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AVB 기반의 버스안전용 멀티뷰어의 FPGA 카메라모듈 설계☆

Design of FPGA Camera Module with AVB based Multi-viewer for Bus-safety

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요 약

본 논문에서는 버스안전을 위한 다중 HD 카메라 기반의 IP통신망 AVB(Audio Video Bridge) 이더넷 케이블을 연동한 FPGA(Xilinx Zynq702)로 멀티뷰어 플랫폼을 제안하였다. 이러한 AVB(IEEE802.1BA) 시스템은 차량용 네트워크에서 다중 HD 비디오와 오디오 디지털 신호의 실시간 전송이 가능하다. 제안한 멀티뷰어 플랫폼은 기존 이더넷 케이블 1Gbps전송과 2-선 100Mbps 스트림 전송방식을 통해 4개의 초광각 HD 카메라로 부터 H.264 비디오 신호를 다중화하기 위한 지연속도의 개선을 위해 FPGA로 설계하였다.

아울러, 차량용 HD 동영상 전송망에서 시간지연을 최소화하기 위한 AVB 플랫폼은 Zynq 702기반의 H.264 AVC 저지연 코덱의 설계 방안을 제안하였다. 이러한 H.264 AVC 코덱의 부호화/복호화 결과확인을 위해 JM 모델을 참조한 PSNR(Peak Signal-to-noise-ratio)을 분석하였다. 설계한 Zynq 702기반의 H.264 AVC CODEC은 다중 HD 카메라의 다중뷰어 동영상 손실 압축에서 화질 손실에 대한 PSNR은 이론 값과 유사한 HW 결과 값을 확인하였다. 이로서 제안한 AVB기반의 다중 HD 카메라 연동형 멀티뷰어 플랫폼은 H.264 AVC CODEC의 저지연 특성이 차량용 특성에 만족함으로서 버스안전을 위한 주변의 오디오와 비디오 영상감시가 가능할 것이다.

☞ 주제어 : AVB, FPGA, 이더넷 케이블, 버스안전시스템, 멀티뷰어 플랫폼

ABSTRACT

In this paper, we proposed a multi-viewer system with multiple HD cameras based AVB(Audio Video Bridge) ethernet cable using IP networking, and FPGA(Xilinx Zynq 702) for bus safety systems. This AVB (IEEE802.1BA) system can be designed for the low latency based on FPGA, and transmit real-time with HD video and audio signals in a vehicle network. The proposed multi-viewer platform can multiplex H.264 video signals from 4 wide-angle HD cameras with existed ethernet 1Gbps. and 2-wire 100Mbps cables.

The design of Zynq 702 based low latency to H.264 AVC CODEC was proposed for the minimization of time-delay in the HD video transmission of car area network, too. And the performance of PSNR(Peak Signal-to-noise-ratio) was analyzed with the reference model JM for encoding and decoding results in H.264 AVC CODEC. These PSNR values can be confirmed according the theoretical and HW result from the signal of H.264 AVC CODEC based on Zynq 702 the multi-viewer with multiple cameras. As a result, proposed AVB multi-viewer platform with multiple cameras can be used for the surveillance of audio and video around a bus for the safety due to the low latency of H.264 AVC CODEC design.

☞ keyword : AVB, FPGA, ethernet cable, bus safety, multi-viewer platform

1. Multi-viewer for bus safety

AVB(audio video bridging) platform provides real time ethernet for automotive network with the Quality of Service in the integration of multiple HD cameras. The Ethernet AVB brings low-cost twisted-pair wiring to the car. This AVB connection is used to connect surround audio, and rear to the head unit cameras replacing coax cabling for cameras or multi-viewer displays with low-latency on the original images, and identification of AV network streams. This AVB carries a multiplicity of AV network streams before video compression H.264 for ethernet transmission, and displays[1].

Fig. 1. Design of HD multi-viewer for bus-safety

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For bus safety, AVB based on multi-viewer with various HD cameras will help driver detect dangerous situation from combining a variety of 4 HD video signals in fig.1[1].

In this paper, we designed multi-viewer with AVB based HD cameras for real-time transmission of Video, Audio and Control signals on bus safety platform.

2. Design of Ethernet AVB

2.1 Analysis of IP-based A/V for AVB

IEEE 802.1 project started in 2005 largely to address the needs of the professional audio market(IEEE 802.1 Audio Video Bridging Task Group (TG)). Originally called "Residential Ethernet (2003)", but that was too limiting and not really in scope for the IEEE 802.3 Ethernet standards.

But also very, very useful to consumer electronics, professional video, and automotive "infotainment". Associated industry compliance and marketing group called "AVnu"

For AVB, multicast IGMP(Internet Group Management Protocol) is accepted to start/stop stream packets in automotive transmission[2].

Table. 1. Standard analysis of AVB protocols

IEEE 802.1BA-2011	Audio Video Bridging Systems
IEEE 802.1Qav-2009	Forwarding and Queuing Enhancements for Time-Sensitive Stream
IEEE 802.1Qat-2010	Stream Reservation Protocol
IEEE 802.1AS-2011	Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks
IEEE 1722-2011	Layer 2 Transport Protocol for Time-Sensitive Applications in a Bridged Local Area Network
IEEE 1733-2011	Layer 3 Transport Protocol for Time-Sensitive Applications in Local Area Networks (w. UDP/IP)
IEEE 1722.1-2013	Enumeration, Connection Management & Control Protocol for AVTP devices

Especially, sufficient synchronization accuracy is proposed with the adopt of IP technologies which consist of the following two technologies:

- ☐ Network Synchronization (gPTP): IEEE802.1AS
- ☐ Stream Reservation (inc. shaping): IEEE802.1Q, IEEE1722, IEEE1733

This gPTP requires specified time-aware switches (AVB Bridges), although stream reservation function is extended to cover an IP (IEEE1733), gPTP is still a L2 technology[2].

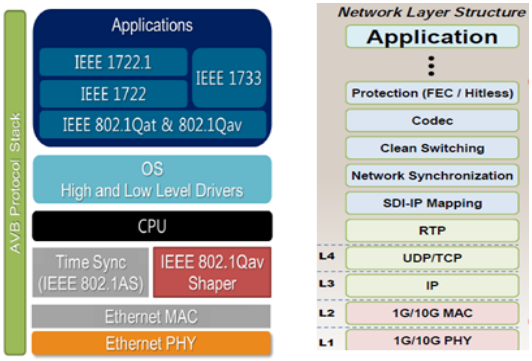

Fig. 2. Analysis of AVB protocol stack & IP network

2.2 Design of AVB platform with cameras

Multiple HD cameras can transmit video signal on Ethernet AVB cable. Multi-viewer with AVB transmission platform was proposed for multiple HD camera modules.

For bus safety, real-time transmission was needed based on Ethernet AVB with multiple HD cameras like as AV stream management[1][2][3]t;

- ☐ manage the cross point matrix and control AV stream routing(Network Resource Management)
- ☐ maintain network topology and manage network resources(Device Management)
- ☐ manage AV network streams and Device capability

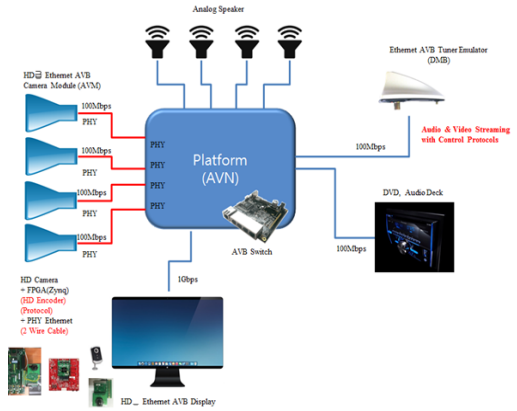

Fig. 3. Design of AVB platform with HD cameras

2.3 FPGA Design of AVB with Zynq702

In this paper, the multi-viewer was designed with linux based real-time HD cameras over AVB networks.

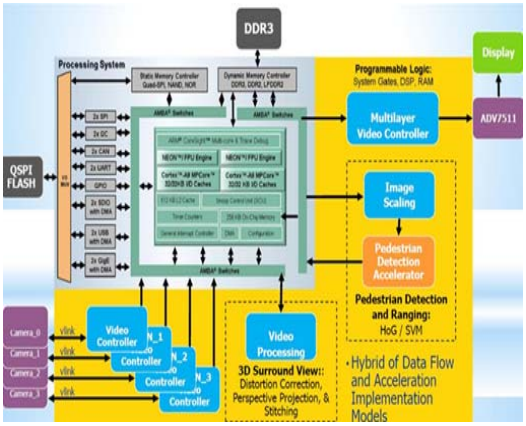

Fig. 4. Zynq archit. for AVB core and peripherals

Especially, FPGA based AVB platform was designed with the Xilinx Ethernet Audio Video Bridging Endpoint LogiCORE IP core as following[7][8][9];

- ☐ IEEE 802.1 AS Ethernet AVB
- ☐ IEEE 1588 V2 PTP/ TCP/IP Protocol Stack
- ☐ IEEE 1722 Packet Parser
- ☐ 1280x720P 60fps 4Ch. MJPEG(H.264 AVC) Decoder
- ☐ Image Synthesis and LVDS Output

In order to analyze multi-viewer of HD cameras, software platform of Audio Video Bridge Listener on ZC702 is followed[4[5][6]];

- ☐ TCP/IP Protocol : LWIP ported
- ☐ Time Synchronization : IEEE 1588 v2 PTP
- ☐ Stream Receiver & Parser : MJPEG(H.264 AVC) encapsulated by IEEE P1722

And Talker on Zed Board

- ☐ Embedded Linux OS
- ☐ Frame Buffer Device Drivers
- ☐ Time Synchronization : LinuxPTP
- ☐ Stream Packetizer & Transmitter MJPEG(H.264 AVC)

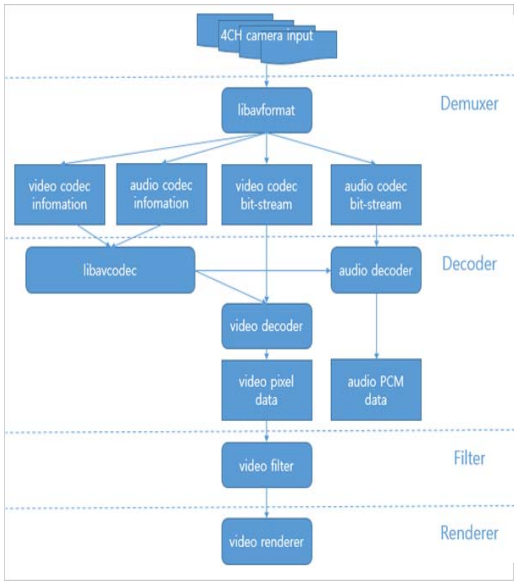

Fig. 5. SW Design of AVB platform for multi-viewer

3. FPGA Design of Multi-viewer

3.1 FGPA design of SoM for AVB module

For the multi-viewer of AVB transmission, multiple HD cameras were designed with ISX016, and FPGA(Xilinx Zynq 702) PHY SoM module(size 200x100mm)[4][9].

Fig. 6. FPGA Design of SoM with Zynq 702

3.2 SoM design of H.264 Encoder for AVB

H.264 Encoder was designed with SoM(system on module) for the multi-viewer of HD cameras over AVB networks displaying with Zynq 702 platform, and multi-format video transmission likes as following[7][8][9];

- ☐ 64-bit AXI interface to access image, stream buffers
- ☐ interleaved color input for variable format

☐ little data formats
☐ Intra mode : 16x16 (except plane mode), 4x4 (except diagonal down left and vertical left mode)
☐ SPS, PPS generation
☐ HD 20Hz encoding or decoding @ 75MHz core clock
☐ minimum image size - horizontal 80, vertical 48 pixel

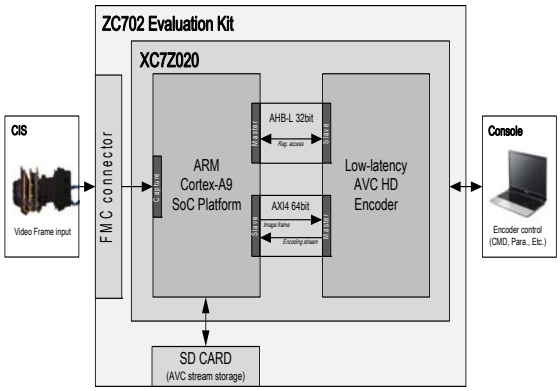

Fig. 7. Design of H.264 encoder with Zynq 702

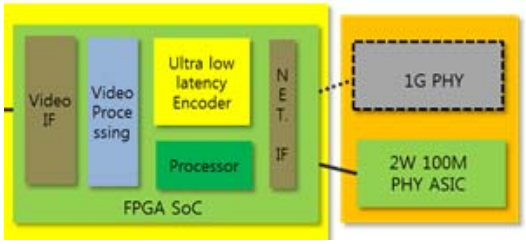

Fig. 8. AVB HW design for HD multi-channels

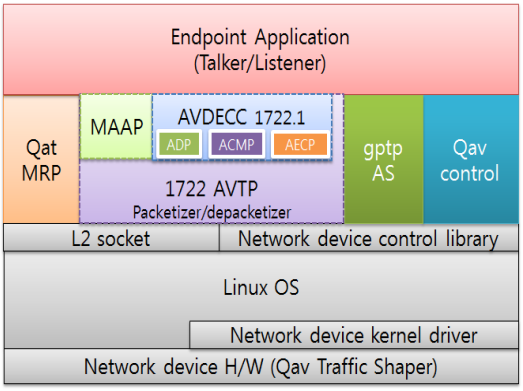

Fig. 9. AVB SW design for HD multi-channels

For the design of H.264 encoder with Zynq 702, there are programmable parameters as following;

☐ source image size : multiplied by 16 (vertical 8)
☐ picture type : intra frame
☐ encoding option : qscale
☐ header parameter : SPS, PPS parameter
☐ buffer address of source, reference and reconstruction
☐ wait cycle control of memory request interval

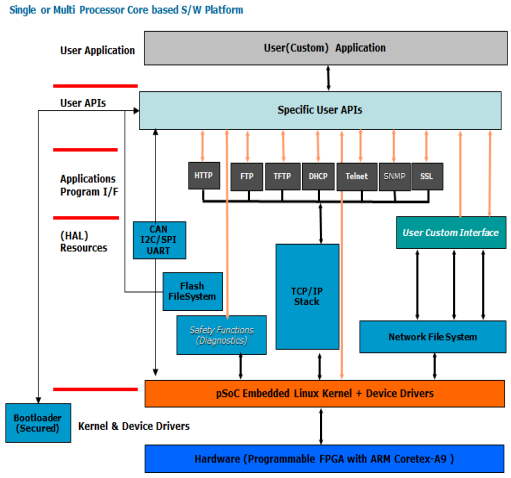

Fig. 10. Design of Linux OS based S/W Platform

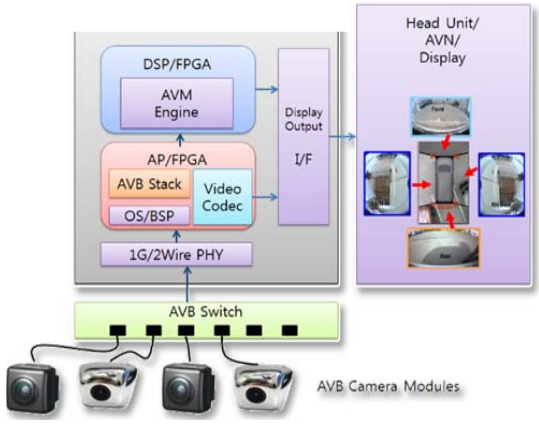

Fig. 11. Zynq 702 design for multi-viewer

3.3 Analysis of FMC for HD camera Tx.

The multi-viewer of HD cameras was designed with Zynq 702 platform for the real-time automotive AVB[4][6];

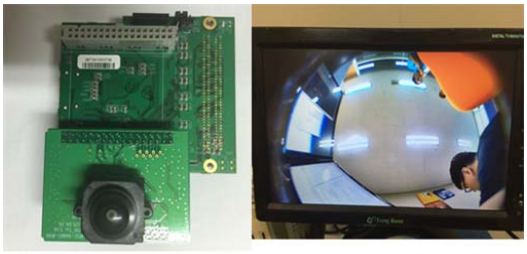

Fig.12. Analysis of HD camera/FMC B'd view result

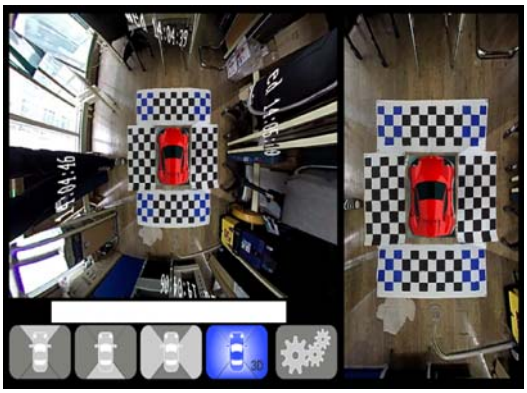

Fig.13. Analysis of HD camera view result

For AVB HD transmission, HD Camera Module is designed for HD automotive with ISX016. This AV transmission module is implemented by PHY module[9].

3.4 Analysis of H.264 AVC compression

For the multi-viewer of bus safety, the low-latency efficiency of H.264 AVC compression was analysed with JM reference software model from HHI(Heinrich- Hertz-Institute). This FPGA CODEC was needed for reducing computing power. The rest of CPU power was reserved for time consuming video analytics. This can support the performance analysis of reference standard for H.264 CODEC in fig.14[10].

In fig.15, the performance of AVC compression efficiency with RD-curve was analyzed with PSNR(Peak Signal-to-noise-ratio) according to the CODEC model of JM encoding/decoding reference[5].

As a result of Zynq 702 based the low-latency AVC design for H.264, the performance of PSNR is similar to the JM CODEC reference mode under 0.5dB[1l][12].

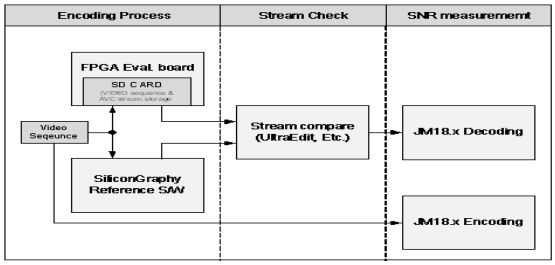

Fig.14. Analysis for AVC compression efficiency

sequence		JM				HW			
HD	QP	22	27	32	37	22	27	32	37
	psnr (dB)	40.93	37.77	34.71	31.76	40.44	37.36	34.42	31.61
	bitrate (kbit/sec)	40558	21857	12494	7236	41139	22658	13572	8172

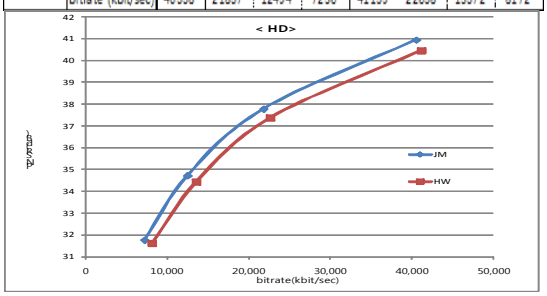

Fig.15. AVC compression efficiency with RD-curve

4. Conclusions

In this paper, the multi-viewer was designed for real-time transmission of AVB based HD cameras for bus safety platform. This multi-viewer can reduce the number of monitors, and build an environmentally conscious system by dividing the screen to display numerous sources on a single AVB monitor. The performance of PSNR(Peak Signal-to-noise-ratio) was similar to the worst case, 0.49dB lower than 40.93dB at Qp 22 [Fig.15]) with the reference model JM for H.264 AVC CODEC of proposed multi-viewer according the theoretical and HW result from the signal of Zynq 702 based H.264 AVC CODEC in the multi-viewer with multiple cameras. As a result, this multi HD platform can adjust the frame line brightness, or turn the frame lines off for use as a multi-image program display in smart bus safety systems.

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