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Packet Drop Rectification Using Luby Transform Code In A Wireless Communication Network- Implementation With Arduino.

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Abstract: Packet losses in computer networks are common phenomenon and are of great concern. Most of the existing methods used to overcome packet losses are time consuming due to the retransmission protocols involved. This paper proposes Luby Transform (LT) Code to overcome packet loss problem in computer networks and to get back the original message at the receiving end. Computer communication network is developed using Arduino and NRF Transceiver with which transmission and reception of data wirelessly is established between computers. The LT codes are effective in getting back the original information in spite of packet loss as it transmits modified packets which contain information about other packets also. The usability and reliability of the proposed LT code is verified by simulating the system in MATLAB and establishing the real time wireless communication system using Arduino and NRF Transceiver.

Keywords: Bipartite Graph, Luby Transform Codes, NRF Transceiver, Arduino, Wireless Networks

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I. INTRODUCTION

Channels with erasures are gaining more importance these days. Information transmitted over the Computer networks are converted to packets. Each of these packets will be received without error or will not be received at all in an erasure channel. For example, when a mail is sent, the recipient either receives the mail or does not receive it. There is no chance for the content to be received incorrectly. Erasure codes are the codes which are effective on erasure channels. When packets are lost, feedback signals are used by the receiver to inform transmitter for resending that packet, in common methods. The receiver send back missing packets once the missing packet signal is received. Here, the sender has to keep track of whether the packets are received by the receiver or not. The retransmission protocols have the advantage that they will work even if erasure probability is high but heavy use of feedback channel will be there and sender will be sending same packets number of times.

Channel coding forms a major aspect in wireless communication system as errors introduced in various types of communication channels need to be detected and corrected.[1] Fountain codes are developed as a solution for reliable communication in lossy networks.[2] They eliminate the need of feedback messages which increases the bandwidth consumption and increases the delay. Luby Transform code is a type of fountain code proposed by M.Luby[3]. Here the source generates m message packets, encodes in to n packets, where n>m and floods each of them into the network. Each recipient retransmits each received packets with certain fixed probability. When a receiver has received sufficient number of packets, it can decode original packets. Another paper by Luby[4] proposes a protocol that closely approximates a digital fountain using a new class of erasure codes for large block sizes of the orders of magnitude faster than standard erasure codes. Authors of paper[5] modifies LT algorithm for Mars mission communication. The LT code developed by authors of paper [6] is referred as systematic LT codes, in which the decoding process is capable of preventing the potentially avalanche-like inter-packet error propagation. The fountain codes are implemented using Tarang F4 module in [6] as embedded system for data encoding and decoding. But in this work, computer communication network is developed using Arduino boards and NRF transceivers. Arduino boards are Open Source electronic prototyping platforms based on flexible, easy to use hardware and software. Paper [7] describes the working principles of Arduino boards and its usage for research. Establishment of communication between two arduino boards with NRF communication modules is dealt in paper [8].

In this paper, Luby Transform (LT) code generation and decoding is simulated and tested in MATLAB, by introducing packet loss. Then a simple computer network using Arduino boards and NRF modules is

developed to test the code in real time scenario. Rectification of packet losses with LT code is tested with MATLAB simulation and real time computer communication network developed with Arduino boards.

II. LUBY TRANSFORM (LT) CODE

LT codes are the first implementation of digital fountain codes in 2002 proposed by Michael Luby[1]. Luby Transform (LT) codes have been invented to reduce the encoding and decoding complexity of random linear Fountain Codes while the small overhead is ensured. In LT codes, data is divided into blocks with fixed size. Each block is divided into fixed size symbols. The encoder of LT codes can generate an infinite number of encoded symbols. Hence it is said to be rate less code. When the number of encoded symbols received is slightly larger than the number of input symbols, this means the decoder of LT codes can recover all input symbols. If the degree of distribution is reduced in linear time encoding and decoding, complexity will be reduced, but it leads to decrease in the reliability of the decoder.

The concept of Bipartite graph comes in to picture in this process. Bipartite graph is defined as a graph whose vertices can be divided into two independent sets. If U and V are two vertices, every edge (u, v) either connects a vertex from U to V or a vertex from V to U. Now using this concept a mapping sequence can be created considering U set as message bits and V set as encoded bits. Here the mapping can be one to many or many to one. The encoded set V is created by performing LT encoding. The encoding procedure is given below:

- Determine the degree 'd' of an encoding symbol. Degree here means number of message symbols used to form an encoded symbol. The degree is chosen at random for a given node with degree distribution P(x).
- Choose d distinct message symbols randomly with ideal soliton distribution. These messages will be neighbors of the encoding symbol.
- Assign the XORed value of the chosen'd' information symbols to the encoding symbol. This process is similar to generating parity bits, but here only the parity bits are transmitted.

Here the degree 'd' considered can be one to one, many to one and one to many mapping between message set U and encoding set V. In this mapping configuration, if an encoded message is having a mapping of degree d = 1, then it is easier to decode the message, since no XOR operation is performed.

The P(x) degree distribution is created using Ideal Soliton Theorem. The Ideal Soliton Distribution is a probability distribution on the integers from 1 to k, where k is the single parameter of the distribution. The Probability mass function is given by ρ(1), . . . , ρ(k), where

$$\rho(i) = \frac{1}{k} \qquad \text{for } i = 1$$

$$\rho(i) = \frac{1}{k(k-1)} \qquad \text{for all } i = 2, \ldots, k$$

The XOR operation can be performed in any order, but for the sake of simulation, it is done using cyclic-modulus XOR method.

Let us take the message "Hello" ASCII value of individual alphabet is considered for transmission.

- H : 0x48 (72).....M1
- e : 0x65 (101).....M2
- l : 0x6C (108).....M3
- l : 0x6C (108).....M4
- o : 0x6F (111).....M5

The distribution P(x) is chosen as [1,2,2,2,3,3,2,1,2,3]. Number of encoded symbols depends on probability of erasure channel. Considering 10 encoded symbols, encoded data will be

- E1 = M1.....0x48 (72)
- E2 = M2⊕M3.....0x09 (09)
- E3 = M3⊕M4.....0x00 (00)
- E4 = M4⊕M5.....0x03 (03)
- E5 = M5⊕M1⊕M2.....0x42 (66)
- E6 = M1⊕M2⊕M3.....0x41 (65)
- E7 = M2⊕M3.....0x09 (09)
- E8 = M3.....0x6C (108)
- E9 = M4⊕M5.....0x03 (03)
- E10 = M5⊕M1⊕M2.....0x42 (66)

Mapping table between encoded symbol with the message symbols are given in table(1) below:

Table(1)

	M1	M2	M3	M4	M5
E1	1	0	0	0	0
E2	0	1	1	0	0

E3	0	0	1	1	0
E4	0	0	0	1	1
E5	1	1	0	0	1
E6	1	1	1	0	0
E7	0	1	1	0	0
E8	0	0	1	0	0
E9	0	0	0	1	1
E10	1	1	0	0	1

For the decoding purpose, first the encoded symbol having d = 1 is looked for, which means that the symbol is received as it is. Then we perform XOR operation with the value of the encoded symbol having d = 1 with the mapped encoded symbol with that message symbol. For example, E1 is having d = 1 and using the value of E1, XOR operation will be performed with E5, E6 and E10 which are mapped to M1. Then again search for d = 1 and perform the same operation again and again until all the values are recovered.

III. SIMULATION AND HARDWARE IMPLEMENTATION

LT code is first simulated in MATLAB. At first P(x) sequence is generated using the in-built 'rand' function and Ideal Soliton probability distribution. This sequence is used to construct the encoded symbols considering a message. Generator mapping matrix is used for decoding process. Fig(1) and Fig(2) shows Encoded and decoded messages in MATLAB command window.

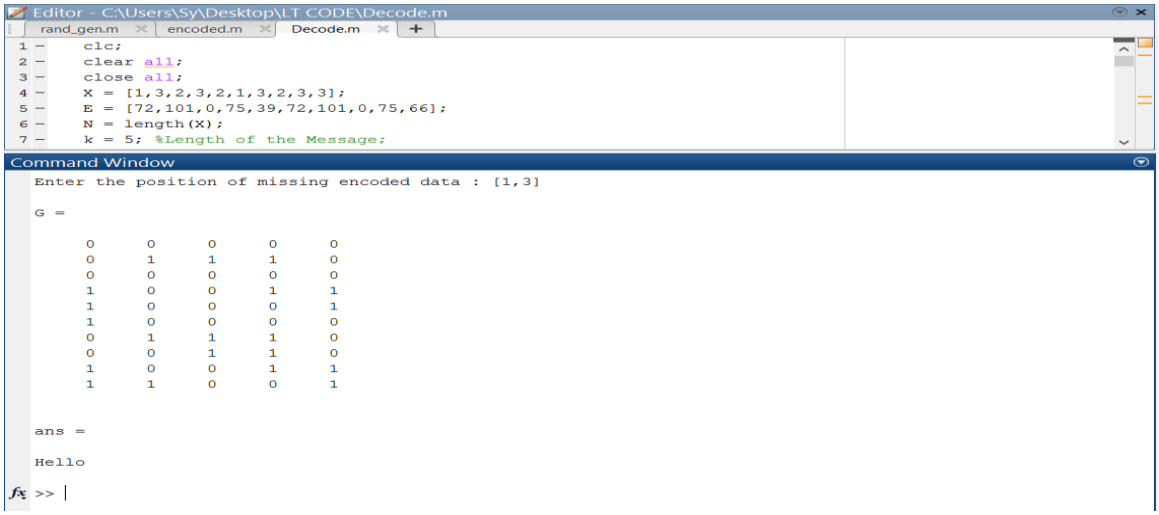
```
>> encoded([1,2,3],[1/3,1/3,1/3],10,'Brother')

X =

     3     3     1     3     2     1     1     2     3     3


ans =

    95   105   111   121    13   101   114    48   105   115
```

Fig(1) Encoded message

```
G =

     1     1     1     0     0     0     0
     0     1     1     1     0     0     0
     0     0     1     0     0     0     0
     0     0     0     1     1     1     0
     0     0     0     0     1     1     0
     0     0     0     0     0     1     0
     0     0     0     0     0     0     1
     1     1     0     0     0     0     0
     0     1     1     1     0     0     0
     0     0     1     1     1     0     0


ans =

Brother
```

Fig(2) Generator matrix and Decoded message

To understand packet loss and recovery, two packets are dropped at the receiver end. LT code still will be able to retrieve all the packets as shown in the fig(3).

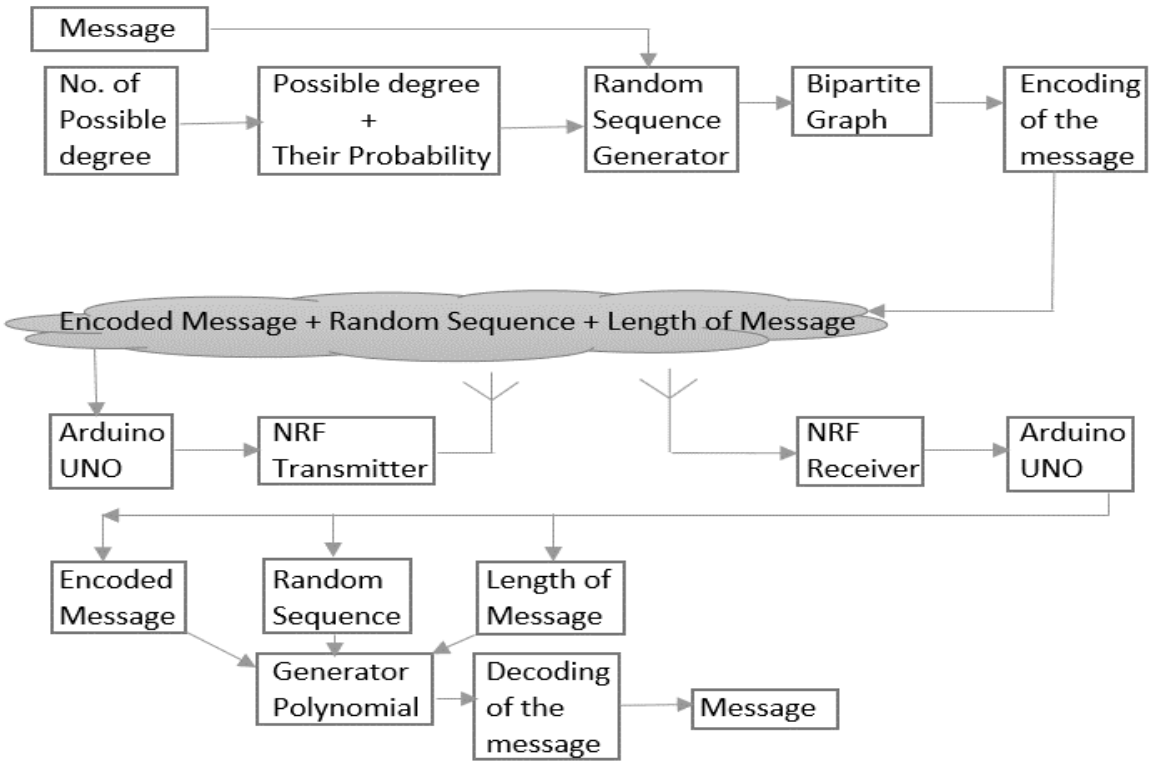


Fig(3) Decoding with dropped messages

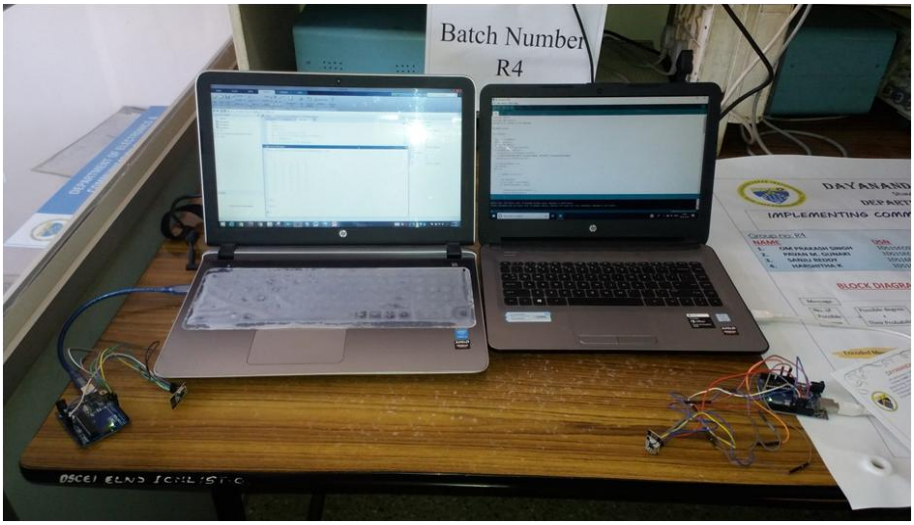
In this case, LT code was able to retrieve all symbols in spite of losing 4 packets provided the lost encoded message's degree is greater than 1.But if messages of degree 1 is dropped, LT code cannot decode proper message.

After the MATLAB implementation and testing, real time scenario of computer communication is developed using Ardiuno Uno and NRF trans-receiver. C code is used to program Ardiuno.

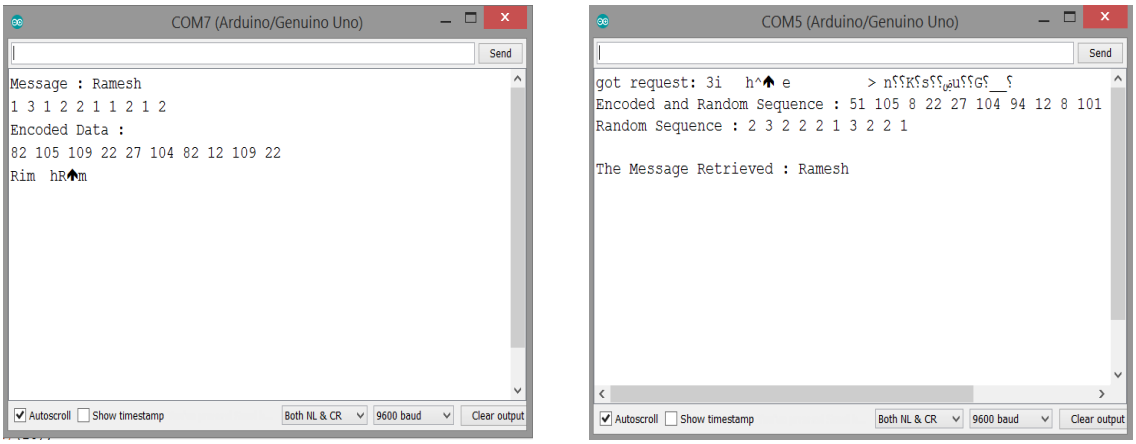
The entire encoding and decoding process is illustrated in the figure(4) below. Figure (5) shows real time set up established with Arduino boards and NRF modules. LT code is used to rectify errors due to dropped out packets.



Fig(4) Process of developing the system for the message transmission and reception with LT code



Fig(5) Wireless transmission of packets between computers-using Ardiuno and NRF modules-real time set up



Fig(6) Transmission and reception of message using LT code with Arduino Uno

At the transmitter end, the message is encoded and sent over wireless communication network along with the random sequence generated. The receiver receives the data and decodes the encoded data into the message which is shown in fig(6). Thus it is evident that with LT code, one can eliminate the feedback messages in the network. The length of encoded data can be varied depending on the bandwidth of the channel and noise present in the channel. Encoding procedure for LT code is simple as it involves only XOR operation. But the disadvantage is, if all the symbols having degree '1' are lost, then decoding cannot be done. To overcome this more number of encoded symbols can be used.

IV. CONCLUSION

This paper proposes Luby transform codes for wireless computer communication network, where packets are transmitted over erasure channels. Packet losses are common in erasure channels. In this work, Arduino UNO with NRF Transceivers are used to develop wireless communication network. Alphabets converted to ASCII values were considered for transmission over wireless channel. To rectify the problem of packet drops, message is encoded with Luby Transform code. Few packets were randomly dropped during transmission over the channel but the message was still recovered because of LT code.

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