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Design, Analysis and Implementation of Modified Luby Transform Code

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Abstract : *Bit losses in erasure channels like computer networks are of great concern. The existing methods to combat bit losses are either inefficient or time consuming due to the retransmission protocols involved. Through this paper, we propose a Modified Luby Transform (MLT) coding scheme to efficiently transmit data over live computer networks. The MLT code can combat bit losses as well as eliminate the need for retransmission. The usability and reliability of the proposed MLT code is verified by testing it on a live computer network.*
Keywords : *Erasure channel, Fountain Codes, Luby Transform Codes , Wired Networks, Wireless Networks*

I. INTRODUCTION

Channels with erasures are of great importance. Files sent over the internet or a wired / wireless LAN network are converted to bits / packets, and each bit / packet is either received without error or not received, that is they behave like erasure channels. Also if you take the case of a mail server, when you send a mail, 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 codes that work on such erasure channels and combat bit losses / erasures. The erasure channel is described by the probability of erasure of that channel. Say if the probability of erasure is 0.1, it means that 10% of the data transmitted would be lost and the rest 90% would be received without any error.

Common methods for communicating over such channels employ a feedback channel from receiver to sender that is used to control the retransmission of erased bits / packets. The receiver might send back messages which enable identification of the missing packets, which are then retransmitted. Alternatively, the receiver might send back acknowledgements for each received packet; the sender keeps track of which packets have been acknowledged and retransmits the others until all packets have been acknowledged.

These retransmission protocols have the advantage that they will work regardless of the erasure probability but if the erasure probability is large, the number of feedback messages sent by the first protocol will be large. If the system uses the second protocol, it is very likely that the receiver will end up receiving multiple redundant copies of many packets, and heavy use is made of the feedback channel [1].

Fountain codes are provided as a solution for reliable communication in lossy networks [2], [3]. They eliminate the need of retransmission request which increases the bandwidth consumption and increases the delay. Luby transform (LT) codes are special case of fountain codes [2]. LT encoder chooses randomly from a set of K packets, and according to a distribution, a subset of d packets, and XOR them [2]. In practice, decoding may be possible from a set S of such encoded packets, for S slightly larger than K.

In [4], a new method was designed to integrate the notion of network coding with the technique of connected dominating set which represents the source independent backbone in order to improve the broadcast process in ad hoc wireless network. When using the source independent backbone, the intermediate nodes are either responsible for retransmitting all or none of packets. This increases network coding efficiency since forwarder nodes use all available packets in encoding [4]. In [5], some of the nodes are chosen to retransmit messages, independent on coding process. Decoding process is improved in [6]. Fountain codes were used in [7] to broadcast n packets from the source. The source generates m encoded packets using LT codes, and floods each of them into the network. Each recipient retransmits each received packet with certain fixed probability. When a recipient has received enough data, it can decode original packets [7].

In all the above cases, LT codes are used along with retransmission protocols or relaying-based protocols to improve the efficiency. But they do not consider the delay caused by these methods. In practical cases, all the above methods cause delays which are inappropriate for live networks.

Through this paper, we propose a Modified Luby Transform (MLT) code which can efficiently combat bit losses and can be efficiently used in a live network without any need for concatenating it with any retransmission or relay-based protocols. Using the MLT codes, we can eliminate the use of the feedback channel and also improve the performance of the receiver.

II. MODIFIED LUBY TRANSFORM (MLT) CODES

We propose a modified decoding algorithm for a particular LT encoding pattern. In the proposed MLT codes, the input bits are divided into sets of four bits and each four bit input is encoded to form an eight bit encoded packet. During encoding, the first and last bit of the encoded packet is set to be the first bit of the input. The other bits of the encoded packet would be the XORed version of the previous bit of the encoded packet with the next input bit. Let [a b c d] be the input bits and [E1 E2 E3 E4 E5 E6 E7 E8] be the bits of the encoded packet, then

E1 = a
E2 = E1 xor b = a xor b
E3 = E2 xor c = a xor b xor c
E4 = E3 xor d = a xor b xor c xor d
E5 = E4 xor a = b xor c xor d
E6 = E5 xor b = c xor d
E7 = E6 xor c = d
E8 = a

The MLT encoding process is depicted in Fig. 1 below

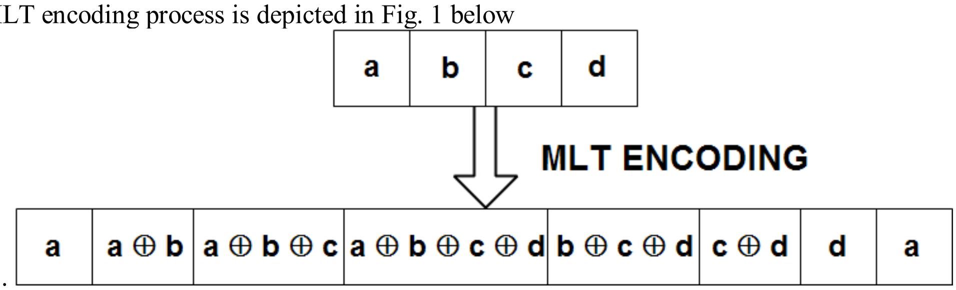

Fig. 1 Modified Luby Transform (MLT) Encoding

While transmitting through the channel, the bits of the encoded packets may get lost. So what we get would be a punctured form of the transmitted bit. At the receiver end, we need to get back the original information from the punctured form of received packet. Here we use a modified decoding algorithm. It is an iterative process. During the first iteration, we make use of the normal LT decoding process in which successive XORing of the bits of the encoded packets will result in the input bits. Since some of the bits of the packet are lost, all the input bits cannot be correctly retrieved. Now, using the retrieved bits and the correctly received bits, we can make further XORed combinations of the input bits. This is used in the next iteration and we look for decoding the input bits by successive XORing of the generated bits in the previous iteration along with the correctly received bits, say we had received 'E4' (b xor c xor d) and correctly retrieved bits, 'b' and 'd' but we could not retrieve 'c'; we can generate a combination 'b xor d' from the correctly retrieved bits and then XOR the generated bit with the 'E4' to correctly retrieve 'c'. The iteration is continued till all input bits are retrieved or if all bits could not be retrieved even after eight iterations levels.

The MLT decoding process is depicted in Fig. 2. below.

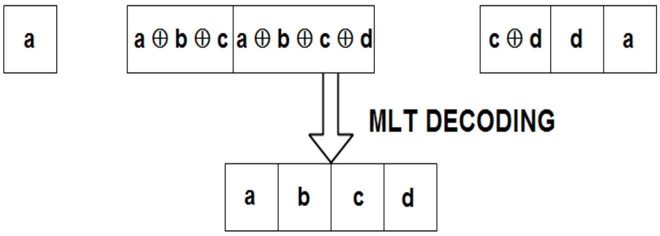

Fig. 2 Modified Luby Transform (MLT) Decoding

III. SIMULATION AND HARDWARE IMPLEMENTATION

The MLT codes were simulated using MATLAB R2012a on a computer with Intel i5 2.4GHz (with turbo boost upto 3.2GHz) processor and 4GB RAM. The simulation results of MLT codes are compared with the results obtained for LT codes and for systems with no encoding.

The MLT codes were implemented on a live peer to peer computer network. All data to be transmitted from one computer to another computer were encoded using MLT codes and the data received at the receiving end is decoded to get back the original data. Results from hardware implementation are compared with the simulation results and are discussed in Section IV.

IV. RESULTS AND ANALYSIS

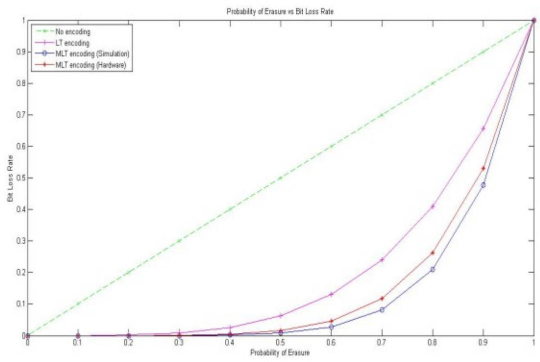

Fig. 3. Performance Analysis using Probability of Erasure vs Bit Loss Rate graph – (a) No encoding (b) LT encoding (c) MLT encoding (Simulation Results) (d) MLT encoding (Hardware Implementation Results)

From Fig. 3, we can see that bit loss rate is considerably reduced using MLT encoding. For channels with probability of erasure less than 0.45, we can see that the bit loss rate is almost zero. This means that we can correctly decode all the data even if almost half of the transmitted data is lost, we can efficiently decode the original data without any need for retransmission. Using LT codes, we can achieve lossless transmission only for channels with probability of erasure less than 0.3. In real situations, probability of erasure would be in range of 0.2 to 0.5 only, if it is more than 0.5, it would mean more or less break in channel or loss of channel as such. Say we have a live network, erasure of over 0.5 occurs when the channel is non-existent or if the router resets itself and is recreating the communication link as such. Even if retransmission is done in any of the above cases, it is more probable that the retransmitted packet is also lost and the retransmission process becomes wasteful and time-consuming. This can be avoided. MLT codes provide an efficient way to transfer data within computer networks by combating bit losses and eliminating retransmission delays.

V. CONCLUSION

A Modified Luby Transform (MLT) code is designed for computer networks and the analysis is done for channels with different probabilities of erasure. The results were compared with the results obtained by using LT codes and those without any encoding. The comparison results show that the bit loss rate can be efficiently reduced using MLT codes. The hardware implementation is done to ensure usability and reliability in live computer networks without using any retransmission process. Thus, we can conclude that by using MLT codes without any retransmission protocol, we can efficiently transmit data over wired / wireless computer networks and avoiding time delays to a large extent.

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