SISO Decoding of Coded Bi-directional Relaying System Using Block Turbo Codes

QingJun Jin†, Ki-Hyeon Park†， Mi-Young Nam†, Hong-Yeop Song†， Jung-Hyun Kim‡ and Kwang-Jae Lim‡

†Department of Electrical & Electronics Engineering, Yonsei University
‡Wireless System Research Department， ETRI

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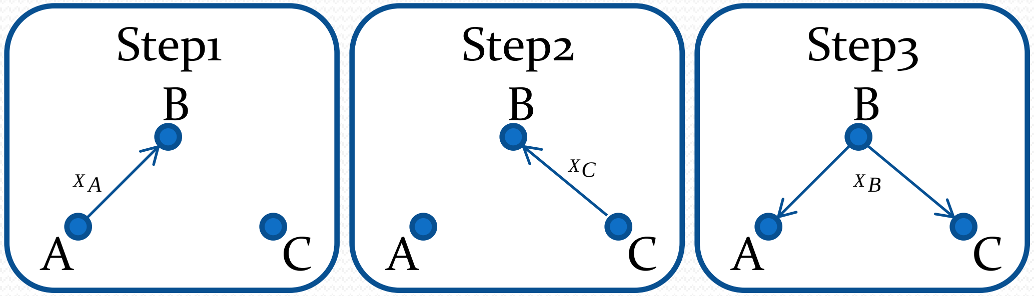
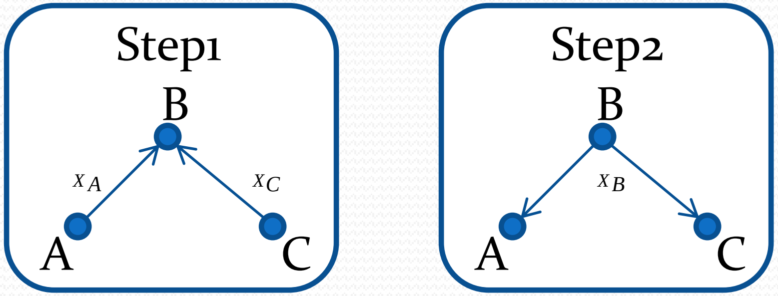
Introduction

◆Coded Bi-directional Relaying

- Three-Step



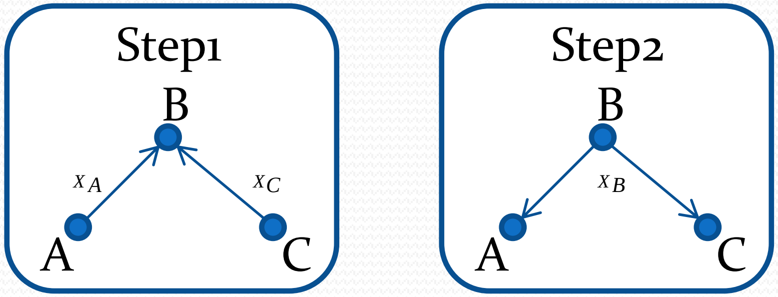
- Two-Step



Introduction

◆Channel Model of Two-Step CBR

- Two-Step



- At first time slot, multiple-access channel at the relay B;

$$Y_B = X_A + X_C + Z_B$$

At next time slot, it is broadcasting channel:

$$Y_A = X_B + Z_A$$

$$Y_C = X_B + Z_C$$

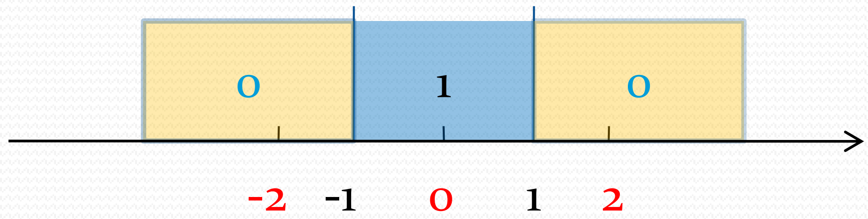
where Z is the Gaussian noise, X is modulated symbol， Y is the received value.

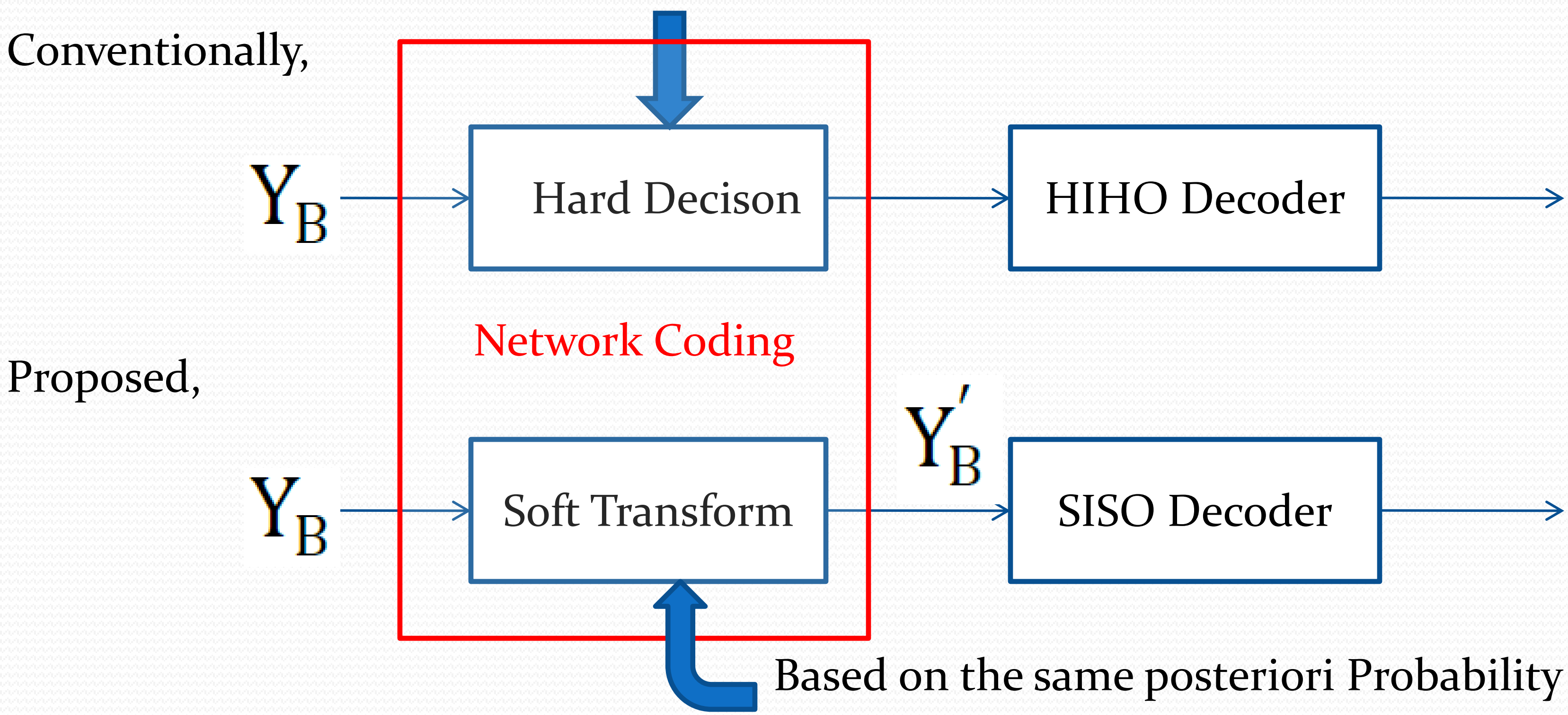
Introduction

◆The problem of direct SISO

- If BPSK modulation is used in this system. Without Gaussian noise, $Y_B \in \{-2,0,2\}$.
- $LLR = \ln(\frac{1}{2} * [\exp(-\frac{2}{\sigma^2}(1-Y_B)) + \exp(-\frac{2}{\sigma^2}(1+Y_B))])$
- $LLR \neq \frac{2}{\sigma^2} Y_B$
- In this case, Chase-Pyndiah algorithms for Block Turbo Codes cannot be applied directly at the relay without complex derivation.

Introduction

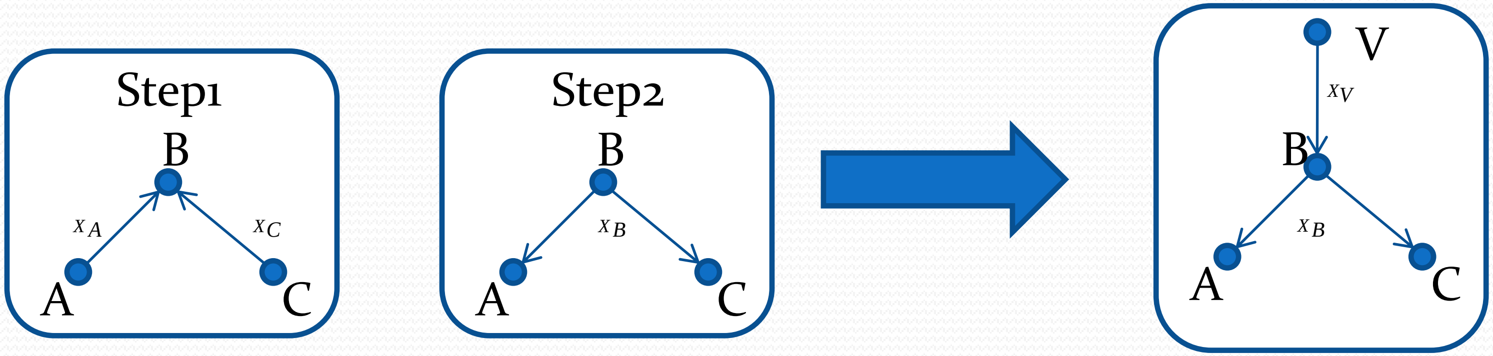




Introduction

◆MAC – P2P channel

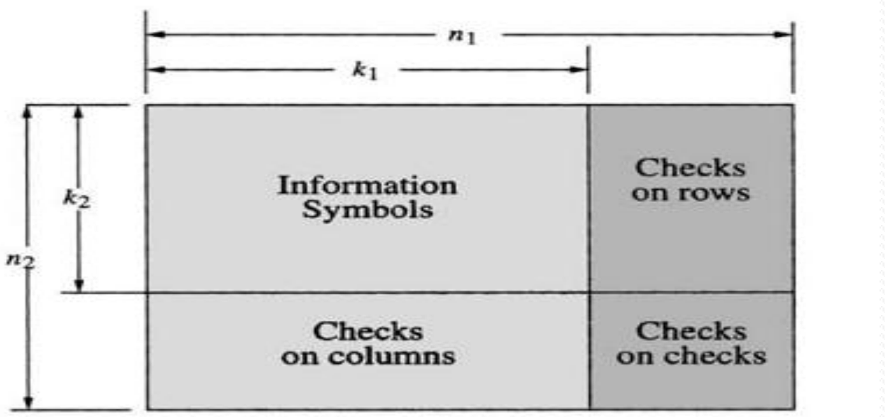
- Under the condition of the same posteriori Probability:



- The node V sent $X_V = X_A \oplus X_C$

Block Turbo Codes

- BTC , also known as Turbo Product Code, is one type of turbo codes, which of constituent code is block codes.
- Consider two systematic linear block codes C1 with parameters(n1,k1,d1) and C2 with parameters (n2,k2,d2). Then the parameters for the turbo product codes P=C1*C2 is (n1*n2,k1*k2,d1*d2).



Soft Transformation

- The posteriori probability $P(X_B = 1 | Y_B)$ can be computed as

$$P(X_B = 1 | Y_B) = \frac{\frac{1}{4} \times P(Y_B | X_A = X_C)}{\frac{1}{4} \times [P(Y_B | X_A = X_C) + P(Y_B | X_A \neq X_C)]}$$

$$P(X_A = 1) = P(X_A = -1) = \frac{1}{2}$$

$$P(X_C = 1) = P(X_C = -1) = \frac{1}{2}$$

Soft Transformation

$$P(X_B = 1 | Y_B) = \frac{\frac{1}{4} \times P(Y_B | X_A = X_C)}{\frac{1}{4} \times [P(Y_B | X_A = X_C) + P(Y_B | X_A \neq X_C)]}$$

$$P(Y_B | X_A = X_C = 1) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}(Y_B - 2)^2}$$

$$P(Y_B | X_A = X_C = -1) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}(Y_B + 2)^2}$$

$$P(Y_B | X_A = -1, X_C = 1) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}Y_B^2}$$

$$P(Y_B | X_A = 1, X_C = -1) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}Y_B^2}$$

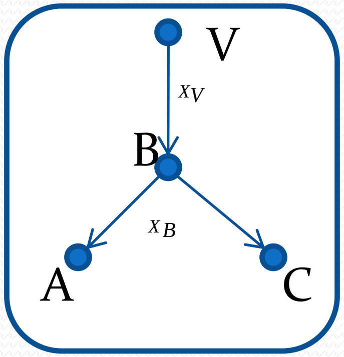
Soft Transformation

- Then,

$$P(X_B = 1 | Y_B) = \frac{1}{1 + \left(\frac{1}{2} \times \left[e^{-\frac{2}{\sigma^2}(1 - Y_B)} + e^{-\frac{2}{\sigma^2}(1 + Y_B)}\right]\right)^{-1}}$$

- The posterior probability of the soft value $Y_B^{'}$ received from virtual node is

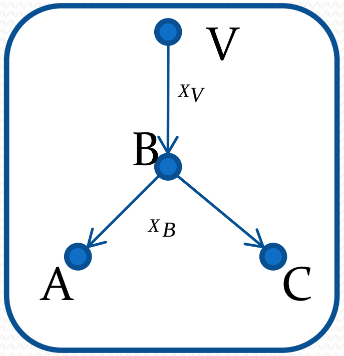
$$P(X_B = 1 | Y_B^{'}) = \frac{1}{1 + e^{\left(-\frac{2Y_B^{'}}{\sigma^2}\right)}}$$



Soft Transformation

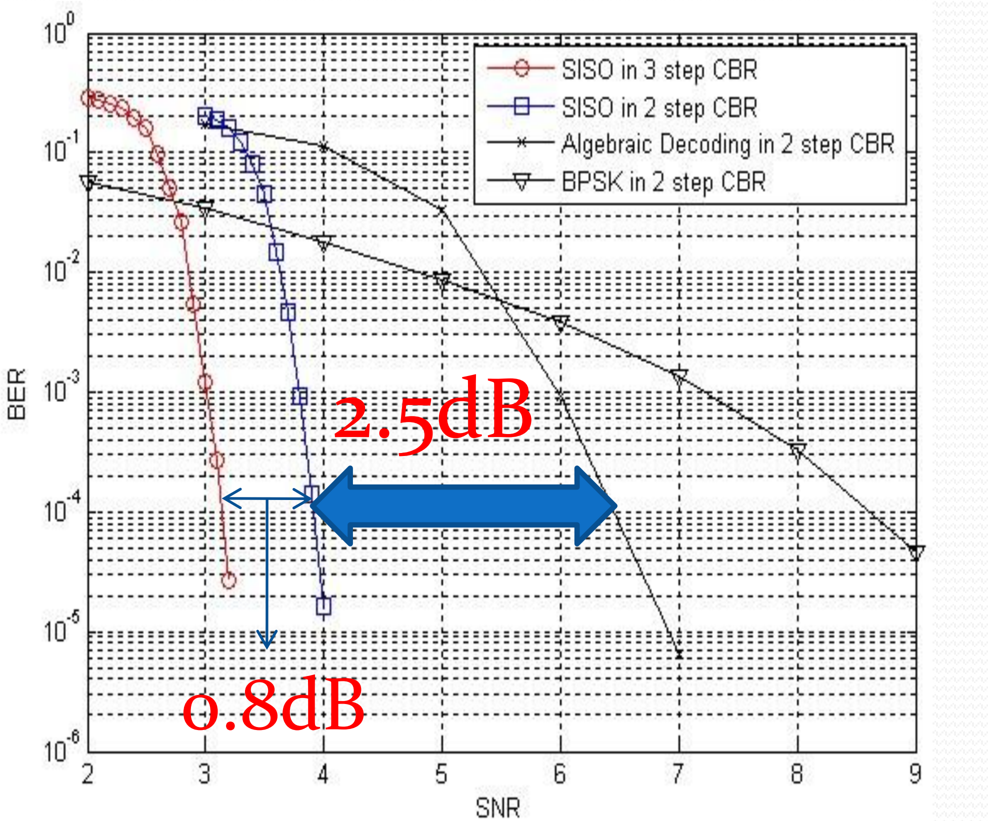
- Under the condition of the same posteriori probability $P(X_B = 1 | Y_B) = P(X_B = 1 | Y_B^{'})$ and using log-max approximation $\ln(e^a + e^b) \approx \max(a, b)$,

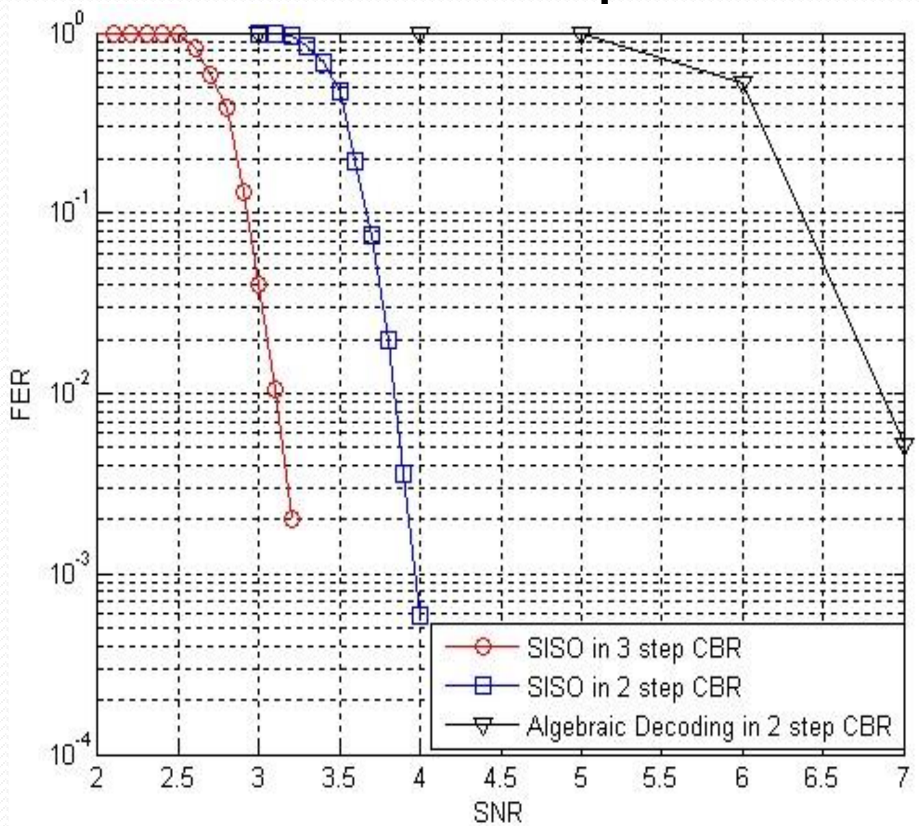
$$Y_B^{'} = \left(\frac{\sigma^2}{2}\right) \times \ln\left(\frac{1}{2}\right) + |Y_B| - 1$$



Simulation Results

- Extended BCH product code (64,51,6)^2 is used in this simulation and Max-iteration number is set to 4.





Conclusion

- Two-Step SISO scheme wins:
  - ✓ 2.5dB coding gain over algebraic decoding
  - ✓ Higher throughput and Lower decoding complexity at the expense of 0.8dB SNR loss than Three-Step scheme

Future Work

- Validation of soft transformation

- Incremental Redundancy Relaying

Thank You

Q&A