Main details

- Availability: https://code.google.com/p/ieee-p1906-1-reference-code/
- Main features: core, em example, molecular example
- Number of classes: 27
- Lines of code: 11800
- Number of files: 57

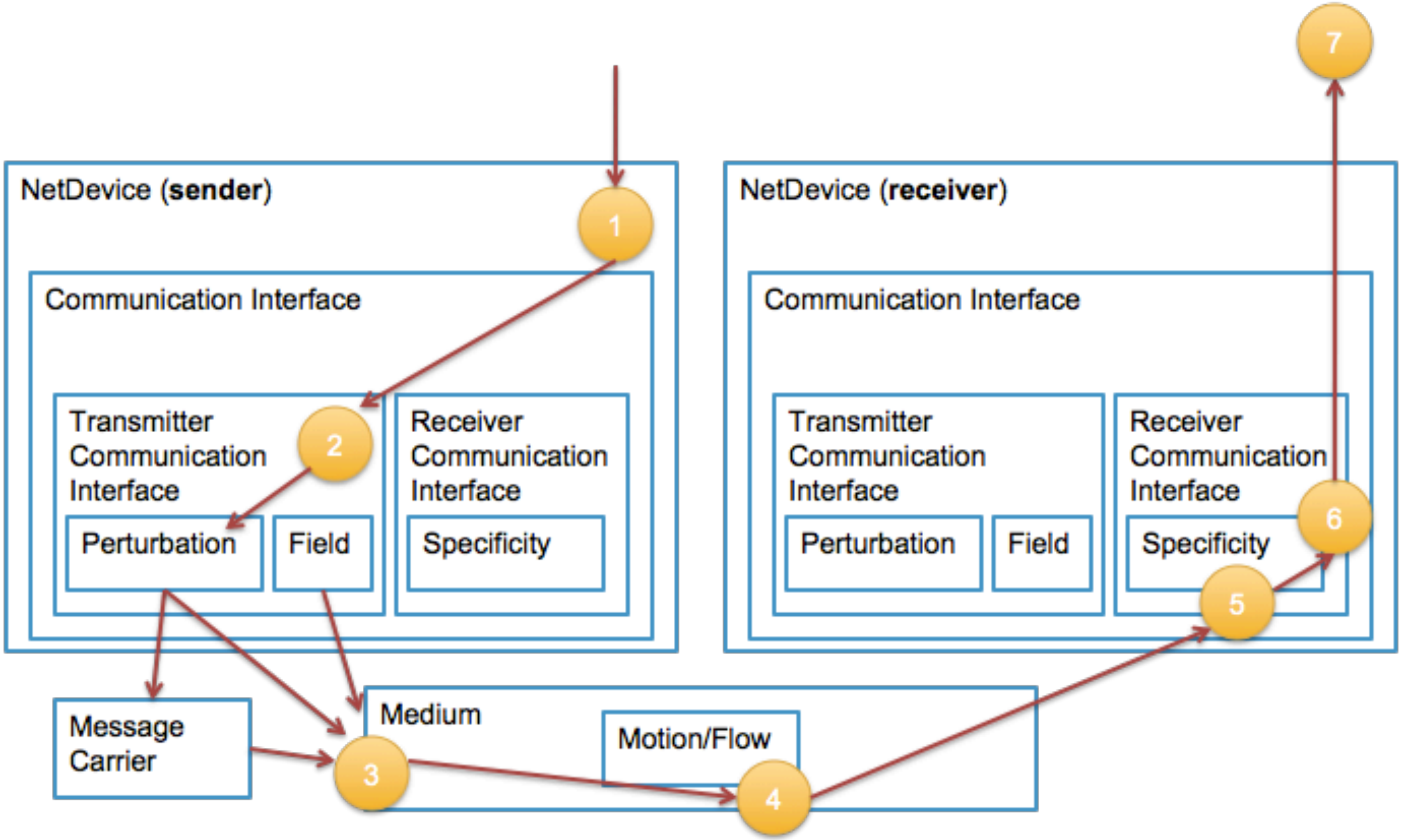
Core of the module

- Components belonging to the P1906.1 framework:
  - MessageCarrier, Motion, Field, Perturbation, Specificity
- Entities belonging to the P1906.1 framework:
  - Medium, Message
- Additional entities:
  - NetDevice, CommunicationInterface, TransmitterCommunicationInterface, ReceiverCommunicationInterface

Components/entities interaction

1. The NetDevice receives a message from upper layers. The message is delivered to the Transmitter Communication Interface
2. The Perturbation component is used to create the Message Carrier
3. The Transmitter Communication Interface triggers the propagation in the medium by passing MessageCarrier, Perturbation, and Field components
4. The Motion component modify properties of the Message Carrier (i.e., propagation loss, delay)
5. The Message Carrier is delivered to the receiver and the Specificity component verifies the compatibility
6. In case of compatibility, the message is delivered to upper layers
7. The message is received by upper layers

Components/entities interaction (2)



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Install and use the tool

- download and install the simulator
  - https://code.google.com/p/ieee-p1906-1-reference-code
  - https://code.google.com/p/ieee-p1906-1-reference-code/source/browse/README
- run the simple example through command line (idea communication)
  - cp ns-3-dev/p1906/example/first-example.cc scratch
  - ./waf --run scratch/first-example

EM example - Main description

- Electromagnetic based communication
- Single transmitter / receiver pair
- THz channel communication
- Reference papers:
  - Ke Yang, Akram Alomainy and Yang Hao, "**In-vivo Characterisation and Numerical Analysis of the THz Radio Channel for Nanoscale Body-Centric Wireless Networks**", IEEE APS/USNC-URSI 2013, Orlando, Florida, USA, 7-13 July 2013
  - Ke Yang, Alice Pellegrini, Alessio Brizzi, Akram Alomainy, Yang Hao, "**Numerical Analysis of the Communication Channel Path Loss at the THz Band inside the Fat Tissue**", IEEE IMWS-Bio 2013, Singapore, 9-11 December 2013
  - Jornet, J.M.; Akyildiz, IF., "**Channel Modeling and Capacity Analysis for Electromagnetic Wireless Nanonetworks in the Terahertz Band**," Wireless Communications, IEEE Transactions on , vol.10, no.10, pp.3211-3221, Oct. 2011

EM example - Message Carrier

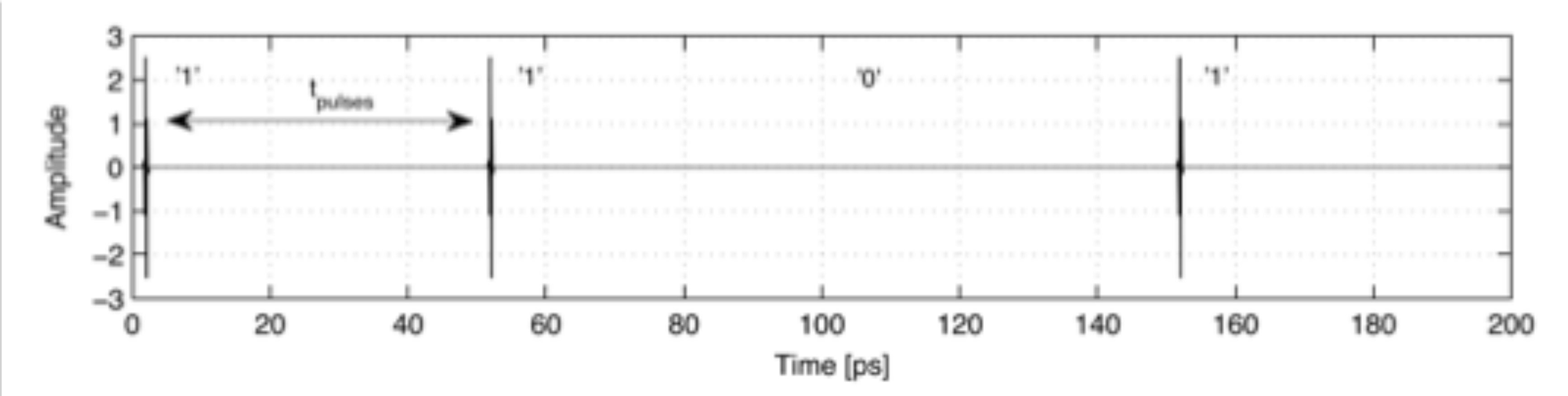
- EM wave transmitted in the THz channel [0.45-1.55] THz
- List of parameters:
  - Number of subchannels, Bandwidth size, Central frequency, Pulse duration, Pulse interval, Starting time, Duration, Spectrum Values (i.e., Power Spectral Density), Message to transmit (packet)
- All the parameters are set by the perturbation component before the physical transmission

EM example - Field

- Ability of wave to be directed in particular direction
- Assumption: omnidirectional antenna

EM example - Perturbation

- TS-OOK Modulation
- List of parameters:
  - Power transmission, Number of subchannels, Bandwidth size, Central frequency, Pulse duration, Pulse interval



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EM example - Motion

- Propagation model of EM waves
- List of parameters:
  - Path loss model as a function of the frequency and the distance (Akram's team contribution)

EM example - Specificity

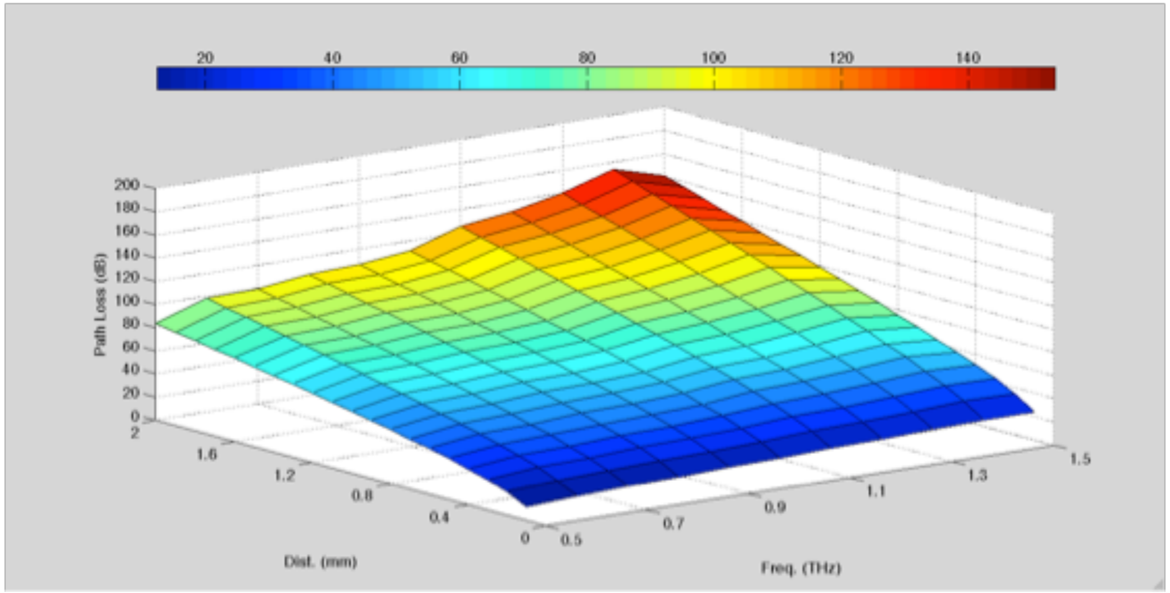
- Ability for receiving the EM wave
- The signal is received only if:
  - transmitter and received use the same channel configuration (bandwidth and central frequency)
  - the channel capacity (Shannon bound) is higher or equal to   the transmission physical data rate

$$C(d) = \sum_i \Delta f \log_2 \left[1 + \frac{S(f_i)\, A^{-1}(f_i, d)}{N(f_i, d)} \right]$$

    - A and N represents the pathloss and the molecular noise, respectively (provided by Akram's team)

EM example - Path loss model

- Provided by Akram’s team and integrated within the Motion compoment



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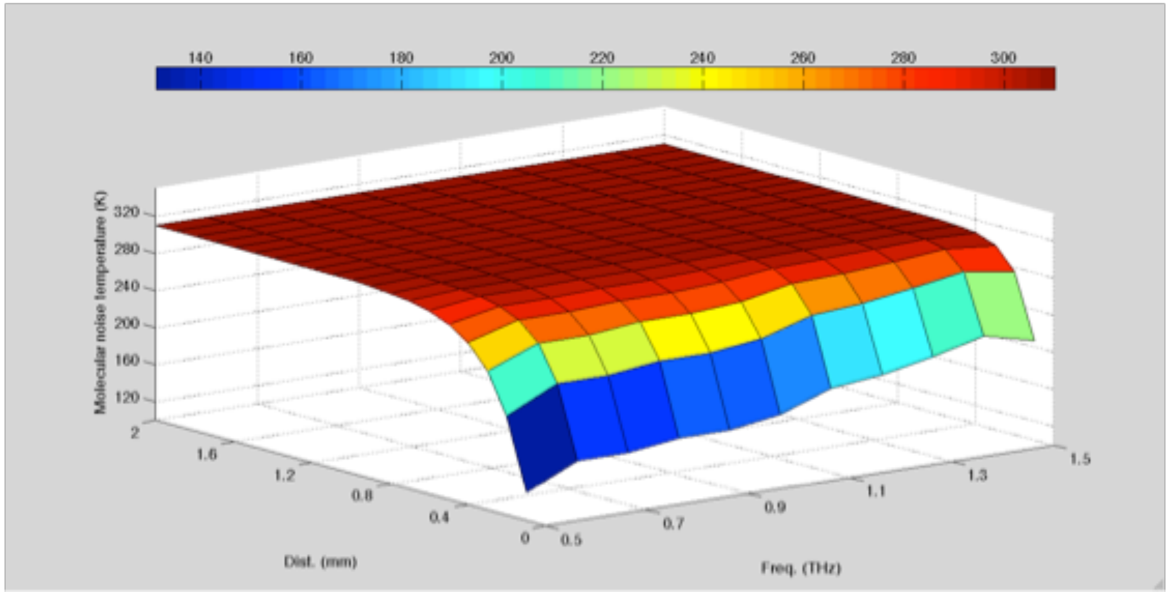
EM example - Molecular noise model

- Provided by Akram's team and integrated within the Specificity component



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Run the EM example

- Default settings:
  - distance among devices = 0.001 m
  - energy pulse = 500 pJ
  - pulse duration = 100 fs
  - pulse interval = 100 ps
  - subchannel size = 0.1 THz
  - bandwidth [0.45-1.55] THz
- Line commands
  - cp ns-3-dev/p1906/example/em-example.cc scratch/
  - ./waf --run scratch/em-example

Molecular example - Main description

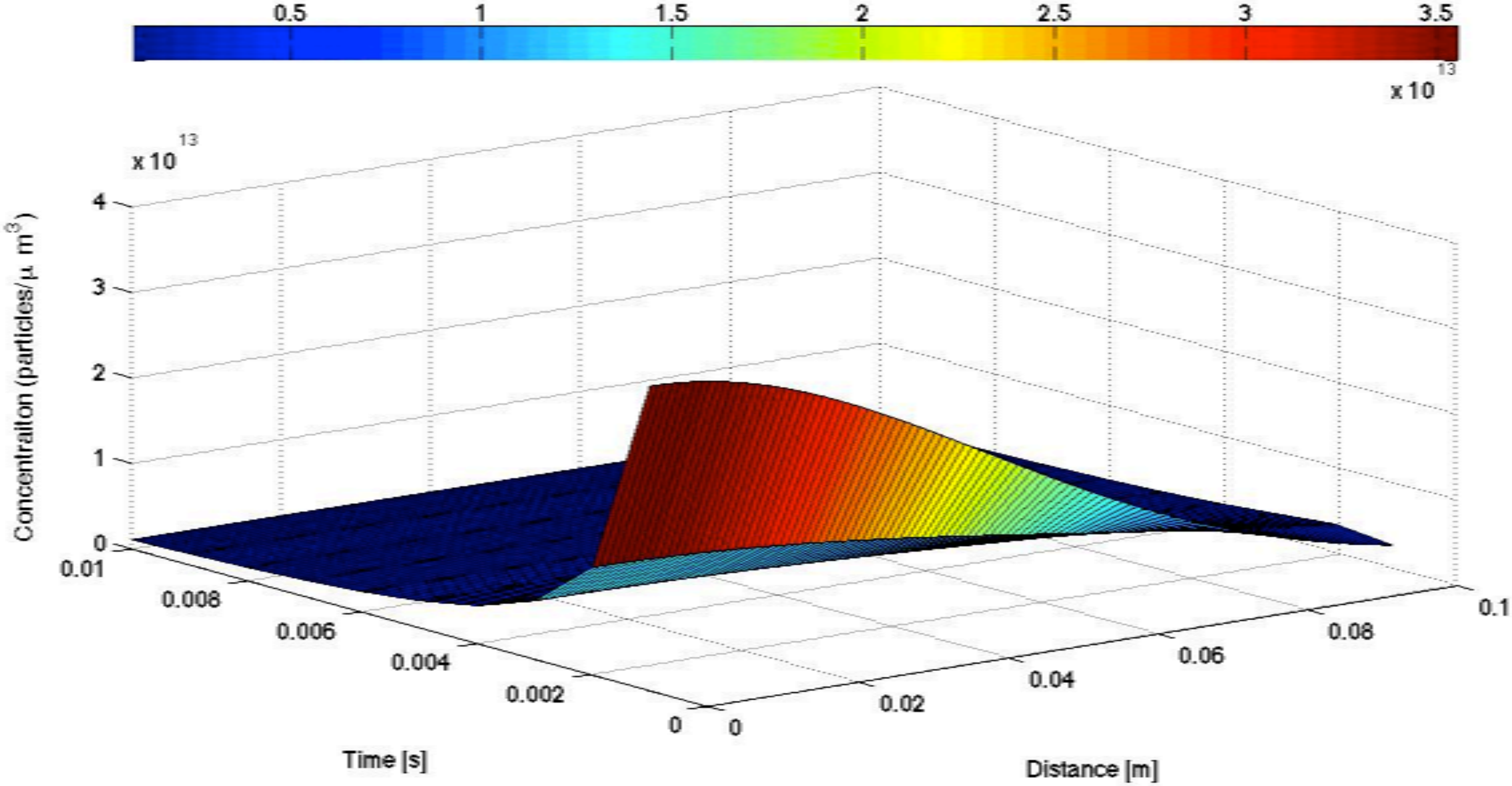
- Molecular based communication
- Single transmitter / receiver pair
- Diffusion-based propagation (Fick's law)
- Reference paper:
  - I Llatser, A Cabellos-Aparicio, M Pierobon, E Alarcón, "Detection Techniques for Diffusion-based Molecular Communication", Selected Areas in Communications, IEEE Journal on 31 (12), 726-734

Molecular example - Fick's law

- If the transmitter releases Q molecules at the time instant t = 0, the molecula concentration at any point in space is given by (D is the diffusion coefficient, r is the distance)

$$c(r,t) = \frac{Q}{(4\pi Dt)^{3/2}} e^{-r^2/4Dt}$$

Molecular example - Fick’s law (2)



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Molecular example - Fick's law (3)

- Assuming to have an Amplitude detection scheme, the propagation delay (t_d) and the minimum allowable pulse width (t_w) are:

$$t_d = \frac{r^2}{6D}$$

$$t_w = t_2 - t_1 = \frac{0.4501}{D} r^2$$

Molecular example - Message Carrier

- Molecules transmitted by the sender
- List of parameters:
  - Number of molecules, Pulse interval, Starting time, Duration, Message to transmit (packet)
- All the parameters are set by the perturbation component before the physical transmission

Molecular example - Field

- Ability of molecules to be directed in particular direction
- Assumption: omnidirectional transmission

Molecular example - Perturbation

- OOK Modulation
- List of parameters:
  - Number of molecules, Pulse interval

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Molecular example - Motion

- Propagation model of molecules
- List of parameters:
  - Diffusion coefficient

Molecules example - Specificity

- Ability of detecting molecules
- The signal is received only if:
  - the channel capacity (Fick’s bound) is higher or equal to the transmission physical data rate

Run the Molecular example

- Default settings:
  - distance among devices = 0.001 m
  - molecules per pulse = 50000
  - pulse interval = 1 ms
  - diffusion coefficient = 1 nm^2/ns
- Line commands
  - cp ns-3-dev/p1906/example/mol-example.cc scratch/
  - ./waf --run scratch/mol-example

Customize simulation parameters

- EM example:
  - ./waf --run “scratch/em-example --nodeDistance=0.01 --energyPulse=500 --pulseDuration=100 --pulseInterval=100”

- Molecular example:
  - ./waf --run “scratch/mol-example --nodeDistance=0.01 --nbOfMoleculas=50000 --pulseInterval=100 --diffusionCoefficient=1”

EM vs Molecular communication

- Goal: evaluate the channel capacity as a function of the distance
- EM parameters:
  - energy per pulse = 500 pJ
  - pulse duration = 100 fs
  - pulse interval = 100 ps
  - node distance = [0 - 0.1] m
- Molecular parameters:
  - molecules per pulse = 50000
  - diffusion coefficient = 1 nm^2/ns
  - pulse interval = 100 ps
  - node distance = [0 - 0.1] m

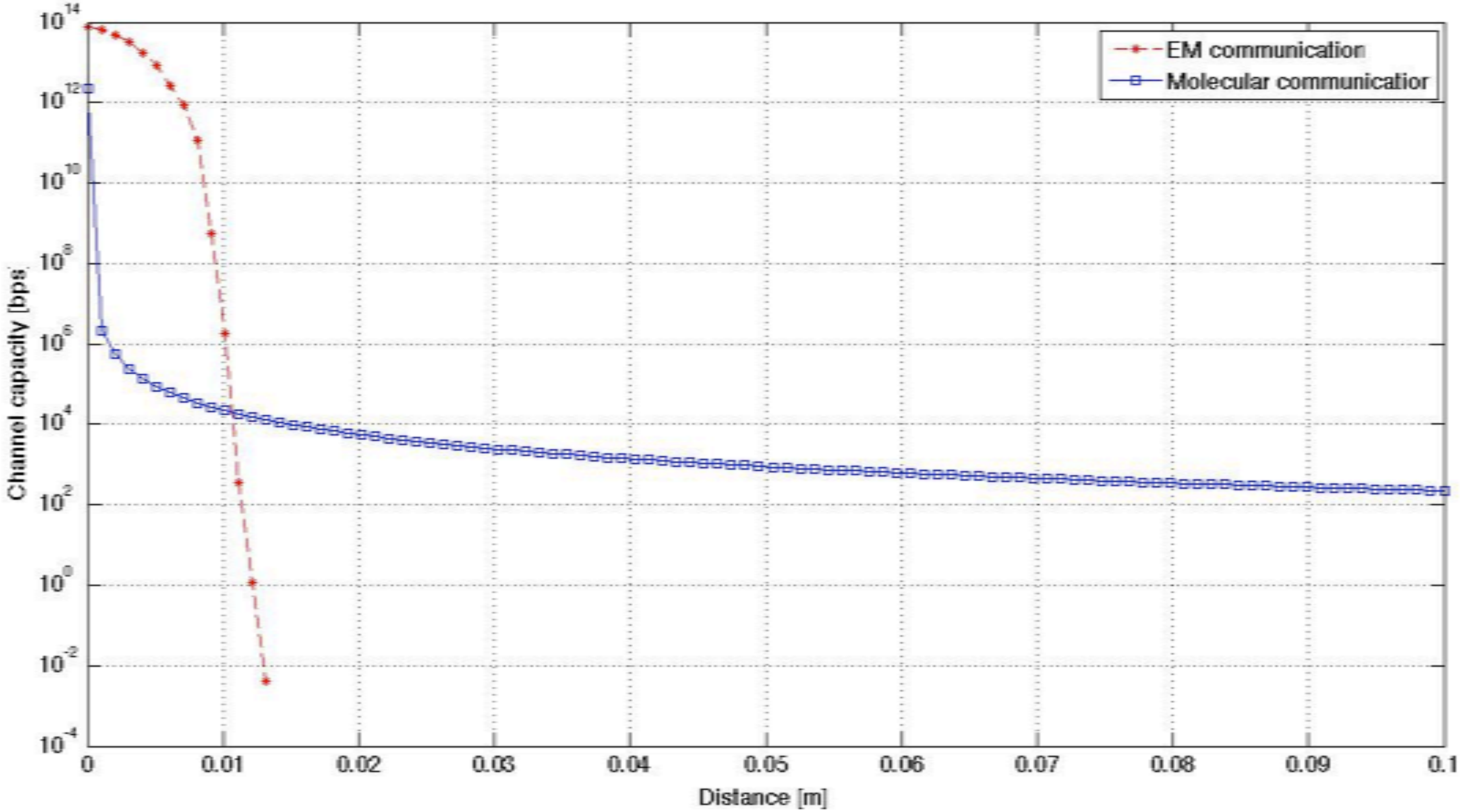
EM vs Molecular communication (2)

- run simulations
  - cp ns-3-dev/p1906/example/_RUN_EM_CHANNEL_CAPACITY_.sh .
  - cp ns-3-dev/p1906/example/_RUN_MOL_CHANNEL_CAPACITY_.sh .
  - sh _RUN_EM_CHANNEL_CAPACITY_.sh
  - sh _RUN_MOL_CHANNEL_CAPACITY_.sh

EM vs Molecular communication (3)

- read outputs
  - RES_EM contains channel capacity computed for the EM example
  - RES_MOL contains channel capacity computed for the Molecular example
  - two columns
    - distance
    - channel capacity
- create graphs
  - matlab, excel, and so on
  - a matlab script is available into the src/p1906/ example folder

EM vs Molecular communication (4)



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