// preface of Introduction

Recently, wireless has become a prominent technology in indoor communications and networking, which are conventionally connected with {\textit *cable spaghetti}*. Among the variety of transmission data, uncompressed high-definition (HD) video streaming communication is of great interest. With the aid of the millimeter wave (mmWave) technology, there are already several standardizations working on wireless uncompressed HD video communications system over WPANs, such as WirelessHD \cite{wirelesshd} and Wireless Gigabit Alliance (WiGig) \cite{wigig}. However, fragile millimeter wave channel with terrible propagation loss results in serious damage to the received video data. In hence, many researches aim to improve such system by establishing a stronger decoder or constructing a better information protection strategy. In this thesis, an UEP scheme is designed for such system in order to provide more important information with better protection through transmission energy management. The detailed introduction is split into 3 sections and presented in the following.

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% Wireless Uncompressed Video Transmission

\section{Wireless Uncompressed Video Transmission}

\label{i:wireless\_uncompressed}

The conventional solution for uncompressed HD video communications is the expensive cables of high-definition multimedia interface (HDMI). It's worth noting thatHowever, it's a difficult challenge for conventional wireless technology to support such large required data rate. Owing to the emergence of mmWave system driving on 57-66 GHz band, multi-Gbps bandwidth supports the required data rate for uncompressed HD video transmission via wireless personal area networks (WPANs). Since the required data rate is provided, many problems incurred by compression at the transmitter and decompression at the receiver are eliminated. First, because end-to-end latency is an important issue for some video streaming systems such as interactive game consoles, the intrinsic latency generated by the processing time of compression and decompression is not suitable for such systems. Second, degradation in video quality subject to the compression process like quantization can never be recovered at receiver. Third, the hardware cost and complexity for supporting compression techniques and the cost of transcodecs for converting between different compression codec can be apparently reduced while the compression and decompression process are removed. Therefore, HD video sequences are usually transmitted without compression in such mmWave system over WPANs 60Ghz band ~\cite{ 60ghz }.

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% Related Works Improving Wireless Uncompressed Video Transmission

\section{Related Works Improving Wireless Uncompressed Video Transmission}

\label{i:works}

In spite of various advantages for transmitting uncompressed HD video using mmWave systems, there are still some precipitous impediments. The propagation loss scales as the square of carrier frequency, so that the mmWave signals tend to be much more fragile, compared to conventional 2.4 or 5GHz signals (60GHz is 21.6dB worse than 5GHz). In other words, such systems could operate in a low signal-to-noise ratio (SNR) condition, and it results in damaged video frames. There are several works providing different approaches to enhance the video quality in an uncompressed video transmission system. In~\cite{60ghz}, pixel partitioning and uncompressed automatic repeat request (UV-ARQ) are proposed, but ARQ scheme would increase the latency and the transmission energy nevertheless. Since in uncompressed video transmission neither the spatial nor the temporal redundancy is removed from the video source, joint source-channel coding (JSCC) ~\cite{JSCC} can be performed to exploit the redundancy by use of soft-in soft-out (SISO) decoder, which computes the likelihood value of each source bit. In JSCC, the reuse of the redundancy improves the communication reliability.

A communication system can achieve better performance by combing the side information along with error correction code. As a result, based on JSCC, iterative source-channel decoding (ISCD)~\cite{ISCD, ISCD2, ISCD3, ISCD4, ISCD5} was developed as a turbo-like~\cite{turbocode} decoding structure to exchange the extrinsic information between channel decoder and source decoder, and thus increasing the error robustness of the receiver. In ~\cite{3D\_MRF}, an ISCD scheme for uncompressed video decoding using 3D Markov Random field (MRF) to model the relationship in bit-plane level between both spatial and temporal neighboring bits is proposed, where the MRF parameters are jointly and iteratively estimated during decoding at the receiver. Numerical results indicate that 3D-MRF based ISCD scheme can significantly enhance the video quality under any SNR conditions. It is worth noting that this scheme can also cooperate with unequal error protection (UEP) strategies in transmitter to achieve further improvement in video quality and transmitter power management.

The basic idea of UEP is to offer the more important bits the stronger protection against the distortion from the error-prone channel by using different modulation and channel coding schemes. In order to obtain the better video decoded quality, UEP principle divides the video into different components according to their prioritization. A two-level UEP partition mode is a common feature adopted by most existing mmWave systems for uncompressed video transmission ~\cite{60ghz} ~\cite{hierarchical}, where each video color component of eight bits is separated into the most significant four bits (MSBs) and the least significant four bits (LSBs). Besides, an uncompressed video usually consists of three color components Y, U and V, where Y is Luminance, and U/V are Chrominance. In ~\cite{ucpv} and ~\cite{adaptiveUEP}, higher level UEP schemes in awareness of the prioritization between different color components are proposed.

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% Main Work in This Thesis

\section{Main Work in This Thesis}

\label{i:main}

In this thesis, we propose a new UEP scheme designed for the ISCD structure presented in ~\cite{3d\_mrf}. The encoder with our proposed UEP scheme for uncompressed video transmission can be aware of the bit-level priority as well as the spatial and temporal redundancy resident in the video sequences, and it accordingly determines the allocation of transmission energy for bits in different bit-planes in order to achieve the optimized efficiency. Firstly, to optimize the energy distribution among different bit-planes, the UEP scheme should be able to precisely predict the decoded video quality before transmission. Therefore, we establish the estimator for the video distortion in terms of peak signal-to-noise ratio (PSNR) by introducing the MRF model into encoder. The proposed estimator can jointly consider the influence from each bit-plane and the introduced MRF model is dependent on the MRF model applied in the decoder. Based on the proposed distortion estimation, we further formulate the optimization problem where the UEP scheme is required to achieve the optimized estimated video quality under the given transmission energy constraint. Then, lagrange multiplier method is adopted for the purpose of solving this constrained optimization problem. Finally, our proposed UEP scheme is constructed with the aid of the lagrange multiplier method and the newton’s method. Additionally, numerical results show that the proposed UEP scheme can manage the transmission energy efficiently and improve the decoded video quality in comparison to Equal Error Protection (EEP) scheme. Besides, it is observed that the quality varying caused by the channel noise as well as content diversity is mitigated by the proposed UEP scheme. It is worth noting that our proposed UEP scheme performs well especially under the low SNR condition which is similar with the mmWave indoor environment mentioned before.

The content of this thesis is organized as follows. In Chapter \ref{b:intro}, the 3D MRF model and the ISCD structure in ~\cite{3d\_mrf} are introduced. The principle of the proposed UEP scheme is described in Chapter \ref{chapter:opt-prob}. The estimation of decoded video quality through ISCD decoder is proposed in Chapter \ref{chapter:estimation}, and the optimization of the power allocation for each bit plane is derived in Chapter ~\ref{chapter:optimization}. Performance simulations and comparison to the encoder with EEP scheme are also presented in Chapter \ref{chapter:optimization}. Finally, the conclusions are made in Chapter \ref{e:conclusions}.