World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:10, No:6, 2016

Network Coding with Buffer Scheme in Multicast for Broadband Wireless Network

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Abstract**—**Broadband Wireless Network (BWN) is the promising technology nowadays due to the increased number of smartphones. Buffering scheme using network coding considers the reliability and proper degree distribution in Worldwide interoperability for Microwave Access (WiMAX) multi-hop network. Using network coding, a secure way of transmission is performed which helps in improving throughput and reduces the packet loss in the multicast network. At the outset, improved network coding is proposed in multicast wireless mesh network. Considering the problem of performance overhead, degree distribution makes a decision while performing buffer in the encoding / decoding process. Consequently, BuS (Buffer Scheme) based on network coding is proposed in the multi-hop network. Here the encoding process introduces buffer for temporary storage to transmit packets with proper degree distribution. The simulation results depend on the number of packets received in the encoding/decoding with proper degree distribution using buffering scheme.

Keywords**—**Encoding and decoding, buffer, network coding, degree distribution, broadband wireless networks, multicast.

I. Introduction

Multicast communication supports one to many and many to many distributions where the information is addressed in BWN [1] i.e. WiMAX, Long Term Evolution (LTE), etc. For simultaneous transmissions, network coding is applied over BWN network in which the multi-radio concept can also be considered. BWN is deployed nowadays significantly in wireless multi-hop networks. Multipath routing helps in increasing consistency in wireless networks while several paths are created for source and destination nodes. While performing routing in multipath between the nodes, more transmission occurs which results in high redundancy in wireless mesh networks. One to many connections offer several paths from an individual source in multi-hop routing which results in PMP (Point to MultiPoint) connection and mesh network. Evaluation of PMP and mesh [2] is discussed. Here centralized scheduling is applied and degree distribution acts as a decision maker to allocate a resource over the buffer in a particular time. Scheduling is an important component in wireless mesh network while performing data transmission from source to destination. Centralized scheduling [3] provides Base Station (BS) that acts as a central controller for all the Subscriber Stations (SS) to perform data communication in a network.

Network coding performs encoding and decoding procedure in IEEE 802.16 network and it is provided as multicast communication. There are several coding schemes [4] which are applied to various networking technologies and coding schemes such as linear network coding and random network coding. For multicast communications, rateless codes are useful which is similar to FEC (Forward Error Correction) to correct errors over reliable data transmission. Several rateless codes are applied to generate infinite streams of output data with largely recoverable data. Error correction mechanism also helps in increasing reliability in wireless networks. Thus network coding with degree distribution helps in improving successful packet delivery and network performance in wireless mesh networks.

In this paper, a BuS (Buffer Scheme) based on network coding is proposed in IEEE 802.16 mesh networks. Proper degree distribution and packet distortion at the encoding / decoding receiver is considered. Coding scheme is applied over the intermediate nodes for both transmitter and receiver. Buffers along with the encoding and decoding process are represented in Fig. 1. Buffers have been structured at the intermediate which supports the FIFO (First In First Out) process. Mainly, degree distribution used in the encoding process acts as the decision maker which will change the buffer action. This action helps in reducing the packet loss at the node and in improving the successful packet delivery in the network. This scheme has been applied over the WiMAX network which supports mesh network. From Fig. 2 (a), Node A multicast three binary symbols B1, B2 and B3 to B, C and D. Then node E encodes B1and B2 (B1 XOR B2) by multicasting B and D. Node F receives encoded packets B1 and B2 (B1 XOR B2) and then transmits the encoded packets to G and H. Nodes G and H decode the received encoded packets into output packets B1 and B2 from G and H. S1, S2, S3 and D1, D2, D3 are represented in multi tree level structure. Centralized multi-radio network structure is represented in Fig. 2 (b).

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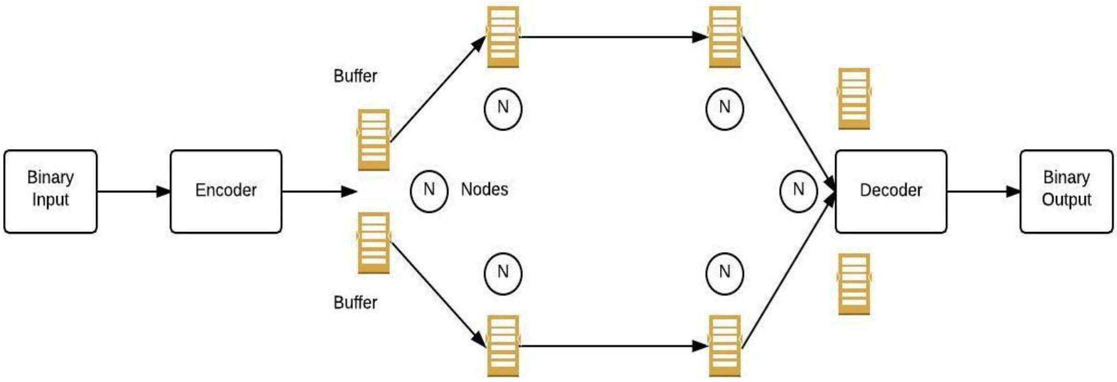
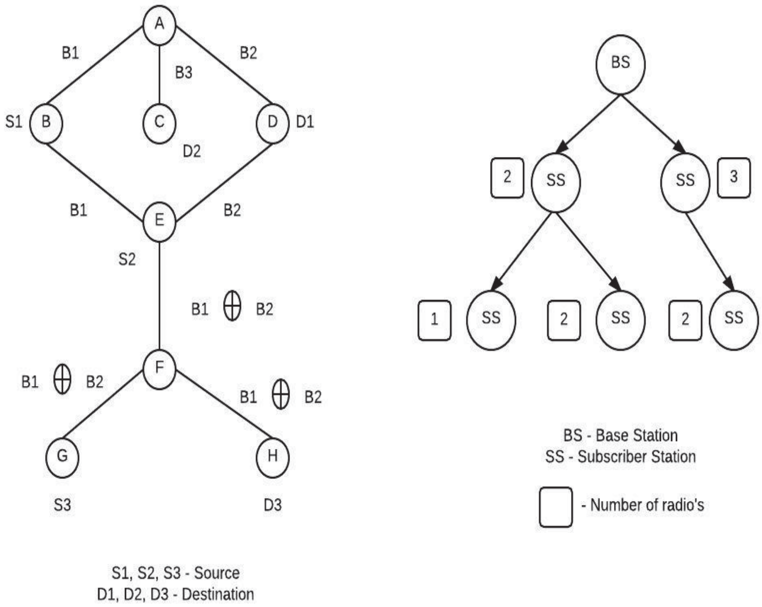


Fig. 1 Encoding and Decoding – Buffer Structure



(a) (b)

Fig. 2 (a) Multicast Network Coding and (b) Centralized WiMAX Network Structure

From Fig. 1, encoding and decoding process is represented as binary symbols which are used to recover original output symbols from binary input from source to destination. Here, the buffer is placed at the encoder and buffer decision switching depends on the degree distribution in the encoder procedure.

Rest of the paper is organized as follows. Related work is discussed in Section II. In Section III, network model with encoding / decoding procedure is discussed. Buffering scheme is detailed in Section IV and conclusion is given in Section VI.

II. Related Work

There are many recent works carried out in various networks regarding network coding for both unicast and multicast [5], [6] transmission. Y. Wu et al. discussed the problem of information exchange [7] in two way relay networks and multicast problems are further discussed on various networking scenarios. A novel QoS (Quality of Service) routing scheme is proposed [8] for both unicast and multicast transmission through network coding. Routing scheme helps in selecting the optimal path in multi-hop network in order to guarantee QoS. In Multi-path routing, discussion on interference problem [9] and multi-path route selection is proposed to maximize the throughput. The network coding features and its applications [10] are discussed. Packets have performed XOR operation at the intermediate node based on encoding and decoding procedure [6] to reduce packet loss. Number of packets received at the destination based on the network coding can be calculated based on the QoS parameters. Kaikai Chi et al. considered the lack of channel capacity problem and proposed the network coding scheme with packet buffering [11] in IEEE 802.11 networks.

To improve recovery of original packets and throughput, [7], [12] considered the buffer scheme based on network coding for both unicast and multicast networks. Recently, every wireless network is moving towards the advance technologies like WiMAX, LTE, etc for various challenges in the network. Cheiochan S. et al. [13] considered the network coding which helps in mixing the random packets before forwarding to the relay nodes. Network coding is concerned with opportunistic overhearing with interference problem related to channel assignment and scheduling in wireless mesh networks. Considering the problem of degree distortion and reliability, this paper proposes a network coding with buffers which result in packets loss delivery in WiMAX network.

III. Network Model

Considering WiMAX network, nodes are categorized into BS (Base Station) and SS (Subscriber Station) in multi-relay network. In a network, G (V, E) where V represents the node and E the edge which supports centralized scheduling. Network coding concerning the proper degree distribution for encoding in IEEE 802.16 wireless mesh network is discussed. Network coding helps to optimize the flow of data to reach the destination from source.

From Fig. 1, here A is assumed as BS that acts as a centralized entity and remaining nodes B, C, .., K are assumed as SS. The node sends a packet from source S1, S2 and S3 to destination D1, D2 and D3. The packets are forwarded to relay nodes and represented in Fig. 2.

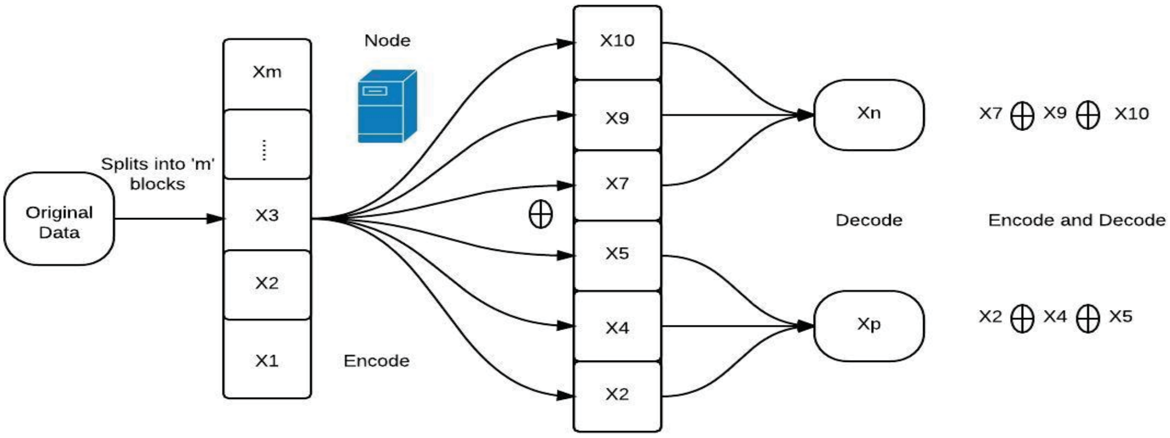


Fig. 3 Architecture of Coding Scheme

From the Fig. 3, original data is split as X_1, X_2, X_3… X_m for 'm' blocks. It performs XOR operation as {(X_2 XOR X_3), (X_5 XOR X_6) …} and broadcasts the coded packet to reach the next node. Then the encoded packets are transferred to the destination node to get decoded.

A. Encoding Procedure

In the beginning, degree 'd' is selected randomly using degree distribution p(d), i.e., discrete probability density function for calculating a degree to the probability of a selected degree. Random 'd' blocks are chosen uniformly, i.e. neighbour as distinct input symbols (Source file consists of blocks X_1. XOR all the chosen symbols), i.e. neighbor to derive the output symbol (E → $X_2 \oplus X_3 \oplus$ . . .).

Here robust soliton degree distribution [14] is constructed with the parameters, number of encoding symbols 'k' and failure probability of message δ, Robust *as* $K = k + O\left(\sqrt{k} * ln^2\left(\frac{k}{\delta}\right)\right)$. From Fig. 4 (a), node E (i.e. encoded node) likes to multicast the encoded output b1 and b2 with robust soliton distribution to D1 and D2. The node S receives and starts decoding to obtain original message. This helps in recovering the number of symbols which is reception efficiency.

In this paper, a robust soliton distribution is constructed in order to avoid redundant coverage of input by the encoding symbols and only one input neighbor symbol is found in the decoding symbol. Then robust soliton distribution μ(d) is as:

Let $R = c * \ln(\frac{K}{\delta})\sqrt{K}$ for suitable constant c > 0 and δ is the failure probability. $\tau(d)$ and $\rho(k)$ are the two functions in the normalization.

$$p(k) = \begin{cases} \frac{1}{k} \; for\ d = 1 \\ \frac{1}{k\,(k-1)} \; for\ all\ d = 2 \ldots . K \end{cases} \quad (1)$$

$$\tau(d) = \begin{cases} \frac{R}{(d*K)} \; for\ d\ = 1..k\,/\,R - 1 \\ (R)\ln(\frac{(\frac{R}{\delta})}{k}) \; for\ d\ = \frac{k}{R} \\ 0 \; otherwise \end{cases} \quad (2)$$

Then obtain β, $\beta = \sum_{k=1}^{n}(\rho(k) + \tau(d))$ from (1), (2).

Robust soliton distribution μ(d) as,

$$\mu(d) = \frac{\rho(k) + \tau(d)}{\beta} \quad \text{For all d = 1,… … k}$$

B. Decoding Procedure

First, a node E is found that has only R_m as a neighbor. If no such node is available, more packets are received until such a node is found. Now E is recovered and set R_m = E. For another output node $E_i = R_m \oplus E$. All the edges between R_m and output nodes, i.e., E_i are removed. All the original data has been recovered, otherwise it is repeated.

IV. Buffer Scheme

When the node AB and AC try to transmit ($X_2 \oplus X_3$, X_4) to E and F, F receives degree distribution alteration in Fig. 1 (a). Robust degree distribution is applied which find degree 'd' ('d' →(d_1, d_2)) based on the discrete probability density function from Fig. 1 (a) based on the buffer in Fig. 2. Similar to Fig. 3, select the degree 'd' which has severe distortions which affect the performance of the network. A buffer scheme based on degree distribution is applied. Degree 'd' is selected from the generated code in encoded process.

Buffering scheme is applied over two cases as in Fig. 4 based on Fig. 2.

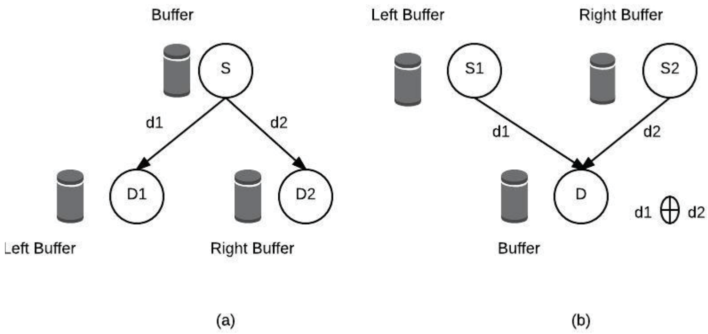


Fig. 4 Buffering Scheme Possible Cases (a) and (b)

TABLE I
ABBREVIATIONS

B_L	Left buffer
B_R	Right buffer
$E_{o(N)}$	Encoded output where $E_{o(N)} \rightarrow N \in 0$ to n
$d(E_{o(N)})$	Degree of encoded output
S	Size of each buffer
$E_L(a)$	a^{th}element of left buffer; where $a = 0$ to $S - 1$
$E_R(b)$	b^{th} element of left buffer; whereb $= 0$ to $S - 1$
P_L andP_R	Pointer to right and left buffer

Case (a): When S1 and S2 are transmitted from S to D1 and D2.

Step 1:
Initialize

N → NULL
// Based on the least traffic demand of the link against the left and right buffer
Then left buffer B_L is assigned
P_L is pointed as 1; otherwise 0
Element in the left buffer moved to 1 to S – 1
$N = N + 1$

Step 2:
If (B_L == True) {
[True → assigned otherwise not assigned]
(B_R == True)
If (P_R) < S)
$(E_R(P_R)) = E_{o(0)}$
P_R + + }
else {
If (P_L) < S)
$(E_L(P_L)) = E_{o(0)}$
P_L + + }

Condition
B_L == True → B_R == True
B_R == True → B_L == True

If has already been used the left buffer then changes it to right side buffer only if degree distribution pair d (d_1, d_2) used concurrently is avoided. The step 2 is considered for right side buffer, otherwise the same is repeated.

From1 Fig. 4, d1 and d2 is transmitted between (S, D1) and (S, D2), Then, E_L (a) and E_R (b) are increased to plus 1 and the pointer P_L and P_R are decreased by minus 1 as left and right side buffer which are used once to transmit d1, d2. The step 2 is repeated till the N < n. Similarly, if $d1 \oplus d2$ are transmitted from source S to the destination d1 and d2 which is as same as in case (a).

Case (b): When two sources S1 and S2 are transmitting d1 and d2 to single destination D.

Left side buffer and right side buffer contain element based on,

$E_L(a) \rightarrow a^{th}\ element\ of\ left\ buffer;\quad where\ a = 0\ to\ S - 1$
$E_R(b) \rightarrow b^{th}\ element\ of\ Right\ buffer;\quad where\ b = 0\ to\ S - 1$
$B_L \rightarrow Transmit\ d1;$
$B_R \rightarrow Transmit\ d2;$

Buffer at destination D is represented as 'B'.

$If\ (B_L == True\ \&\&\ B_R == True)\ \{$
$If\ ((P_R)\ \&\&\ (P_L) < S)\{$
$(E_R(P_R)) = E_{o(0)};$
$(E_L(P_L)) = E_{o(0)};$

These two buffers maintain two buffers at destination 'D' to generate output symbol as,

$B \rightarrow Output\ symbol = d1 \oplus d2;$
$P_R + +;$
$P_L + +;$
}
}

V. Performance Analysis

The aim of the proposed buffer scheme based on network coding is to improve the performance without degrading WiMAX network. Considering the problem of performance based on degree distribution, proper degree distribution is used in BuS through the centralized tree network. In Fig. 5, the number of nodes (up to 500) with packet drop is analyzed. BuS based on network coding has more variation when compared to network coding based on the number of nodes. In Fig. 6, transmitting packets with probability successful density as buffer scheme are effective as the number of packets increases. The performances based on these parameters are analyzed.

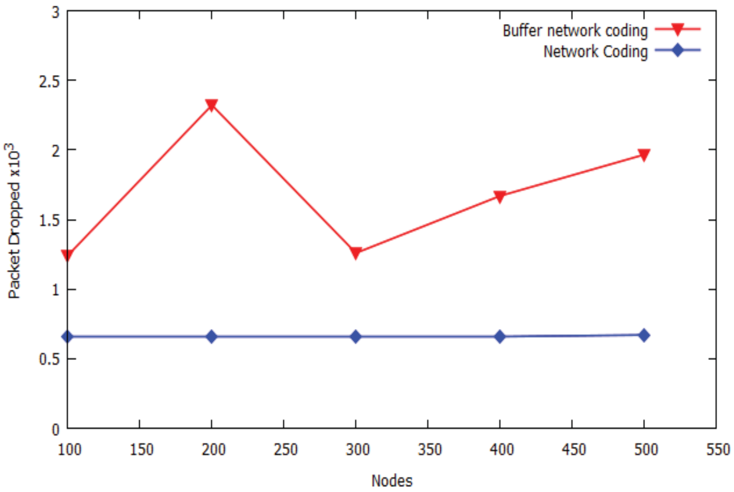


Fig. 5 Number of Nodes Vs Packet Drop

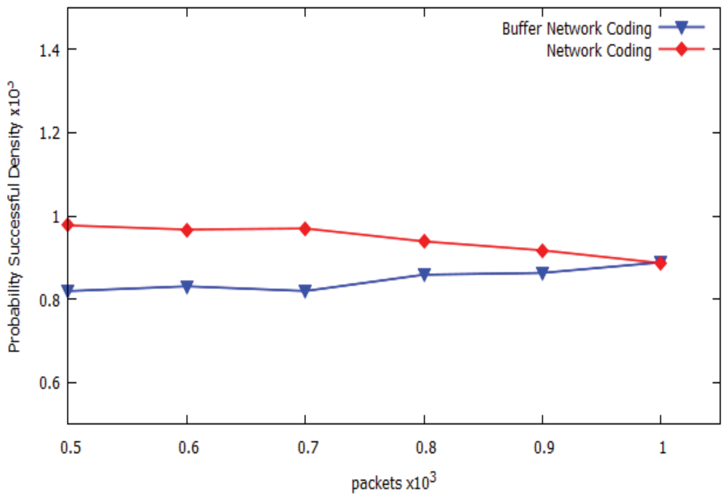


Fig. 6 Number of Packets Vs Probability Successful Density

VI. Conclusion

The buffer scheme that makes decision against falsified degree distribution and performance overhead is proposed in WiMAX network. The proper degree distribution construction helps in making a proper decision in the buffer and improves the successful packet delivery in the wireless mesh network. In the simulation analysis, network coding with BuS and network coding without BuS based on packet drop and successful density are compared. Based on the analysis, performance increase is made without degrading the overall performance in the network. In a future work, analysis can be made for both uplink/downlink in advanced broadband networks like LTE, 5G networks, etc. Performance can be made for some other parameters to prove that the algorithm can be more effective.

Acknowledgment

Gunasekaran Raja, Ramkumar Jayaraman, Rajakumar Arul, kottilingam kottursamy gratefully acknowledges support from NGNLabs, Department of Computer Technology, Anna University, Chennai.

References

[1] Ismat Aldmour, LTE and WiMAX: Comparison and Future Perspective, DOI: 10.4236/cn.2013.54045, 2013.
[2] Djohara Benyamina, Abdelhakim Hafid and Michel Gendreau, “Wireless Mesh Networks Design – A Survey,” *IEEE Communications Surveys & Tutorials*, Vol. 14, No. 2, pp. 299-310, Second Quarter 2012.
[3] Miray Kas, Burcu Yargicoglu, Ibrahim Korpeoglu, and Ezhan Karasan, “A Survey on Scheduling in IEEE 802.16 Mesh mode.” *IEEE Communications Surveys & Tutorials*, Vol. 12, No. 2, Second Quarters, pp. 205 – 22, 2010.
[4] Takaniro Matsuda, Taku Noguchi and Tetsuya Takine, “Survey of Network coding and Its Applications,” *IEICE transaction on Communication*, Vol. E94-B, No. 3, pp. 698 – 717, Mar. 2011.
[5] Lei Wang, Yuwang Yang and Wei Zhao, “Network coding-based multipath routing for energy efficiency in Wireless sensor networks,” EURASIP Journal on Wireless Communication and Networking, Mar. 2012.

[6] Dong Nguyen, Tuan Tran, Thinh Nguyen, and Bella Bose, "Wireless Broadcast Using Network Coding," *IEEE Transactions on Vehicular Technology*, Vol. 58, No. 2, Feb. 2009.

[7] Y. Wu, P.A. Chou, and S.Y Kung, "Information Exchange in Wireless Networks with Network Coding and Physical –Layer Broadcast" *Conference on Information Science and Systems*, Mar. 2005.

[8] Saran Tarnoi, Wuttipong Kumwilaisak, Poompat Saengudomlert, Yusheng Ji and C–C Jay Kuo, "QoS-aware routing for heterogeneous layered unicast transmissions in wireless mesh networks with cooperative network coding," *EURASIP Journal on Wireless Communications and Networking*, pp.1 – 18, May 2014.

[9] Faiza Iqbal, Muhammad Younus Javed and Anjum Naveed, "Interference-aware multipath routing in wireless mesh network," *EURASIP Journal of Wireless Communications and Networking*, pp. 1-16, Aug. 2014.

[10] Muriel Medard and Alex Sprintson, "Network Coding: Fundamentals and Applications," *Elsevier Publications*, 2012.

[11] Kaikai Chi, Yi-hua Zhu, Yongchao Wu, Victor C. M. Leung, "A Network Coding Scheme to Improve Throughput for IEEE 802.11 WLAN," *Journal on Mobile Networks and Applications*, 2015.

[12] C. Hausl and J. Hagenauer, "Iterative Network and Channel Decoding for the Two-Way Relay Channel," *IEEE International Conference on Communications*, 1568 – 1573, 2006.

[13] Chieochan, S. and Hossain, E., "Channel Assignment for Throughput Optimization in Multichannel Multiradio Wireless Mesh Networks Using Network Coding," *IEEE Transaction on Mobile Computing,* Vol. 12, Issue. 1, pp. 118 – 135, Jan. 2013.

[14] Kuo-Kuang Yen, Yen-Chin Liao, Chih-Lung Chen, Hsie-Chia Chang, "Modified Robust Soliton Distribution (MRSD) with Improved Ripple Size for LT Codes," *IEEE Communication Letters*, Vol.5, Issue. 5, 2013.