SBN: Simple Block Nanocode for nanocommunications

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Introduction

- Nanothings have energy constraints
- THz band has high molecular absorption and high molecular noise => transmission errors
- We need to improve robustness of transmission
- FEC, ARQ are too complex
- We propose a simple code to provide reliability in THz band
  - we analyse its robustness
  - we measure energy consumed to transmit an image and check if perpetual image transmission is possible

SBN

- SBN = NME code followed by block code
- NME code [Zainuddin&Dedu&Bourgeois 2014]:
  - reduce the number of bits 1 to send, since bits 1 consume energy (pulses) and bits 0 do not
  - most frequent symbols are mapped to codewords with fewer bits 1
  - input symbols and codewords have same length
  - energy reduction depends on type of input data (no reduction for compressed images, high reduction for other types of data)

Input sym.	Sym. freq.	NME
111	80	000
110	70	010
101	60	001
100	50	100
011	40	101
010	30	011
001	20	110
000	10	111

Block encoder

- Input u: n bits (i.e. NME output)
- Output v: m bits (m>n)
- Generator G: random matrix on left, identity matrix on right
- v = u*G

Generator for SBN(6,3):

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

Mapping table:

NME bits u	Codewords v
000	000000
001	011001
010	111010
011	100011
100	110100
101	101101
110	001110
111	010111

Block decoder

Syndrome S	Error patterns $\hat{e}$
000	000000
100	100000
010	010000
001	001000
110	000100
111	000010
011	000001
101	101000

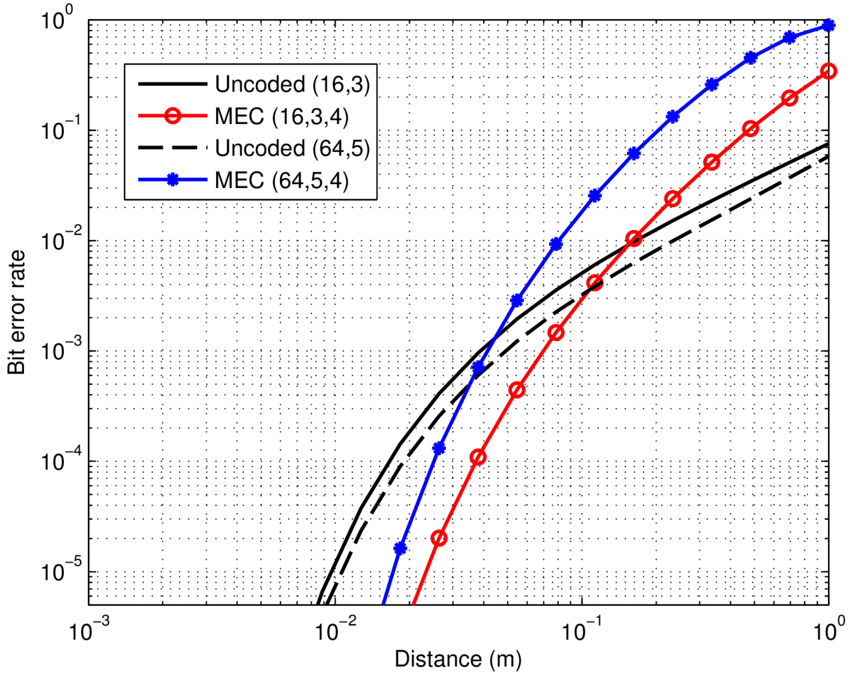
- Decoder has a syndrome table computed from generator G
- Upon reception of a codeword, receiver:
  - computes the syndrome to get the error pattern
  - add the error pattern to the codeword to get the corrected codeword (which should be equal to transmitted codeword, if error correction was ok)
- SBN(6,3) perfectly corrects one bit error
- SBN(16,3) and SBN(16,5) perfectly correct 1 and 2 error bits, and up to 7, resp. 6 error bits (depending on error patterns)

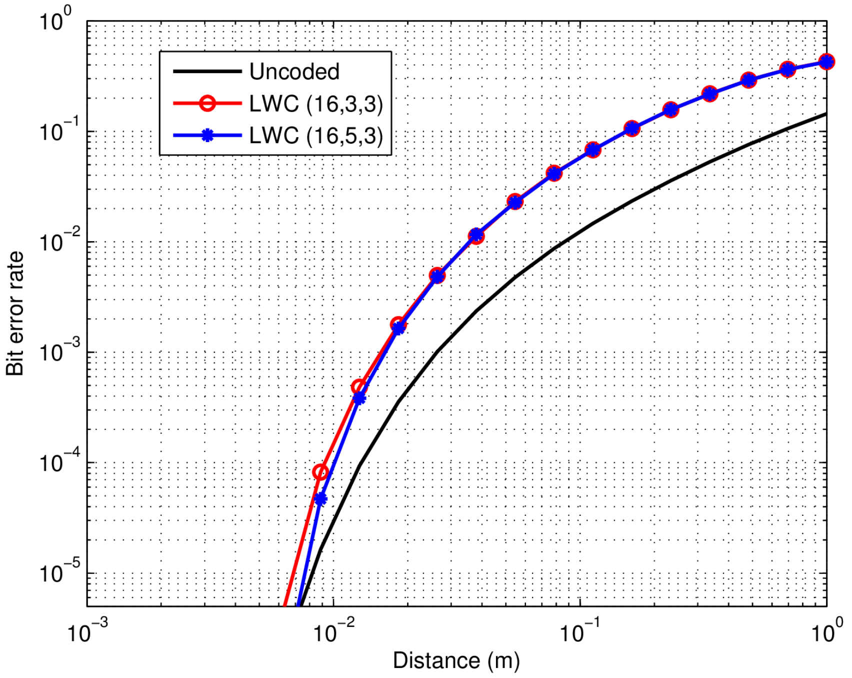
Results – BER

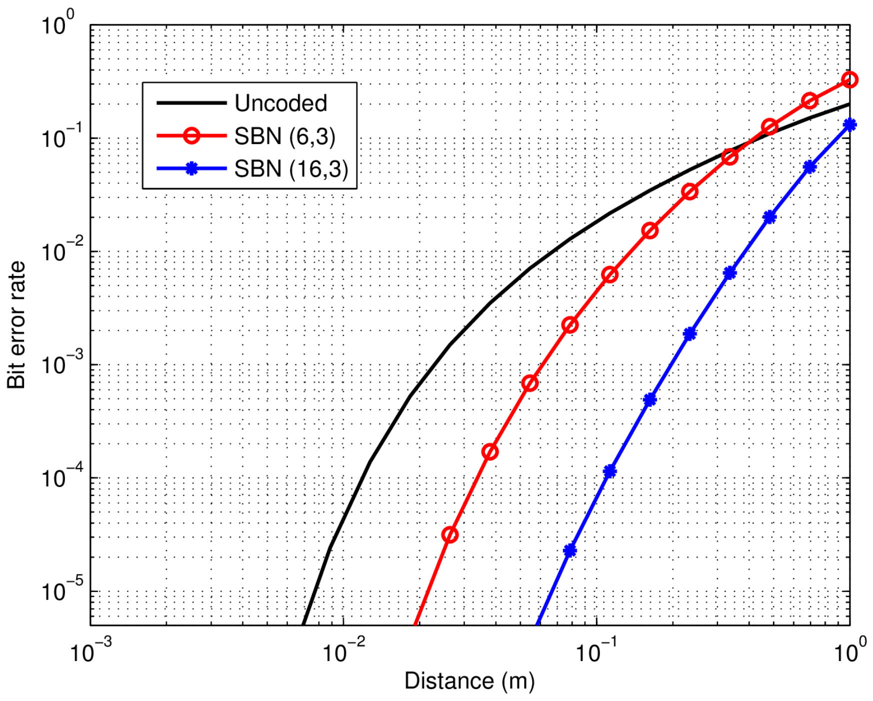
- Hypothesis: 1 aJ to send a pulse, 0.1 aJ to receive a pulse, just one point-to-point communication
- We compare SBN with the two other error-correction nanocodes found in the literature:
  - MEC(m,n,dmin) [Kocaoglu&Akan 2013]
  - LWC(m,n,w) [Jornet 2014]

Input sym.	Sym. freq.	NME	MEC	LWC
111	80	000	0...0011	10011
110	70	010	0...1100	01101
101	60	001	.	10101
100	50	100	.	11001
011	40	101	.	01110
010	30	011	.	10110
001	20	110	0011...0	11010
000	10	111	1100...0	11100

- Simulation results, using Matlab:
  - generate 10^6 random bits, encode, transmit, and compute number of error bits using different error probabilities for 0 and for 1







As expected:

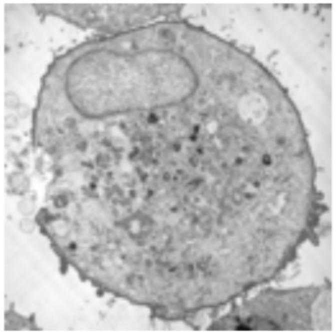
- BER increases with distance

Conclusions (wrt to BER):

- SBN outperforms MEC and LWC, and also uncoded up to some distance

Results – Sensor application (image)

- Motivation of image transmission: Internet of multimedia nanothings, high resolution nanocameras to come, cancer cell detection
- Scenario: 128x128 image, cancer.bmp, 10 cm distance



- Conclusion: SBN consumes more energy than uncoded, MEC and LWC (e.g. 2.7 times more), but is much more reliable (e.g. BER 667 times smaller)
- Feasibility of image transmission from energy pov, an example with state of the art components (800 pJ battery, 9 nF nano-capacitor charged at 0.42 V, 2500 vibration cycles, 50 Hz):
  - for uncoded, transmission uses ~73000 aJ => 11000 images to send with a full battery
  - => 50 sec to fully charge the battery => 220 fps for uncoded, and 50 fps for SBN(16,3) in perpetual operation

Conclusions

- We proposed an error correction block code appropriate to nanonetworks
- Compared to the two other error-correction nanocodes found in the literature, it consumes more energy and is much more robust
- A nanosensor can harvest enough energy for perpetual image transmission (128x128 pixels, 50 fps, BER<10^{-5})
- **Perspectives:** joint source-channel coding to further reduce energy consumption