Information Theory for Molecular Communication in Nanonetworks

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Towards an Information Theory for Molecular Communication

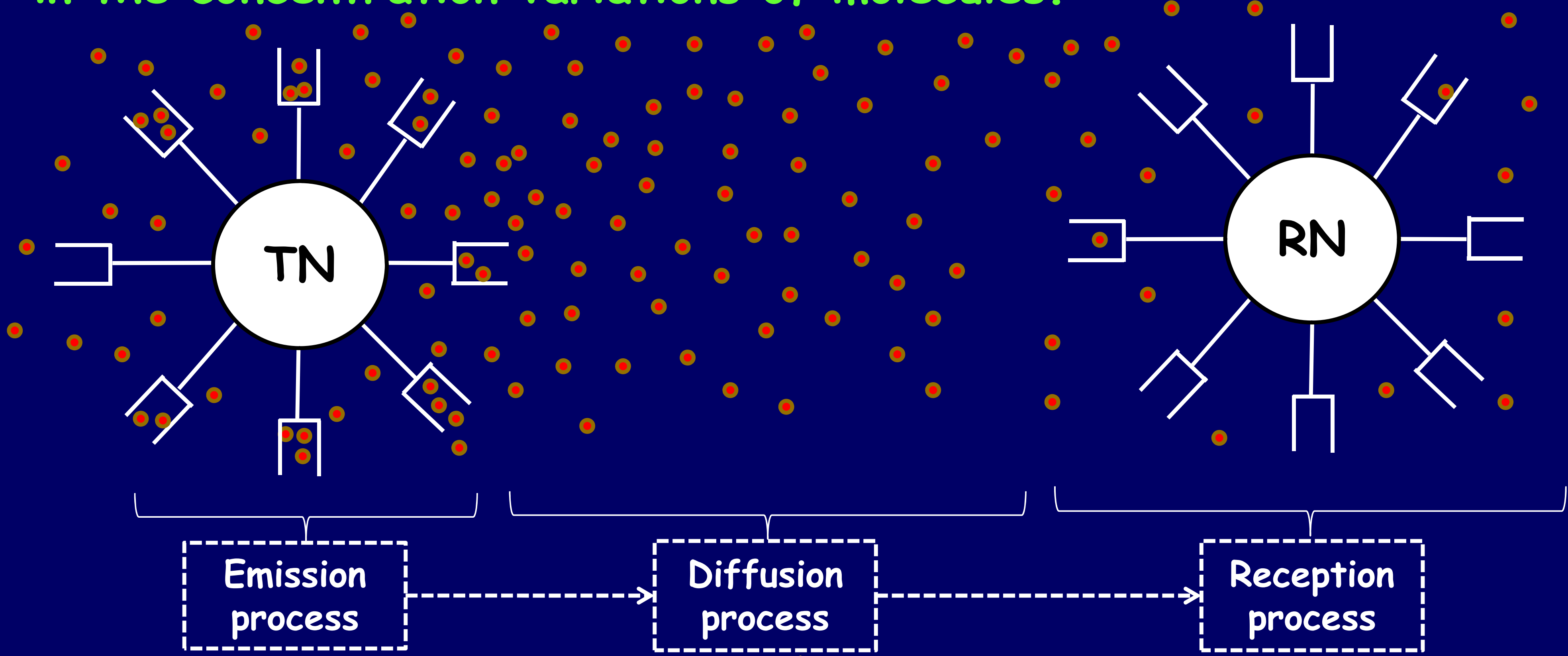
- Physical Channel Model
  - How information is transmitted, propagated and received when a molecular carrier is used
- Noise Representation
  - How can be physically and mathematically expressed the noise affecting information transmitted through molecular communication
- Information Encoding/Decoding
  - How can information be encoded for a proper transmission using molecular communication

} Molecular Channel Capacity

Physical Channel Model: Molecule Diffusion

M. Pierobon, and I. F. Akyildiz, ``A Physical Channel Model for Molecular Communication in Nanonetworks,'' *submitted for journal publication*, March 2009.

- **Molecule Diffusion Communication:** Exchange of information encoded in the concentration variations of molecules.



Objective of the Physical Channel Model

M. Pierobon, and I. F. Akyildiz, ``A Physical Channel Model for Molecular Communication in Nanonetworks,'' *submitted for journal publication*, March 2009.

Derivation of DELAY and ATTENUATION

as functions of the frequency and the transmission range

- Non-linear attenuation with respect to the frequency
- Distortion due to delay dispersion

Modeling Challenges for the Physical Channel

M. Pierobon, and I. F. Akyildiz, ``A Physical Channel Model for Molecular Communication in Nanonetworks,'' *submitted for journal publication*, March 2009.

- **Transmitter**
  - How chemical reactions allow the modulation of molecule concentrations as transmission signals?
- **Propagation**
  - How the "particle diffusion" controls the propagation of modulated concentrations
- **Receiver**
  - How chemical reactions allow to sense the modulated molecule concentrations from the environment and translate them into received signals

Molecule Diffusion Channel Model

M. Pierobon, and I. F. Akyildiz, ``A Physical Channel Model for Molecular Communication in Nanonetworks," *submitted for journal publication*, March 2009.

Transmitter Model

- Design of a chemical actuator scheme (chemical transmitting antenna)
- Analytical modeling of the chemical reactions involved in an actuator
- Signal to be transmitted → Modulated concentration

Molecule Diffusion Channel Model

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Propagation Model

- Solution of the diffusion physical laws (FICK's First and Second Laws (1855), Relativistic Diffusion Process) in the presence of an external concentration modulation
- Modulated concentration → Space-time concentration evolution

Molecule Diffusion Channel Model

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Receiver Model

- Design of a chemical receptor scheme (chemical receiving antenna)
- Analytical modeling of the chemical reactions involved in a receptor
- Propagated modulated concentration → Received signal

Conclusions

M. Pierobon, and I. F. Akyildiz, ``A Physical Channel Model for Molecular Communication in Nanonetworks,'' *submitted for journal publication*, March 2009.

- A mathematical model for the physical molecular diffusion channel
- Non-linear channel attenuation both in frequency and Tx-Rx range
- Channel Tx-Rx delay varies in frequency → dispersion phenomena when the signal propagates

Current Research

- Noise → incorporated into the channel model

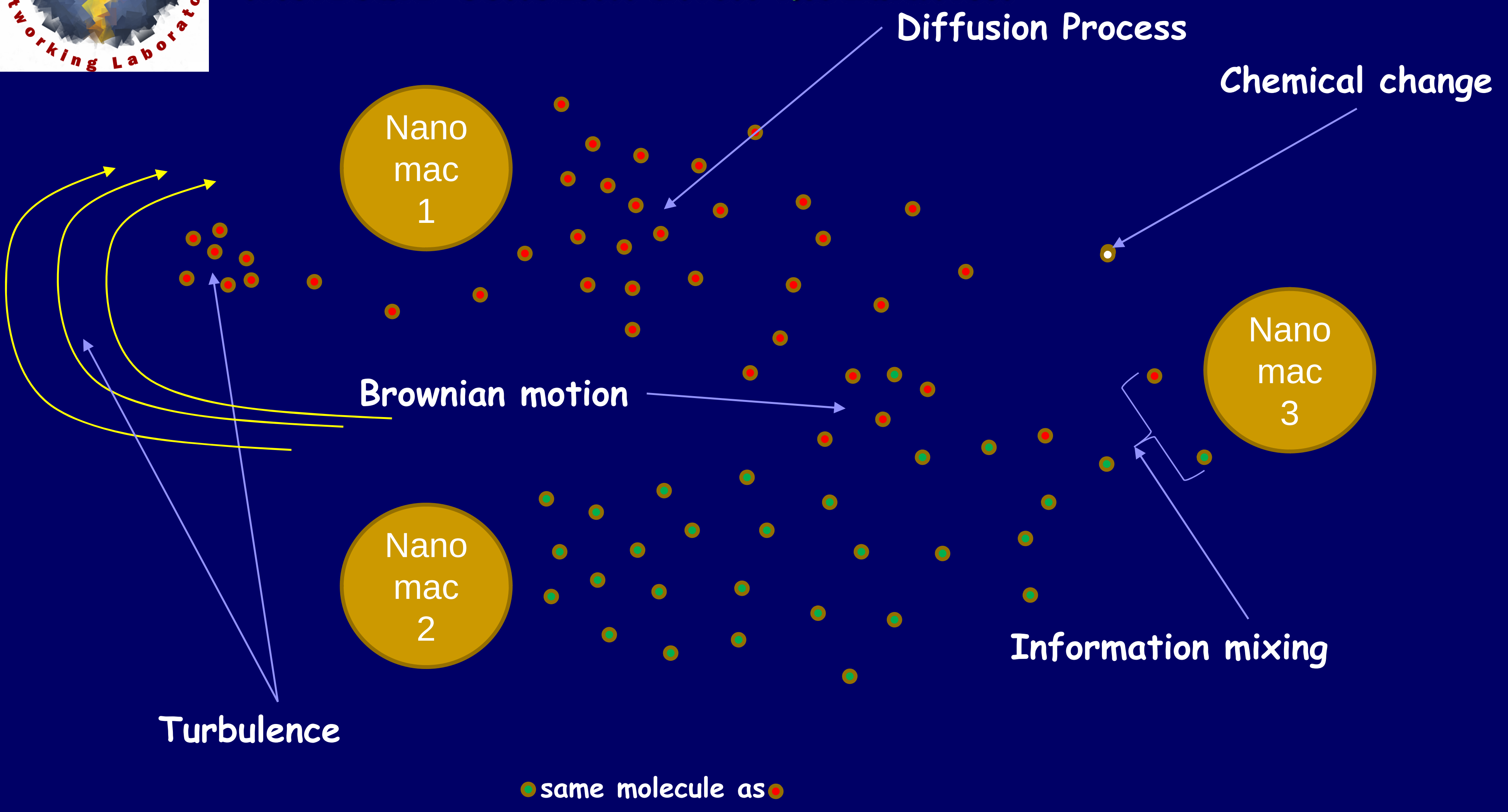
- Study of possible noise sources:

  - When information modulates the molecule concentration

  - When information is encoded into molecule chemical features (e.g., type, structure, polarization, etc.)

Noise Representation

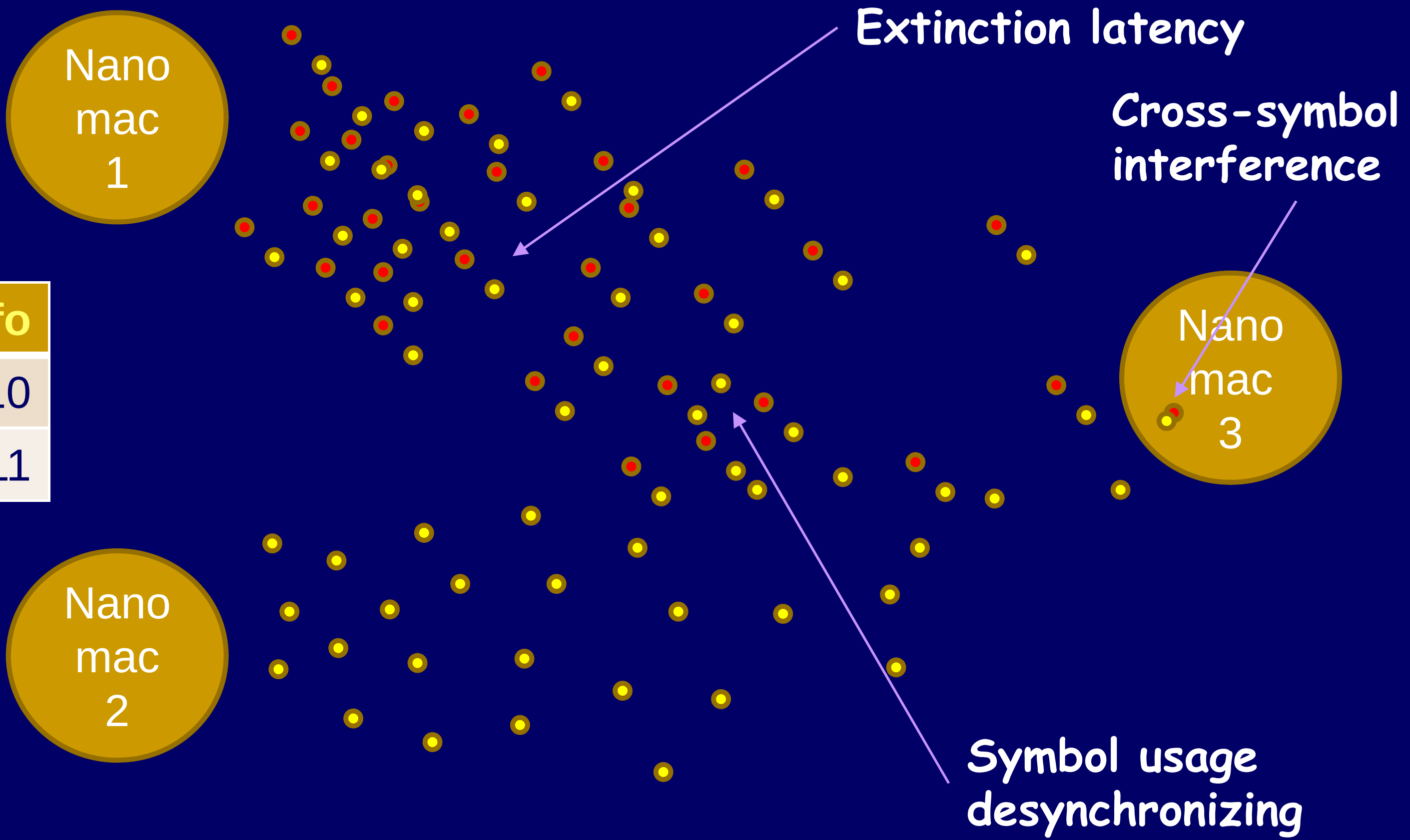
Molecule concentration modulation



Noise Representation

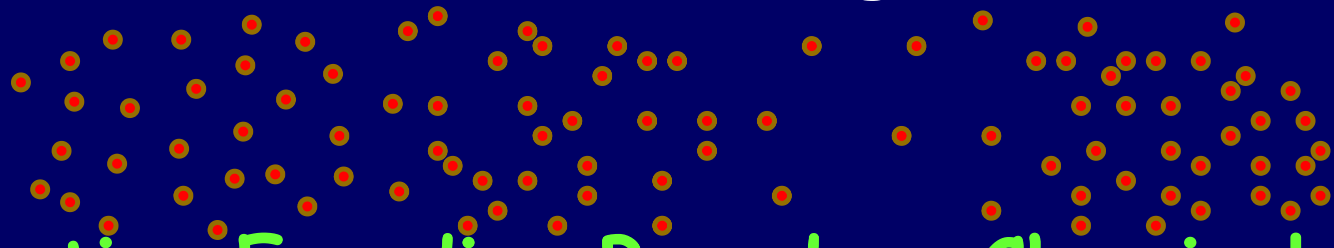
Molecule chemical feature encoding

Symbol	Info
● (red)	0110
● (yellow)	0111

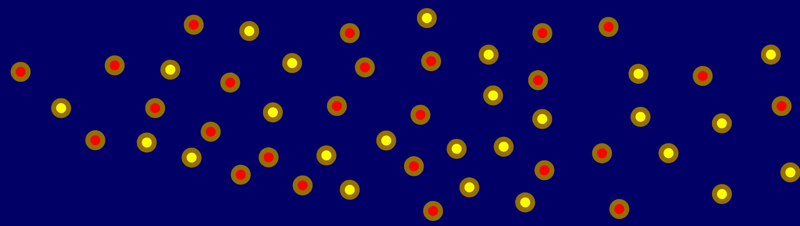


Information Encoding/Decoding

- Concentration Modulation (e.g. Ca^{2+} ion signaling)



- Information Encoding Based on Chemical Features (e.g. pheromone communication)



- Encapsulation of Information Carriers (e.g. DNA vesicle encapsulation, pollen/spores communication)

Future Research and Challenges

- Properly model all the noise sources
- Information encoding/decoding and modulation pattern
- Channel Capacity computation
- Channel multiple access problem
- Addressing issue (routing problem)
- Higher layers development

Thanks for your attention

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