Distributed Source Coding in Wireless Sensor Networks using LDPC Codes: a Non-Uniform Framework

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In this paper, we study the problem of distributed source coding of correlated nodes in wireless sensor networks using LDPC codes. First, we consider a system of two statistically dependent signals, X_1 and X_2. The correlation between signals X_1 and X_2 is modeled as the input and output of a binary symmetric channel with the crossover probability $P[X_1 \neq X_2|X_1] = p$. We study the distributed source coding at the asymmetric rate. X_1 is compressed conventionally and sent at full rate and X_2 is encoded as follows: X_2 is fed into a rate R systematic LDPC encoder. At the output of the encoder, we only send the corresponding parity bits, P_{X_2}, of the codewords. This results in an encoding rate of $R_{X_2} = \frac{1}{R} - 1$ bits per input bit. We demonstrate the source coding of X_2 with side information X_1 available at the decoder as transmission of the bits over two different independent channels. Information bits and parity bits are passing through the dependency and wireless channel, respectively. We propose to design a non-uniform LDPC code that considers the fact that different bits are subject to different sources of noise. The simulation results show that our proposed method improves the performance of the source coding considerably. The convergence of the non-uniform LDPC code of our method is almost 60% closer to the Slepian-Wolf limit than the methods studied before.

We further study an extension of our approach to three correlated nodes. For simplicity, we consider the case that sources are pairwise correlated with the same correlation probability p. We show that the the model of the correlation between X_3 and both X_2 and X_1 is as follows: With probability p, X_3 is the input to a BSC with crossover probability $\frac{p/2}{1-p}$ and with probability $1-p$ it is the input to a BSC channel with crossover probability $\frac{1}{2}$. The output of the channel with crossover probability $1/2$ must be considered as erased (punctured) bits. Therefore, X_1 is the punctured version of the X_3 that has passed through a BSC with crossover probability $\frac{p/2}{1-p}$. To design the LDPC encoder, we consider the fact that some bits are punctured randomly. We construct an LDPC code as a parent code whose performance does not degrade after puncturing. In this design, we consider the non-uniform LDPC code design criteria to get a code with better performance. This is a new formulation for distributed source coding using LDPC codes. The simulation results for code of length 1000 shows that the convergence of the LDPC code is only 0.08 away from the Slepian-Wolf limit.

A natural question is to generalize this method to more than three sources. Specifically, can we assume the same correlation probability model for distributed source coding of more than three sources? We show that the assumption of having pairwise correlated sources with the same correlation probability, can not be generalized to more than three sources. In this case, the fourth source will not be a random variable and it can be identified by the first three sources.

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