Collaborative Coding Multiple Access

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July 2007

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Introduction

Multiple Access Communication

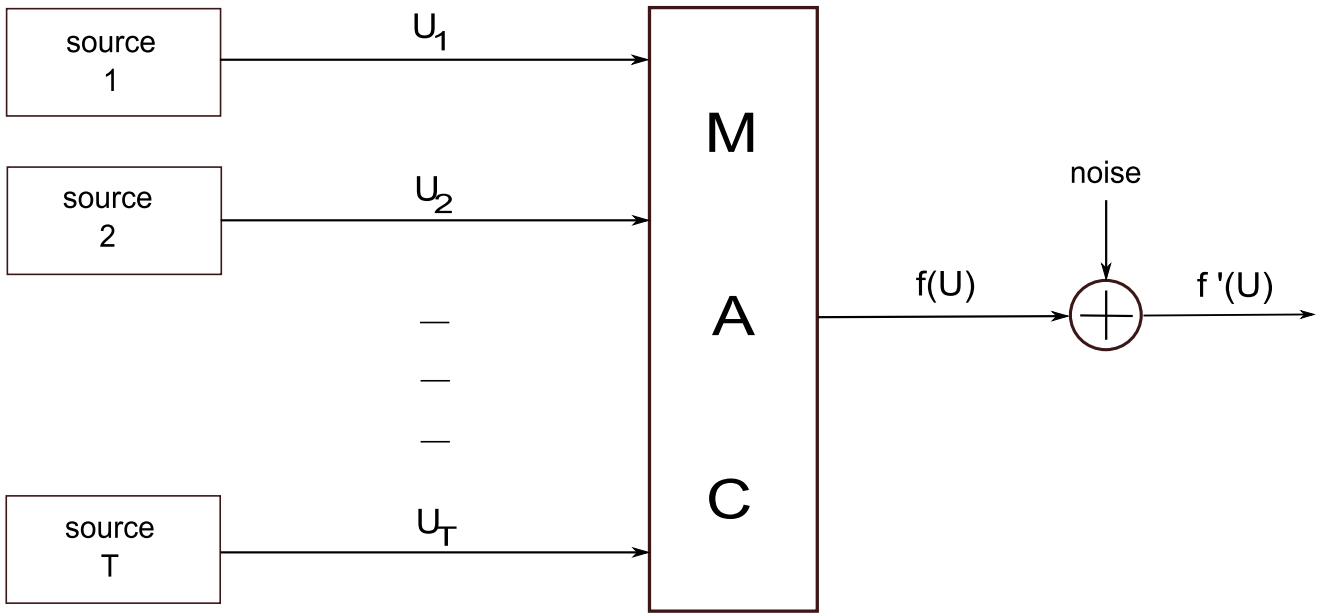

Figure: Block diagram of T-user multiple access system

Introduction

Techniques for multiple access

1. Time division multiple access.
2. Frequency division multiple access.
3. Code division multiple access.

Introduction

Techniques for multiple access

There exists a multiple access technique that does not employ time, frequency or spread spectrum code division.

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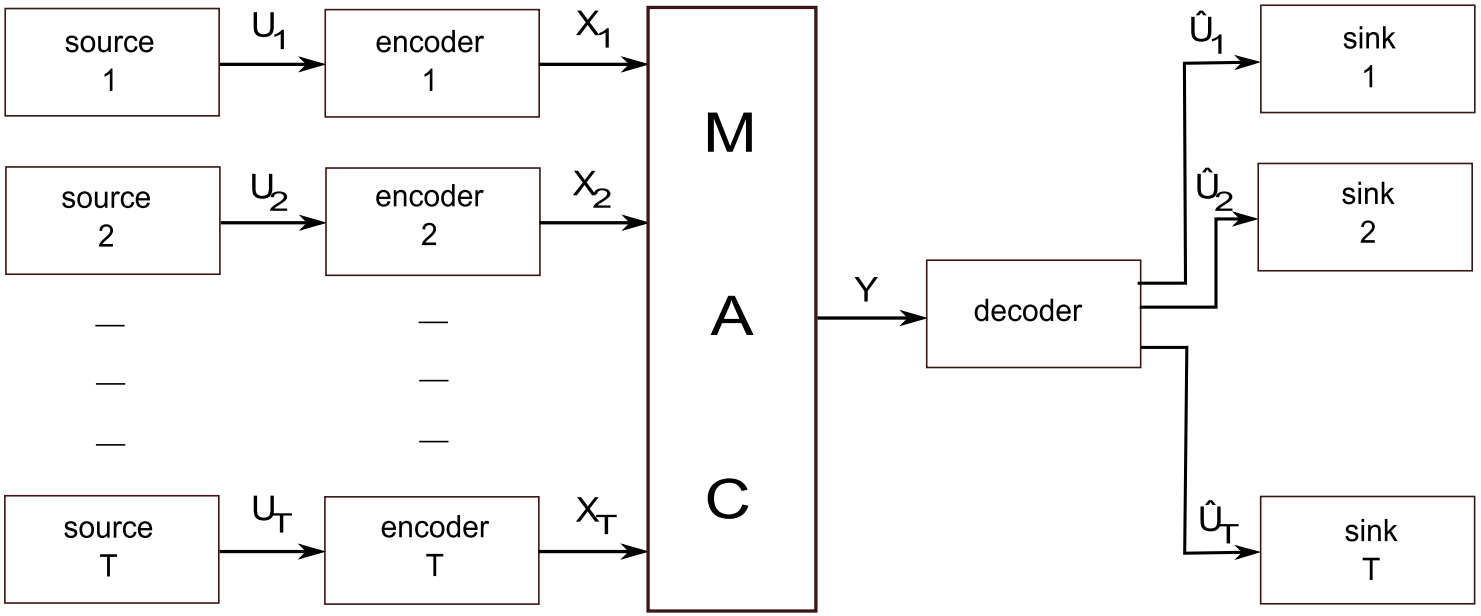
T-user multiple access channel system



Collaborative Coding Multiple Access

Collaborative code

- The T codes $C_1, C_2, ..., C_T$ are called a 'T-user collaborative code', where each component is termed a 'constituent code'.
- Consider that each constituent code C_i is a binary block code with words of length N.

$$R_i = \log_2(CW_i)/N$$

$$R_{sum} = \sum_{i=1}^{T} \log_2(CW_i)/N$$

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Unequal error protection

Unequal error protection (UEP) can be achieved by CCMA schemes if each constituent code has a different rate. Priority will be provided for users with higher rates.

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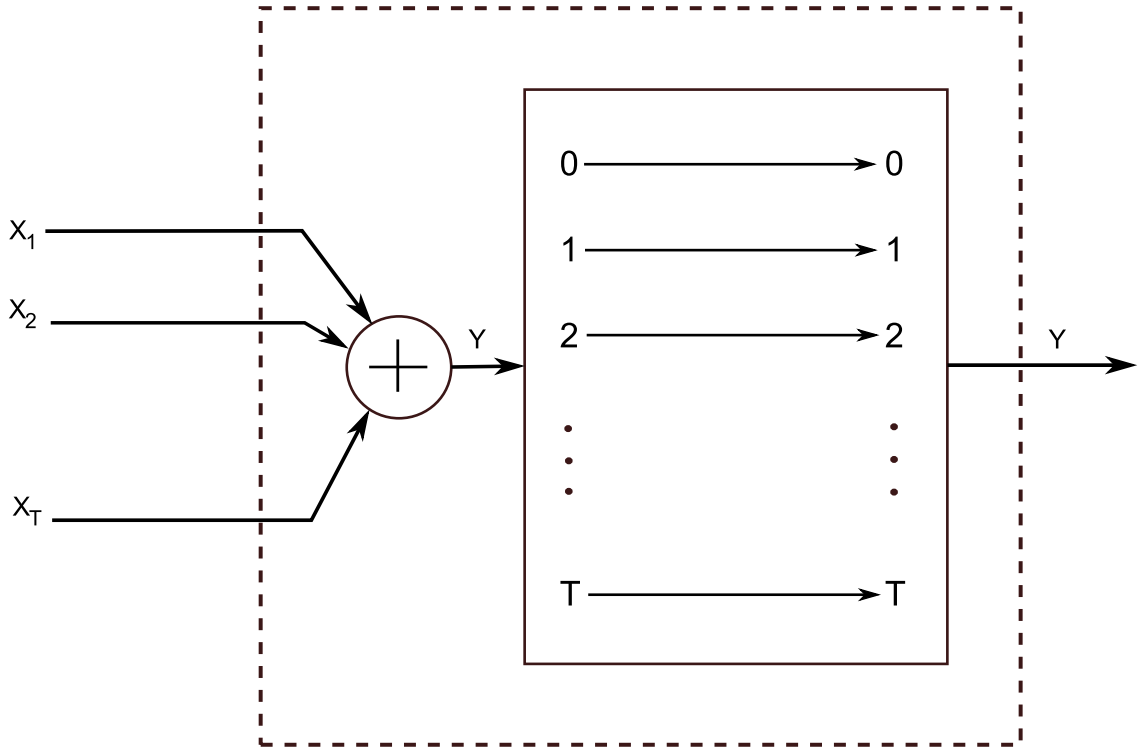
Noiseless T-user binary adder channel



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Capacity of the T-user binary adder

The capacity of the noiseless T-user binary adder is:

$$\sum_{i=0}^{T} \frac{\binom{T}{i}}{2^T} \log_2 \frac{2^T}{\binom{T}{i}},$$

what implies:

$$0 \leq R_1 + R_2 + ... + R_T \leq \sum_{i=0}^{T} \frac{\binom{T}{i}}{2^T} \log_2 \frac{2^T}{\binom{T}{i}}.$$

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Example for the two users case

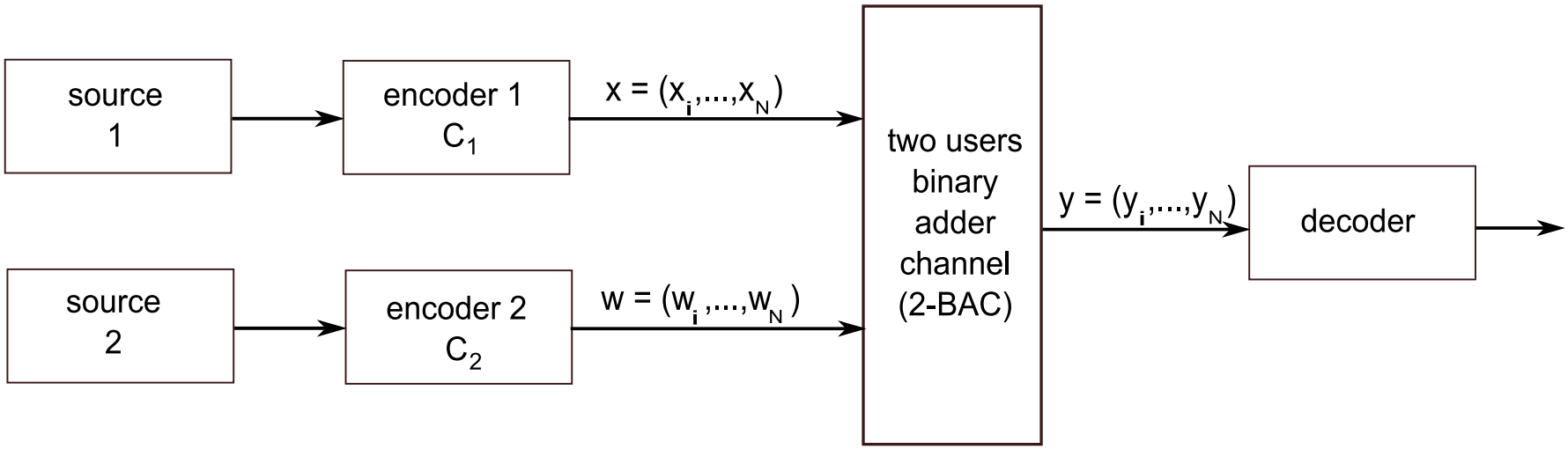
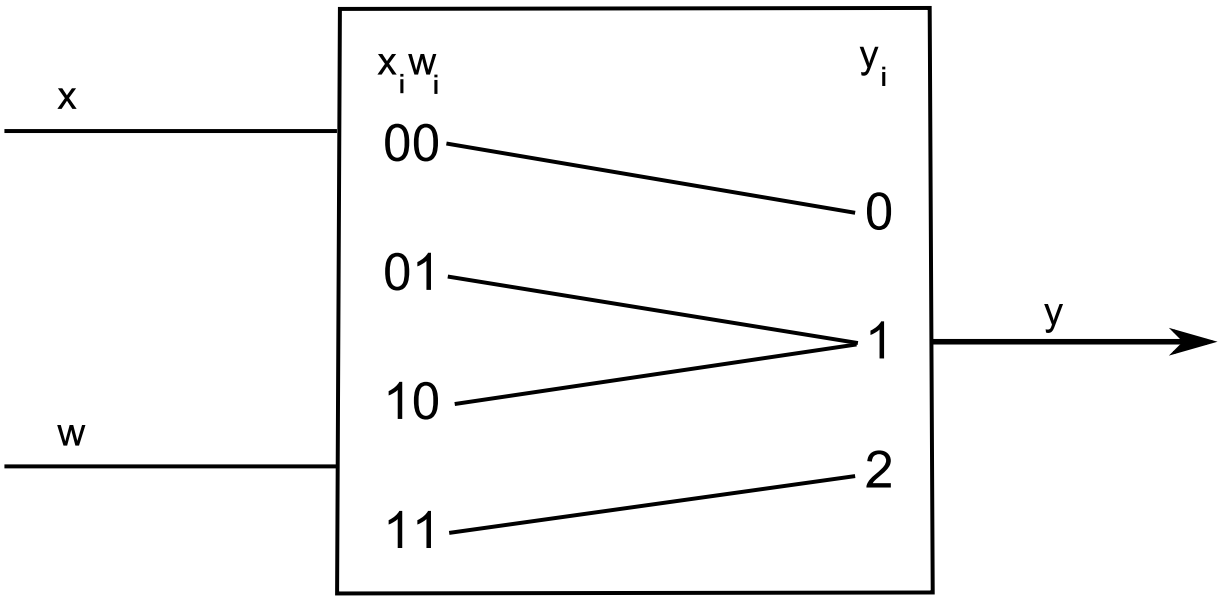


Figure: Block diagram of 2-user multiple access channel

Collaborative Coding Multiple Access

Example for the two users case



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Uniquely decodable codes

The T-user code $(C_1, C_2, ..., C_T)$ is said to be *uniquely decodable* if and only if, for every such distinct pair $(X_1, X_2, ..., X_T)$ and $(X'_1, X'_2, ..., X'_T)$

$$X_1 + X_2 + ... + X_T \neq X'_1 + X'_2 + ... + X'_T$$

where the plus sign denotes real addition and the addition operation is performed componentwise.

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Uniquely decodable codes

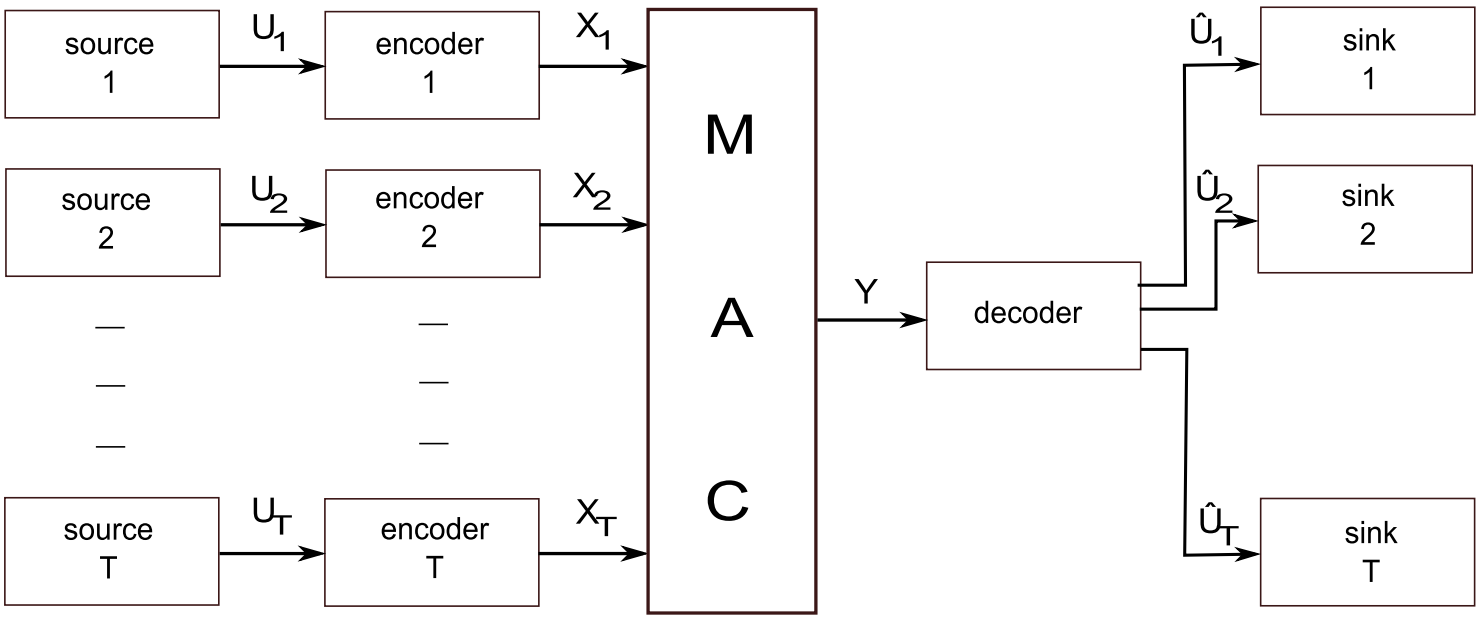

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Table: Two-user uniquely decodable code

	$C_1 + C_2$	(C_1)	
		$(0\ 0)$	$(1\ 1)$
	$(0\ 0)$	$0\ 0$	$1\ 1$
(C_2)	$(0\ 1)$	$0\ 1$	$1\ 2$
	$(1\ 0)$	$1\ 0$	$2\ 1$

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Decoding techniques

- Hard decision (HD) decoding.
- Maximum likelihood.

Decoding techniques for the noisy channel

Hard decision (HD) decoding

- T decision thresholds to detect $(T+1)$ possible signal levels.
- Each of the N received symbols detected independently (symbol-by-symbol HD - SBS-HD).
- SBS-HD may result in not admissible codewords.

Decoding techniques for the noisy channel

HD-CCMA decoding technique (F.Ali and B. Honary)

- L-distance HD decoding is used with SBS-HD to resolve ambiguity.
- This complete technique is referred to as HD-CCMA.

The distance between two codewords is defined as:

$$d_L(Z, Z') = \sum_{i=1}^{N} |z_i - z_i'| = ||Z - Z'||$$

Decoding techniques for the noisy channel

HD-CCMA decoding technique (F.Ali and B. Honary)

Number of errors that can be corrected under this decoding is:

$$t = \left\lfloor \frac{d_{min} - 1}{2} \right\rfloor$$

where $d_{min} = L_{min}$.

Decoding techniques for the noisy channel

Maximum likelihood

- Calculates the Euclidean distances between the received codeword and all admissible codewords.
- Difficult to implement due to storage requirements.

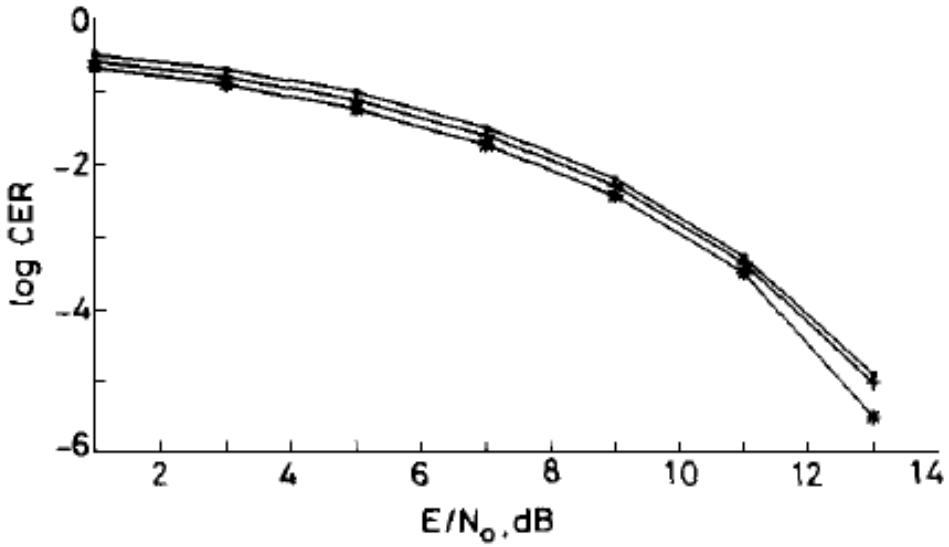
Decoding techniques for the noisy channel

Maximum likelihood soft decision - MLSD-CCMA (F.Ali and B. Honary)

- Combines the reliability of ML with less implementation complexity.
- Reduces the number of computations required to decode a received codeword.

Decoding techniques for the noisy channel

Performance

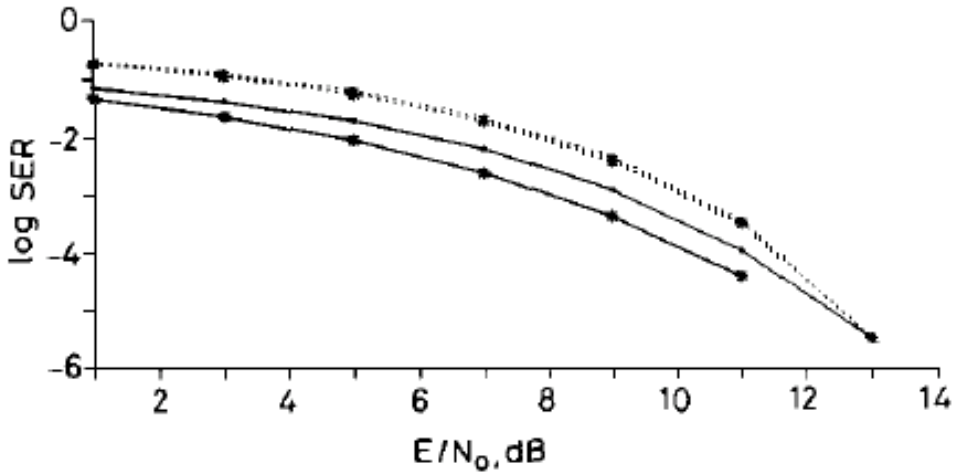


CCMA decoding schemes CER

SBS_HD
HD_CCMA
MLSD_CCMA

Decoding techniques for the noisy channel

Performance



CCMA decoding schemes users sink SER

User 1 HD_CCMA
User 1 MLSD_CCMA
User 2 HD_CCMA
User 2 MLSD_CCMA

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Limitations

- Synchronization.
- T-users must be active at the same time.
- Most studies concentrate on the 2-user case.

Intended Research

1. Expand results obtained for the 2-BAC for the T-users case.
2. Create low complexity iterative algorithms for decoding (LDPC?).
3. Study combined CCMA and COFDM systems.

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