Nanonetwork Minimum Energy coding

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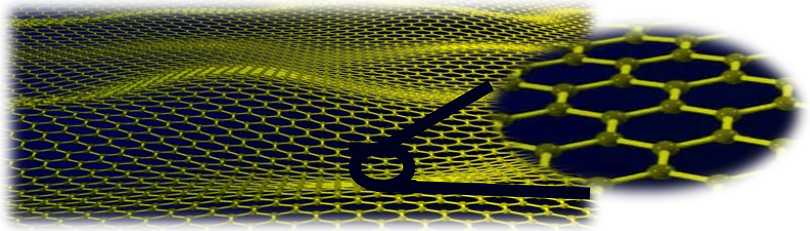
Outline

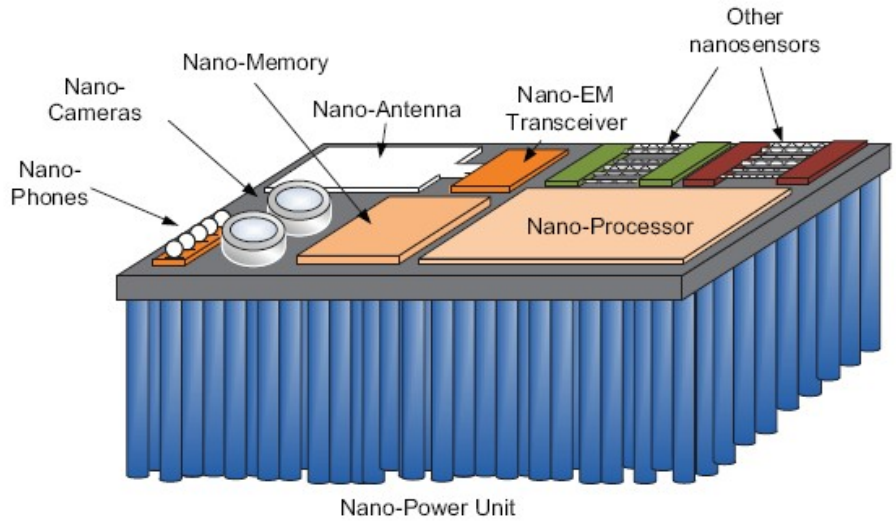
- Background: Nanosensor Networks
- Nanonetwork Minimum Energy (NME) Coding
  - Method
  - Simulation results
- Conclusion & Future works

Nanosensor Networks

- Nanotechnology enables nano-devices to generate, process, and transmit information at atomic scale
- Material: Graphene, a one-atom thick planar sheet of bonded carbon atoms in a honeycomb crystal lattice
- Nanosensor components: nano-processors, nano-merories, nano-sensors, and nano-transcievers



< 1 nm

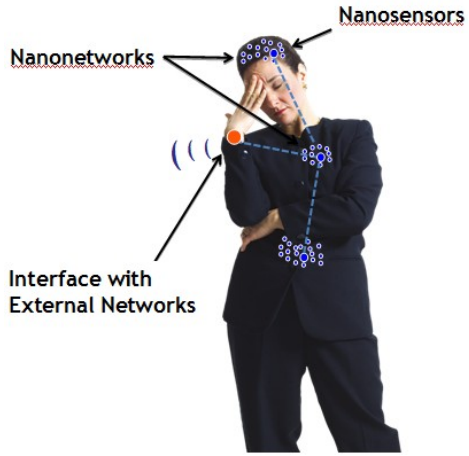


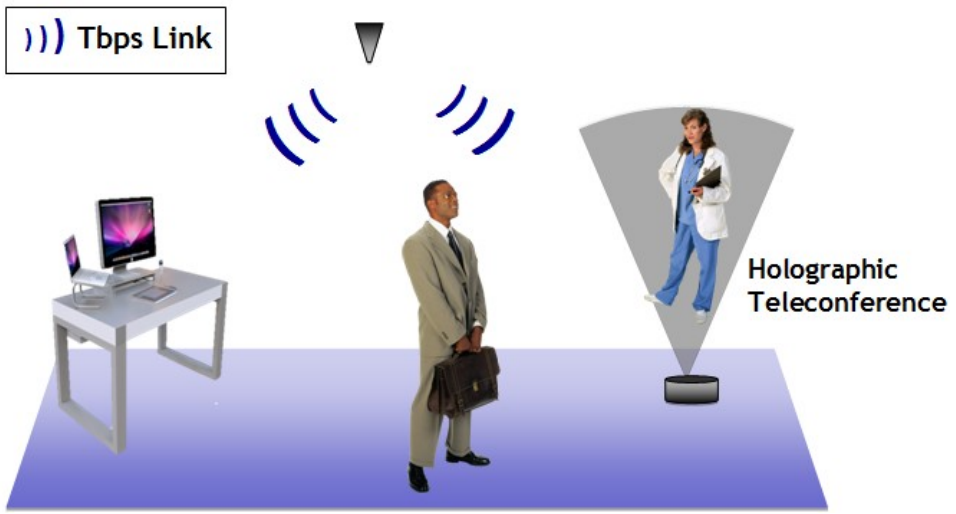
Total volume: a few cubic micrometers

Nanosensor Networks

Application:

- Biomedical: Anti-microbiology, drug delivery system
- Secure and Defence: forensic, NBC attack
- Multimedia: 3D holographic video conference





Nanosensor Networks

Problems:

- Small dimension -> small capabilities:

  Battery capacity, complexity, transmission range

Solutions:

- Nanonetwork: networking of nanosensors.
- Coding and Modulation:
  - Time Spread – On Off Keying (TS-OOK)
  - Minimum Energy Source coding

NME Coding

- Reducing the number of bit 1:
  - Energy efficiency
  - Reduce: molecular absorbtion noise and multi-user interference
  - Increase: channel capacity
- NME algorithm:
  - Segmentize the binary input sequence into blocks (symbols) of n bits
  - Create a table of used symbols and their frequency
  - Create another table by sorting the symbols in decreasing order of frequency and maps to codeword with fewer bit 1

NME Coding

Simulation results:

- Validation: real files
- Metrics to evaluate NME:
  - Energy Efficiency
  - Robustness during transmission
    - Codeword Error Rate
    - Peak Signal to Noise Ratio (PSNR) in Image transmission

NME Coding

Energy Efficiency

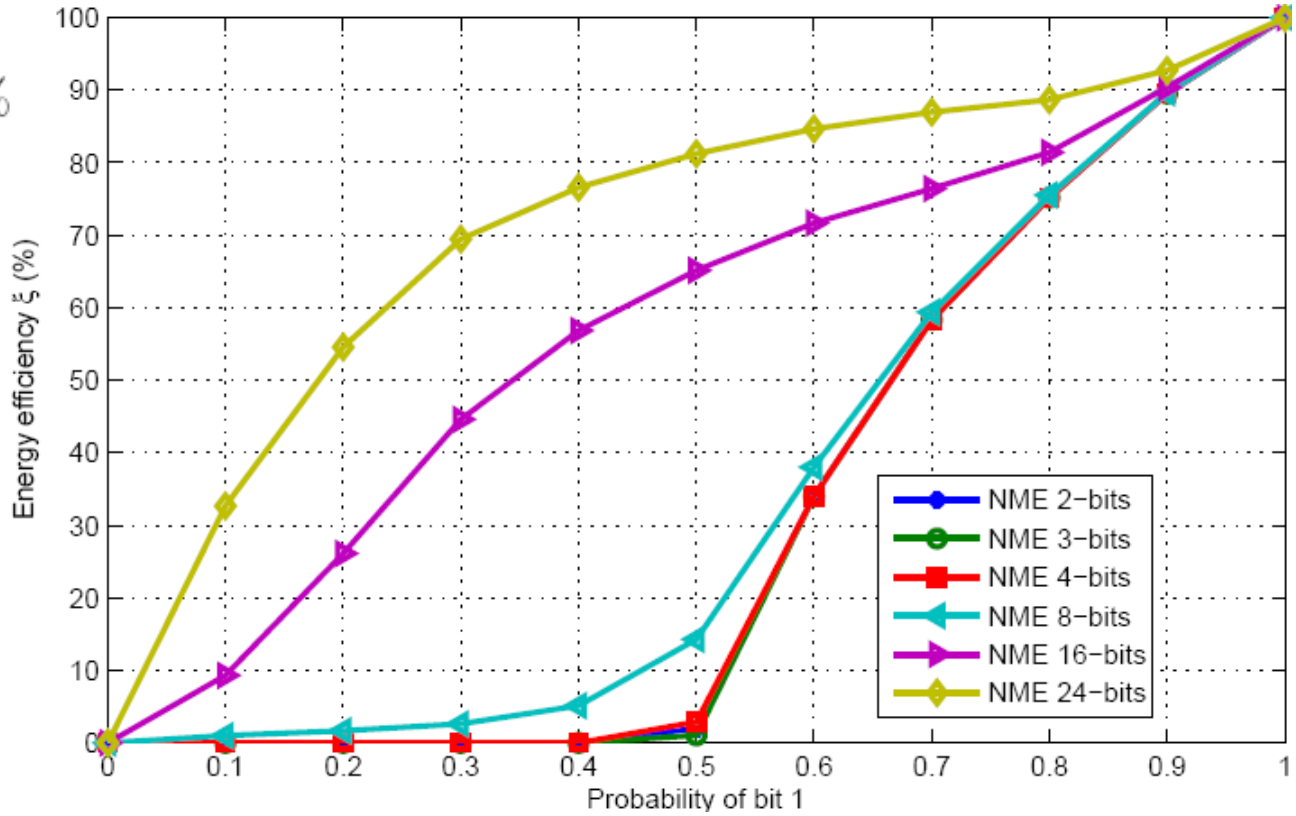
$$\xi = \frac{E_{original} - E_{NME}}{E_{original}} \times 100\%$$

where:

ζ : Energy efficiency (%)

$E_{Original}$: Uncode energy

E_{NME} : NME energy



NME Coding

Energy efficiency

Coding	Number of 1s in dictionary (bits)	Number of 1s in data (bits)	Number of 1s in total (bits)	Energy efficiency (%)	Dictionary length (byte)	Max dictionary length (byte)
Original	–	–	3,763,743	–	–	–
NME 2 bit	4	3,735,368	3,735,372	0.76	1	1
NME 3 bit	12	3,716,347	3,716,359	1.26	3	3
NME 4 bit	32	3,708,997	3,709,029	1.45	8	8
NME 8 bit	1,024	3,665,543	3,666,567	2.58	0.25 k	0.25 k
NME 16 bit	523,358	3,389,503	3,912,861	−3.96	127.8 k	128 k
NME 24 bit	3,708,769	1,961,620	5,670,389	−50.66	923 k	48 M

NME PERFORMANCE FOR NEWS_CIF.MP4 FILE (0.92 MB)

Coding	Number of 1s in dictionary (bits)	Number of 1s in data (bits)	Number of 1s in total (bits)	Energy efficiency (%)	Dictionary length (byte)	Max dictionary length (byte)
Original	–	–	5,607,698	–	–	–
NME 2 bit	4	5,569,261	5,569,265	0.69	1	1
NME 3 bit	12	5,392,470	5,392,482	3.84	3	3
NME 4 bit	32	4,428,079	4,428,111	21.04	8	8
NME 8 bit	1,024	3,326,281	3,327,305	40.67	0.25 k	0.25 k
NME 16 bit	271,466	2,372,978	2,590,444	53.81	54.3 k	128 k
NME 24 bit	1,980,761	1,891,442	3,872,203	30.95	0.5 M	48 M

NME PERFORMANCE FOR BUS_QCIF.YUV FILE (1.38 MB)

NME Coding

Energy efficiency

Coding	Number of 1s in dictionary (bits)	Number of 1s in data (bits)	Number of 1s in total (bits)	Energy efficiency (%)	Dictionary length (byte)	Max dictionary length (byte)
Original	–	–	260,762	–	–	–
NME 2 bit	4	245,266	245,270	5.94	1	1
NME 3 bit	12	252,038	252,050	3.34	3	3
NME 4 bit	32	223,466	223,498	14.29	8	8
NME 8 bit	1,024	198,315	199,339	23.56	0.25 k	0.25 k
NME 16 bit	76,974	131,903	208,877	19.90	19.3 k	128 k
NME 24 bit	229,518	89,270	318,788	−22.25	57.3 k	48 M

NME PERFORMANCE FOR LENA.BMP FILE (65.1 KB)

Coding	Number of 1s in dictionary (bits)	Number of 1s in data (bits)	Number of 1s in total (bits)	Energy efficiency (%)	Dictionary length (byte)	Max dictionary length (byte)
Original	–	–	132,740	–	–	–
NME 2 bit	4	132,386	132,390	0.26	1	1
NME 3 bit	12	132,294	132,306	0.33	3	3
NME 4 bit	32	130,010	130,042	2.03	8	8
NME 8 bit	1,024	122,955	123,979	6.60	0.25 k	0.25 k
NME 16 bit	108,405	82,463	190,868	−43.79	26.7 k	128 k
NME 24 bit	132,011	42,469	174,480	−31.44	33 k	48 M

NME PERFORMANCE FOR LENA.JPG FILE (33.2 KB)

NME Coding

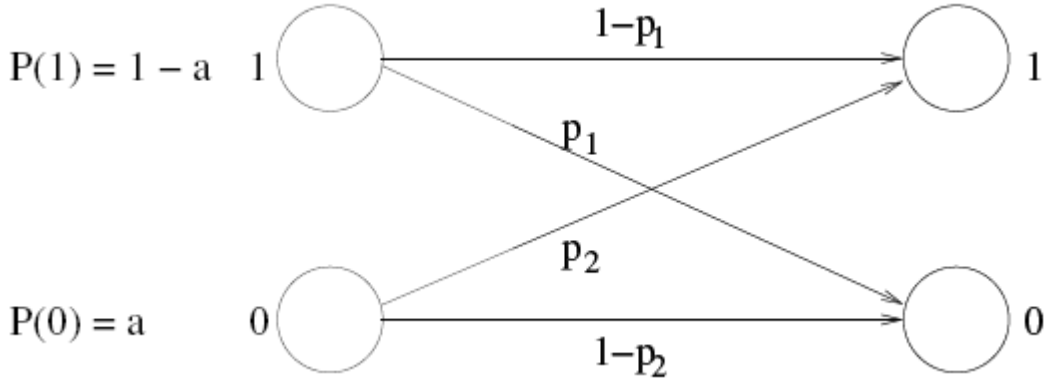
Coding	Number of 1s in dictionary (bits)	Number of 1s in data (bits)	Number of 1s in total (bits)	Energy efficiency (%)	Dictionary length (byte)	Max dictionary length (byte)
Original	–	–	1,680,819	–	–	–
NME 2 bit	4	1,518,325	1,518,329	9.67	1	1
NME 3 bit	12	1,544,009	1,544,021	8.14	3	3
NME 4 bit	32	1,382,547	1,382,579	17.74	8	8
NME 8 bit	1,024	1,093,100	1,094,124	34.91	0.25 k	0.25 k
NME 16 bit	212,215	820,857	1,033,072	38.54	53.7 k	128 k
NME 24 bit	726,974	596,478	1,323,452	21.26	0.19 M	48 M

NME PERFORMANCE FOR ADOBEUPDATER.DLL FILE (0.49 MB)

NME Coding

Robustness during transmission

Channel model: Binary Asymmetric Channel (BAC)



Where:

P(1) : probability of bit 1

P(0) : probability of bit 0

p_1 : probability of receive 0 when transmitte 1

p_2 : probability of receive 1 when transmitte 0

NME Coding

Robustness during transmission

Codeword Error Rate

$$CER = 1 - (1 - p_2 P(0) - p_1 P(1))^n$$

Where:

CER: Codeword error rate

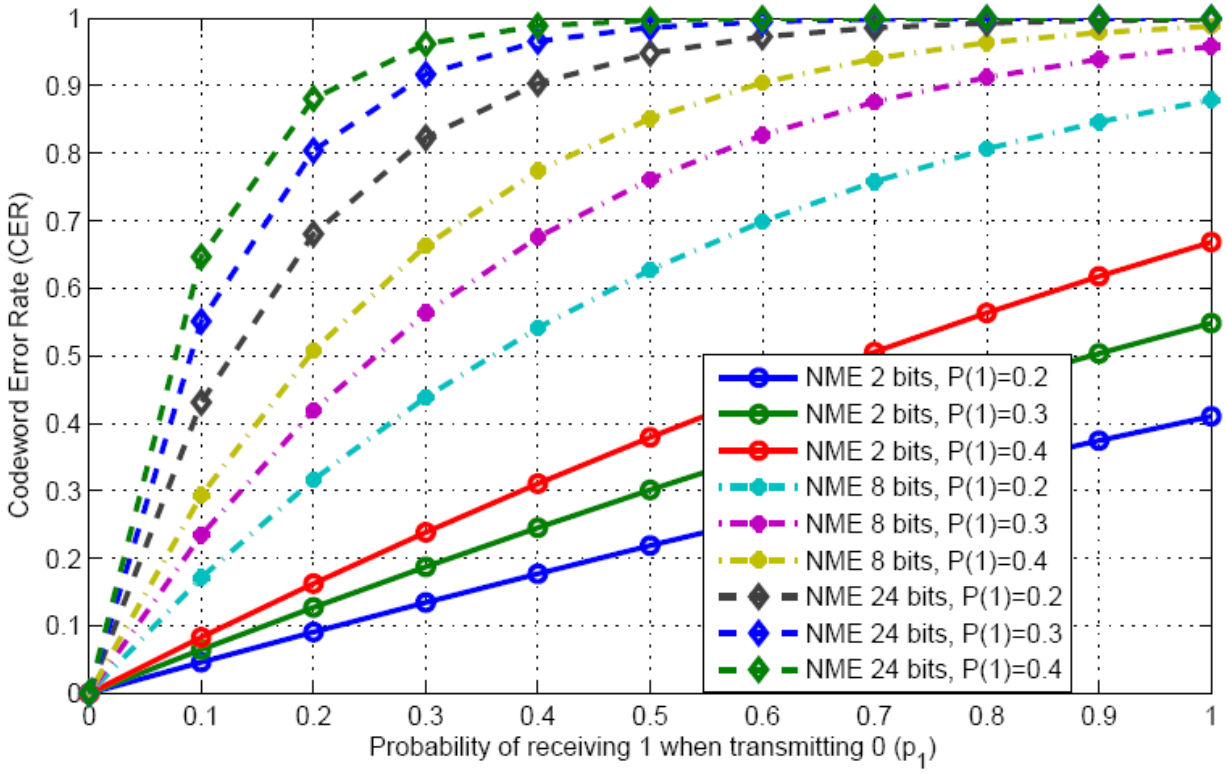
P(1) : probability of bit 1

P(0) : probability of bit 0

p_1 : probability of bit 1 error

p_2 : probability of bit 0 error

n : NME n bits



NME Coding

Robustness during transmission

Image transmission: lena256.bmp

$$e(x,y) = I_i(x,y) - I_o(x,y)$$

$$E_{ms} = \frac{1}{AB}\sum_{x=0}^{A-1}\sum_{y=0}^{B-1} e(x,y)^2$$

$$PSNR(dB) = 10\log_{10}\left(\frac{255^2}{E_{ms}}\right)$$

Where:

e(x,y) : distortion

$I_i(x,y)$: transmitted image

$I_o(x,y)$: received image

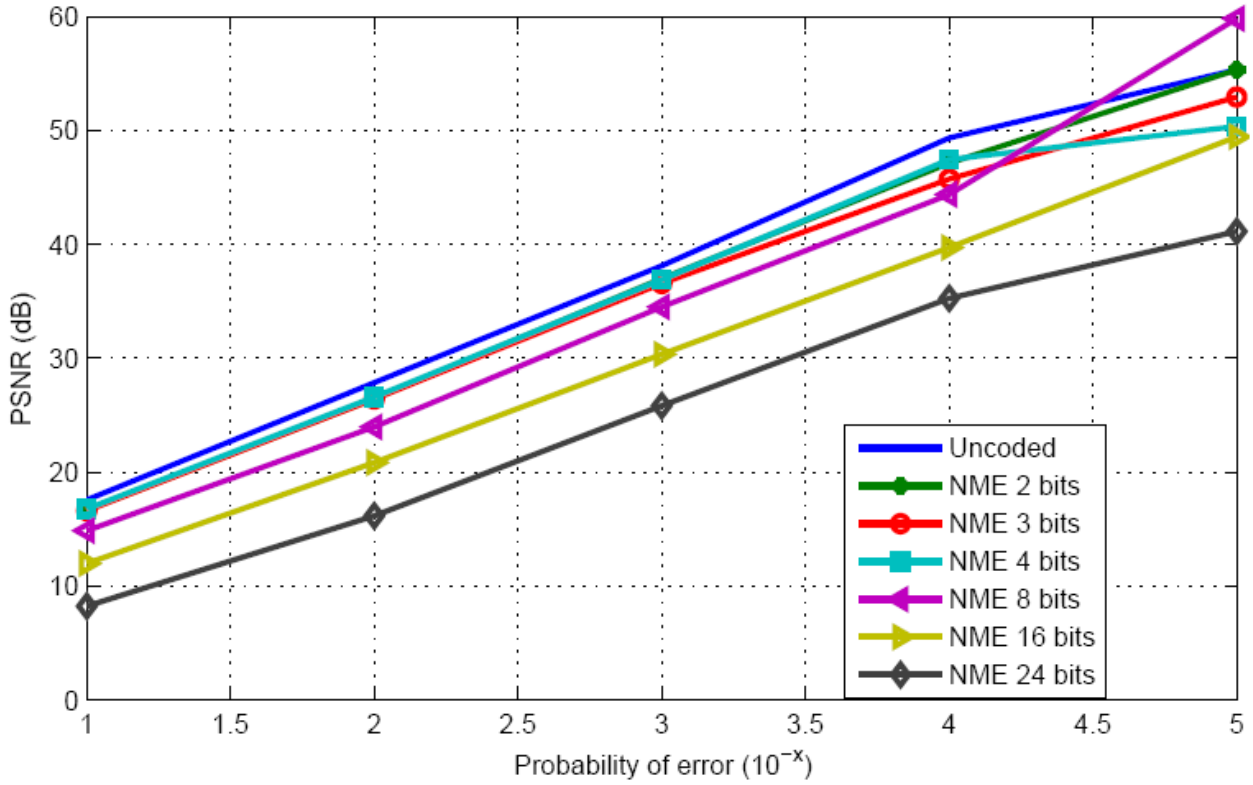
E_{ms} : mean square error

PSNR : Peak signal to noise ratio

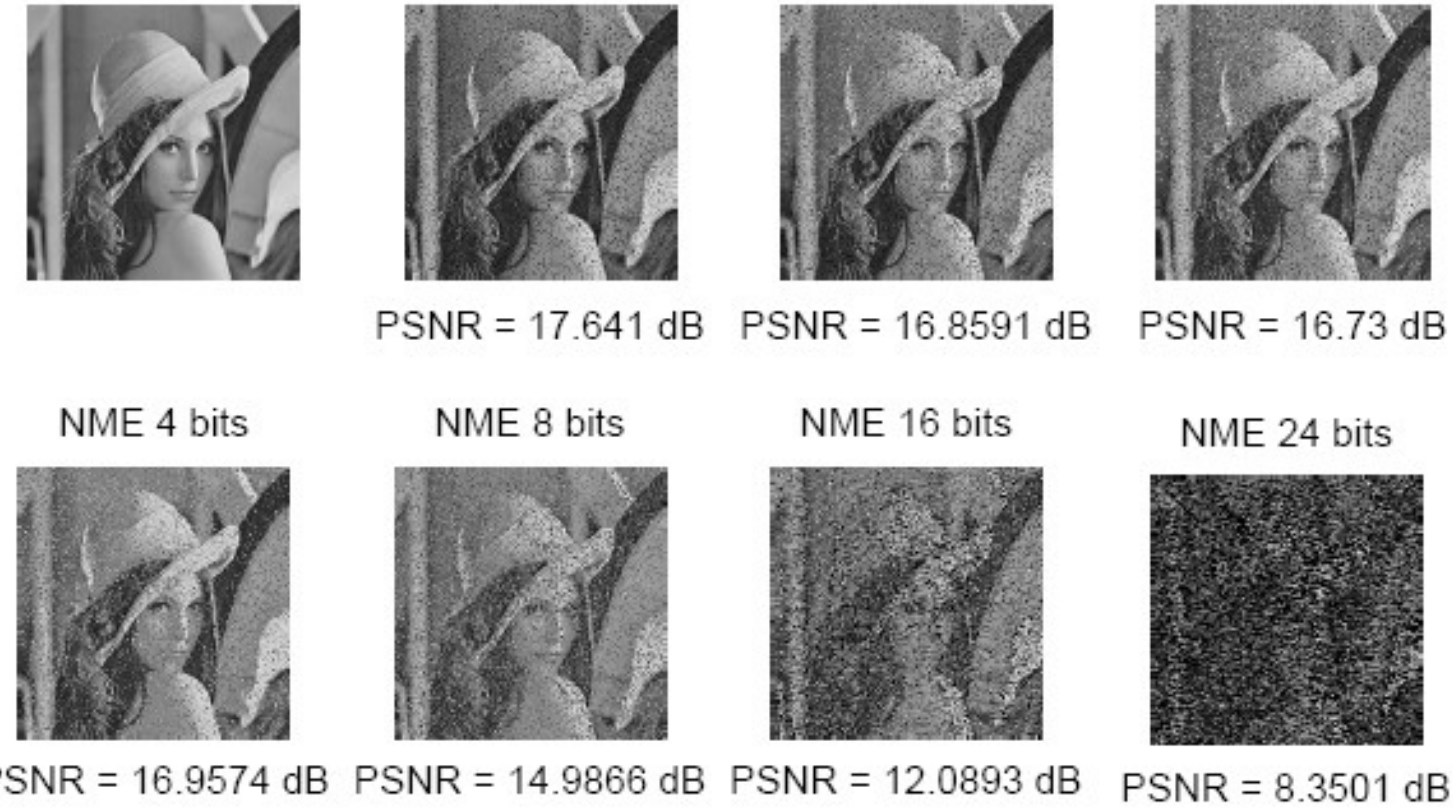
NME Coding

Robustness during transmission

Image transmission: lena256.bmp



NME Coding



Received `lena.bmp` image when transmitted through a BAC channel with $p_1 = 0.1$ and $p_2 = 0.004$

Conclution & Future Works

Conclusion

- Nanonetwork has limitation in battery capacity
- NME code is able to reduce the energy consumption (number of 1) in transmitted data
- The larger number of n bits in NME code is able to increase energy efficiency but more vulnerable to error during transmission

Conclution & Future Works

Future works

- We will compare the code performance with other source codes for nanonetwork
- We will investigate the code performance in molecular noise and multi-user interference reduction

References

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