Near-Capacity-Achieving Simple BICM-ID

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CONTRIBUTION

- We propose a very simple Bit-Interleaved Coded Modulation with Iterative Detection/Decoding (BICM-ID) system.
- The irregular repetition and single parity check codes, combined with partial accumulator and Extended Mapping (EM) are used.
- We also propose EXIT-constraint Binary Switching Algorithm (EBSA) to determined optimal labeling patterns for allocating to each constellation point. Furthermore, we combine the techniques described above together with modulation doping.
- Bit Error Rate (BER) simulation results show that using our proposed technique, at a signal-noise ratio (SNR) point of only roughly **0.5**dB away from the Shannon limit, clear threshold SNR happens even though required complexity is very low.

SYSTEM MODEL

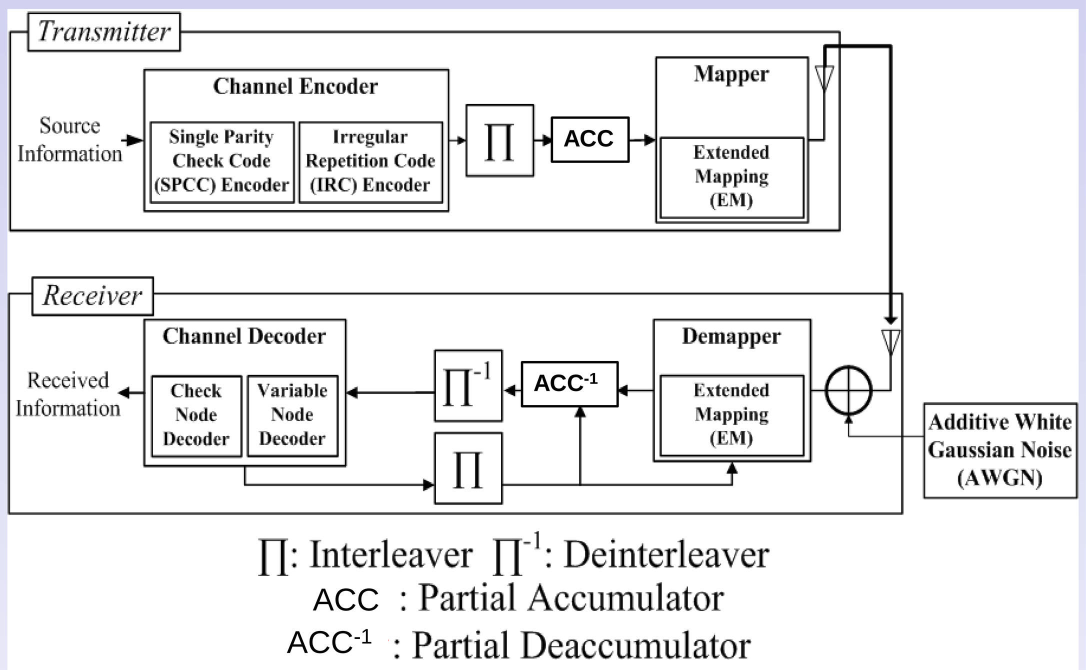


Figure 1: System Model of proposed BICM-ID Extended Mapping

- The binary information sequence is encoded by channel encoder using single parity check code, and irregular repetition code.
- The encoded bit sequence is bit-interleaved, accumulated, and then mapped on to one of the constellation points.
- At the receiver side, the iterative processing is invoked, where extrinsic information is exchanged between the demapper and decoder.

MODULATION DOPING

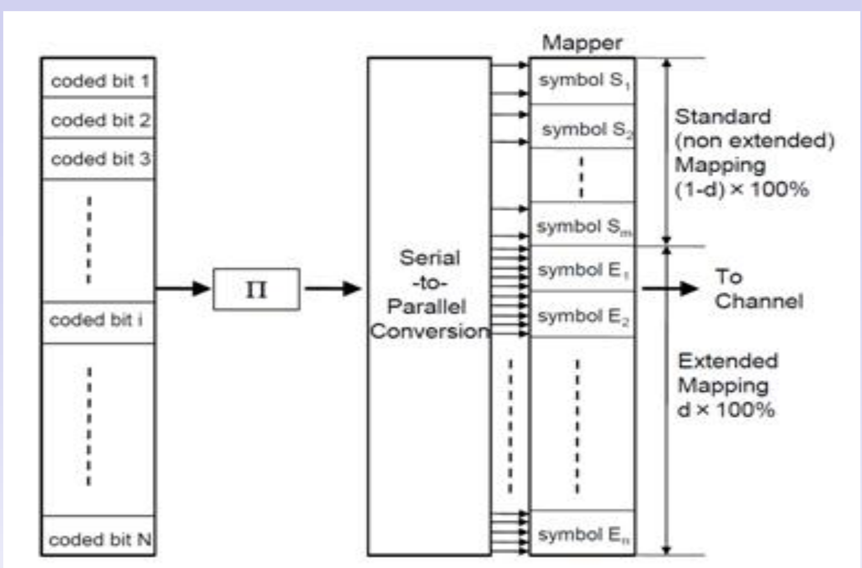


Figure 2: Modulation Doping Technique

- The idea of modulation doping is that to mix the modulation symbols having different labeling patterns (e.g., extended mapping and Gray mapping).
- It aims to lift up the left most part of the demapper EXIT curve.

LABELING PATTERN OBTAINED FROM EBSA

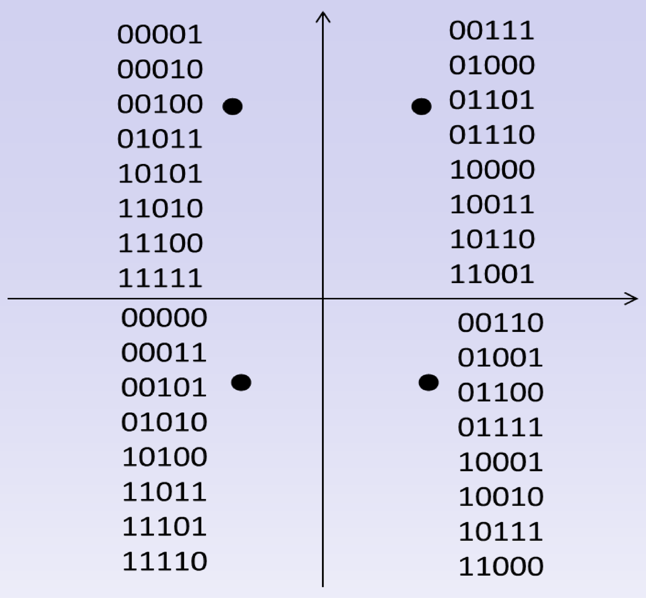


Figure 3: Labeling pattern obtained from EBSA

- As using the above labeling pattern, the crossing point of the demapper and decoder EXIT curve is at (0, 0) of the mutual information point, and therefore, the trajectory does not start.
- Therefore, we introduce modulation doping technique.

DEMAPPER AND DECODER CALCULATIONS

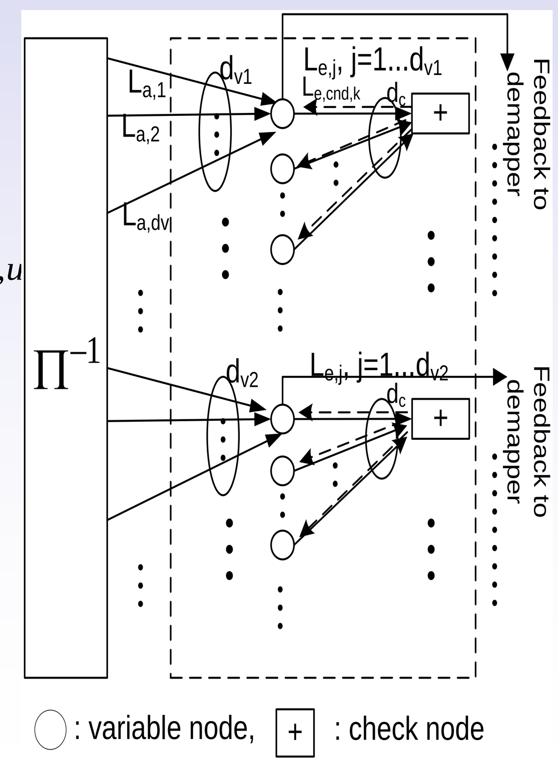
- Demapper:

$$L_e[b_\mu(k)] = \ln \frac{\sum_{s\in S_0} e^{\left(-\frac{|y-s|^2}{\sigma_N^2}\right)} \prod_{v=1, v\neq\mu}^{l_{map}} e^{(-b_v(s)L_a(b_v(s)))}}{\sum_{s\in S_1} e^{\left(-\frac{|y-s|^2}{\sigma_N^2}\right)} \prod_{v=1, v\neq\mu}^{l_{map}} e^{(-b_v(s)L_a(b_v(s)))}}$$

- Decoder:

$$L_{e,j} = L_{e,cnd,k} + \sum_{u=1, u\neq j}^{d_v} L_{a,u}$$

$$L_{e,cnd,k} = \sum_{u=1, u\neq k}^{d_c}\boxplus L_{a,cnd,u}$$



EXIT-CONSTRAINT BINARY SWITCHING ALGORITHM (EBSA)

We denote total cost $\hat{Z}$ as the following:

$\hat{Z} = Z\lambda^t = [Z_0 Z_1 Z_2 Z_3 Z_4 Z_5]\,[\lambda_0 \lambda_1\, \lambda_2 \lambda_3\, \lambda_4\, \lambda_5\,]^t$

Initialize the weight coefficient vector $\boldsymbol{\lambda} = [\lambda_0 \dots \lambda_{lamp-1}] = [0 \dots 1]$;
Initialize the desirable vertical epsilon values. e.g., $\varepsilon^v = [0.001][1, \dots, N]$.
repeat
  for i = 1 **to** 100 **do**
    Randomly generate labeling pattern.
    Perform *BSA*.
  end for
Select the labeling pattern with minimum cost from *BSA*.
Perform *LP* to determine the optimal node degree allocation.
    Draw demapper EXIT curve and *LP*-based decoder EXIT curve and evaluate the horizontal gap (ε^h) between this two curves.
  if the gap around Z_{ap} is larger than initialized epsilon (ε^v) then
    $\lambda_{ap} = \lambda_{ap} - 1, \quad 0 < ap < l_{map}-1$
end if
until the minimum gap is obtained

Figure 4: EBSA algorithm

EXIT CHART ANALYSIS

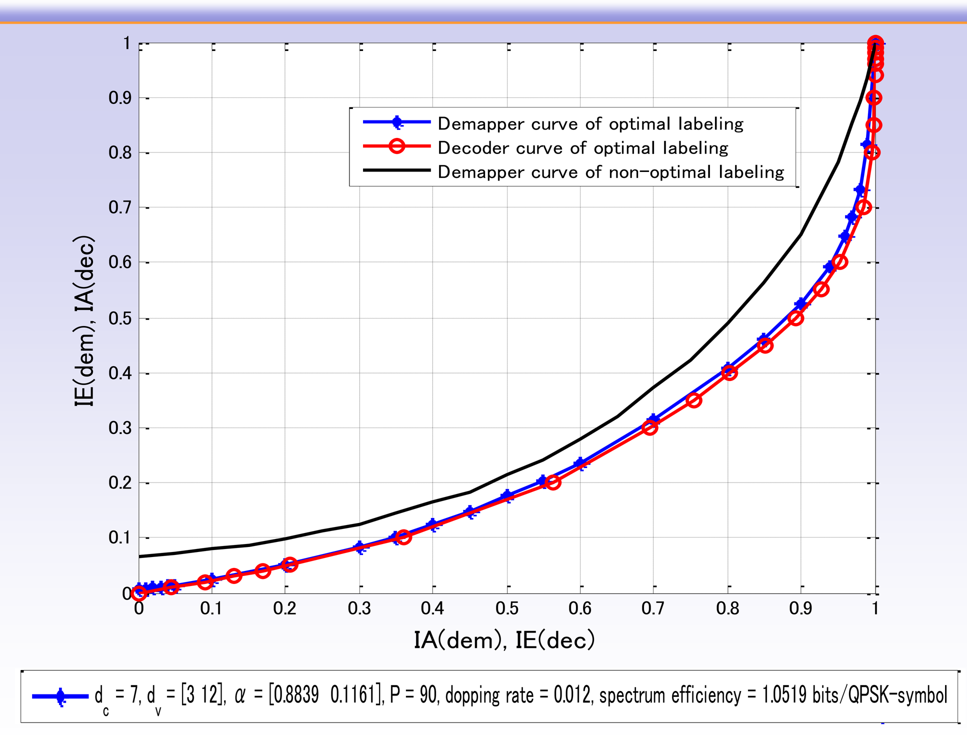


Figure 5: EXIT charts of proposed BICM-ID

BER PERFORMANCE

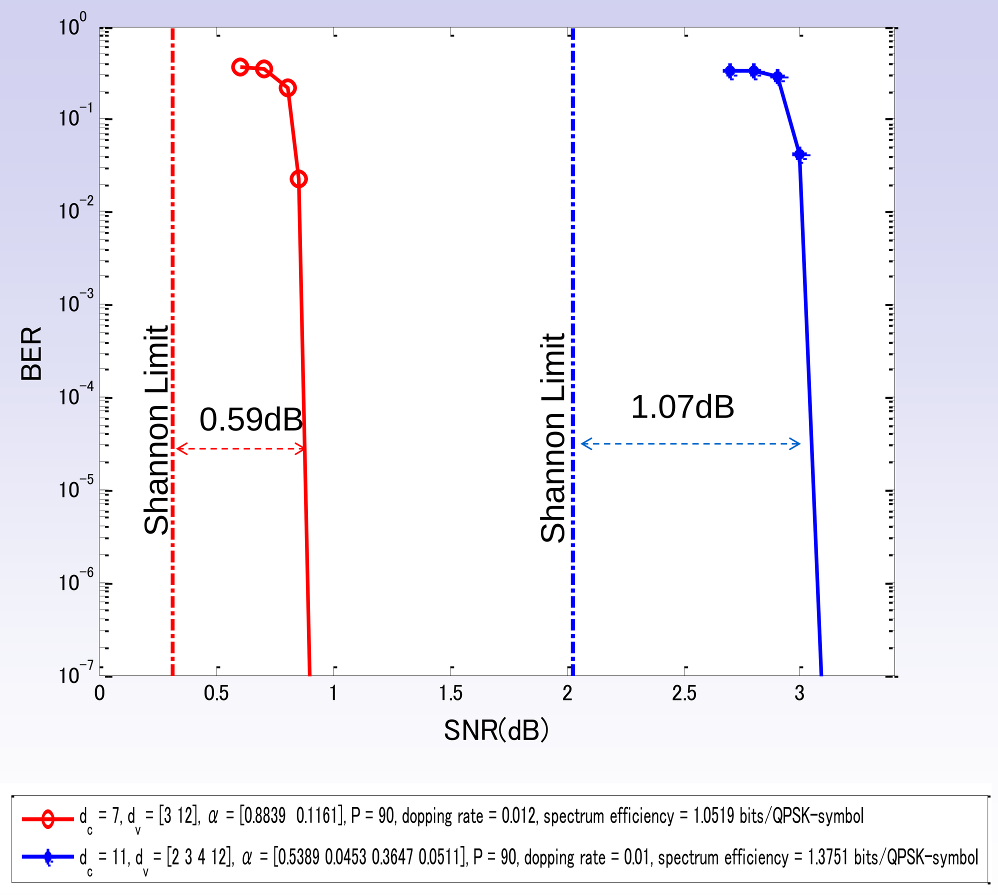


Figure 6: BER performance of proposed BICM-ID

CONCLUSIONS

- The very simple close Shannon limit achieving BICM-ID with Irregular repetition code and single parity check codes has been proposed.
- Using the modulation doping technique, the left most part of demapper EXIT curve is pushed up, and thereby, the trajectory starts.
- The BER simulation results show that with the proposed system model combined with EBSA technique, the demapper and decoder curve match each other very well, and therefore, the clear turbo-cliff, corresponding to the threshold SNR, is achievable roughly only **0.5**dB away from the Shannon limit.
- The complexity of the proposed technique is at an order of that required for a turbo code using memory-2 convolutional constituency codes.

REFERENCES

[1] D. Zhao, A. Dauch, and T. Matsumoto, "BICM-ID Using Extended Mapping and Repetition Code with Irregular Node Degree In Vehicular Technology Conference, 2009 . VTC Spring 2009. IEEE 69th, pp. 1098 – 1101, 1952
[2] D. Zhao, A.Dauch and Tad Matsumoto, "Modulation Doping for Repetition Coded BICM-ID with Irregular Degree Allocation", WSA 2009.