Efficient large electromagnetic problem solving on Grid'5000

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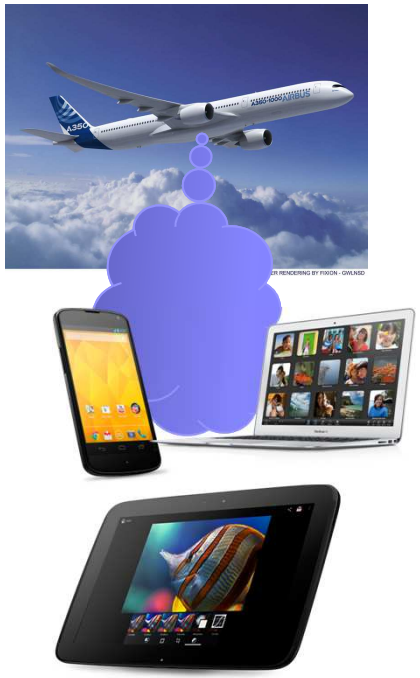
Hervé Aubert	MINC-LAAS
Thierry Monteil	SARA-LAAS
Patricia Stolf	SEPIA-IRIT

Résultats d'une partie de la thèse de Mihai Alexandru

Outlook

- Transmission-Line Matrix (TLM) principles
- TLM/ Modal Hybrid Approach
- TLM parallelization
- Time Prediction Model
- Conclusion/HEMERA

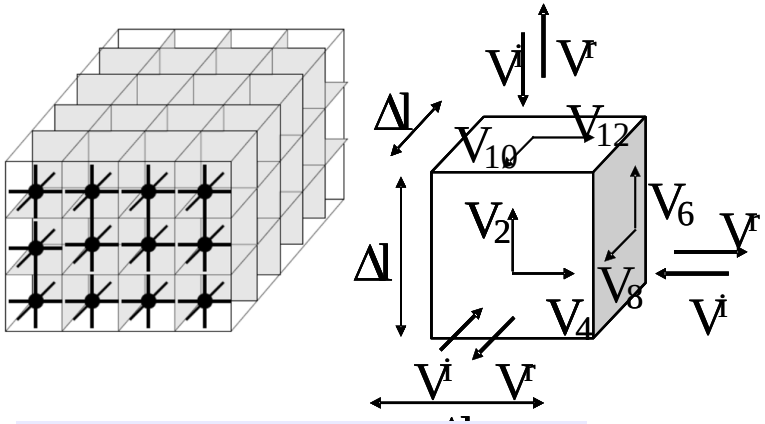
Introduction



- More and more wireless communication
- Need to design and validate communication propagation
- Example in the aeronautic domain:
  - Service for users: computer, smartphone, tablet, etc
  - Decrease the number of cable
  - Decrease the weight of plane
- Easier to simulate than real experiments
- Complexity of the simulated environment:
  - Oversized structure
  - Full-wave
  - Which numerical method
- Electromagnetic modelling of large and complex electrical structures by TLM and modal technics: hybrid approach
- Need of large scale parallel systems such as Grid Computing and Supercomputer

Transmission-Line Matrix (TLM) 3D principles

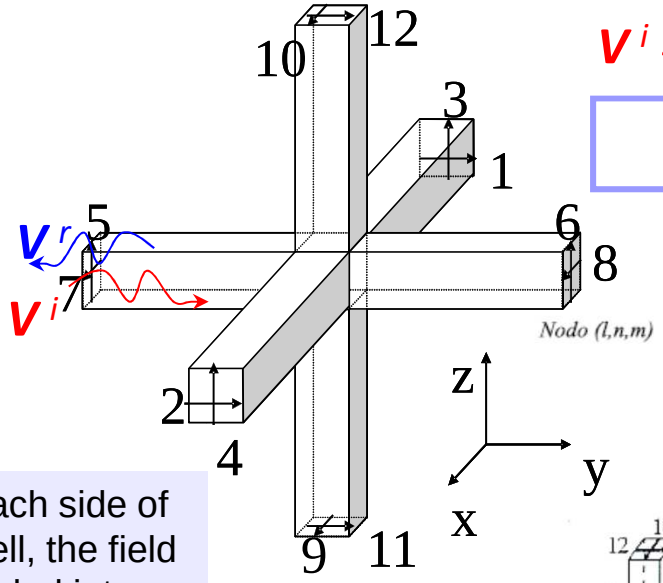
➢The space discretized with rectangular cells

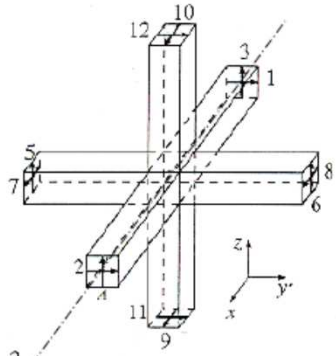


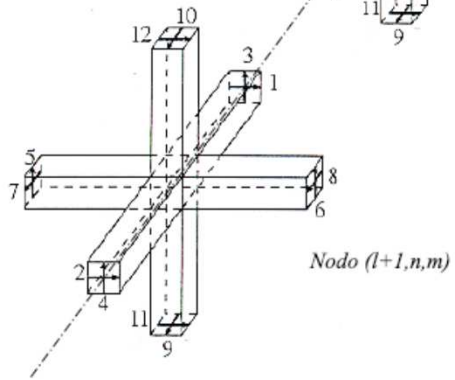
$\boldsymbol{V}^r = [V_1^r, V_2^r, \ldots V_{12}^r]^T$

$\boldsymbol{V}^i = [V_1^i, V_2^i, \ldots V_{12}^i]^T$

$${}_k\boldsymbol{V}^r = \boldsymbol{S}\ {}_k\boldsymbol{V}^i$$



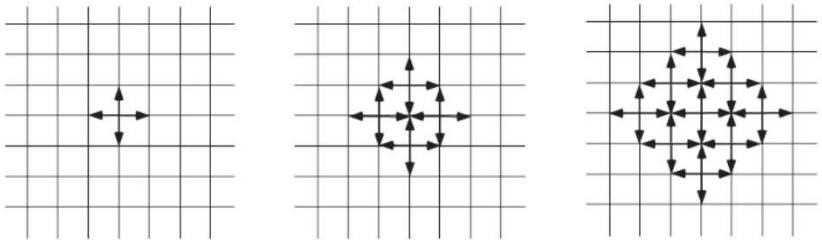




➢The 2 groups of 12 values representing the incident wave and the reflected wave are stored in different vectors

➢S=scattering matrix

On each side of the cell, the field is divided into two polarizations

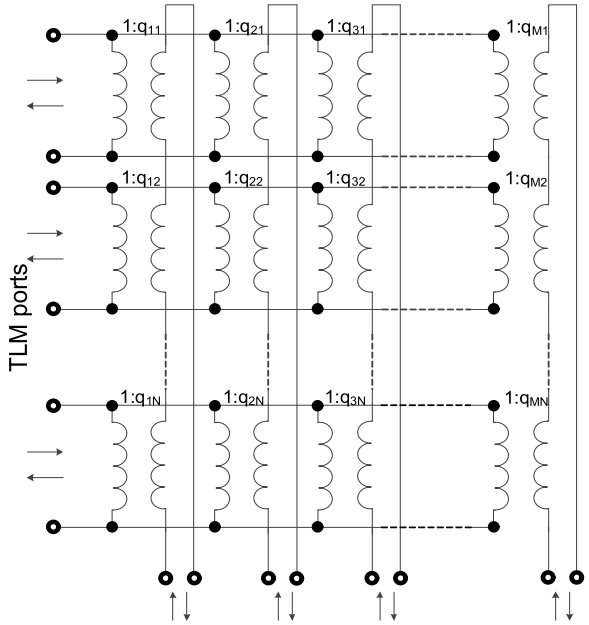


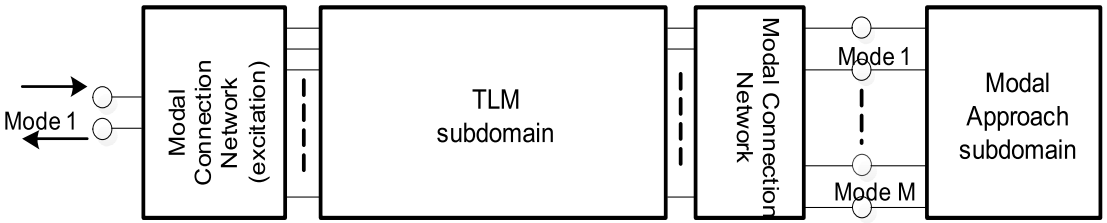
Continous model of propagation: Huygens principle

The waves travels through the lines and it is scattered at the node in a time equal to the time step Δt: $\Delta t = \Delta l / (2c_o)$

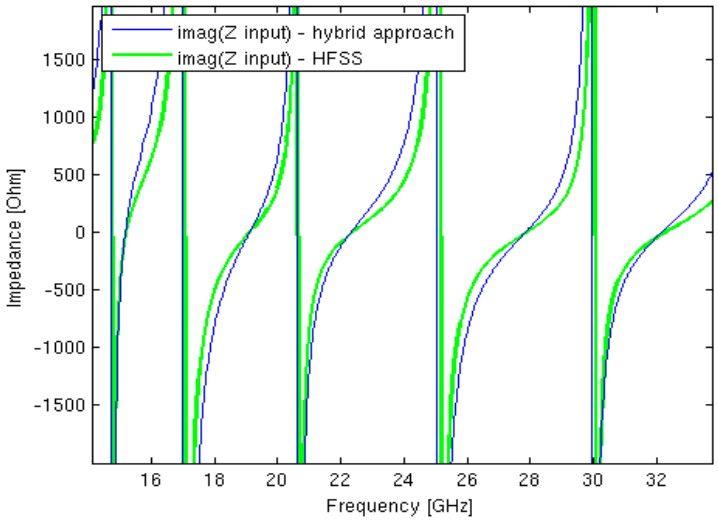
Hybrid method TLM/modal

- Fine discontinuity inside structure : to heavy with space decomposition
- Planar structures with discontinuity: modal approach (the field is a linear combination of modes)
- Each subdomains are separately calculated and connected with convolution product at each time step
- Use of coupling matrix to build the propagation of the field





Input impedance (imaginary part) of a non homegeneous waveguide length filled with r = 2,54 and terminated by a short-circuit



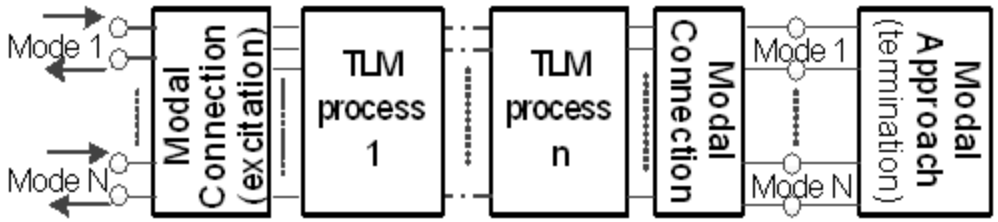
TLM parallelization

- TLM calculation may be too heavy compared to computing resources available on a PC, depending on the size of the problem;

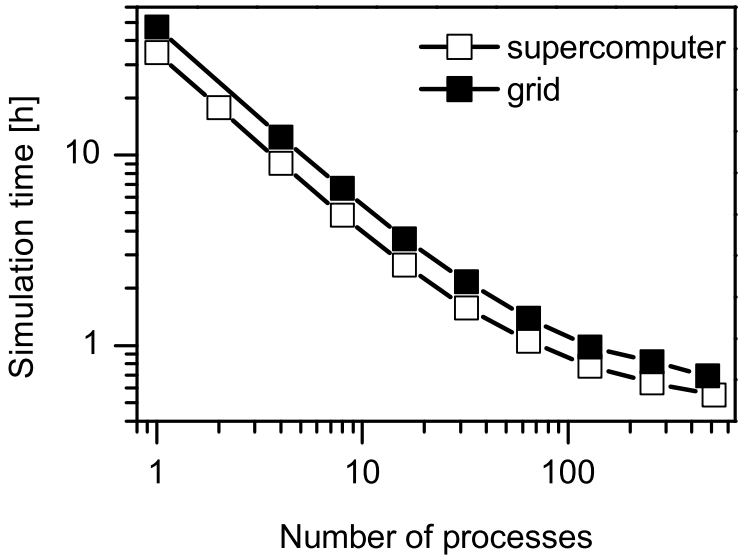
- The discretized subdomain can be divided into several parts which will be computed in parallel on multiple CPUs;

- Different CPUs communicate each other to accomplish the entire job, by an exchange of messages - Message-Passing Interface(MPI).

- *SPMD model (Single Program Multiple Data):* same program on different data
- Grid'5000 tools:



First TLM parallelization

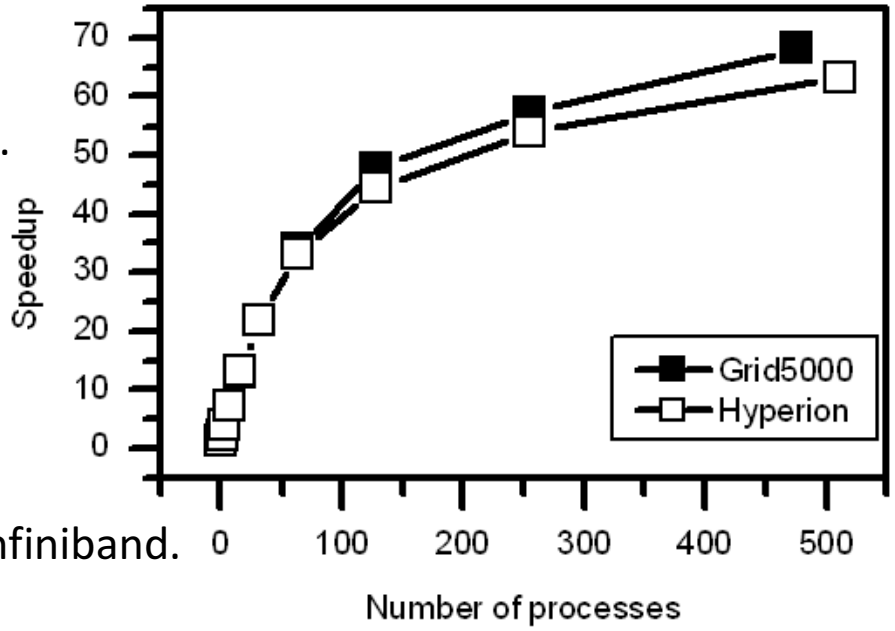


- Simulations have been performed on grid environment – Grid5000 and on a supercomputer - Hyperion.

- Electromagnetic simulation of TE_{10} mode propagating inside a matched rectangular waveguide (345 mm width, 173 mm height, 2432 mm length, TLM mesh step 1 mm and 10000 iterations) by TLM/modal hybrid approach.

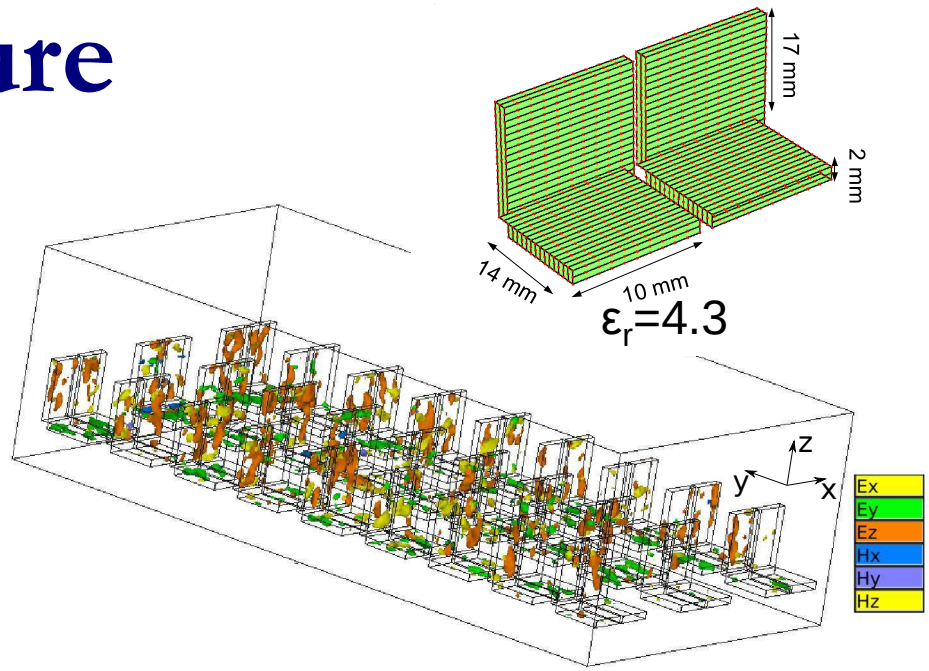
- Grid5000 – nodes from 5 distributed clusters, connected by the ethernet network at 1 Gbps inside a cluster and at 10 Gbps between clusters.

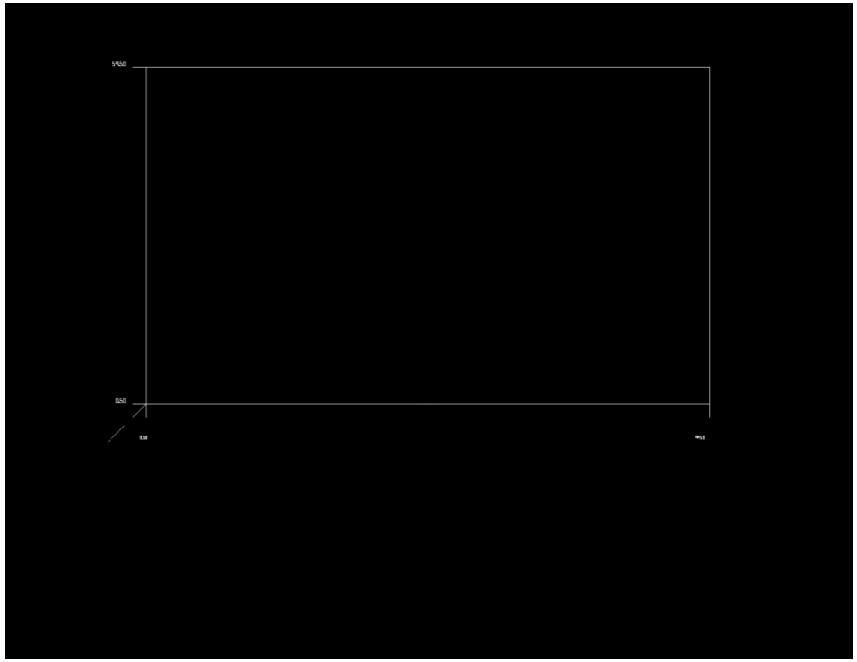
- Hyperion (Calmip) – 352 computing nodes with 2 quad-core Nehalem at 2.8 GHz, connected by Infiniband.



Oversized structure

- Complexe and oversized structure: plane cabin
- Modelling: seats and cabin
- Experimental condition:
  - frequency (3.7 GHz IEEE WLAN 802.11y-2008)
  - Cell of 8 mm
  - 30869 time step
  - 1.6 billion of TLM cells
  - 360 seats
  - 226 Go of memory
  - 320 MPI processes on Grid'5000 (Lille, Nancy and Rennes clusters)
- Big run:
  - Parallel execution: 51 hours
  - Estimated sequential execution: 1 year
  - 1320 cores

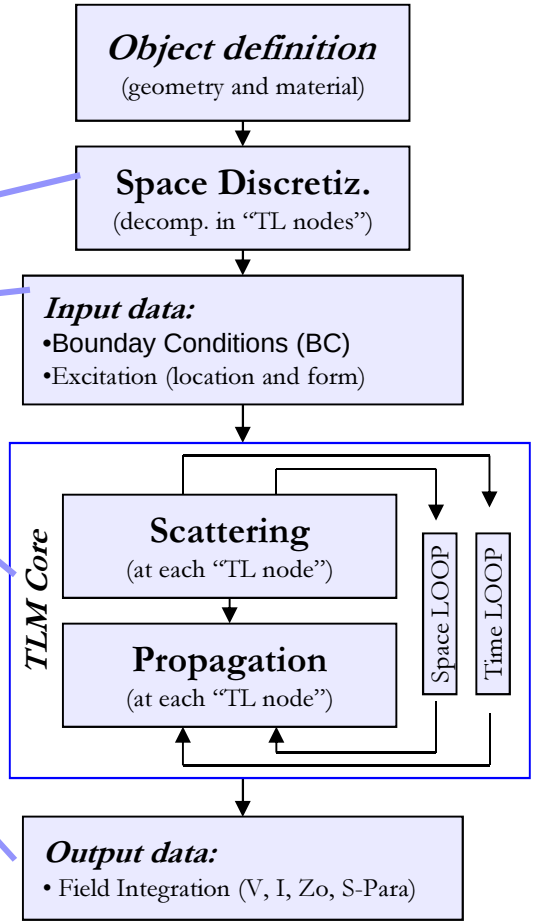




Computation time prediction model for Grid5000 platform

- The prediction model is based on a set of past experiences and on the profile of the application - the hybrid TLM / modal.

$$T_{cal} = c_1 + XY\,c_2 + tXY\,c_3 + tXYZ\,c_4$$

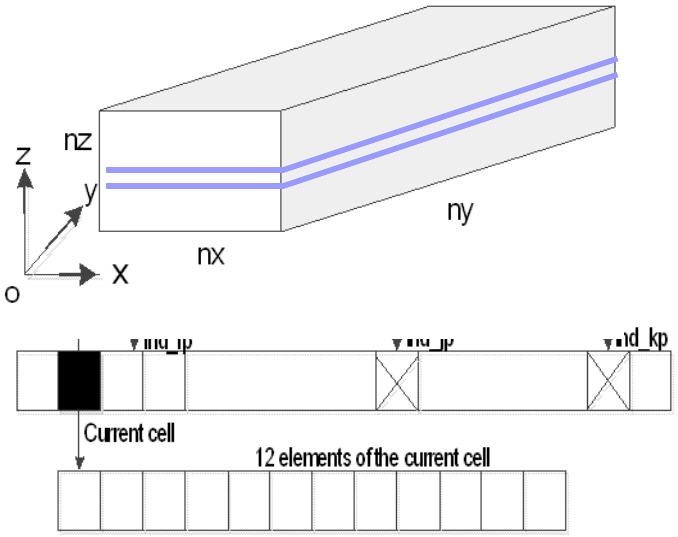


- During the simulation, the processor spends more than 90% of computing time in the TLM's core.

- Scattering block -> the diffusion phenomena occurring at each TLM cell, at each time step, is modeled.

- Propagation -> the connection between neighboring cells -> the incident signal is calculated on each cell for the next time step.

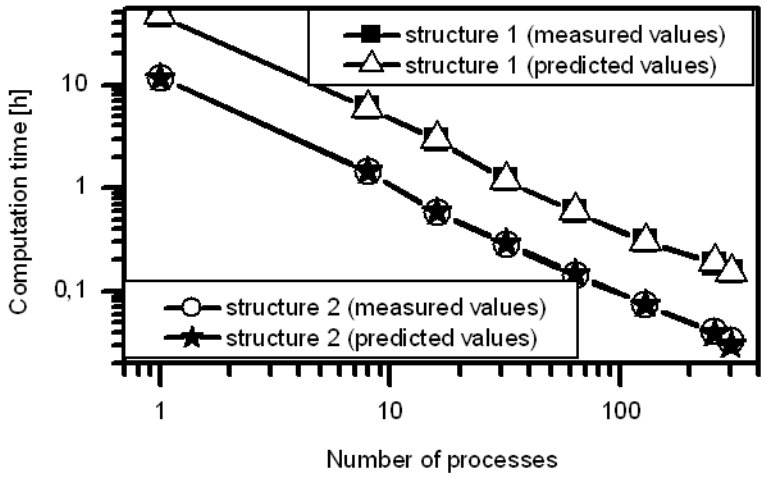
Computation time prediction model for Grid5000 platform



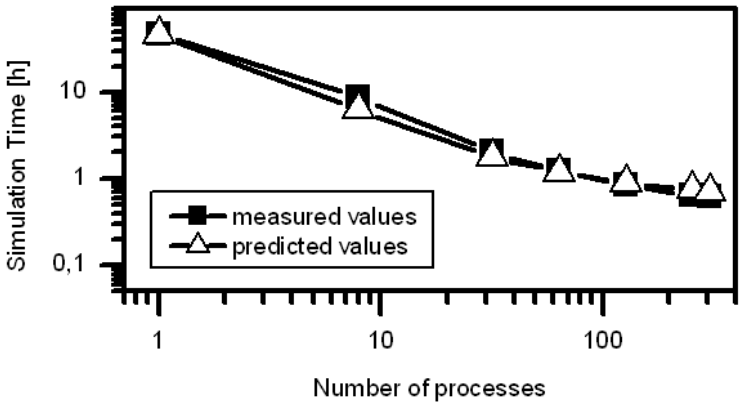
- The cache misses that occur during the Propagation block must be considered in the prediction model, in the case of architectures with hierarchical memory.
- Access to data cells with planar scheme
- In order not to charge twice the same data in the cache, the referenced cell with the index ind_kp must remain in cache until it becomes the current cell.
- During Propagation block, the processor requires the access to a total volume of data : 2 *nx *ny *12 *8 octets.

- Two prediction models for the computation time have been designed:
  - 2 * nx * ny * 12 * 8 bytes inferior or superior of cache size
- Computing nodes used for these simulations are equipped with the Intel Xeon 5420. Up to 6 MB of L2 Cache can be attributed to a core.
- The space required to store 2 * nx * ny * 12 * 8 bytes is limited to 6MB.

Computation time prediction model for Grid5000 platform



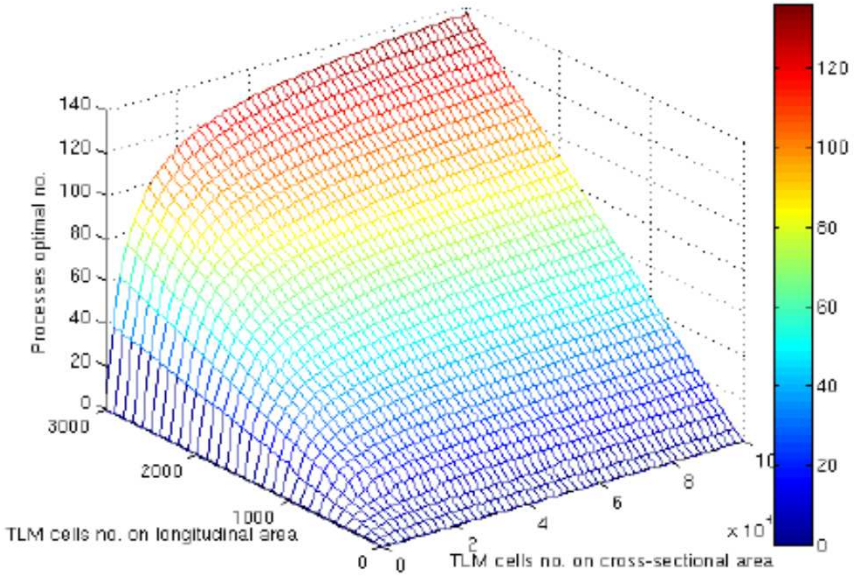
Structure 1: average error 1.51%
Structure 2: average error 2.18%



4 distributed clusters
average error 10.6%

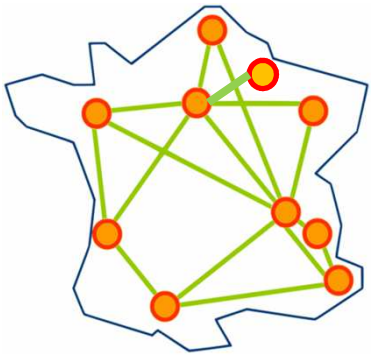
Maximum number of processes *n* required for computing the structure with a given efficiency *e*

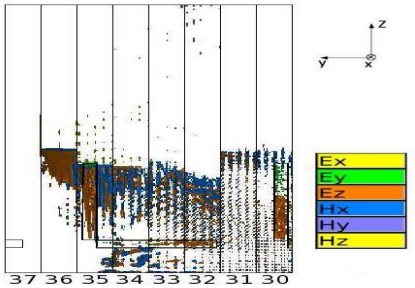
$$n \leq \frac{c_1^A + n_x n_y n_z t(c_2^A - e c_2^B)}{e(c_1^B + 4tT_{com})}$$



Conclusions

- Hybrid method: TLM (in the volume) and modal (on surface)
- Solution for strict calculation of the electromagnetic field within very large and complex structures such as a cabin of plane
- Parallelization on grid and supercomputer:
  - Very good behaviour in grid context
- Prediction model to:
  - Find the good number of processors depend on inputs
  - Estimation of reservation time for OAR
- New possibilities:
  - Billions of cells
  - Multi-scale structure
- Diffusion:
  - New software
  - Publications: IMS, EuMc, HPCS (selected for publication in Concurrency and Computation: Practice and Experience), …





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- Cooperation with Olivier Richard – Mescal –INRIA – Grenoble
  - Phd student funded by INRIA/HEREMA: C. Ruiz:
  - Facilities to create experiments on grid
  - Fine analysis of TLM code
  - One use case for expo framework
- Phd Student: examinator - C. Perez
- Open problem for storage: could generate 4TB of data for animation
- Need to explore different configurations with multi-parametric executions

  => design of antenna
- Utilization of multithreading and MPI over grid (First measures with openMP: D. Balouek, C. Ruiz)
- Collaboration between application, middleware and platform: experimentation management (Under Work: C. Ruiz Thesis)
  - Expo to describe experiments
  - Diet to execute as a service in the case of multi-scale structure (first discussion with C. Perez and D. Balouek)
  - FrameSelf for runtime adaptation:
    - Breakdown or performance loss of a set of machines
    - Autonomic exploration of new solutions in multi-parametric mode

Thank you