EARLY STOPPING CRITERION FOR LDPC CODES

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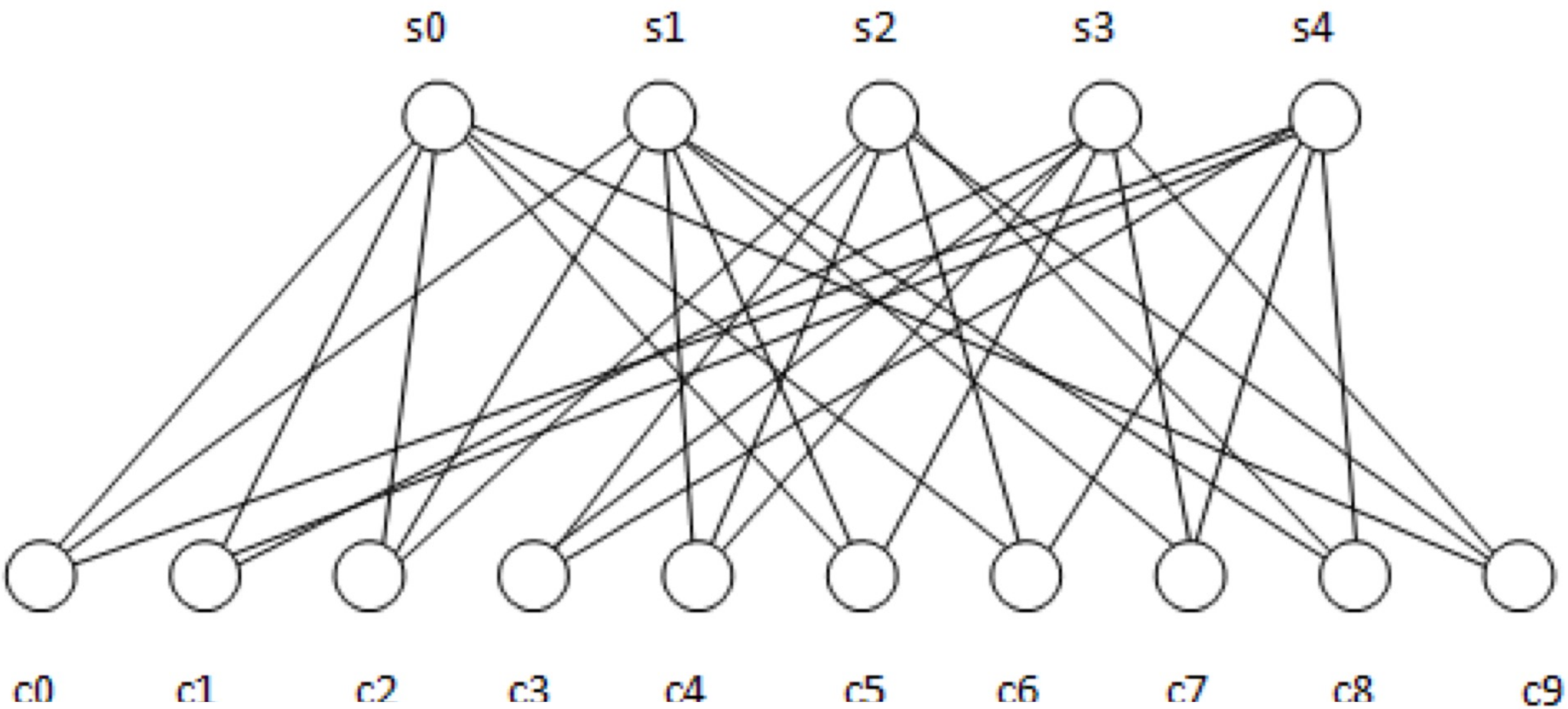
STOPPING CRITERION

- LDPC decoder will iterate until valid codeword found or maximum number of iterations Lmax reached.
- Stop decoder if further iterations are unlikely to yield a valid code word.
- Very useful at low SNRs and latency critical applications

LOW DENSITY PARITY CHECK (LDPC) CODES



$$s_4 = c_0 + c_1 + c_3 + c_6 + c_7 + c_8$$

$$\mathbf{H} = \begin{array}{c} \\ s_0 \\ s_1 \\ s_2 \\ s_3 \\ s_4 \end{array} \begin{array}{c} \begin{array}{cccccccccc} c_0 & c_1 & c_2 & c_3 & c_4 & c_5 & c_6 & c_7 & c_8 & c_9 \end{array} \\ \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix} \end{array}$$

Code rate 1/2
(M = 5, N = 10)
LDPC code

WIMAX 802.16E RATE 1/2 (M=288, N = 576) LDPC CODE

- The index n of the bit nodes n = 0, 1, …, 575 and m = 0, 1, …, 287

- The set of bit nodes connected to the 288th check node are

$$\mathbb{N}^*_{287,n} = \{9, 135, 177, 269, 288, 575\}$$

PROPOSED STOPPING CRITERION

- For a sequence of K independent binary digits, the probability that the whole sequence contains an even number of binary digit ones is given by

$$\left[\frac{1}{2} + \frac{1}{2}\prod_{i=0}^{K-1}(1-2p_i)\right]$$

- where pi is the probability of the binary digit being a one.

- Let $\mathbb{N}^*_{m,n}$ represent the bit nodes connected to the nth check node, including the nth bit node.

- Probability (good approximation)

$$P(s_m = 0|\mathbf{r}) = \frac{1}{2} + \frac{1}{2} \prod_{n \in \mathbb{N}^*_{m,n}} \left(1 - 2P\left(c_n = 1|\mathbf{r}\right)\right)$$

$$P\left(c_n = 1|\mathbf{r}\right) = \frac{e^{\lambda_n^{[l]}}}{1 + e^{\lambda_n^{[l]}}}$$

The bit nodes are sparsely separated

- At the lth iteration, calculate

$$\Lambda^{[l]} = \log_e \left(\frac{P\left(s_{287} = 0 | \mathbf{r}\right)}{1 - P\left(s_{287} = 0 | \mathbf{r}\right)} \right)$$

where

$$P(s_{287} = 0 | \mathbf{r}) = \frac{1}{2} + \frac{1}{2} \prod_{n \in \mathbb{N}^*_{287,n}} \left(1 - 2 \frac{e^{\lambda_n^{[l]}}}{1 + e^{\lambda_n^{[l]}}} \right)$$

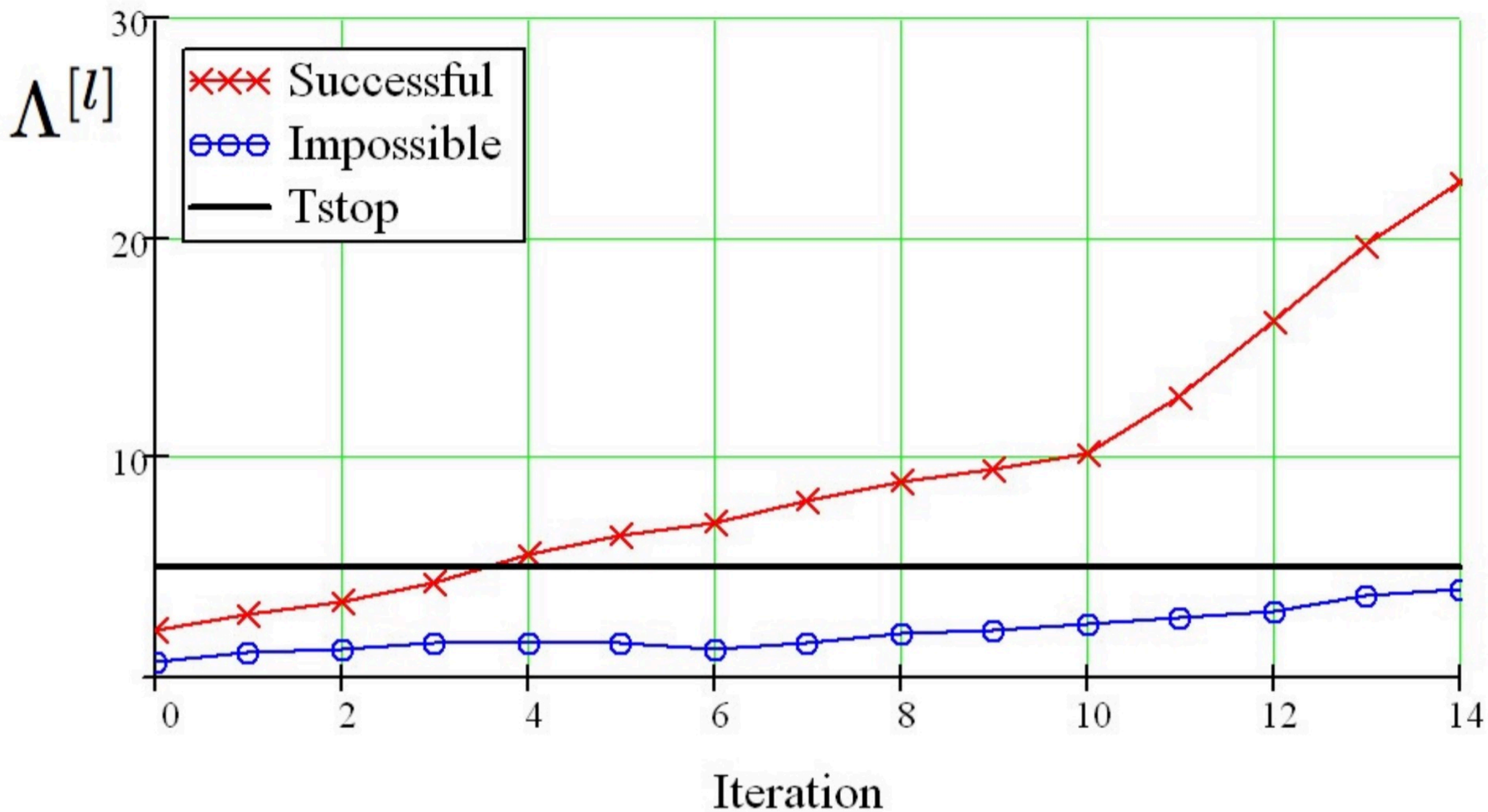


Fig. 3. $\Lambda^{[l]}$ variation with each iteration at a SNR = 1dB.

SNSC Algorithm

S0 Initialisation: Set alert-flag = 0, $l = 0$ and $\eta_{m,n}^{[0]} = 0$ for all (m, n) with $H(m, n) = 1$

S1 Set $\lambda_n^{[1]} = L_c r_n$

S2 While $l < L_{\max}$ continue to S3

S3 Increase l by one and for each (m, n) with $H(m, n) = 1$, compute $\eta_{m,n}^{[l]}$

S4 For $n = 0, 1, \cdots N - 1$, compute $\lambda_n^{[l]} = L_c r_n + \sum_{m \in \mathbb{Z}_n} \eta_{m,n}^{[l]}$

S5 If $\lambda_n^{[l]} > 0$, set $\widehat{c}_n = 1$, otherwise set $\widehat{c}_n = 0$

S6 If $\mathbf{H}\widehat{\mathbf{c}}^{(l)} = \mathbf{0}$ stop decoding, otherwise continue to S7

S7 If $\Lambda^{[l]} > T_{stop}$, then set alert-flag = 3

S8 If alert-flag = 1, then go to S9, otherwise skip to S10

S9 If $\left|\Lambda^{[l]} - \Lambda^{[l-1]}\right| < T$, then stop decoding, otherwise reset alert-flag = 0

S10 If alert-flag = 0 **and** $\left(\Lambda^{[l]} < \Lambda^{[l-1]}\right)$ **and** $(l > L_{\min})$ then set alert-flag = 1.

S11 Go to S2

If Λ[l] > Tstop, then switch off algorithm.

If Λ[l] < Λ[l−1], then on the next iteration, stop the decoder if the magnitude of the change is less than T.

If this change is larger than T, whether it be positive or negative, this would be a good indication that the iteration process is still beneficial and the decoder allowed to iterate.

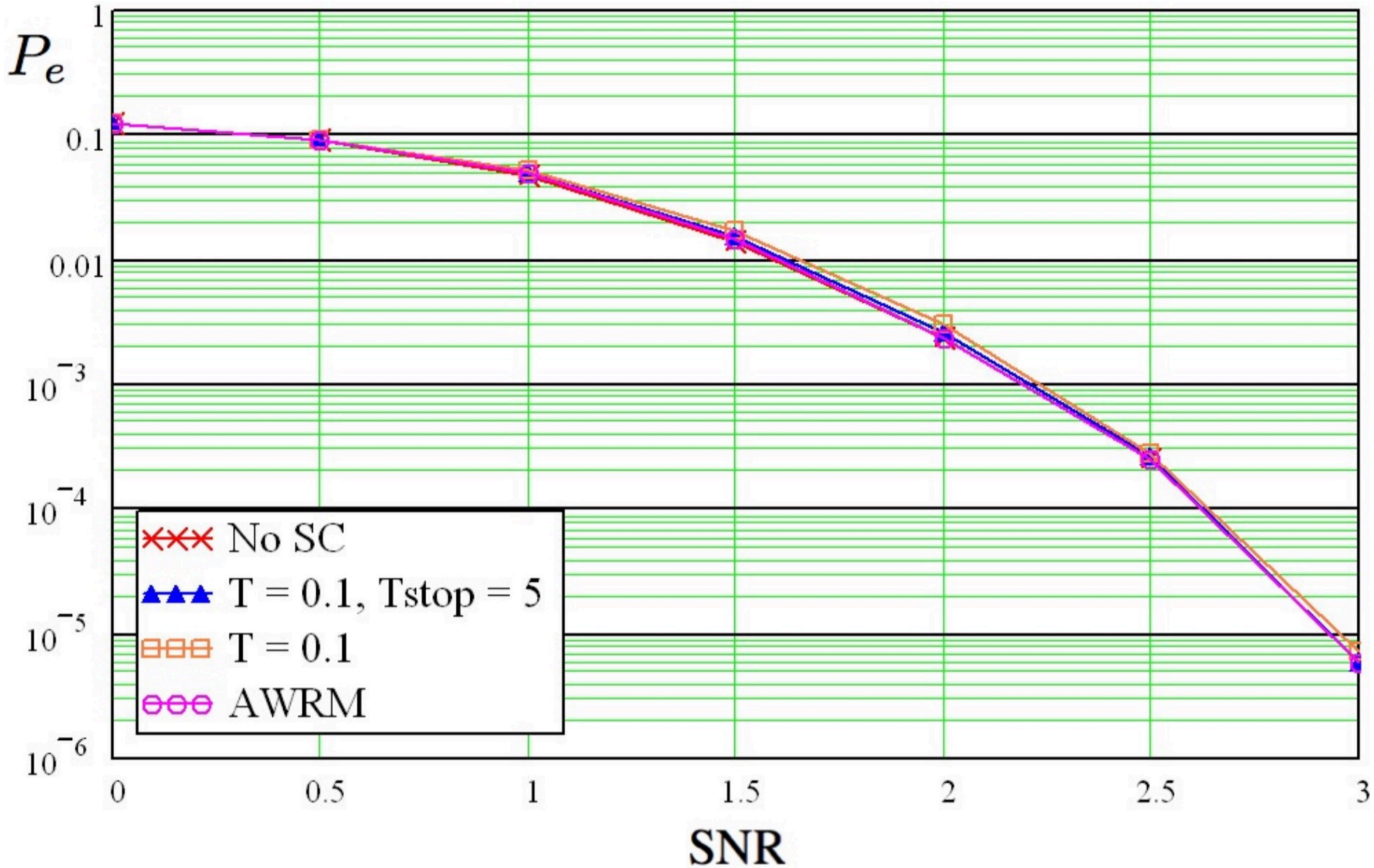


Fig. 4. LDPC decoder performance.

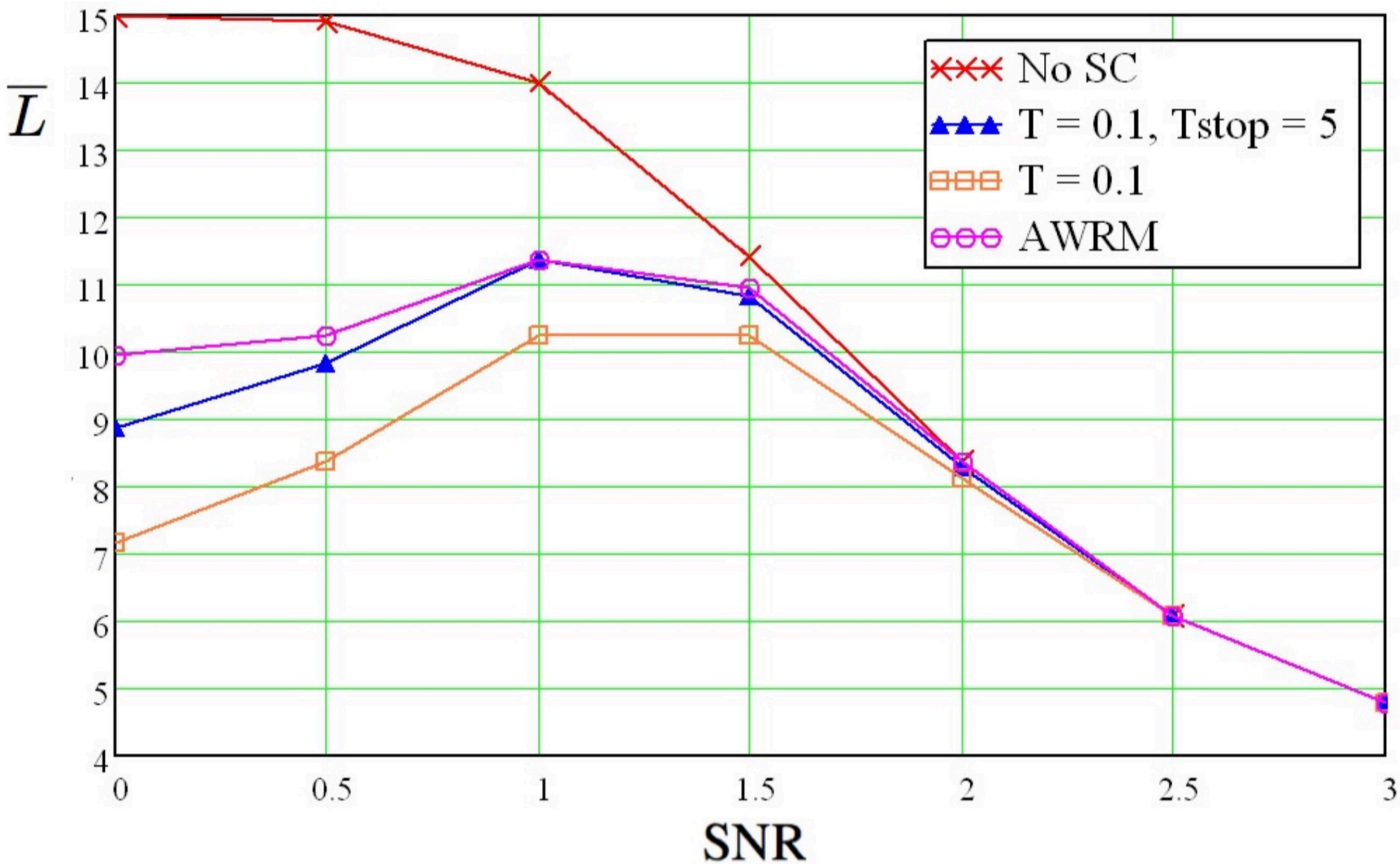
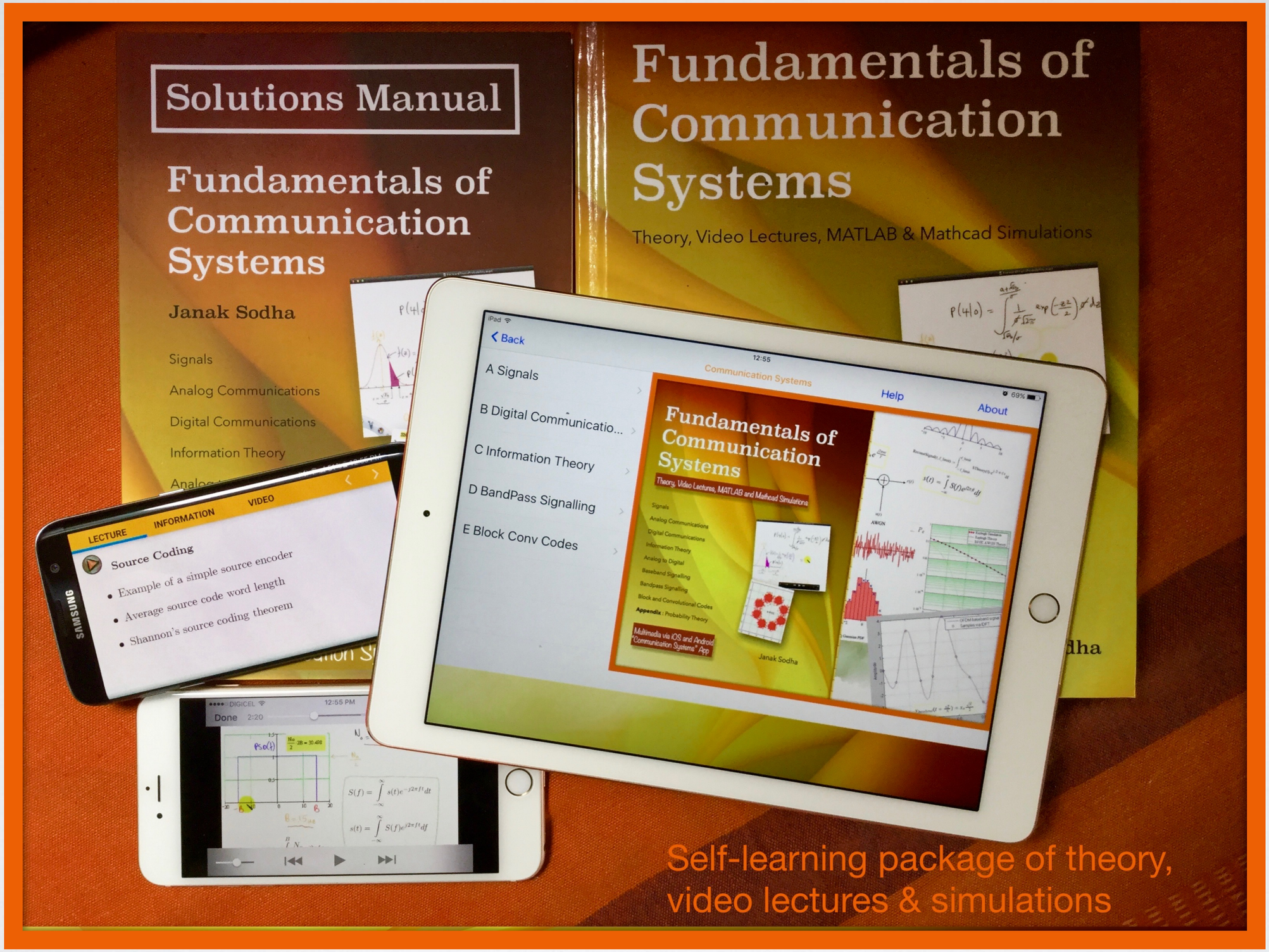


Fig. 5. Average number of iterations $\overline{L}$.

Conclusions

- Proposed early stopping criterion does not adversely effect the BER at high SNRs.
- Algorithm disables the stopping criterion at high SNRs
- Algorithm reduces the time taken to decode, with a much lower complexity than existing algorithms.
- Only the specification of Lmin, T and Tstop for a given LDPC code.
- Ongoing research will investigate the performance of this algorithm for other LDPC codes.

- http://book.janaksodha.com



- Book supported with video lectures and simulations (MATLAB and Mathcad)