Network Lab Report

Shuvayan Ghosh Dastidar
001810501044
JU-BCSE - III

Assignment 4:
Implement CDMA with Walsh Code.

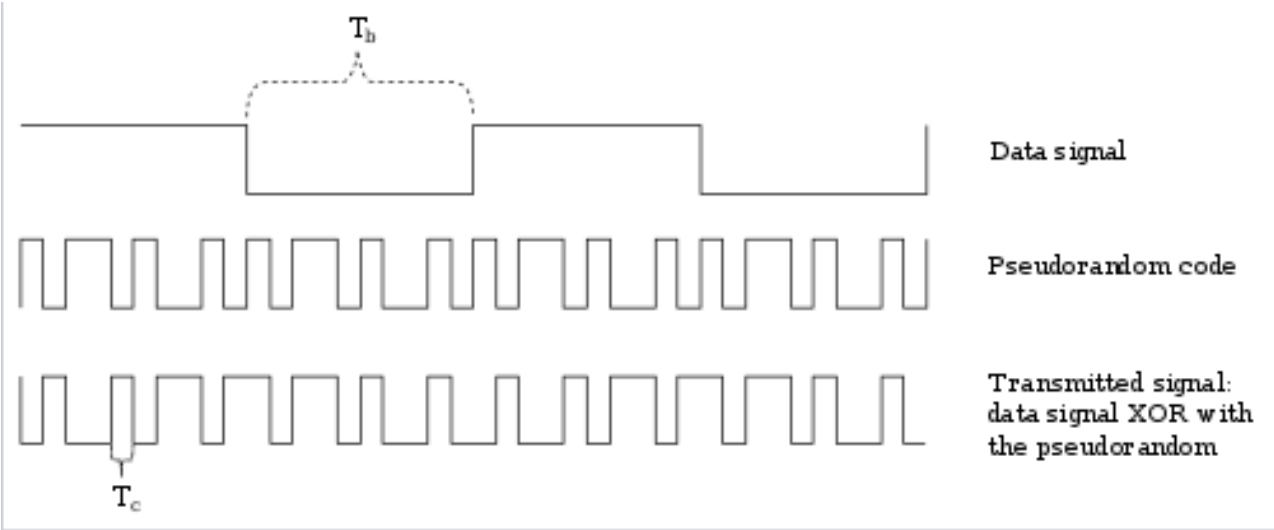
Theory

Code-division multiple access (**CDMA**) is a channel access method used by various radio communication technologies. CDMA is an example of multiple access, where several transmitters can send information simultaneously over a single communication channel. This allows several users to share a band of frequencies (see bandwidth). To permit this without undue interference between the users, CDMA employs spread spectrum technology and a special coding scheme (where each transmitter is assigned a code).

Uses of CDMA

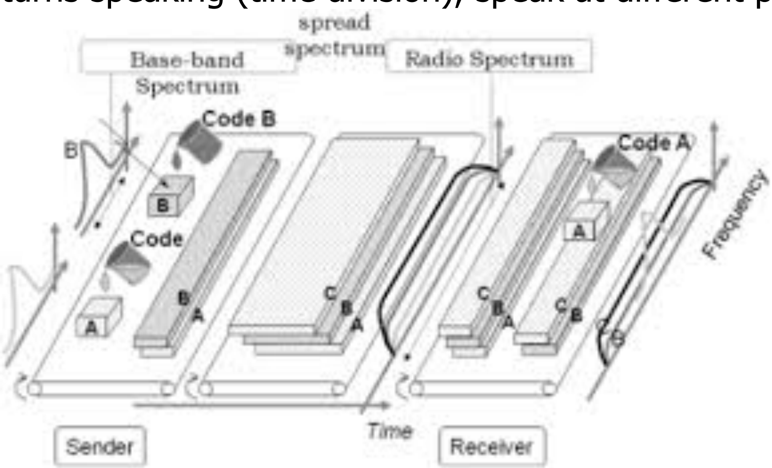
- Synchronous CDM (code-division 'multiplexing', an early generation of CDMA) was implemented in the Global Positioning System (GPS). This predates and is distinct from its use in mobile phones.
- The Qualcomm standard IS-95, marketed as cdmaOne.
- The Qualcomm standard IS-2000, known as CDMA2000, is used by several mobile phone companies, including the Globalstar network.[nb 1]
- The UMTS 3G mobile phone standard, which uses W-CDMA.[nb 2]
- CDMA has been used in the OmniTRACS satellite system for transportation logistics.

CDMA is a spread-spectrum multiple-access technique. A spread-spectrum technique spreads the bandwidth of the data uniformly for the same transmitted power. A spreading code is a pseudo-random code that has a narrow ambiguity function, unlike other narrow pulse codes. In CDMA a locally generated code runs at a much higher rate than the data to be transmitted. Data for transmission is combined by bitwise XOR (exclusive OR) with the faster code. The figure shows how a spread-spectrum signal is generated. The data signal with pulse duration of (symbol period) is XORed with the code signal with pulse duration of (chip period). (Note: bandwidth is proportional to , where = bit time.) Therefore, the bandwidth of the data signal is and the bandwidth of the spread spectrum signal is . Since is much smaller than , the bandwidth of the spread-spectrum signal is much larger than the bandwidth of the original signal. The ratio is called the spreading factor or processing gain and determines to a certain extent the upper limit of the total number of users supported simultaneously by a base station.



Each user in a CDMA system uses a different code to modulate their signal. Choosing the codes used to modulate the signal is very important in the performance of CDMA systems. The best performance occurs when there is good separation between the signal of a desired user and the signals of other users. The separation of the signals is made by correlating the received signal with the locally generated code of the desired user. If the signal matches the desired user's code, then the correlation function will be high and the system can extract that signal. If the desired user's code has nothing in common with the signal, the correlation should be as close to zero as possible (thus eliminating the signal); this is referred to as cross-correlation. If the code is correlated with the signal at any time offset other than zero, the correlation should be as close to zero as possible. This is referred to as auto-correlation and is used to reject multi-path interference.

An analogy to the problem of multiple access is a room (channel) in which people wish to talk to each other simultaneously. To avoid confusion, people could take turns speaking (time division), speak at different pitches (frequency division), or



speak in different languages (code division). CDMA is analogous to the last example where people speaking the same language can understand each other, but other languages are perceived as noise and rejected. Similarly, in radio CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only users associated with a particular code can communicate.

Implementation

Approach

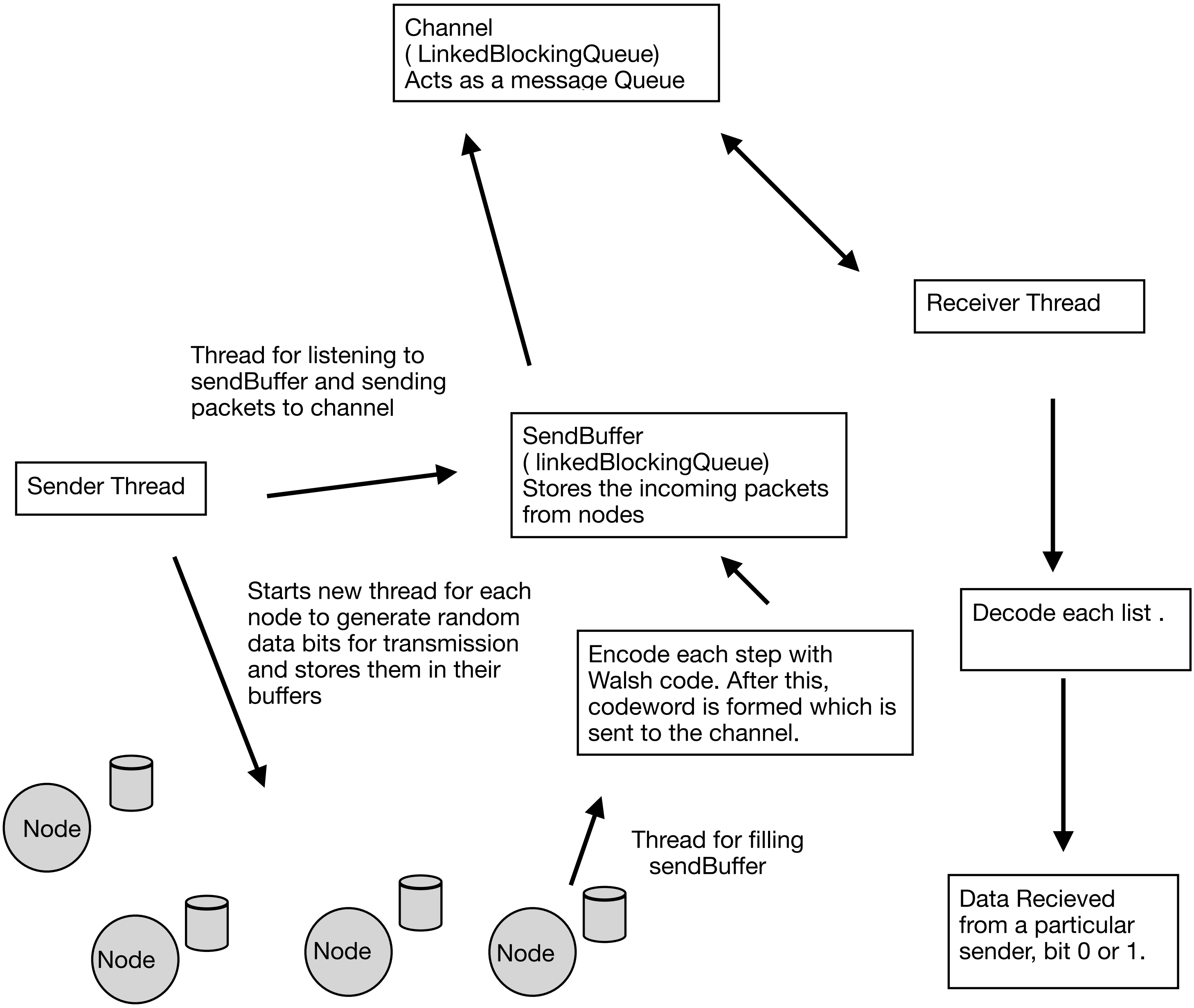
The simulation was done in Java language. The senders were simulated as independent threads and data bits were encoded and sent to a common channel as packets and then received on the receiver end and then decoded to get the required data.

Frame Format

The incoming encoded data payload was converted into frames before sending them to the common channel.

Preamble	Data Payload	End of Frame

Schematic Diagram of WorkFlow



Node contains:

- buffer containing random frames
- sender_index for identification

Walsh Tables

In mathematics, a **Walsh matrix** is a specific square matrix of dimensions 2^n, where n are some particular natural number. The entries of the matrix are either +1 or −1 and its rows as well as columns are orthogonal, i.e. dot product is zero. The Walsh matrix was proposed by Joseph L. Walsh in 1923. Each row of a Walsh matrix corresponds to a Walsh function.

The naturally ordered Hadamard matrix is defined by the recursive formula below, and the sequency-ordered Hadamard matrix is formed by rearranging the rows so that the number of sign changes in a row is in increasing order. Confusingly, different sources refer to either matrix as the Walsh matrix.

The Walsh matrix (and Walsh functions) are used in computing the Walsh transform and have applications in the efficient implementation of certain signal processing operations.

The Hadamard matrices of dimension 2^k for $k \in N$ are given by the recursive formula (the lowest order of Hadamard matrix is 2)

$$H\left(2^1\right) = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$H\left(2^2\right) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix},$$

and in general,

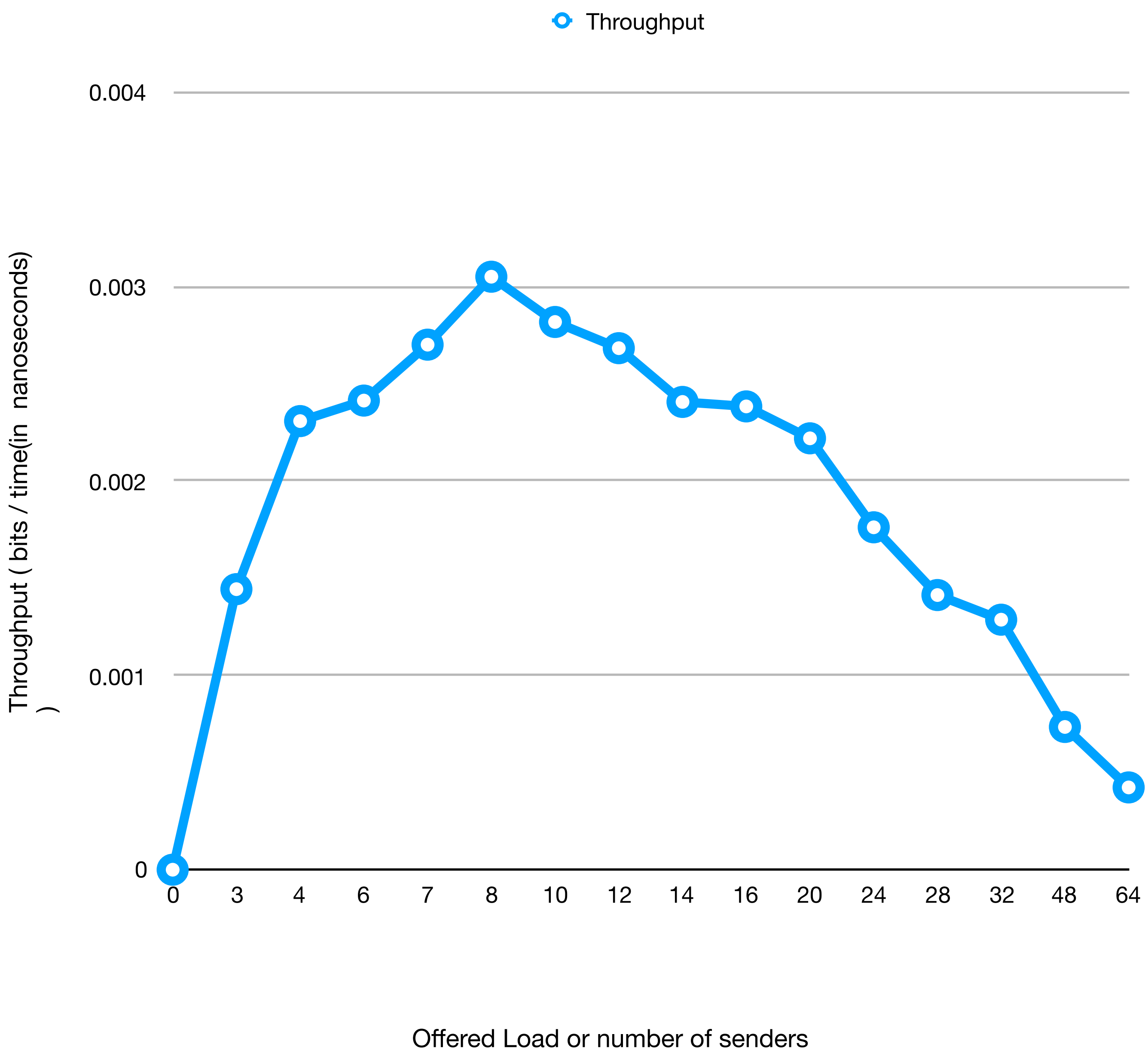
$$H\left(2^k\right) = \begin{bmatrix} H\left(2^{k-1}\right) & H\left(2^{k-1}\right) \\ H\left(2^{k-1}\right) & -H\left(2^{k-1}\right) \end{bmatrix} = H(2) \otimes H\left(2^{k-1}\right),$$

As we have used synchronous CDMA for this experiment,

the sender chip codes are to be as in the walsh table and are to encoded with the data bits and added linearly to be decoded at the receiver end.

Analysis

The performance of CDMA can be calculated on basis of it's throughput vs offered load graph.
The throughput is calculated as ratio of total number of bits transferred to the time taken in doing so.



As the number of nodes increases, the throughput increases upto a certain extent. From the graph, the maximum throughput is obtained when the number of senders is 8 and then it decreases with increase in payload.

The below table shows the number of bits transferred and time taken (in nanoseconds) by increasing the number of senders.

NUMBER OF SENDERS	BITS TRANSMITTED	TIME TAKEN (IN NANOSECONDS)	THROUGHPUT
3	1497	1037189.524	0.00144332348655693
4	1996	864863.884	0.0023078776174217
6	2988	1238096.788	0.00241338159420215
7	3479	1288017.188	0.00270105091175227
8	3976	1303351.083	0.00305059784110372
12	5940	2213952.732	0.0026829841098884
14	6916	2873971.369	0.00240642619985683
16	7888	3309516.02	0.00238343007023728
20	9820	4424950.032	0.00221923409959085
24	13636	9650305.75	0.00141301222502717
32	15520	1.2066593445E+07	0.00128619565005987
48	22896	3.1173355074E+07	7.34473397093414E-04
64	30016	7.0894198935E+07	4.2339148267294E-04

Key Takeways

- On increasing the load on the network, the throughput first increases and then decreases due to congestion and queuing delays.
- CDMA can take a huge number of senders all acting simultaneously and being decoded at the receiver quite correctly as it is based on Walsh code.
- CDMA is good for mobile senders with relatively small amount of senders.

Comments

This was a relatively easy assignment and was able to implement to the concept of CDMA using Walsh Table. This assignment helped in understanding the efficiency of CDMA with respect to mobile networks.