MINI-ROBOT VIA WIRELESS COMMUNICATION

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ABSTRACT

The Emergence Of Nano-Electromagnetic Communications Supported Graphene Nano-Antennas Has Opened New Perspectives For Communications Between Small Things, Referred As To The Web Of Mini-Things Or Maybe Because The Internet Of Nano-Things. However, These Antennas Make Use Of The Terahertz Band Which Raises Many Problems Just Like The Absorption Of Entire Range Of The Available Bandwidth By Any Molecule. Meanwhile, Recent Advances Are Made Within The Design And Fabrication Of Mini-Robots Enabling Formation Of Minirobots Networks. Nano-Antennas Are A Stimulating Way Of Communicating Between Mini-Robots. We Envision Two Types Of Bene_Ts Using Integrated Nano-Antennas In Mini-Robots. Second, nano wireless communications can create new applications and new applications.This Article Presents A Simulation Framework For Mini-Robots Using Nano-Wireless Communications And An Application Being Developed Within Our Simulator.

KEYWORDS

Nano-Wireless Communications, Simulation, Mems Mini-Robots

1. INTRODUCTION

These last years, di_erent works have opened new perspectivesfor nano-electromagnetic communications. First studies have de_ned the research challenges and possible applicationsof nano-communications using carbon nano-tubes This work has been funded by the Labex ACTION program or nano-wireless communication while some others have denied the idea of nano-wireless communications using grapheme nano-antennas. These works have changed the perspectives for communicating between small things.

The internet of things (IoT) changed his scale to travel mini with the internet of mini-things or maybe smaller with the internet of nano-things. However, these antennas make use of the Terahertz band which raises many problems just like the absorption of entire ranges of the available bandwidth by interactions with all molecules or proposing an energy-e_cient physical layer. These properties are varying regarding to the environment and the application.

Absorption is indeed not the same if the transmission is formed in an open environment composed of air, during a body or inside an ensemble of mini-robots. the large bandwidth of the Terahertz band o_ers many di_erent possibilities for the planning of the physical layer and variety of potential applications will have di_erent needs starting from multimedia transmission, mini-robots communications, distributed intelligent mini-electro-mechanical-systems (MEMS), to replacement of bus for core to memory communications.

We therefore think that a cross-layer approach is required in the design of the communication layers of nano-wireless communications. Recent advances within the _eld of MEMS, are enabling the planning and fabrication of distributed intelligent MEMS (Di-MEMS). A node during a DiMEMS system is essentially composed of actuators, sensors, a processing unit and communicationcapabilities, which makes it a mini-robot.

It is the interconnection of those mini-robots that triggers the emergence of a worldwide behavior. All the present projects on DiMEMS systems are using wired or communications bycontact. If nano-antennas are integrated in DiMEMS systems, it might be a stimulating way of communicate between mini-robots. We envision two sorts of bene_ts using integrated nano-antennas within a mini-robots ensemble.

First, nano-wireless communications can enhance existing applications and enable broadcasting over a longer communication distance within a group.Second, nano-wireless communications can create new applications and new applications.during a previous work , we've studied the integration of wireless capabilities in mini-robots of the Claytronics project, showing the enhancement created by wireless communications, but nano-wireless communications was out of the scope of this former article. This article presents a simulation framework for mini-robots using nano-wireless communications, and several applications are being developed within this simulator.

2. RELATED WORKS

2.1 Modular mini-robots

The programmable matter (i.e. _gure 1) _eld makes use of small robots that fall within the "`modular robots"' category. Here, robots have scale starting from a couple of centimetre. Those small to very small robots attach (or detach) to make virtually any macro-structure they're required to. By actuating their features, catoms are ready to move around their direct neighbours similarly as a stepper motor.

2.2 Wireless network simulation for modular robots

There are several network simulators that propose wireless network simulations. the 2 most utilized in the research community are NS3 they provide support for mobility and this characteristic could enable their usage for network simulation of modular robots.

Unfortunately, these simulators don't physics and real-world modeling: mobile network nodes are only 2D objects with no support for collision then on. However, it might be possible to plug an external simulator which could lookout of the physics but the network simulation is just too detailed for our needs which limits the scalability to thousands of node. The same comments apply to other simulators like,

- SSFNet,
- OPNET,
- QualNet or J-Sim
- Nano-wireless simulation

It's still in an early stage. Preliminary works are done in Nano-Sim a plugin of NS-3. Although this simulator is a very interesting achievement, Nano-sim doesn't model physics nor real-world constraints and scalability is limited to few thousands of nodes.

It does neither take into account the radio propagation delay which will be of utmost importance at the considered scales.Many modular robots simulators are designed over the years. Very _rst works are simulators which are dedicated to speci_c hardware like Molecubes or Cross-Cube and thus lack of genericity. ARGoS is fast and can simulate 100,000 robots. However, ARGoS targets are robots and not really modular robots.Finally, DPRSim appears to be unbeatable for the scalability as the most enceinte simulators report 100x less simulated number of nodes.

3. CONTEXT

3.1 DPRSim

Dynamic Physical Rendering Simulator (DPRSim) has been developed by Intel since 2006 for the Claytronics project of the Carnegie Mellon University. The simulator is meant to support a potentially very large number (up to many millions) of Claytronics mini-robots called catoms. DPRSim internally makes use of ODE (Open Dynamics Engine, a rigid body dynamic library) and may provide detailed physical simulation for its virtual world (albeit activating physical simulation signi_cantly reduces the number of simulated elements). An optional 3D graphical interface is additionally provided through Drawstu_, the default 3D environment visualization tool included in ODE. For performance considerations, DPRSim is written in C++ and may also add mono or multi-threaded mode.

In DPRSim, each catom is individually represented by an object instance, and therefore the code running on a catom is named a "CodeModule"which is additionally individually instantiated. Someone designing a replacement Claytronics application has got to write its own CodeModule then load it into the simulated catoms.

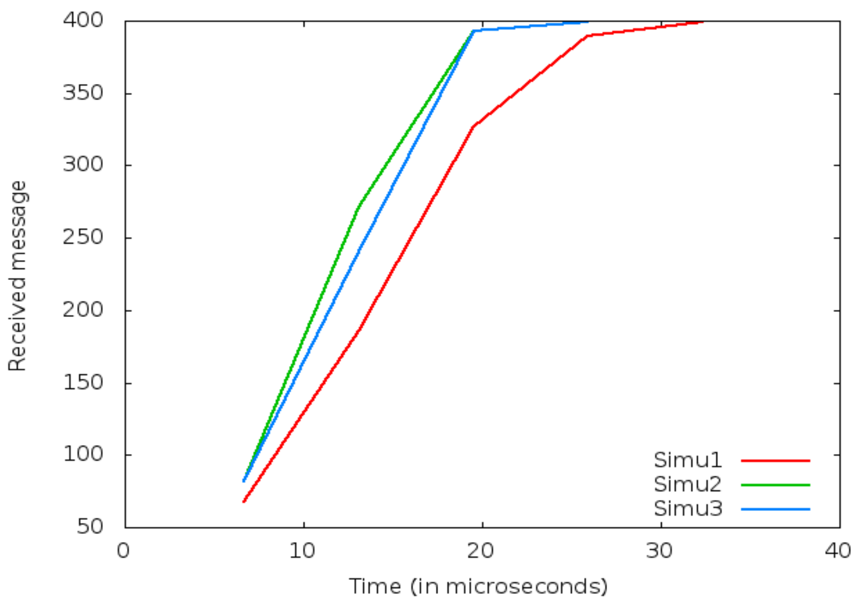
CodeModules are often written in C++ but, part of the claytronics project, is additionally the Meld language. Meld is a declarative language aiming at easing the event of large scale distributed applications. One can write melt programs that are automatically converted into code-modules that are ready to run in DPRC.

In we expanded DPRSIM by adding a wireless communication capability to the simulated catoms. Allowing wireless transmission in such an environment open the trail to new area of thrilling applications. This extension for DPRSIM had to integrate well with the simulator's internal work, especially the time-division system.

DPRSim uses a time-slicing approach, with an atomic duration step (called a "tick"), and processes the entire simulation step by step. A tick isn't a divisible duration and this has many repercussions, especially on the messaging system.

If activated, the physical simulation (ODE library) uses it own time-slicing - which is independent but has got to be con-_gured conjointly with the most DPRSim's time-slicing. We developed a replacement simulator component called "Vouivre" able to handle the radio channel and therefore the its concurrent access. Vouivre are often used as a standalone wireless network simulator, but also can be used as a library during a slightly modi_ed DPRSIM or other network simulator. Vouivre is discrete-event based, and proposes an adaptable tradeo_ between complexity and realism of the network. Going for millions of nodes sharing a medium isn't possible at this point , but it's still possible to tune it to travel largely over the few thousands most dedicated and detailed network simulators can do.

To link DPRSim with our new network simulator, 3 majors changes are delivered to DPRSim:The _rst one and most vital for the work later presented in this paper is to invoke at each Tick, a progression of the simulated network time.From the purpose ofview of Vouivre, the duration of a DPRSim's tick is de_ned as constant. it's important to con_gure this point jumping duration to be an equivalent because the duration of the intra-tick time interval de_ned for the physics engine ODE. Consequently, in the _gure 3, the duration between t0 and t1 is that the same for Vouivre and ODE. Failing to try to to so, the network time would ow slower or faster than the physics time and therefore the data rates of network interfaces wouldn't have sense anymore.



During each tick processing, DPRSim lets Vouivre process the discrete events which are scheduled for this time interval. From a di_erent perspective, we should consider that the network simulation is periodically stalled to allow DPRSim to simulate CodeModules of catoms and to allow ODE to simulate physics.The The second change is to disable the previous method dedicated to communications on wire interfaces.

The prevailing mailbox system of DPRSim has still been preserved to keep compatibility with already existing CodeModules and Meld applications.

To avoid the synchronism barrier induced by the time-slicing operating mode, the prevailing mailbox callback system need to be utilized in "live mode" instead of "delayed" mode. this enables for multiple small messages to be exchanged back and forth during an equivalent DPRSim tick. a replacement sort of interface has been added, because the WirelessNetworkAdapter, which enables access to a shared radio channel. NetworkAdapters like the traditional wired interfaces have also been modi_ed to be managed by our network simulator. allowing simulations of wired communication over shared mediums like wired buses. The last important change may be a mapping between DPRSim structures representing catoms and therefore the corresponding Vouivre network nodes. Each network node can have several network interfaces. they will be wired or wireless interfaces. This mapping is built on the creation of a depressing simulation universe in the world of "Cadam World".

3.2 Nano-wireless communications

this text de_nes the di_erent sorts of nanonetworks media (nanomechanical, acoustic, electromagnetic and chemical or molecular) and de_nes the nanomachines in a similar thanks to Berlin in but extended it to a bio-hybrid approach. during this article, the molecular communication is preferred to because the electromagnetic one. In following articles, Jornet, Akyildiz and al. present the concept of CNT-based nano-antennas in along side a _rst attempt to de_ne its characteristics .In the HIgh resolution proposed a path loss model using the TRANsmission molecular absorption database (HITRAN).

HITRAN measure the absorption electro-magnetic radiation for di_erent frequencies transmitted in di_erent gas. Started within the 60s, with only seven gas within the infrared, they need now a good range of gas and frequencies

4. NANO-WIRELESS COMMUNICATIONS IN DPRSIM

4.1 Implementation

In, we had already interfaced the time-slicing DPR Simsimulator with our own discrete-event simulator called Vouivre.In the current paper, we used this as a base to implement nano-wireless communications into DPRSim. The thanks to imbricate the timelines (as shown on Figure 3) developed for the previous version of Vouivre might be kept as is. The timescale necessary to represent the events happening in nano-wireless communications has got to be extremely small. Nano-networks add multiple THz wide band and therefore the duration of a TS-OOK pulse is bellow one picosecond.

This is not a drag for a discrete-event simulator like Vouivre. But the appliance code processing the received messages is executing in DPRSim and is merely called at each DPRSim TICK. This was causing an usually long latency between the reception of a message and its processing. To prevent this it had been necessary to scale back the duration of a TICK. As a side-e_ect, as DPRSim also call ODE (its physic simulation engine) between each TICK to update position and velocity, the simulation performances could have degraded a lot. To be ready to correctly simulate TS-OOK nano-communications and still have reasonably fast simulation, we decided for a 100 picoseconds TICK duration as a trade-o_. Up to the present duration is however added as a delay before processing a message. In most scenarii this will be considered harmless.

In our previous work , we used the Friss propagation model employing a 2.4GHz centered waveband . Such long range radio transmitters were kept in Vouivre/DPRSim to allow ulterior studies of hybrid systems.Using nano-communications between nodes along side larger ones ready to communicate over relatively long distance could indeed pave to thanks to exciting applications.

We implemented new interfaces using TS-OOK over an equivalent discreteevent model we used before. The channel model can now be changed on the y. within the following work, only the TS-OOK interface were used with logical "1" being the _rst derivative of a 100 femtosecond long Gaussian pulse and a duration between symbols of 5 picoseconds.

At the envisioned physical scale (nano-devices scattered over areas starting from square centimeters to face meters) and because of the extremely small duration of the pulses, the signal propagation delay has got to be taking under consideration . The propagation (~3 nanoseconds per meter) delay are often greater than the duration of a pulse and intrinsically collisions can easily occur.

Sender S1 sends a "1" (as a pulse) and S2 later send a "0" as an absence of pulse. Because receiver R1 is at the same distance from S1 and S2, it received those symbols one after the opposite and decodes them correctly. Receiver R2 is much closer from S2 than from S1. because the propagation delay from S1 is longer, the 2 symbols overlap and therefore the "0" from S2 is masked by the "1" from S1. Moreover, catoms are mobile objects and therefore the distances can vary over time.

As pulses are comparatively very short to the time between them, the probability of a collision is small. If the symbol being received for the present packet may be a "1", other concurrent "1" or "0" won't directly a_ect it. only receiving a "0", if a "1" is transmited at the same there'll be a knowledge corruption.

4.2 Multi hop flooding during a dense environment

In the following scenario, an initial phase will send a 53 byte packet to its neighbors.This packet will then be retransmitted hop by hop until the entire network has been covered. to raised illustrate the behavior of the protocol, receiving this packet will trigger the coloring of the catom on the screenshots. the colour itself will depend upon the last re-transmitter. to stop an everlasting ooding, the message contains a sequence number and may by re-transmitted only one time per catom.

5. CONCLUSION

We presented a simulation framework for electromagnetic nano-wireless network within the Terahertz band. This simulator called Vouivre is plugged during a modular robots simulator environment called DPRSim. so as to simulate the communications we integrated the model proposed by Jornet and Akyildiz. We precomputed the transmission parameters to allow fast simulations and that we took under consideration the propagation delay which may completely change the perturbations. We keep the simulation as accurate as possible by counting the number of simultaneous communications so because the probability of reception might be modied consistent with this number. One problem remains, as nano-wireless uses very short periods of your time , the physics has got to be cut briefly periods of time also slowing down the simulation. Our main future work are going to be to use an entire discrete-event simulator which will be ready to manage nano-communications and physics as events. the event of this simulator called VisibleSim has already begun.

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