BitSimulator, an electromagnetic nanonetworks simulator

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http://eugen.dedu.free.fr/bitsimulator

NanoCom conference
Reykjavik, Iceland, September 5-7, 2018
THz wireless nanonetworks

Nanonetworks = wireless communicating nanomachines

- Small communication range: ~ cm
  => Need multi-hop for longer comm distances

- Nanonodes have not yet been built because of technological challenges
  => Need to develop simulation tools

- Nanonodes have unusual characteristics:
  - specific modulation (TS-OOK)
  - specific collisions
  - ...

Integration of several nano-machines into a single functional entity


Complete machine of µm size
TS-OOK

- To send bits "1" sender sends pulse, while for bits "0" a silence is used. Pulses are very short (e.g. ~100 femtoseconds).

- Pulses from a given frame are spread over a period much bigger than the pulse duration (e.g. 1000 times longer). This high spreading ratio makes frames from different communication overlap.

- At this scale, node positions influence the reception date. => the propagation delay (speed of light) cannot be neglected in studies.
Collisions

Collisions appear when several bits from different frames arrive at a receiver at (almost) the same time.

Not all collisions lead to errors; for instance those two frames are sent:

- **Packet 3 from S3**
  - **Signal:** 1, 1, 0, 1

- **Packet 4 from S4**
  - **Signal:** 1, 0, 1, 1

The only error occurs when the 1 bit from S3 hides the 0 bit (silence) from S4 at the receiver R2.

- **Signal received at R2:** 1, 1, 1, 1

- **Packet 3 value:** 1, 1, 1, 1

- **Packet 4 value:** 1, 1, 1, 1

Collisions appear differently on different nodes due to the propagation delay.
State of the art
NS3: NanoSim

• NanoSim: an NS3 extension

• Do not consider payload and propagation delay is not very precise
  => collisions cannot be correctly computed.

• Cannot handle networks with very high number of nodes
State of the art
COMSOL Multiphysics

- COMSOL Multiphysics is a very low level simulator: it can simulate physics behavior

- It is extremely precise

- It is very slow: can take several hours to simulate a scenario with a few nodes. It is useless on scenarios involving huge number of nodes. Our simulator can run scenarios with several thousands of nodes
State of the art

Vouivre

- Developed by our team
- Simulates a high number of nodes
- Does not take payload into account
- Uses a statistical model to compute collisions on frames
- Very difficult to lead some precise studies (e.g. on bit encoding)
Proposed simulator: BitSimulator

- Specific to nanonetworks
- Discrete event simulator
- Can handle numerous nodes: hundreds of thousands
- Time precision: 1 femtosecond
- Space precision: 1 nanometer
- Simulates each communication at bit level: can compute each collision individually
Implemented features

- Node memory (reception queue) can be configured
- Packet generation: CBR
- General routing protocols: Pure flooding, Probabilistic flooding
- Specific routing protocols: SLR, Backoff flooding, SLR backoff flooding
- Specific network protocol: Density Estimator for Dense Networks (DEDeN)
- Under active development

Network layers

- Applications: CBR
- Network: Several protocols
- Modulation: TS-OOK (simplified)
SLR / Backoff Flooding

SLR: Stateless Linear Routing

- Designed for nanonetworks
- Geocasting routing using relative positioning

Backoff flooding

- Enhancement of pure flooding that reduce the number of packet sent
- Compatible with SLR

[Diagram of SLR and Backoff Flooding]
DEDeN

- Density Estimator for Dense Networks
- An algorithm implemented in BitSimulator
- Designed for very dense networks (as nanonetworks can be)
- Can handle very wide range of densities: from few to several thousands of neighbors
- Divided in several rounds with increasing probabilities of sending local probes
  Tunable confidence using pre-computed probe threshold
- High performance in terms of estimation error and number of packets generated
Log system

● Various events are traced during the simulation (receptions, transmissions, collisions, …)

eventType   date(fs)   nodeID   packetType   flowId   sequenceNumber   collidedBits
4(reception) 3900234   2         3(densityInit) 1        0                       0

● Easy to add/remove items in log lines

● Easy to add/remove new types of line to trace various information during the simulation

● A log reader library is provided to automatically read and process logs

● Is used by VisualTracer …
VisualTracer

- Visualization tool for BitSimulator logs

- Shows step by step the propagation of frames through the network

- Separately displays node currently sending, correctly receiving and receiving a corrupted frame (due to a collision)

- Can also follow a node point of view in a chronogram mode
Conclusion

- BitSimulator is fully functional
- Specific to nanonetworks
- Some results have been validated with mathematical models
- The only simulator to treat collisions individually and allow a very high number of nodes
- Allows to test and develop new algorithms and protocols
- Reproducible simulations
- Easy to start with thanks to XML configuration files
- Actively developed
- Free software [http://eugen.dedu.free.fr/bitsimulator](http://eugen.dedu.free.fr/bitsimulator), new contributors are welcome