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Nano-Sim:
simulating electromagnetic-based nanonetworks in the Network Simulator 3

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Outline

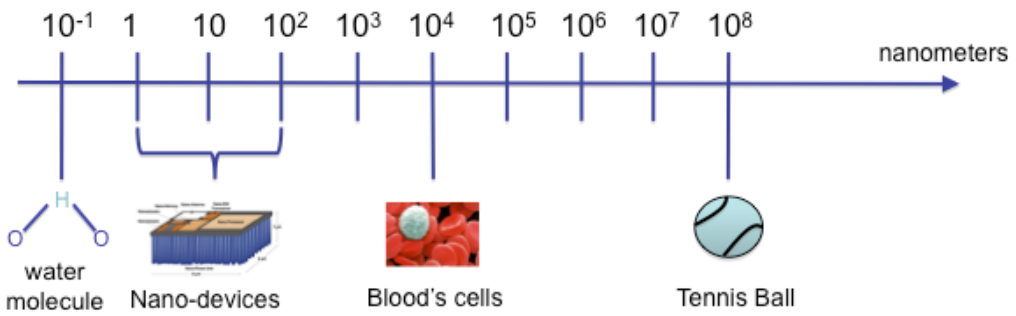
- Introduction on Wireless Nano Sensor Networks
  - what is a WNSN ?
- Research activities on WNSN
  - what has been aready done in literature ?
  - why we need for a WNSN network simulator ?
- NANO-SIM: our proposal
  - main features
  - performance evaluation of WNSNs in a health-care application
- Conclusions and future works

Introduction on WNSN

A **Wireless Nano Sensor Network** is composed by integrated machines (at the nano scale), which interact on cooperative basis through EM communications.

WNSN is not a WSN

- Devices size ranging from one to few hundred of nanometers;
- Graphene-based nanoantennas supporting EM communications in the THz band;
- Bit rates extremely higher (terabit/s);
- Very little transmission ranges (tens of millimeters)
- It is impossible to transmit signals with long duration;



Research activities on WNSN

Consolidated activities:

- characterization of the channel at the nano scale

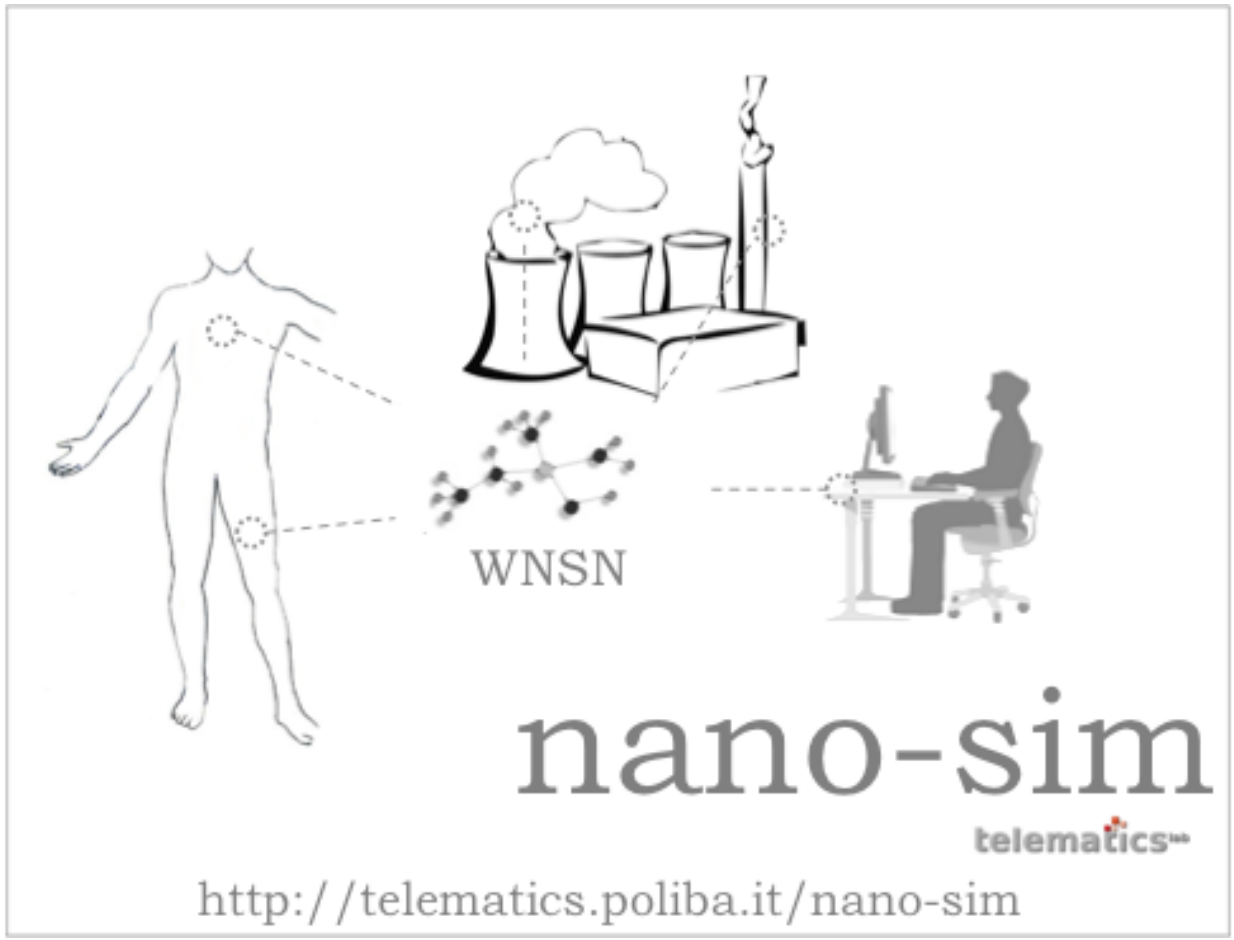
Ongoing activities:

- design of the protocol stack, including channel access procedures and routing strategies

What do we need ?

- a flexible simulation tool

NANO-SIM is open-source tool for simulating WNSN, implemented within the NS-3 simulator



NANO-SIM – main features

At the present stage, it implements:

NANO-SIM – main features

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- **different kinds of devices forming a WNSN**
  - **Nanonode**: tiny device; scarce energy, computational, and storage capabilities; diffused into a target area for sensing the environment;
  - **Nanorouter:** aggregate and process the information coming from nanonodes;
  - **Nanointerface:** inter-networks the WNSN with the rest of the world.

NANO-SIM – main features

At the present stage, it implements:

- different kinds of devices forming a WNSN;
- **message processing unit**
  - CBR application

NANO-SIM – main features

At the present stage, it implements:

- different kinds of devices forming a WNSN;
- message processing unit;
- **routing module**
  - it handles both selective flooding and random strategies

NANO-SIM – main features

At the present stage, it implements:

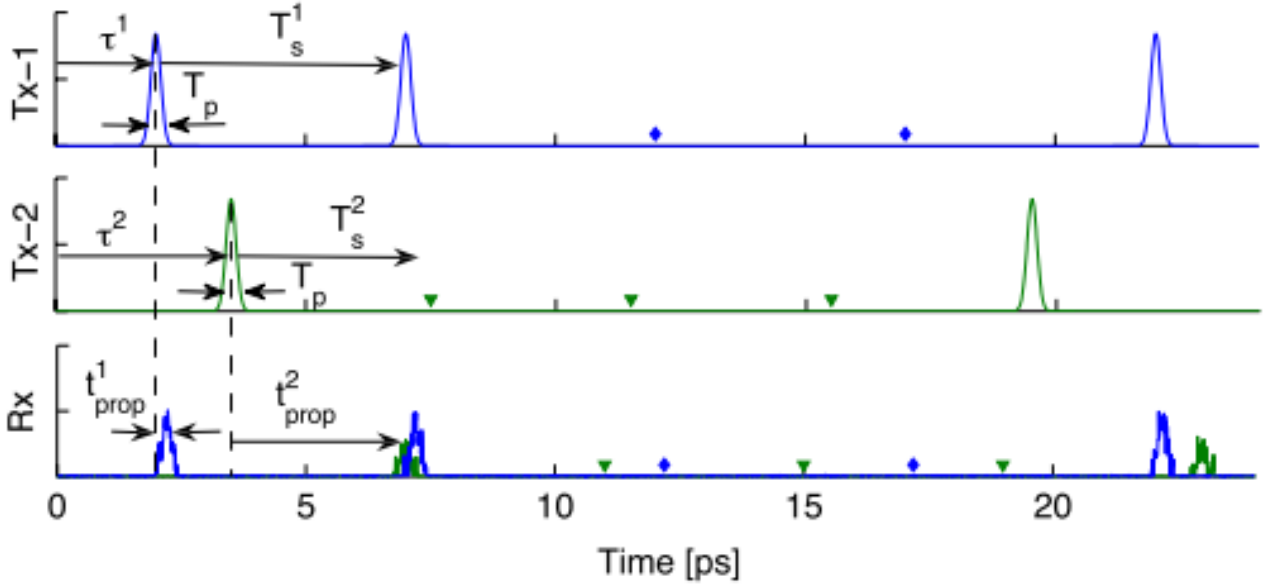
- different kinds of devices forming a WNSN;
- message processing unit;
- routing module;
- **two different Media Access Control protocols**

  - **Transparent-MAC**: the packet is directly delivered to the PHY interface
  - **Smart-MAC**: a handshake procedure is used for discovering nanomachines within transmission range; the packet is delivered when at least one node has been found

NANO-SIM – main features

At the present stage, it implements:

- different kinds of devices forming a WNSN;
- message processing unit;
- routing module;
- two different Media Access Control protocols;
- **a physical interface based on the Time Spread On-Off Keying (TS-OOK) modulation**

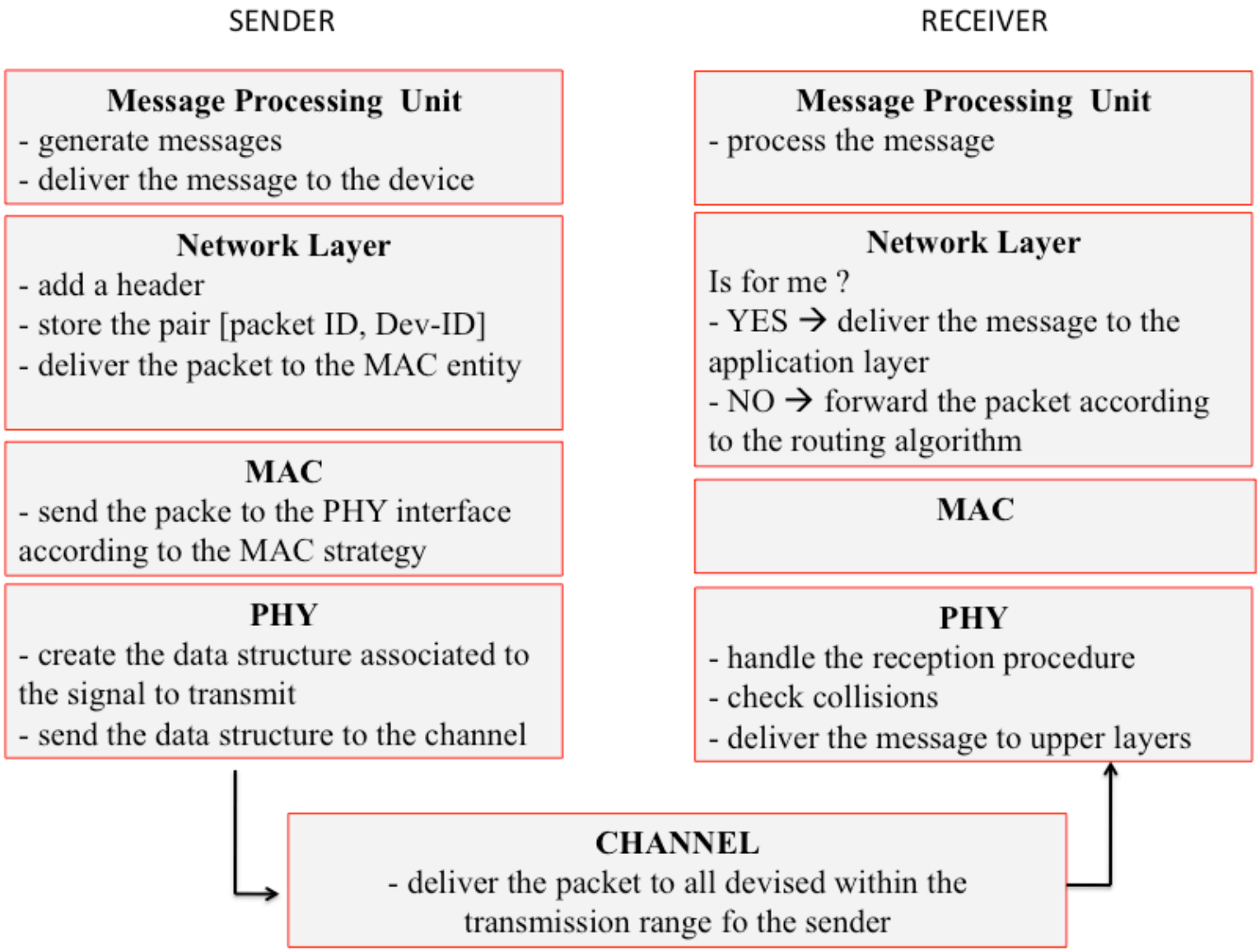


NANO-SIM – main features

At the present stage, it implements:

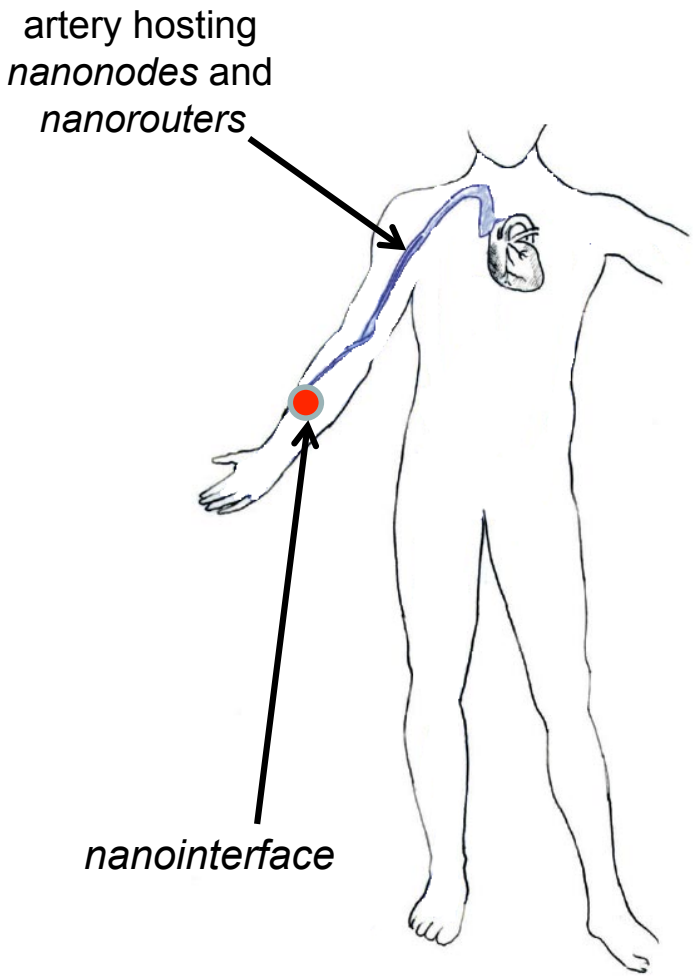
- different kinds of devices forming a WNSN;
- message processing unit;
- routing module;
- two different Media Access Control protocols;
- **PHY and channel entities have been implemented by extending the Spectrum Framework**
  - at this moment, the transmission is based on the knowledge of the transmission range

NANO-SIM – device's structure



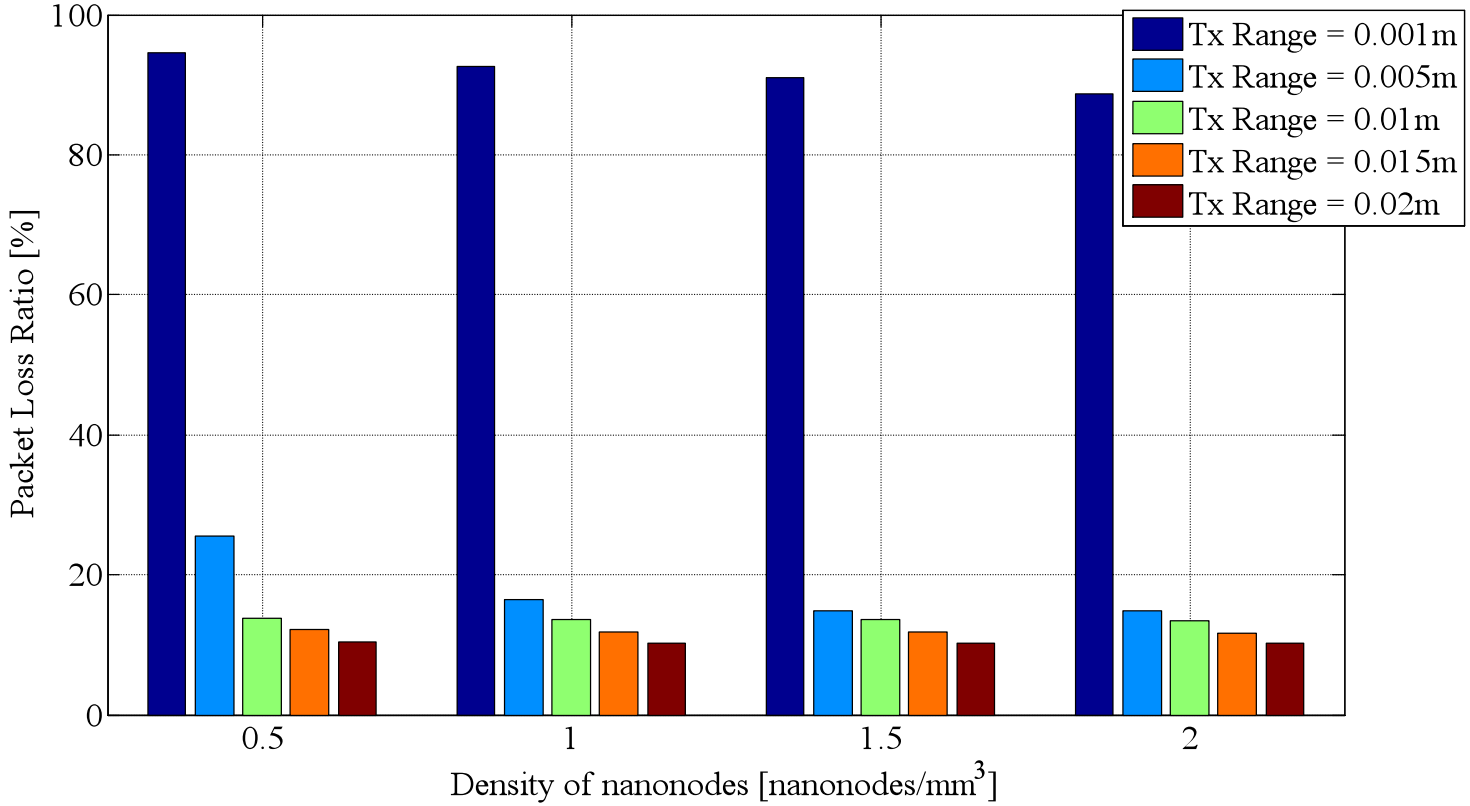
NANO-SIM – Performance Evaluation

We studied an health-monitoring system based on WNSN



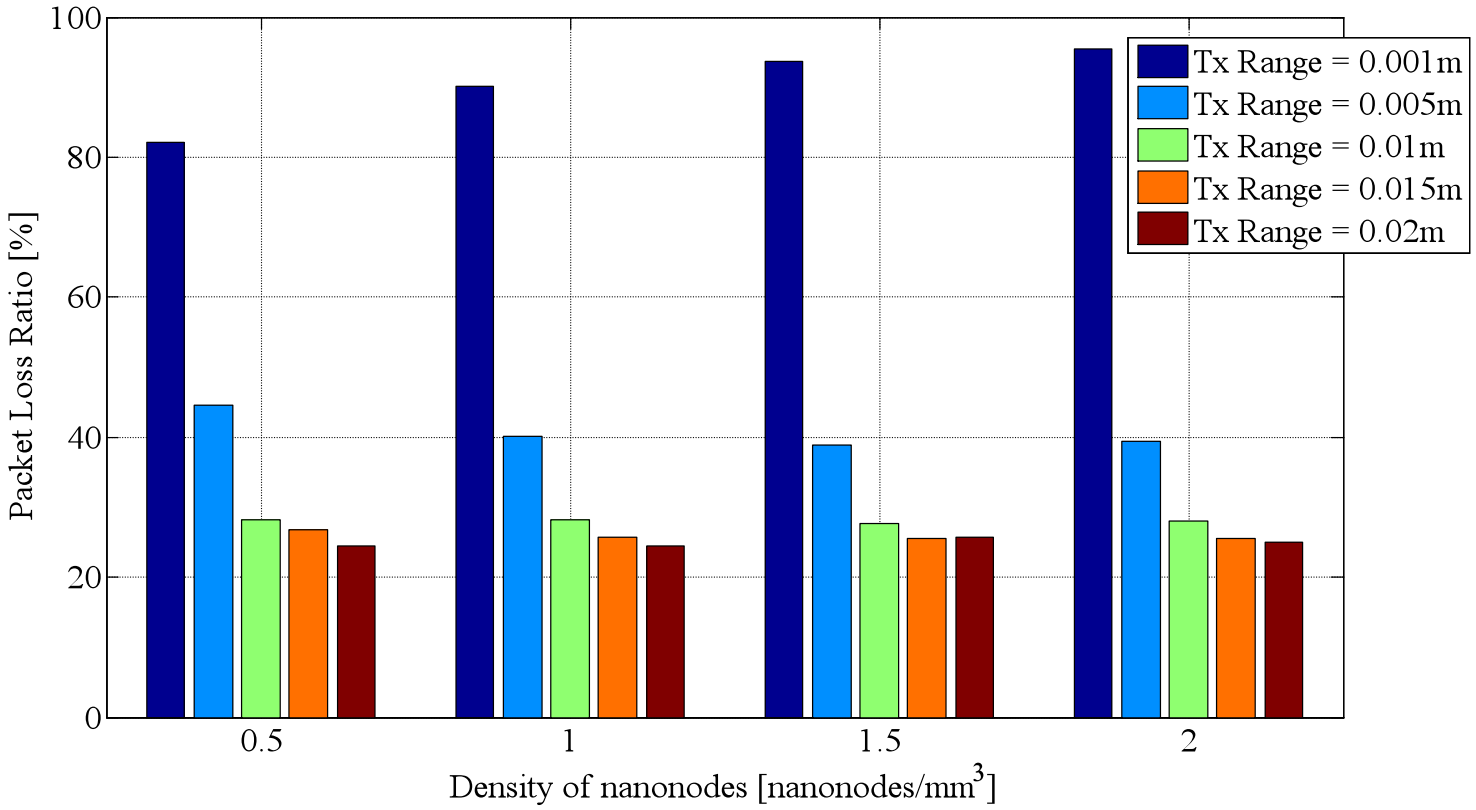
Parameter	Value
System parameters	
Simulation duration	5 s
Density of nanonodes	[0.5 - 2] $nodes/mm^3$
Number of nanointerfaces	1
Number of nanorouters	50
Artery size	$10^{-3} \times 10^{-3} \times 1.15\ m^3$
PHY details	
Pulse energy	100 pJ
Pulse duration	100 fs
Pulse Interarrival Time	10 ps
TX range of nanonodes	[0.001 - 0.02] m
TX range of nanorouters	0.02 m
MAC	
Backoff interval (only for the *Smart-MAC*)	[0 ns, 100 ns]
Network Layer	
Initial TTL value	100
MessageProcessingUnit	
Packet size	128 bytes
Message generation time interval	0.1 s

PLR – Transparent-MAC and Selective Flooding



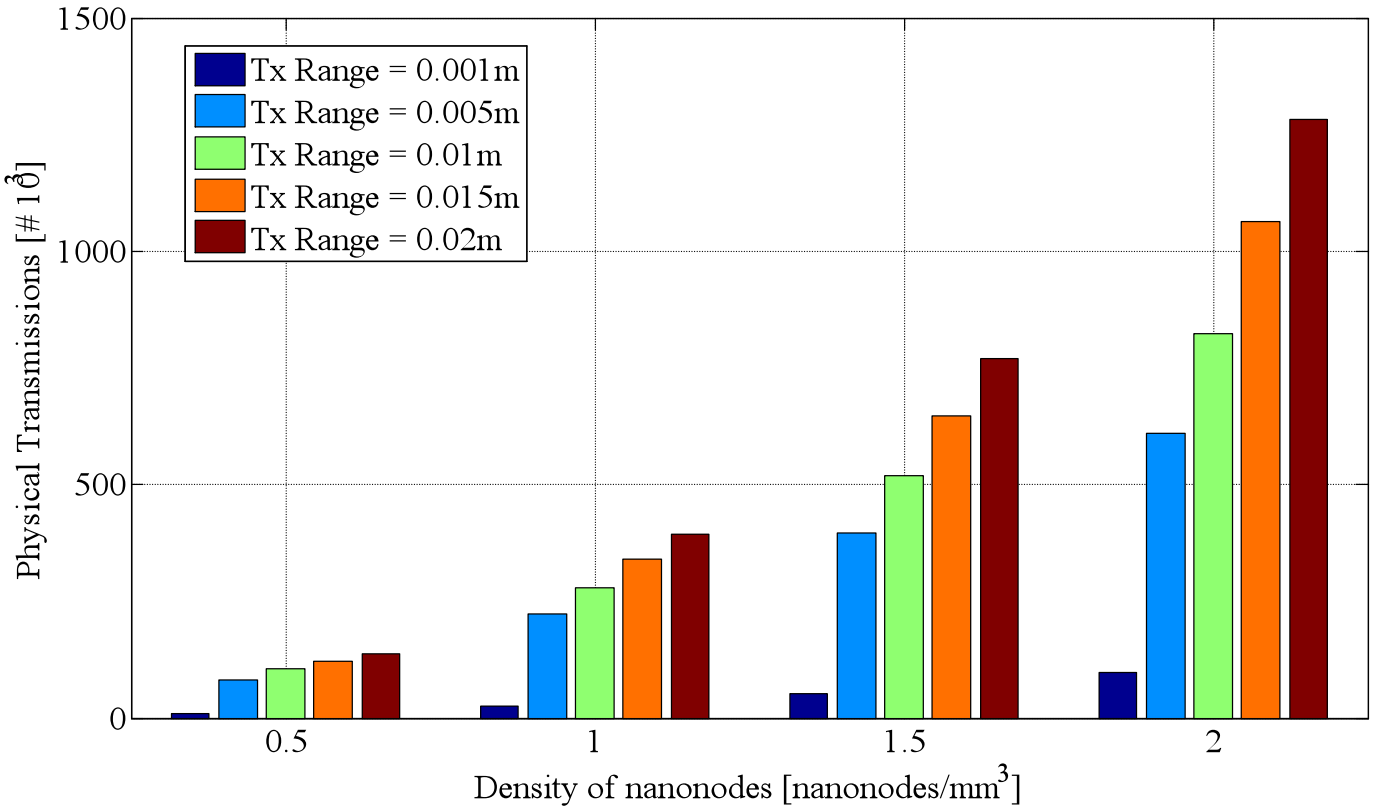
The PLR decreases as the density of nanonodes and their transmission range increase because there are more chances to find a multi-hop path to the nanorouter/nanointerface.

PLR – Smart-MAC and Random Routing



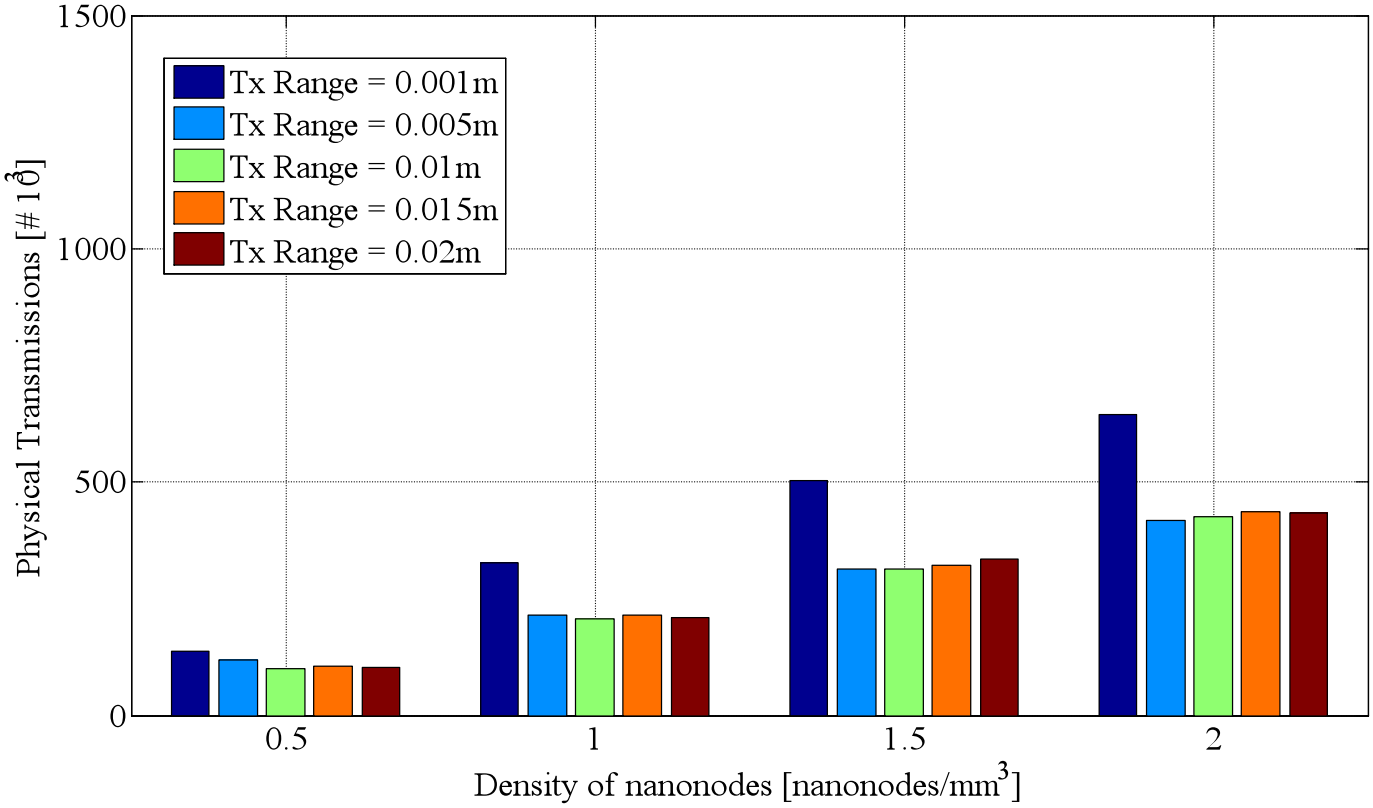
The random routing algorithm leads to a slight increase of the PLR: the random selection of the next hop may prevent to some packets to reach the destination before the expiration of the TTL.

Number of PHY Transmissions – Transparent-MAC and Selective Flooding



PHY transmissions increase with the density of nanonodes and the transmission range

PHY Transmissions – Smart-MAC and Random Routing



The random routing strategy is able to decrease the number of PHY transmissions

Conclusions and future works

We developed an open source tool modeling WNSNs within the NS-3 simulator.

We believe that, thanks to its extremely modularity, NANO-SIM has all the characteristics to become a reference tool for researchers working in the area of nano-networks.

As next steps of our work, we plan to extend the simulator by implementing new features, i.e., better routing and MAC protocols and more sophisticated PHY and channel models.

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Many thanks for your attention!

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