Communication Efficient Data Exchange Among Multiple Nodes

Midterm Report Summary

by

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Abstract

Multiple parties observing correlated data seek to exchange their data using minimum amount of communication. In case the underlying joint distribution is known, a rate optimal solution to this problem is offered by Slepian-Wolf compression. In absence of this knowledge, interactive communication is necessary to attain universal optimality. In both the cases, decoding is of exponential complexity. However, Slepian-Wolf compression can be implemented using structured channel codes. In this project, we design rateless Polar codes to enable universal Slepian-Wolf compression and data exchange, when the underlying distribution generating the data is unknown.

A key observation driving our project is the similarity between the interactive Slepian-Wolf compression and the design of an Hybrid ARQ protocol for communication over a network. Unlike H-ARQ, in our setting, the error-detection capability offered by higher layers is not available. Hence, we propose a PHY-layer error-detection scheme based on soft outputs of the Successive Cancellation decoder of Polar codes. We present simulation results that exhibit the performance of the considered methods. Besides offering a solution to our problem, this scheme provides a CRC-free Rateless Polar Code which promises rate gains for short packet length communication and may be of independent interest.

Proposed implementation of Recursive Data Exchange

Our approach towards implementation of a solution to the *Data-Exchange* problem can be summarised as below,

- Use Rateless Polar Codes with Incremental Freezing to implement RDE.
- Use a PHY layer error detection as retransmission criterion in Incremental Freezing.

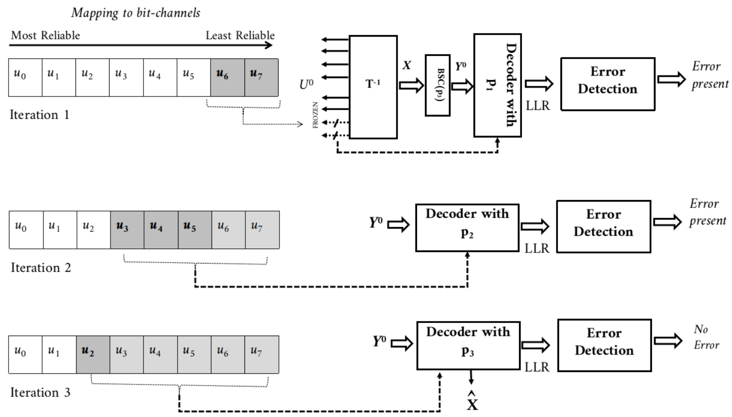


Figure 1: Iterative SW compression with Incremental Freezing.

Here, a compound BSC channel $\mathcal{C} = \{p_1 \leq p_2 \leq p_3 \leq p_4\}$ is considered, where p_i is the flipover probability of channel i. The flipover probability of the true channel is $p_{channel}$. In the first iteration the scheme guesses the best channel as the true channel and sends the bits that are ought to be frozen with this guess to the receiver over an error-free channel.The decoder uses the log-likelihood ratios for error detection and sends ACK/NACK feedback. In the subsequent iteration the scheme guesses next best channel and the operation is repeated. The scheme terminates on receiving a NACK from receiver or after few iterations. This scheme has been called Incremental Freezing (Inc-Frz).

PHY Layer Error Detection (PHY-ED)

Let there be K good bit-channels after polarization N channels. Since Inc-Frz guesses the best channel first, we can say that at j^{th} iteration $p_{guess} = p_j$. Let $\Lambda_j^i(k)$ be the magnitude of the LLR of k^{th} bit-channel, $k \in 1, 2, ...N$ at the output of the decoder at the end of j^{th} iteration such that $p_{guess} = p_j$ for $p_{channel} = p_i$. Error detection may be seen as a hypothesis test where,

$$\begin{aligned}
\mathcal{H}_0 &: \text{The channel is the current guess, i.e., } j = i \\
\mathcal{H}_1 &: \text{The channel is worse, i.e., } j < i
\end{aligned}$$

TEST : A given fraction of good channels are above a threshold. In this test $p_{guess} = p_{channel}$ is declared if the |LLR| of a certain fraction of the good channels clear a threshold. The fraction is dependent on the iteration number. After j^{th} iteration,

$$\begin{aligned}
& j = i, \text{ if, } \frac{1}{K} \sum_{k=1}^{K} \mathbb{1}_{\{\Lambda_j^i(k) > \lambda\}} > \Theta_j \\
& j < i, \text{ o.w.}
\end{aligned}$$

The results of Monte-Carlo simulation for estimating P_M and P_F for $\mathcal{C} = \{p_1 = 0.04, p_2 = 0.15, p_3 = 0.2, p_4 = 0.25\}$ after first iteration is shown in figure 2. Note, in the figures Θ is considered to be percentage.

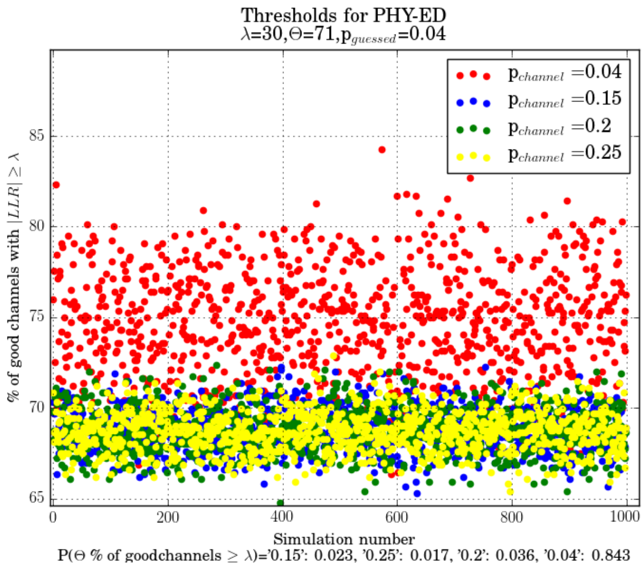
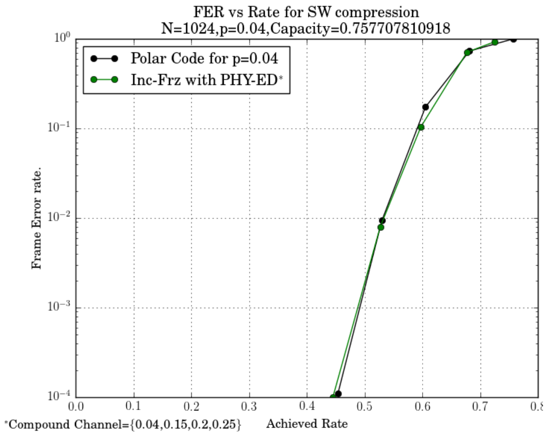
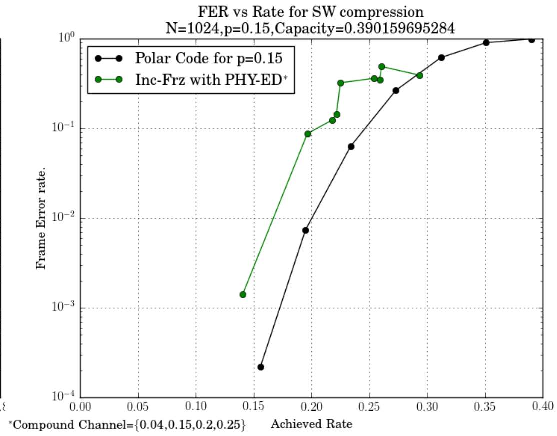


Figure 2: P_M and P_F estimation for ED after 1^{st} iteration, $p_{guess} = 0.04$.

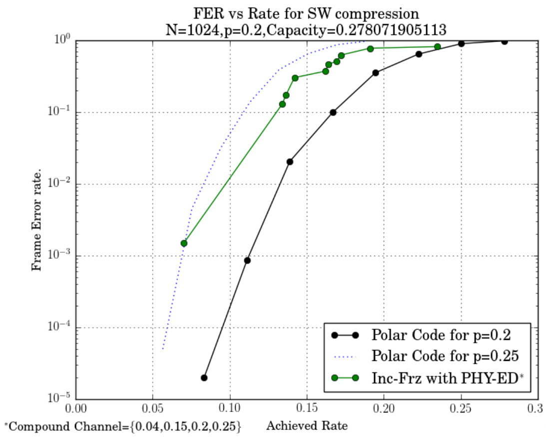
Performance Evaluation



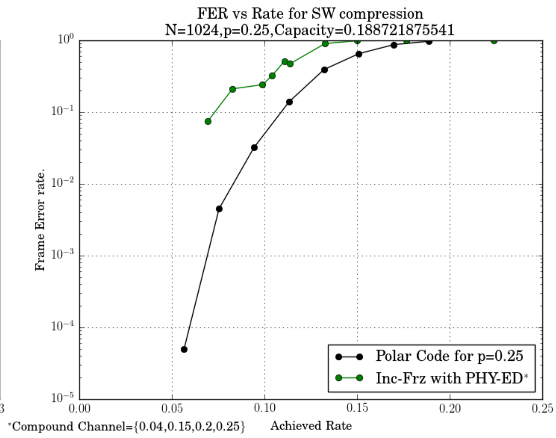
(a) $p_{channel} = 0.04$



(b) $p_{channel} = 0.15$



(c) $p_{channel} = 0.2$



(d) $p_{channel} = 0.25$

Figure 3: FER vs Rate of SW compression with Inc-Frz and PHY-ED.

Simulation results for the scheme in figure 1 used for iterative SW compression with Inc-Frz and PHY-ED are presented in figure 3. Let K be the number of bit-channels assumed to be good at the first iteration. For simulation, K is varied from 0 to K^* such

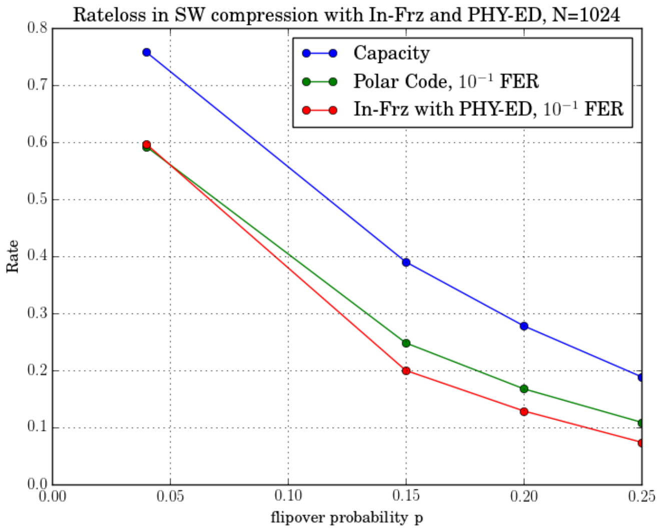


Figure 4: Rate loss for SW compression with Inc-Frz.

that K^*/N is the capacity of the best channel. In case of SW compression the number of bits that remain unfrozen after the final iteration divided by N is viewed as the achieved rate. The FER has been plotted against the achieved rates for performance evaluation.

Conclusion and Future work

The proposed scheme is an implementable solution to the *Data-Exchange* problem. It reduces the communication among nodes. The CRC-free universal polar code promises considerable rate gain for communication using short packet lengths. There are few channels which are good for use during the entire transmission. Communicating critical data over these channel ensure high reliability and availability .

- Future work.
  - Extensive performance analysis and theoretical analysis of proposed error detection scheme as a RB-HARQ for Polar Codes.
  - Implementation of the scheme for multiparty data exchange.