



2011 한국통신학회 추계학술대회

NEW Decoding Method of Duo-binary Turbo Codes

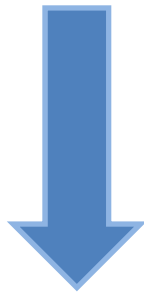
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2011 / 11 / 17
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1. original turbo codes 소개

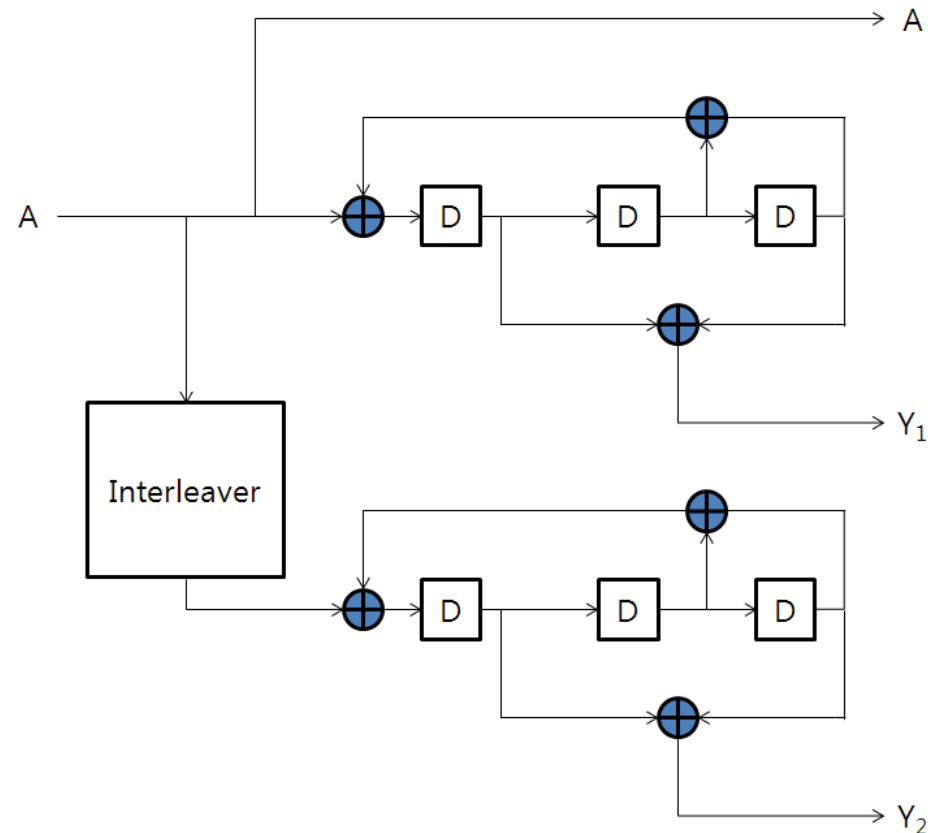
Original turbo codes(3GPP standard)

- BER 10^{-5} 에서 error floor 발생.
 - poor minimum hamming distance(MHD)



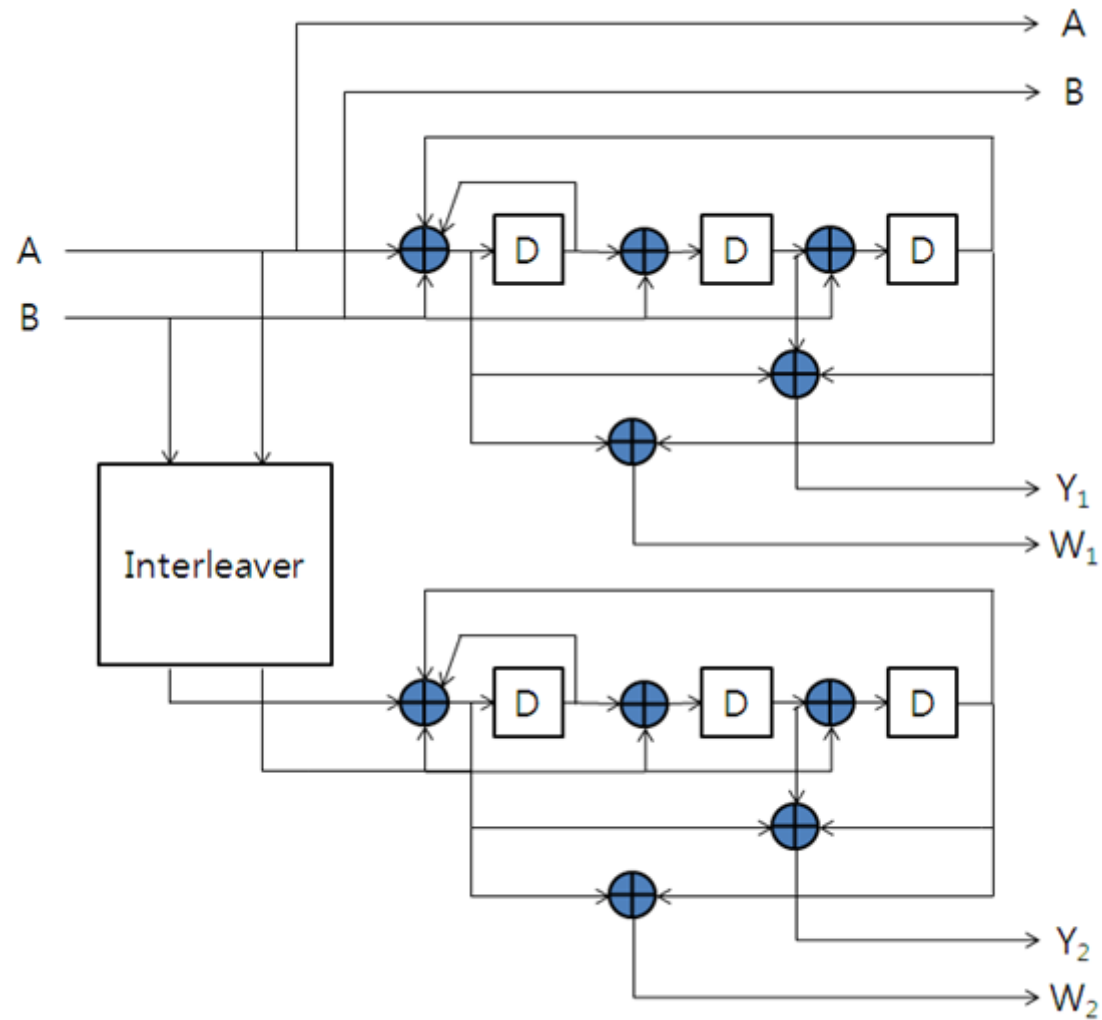
Solution

1. Using good interleaver
2. Increasing the number of memory
3. Using the Non-binary code
 - Duo binary turbo codes, 3D turbo codes



3GPP standard turbo code encoder

2. Duo-binary turbo codes & encoder



Duo-binary turbo codes encoder

s_i : trellis state at time i

A : state matrix

C : observation matrix

B : control matrix

D : transition matrix

$$A = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}, B = \begin{bmatrix} 1 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}, C = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix}, D = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{bmatrix}$$

802.16e encoder standard matrix

$$s_{i+1} = As_i + Bu_i^T, V_i^T = Cs_i + Du_i^T$$

3. Multidimensional LLR(MLLR) for Duo-binary turbo code decoding

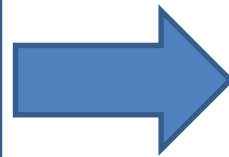
Decoder 입력을 위한 MLLR(Multidimensional LLR)

- channel MLLR 값은 information bit A,B의 생성이 독립적이므로 A,B 각각의 LLR 값을 L_{chA}, L_{chB} 로 정의하면 다음과 같이 초기 MLLR 을 계산 할 수 있다.

$$L_{ch,1} = \log \frac{P(u_k = (0,1)|y)}{P(u_k = (0,0)|y)}$$

$$L_{ch,2} = \log \frac{P(u_k = (1,0)|y)}{P(u_k = (0,0)|y)}$$

$$L_{ch,3} = \log \frac{P(u_k = (1,1)|y)}{P(u_k = (0,0)|y)}$$



$$L_{ch,1} = L_{chB}$$

$$L_{ch,2} = L_{chA}$$

$$L_{ch,3} = L_{chA} + L_{chB}$$

4.MLLR 을 이용한 decoding 과정

Symbol-wise LLR(MLLR) 을 이용한 metric 의 계산

$$\left\{ \begin{array}{l} \alpha_k(s) = \sum_{s'} (\gamma_k(s',s) \cdot \alpha_{k-1}(s')) \\ \beta_{k-1}(s') = \sum_s (\gamma_k(s',s) \cdot \beta_k(s)) \\ \gamma_k(s',s) = \exp\left(\frac{1}{\sigma^2} \left(\sum_{l=1}^{m+n} x_{kl} \cdot y_{kl}\right) + \underbrace{\ln \frac{P(u_k \text{ s.t } s' \rightarrow s)}{P(u_k = (0,0))}}_{L_a}\right) \end{array} \right.$$

α, β, γ 계산

$$L_{out,1} = \ln \frac{\sum_{s' \rightarrow s} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)}{\sum_{s' \rightarrow s} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)}$$

$$= \ln \frac{P(y|u_k = (0,1))}{P(y|u_k = (0,0))} + \ln \frac{P(u_k = (0,1))}{P(u_k = (0,0))}$$

(1)
(2) = $L_{ex,1}$

channel 출력의 LLR + A priori LLR

extrinsic LLR

- 같은 방법으로 $L_{ex,2}$, $L_{ex,3}$ 또한 계산가능
- decoder의 출력은 A,B 가 서로 joint 된 확률 값 으로 계산
- decoder 의 입·출력은 MLLR
 - interleaver 의 길이는 N

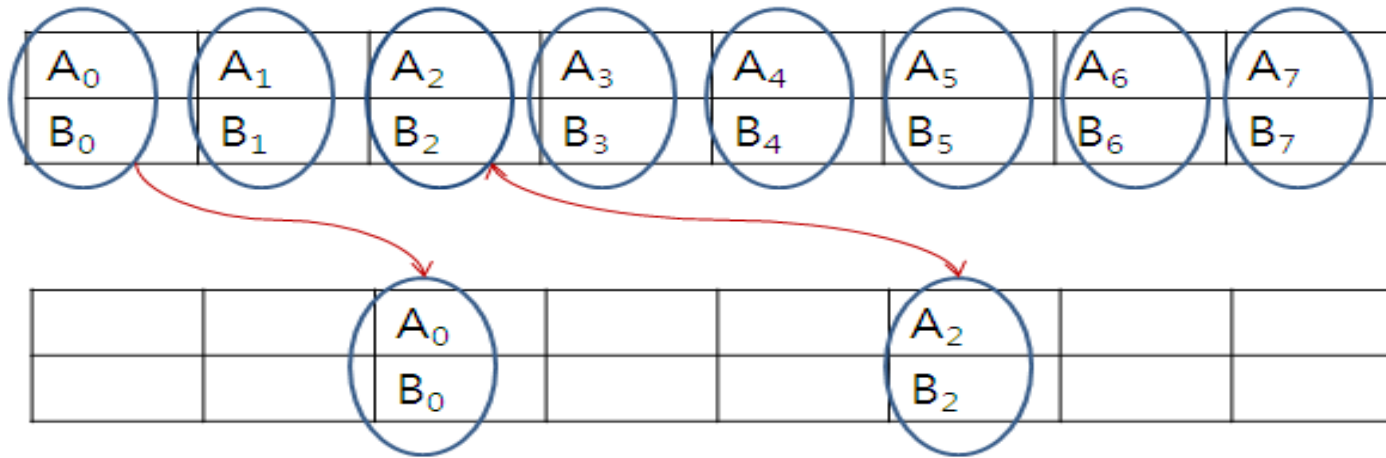
5.Bit-wise LLR 을 사용한 decoding 과 interleaver 의 변화

$$P(A_k = 0) = [P((A_k, B_k) = (0,0))] + [P((A_k, B_k) = (0,1))]$$

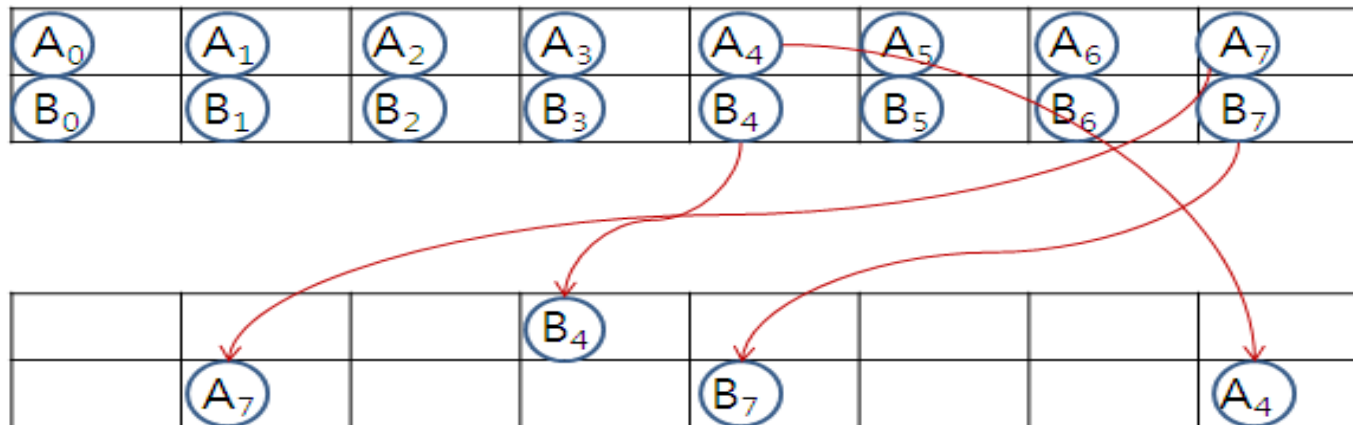
이용하여 A_k, B_k 의 bit-wise LLR을 사용할 수 있게 하면 interleaver 의 길이를 N 에서 $2N$ 의로 사용할 수 있게 된다. 하지만 이렇게 변형된 bit-wise LLR은 A_k, B_k 가 서로 독립이 아니라면

$$[P((A_k, B_k) = (0,0))] = P(A_k = 0) \cdot P(A_k = 0 | B_k = 0) \neq P(A_k = 0) \cdot P(B_k = 0)$$

처럼 MLLR 값을 구할 수가 없다



길이 N 인 symbol-wise interleaving



길이 $2N$ 인 Bit-wise interleaving

Bit-wise LLR을 이용한 decoding algorithm

$$\ln \frac{P(u_k = (0,1))}{P(u_k = (0,0))} \Rightarrow L_{ex}(B_k)$$

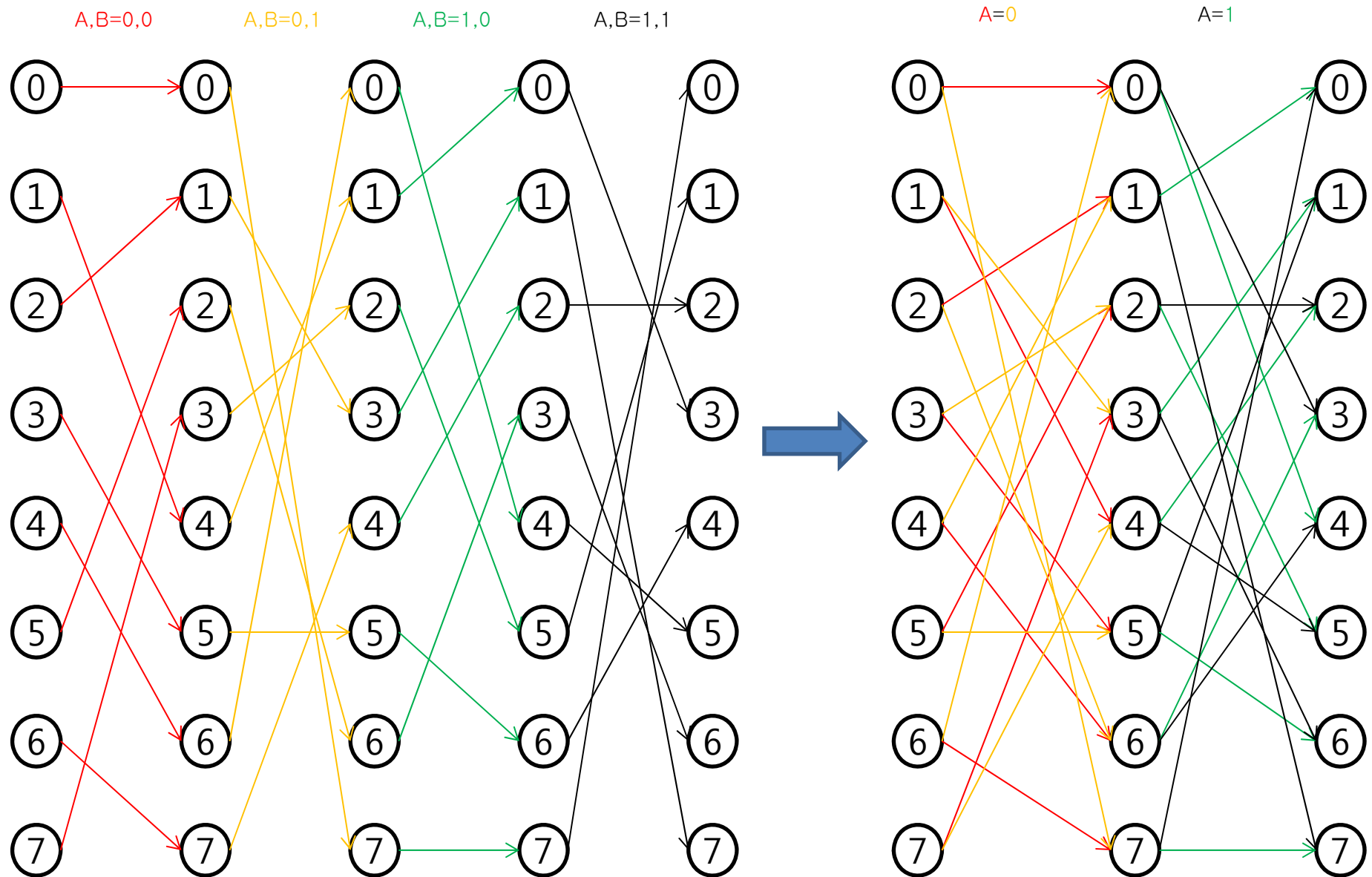
$$\ln \frac{P(u_k = (1,0))}{P(u_k = (0,0))} \Rightarrow L_{ex}(A_k)$$

$$\ln \frac{P(u_k = (1,1))}{P(u_k = (0,0))} \Rightarrow L_{ex}(A_k) + L_{ex}(B_k)$$

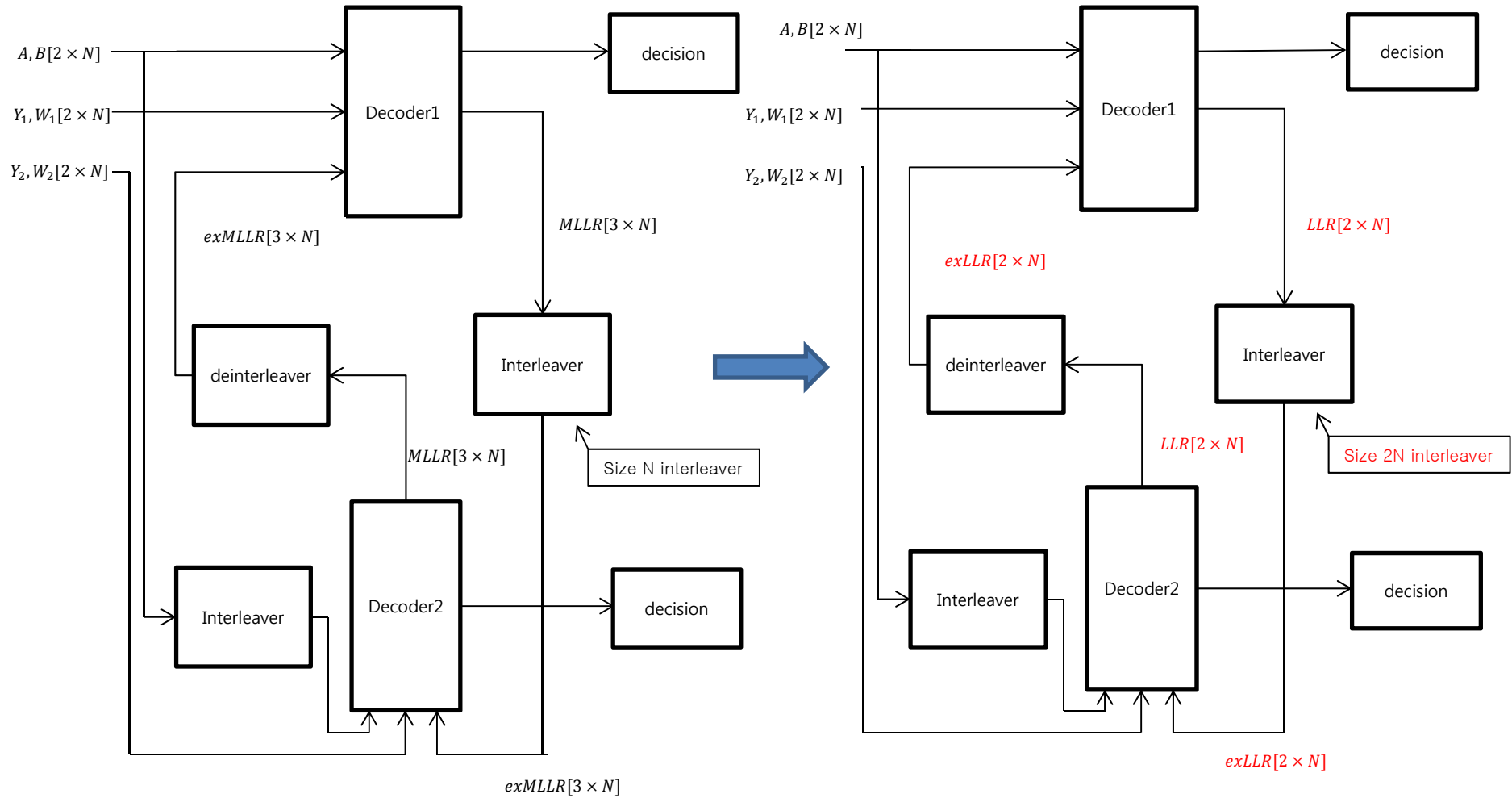
$$L_{out}(A_k) = \frac{\sum_{A_k=1} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)}{\sum_{A_k=0} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)} = L_{ch}(A_k) + L_{app}(A_k) + L_{ex}(A_k)$$

$$L_{out}(B_k) = \frac{\sum_{B_k=1} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)}{\sum_{B_k=0} \alpha_{k-1}(s') \gamma_k(s',s) \beta_k(s)} = L_{ch}(B_k) + L_{app}(B_k) + L_{ex}(B_k)$$

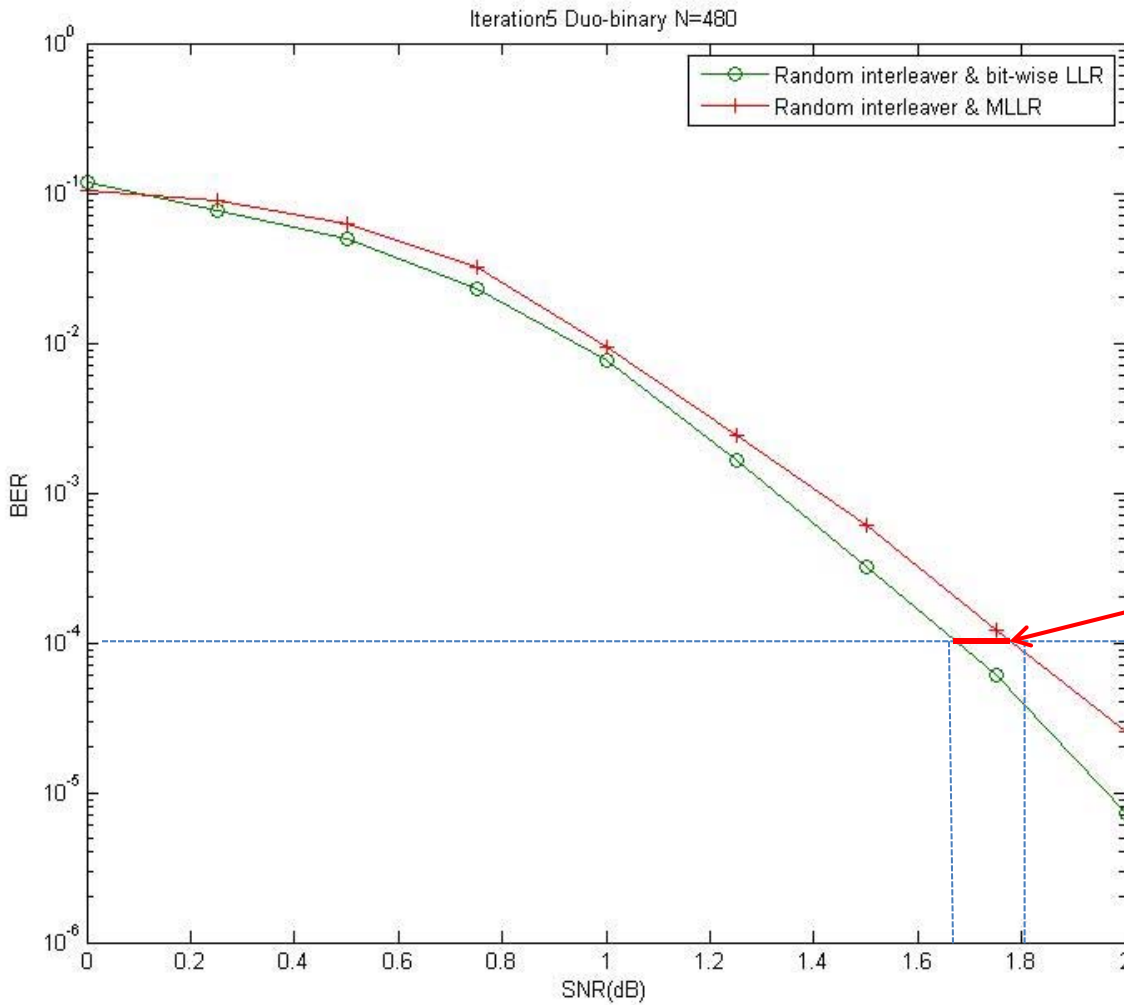
Trellises diagram



Duo-binary turbo code Decoder



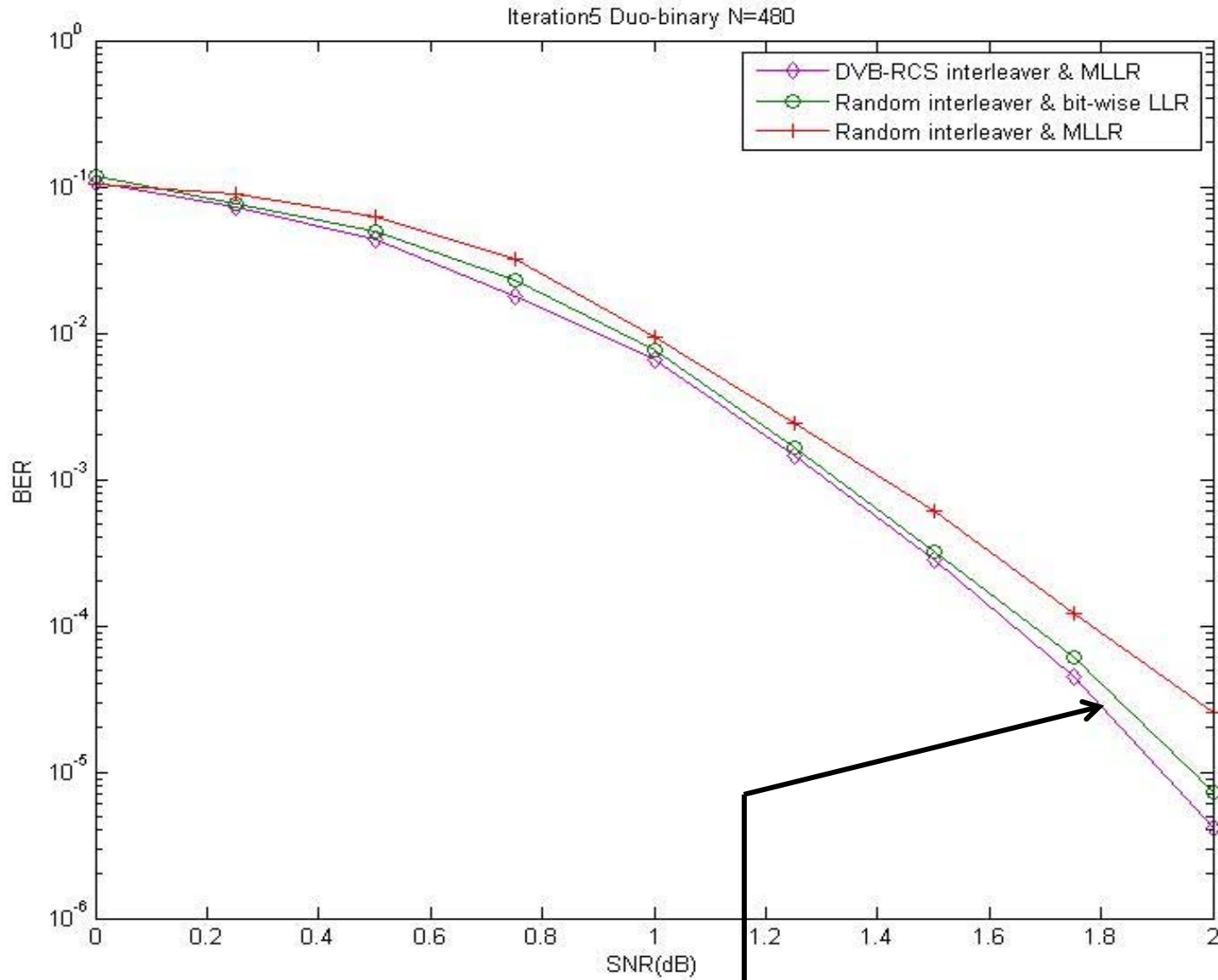
6.Simulation result



Simulation parameter

- AWGN channel
- Code rate = 1/3
- Circular coding
- Random interleaver

Target ber 10^{-4} 에서
0.15dB 성능 향상



DVB-RCS,802.16 standard Interleaver를 이용한 BER 성능 curve

7.결론

- Duo-binary turbo codes 의 bit-wise decoding 방법을 제시
- Random interleaver 을 사용하여 symbol-wise decoding 과 bit-wise decoding 시 BER 성능 비교
- DVB-RCS, 802.16 standard Interleaver 와 MLLR 을 이용한 decoding 방법의 BER 성능보다 뛰어난 새로운 bit-wise interleaver의 발견 필요

