WSim et WSNet : outils de simulation pour le développement d'application de réseaux de capteurs

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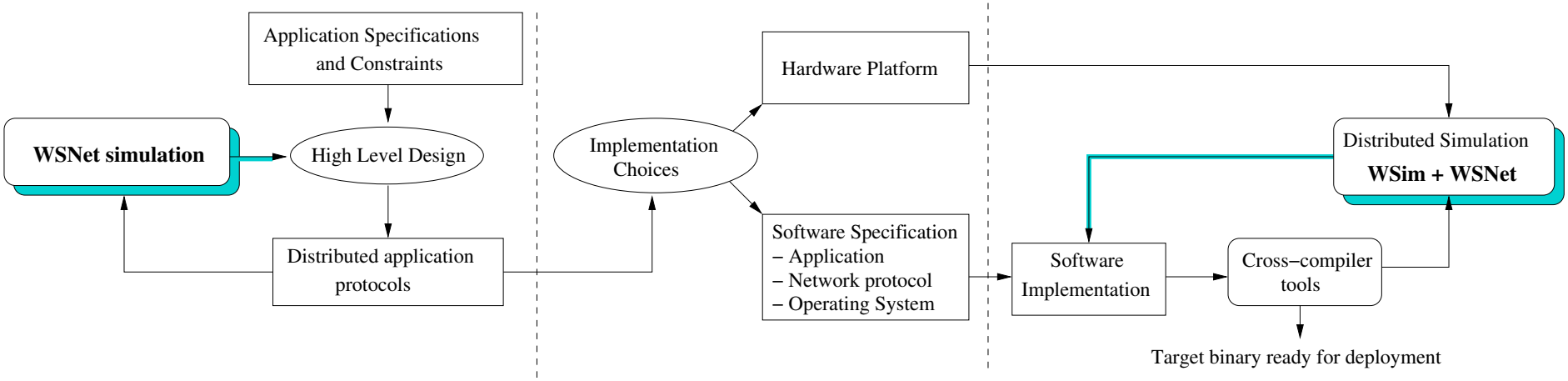
Utilisation des outils dans la conception



High Level Design of Distributed Application | **Design Implementation Choices** | **Performance Evaluation and System Validation**

Outils

WSim : simulation de la plate-forme matérielle

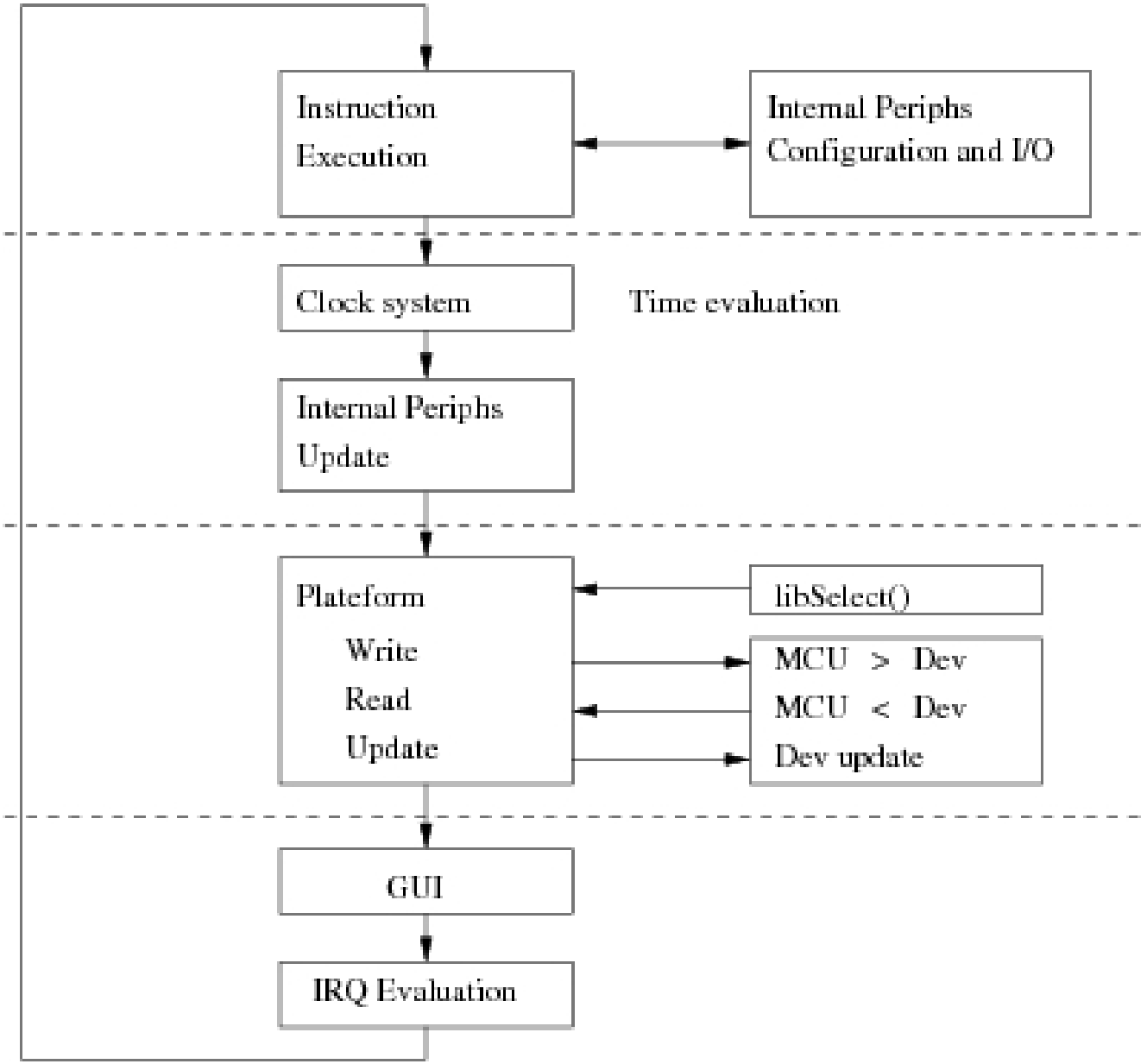
- Simulation précise en temps
- Plateforme complète
- Intéraction avec WSNet pour la simulation du réseau
- Utilise le binaire final de l'application

WSNet : Simulateur de réseau radio

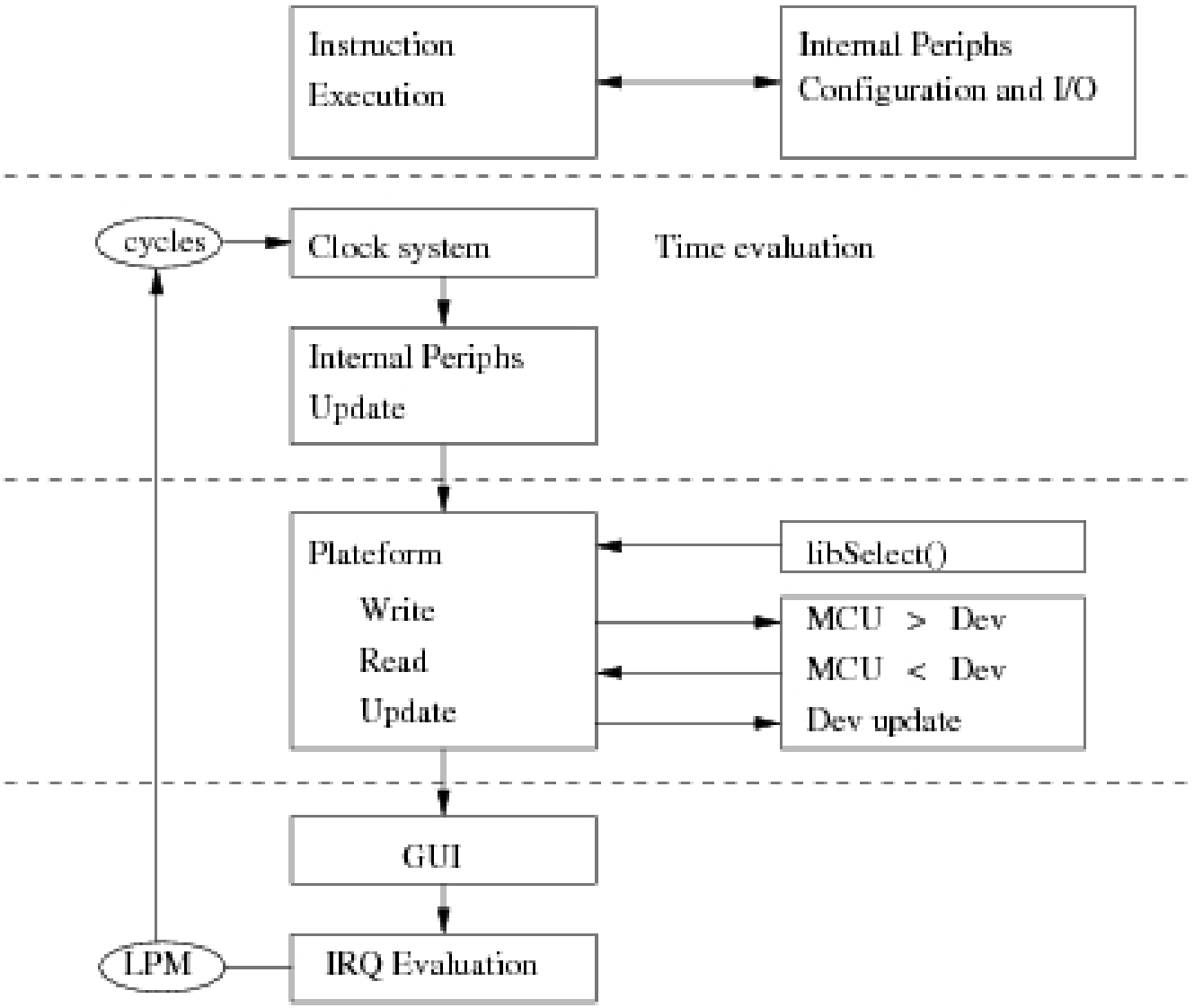
- Simulation événementielle
- Utilisation du simulateur pour les couches physique et radio
- Fonrtend UDP/IP (multicast)

WSNet + WSim : complete distributed system simulation

WSim : boucle de simulation



WSim : boucle de simulation



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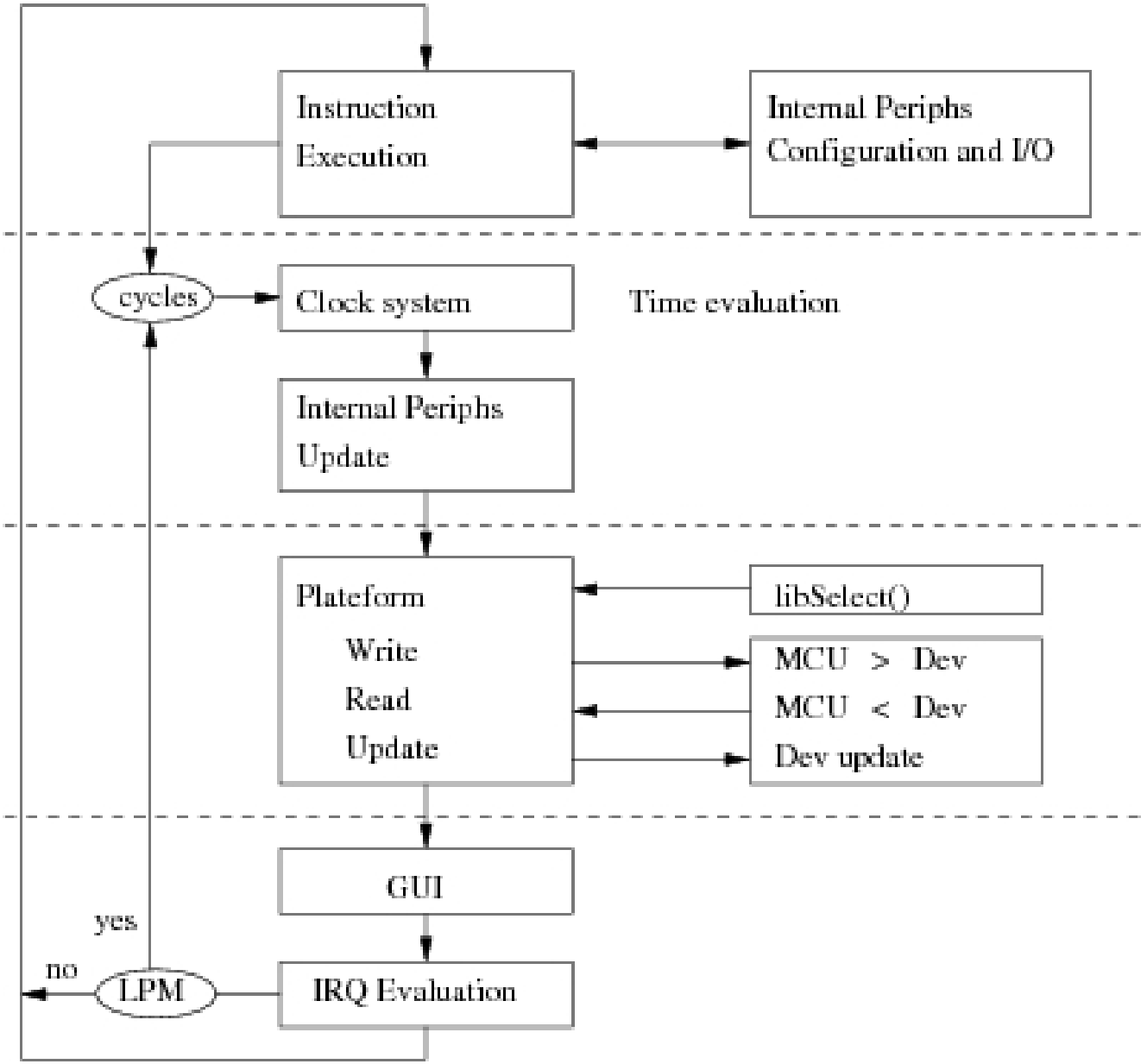
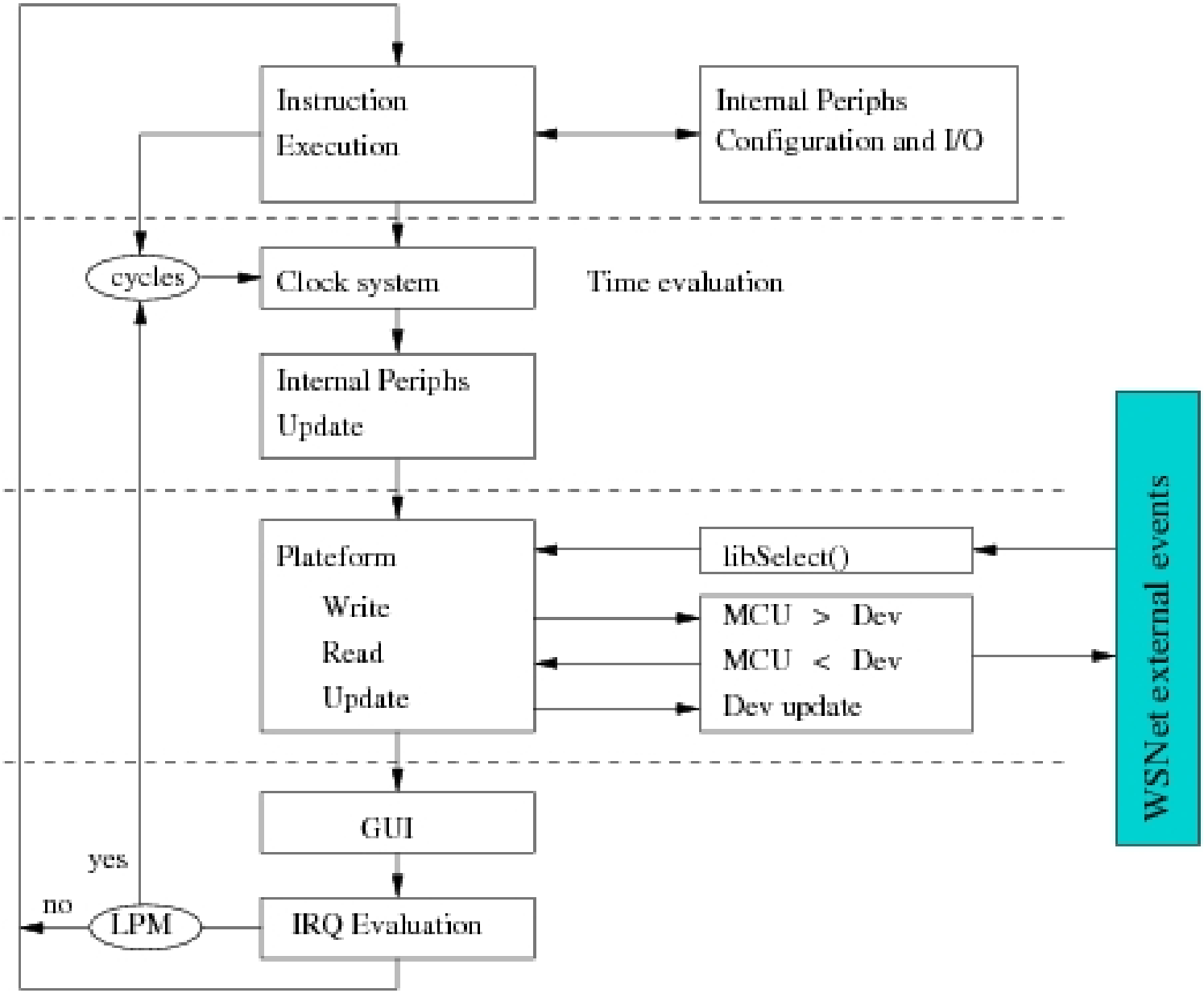
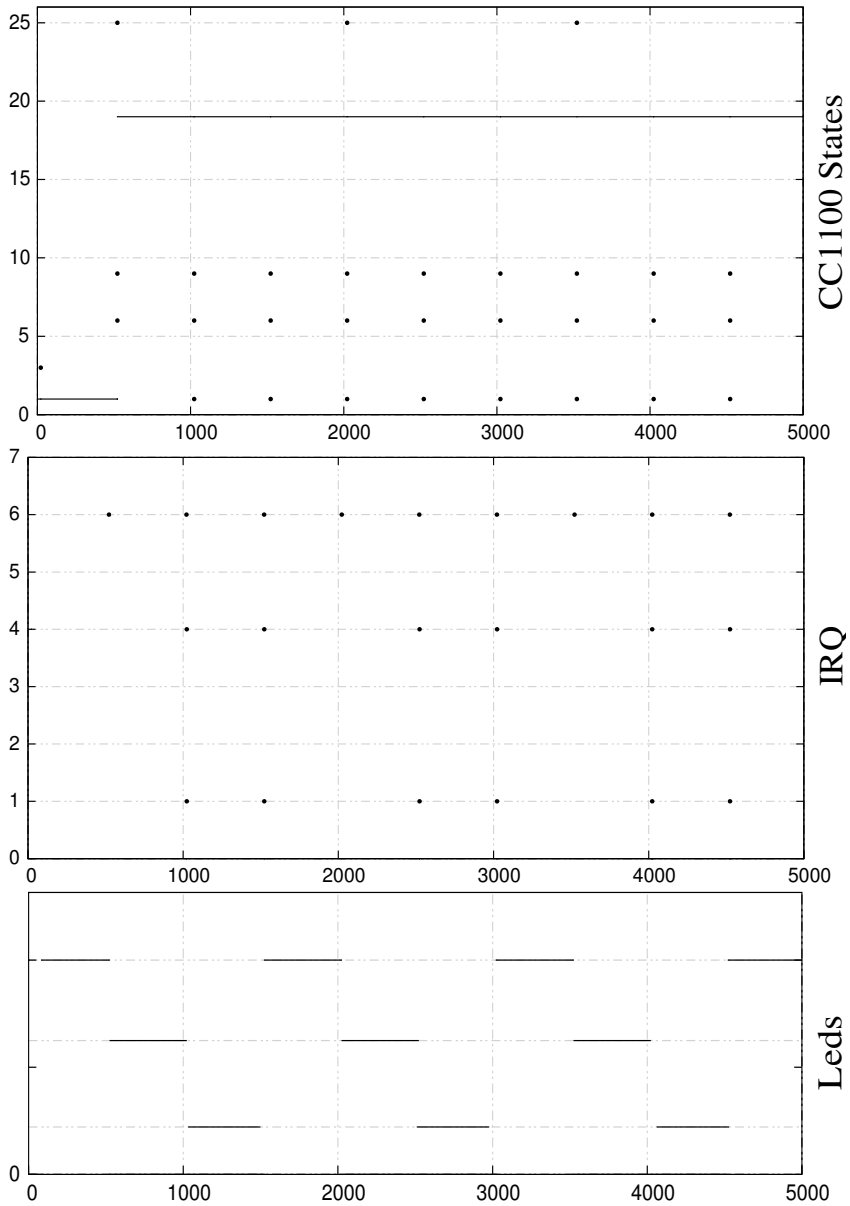


WSim : boucle de simulation



Simulation précise à l'instruction



Traces générées

- Interruptions / activité
- Mode de veille
- Communications

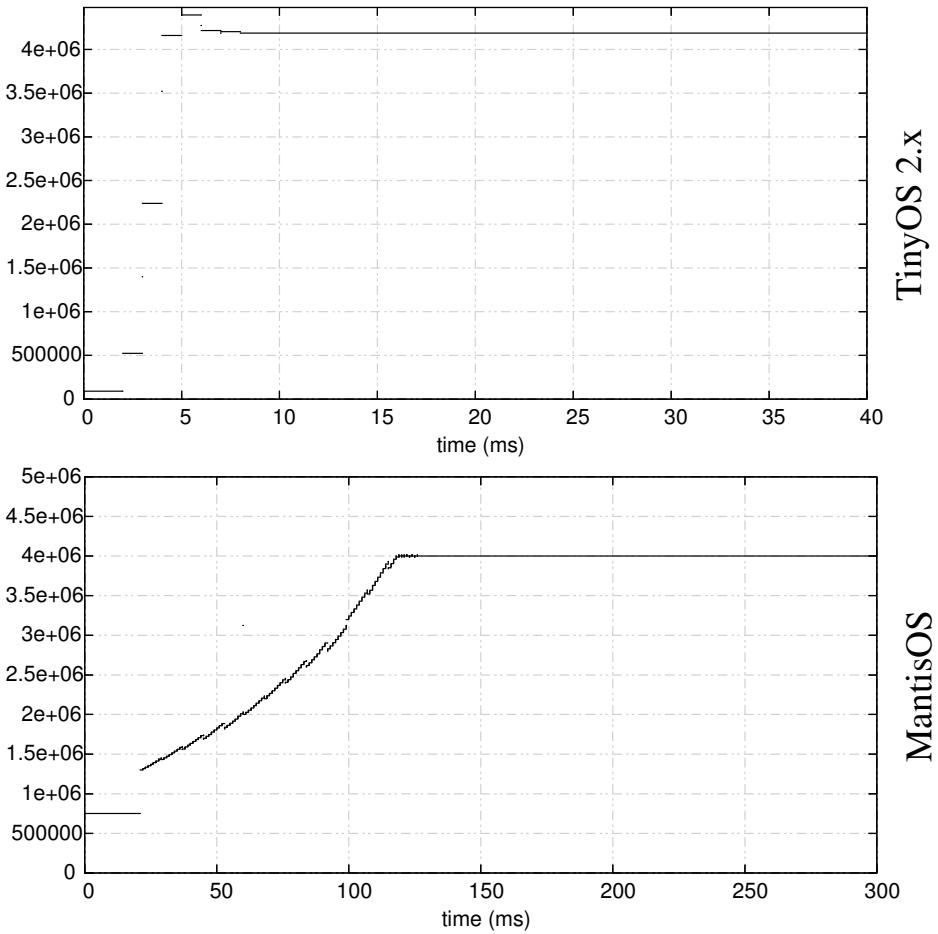
Activité des nœuds

- Evénements radio
- Analyse hors-ligne

Evaluation de performance

- Instructions
- Emprunte Mémoire
- *Consommation*

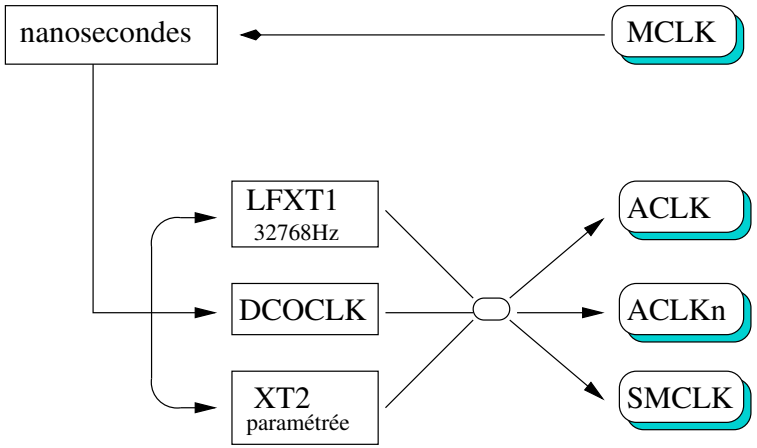
Gestion des fréquences des micro-contrôleurs



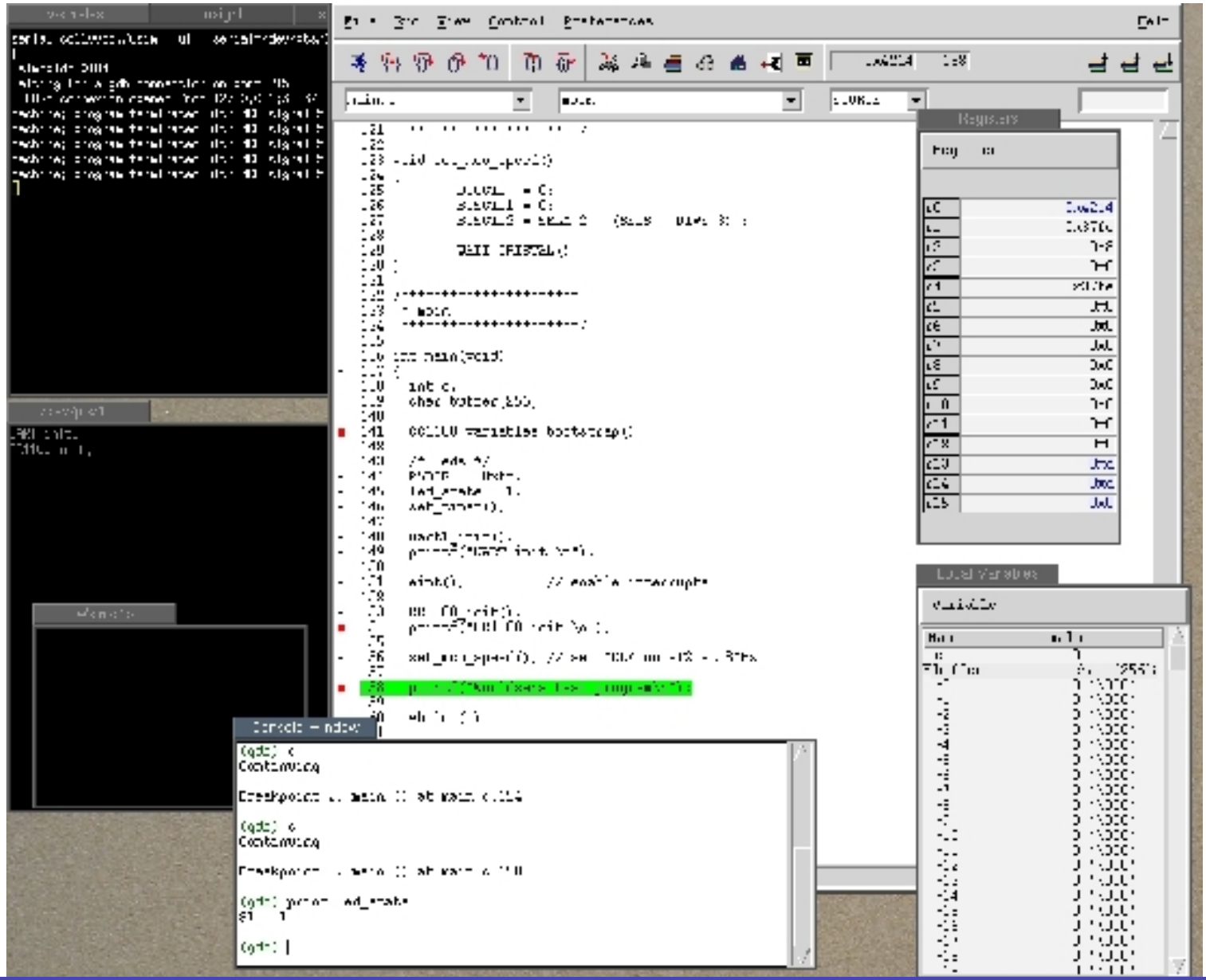
Clock modules simulation

- Fréquences variables
- Dérive d'horloge
- Estimation de la puissance et énergie

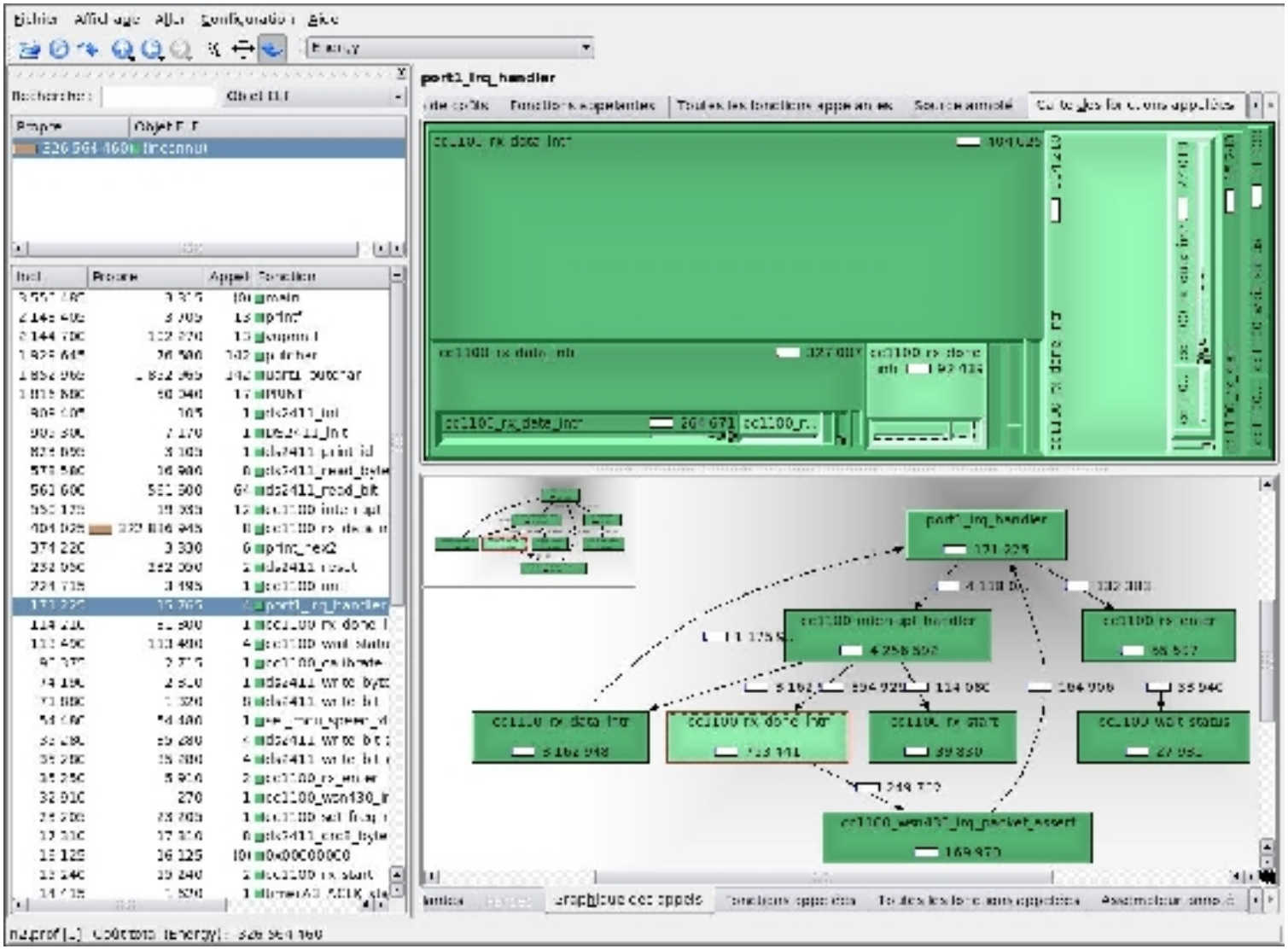
Simulation du système d'horloge



Debug



Annotation du code source

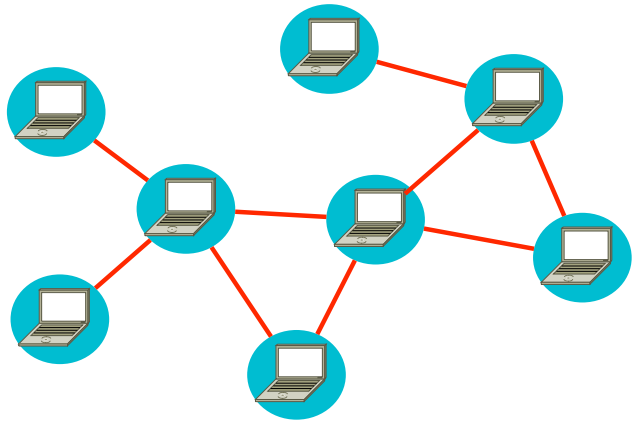


Utilisation d'eSimu, travail de thèse de Nicolas Fournel.

Performance evaluation of wireless Networks

Wireless multi-hop networks (adhoc/sensor/mesh) :

- Large number of wireless nodes
- Self-organizing network
- Unreliable radio link
- Application-specific constraints : mobility, energy, *etc.*



Performance evaluation of wireless systems :

- Analytical models (stochastic geometry, percolation, random processes, Markov chains)
- One-shot experiments or setting-up of large scale tesbeds
- Simulation is generally the most convenient performance evaluation methodology

Simulation of wireless networks : bestiary

A wide range of alternatives : NS-2, NS-3, Glo- MoSim, JiST/SWANS, GTSNetS, OPNET, OMNeT++, J-Sim, QualNet, *etc.*

Same global architecture → discrete time event-driven simulation

But differs in many aspects :

- implementation :
  - *user interface* : simulation scripting, simulation monitoring
  - *developper interface* : programing language, development integration
  - *simulator internal* : mobility management, event management
- modeling :
  - node architecture
  - radio medium properties
  - environment

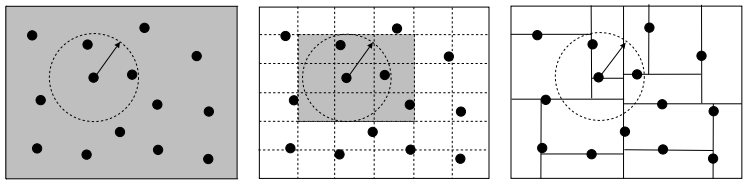
Simulation of wireless networks : bestiary

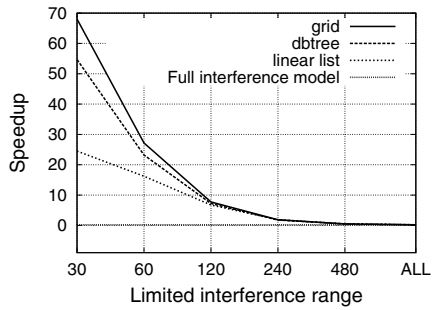
	Jist/Swan	GTNets	GlomoSim	NS-2
Licence	Academic	GPL	Academic	GPL
Language / API	Java	C++	C/C++	C/TCL
Area dimension	2D	2D	2D	2D
Space partitioning	Hierarchical binning	Flat	Flat	Flat/Grid
Event queue	Heap	B tree	Splay tree	List

E.g. mobility management

What are the nodes y such that $d(x, y) < l$?

Node position management : `flat` / `grid` / `dbtree`/ `quadtree` architectures.





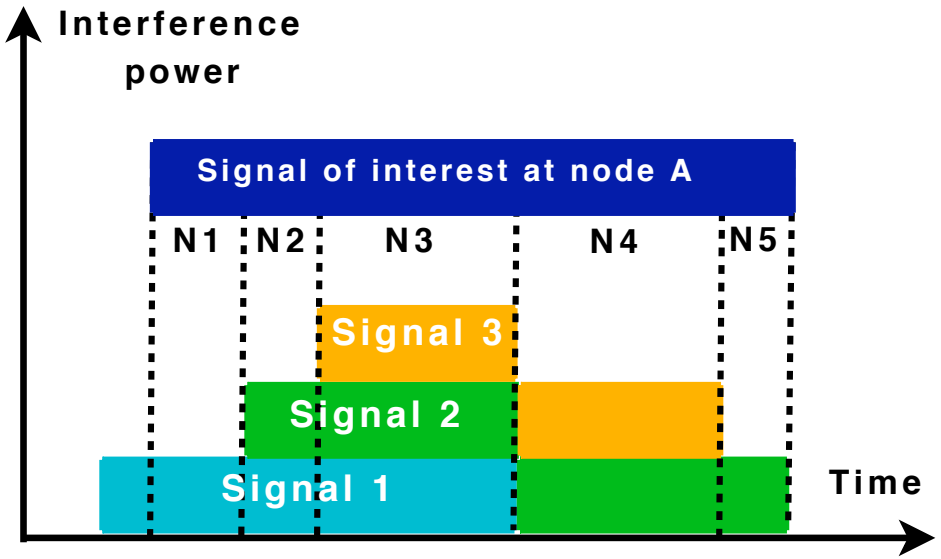
When to update node locations ?

- *when needed :* event-driven
- *periodically :* time-driven
- *hybrid :* $max(time, event)$-driven

E.g. radio modeling

SINR computation vary from a simulator to another :

- strongest : $SINR_A = \frac{N_A}{N3}$
- cumulative : $SINR_A = \frac{N_A}{N5}$
- adaptative : $SINR_{A_1} = \frac{N_A}{N1}$, $SINR_{A_2} = \frac{N_A}{N2} \ldots$



E.g. radio modeling

Models	NS2	GloMoSim	JiST/SWANS	GTSNetS	WSNet
Pathloss	freespace tworay	freespace tworay	freespace tworay	freespace tworay	freespace tworay
Shadowing	log-normal	log-normal	-	-	log-normal
Fading	rician,rayleigh	rician,rayleigh	rician,rayleigh,...	-	rician,rayleigh
Radio link	threshold	threshold,BER	threshold,BER	threshold	threshold,BER
Modulation	-	BPSK,QPSK	BPSK	-	BPSK,OQPSK,...
Interference	limited	limited	limited	limited	limited,full
SINR	strongest signal	adaptive	cumulative	strongest signal	adaptive cumulative

Interference modeling is the point where current simulators differ the most largely.

Other aspects not addressed here : capture effect, propagation delay, adjacent-channel inteference, antenna radiation patterns, *etc.*

Simulation of wireless networks

Numerous simulators have been proposed. However :

- Optimizations are made to cope with the complexity of wireless communication
- The PHY-modeling accuracy varies from one simulator to another
- The behavior of protocols may radically differ from one simulator to another

Motivation :

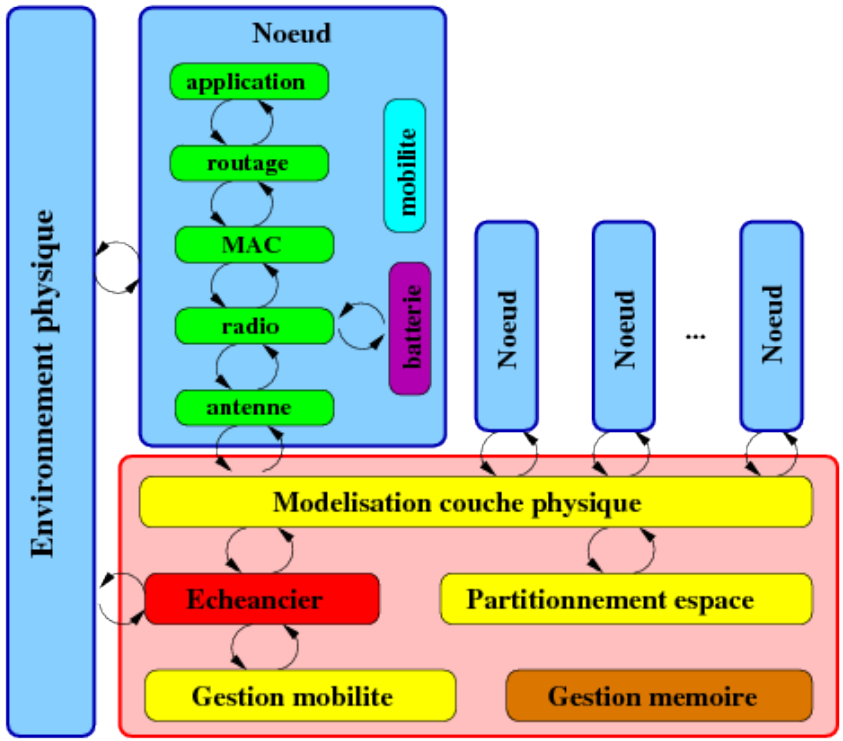
- In-depth analysis of the modeling of wireless networks
- Comparative study for existing simulators
- The impact of the PHY-modeling on the simulation results
- The impact of the protocol parameters on the simulation results

WSNet

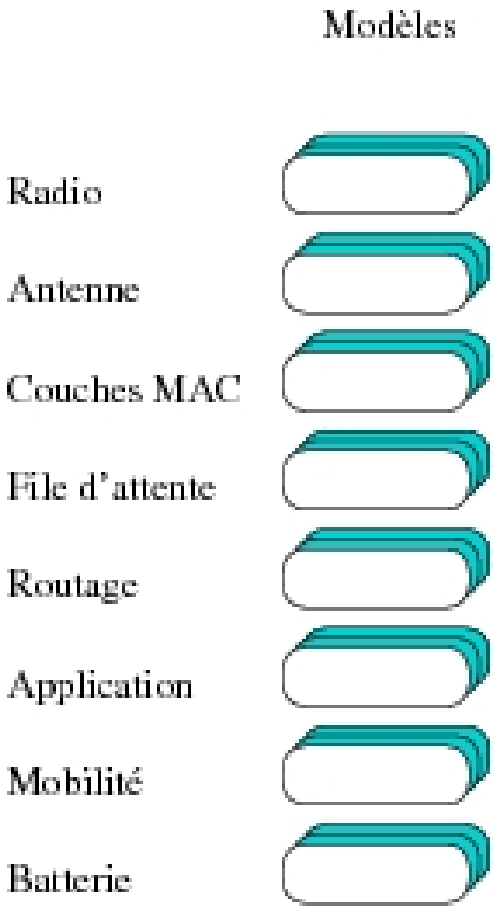
WSNet architecture :

- simulator core : event queue, mobility management, packet queue, *etc.*
- dynamic libraries : implement node / medium / environment models.

A simulation must specify which models are to be used.



WSNet : Entities/Bundles/Nodes



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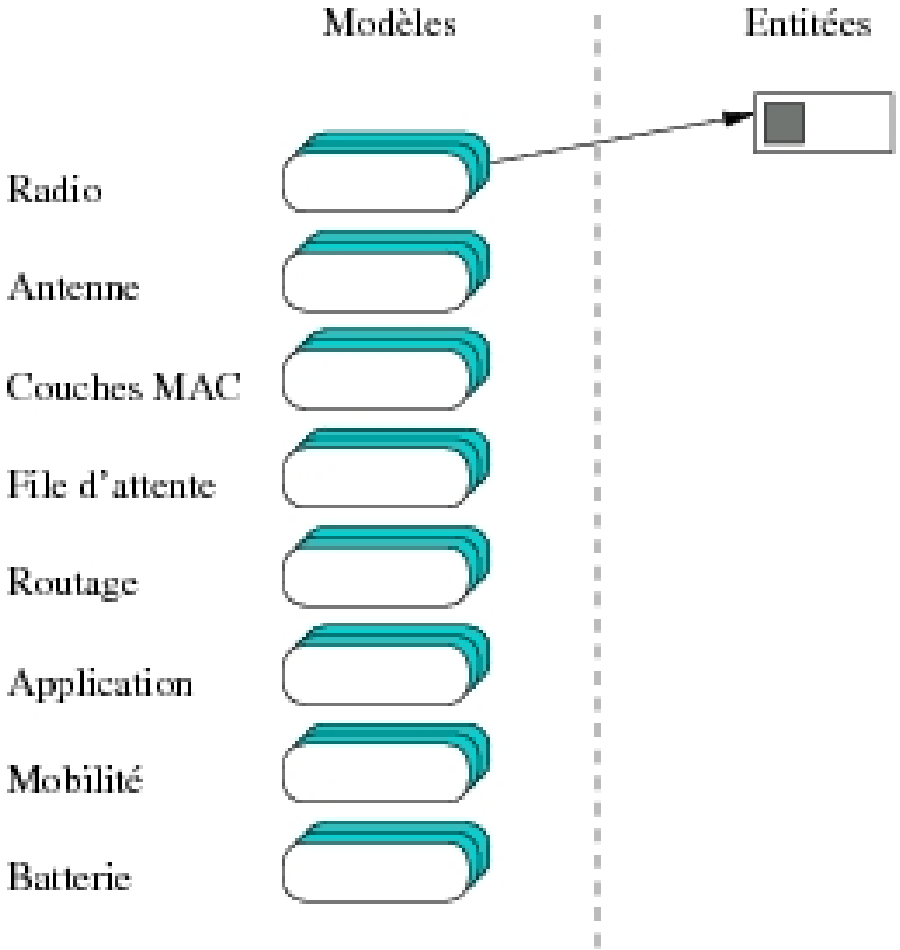

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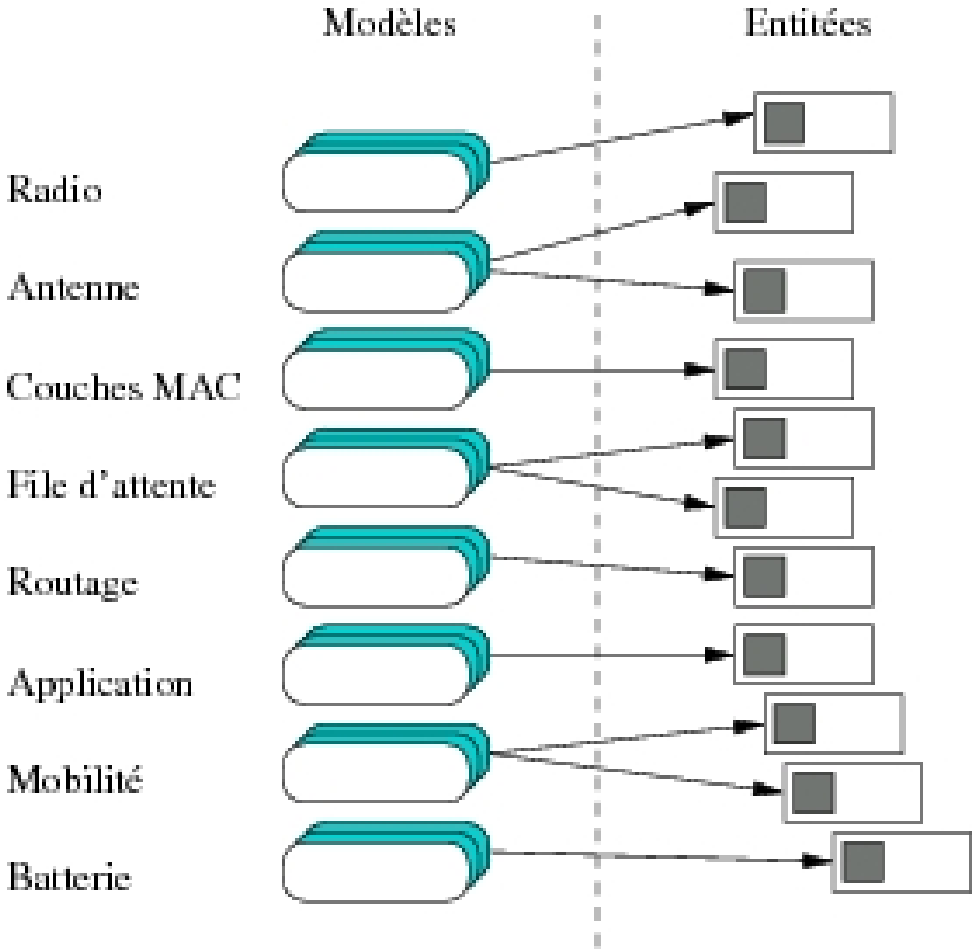

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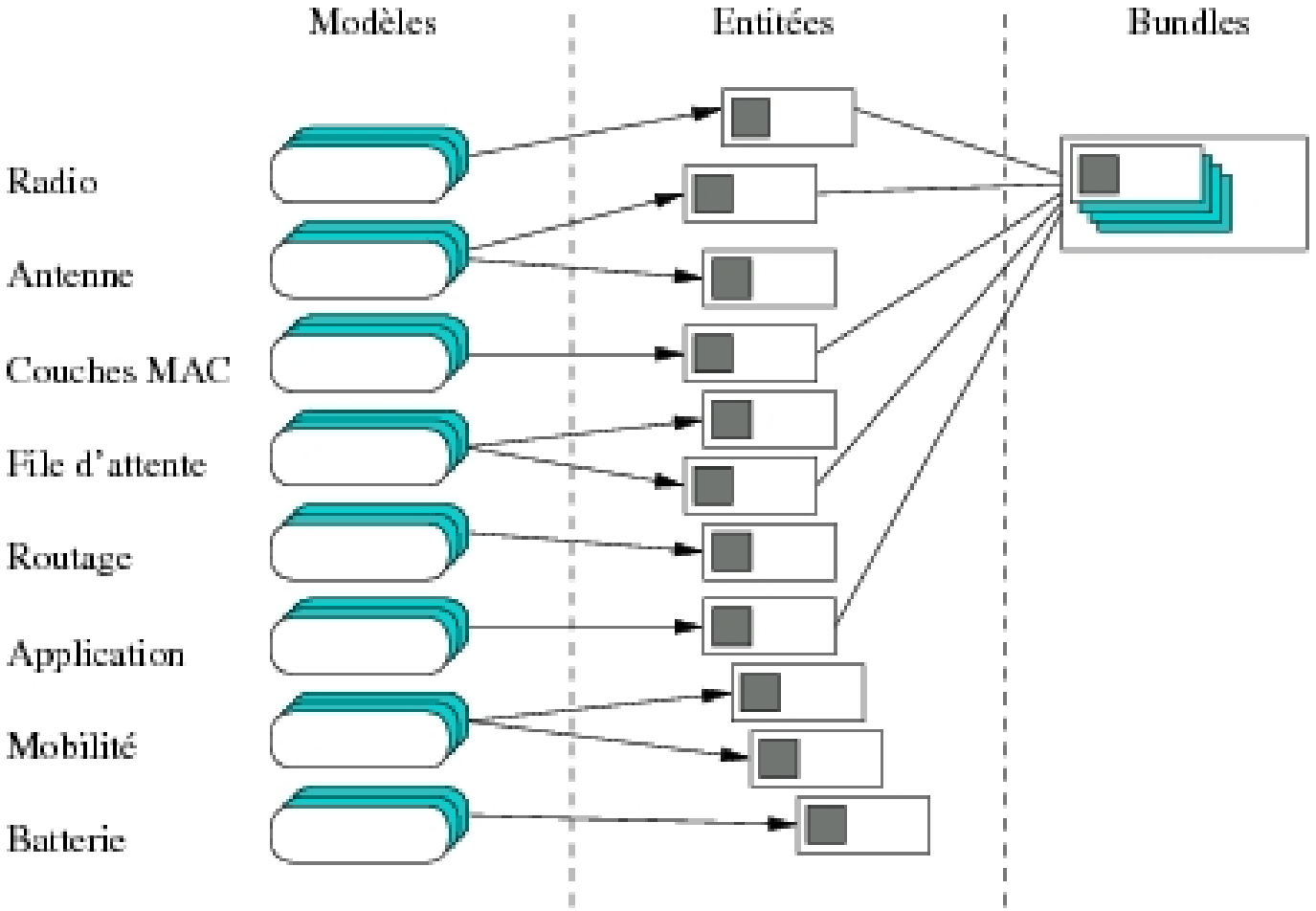

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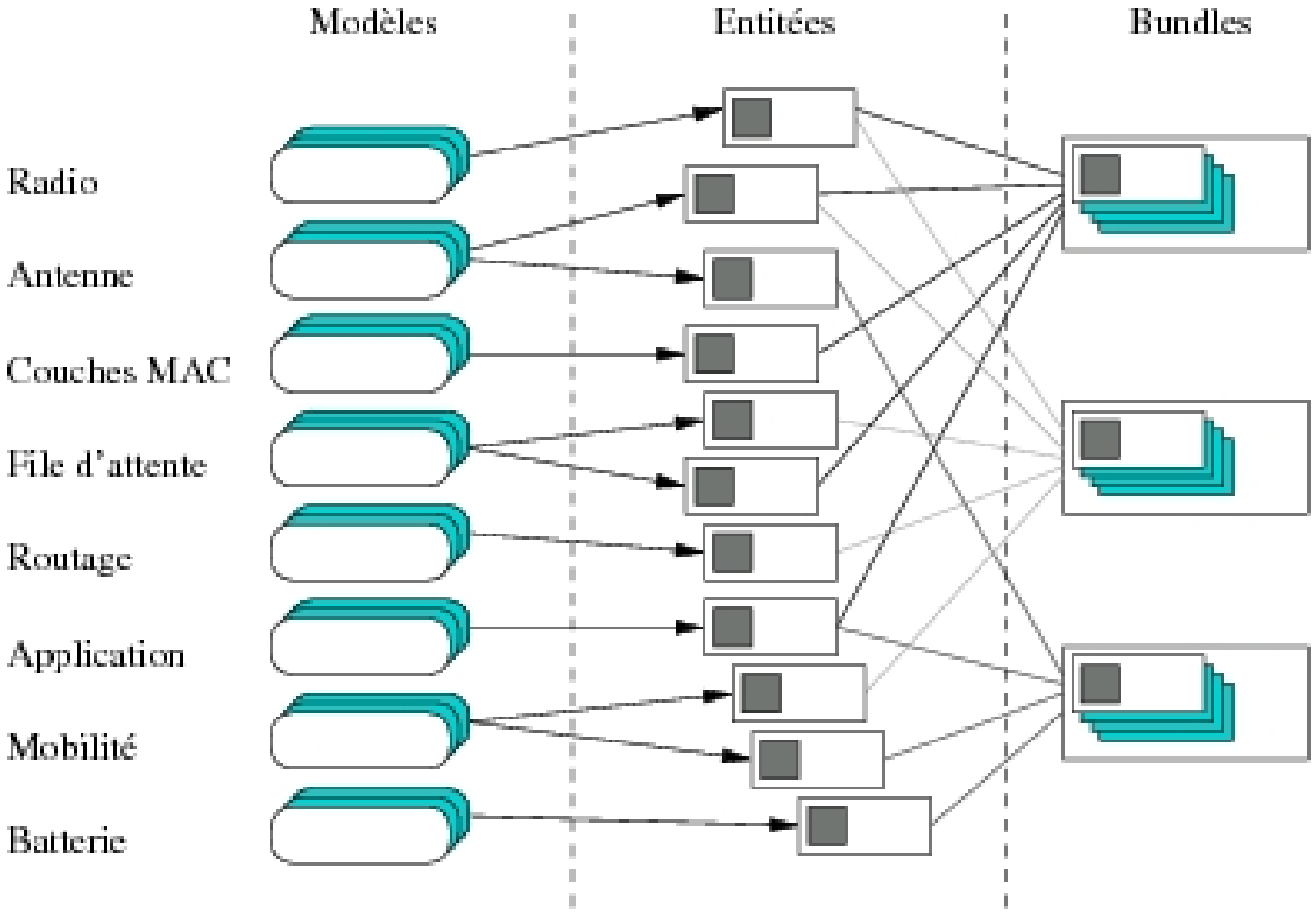

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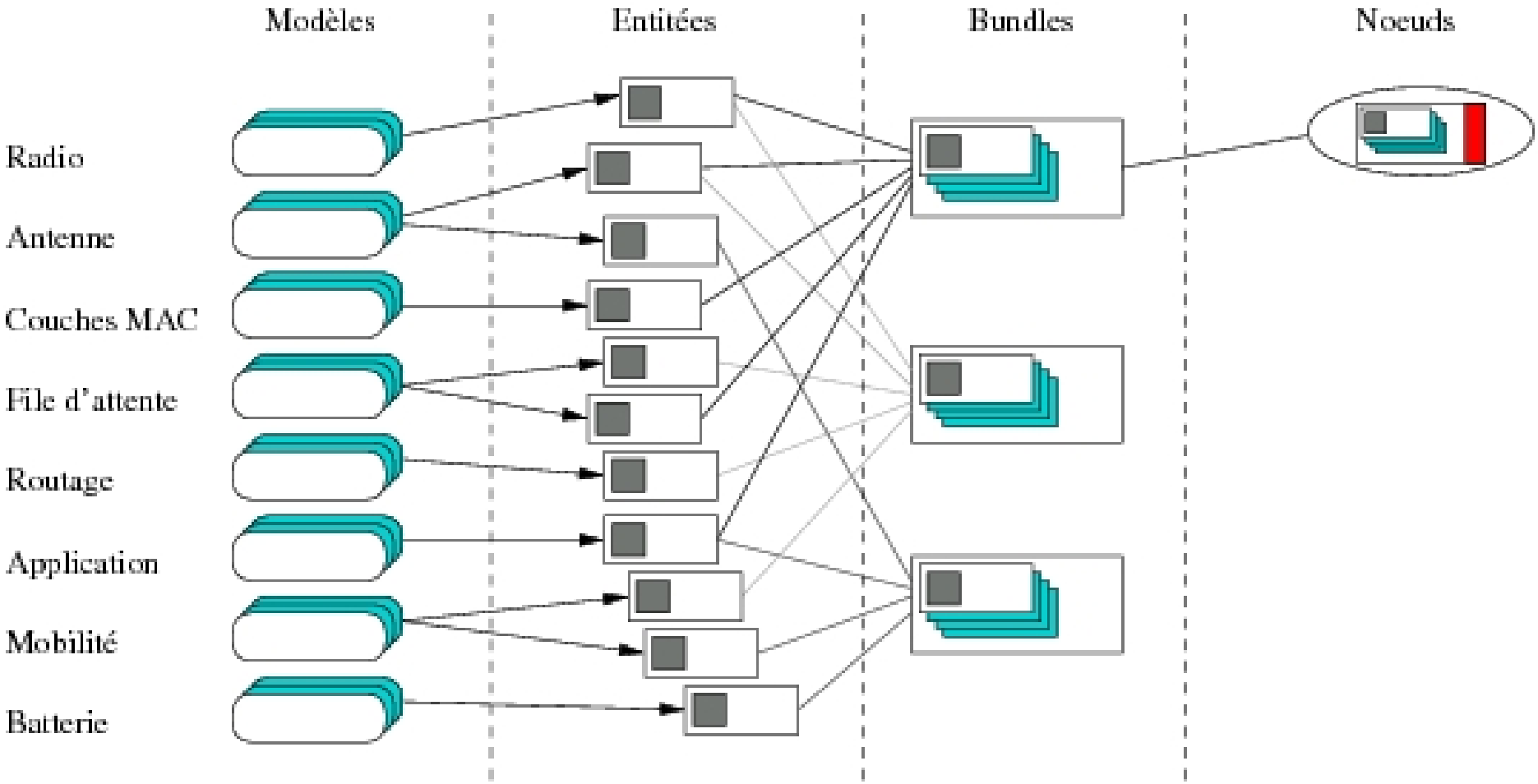
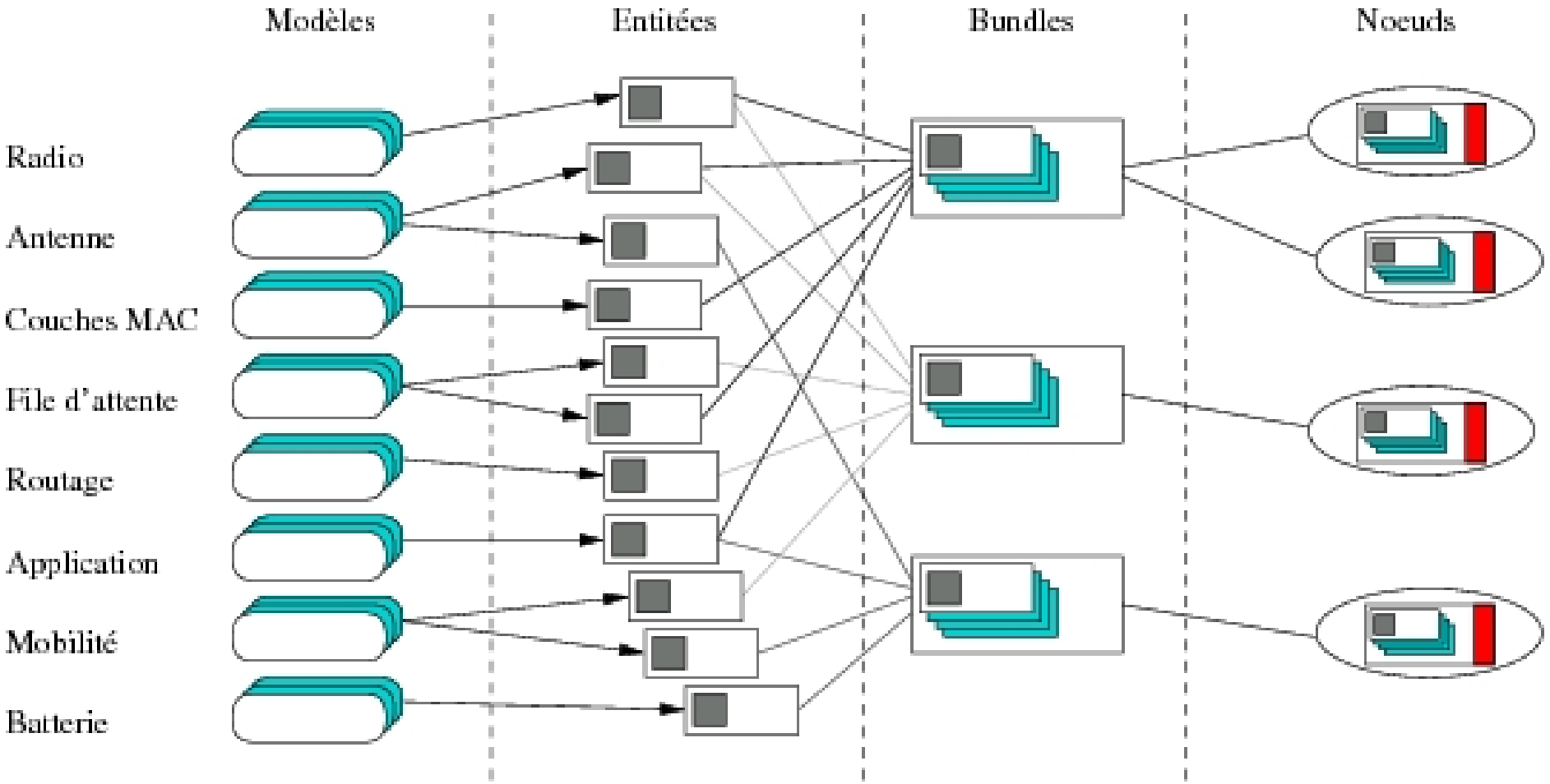


WSNet : Entities/Bundles/Nodes



WSNet : simulation configuration

Format XML

```
<simulation nodes="5" packeterror="true"/>

<!-- Entities instantiation -->
<entity name="position0" model="billiard-group">
  <init   x="100"   y="100"   z="100"  maxspeed="10"/>
</entity>

<entity name="position1" model="billiard-group">
  <init   x="10"   y="10"   z="10"  maxspeed="20"/>
</entity>

  [...]
```

WSNet : simulation configuration

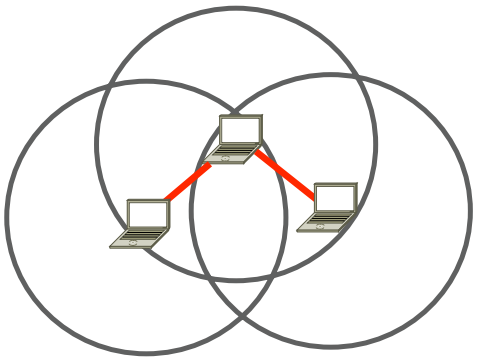
Format XML

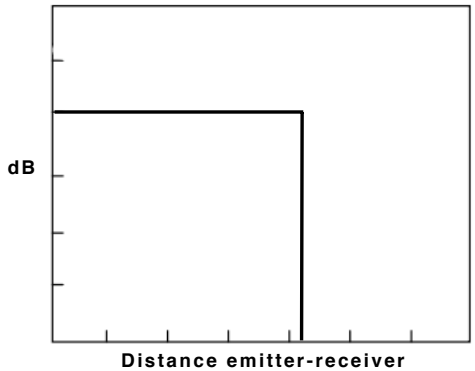
```
<!-- Bundles instantiation -->
<bundle name="sensor" default="true">
  <with entity="position0"/>
  [...]
</bundle>

<bundle name="sensor1">
  <with entity="position1"/>
  [...]
</bundle>

<!-- Nodes instantiation -->
<node id="4" as="sensor0">
  <for entity="position" x="1" y="2" z="3"/>
</node>

<node id="4" as="sensor1">
</node>
 [...]
```

PHY-layer modeling in WSNet

In analytical studies as in simulation, the unit disk model has been widely used :

- Strong assumptions : time stationarity, independence, symmetry, switched link, isotropy, *etc.*
- Unrealistic PHY model : radio range is constant, radio link is switched, interference free network



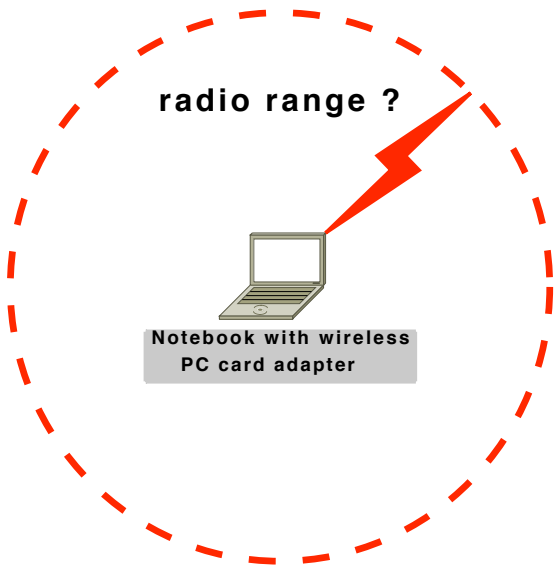


Three main steps towards a realistic radio medium modeling :

- Radio range modeling
- Radio link modeling
- Interference modeling

WSNet : radio range modeling (1/3)

The range of a radio system is based upon the definition of a *SNR* threshold noted $\bar{\gamma}_{ij}$



If the system is interference free, the range is constant and the radio link l_{ij} is defined by :

$$l_{ij} : \Omega^2 \mapsto B = \{0, 1\}$$

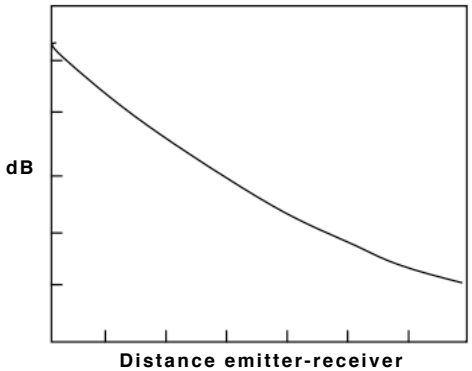
$$(x_i, x_j) \mapsto l(x_i, x_j) = \begin{cases} 1 & \text{if } \bar{\gamma}_{ij} \geq \bar{\gamma}_{lim} \\ 0 & \text{else} \end{cases}$$

where : $\bar{\gamma}_{ij} = h_{ij} \cdot \frac{P_i}{N_j}$

h_{ij} depends on several physical phenomena (*i.e.*, pathloss, fading, shadowing).

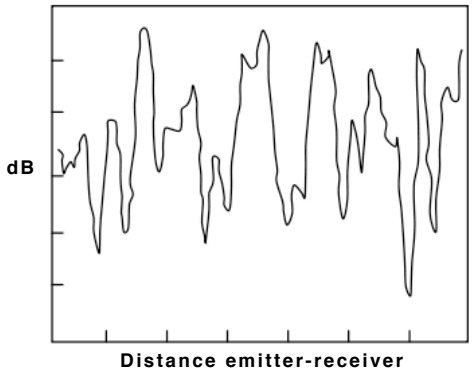
WSNet : radio range modeling (2/3)

pathloss
(signal attenuation in fct. of the distance)



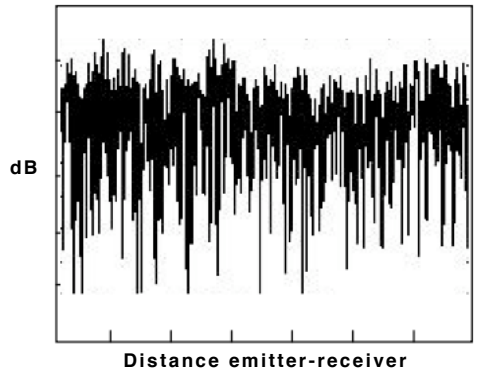
e.g. : freespace, tworay

shadowing
(slow signal fluctuation due to obstacles)



e.g. : log-normal

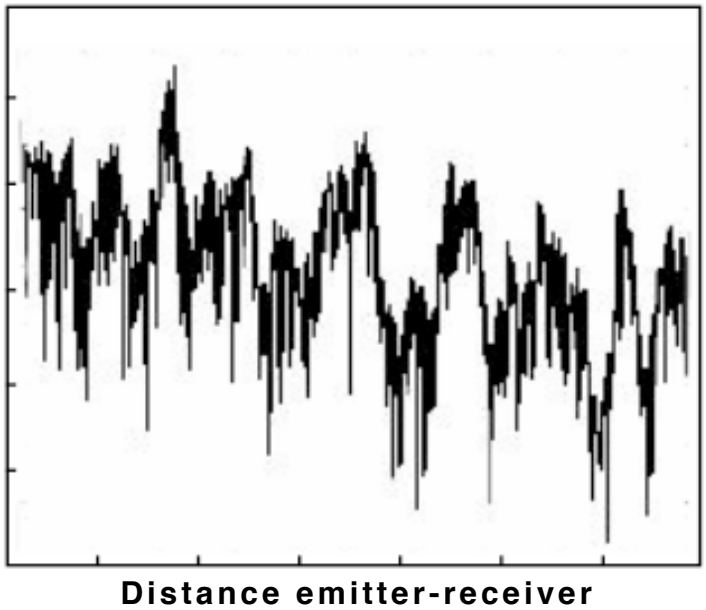
fading
(fast signal fluctuation due to multipath)



e.g. : rician, rayleigh

WSNet : radio range modeling (3/3)

pathloss + shadowing + fading



The radio link l_{ij} is then defined by :

$$l_{ij} : \Omega^2 \mapsto B = \{0, 1\}$$

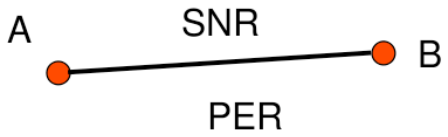
$$(x_i, x_j) \mapsto l(x_i, x_j) = \begin{cases} 1 & \text{if } \bar{\gamma}_{ij} = h_{ij} \cdot \frac{P_i}{N_j} \\ 0 & \text{else} \end{cases}$$

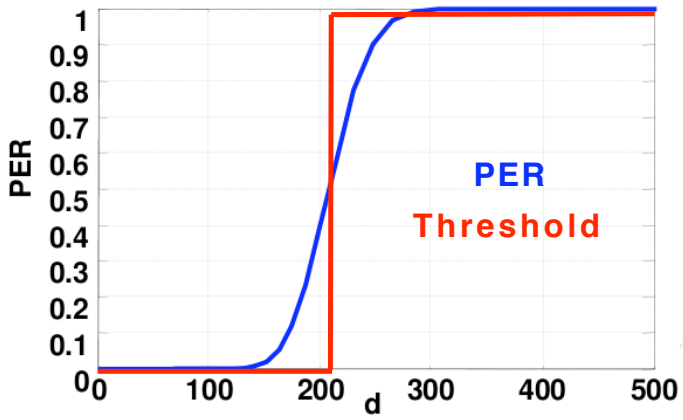
where :

$$h_{ij} = \mathbf{g}_{ij} \cdot \mathbf{s}_{ij} \cdot \mathbf{f}_{ij}(t) \cdot g_i(\theta_{ij}, \phi_{ij}) \cdot g_j(\theta_{ji}, \phi_{ji})$$

WSNet : radio link modeling

A more realistic link modeling is to substitute the *SNR* threshold by a packet error rate (*PER*) which depends on the bit error rate (*BER*). This *BER* is computed according to the *SNR* and the modulation scheme.

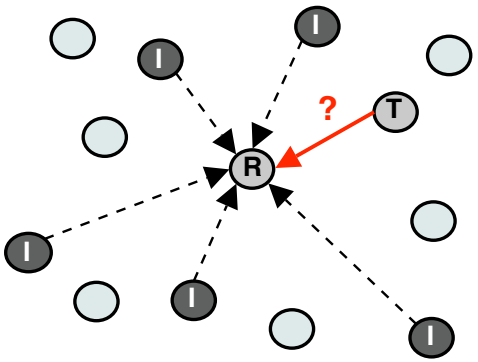




- The probability to receive a bit : $BER = f_{modulation}(SNR)$
- The probability to receive a packet of N bits : $PER = 1 - (1 - BER)^N$

WSNet : interference modeling

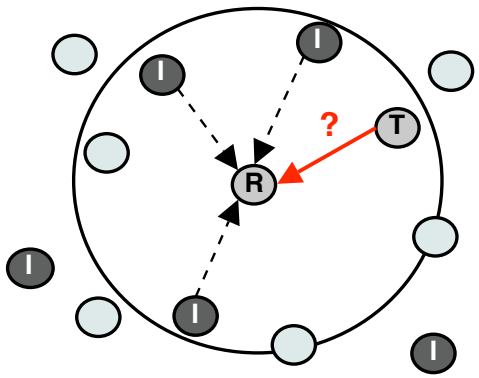
Inteference is a major limiting factor for wireless communication systems



The *SNR* is replaced by a signal to interference plus noise ratio (*SINR*) defined in the shotnoise model by :

$$\bar{\gamma}_{ij} = h_{ij} \cdot \frac{P_i}{N_j + \sum_{k \neq i,j} \alpha_{ik} \cdot h_{kj} \cdot P_k}$$

Numerous simulators limit the range at which a signal can propagate and thus can interfere. This privileges the scalability at the cost of accuracy.



Impact of radio range models

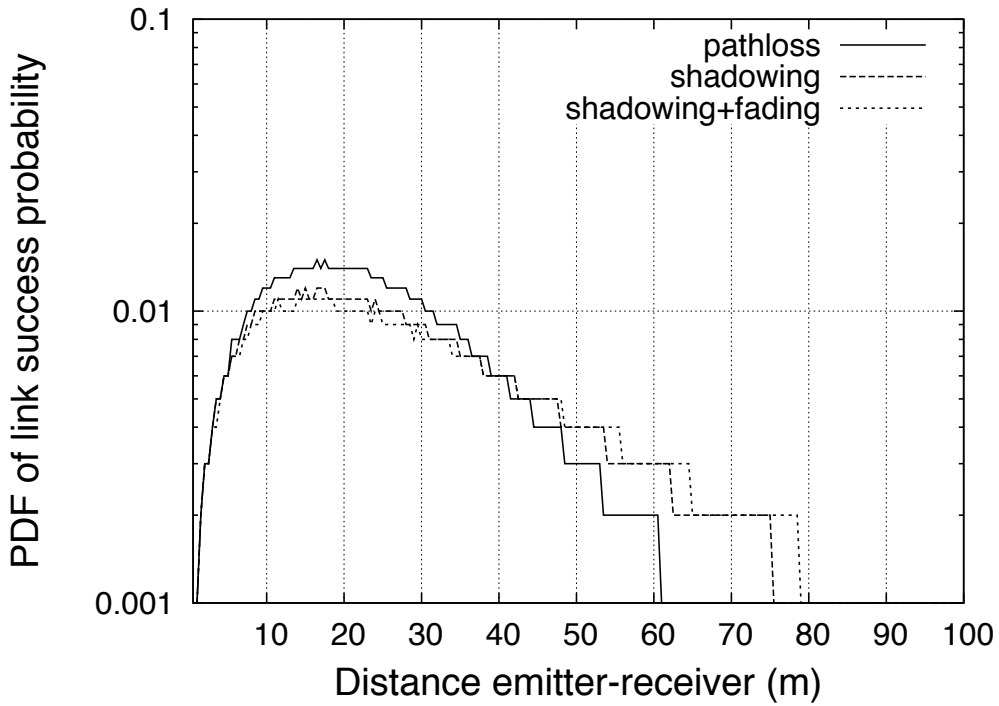


Fig.: *Impact of the radio range modeling on the link success probability (**without** interference modeling).*

Impact of radio link models

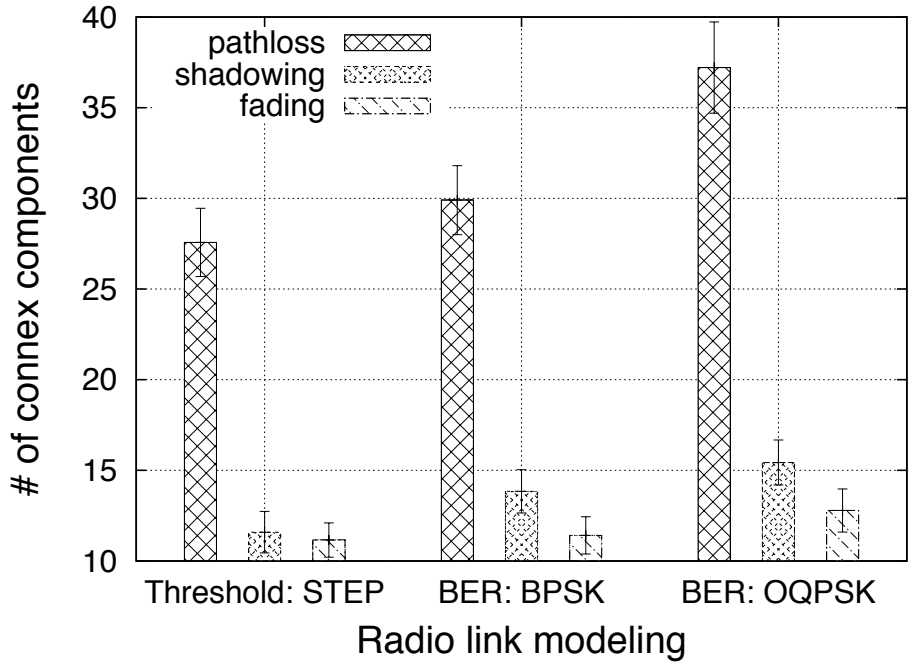


Fig.: *Impact of the radio link modeling on the average number of connex components (**without** interference modeling).*

Impact of interference

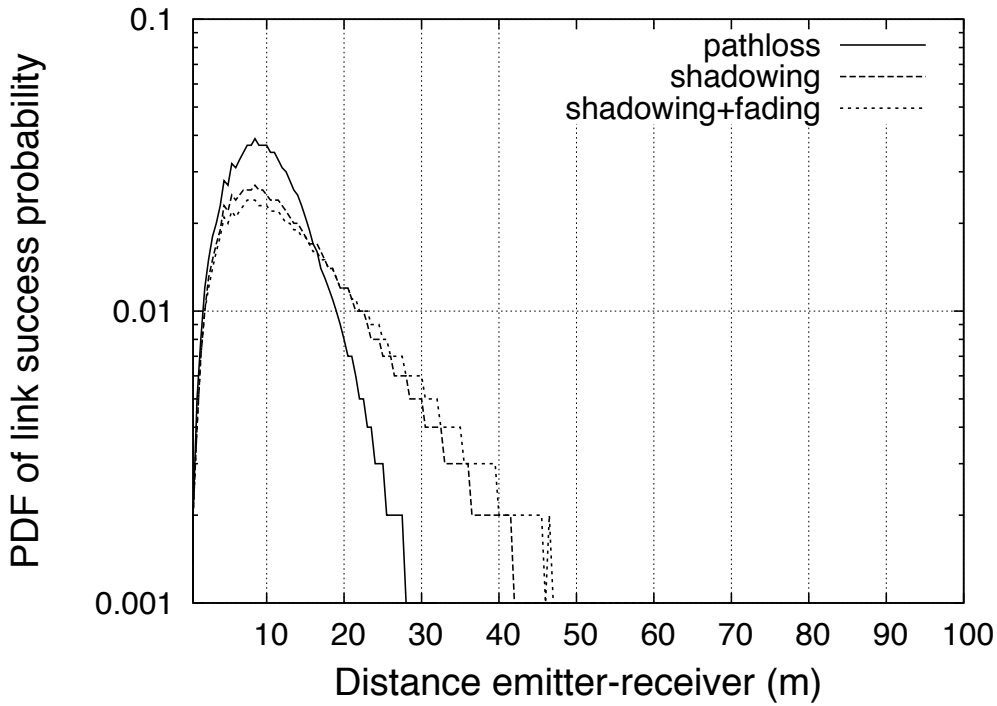
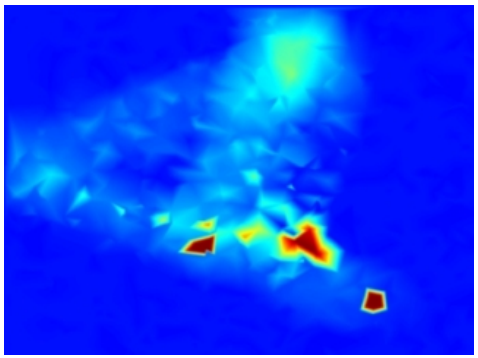


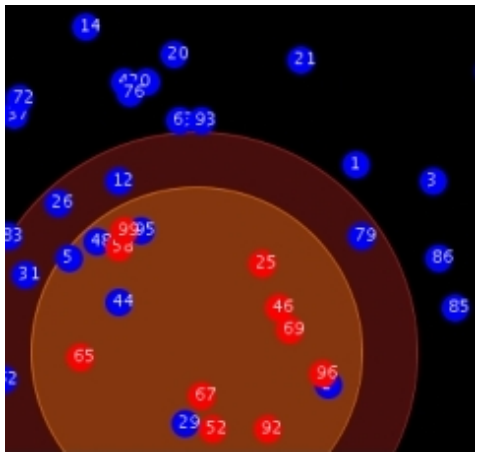
Fig.: *Impact of the radio range on the link success probability (**with** interference modeling).*

WSNet : environment

Environment simulation :

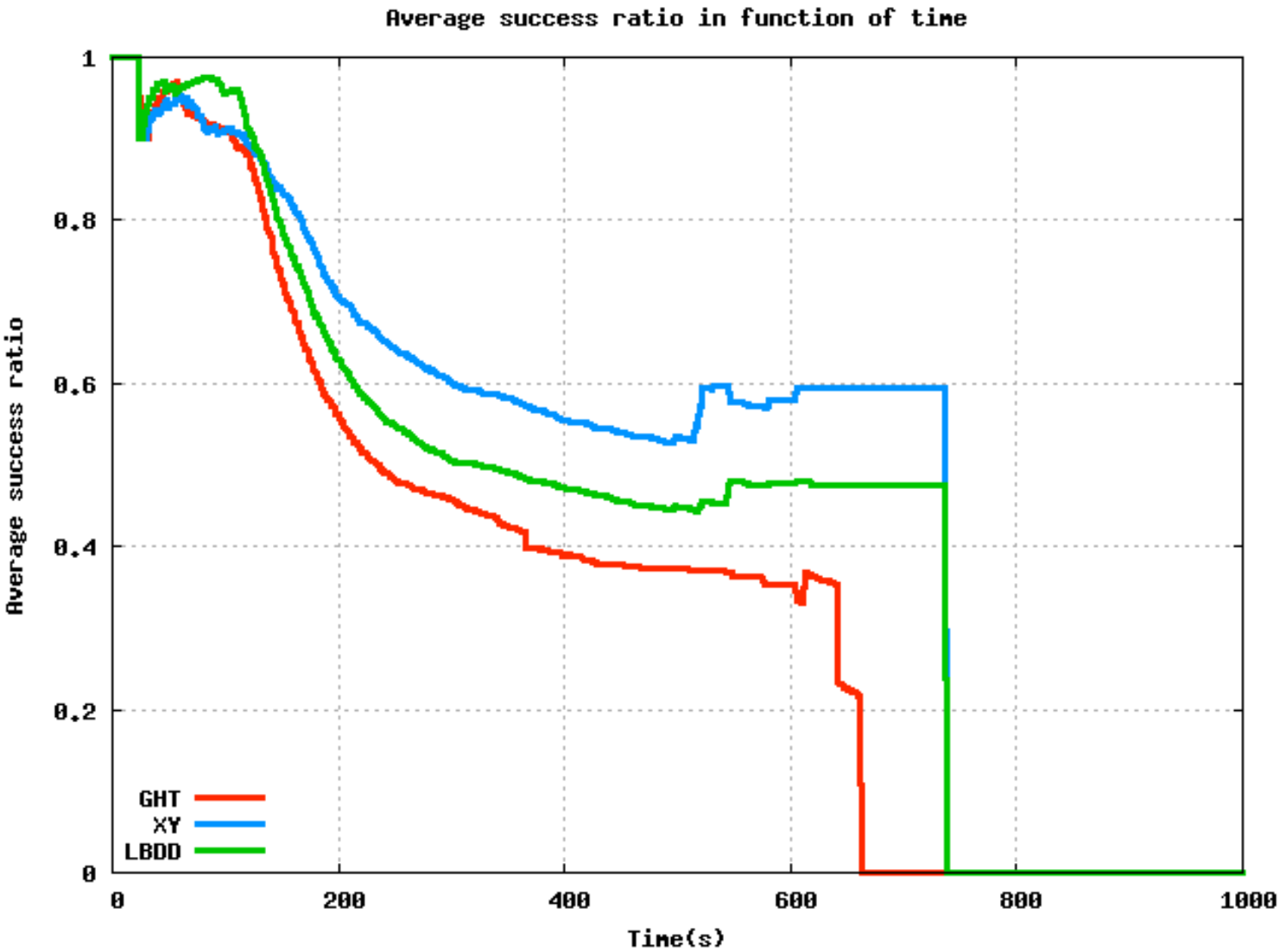
- *Environment* $\longrightarrow$ *node* interactions : sensing, node death
- *Node* $\longrightarrow$ *environment* interactions : actuators





WSNet : network lifetime

A network does not die when the first node dies.



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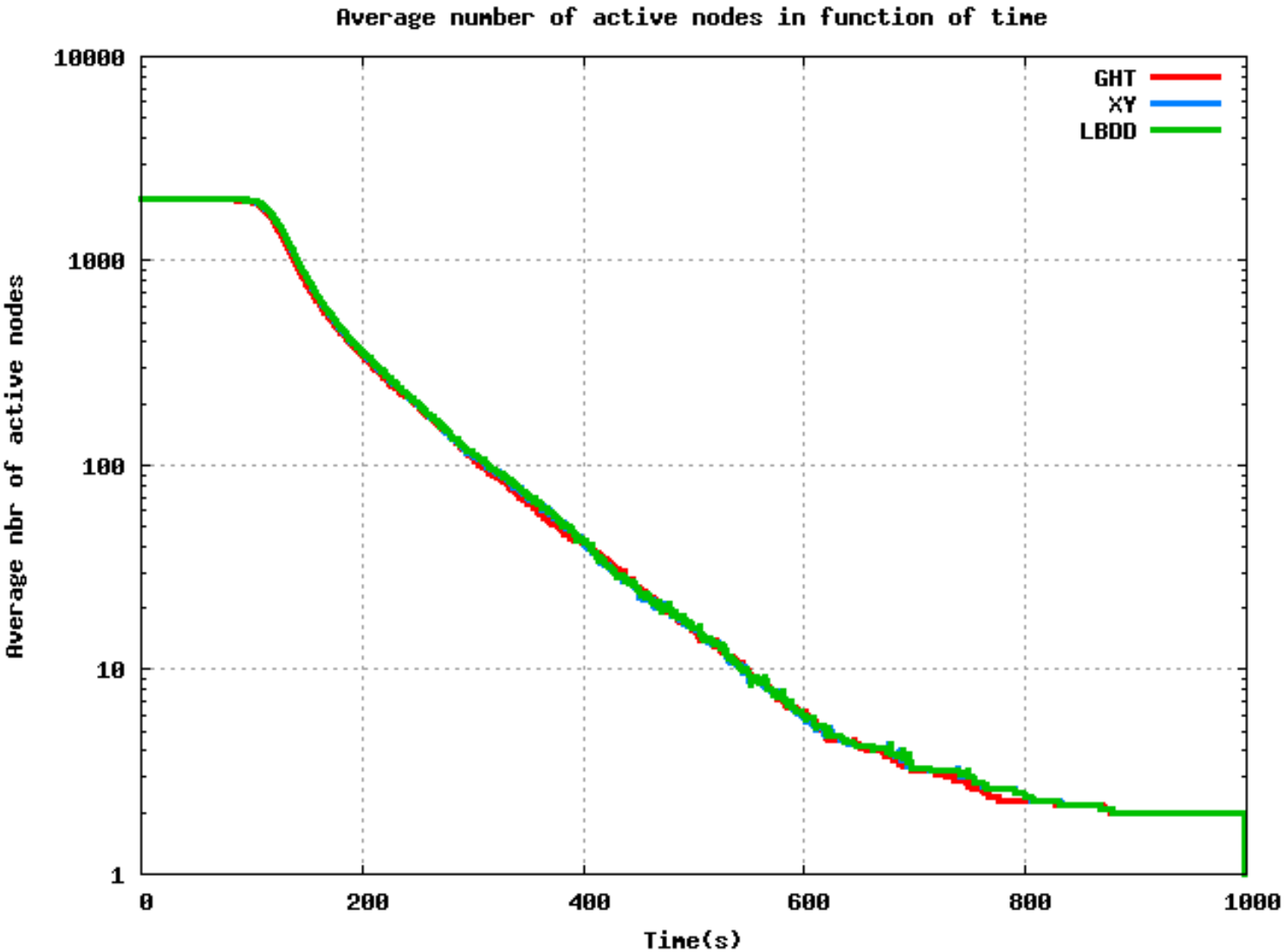


The future of WSNet...

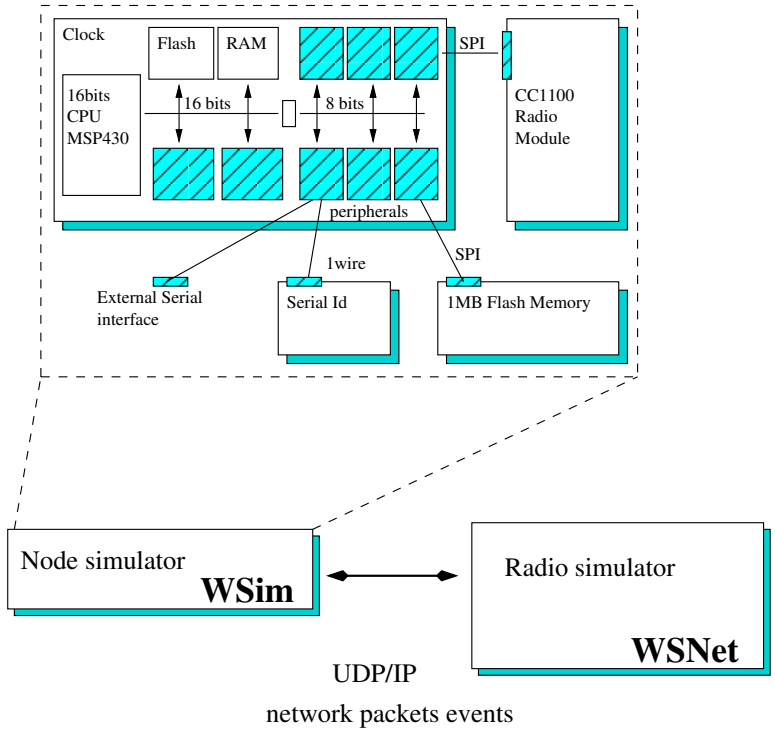
WSNet-3 is now under development :

- *High Level Languages* for model development (*e.g.* Ruby, Python)
- *Packet typing* : easier protocol developments, better result synthesis.
- *Rethinking the medium model* : UWB support ? better support of multi-channels, MIMO systems, *etc.*
- *Rethinking the environment support*

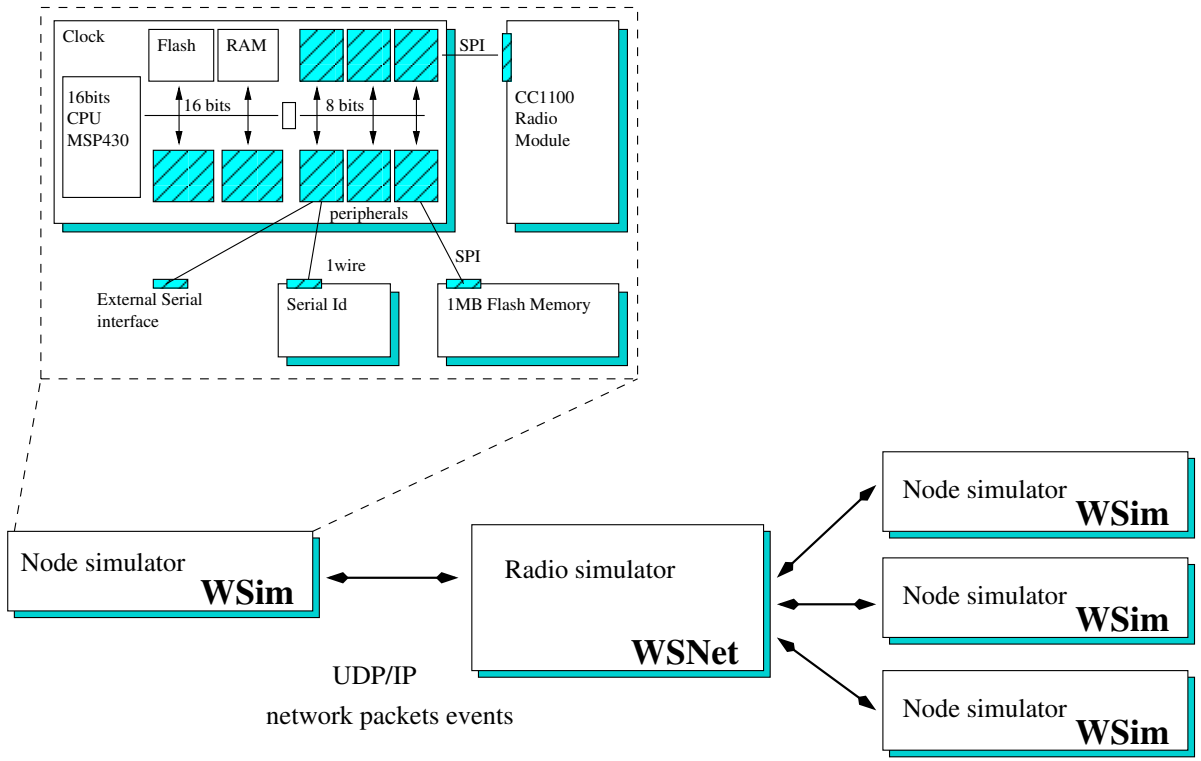
Anyway, at that time, please go and refer to :

`http://wsnet.gforge.inria.fr`

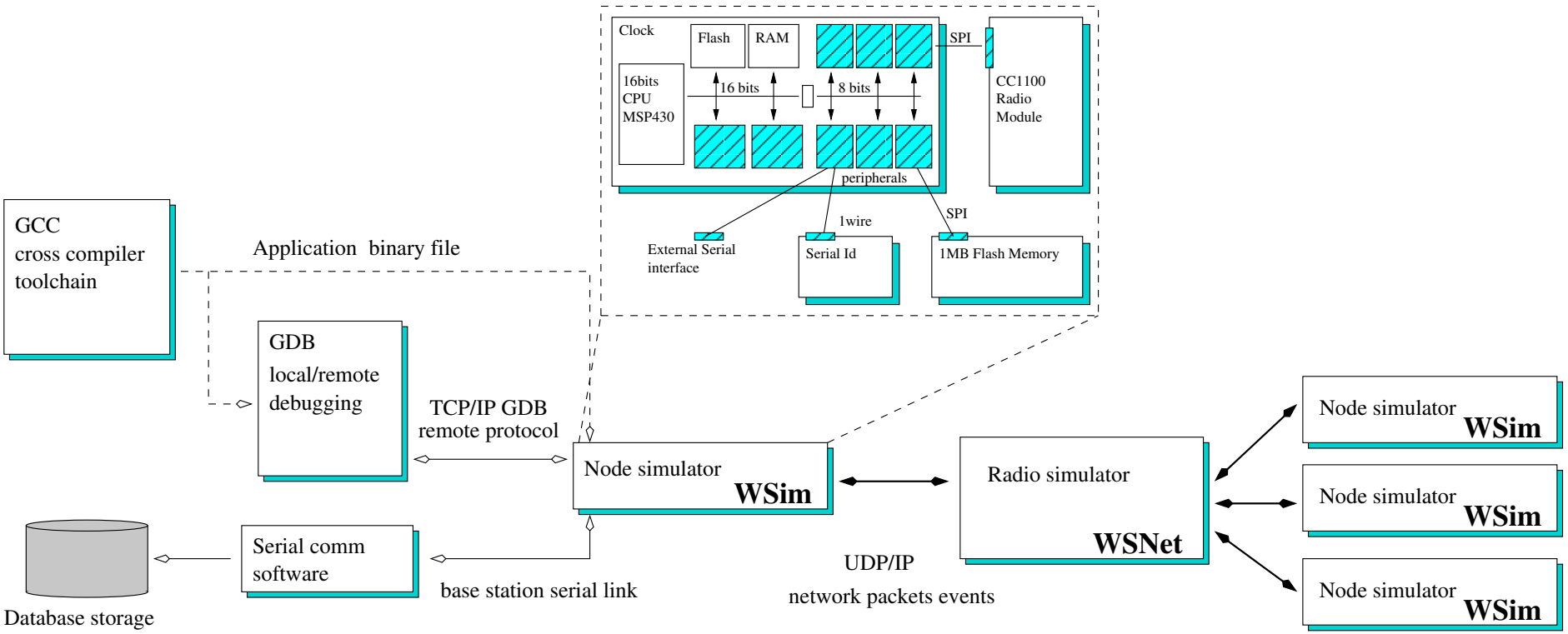
Simulation mixte



Simulation mixte



Simulation mixte



Simulation mixte

- La simulation distribuée permet de faire du pas à pas sur l'application de façon globale
- Les mesures de performances locales associées aux communications permettent de faire ressortir le comportement de l'application complète.
- La mesure de consommation en analyse hors-ligne permet de mesurer les divers compromis existant dans l'architecture entre calcul et communication.
- Des changements d'annotation de consommation permettent de détecter les composants du système qui sont les plus consommateurs en fonction de l'application.

Sites web

Outils développés :

esimu.gforge.inria.fr, analyse de trace, annotation de code source avec information de performance et de consommation.

wsim.gforge.inria.fr, émulateur de plateforme de capteur

wsnet.gforge.inria.fr, simulateur de réseau radio