Optimal Source-Channel Decoder for Correlated Markov Sources over Additive Markov Channels *

M. A. Haleem and K. P. Subbalakshmi
Department of Electrical and Computer Engineering,
Stevens Institute of Technology, Hoboken, NJ 07030.
{mhaleem, ksubbala}@stevens.edu

In this paper we propose an optimal joint source channel decoder (JSCD) for two mutually correlated sources each having memory that can be represented by first order Markov processes, and are transmitted through channels with memory representing slow fading wireless channels. We use the additive markov channel (AMC) model and multiple access source codes (MASC).

Let the set of all symbol sequences generated by the quantization process be $\mathbf{C}^x$ and $\mathbf{C}^y$, for sources X and Y respectively. Then the jth such sequence can be represented as $\mathbf{c}_j^x = \{c_{j,i}^x\}_{i=1}^{n(j)}$ and $\mathbf{c}_j^y = \{c_{j,i}^y\}_{i=1}^{n(j)}$, with length in bits B^x and B^y respectively. Here $c_{j,i}^{x/y}$ is the codeword for the ith symbol in the jth sequence and $n(j)$ is the number of symbols in the jth sequence. Let the bit sequence corresponding to the MASC encoded sources be denoted by $\mathbf{b}^x$ and $\mathbf{b}^y$ for sources X and Y respectively. Since we assume that the channels on which $\mathbf{b}^x$ and $\mathbf{b}^y$ are transmitted are independent of each other, the received bit sequences for X and Y are given by $r_i^x = b_i^x \oplus z_i^x$; where z_i^x is the ith noise bit along channel X and similar equation for source Y. Further since, both channels are modeled as additive Markov channels, the noise processes Z^x and Z^y are associated with a correlation coefficient ρ^x and ρ^y respectively and transition probabilities, $Q^x[z_i^x|z_{i-1}^x]$, similar for y. The maximum aposteriori probability (MAP) decoder can be summarized by $(\hat{\mathbf{c}}_j^x, \hat{\mathbf{c}}_j^y) = \arg\max_{(\mathbf{c}_j^x, \mathbf{c}_j^y)} Pr(c_{j,1}^x, c_{j,1}^y) \prod_{k=2}^{n(j)} Pr[(c_{j,k}^x, c_{j,k}^y)|(c_{j,k-1}^x, c_{j,k-1}^y)] \epsilon_1^{z_{j,1}^x}(1-\epsilon_1)^{(1-z_{j,1}^x)} \epsilon_2^{z_{j,1}^y}(1-\epsilon_2)^{(1-z_{j,1}^y)} \prod_{m=2}^{B_x} Q(z_{j,m}^x|z_{j,m-1}^x) \prod_{m=2}^{B_y} Q(z_{j,m}^y|z_{j,m-1}^y)$. Here $z_{j,m}^{x/y}$ is the mth noise bit associated with the noise process applied to source x/y under the jth partition. ϵ_1 and ϵ_2 are the channel bit error probabilities. $Pr(\cdot,\cdot)$, $Pr[(\cdot,\cdot)|(\cdot,\cdot)]$, and $Q(\cdot|\cdot)$ denote respectively the joint probability of the sources, the transition probability of the sources, and the transition probability of the channel. In order to solve the MAP problem, we cast it as a dynamic program with the appropriate state-space. A Viterbi-like delayed decision decoding algorithm was developed based on this formulation.

Two first order Gaussian distributed auto regressive (AR(1)) processes were simulated with correlation coefficient $\rho = 0.9$. The correlation coefficient and the error range of the channels were set to respectively 0.9 and $10^{-3} - 10^{-1}$. We observed that optimal decoder is consistently significantly better than the simpler (suboptimal) decoders. Gains of upto 3dB in the SNR have been obtained around $\epsilon = 10^{-1}$ which reduces to 2dB around $\epsilon = 10^{-2}$. This gain also is complemented by significant performance improvement in the symbol error rates in terms of Levenshtein distance.

*This work was partly funded by ONR/Stevens Maritime Security Laboratory

2007 Data Compression Conference (DCC'07)
0-7695-2791-4/07 $20.00 © 2007 IEEE