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

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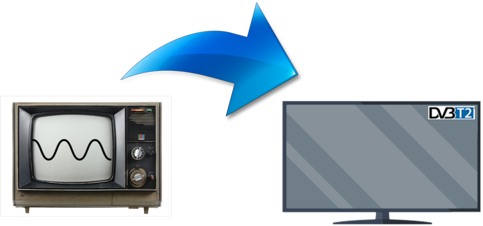
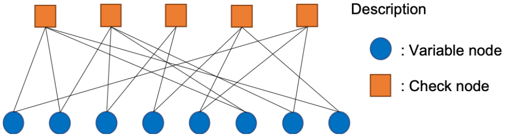
Outline

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.

Minisitry of Communications and Informatics Indonesia Regulation Number: 05/PER/M.KOMINFO/2/2012.

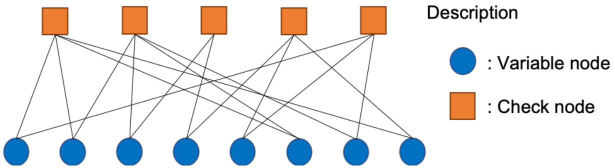
Low Density Parity Check (LDPC) Codes

Block length (n)

$$
H = \begin{array}{c}
\left[\begin{array}{cccccccc}
1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\
0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\
0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 & 1 & 0
\end{array}\right]
\end{array}
\begin{array}{l}
d_c = 4 \\
\\
d_c = 2 \\
\\
d_c = 3
\end{array}
$$

$$d_v = 2$$

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.

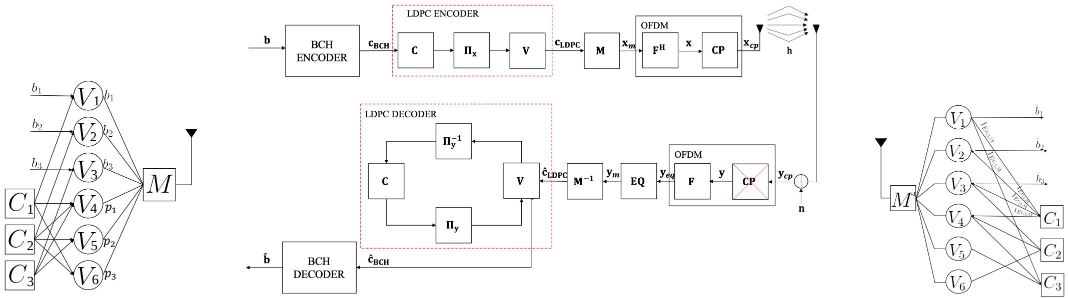
$$\Lambda(x) = x^2, \tag{1}$$

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

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.

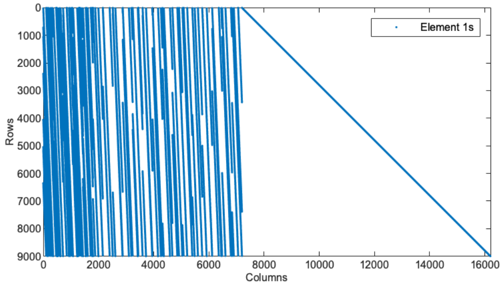
System Model of DVB-T2



- The structure of LDPC encoder and decoder are adapted from ETSI TS 102 831 V1.2.1.
- The modulation $\mathbf{M}$ is Quadrature Phase Shift Keying (QPSK).
- This thesis consider multipath channel $\mathbf{h}$ using 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.

DVB-T2 LDPC Codes

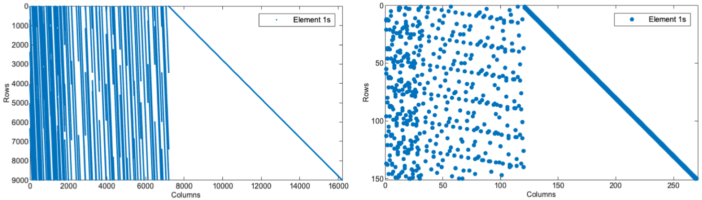


Code rate		Column weight					
R_n	R_e	13	12	8	3	2	1
1/2	4/9			1800	5400	8999	1
3/5	3/5		3240		6480	6479	1
2/3	2/3	1080			9720	5399	1
3/4	11/15		360		11520	4319	1
4/5	7/9				12600	3599	1
5/6	37/45	360			12960	2879	1

- 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 $R = \{\frac{4}{9}, \frac{3}{5}, \frac{2}{3}, \frac{11}{15}, \frac{7}{9}, \frac{37}{45}\}$.
- 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 $p_1(j), p_2(j), p_3(j), \ldots, p_q(j), j = 1, 2, 3, \ldots, J$ and $q = 1, 2, 3, \ldots, Q$ with the value of addresses parity bit accumulator.
- Calculate $r_1(j), r_2(j), r_3(j), \ldots, r_q(j)$

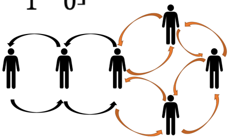
$$r_q(j) = mod\{[p_q(j) + J \times (k-1)], [P/s_f]\},$$

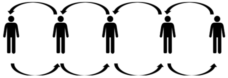
$$1 < k \leq (360/s_f). \quad (3)$$

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

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

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





- 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 Algortihm 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 $R = \frac{4}{9}$

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

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

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

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

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

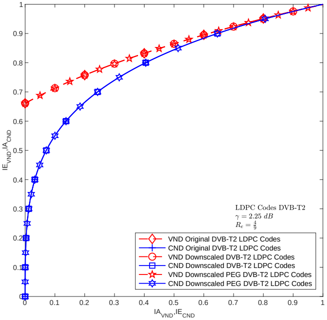
Downscaled LDPC codes using PEG $R = \frac{4}{9}$

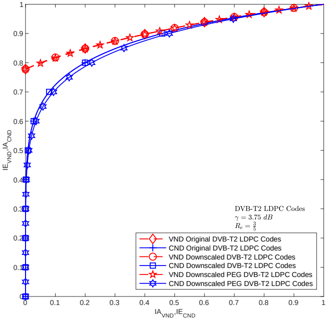
$$\Lambda(x) = \frac{1}{270}x + \frac{149}{270}x^2 + \frac{90}{270}x^3 + \frac{30}{270}x^8, \tag{8}$$

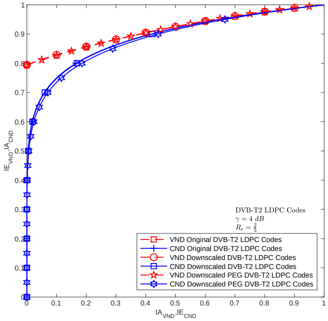
$$\Omega(x) = \frac{25}{150}x^4 + \frac{53}{150}x^5 + \frac{60}{150}x^6 + \frac{12}{150}x^{12}, \tag{9}$$

for others code rate please read the thesis book.

EXIT Chart Evaluation

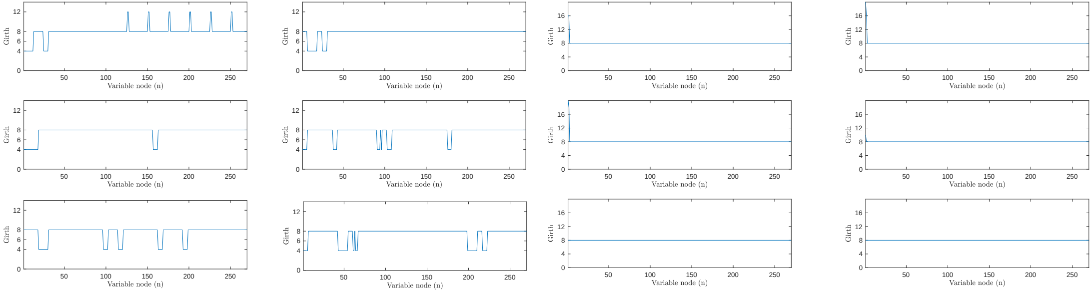






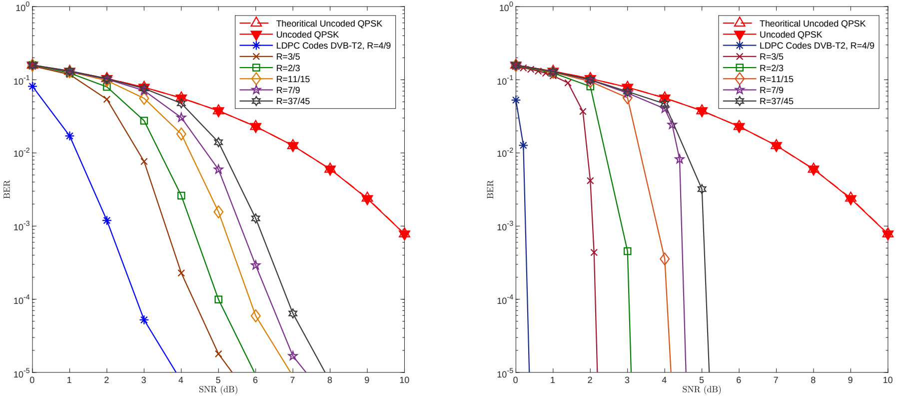
From all EXIT curve, the original DVB-T2 LDPC codes's EXIT chart have slightly better curve than the others proposed LDPC codes.

Girth Evaluation for The Proposed PEG



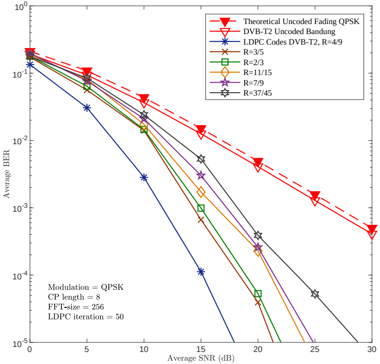
- Girth of LDPC codes calculated using proposed technique.
- The girth distributions show that every constructed LDPC codes using downscaled technique have girth 4 in any code rate.
- The proposed PEG and Anti Girth 4 algorithm successfully avoided the girth 4.

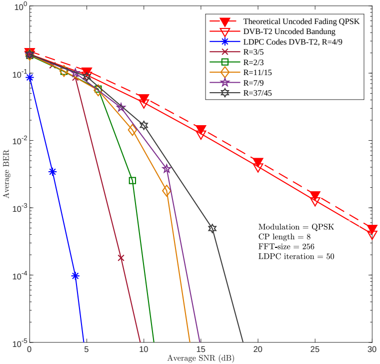
Performance Evaluation in AWGN Channel



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

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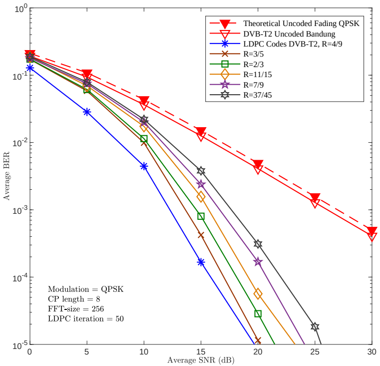
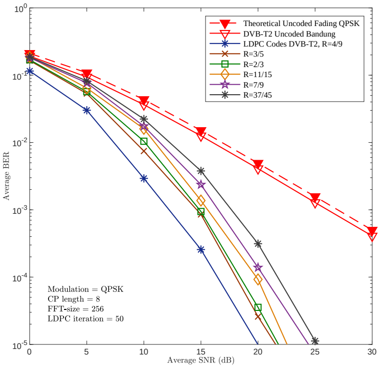
Performance Evaluation in Bandung DVB-T2 Channel Model (2/2)





- 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.