Abstract—Reliable transmission of a pair of arbitrarily correlated sources over a discrete memoryless cognitive radio channel is studied. We derive a sufficient condition for lossless transmission of such communication scenario using superposition coding, correlation preserving technique, random source partition, a binning scheme and joint typicality decoding. This sufficient condition reduces to the known rate regions for interference channels with independent, specially correlated and arbitrarily correlated sources.

Index Terms—Cognitive radio channels, correlated sources, joint source-channel coding.

I. INTRODUCTION

SHANNON’S source-channel separation theorem, which is one of the most important practical theorems of information theory for designing the architecture of communication systems, states that separate source and channel coding is asymptotically optimal for point-to-point communication. However, it has been shown that such separation architecture is not optimal in general for lossless transmission of correlated sources over multiuser channels, and finding the necessary and sufficient conditions for such transmission is an open problem and a topic of research interest for many multiuser networks. Cover, El-Gamal, and Salehi [1] provided a sufficient condition for lossless transmission of a pair of arbitrarily correlated sources over a discrete memoryless multiple access channel (DM-MAC) using a correlation preserving codebook generation technique. A sufficient condition for lossless transmission of arbitrarily correlated sources over a DM broadcast channel (DM-BC) was obtained by Han and Costa [2] (corrected by Kramer and Nair [3]) using random source partition technique. Recently, Liu and Chen [4] derived a sufficient condition for lossless transmission of arbitrarily correlated sources over a DM interference channel (DM-IC) using correlation preserving coding and random source partition. Moreover, simple examples have been provided in [1], [2] and [4] that show separate source-channel coding is strictly suboptimal for transmitting correlated sources over DM-MAC, DM-BC and DM-IC.

Our motivation and work: Cognitive radios are of particular interest due to their capabilities to overcome the spectrum inefficiency problem. In a two-user genie-aided cognitive radio channel (CRC), one of the users, called the “cognitive” user, is non-causally aware of the encoded message to be sent by the other user, called the “primary” user, while the primary user is only aware of its own message. CRC with arbitrarily correlated sources is of theoretically importance and includes all previously studied models as its special cases. Practically, e.g., in a wireless sensor network with two fusion centers, it is highly likely that neighboring sensors are close enough such that their observations are correlated. The CRC studied in this letter can model these fusion centers, where one of them is a cognitive transmitter.

In this paper, we obtain a general sufficient condition for lossless transmission of a pair of arbitrarily correlated sources over a discrete memoryless cognitive radio channel (DM-CRC) using a combination of correlation preserving technique, random source partition, superposition coding, a binning scheme and joint typicality decoding. Then, we show that the obtained sufficient condition includes the known rate regions for the ICs with independent, specially correlated and arbitrarily correlated sources. It is worth mentioning that the results for the CRC we have studied in this letter can be extended to three-user CRC, however, by considering different models, in order to obtain various special results. Due to the lack of space, this detailed extension may be a future work.

II. DEFINITIONS

In this section, we define the problem of lossless communication of a pair of correlated DM sources \((S_1, S_2)\) over the two-user DM-CRC \(p(y_1, y_2 | x_1, x_2)\), as depicted in Fig. 1. Let \((S_1^n, S_2^n)\) be a DM sequence generated by repeated independent drawing of a pair of random variables \(S_1, S_2\) with joint distribution \(p(s_1, s_2)\), i.e., \(p(s_1^n, s_2^n) = \prod_{i=1}^{n} p(s_{1,i}, s_{2,i})\). Here, transmitter \(i, i = 1, 2\), wants to transmit its source sequence \(S_i^n\) losslessly to its respective receiver. A source-channel block code for the channel consists of an integer \(n\), two encoding functions \(\Phi_1: S_1^n \rightarrow X_1^n\) and \(\Phi_2: S_2^n \rightarrow X_2^n\), and two decoding functions \(\Psi_1: Y_1^n \rightarrow S_1^n\) and \(\Psi_2: Y_2^n \rightarrow S_2^n\).

Definition 1: A source pair \((S_1, S_2)\) is called admissible for the cognitive radio channel if for any given \(0 < \varepsilon < 1\) and for any sufficiently large \(n\), there exists a sequence of block codes \((\Phi_1, \Phi_2, \Psi_1, \Psi_2)\) such that \(\max\{P_{e_1}^{(n)}, P_{e_2}^{(n)}\} \leq \varepsilon\), where the error probability at the decoder \(i, i = 1, 2\), is defined as:

\[
P_{e_i}^{(n)} = \sum_{s_i^n \in S_i^n} p(s_i^n) p_r(y_i) = s_i^n | s_i^n \text{ sent}. \quad (1)
\]

III. PROBLEM STATEMENT AND MAIN RESULTS

In this section, we find a class of source-channel matching conditions between the source and the channel in terms of the source variable \((S_1, S_2)\), the channel probability density function \(p(y_1, y_2 | x_1, x_2)\), and the auxiliary random variables \(W_0, W_1, W_2, U_2\). Auxiliary random variable \(W_0\) carries the