II.3. Multiple Description Coding for Video Delivery

Prof. Chia-Wen Lin
Department of CS
National Chung Cheng University
886-5-272-0411 ext. 33120
cwlin@cs.ccu.edu.tw

Introduction

- Multiple description coding (MDC)
  - Encoder generate two or more bitstreams (Descriptions)
  - Receive any of them can reconstruct the video with lower quality
  - Receive all of them can reconstruct the video with full quality

Introduction (Cont.)

- MDC can provide acceptable video quality without retransmission
  - Good for real time application, such as video phone and video conferencing
  - Simplify the network design, feedback and retransmission are burdens, they need more actions in both the server and clients

Introduction (Cont.)

- MDC can cooperate with multiple path transport (MPT)
  - Traffic dispersion and load balancing
  - Avoid congestion problem at hotspots, increase the overall throughput
  - Single description coding will need more complex scheduling scheme than MDC in an MPT environment

Introduction (Cont.)

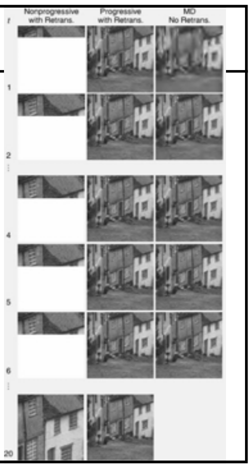
- Multiple Description coding (MDC) vs. Layered Coding (LC)
  - Layered coding generate the bitstream which can be depart into several layers
  - Contrast to MDC, the layers in LC are with different importance, enhancement layers will be useless if the base layer is not received

Video Delivery with Transmission Errors: MDC vs. SDC

Single Description Coding

Multiple Description Coding

Scalable Coding vs. MDC



MDC: Disadvantages & Goal

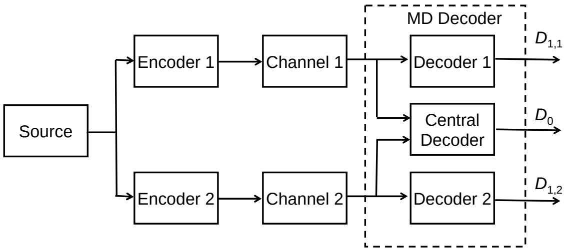
- Disadvantage of MDC
  - Lower compression rate than ordinary coder
- Goal of designing MD coder
  - Minimize the redundancy
  - Reconstruct an acceptable video when packet loss (some descriptions lost)

General MD Coder

- Two main design issues with an MD coder
  - Mismatch control: mismatch between encoder and decoder cause the drift problems
  - Redundancy allocation: to reduce the mismatch, redundancy is required
- If a coder can dynamically adopt itself
  - Can exploit the variety of channel conditions and video statistics

General MD Coder (Cont.)

- MD coding allows a video decoder to extract meaningful information from a subset of the bitstream
- An encoder produces two descriptions (may be equally important) that are transmitted over two channels



General MD Coder (Cont.)

- The basic framework for MDC
  - Coder creates two descriptions with rate = R_1 and R_2 and send them across two channels
  - Receive two descriptions, central decoder can decode a high-quality video with distortion = D_0
  - Receive only one description, side decoder can decode lower quality video with distortion = $D_{1,1}$ or $D_{1,2}$
  - A balanced design will set $R_1 = R_2$ and $D_{1,1}= D_{1,2} = D_1$

Multiple Description Scalar Quantizer [Vaishampayan 93]

- The input signal x is quantized to yield an integer index $l = q(x)$, where $q(\cdot)$ is a uniform quantizer
- Information about l is mapped to a pair of indexes $(i,j) = a(l)$
- The index i is transmitted on channel 1, while the index j is transmitted on channel 2
- If information for channel 1 or 2 only is received, the distortion level D_1 or D_2 will be incurred, respectively
- Receiving both information can obtain the full quality
- If only one index is received, it is possible to estimate the index l by choosing the central index in the row/column of the received index i or j, respectively
- Has been applied to intra coding of blocks in a DCT-based image/video coding framework

Example of MDSQ Quantizer Assignment

i →

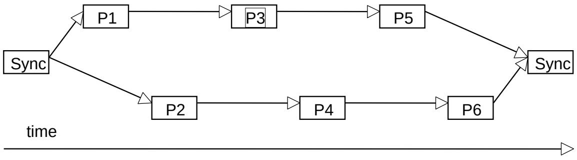
j ↓

1	3						
2	4	5					
	6	7	9				
		8	10	11			
			12	13	15		
				14	16	17	
					18	19	21
						20	22

Multiple-Description Subsampling

- Spatial domain
- Temporal domain
- Frequency domain

Temporal-Domain Subsampling (Video Redundancy Coding in H.263+)



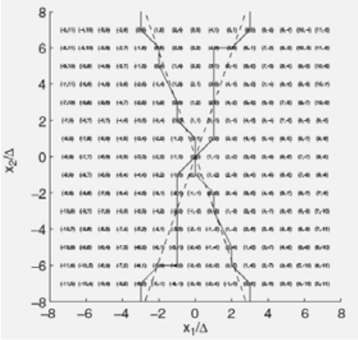
MDC Using Correlating Transforms

- – Force dependencies between pairs of transformed coefficients so that either coefficient can be estimated from the other when one is lost
- – Transform-based MD method:

$$\begin{bmatrix} C \\ D \end{bmatrix} = \mathbf{T}\begin{bmatrix} A \\ B \end{bmatrix}$$

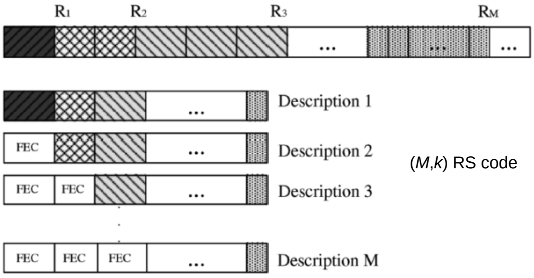
- – Redundancy is added by controlling the correlation in the pair (*C*,*D*) of transform coefficients through **T**
- – A transform MD method for blocks of transform coefficients in a DCT-based video coder
  - Quantized DCT coefficients of the same frequency belonging to spatially neighboring blocks are paired as (*A*,*B*)
  - A correlating transform T is designed for each group of paired coefficients
  - DC coefficients would be coded with high redundancy

MDC Using Correlating Transforms (Cont.)



V. K. Goyal, “Multiple description coding: Compression meets the network,” *IEEE Signal Processing Mag.*, vol. 18, pp. 74–93, Sep. 2001.

Multiple-Description FEC (MD-FEC) for Scalable Video

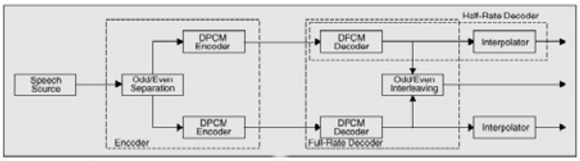


(*M*,*k*) RS code

The decoder can recover the first *k* layers from any *k* descriptions

MDC for Speech coding (AT&T Bell Lab)

The information of a single call could split and sent between two different links or paths.
An MD speech coding example is sending odd number samples on one channel and the even to the other and we do not having too much aliasing because the Nyquist rate (6.4KHz) is less enough comparing to sampling rate (12KHz). Assuming that voice spectrum is 3.2KHz.



1. Speech coding for channel splitting as proposed by Jayant Speech sampled at 12 kHz is split into odd and even streams. These are separately encoded by DPCM.

Design of Predictive MDC

- To measure the efficiency of an MD coder, redundancy-rate distortion (RRD) curve is useful
- Traditional SD coder minimizes D_0 subject to a fixed rate *R*
- An MD coder need to minimize both D_0 and D_1 subject to a rate constraint

$$\min_{Z,M} ((1-p)^2 D_0 + 2p(1-p)D_1 + \lambda R) \qquad (1)$$

subject to $R \le R_{\max}$

Design of Predictive MDC (Cont.)

- The central distortion depends on $\mathcal{Z}$ only, and the side distortion depends on both $\mathcal{Z}$ and $\mathcal{M}$.
- The total rate R can be expressed as
  $R = R^*(\mathcal{Z}) + \rho(\mathcal{M},\mathcal{Z})$

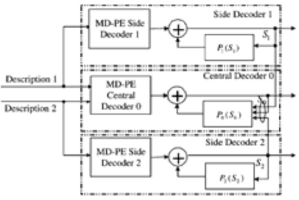
Thus the optimization becomes

$$\min_{Z} \{(1-p)^2 D_0(Z) + \lambda R'(Z) + \min_{M} [2p(1-p)D_1(Z,M) + \lambda\rho'(Z,M) \qquad (2)$$

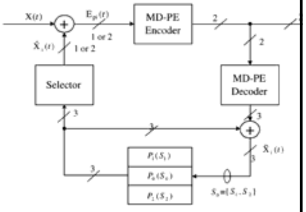
Prediction MC Coding

- Predictive coding is popular in today's video coder
- The encoder tracks the state *S*, expects to be present at the decoder bases the predictor *P* upon the state
- In a P-MD decoder, the central and side decoders are each typical predictive decoders
- Depend on which descriptions are received, the decoder has three possible states, but encoder can never know that
- If encoder use the predictor depends on state not available at the decoder, mismatch and error propagation occurs

Prediction MC Coding (Cont.)



P-MD Decoder



P-MD Encoder

Prediction MC Coding (Cont.)

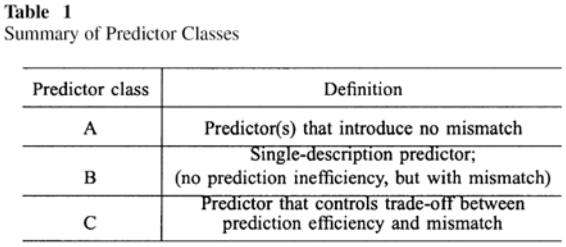


Table 1
Summary of Predictor Classes

Predictor class	Definition
A	Predictor(s) that introduce no mismatch
B	Single-description predictor; (no prediction inefficiency, but with mismatch)
C	Predictor that controls trade-off between prediction efficiency and mismatch

Prediction MC Coding (Cont.)

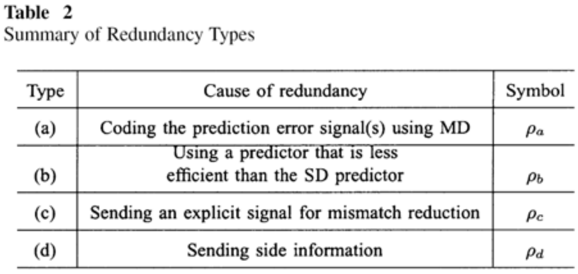


Table 2
Summary of Redundancy Types

Type	Cause of redundancy	Symbol
(a)	Coding the prediction error signal(s) using MD	ρ_a
(b)	Using a predictor that is less efficient than the SD predictor	ρ_b
(c)	Sending an explicit signal for mismatch reduction	ρ_c
(d)	Sending side information	ρ_d

$R = R' + \rho = R' + \rho_a + \rho_b + \rho_c + \rho_d$

MDC vs. Multiple Path Transport (MPT)

- Errors in MDC
  - **Problem:** Descriptions of the same frame are both lost
  - This will be same as the frame lost in an ordinary coder
  - Descriptions of the same frame are always transmitted successively
  - Network bursty errors will damage multiple continuous packets
- A huge risk that the descriptions of same frame will be lost
- MPT can be used to solve this problem

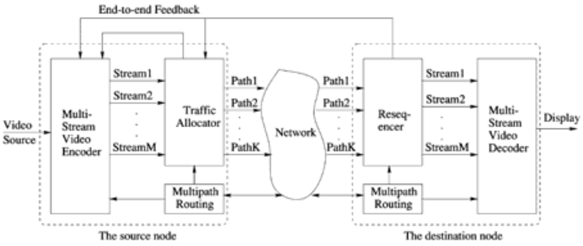
MDC vs. Multiple Path Transport (MPT)

- Features of MPT
  - The chance that two paths failure simultaneously will be very low
  - Load balancing: Reduce the congestion problem
  - More network bandwidth then Single Path Transmission (SPT)

MDC vs. Multiple Path Transport (MPT)

- General System Architecture
  - MD coder generate *M* bitstreams
  - Multipath Routing finds *K* paths from the network
  - Traffic allocator distribute the *M* descriptions among *K* paths
  - Feedback is desirable, but not necessary, many MD coder can work without feedback

MDC vs. Multiple Path Transport (MPT)

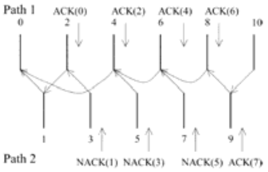


MDC vs. Multiple Path Transport (MPT)

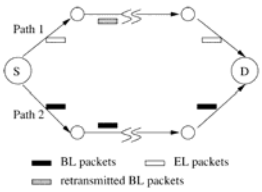
- Video streaming in Ad Hoc Networks
  - Wireless networks without infrastructure
  - Every devices may act as a relay node
- MPT is good for ad hoc networks
  - Paths may break down due to node movement
  - Links are unreliable, with high packet loss rate
  - Individual links are able to aggregate to support high bandwidth

S. Mao *et al.*, “Video transport over ad hoc networks: Multistream coding with multipath transport,” *IEEE J. Select. Areas Commun.*, vol. 21, pp. 1721–1737, Dec. 2003.

MDC vs. Multiple Path Transport (MPT)



Feedback based RPS



Layered coding with selective ARQ

Performance of MDC + MPT

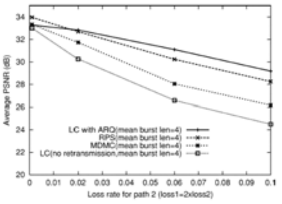
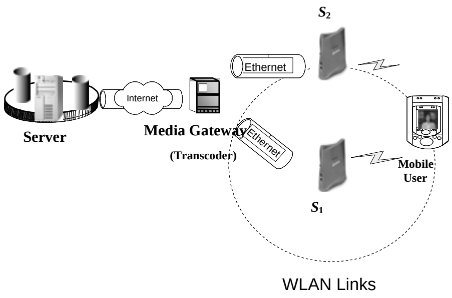


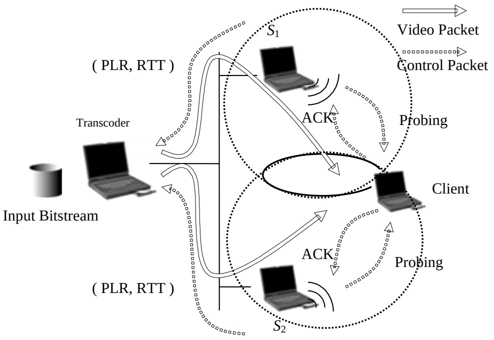
Table 4
OPNET simulation results using the MDMC coder

Transport Scheme	Average PSNR	Packet Loss Rate on Each Description
SPT	29.07 dB	6.3%
MPT	31.73 dB	3.0%

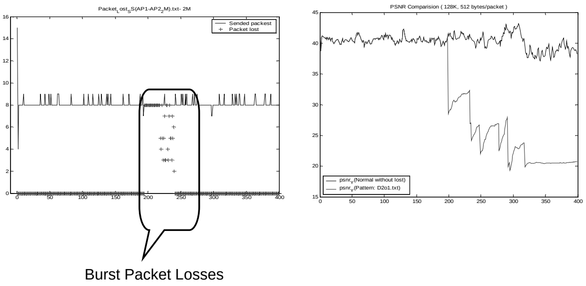
Example: Multipath Streaming in a Three-Tier Streaming System



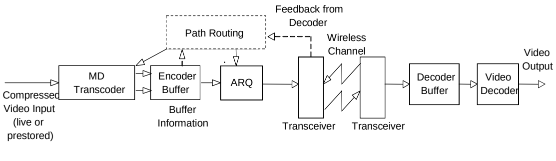
Roaming of a Mobile Terminal in WLANs



Quality Degradation due to Channel Switching

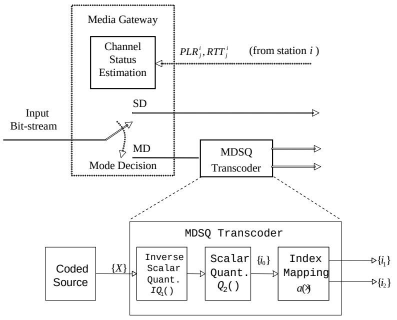


Channel-Aware Multiple-Description Transcoding

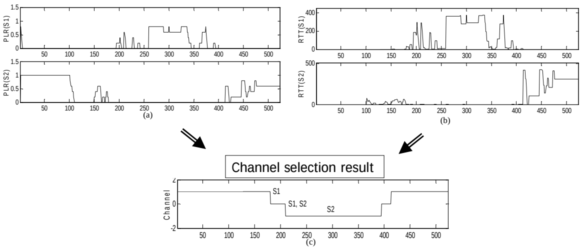


- Channel-Aware MD error resilience transcoding
  - MD Coding + Multipath Transport
  - Realtime channel estimation based on RTT and PLR

Channel-Aware Multiple-Description Transcoding

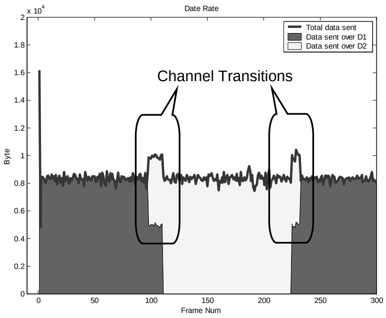


Channel estimation Result



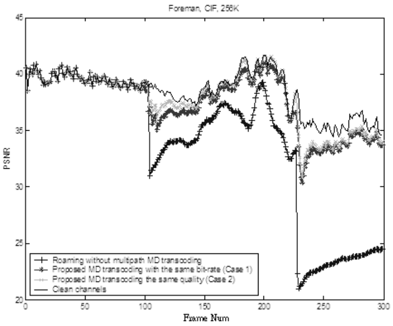
Channel selection result

Channel Utilization with MD Transcoding



Channel Transitions

Performance Comparison



Summary

- Various techniques for MDC are discussed
- Factors that must be considered when designing an MD video coder are addressed
- MDC+MPT is good in improving error resiliency
- A research example about multipath streaming with MDC is presented