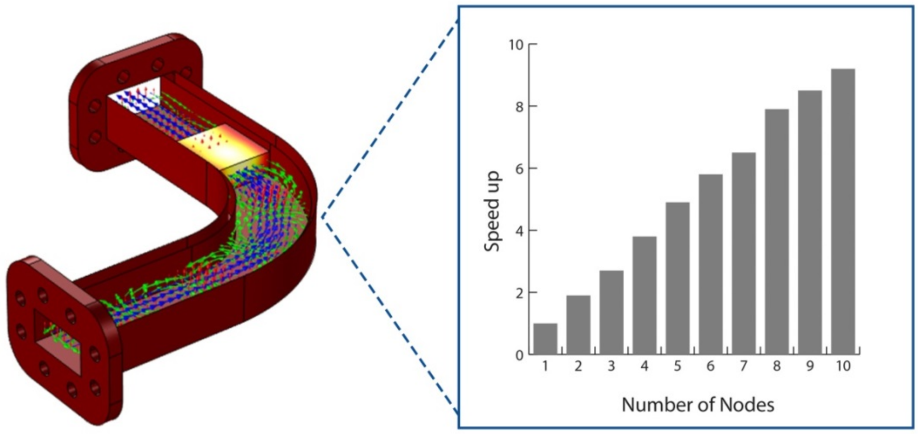
Acoustic Modelling and Parametric Radio Frequency Heating in the Cloud with COMSOL Multiphysics

An UberCloud / COMSOL Cloud Experiment



With Support From:

UberCloud Case Study 175

http://www.TheUberCloud.com

September 13, 2015

Welcome!

The UberCloud*** Experiment started July 2012, with a discussion about cloud adoption in technical computing and a list of technical and cloud computing challenges and potential solutions. We decided to explore these challenges further, hands-on, and the idea of the UberCloud Experiment was born, also due to the excellent support from INTEL generously sponsoring these experiments!

We found that especially small and medium enterprises in digital manufacturing would strongly benefit from technical computing in HPC centers and in the cloud. By gaining access on demand from their desktop workstations to additional compute resources, their major benefits are: the agility gained by shortening product design cycles through shorter simulation times; the superior quality achieved by simulating more sophisticated geometries and physics and by running many more iterations to look for the best product design; and the cost benefit by only paying for what is really used. These are benefits that increase a company's innovation and competitiveness.

Tangible benefits like these make technical computing - and more specifically technical computing as a service in the cloud - very attractive. But how far away are we from an ideal cloud model for engineers and scientists? In the beginning, we didn't know. We were just facing challenges like security, privacy, and trust; conservative software licensing models; slow data transfer; uncertain cost & ROI; availability of best suited resources; and lack of standardization, transparency, and cloud expertise. However, in the course of this experiment, as we followed each of the 175 teams closely and monitored their challenges and progress, we've got an excellent insight into these roadblocks, how our teams have tackled them, and how we are now able to reduce or even fully resolve them.

This case study from Team 154 is about CFD Analysis of Geo-Thermal Perforation in the Cloud. This experiment studied computational fluid dynamics (CFD) performed on various setups of perforation using Ansys Fluent software at Foro Energy, Littleton, CO. The scope is to characterize the flow propagation through the test setup and recommend design changes needed to improve the flow propagation. The end user was interested in reducing simulation time while also improving result accuracy through the ability to refine the mesh size within their model.

We want to thank the team members for their continuous commitment and voluntary contribution to this experiment, and thus to our technical computing community. And we want to thank our main Compendium sponsor INTEL for generously supporting these 175 UberCloud experiments.

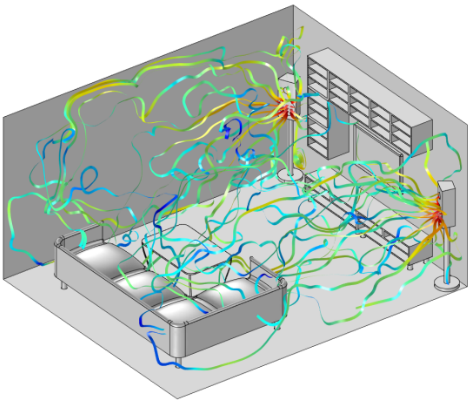
Now, enjoy reading!

Winfried Geis*, Pär Persson Mattsson*, Wolfgang Gentzsch**, and Burak Yenier**

**COMSOL Multiphysics GmbH, **UberCloud Inc.*

****) UberCloud is the online community and marketplace where engineers and scientists discover, try, and buy Computing Power as a Service, on demand. Engineers and scientists can explore and discuss how to use this computing power to solve their demanding problems, and to identify the roadblocks and solutions, with a crowd-sourcing approach, jointly with our engineering and scientific community. Learn more about the UberCloud at: http://www.TheUberCloud.com.*

Team 175
Acoustic Modelling and Parametric Radio Frequency Heating in the Cloud with COMSOL Multiphysics



"Utilizing cloud services make it easy to extend your on premise hardware for demanding applications. The license models and technology of today provides HPC with just a few mouse clicks."

MEET THE TEAM

End user and Team Expert – Pär Persson Mattsson, Technical Support Engineer and HPC Consultant at COMSOL Multiphysics GmbH
Software Provider – Winfried Geis, Branch Manager at COMSOL Multiphysics GmbH
Resource Provider – Thomas Gropp, Engineer IT-Systems, and Christian Unger, Project Manager Resource Area, both at CPU 24/7 GmbH. CPU 24/7 is a leading provider of CAE as a Service solutions for all application areas of industrial and academically/university research and development. Headquartered in Potsdam/Germany, CPU 24/7 develops and operates unique on demand services for High Performance Computing that are based on the latest globally accepted industry standards for hardware, software, and applications.

USE CASE

In this test project, we wanted to find out how the cloud can help in speeding up and enabling high performance FEM simulations with COMSOL Multiphysics®. The aim of the project was to find out how HPC cloud providers can augment the internal on premise hardware to allow for more detailed and faster simulations.

COMSOL Multiphysics is a general-purpose software platform, based on advanced numerical methods, for modeling and simulating physics based problems. COMSOL Multiphysics, with its multiphysics capabilities, is especially suited for coupled and multiphysics simulations, making the description of real-world multiphysics phenomena and systems possible.

For this project two COMSOL applications were used; one acoustic model and one parametric radio frequency (RF) heating model from the COMSOL Multiphysics application library. The acoustic model simulates the acoustic pressure at certain frequencies in a typical living room equipped with stereo speakers and other typical living room furniture. The RF model is a model from the COMSOL Multiphysics application library. It shows dielectric heating of an insulated block, caused by microwaves travelling in an H-bend waveguide.

These two models were chosen since they represent two different forms of parallelization of multiphysics simulations. In the acoustic model, where higher frequencies require a finer mesh, each frequency step is parallelized and the matrix is divided among the different cores and nodes, computing one frequency after another.

On the other side of the spectrum there is the RF model, which is a small model that could easily be computed on a modern laptop, but where a large amount of parameters need to be computed. It can be parallelized so that several frequencies and geometric parameters are computed at the same time. This model yields what is called an embarrassingly parallel computation.

CHALLENGES

Both of the models used in this project bring with them their own challenges:

- In the case of the RF model, the model is small and possible to compute on almost any modern computer, but the amount of frequencies that needs to be computed, together with the different geometric parameters, causes a high number of simulations that need to be performed. Even if the computation of one parameter only takes 30 minutes, the total computation times can become unacceptably large when the number of parametric values increases.
- For a frequency model with a large geometry where higher frequencies are of interest, a large amount of memory is needed to be able to compute the model at all. Many users in small or medium companies do not have the hardware needed on premise, but might still need to handle these types of models sporadically.

PROCESS AND BENCHMARK RESULTS

The computations were performed on a 10 node class "medium" cluster, where each node was equipped with dual socket Intel® Xeon® X5670 and 24 GB of RAM, giving a total count of 120 cores and 240 GB of RAM. The nodes were connected with Mellanox Infiniband QDR. This hardware setup was chosen since it is suitable for a first test of the capabilities of HPC computing in the cloud. The hardware (bare-metal, non-shared infrastructure) was supplied by CPU 24/7, and COMSOL Multiphysics was pre-installed by CPU 24/7's technicians.

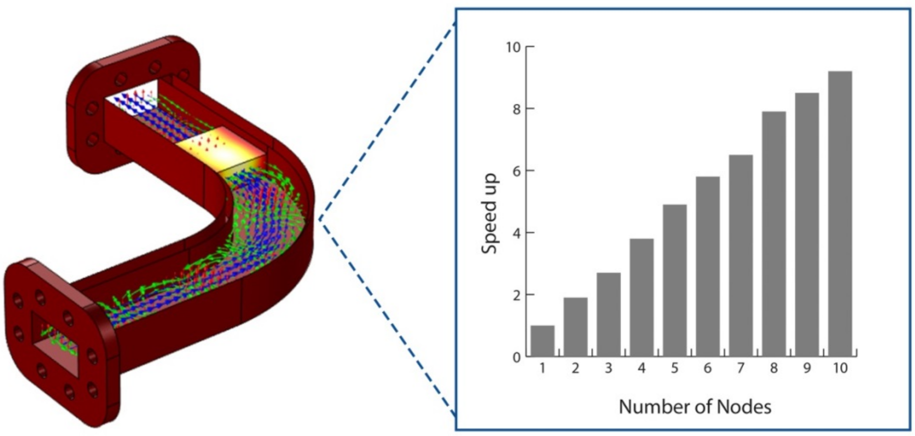


Figure 1 - The H-Bend Waveguide simulated. The image to the left shows the magnetic field (Arrows) of the waveguide and the temperature in the dielectric block (yellow). The image to the right shows the almost perfect speed up gained when adding more compute nodes.

Since the COMSOL Floating Network License (FNL) and the COMSOL Server License (CSL) allow for remote and cloud computing out of the box, the only thing we needed to do was to use the built in COMSOL Multiphysics functionality for starting jobs on remote clouds and clusters, and forwarding access to the on premise license manager. Once the functionality is configured, any model can be sent to the cloud cluster in a matter of seconds.

The benchmarks were performed for one through ten nodes (each equipped with dual Intel® Xeon® X5670 processors and 24 GB of RAM) for the RF model, and for the acoustics model a local workstation (equipped with a single Intel® Xeon® E5-2643 processor and 32 GB) was used as a reference system, while one run where all ten nodes were performed on the cluster. After the simulations finished the computed results were collected and evaluated.

For the RF model the interesting property was the decreased solution time for the parametric computation of the model, which is demonstrated in Figure 1. Since the RF model is a model with a large parametric sweep, i.e. an embarrassingly parallel computation, the almost perfect speed up is expected.

For the acoustics model, we were less interested to see the change in computation speed as we added more nodes, but rather what frequency we could compute in comparison with a standard high end workstation equipped with 32 GB of RAM. As can be seen from Figure 2 a finer mesh could be used in the cluster simulation, compared to the simulation made on the workstation. In this particular model, it meant going from being able to compute frequencies up to 500 Hz the local workstation, to frequencies up to 1200 Hz on the cluster.

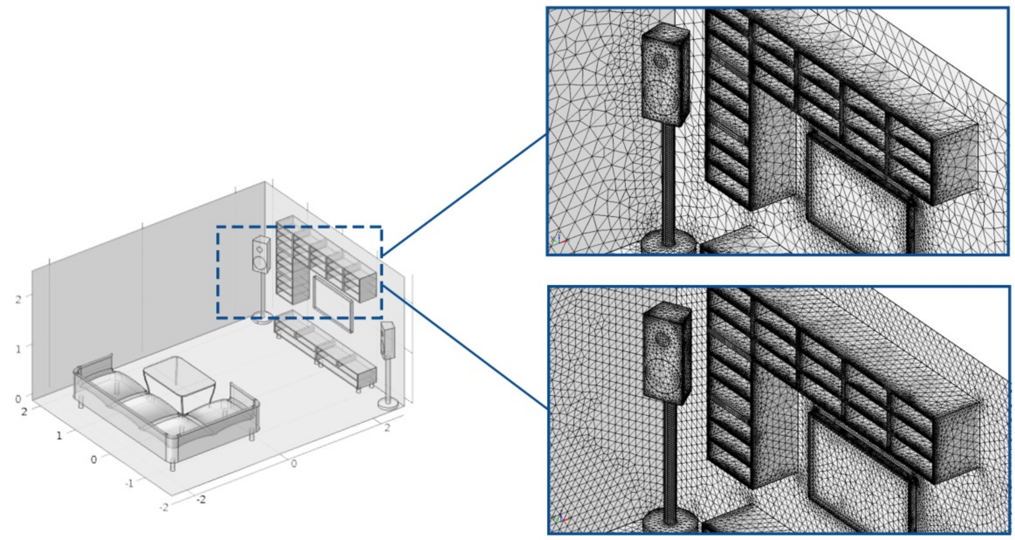


Figure 2 - The geometry simulated in the acoustics model. The images to the right show the resolution of the mesh that was possible on the workstation (top) and on the ten node cluster (bottom). The finer resolution made it possible to simulate up to 1200 Hz on the cluster, in comparison to 500 Hz on the workstation.

BENEFITS

For the user, the use of COMSOL together with the HPC cloud services from CPU 24/7 brings with it many advantages. A few of them are:

- Increased number of cores and memory channels yield higher throughput for time critical projects.

- The increased amount of memory and the faster memory access obtained from an increased number of processors allows us to compute more realistic and detailed models, which might be impossible to compute on local hardware.
- One can have fast access to a bare-metal cluster in the cloud, thanks to the fast and competent support from CPU 24/7. Since COMSOL Multiphysics was preinstalled by the CPU 24/7 technicians, and access was enabled both via remote desktop solutions and SSH, there was no reduction in usability compared to an on premise cluster.
- The easy access to the cloud through the COMSOL Multiphysics GUI, and the possibility to forward your license makes it easy to extend your on premise hardware when needed.

CONCLUSIONS

- It has been shown that the CPU 24/7 HPC bare-metal cloud solution is a beneficial solution for COMSOL users who want to obtain higher throughput and more realistic results in their simulations.
- For parametric studies, the speed up on the cloud based clusters delivered by CPU 24/7 has been shown to be almost perfect, meaning that a ten node cluster can increase productivity almost tenfold.
- To use cluster computing, there is no investment in in-house HPC expertise needed, since CPU 24/7 offers permanently available and tailored HPC bare-bone cloud cluster solutions.
- The time invested from when CPU 24/7 had provided access to their cloud based cluster, until the first job was sent was approximately two hours, including the initial configuration of the remote computing settings in the COMSOL GUI.

Case Study Author – Pär Persson Mattsson, COMSOL Multiphysics GmbH

Thank you for your interest in the free and voluntary UberCloud Experiment.

If you, as an end-user, would like to participate in this Experiment to explore hands-on the end-to-end process of on-demand Technical Computing as a Service, in the Cloud, for your business then please register at: http://www.theubercloud.com/hpc-experiment/

If you, as a service provider, are interested in promoting your services on the UberCloud Marketplace then please send us a message at https://www.theubercloud.com/help/

1st Compendium of case studies, 2013: https://www.theubercloud.com/ubercloud-compendium-2013/
2nd Compendium of case studies 2014: https://www.theubercloud.com/ubercloud-compendium-2014/
3rd Compendium of case studies 2015: https://www.theubercloud.com/ubercloud-compendium-2015/

HPCwire Readers Choice Award 2013: http://www.hpcwire.com/off-the-wire/ubercloud-receives-top-honors-2013-hpcwire-readers-choice-awards/
HPCwire Readers Choice Award 2014: https://www.theubercloud.com/ubercloud-receives-top-honors-2014-hpcwire-readers-choice-award/

In any case, if you wish to be informed about the latest developments in technical computing in the cloud, then please register at http://www.theubercloud.com/. It's free.