Going for large scale with nano-wireless simulations

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ABSTRACT

This material is based on work in progress.
With the advance of electronic and Micro Electro Mechanicals Systems (MEMS), swarm of communicating and collaborating micro-robots became very attractive. In this paper, we revisit Vouivre, a nano-wireless simulation library we previously developed. Using the specificities of the Terahertz radio channel as a foundation, we discuss and present an implementation that allows simulation of a larger number of concurrent transmissions between an even larger number of individual elements

1. INTRODUCTION

Reducing the size of the communication components and antennas down to the nano-metric scale considerably affects the system design compared to traditional radio systems and especially the working frequency that has to stick to the Teraherz range recently modeled in [5]. Concurrently, for simplicity and feasibility reasons, a simple pulse-based encoding scheme such as Time-Spread OnOff Keying (TS-OOK) [7] is required. In this context, we previously developed Vouivre [4, 3], a simulation library. This library aims at simulating nano-wireless communications using the channel model from [6]. It can be used in stand-alone mode or in conjunction with other simulators (such as DPRSIM [1] from the Claytronics project) who let Vouivre handle the communications while taking care of the interactions with the physical environment.

A tradeoff between simulation speed and precision in the computations had to be selected. The initial architecture of Vouivre was confortable with up to a few thousand simultaneous transmitters. But, as applications such as Claytronics may require much more individual elements, we present in this paper an extended version of Vouivre that scales to larger numbers of simulated elements.

2. SIMULATING LARGE SCALE NANO-COMMUNICATIONS

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A necessary tradeoff between level of detail and computation load has to be found when doing networking simulations. We decided for an event-based model as it was potentially very precise yet easily tunable to reduce the computation time.

2.1 Radio propagation and channel simulation

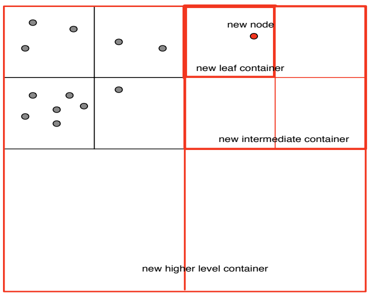
The radio channel model and the modulation used for nano-wireless are quite specific. For scalability reasons, we decided to use the statistical model from [7] which considers an environment with a constant transmitters density. Using the distance from the transmitter to the receiver along with the density, this mostly pre-computed model is able to give the attainable information rate for the given modulation parameters (pulse duration and β). In turn, the acceptance rate depends on the size of a packet (the longer the packet, the higher the probability to contain erroneous bits) and the type of redundancy and coding used, both informations easily available at simulation time.

2.2 Memory bottleneck

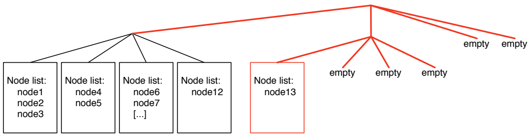
To compute the acceptance of each packet, we need to retrieve the currently applicable information rate. The information rate itself depends, among others, on the number of other active transmitters in the vicinity of the receiver. The number of active transmitters is tracked through an internal counter easily implemented thanks to the event model. To correctly increment and decrement this counter, for each transmission we have to query the geographical database for nodes in the detection range. Optimizing those queries is central to the scalability.

A mechanism is thus required to reduce the memory footprint of this database, similarly to what was done in [2]. We decided for an octree based algorithm.It it is efficient - $O(log(n))$ complexity - and predictable in its access time, and is also efficient in memory usage. A main advantage of this data structure is its ability to handle an almost infinite environment. The process of increasing the coverage of the data structure is illustrated in 2D on figure 1. New containers are created to encompass a new node, deepening the tree if necessary (added containers appears in red on figure 1(b)).

Using this structure as a foundation, when a node start to transmit, reception events have to be scheduled for all nodes in its vicinity. We query the octree for all the nodes in a given radius around a transmitter. As we will see, the size of the so called "bag" will have a strong effect on the performances but may hamper the quality of the results if set too small.



(a) New cells are created to enclose a new node



(b) The extended corresponding quad-tree

Figure 1: 2D illustration: extending the quad-tree to include a new outside node

3. SIMULATIONS AND ANALYSIS

Depending on simulations, the universe contains from 40 to 100 000 nodes. All nodes are configured to continuously send 20 bytes messages.In the presented scenario, in order to increase performances, the binary content of messages is not specified.

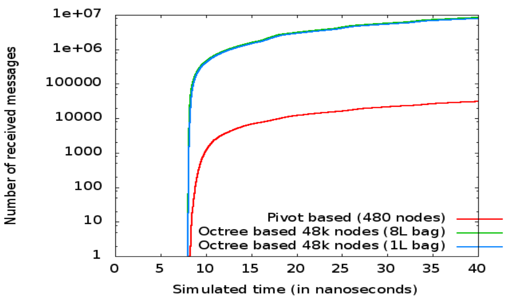


Figure 2: Received messages in function of the simulated time (for 480 nodes pivot based simulation and for 48 000 nodes octree based simulations)

The figure 2 shows the number of received messages in function of the simulated time. Initial packets reception is delayed due to the nodes boot sequence along with the propagation delay (3ns/meter). The superiority in simulation time of the octree model is clear, but the bag size also has an impact on the performances.

To compare simulation quality results of the pivot and octree based systems, we conducted 5 simulations with 1 000 nodes. The first one is pivot based. For others, the bag volume was respectively 1, 27, 216 and 1000 liters. Detailed graphics are not shown due to space constrains. The pivot model is inherently more accurate, but basically a bigger bag means concurrent transmissions are taken into account farther from the transmitter and consequently an increasing accuracy.

A tradeoff exists between the CPU cost and the simulation accuracy in terms of received messages.A bigger bag is the more accurate because it models more interactions between nodes and octree areas. However, the figure 3 indicates that increasing the bag volume over a liter consume more and more CPU.

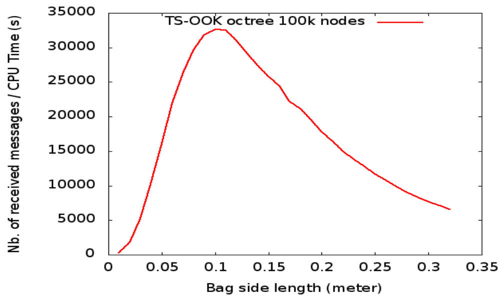


Figure 3: Tradeoff between CPU ressources cost and simulation accuracy

4. CONCLUSION

This paper proposes a new octree based algorithm to simulate nanowireless communications. Large scale simulations implies tradeoffs between the quality of simulations and scalability. The previous algorithm based on pivot system is more accurate but is unable to simulate more than 1 000 concurrent transmitters in an reasonable time. The algorithm proposed here is able to simulate hundred of thousands of nodes with the same ressources by using a good tradeoff.

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