

Study on LDPC Codes for Indonesia Digital Video Broadcasting Terrestrial 2nd Generation (DVB-T2)



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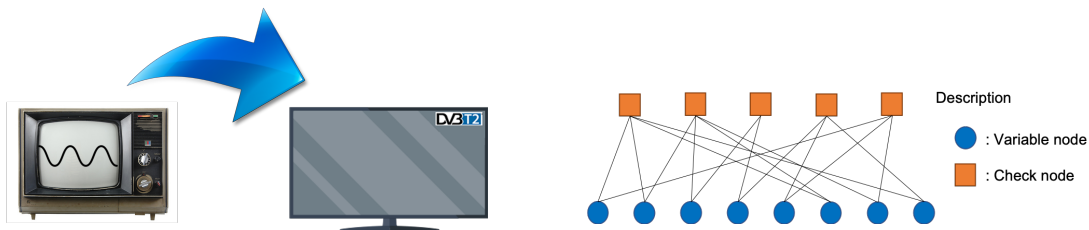
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Problems and Motivations



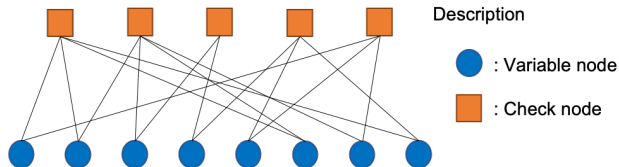
- The unavailability of lower band spectrum in Indonesia, because the frequency usage of traditional Indonesia Television.
- DVB-T2 standard is used as the Indonesia terrestrial digital television standard having possibility to free up some frequency band.
- The suitable Low Density Parity Check (LDPC) codes for Indonesia channel model leading to an optimal performances is absence.
 - 1 Degree distribution.
 - 2 Constructing structure.

Low Density Parity Check (LDPC) Codes

Block length (n)

$$H = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix} \begin{matrix} d_c = 4 \\ d_c = 2 \\ d_c = 3 \\ d_v = 2 \end{matrix}$$

Parity Check Matrix of Random Irregular LDPC Codes.



- LDPC codes have been proved to be capable of closely approaching the channel capacity.
- LDPC codes are codes specified by a matrix containing mostly 0's and only a small number of 1's.
- Parity check matrix of LDPC codes \mathbf{H} can be represent as a graph using Tanner graph and degree distribution.

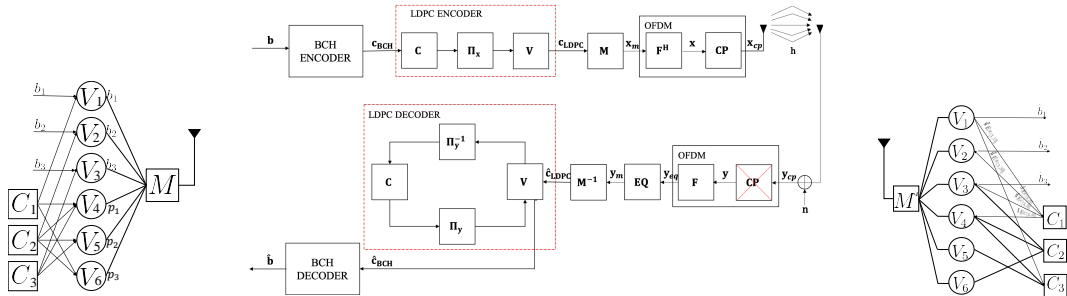
$$\Lambda(x) = x^2, \quad (1)$$

$$\Omega(x) = \frac{1}{5}x^2 + \frac{2}{5}x^3 + \frac{2}{5}x^4. \quad (2)$$

Todd K. Moon, "Error Correcting Coding Mathematical methods and Algorithms", p. 634-679, 2005.

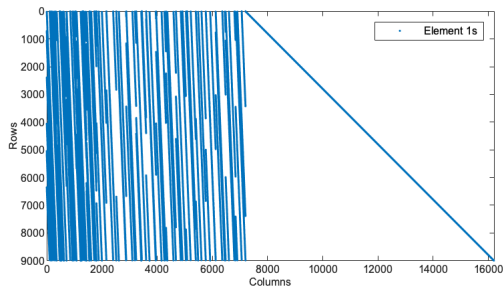
R. Tanner, "A recursive approach to low complexity codes," in IEEE Transactions on Information Theory, vol. 27, no. 5, pp. 533-547, September 1981.

System Model of DVB-T2



- The structure of LDPC encoder and decoder are adapted from ETSI TS 102 831 V1.2.1.
- The modulation M is Quadrature Phase Shift Keying (QPSK).
- This thesis consider multipath channel h using Bandung DVB-T2 channel model.

DVB-T2 LDPC Codes

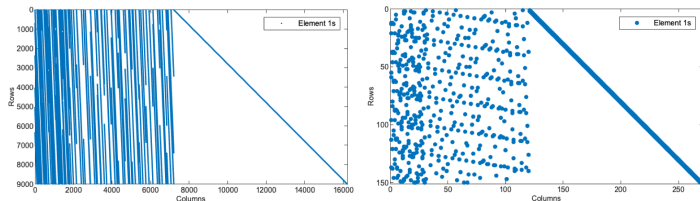


Code rate		Column weight					
R_n	R_e	13	12	8	3	2	1
1/2	4/9			1800	5400	8999	1
3/5	3/5		3240		6480	6479	1
2/3	2/3	1080			9720	5399	1
3/4	11/15		360		11520	4319	1
4/5	7/9				12600	3599	1
5/6	37/45	360			12960	2879	1

- DVB-T2 LDPC codes according to ETSI TS 102 831 V1.2.1 have block-length $N_{LDPC} = 16200$ and $N_{LDPC} = 64800$.
- LDPC codes with $N_{LDPC} = 16200$ have code rates $R = \left\{ \frac{4}{9}, \frac{3}{5}, \frac{2}{3}, \frac{11}{15}, \frac{7}{9}, \frac{37}{45} \right\}$.
- The parity check matrices of DVB-T2 LDPC codes \mathbf{H} are constructed according to the value from addresses parity bit accumulator and column weight distribution of each code rate.

ETSI, Digital Video Broadcasting (DVB); Frame Structure Channel Coding and Modulation for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2), 1st ed., ETSI, July 2015.

Proposed (1): Downscaling Technique for DVB-T2 LDPC Codes



- State the scaling factor s_f , where the factor must be divisors of 360. 360 is the number of node indices of DVB-T2 LDPC codes.
- Fill $p_1(j), p_2(j), p_3(j), \dots, p_q(j), j = 1, 2, 3, \dots, J$ and $q = 1, 2, 3, \dots, Q$ with the value of addresses parity bit accumulator.
- Calculate $r_1(j), r_2(j), r_3(j), \dots, r_q(j)$

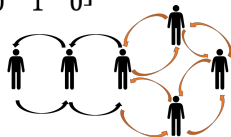
$$r_q(j) = \text{mod}\{[p_q(j) + J \times (k - 1)], [P/s_f]\},$$

$$1 < k \leq (360/s_f). \quad (3)$$

- The new table of addresses parity bit accumulators r_q are obtained.

Proposed (2): Progressive Edge-Growth (PEG) Algorithm

$$H = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}$$



$$H = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$



- Girth is the shortest cycle of LDPC codes that affect the LDPC codes performances, small girth will leave a bad effect on the LDPC codes decoders.
- PEG is one of the method for constructing Tanner graphs having a large girth in a best-effort sense by progressively establishing edges between symbol and check nodes in an edge-by-edge manner.
- The proposed PEG Algorithm use the second method of PEG and use proposed algorithm to avoid girth-4 in LDPC codes.

M. Sipser and D. A. Spielman, "Expander codes," in IEEE Transactions on Information Theory, vol. 42, no. 6, pp. 1710-1722, Nov. 1996.

Xiao-Yu Hu, E. Eleftheriou and D. - Arnold, "Progressive edge-growth Tanner graphs," GLOBECOM'01. IEEE Global Telecommunications Conference (Cat. No.01CH37270), San Antonio, TX, 2001, pp. 995-1001 vol.2.

The Proposed Degree Distributions DVB-T2 LDPC codes

Original LDPC codes with $R = \frac{4}{9}$

$$\Lambda(x) = \frac{1}{16200}x + \frac{8999}{16200}x^2 + \frac{5400}{16200}x^3 + \frac{1800}{16200}x^8, \quad (4)$$

$$\Omega(x) = \frac{1441}{9000}x^4 + \frac{3239}{9000}x^5 + \frac{3600}{9000}x^6 + \frac{720}{9000}x^7, \quad (5)$$

Downscaled LDPC codes $R = \frac{4}{9}$

$$\Lambda(x) = \frac{1}{270}x + \frac{149}{270}x^2 + \frac{90}{270}x^3 + \frac{30}{270}x^8, \quad (6)$$

$$\Omega(x) = \frac{92}{150}x^5 + \frac{58}{150}x^6, \quad (7)$$

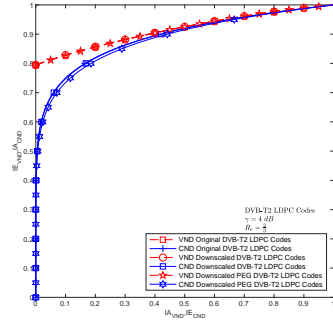
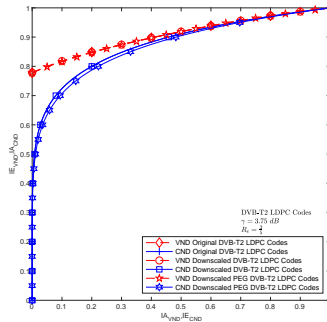
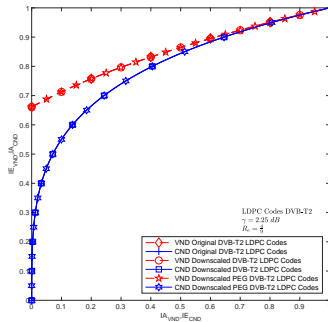
Downscaled LDPC codes using PEG $R = \frac{4}{9}$

$$\Lambda(x) = \frac{1}{270}x + \frac{149}{270}x^2 + \frac{90}{270}x^3 + \frac{30}{270}x^8, \quad (8)$$

$$\Omega(x) = \frac{25}{150}x^4 + \frac{53}{150}x^5 + \frac{60}{150}x^6 + \frac{12}{150}x^{12}, \quad (9)$$

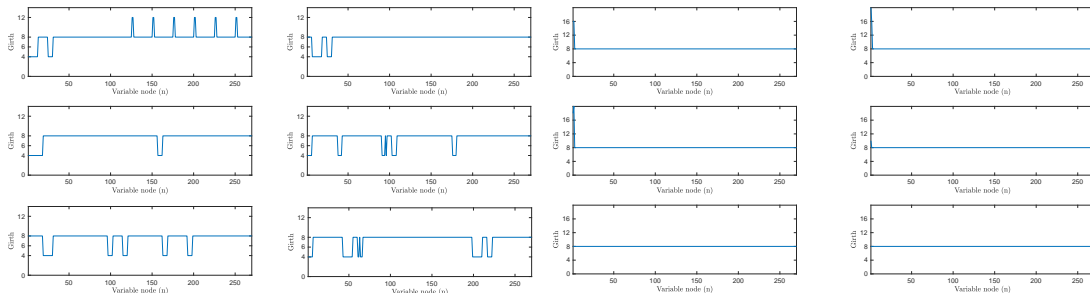
for others code rate please read the thesis book.

EXIT Chart Evaluation



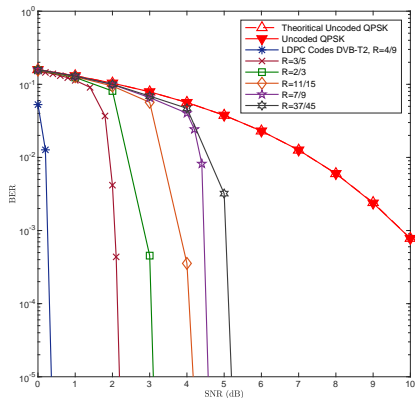
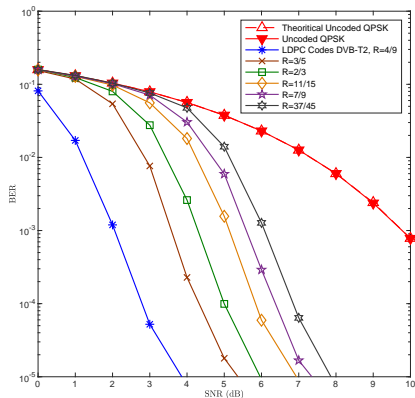
From all EXIT curve, the original DVB-T2 LDPC codes's EXIT chart have slightly better curve than the others proposed LDPC codes.

Girth Evaluation for The Proposed PEG



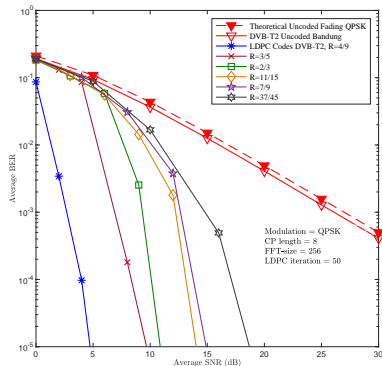
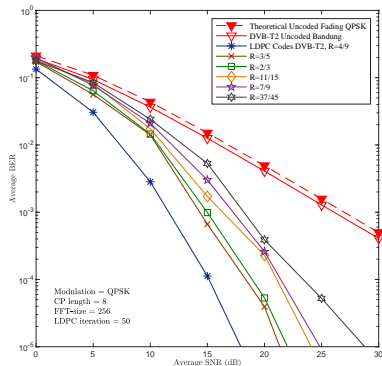
- Girth of LDPC codes calculated using proposed technique.
- The girth distributions show that every constructed LDPC codes using downscaled technique have girth 4 in any code rate.
- The proposed PEG and Anti Girth 4 algorithm successfully avoided the girth 4.

Performance Evaluation in AWGN Channel



- The best performance of downscaled LDPC codes DVB-T2 in AWGN channel is achieved 10^{-4} at signal to noise ratio (SNR) $\gamma = 2.83 \text{ dB}$, while the best performance of original LDPC codes DVB-T2 achieved at $\gamma = 0.2 \text{ dB}$.
- Gap between original LDPC codes and downscaled LDPC codes for any rate is about 2 dB .

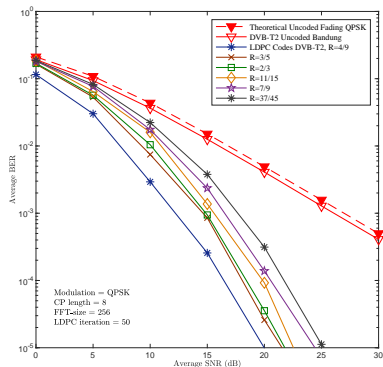
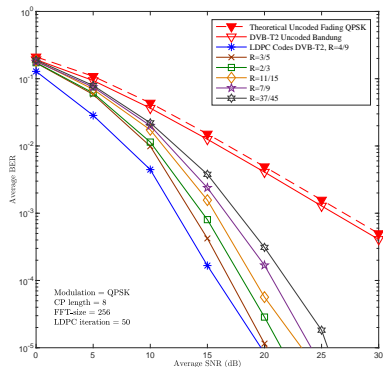
Performance Evaluation in Bandung DVB-T2 Channel Model (1/2)



- The best performance of downscaled LDPC codes DVB-T2 in DVB-T2 Bandung channel model is achieved 10^{-4} at $\gamma = 15$ dB, while the best performance of original LDPC codes DVB-T2 achieved at $\gamma = 4$ dB.
- The simulation results show acceptable Bit Error Rate (BER) performances of downscaled LDPC codes DVB-T2 in Bandung DVB-T2 channel model.

D. Fitriyani, K. Anwar, and D. M. Saputri, "Study on Radio Frequency Profile of Indonesia Digital Television DVB-T2 for Urban Areas", in ICONISTECH 2019.

Performance Evaluation in Bandung DVB-T2 Channel Model (2/2)



- The best performance of downscaled LDPC codes using PEG and accumulator in DVB-T2 Bandung channel model is achieved 10^{-4} at $\gamma = 16$ dB, while the best performance of downscaled LDPC codes using PEG and LDGM codes achieved at $\gamma = 17.15$ dB.
- The combination PEG with accumulator has slightly better performances than PEG with LDGM in DVB-T2 Bandung channel model.

Conclusion

This thesis has proposed degree distribution for DVB-T2 LDPC codes with $N_{LDPC} = 16200$, DVB-T2 LDPC codes with $N_{LDPC} = 270$ using downscaled technique, and DVB-T2 LDPC codes with $N_{LDPC} = 270$ using PEG. Some results of this thesis are provided as follows:

- This thesis has proposed PEG algorithm with Anti Girth 4 and technique to calculate girth of LDPC codes.
- This thesis has provided the EXIT chart evaluations, girth evaluations, and BER performances comparison between all proposed DVB-T2 LDPC codes in AWGN channel and Bandung DVB-T2 channel model.
- This thesis proved that accumulator has better performance than LDGM codes in PEG based matrix.
- This thesis also proved that bigger girth does not guarantee better performance, but the sparseness of LDPC codes become an important parameter.
- The results are expected provide contribution to the development of the practical implementation of DVB-T2 in Indonesia and for application in device consuming low power and low complexity.