1 Introduction

This paper deals with study of capacity regions with two senders and two transmitters, when they have deterministic interference channel or gaussian interference channel, capacity when there is interference channel with source/destination cooperation, unidirectional cooperation, only transmitter cooperation, when the channel is full-duplexed or half-duplexed, when the channel has a feedback. This paper is a survey made on calculating and comparing different capacity regions of all the above strategies. [1] calculates the capacity region for channels in communication situation. [2] discusses the capacity of deterministic interference channels. It establishes the capacity bounds for (Discrete Memoryless Channel)DMC interference channel. The system model is designed such that the decoder gets information from both the channels. It differentiates between the actual message and the interference from other channel. [10] establishes the capacity regions when both source and destinations cooperate with each other. This achievable rate is found to be better when compared to non-cooperating channels. [6] establishes inner and outer bounds of interference channels with a cognitive transmitter.capacity bounds were calculated with only transmitter cooperation in [12]. It is found that the outer bound for Interface Channel- Generalised Feedback(IC-GF) is tighter than the cutset bound. It is also found that this improves if there is Interference channel with user cooperation (IC-UC). [8] derives conditions under which capacity region of the channel where one encoder knows the message at other and not vice versa, coincides with the channel where both messages are decoded at both receivers. [11] shows that feedback provides unbounded gain. New outer bound is derived to show that a proposed scheme can achieve symmetric capacity to within one bit for all channel parameters. [4] develops results for memoryless channels in gaussian and binary cases and shows that the capacity is more in systems when there is side information available at the transmitters, when related to systems where there is no such side information. It also shows that the systems which have no side information on the receiver side has less capacity when compared to systems which have the side information available on receivers. [9] proves that the capacity of a two-sender two-receiver channels is used with partial transmitter cooperation. The capacities of Interference channel with common information(ICCI) and Interference channel with unidirectional cooperation(ICUC) is determined in strong interference, and it is found that this coincides with the capacity region of compound MAC with compound information.

2 Capacity of Channels with two senders and two receivers

[1] discusses the general case of two senders and two receivers, denoted by \((P, T_{22})\). The system is defined as \(S_X\) sending to \(R_X\) and \(S_Y\) sends to \(R_Y\), denoted by \((P, T_{22}, I)\). In case \(S_X\) sends message
only to \( R_X \) and \( S_Y \) sends message only to \( R_Y \), a satisfactory characterization of the capacity region is not obtained. This paper proves that the capacity region cannot be obtained if the sources are independent. The situation in which \( S_X \) and \( S_Y \) both send to \( R_X \) and \( R_Y \), is called \((P,T_{22},II)\). This paper mainly characterizes the capacity regions of \((P,T_{22},I)\), which can be extended to \((P,T_{22},II)\). The purpose of this survey is to find different ways of improving this capacity regions and compare them. This also discusses which way is easier to implement.

[4] introduces a model shown in figure 1 which is taken from the same paper figure 1. The channel outputs \( Y^n_1, Y^n_2, \ldots, Y^n_k \) depend on \( X^n \) and \( S^n_1, S^n_2, \ldots, S^n_k \)

\[
Y^n_k = X^n \oplus S^n_k \tag{1}
\]

One lower bound corresponds to a time-sharing approach that precancels the interference of one of the receivers at a time, yielding a rate of \( R_{TS} = \frac{1}{2} \). the other lower bound corresponds to ignoring the transmitter interference. This yields a rate of \( R_{TS} = 1 - \max H(S_1), H(S_2) \).

Figure 1: Two-user memoryless, noiseless binary multicast channel with additive interference.

3 capacity of interference channels

Figure 2 is taken from figure 1 of [2]. This paper establishes the capacity of DMC interference channels. In this \( Y_1 \) and \( Y_2 \) are deterministic functions such that

\[
H(Y_1|X_1) = H(V_2) \tag{2}
\]

\[
H(Y_2|X_2) = H(V_1), \tag{3}
\]

where \( V_1 \) and \( V_2 \) are functions of \( X_1 \) and \( X_2 \). The decoder gets information from both the senders. Thus it decides which is the correct channel and which message is due to interference from another channel. Thus it decodes the correct message properly. This paper proves theorems determining the capacity regions, when both senders send only to one receiver and another case where both senders
send to both receivers. This can be extended to M transmitter and M receivers case. Equations (1) and (2) are requirements that each receiver, after decoding its senders message, will know exactly the interference caused by other sender.

\[
C = 1 - \frac{1}{2} H(S_1 \oplus S_2)
\]  \hspace{1cm} (4)

4 capacity of interference channels with cooperation

[10] uses the model in figure 3(Figure 1 of [10]). There are two users and two receivers all of which can talk and listen. Cooperation in interference management is discussed in this paper and how to achieve it. the channel is a two-user linear deterministic interference channel and the nodes operate in full-duplex mode. This paper mainly concentrates on (i) when the two receivers cooperate (ii) when the two transmitter cooperate. It is proved with examples that both ways the capacity is improved.

The source nodes are 1 and 2 and 3 and 4 are the receive nodes.
\[ Y_1(t) = h_{2,1}(X_2(t)), \quad (5) \]
\[ Y_2(t) = h_{1,2}(X_1(t)), \quad (6) \]
\[ Y_3(t) = h_{1,3}(X_1(t)) + h_{2,3}(X_2(t)), \quad (7) \]
\[ Y_4(t) = h_{2,4}(X_2(t)) + h_{1,4}(X_1(t)) \quad (8) \]

where we define the functions:
\[
h_{2,1}(X_2) = S^{n-c}X_2 \\
h_{1,2}(X_1) = S^{n-c}X_1 \\
h_{1,3}(X_1) = S^{n-D}X_1 \\
h_{2,3}(X_2) = S^{n-D}X_2 \\
h_{2,3}(X_2) = S^{n-L}X_2 \\
h_{1,4}(X_1) = S^{n-L}X_1
\]

where \( S \) is the \( n \times n \) shift matrix
\[
\begin{bmatrix}
  0 & 0 & 0 & \cdots & 0 \\
  1 & 0 & 0 & \cdots & 0 \\
  0 & 1 & 0 & \cdots & 0 \\
  \vdots & \ddots & \ddots & \ddots & \vdots \\
  0 & \cdots & 0 & 1 & 0
\end{bmatrix}
\]

There is a causality restriction on what the sources are allowed to transmit. The model for the destination cooperation is described as follows:
\[
Y_3(t) = h_{1,3}(X_1(t)) + h_{2,3}(X_2(t)) + h_{4,3}(X_4(t)) \quad (9) \\
Y_4(t) = h_{2,4}(X_2(t)) + h_{1,4}(X_1(t)) + h_{3,4}(X_3(t)) \quad (10)
\]

The source cooperation is described as follows: The inputs would be
\[
x_1(t) = \begin{bmatrix} v_1(t) \\ v_2(t-1) \\ u_1(t) \\ z_1(t) \end{bmatrix} \quad \text{and} \quad x_2(t) = \begin{bmatrix} v_2(t) \\ v_1(t-1) \\ u_2(t) \\ z_2(t) \end{bmatrix}
\]

Hence the destination 3 receives
\[
y_3(t) = \begin{bmatrix} v_1(t) \\ v_2(t-1) \\ u_1(t) + v_2(t) \\ z_1(t) + v_1(t-1) \end{bmatrix}, \quad t = 0, 1, \ldots, T - 1
\]
It is proves that with \( n_D/2 = n_I = n_C/3 = 1 \), without cooperation the sum capacity is 2 and with cooperation it is 4.

[8] says that instead of both transmitters knowing the messages from the other transmitters, it is enough that one transmitter knows the information. It proves that both achievable rates coincide. Hence there will be no penalty in decoding both messages at both the decoders in the interference channel with unidirectional cooperation. Figure 4 shows the setup of this problem.

Capacity in case of strong interference satisfies

\[
I(X_1; Y_1|X_2) \leq I(X_1; Y_2|X_2) \tag{11}
\]

\[
I(X_2; Y_2|X_1) \leq I(X_2; Y_1|X_1) \tag{12}
\]

The same setup can be considered as the cognitive transmitter since one transmitter knows the message of the other in advance [6]. The extra information received allows the cognitive user to cooperate by forming channel inputs based on both users’ messages. It is proved that this improves the rate of the transmitters. Outer bounds and inner bounds of the scenario is calculated.

5 capacity of Gaussian IC with User cooperation

6 conclusion

[9], [12], [13], [5], [7], [10], [1], [3], [8], [6], [2], [4], [14], [11]
References


