received
This unit has dealt with the introduction, the digitization of signals, the advantages and the elements of digital communication.

Information Theory

Information is the source of a communication system, whether it is analog or digital. Information theory is a mathematical ~~theory~~ approach to the study of coding of information along with the quantification, storage and communication of information.

The foundation of information theory was laid in a 1948 paper by Shannon titled "A mathematical theory of communication". Shannon was interested in how much information a given communication channel could transmit. (*) →

Information theory is based on a measure of uncertainty known as entropy (designated by "H").

(*) → In neuroscience, you are interested in how much information the neuron's response can communicate about the experimental stimulus.

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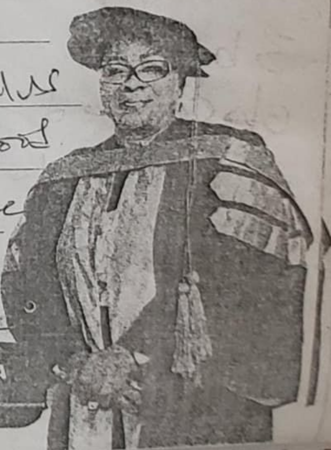
For example, the entropy of the stimulus S is written H(S) and is defined as follows:

$$H(S) = -\sum_S P(S)\log_2 P(S)$$

where subscript S underneath the summation simply means to sum over all possible stimuli S = [1, 2 . . 8]. This expression is called "entropy" b/cos it is similar to the definition of entropy in thermodynamics. Thus, the preceding expression is sometimes referred to as "Shannon entropy".

The entropy of the stimulus can be intuitively understood as "how long of a message (in bits) do I need to convey the value of the



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Stimulus? For example, suppose the center-out task had only two peripheral targets ("left" and "right") which appeared with an equal probability. It would take only one bit (a 0 or a 1) to convey which target appeared; hence, you would expect the entropy of this stimulus to be 1 bit. That is, what the preceding expression gives you, as

$P(S) = 0.5$ and $\log_2(0.5) = -1$.

The center-out stimulus in the dataset can take on eight possible values with equal probability, so you expect its entropy to be 3 bits. However, the entropy of the observed stimuli will actually be slightly less than 3 bits bcos. the observed probabilities are not exactly uniform.

Next, you want to measure the entropy of the stimulus given response, $H(S|R)$. For one pa

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stimulus, the entropy is defined similarly to the previous equation:

$$H(S|R) = -\sum_S P(S|R) \log_2 P(S|R)$$

To get the entropy $H(S|R)$, you just average over all possible responses:

$$H(S|R) = -\sum_R \sum_S P(R)\, P(S|R) \log_2 P(S|R)$$

Then, you can define the information that the response contains about the stimulus. This is known as Mutual information designated I), and it is the difference b/w the two entropy values just defined:

$$I(R;S) = H(S) - H(S|R) = \sum_R \sum_S P(R)\, P(S|R) \log_2 \left(\frac{P(S|R)}{P(S)}\right)$$

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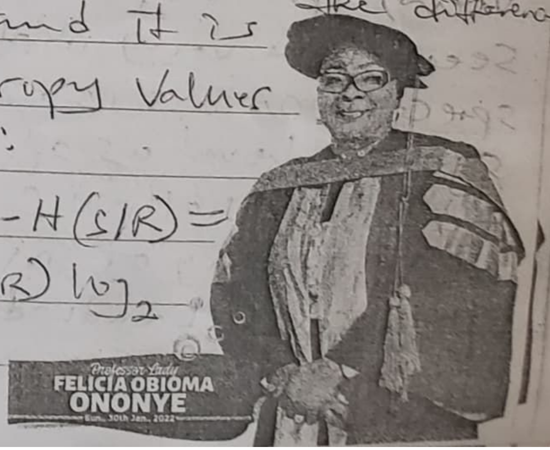

- many data streams improve visual and auditory quality. They also decrease the chance of lost data packets.

Cooperative communication

Cooperative communication refers to a system where users share and coordinate their resources to enhance the information transmission quality. It is a generalization of the relay communication in which multiple sources also serve as relays for each other.

~~cooperative~~

Difference b/w Transmission and communication should be discussed.
Transmission means the transfer of data from the source to the destination while communication is the process of sending and receiving data by means of a data cable that is connected externally.

cooperative communication/Txn uses terminals as relay stations to reduce power consumption

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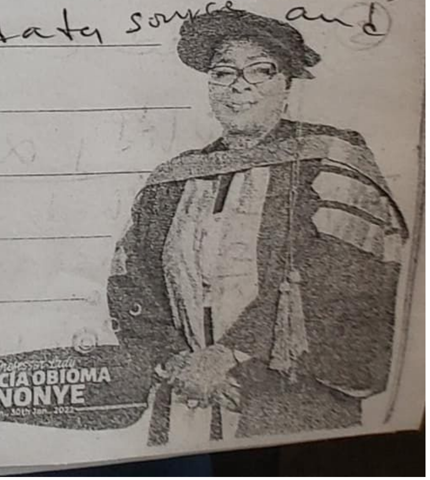
of mobile terminals, resulting in longer operating times. cooperative communication can also increase the capacity, data rates and performance of wireless networks.

cooperative communication can contribute to increasing the transmission coverage area of both mobile networks and adhoc networks.

An example of cooperative communication is presented in the figure below where two mobile networks (T_1 & T_2) are simultaneously data sources and the relays.



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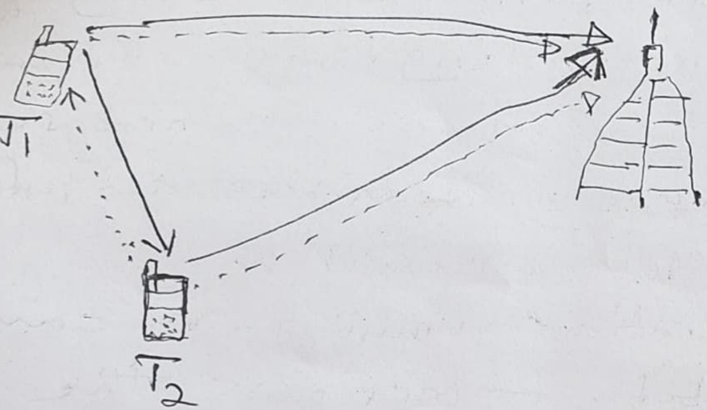


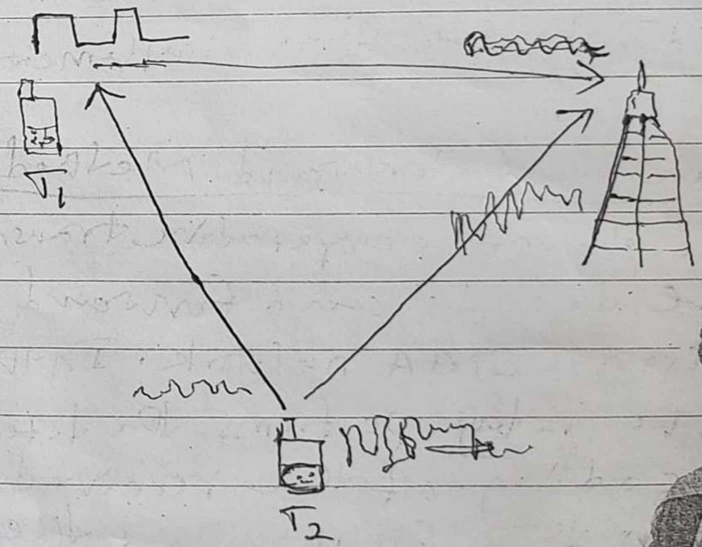
In case cooperative communication, each terminal can be both a data source and a relay.

Types of cooperative communications

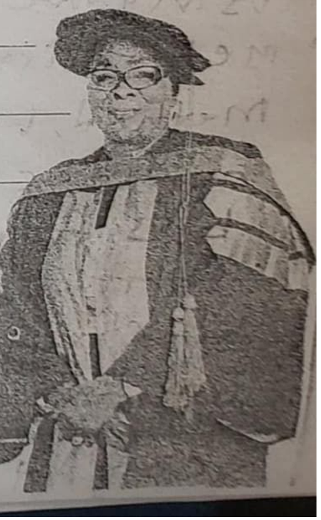
1. Amplify and forward Methods
2. Decode and forward Method
3. Coded cooperation methods.

Amplify & forward Methods

In this method, each terminal receives a noisy version of the signal transmitted by another terminal. According to the method name, the terminal, after receiving the signal from another terminal, amplifies it and then retransmits it (to the destination node of the transmission, e.g. the base station). The destination node combines the signal received directly from the sender and retransmitted by the relay and makes final decision on the transmitted data bits.



Amplify & forward Method



In this method, the signal is amplified with noise, but the situation that the destination receives two independently faded versions of the signal improves the detection of the information signal, improving the transmission quality. In this method, it is assumed that the destination node knows the interuser channel coefficients to do optimal decoding. The mechanism of exchanging or estimating this information must be included into the final implementation.

Decode and forward Method

An example of cooperative transmission using the decode and forward method in a CDMA network. In this method, the relay performs the detection and decoding of the received bits from the source and then retransmit these bits to the destination node.

An example of ~~the~~ analysis of ~~the~~ ~~method~~ use of this method in CDMA transmission.

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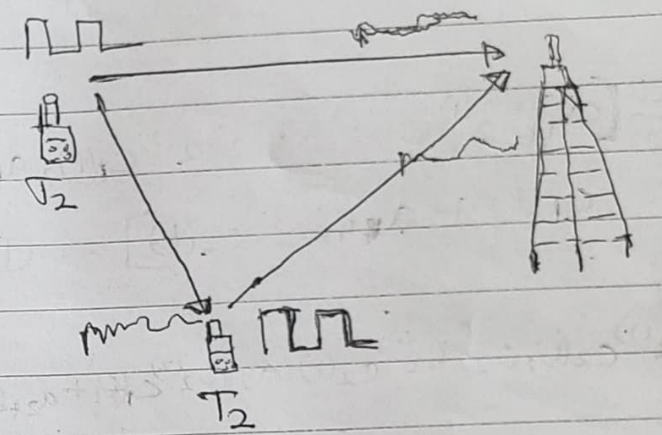
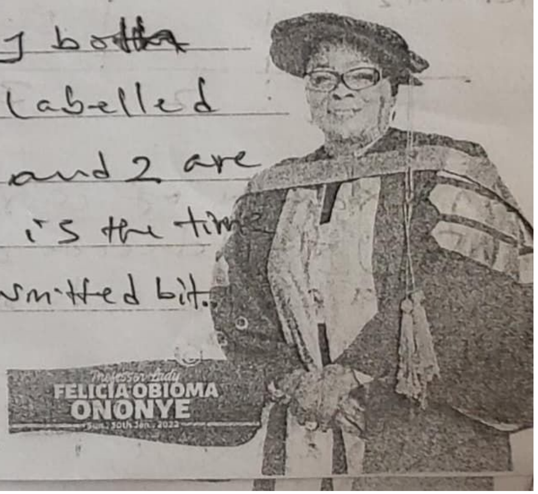


Decode and forward method

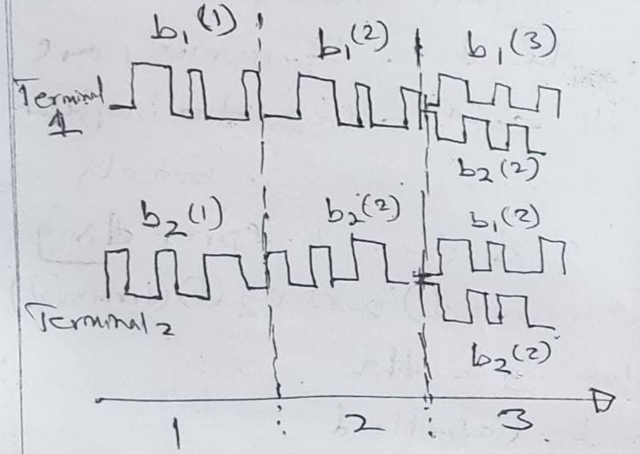
In this example, two terminals are connected with each other to implement cooperative transmission. Each of them has a different spreading code $c_1(t)$ (terminal 1) and $c_2(t)$ (terminal 2). Bits transmitted by both terminals can be labelled $b_i(n)$, where $i = 1$ and 2 are user numbers, n is the time index of the transmitted bit.



The signals of both the terminals can be saved by the following formulas

$$X_1(t) = [a_{11} b_2^{(1)} c_1(t), a_{12} b_2^{(2)} c_1(t), a_{13} b_1 c_1(t) + a_{14} b_2^{(2)} c_2(t)] \quad \ldots (1)$$

$$X_2(t) = [a_{21} b_2^{(1)} c_2(t), a_{22} b_2^{(2)} c_2(t), a_{23} b_2^{(2)} c_1(t) + a_{24} b_2^{(2)} c_2(t)] \quad \ldots (2)$$



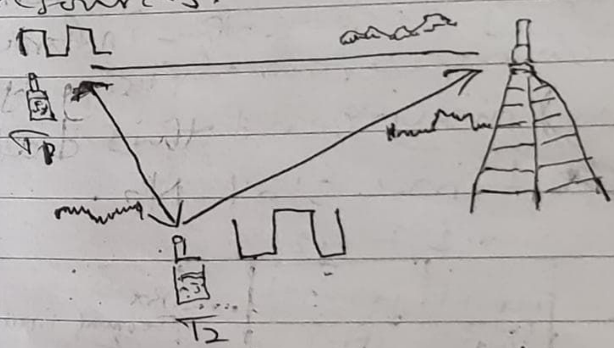
An example of cooperative transmission using the decode and forward method in a CDMA network.

Where a_{ij} coefficients represent the amplitude of the signal, while signals $X_1(t)$ and $X_2(t)$ have duration of three ...

each terminal transmits its own bits.

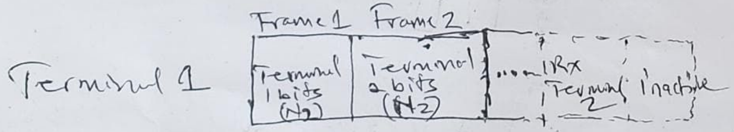
Coded cooperation

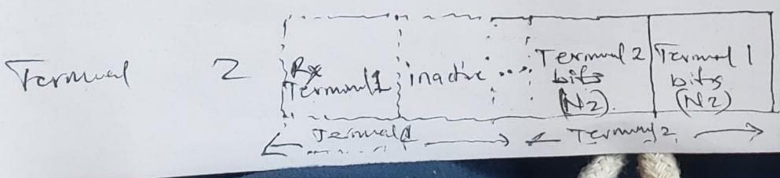
We assume that the wireless system uses a rate R channel code, the idea of coded cooperation is to use the same overall rate for coding and transmission, however, the coded symbols are rearranged b/w two users. In this case there will be no need for additional resources.



coded cooperation

If each user has K bit data block and N bit data block after channel encoding, coding rate $R = K/N$. We divide the N bit data block after encoding into two successive time frames, one with length N_1 and the other with length N_2 ($N_1 + N_2 = N$). In this first frame, the code rate is $R = K/N_1$. These data (frame) is broad-cast by the user terminal are received by the second terminal and the base station (destination node). Each terminal will thus receive a noisy version of the coded information from the second terminal in the network. If the terminal 1 can correctly decode the information sent by the second terminal (using eg. CRC coding) may send this data frame in time slot N_2.





An example of coded corperation in a TDMA

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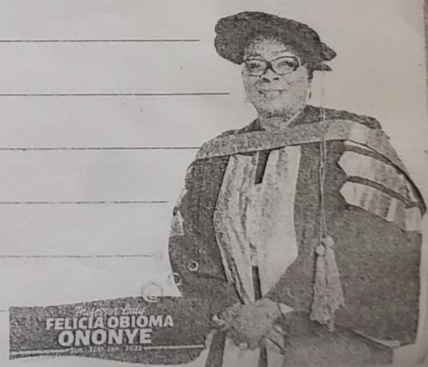
(TDMA) ⇒ Time Division Multyple Access.



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