for Wireless Personal Area Networks (WPAN).The fundamental issue of UWB is that the transmitted signal can be spread over an extremely large bandwidth with a very low Power Spectral Density (PSD). The Federal Communications Commission (FCC) agreed to allocate 7500 MHz spectrum in the 3.1-10.6 GHz band for unlicensed use for UWB devices and limited the UWB Effective Isotropic Radiated Power (EIRP) to 41.3dBm/MHz Fig. 2 shows the division of spectrum from 3 to 10GHz.

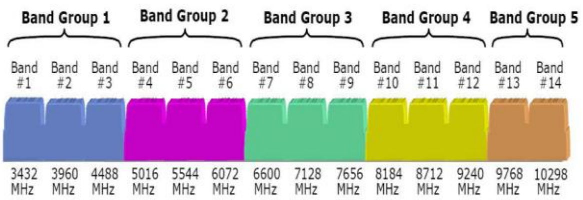

Fig. 2:The figure above shows the division of spectrum from 3 to 10 GHz.The initial wave of UWB products commonly occupies Band Group 1 whichrepresents 1.7 GHz of spectrum.

HDMI source is given to the compressor where suitable lossless compression takes place.
Then the compressed digital audio video signal is sent to encryption.

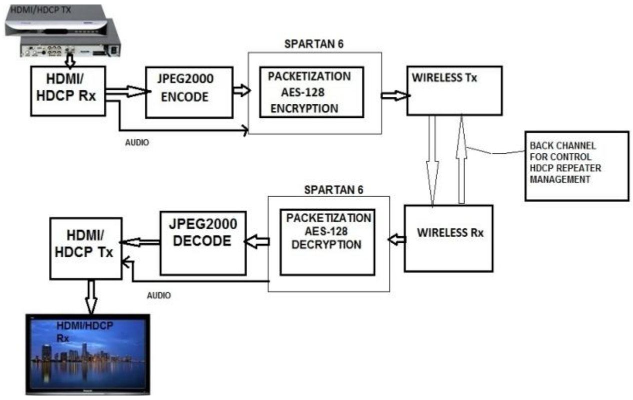

Fig. 3: system model of UWB based wireless HDMI

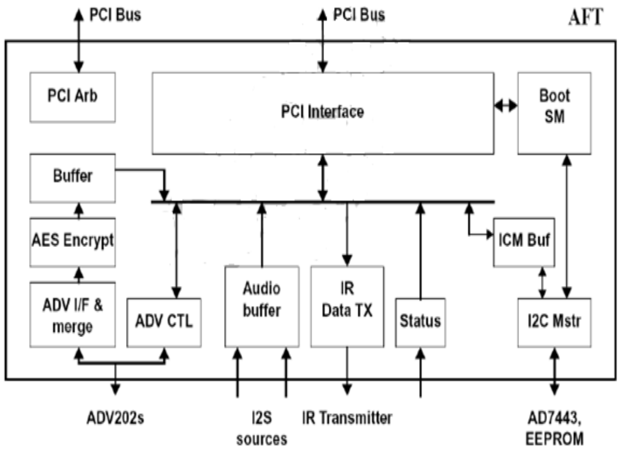

Fig.4: Transmitter FPGA block diagram [7]

Advanced Encryption Standard (AES) is a specification for the encryption of electronic data. It supersedes DES. The algorithm described by AES is a symmetric-key algorithm, meaning the same key is used for both encrypting and decrypting the data. Encryption is needed for any wireless transmission. Then it is transmitted in air by UWB bandwidth. The system model of UWB based wireless HDMI is shown in Fig. 3.

4.1 Transmitter FPGA Block Descriptions

PCI Arbiter: Very simple, after boot up the Radio is always given the bus.Video Data Buffers: Circular buffers, Headers identify the frame and sequence of the video data which is encrypted. AES128 Encryption: Merged video data is encrypted before being placed in the video databuffers. Audio Buffers: I2S Audio data is accumulated and stamped with a matching frame ID. I2C: I2C Master allows the host to program the HDMI parts. ADV212 Host Control & Stream Merge: Bridges the ADV212 Host bus to the PCI, Merges Luma and Chroma data into a single compliant JPEG2000Code stream. IR Blaster: Takes data from the receiver side and drives an IR LED, used to extend IRremote controls for the source devices.

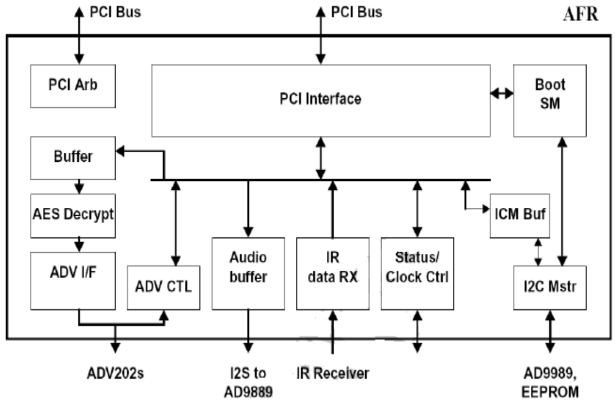

Fig. 5: Receiver FPGA block diagram [8]

4.2 Receiver FPGA Block Descriptions

PCI Arbiter: Very simple, after boot up the Radio is always given the bus. Video Data Buffers: Circular buffers, Host writes video data into them as they become available. AES128 Decryption: Merged video data is decrypted before being sent to the decompression engine. Audio Buffers: I2S Audio data is written here and then clocked out to HDMI and the DAC. I2C: I2C Master allows the host to program the HDMI parts.

4.3Brief overview of JPEG2000

Compressing a high-definition video stream and then sending it over awireless link presents three major challenges: latency, imagequality, and error resiliency in the face of variable channel bandwidth. JPEG2000 compression is performed on an intra-frame basis which inherently decreases process latency compared to any temporal compression. The ADV202 shortens process latency even further by using a patented technology called SURF™ (Spatial Ultra-efficient Recursive Filtering) by performing the wavelet transform on aline-by-line basis.JPEG2000 [3], the new still and moving image compression standard from the JPEG Committee, was designed to address the shortcoming of JPEG.

Better image quality Up to 50% better Pixel SNR performance than JPEG, Lossless compression possible. It uses wavelet-based transform to achieve better compression. Better error-resilience compared to other compression standards.Better error resilience compared to JPEG and MPEG.

5. CONCLUSION

We proposed a new simple yet effective UWB solution for wireless video applications. Convergence of UWB with the JPEG2000 is used to solve various QoS technical problems. This approach can achieve long time stable high-qualityvideo streaming performance even in the NLOS blocking situations.

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