Abstract—The interference channel with a cognitive relay is a variation of the classical two-user interference channel in which a relay aids the transmission among the users. The relay is assumed to have genie-aided cognition: that is it has full, a-priori, knowledge of the messages to be transmitted. We obtain a new outer bound for this channel model and prove capacity for a class of channels in which the transmissions of the two users are non-interfering. This capacity result improves on a previous result for the Gaussian case in which the capacity was proved to within a gap of 3 bits/s/Hz.

Index Terms—Semi-deterministic interference channel with a cognitive relay, Parallel channel with a cognitive relay.

I. INTRODUCTION

COGNITION is defined as the ability of a wireless node to overhear simultaneous communications taking place over the network and adapt its transmission strategies to the acquired knowledge. Information theory considers the limiting case in which the cognitive node is able to obtain perfect knowledge of the messages transmitted over the network: although idealistic, this approach provides an outer bound to the limiting performance of a cognitive system. The first cognitive model considered in the literature is the the cognitive interference channel of [1] and studied in several subsequent publications (please see [2] and references therein). The Cognitive InterFerence Channel (CIFC) is obtained from the classical InterFerence Channel (IFC) by providing one user with full and non-causal knowledge of the other user’s message.

In recent years, various extension of the CIFC has been considered in the literature. In this letter, we consider one such extension: the InterFerence Channel with a Cognitive Relay (IFC-CR). This model is obtained by adding a relay node to the IFC which has full non-causal message knowledge of the message of both two users. The IFC-CR was first introduced in [3], where an achievable rate region was proposed. In [4], the rate region was improved upon and a sum-rate outer bound was also provided. In [5], where the IFC-CR was referred to as “Broadcast Channel with Cognitive Relays”, an achievable rate region containing previously proposed regions was derived. In [6], a more general achievable rate region was provided that included the region of [5] as a special case. The first outer bound for the non-Gaussian IFC-CR was derived in [7].

Our work: In this letter, we derive a new outer bound for a class of semi-deterministic IFC-CRs. This outer bound is to be capacity region when the semi-deterministic IFC-CR reduces to a (semi-deterministic) PC-CR. The capacity for the semi-deterministic PC-CR was previously only known to within 3 bits/s/Hz in the subclass of Gaussian PC-CR, in which the channel outputs are obtained as a linear combinations of the channel inputs plus a Gaussian distributed noise term [12]. Our result establishes the capacity of this model exactly.

The rest of the paper is organized as follows. In Section II, the channel model is introduced. In Section III, we review related results available in the literature. In Section IV, we provide a new upper bound leading to the capacity of Gaussian PC-CR. Section V concludes the paper.

II. CHANNEL MODEL AND NOTATIONS

We denote random variables and their realizations by uppercase and lowercase letters, respectively. The probability distribution of random variable $X$ is denoted by $p_X(x)$, where $x \in \mathcal{X}$. In the following, we drop the subscripts of probability distributions if the arguments of the distributions are lower-case versions of the corresponding random variables.

In discrete and memoryless IFC-CR model depicted in Fig. 1, we consider finite input alphabets $\mathcal{X}_1$, $\mathcal{X}_2$, $\mathcal{X}_c$, finite output alphabets $\mathcal{Y}_1$, $\mathcal{Y}_2$, and transition probability function $p(y_1, y_2|x_1, x_2, x_c)$. The channel is memory-less and time-invariant. An $((2^nR_1, 2^nR_2), n)$ code for this channel model includes two message sets $M_i = \{1, \ldots, 2^{nR_i}\}$, three encoding functions $f^{enc}_i : M_i \to \mathcal{X}_i^n$, and $f^{enc}_i : M_1 \times M_2 \to \mathcal{X}_c^n$ and two decoding functions $g^{dec}_i : \mathcal{Y}_i^n \to M_i$, $i = 1, 2$. In the above, $R_i$ denotes the transmission rate of sender $i$. Assume that in transmitter $i$, the message index $M_i$ is selected uniformly from the message set $M_i$ and decoder $i$ estimates the transmitted message index as $\hat{M}_i = g^{dec}_i(\mathcal{Y}_i^n)$. Then, the