Bringing Clarity 3D Solver EM Analysis of Complex Systems to the Cloud

The new Cadence® Clarity™ 3D Solver Cloud is a straightforward, secure, and cost-effective approach to executing Clarity 3D EM simulations using the robust compute resources available in the cloud.

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Design Overview

The growing demand to build intelligent systems across vertical markets such as hyperscale, aerospace and defense, Industrial Internet of Things (IIoT), and automotive, are driving the size and complexity of systems. Together with fast data rates, safety-driven requirements for data integrity are raising simulation requirements to levels no longer achievable with legacy solutions. These requirements need a new, massively parallel architecture, one that is scalable in an unbounded way across thousands of cores in the cloud.

Historically, all 3D EM simulations are taxing in terms of analysis time and computational resources. Hence, jobs are segmented into smaller portions, analyzed separately, and then stitched together, adding risk to the design cycle. To address these issues, the industry needs a true 3D EM solver that is efficient and scalable, and with the ability to address large problems quickly locally or in the cloud.

The Cadence Clarity 3D Solver enables engineers to tackle the most complex EM challenges when designing systems for 5G, automotive, high-performance computing (HPC), and machine learning applications with gold-standard accuracy. Industry-leading Cadence distributed multiprocessing technology enables the Clarity 3D Solver to deliver virtually unlimited capacity and 10X speed required to address these larger and more complex structures efficiently and effectively.

Cadence now offers a straightforward, secure, and cost-effective approach to executing Clarity 3D EM simulations through the robust compute resources available in the cloud. Clarity 3D Solver Cloud provides the ability to scale 3D finite element method (FEM) simulation capacity from 32 cores to thousands of cores using secure connections to Amazon Web Services (AWS).

Clarity 3D Solver

Many 3D EM solvers on the market solve using Maxwell’s equations; however, it is the way in which Clarity solves these equations that makes it unique. Figure 1 depicts the classic 3D EM solver flow that Clarity 3D Solver also uses.
First, the design is imported into Clarity 3D Solver through the MCAD or ECAD process and then the initial mesh is done, followed by the adaptive mesh refinement. Most 3D EM tools offer mesh refinement; however, the process is automated in the Clarity 3D Solver. Next, the frequency sweep is done with interpolation of frequencies, and finally, S-parameters are generated.

The Clarity 3D Solver solves the matrices differently from other tools because it uses a state-of-the-art massively parallelized matrix solver with breakthrough algorithms in the initial mesh, adaptive mesh refinement, and frequency sweep processes. The elastic compute architecture is partitioned automatically and can be used on any capacity machines with unbounded scalability. The cloud-optimizing distribution provides dynamic deployment and fault-tolerant restart and prioritizes lower cost (Figure 2).

Solve Bigger Problems with a Smaller Memory Footprint

Figure 3 shows a legacy distributed processing flow. The data is either imported or created in the tool on a primary computer, the tool then creates the initial mesh, followed by the adaptive mesh. These processes have not been distributed; they have been created on the local machine. After the adaptive mesh is created on the primary computer, the legacy flow distributes the frequencies to individual machines. Each individual machine requires the same large capacity as the primary machine that created the adaptive mesh. This flow is not very efficient, and most 3D analysis designers often choose the divide and conquer approach.
The Clarity 3D Solver distributed processing flow uses a new technique called massively parallelized matrix solver that applies to both the adaptive meshing and frequency sweeping stages. A breakthrough algorithm with near-linear scalability without any loss in accuracy supports multi-threading, distributed processing, and cloud computing.

Figure 4 shows the big jobs being split into small ones and distributed to different machines, each with a small amount of memory. This is the main essence of the Clarity 3D Solver—it does not need big machines and machines with a large amount of RAM. In addition, this is all happening in parallel, which enables scalability and efficiency. This distribution architecture also makes Clarity 3D Solver a unique candidate for cloud computing.

Figure 5 highlights a multi-CPU parallelism comparison between Clarity 3D Solver and a legacy tool.
Case Studies: Integration, Speed, and Capacity with Accuracy

Full End-to-End System Design

Figure 6 shows the end-to-end Cadence system design flow of a camera sensor module. The flow starts with Allegro® PCB Designer, moves to Clarity 3D Solver, and then to Sigrity™ SystemSI™ for the MIPI® compliance check on the systems side. All the tools are integrated within the entire workflow, enabling a straightforward flow from end to end.

PCB and IC Packaging

The case studies highlighted in Figures 7 and 8 prove the speed and performance of the Clarity 3D Solver in tackling large, complex, system-level design challenges. Figure 7 lists PCB test cases where the software returns 6X–20X speed improvement, and simultaneously, a memory reduction of 50%–75% over last-generation EM solvers on the market.

<table>
<thead>
<tr>
<th>PCB Test Cases</th>
<th>CPU cores</th>
<th>Clarity</th>
<th>Legacy</th>
<th>Performance Gain</th>
<th>Clarity Memory Requirement per slot</th>
<th>Clarity Memory Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB Card</td>
<td>64</td>
<td>2.3h</td>
<td>14.5h</td>
<td>6.3X</td>
<td>12.8 GB</td>
<td>65%</td>
</tr>
<tr>
<td>Smart Speaker</td>
<td>32</td>
<td>22.1h</td>
<td>168h</td>
<td>7.6X</td>
<td>25.1 GB</td>
<td>68%</td>
</tr>
<tr>
<td>Multi-Processor Communications PCB</td>
<td>240</td>
<td>12.7h</td>
<td>140h</td>
<td>11X</td>
<td>34 GB</td>
<td>70%</td>
</tr>
<tr>
<td>PCIe: Package + PCB</td>
<td>32</td>
<td>12.2h</td>
<td>75h</td>
<td>6.2X</td>
<td>24 GB</td>
<td>76%</td>
</tr>
<tr>
<td>Rigid-Flex PCB</td>
<td>200</td>
<td>8.7h</td>
<td>can’t run</td>
<td>N/A</td>
<td>48 GB</td>
<td>N/A</td>
</tr>
<tr>
<td>Memory Board</td>
<td>128</td>
<td>11.1h</td>
<td>94h</td>
<td>8.5X</td>
<td>34 GB</td>
<td>71%</td>
</tr>
<tr>
<td>DIMM Card</td>
<td>240</td>
<td>7.6h</td>
<td>91h</td>
<td>12X</td>
<td>32 GB</td>
<td>63%</td>
</tr>
<tr>
<td>Flex PCB</td>
<td>320</td>
<td>7h</td>
<td>138h</td>
<td>19.7X</td>
<td>32 GB</td>
<td>56%</td>
</tr>
</tbody>
</table>

Figure 7: PCB test cases
Figure 8 lists IC package test cases where the Clarity tool scales to enable the use of the large CPU cores needed for complex designs. Compared to legacy tools, the Clarity 3D Solver shows an average performance gain of 10X, as well as a significant reduction in memory requirements.

<table>
<thead>
<tr>
<th>IC Package Test Cases</th>
<th>CPU cores</th>
<th>Clarity</th>
<th>Legacy</th>
<th>Performance Gain</th>
<th>Clarity Memory Requirement per slot</th>
<th>Clarity Memory Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flipchip PDN (1)</td>
<td>32</td>
<td>4h</td>
<td>41.6h</td>
<td>10.4X</td>
<td>42 GB</td>
<td>74%</td>
</tr>
<tr>
<td>Flipchip PDN (2)</td>
<td>64</td>
<td>2.75h</td>
<td>19.25h</td>
<td>7X</td>
<td>60 GB</td>
<td>69%</td>
</tr>
<tr>
<td>28 signals on 28 layer package</td>
<td>320</td>
<td>2.8h</td>
<td>18.5h</td>
<td>6.6X</td>
<td>30 GB</td>
<td>70%</td>
</tr>
<tr>
<td>Long Channels on SiP</td>
<td>256</td>
<td>6.9h</td>
<td>66h</td>
<td>9.5X</td>
<td>29 GB</td>
<td>72%</td>
</tr>
<tr>
<td>32 DDR Signals on 6 layer package</td>
<td>320</td>
<td>44m</td>
<td>6.25h</td>
<td>8.5X</td>
<td>13 GB</td>
<td>73%</td>
</tr>
<tr>
<td>15 Layer Flipchip BGA Package</td>
<td>128</td>
<td>6.5h</td>
<td>66.3h</td>
<td>10.2X</td>
<td>32 GB</td>
<td>61%</td>
</tr>
<tr>
<td>15x15mm Package</td>
<td>64</td>
<td>7.5h</td>
<td>80h</td>
<td>10.7X</td>
<td>38 GB</td>
<td>63%</td>
</tr>
<tr>
<td>8 layer BGA (2 power nets, 62 signal nets)</td>
<td>256</td>
<td>17h</td>
<td>138h</td>
<td>8.1X</td>
<td>32 GB</td>
<td>65%</td>
</tr>
</tbody>
</table>

**Figure 8: IC package test cases**

**DDR Board**

Lenovo, a Cadence customer, investigated a double-data rate (DDR) tabbed routing design using Clarity 3D Solver (Figure 9). It is a 16-layer structure, which after simulation, created 12 million mesh elements. The total simulation time was 45 hours. Other full-wave 3D solvers failed to solve for a problem as large and complex as the DDR bus with tabbed routing. However, Clarity 3D Solver was up to the task.

This case study is a perfect example of how Clarity 3D Solver can solve problems that are too large for last-generation 3D EM solvers to address. The paper on this case study concluded that far-end crosstalk is reduced at high frequency, and with further simulations, they would be able to strategize and optimize crosstalk reduction using a tab structure. It was determined that Clarity 3D Solver should be used in further research.

**Conclusion:** Far-end crosstalk is reduced at high frequency. More research required to optimize the tab structure. Clarity must be used to further the research.
System Laptop

The example in Figure 10 was simulated in the Clarity 3D Solver, which delivered unprecedented performance and capacity. It shows the mesh, field view, and resources for a full system design of a laptop computer. The entire laptop was simulated and the mesh, fields, and the level of detail captured using the tool are visible. On the right is a simple animation view of the fields interacting with the monitor and keyboard of the laptop at the bottom. A presentation video of the simulation is available at the link listed in the references.²

Cloud Scalability

Cadence first announced its Cloud solutions in 2018 and usage has grown exponentially over the years as companies take advantage of its several forms, which include:

- **Cloud Passport**: Cadence provides cloud-ready tools and licenses, and the customer’s IT team performs the day-to-day setup, management, and support
- **CloudBurst**: Cadence manages the fully-cloud based or hybrid-cloud environment in a turnkey manner, with no effort necessary from the customer’s IT team
- **Palladium Cloud**: Customers rent time on Palladium emulators installed in Cadence-managed datacenters

Figure 11 provides an infographic of these different cloud offerings.
The newly announced Clarity 3D Solver Cloud is one of the first Cadence products called Hybrid tools. The Clarity 3D Solver is highly scalable and can take advantage of literally hundreds of cores; however, it can take a long time for this much capacity to be available simultaneously on-premises. Clarity 3D Solver Cloud (Clarity Cloud, for short) enables customers to simply click on a menu item in the Clarity 3D Solver, and simply run the system analysis in the cloud, instead of waiting for hundreds of cores to become available on-premises.

This inventive approach gives users the option to simulate using local compute resources or cloud simulation resources without having to add to either on-premises or cloud computing budgets. Cloud simulations keep design data safe on local computers while sending only encrypted simulation-specific data to the cloud. Using the ISO 27001 security-certified Cadence CloudBurst platform, Clarity Cloud automatically sets up a private and secure AWS chamber, and simulates accessing the user-defined number of compute cores. Simulation results are returned to the local on-premises computer(s) while the data in the secure AWS chamber is immediately deleted. This ensures that 3D EM data is safe, protected, and only discoverable on the customer’s local device.

The Clarity 3D Solver approach enables users to choose any of three ways to simulate, depending on the size and scope of the job (Figure 12).

1. The tool can be used on a local machine.
2. For larger designs, users can increase capacity by using an internal farm, if the organization has one. This requires requesting the machine resources, queuing the job, and heavy-duty computation. Many companies have on-premises data centers, some of which are very large with hundreds of thousands of cores. However, in a large company with multiple designs working simultaneously, even a large data center is often insufficient for peak loads. Verification, in particular, is always backlogged and can soak up any amount of capacity. Running Clarity 3D Solver, one of the most scalable Cadence tools, can take the advantage of literally hundreds of cores but also requires long wait times for enough cores to be available simultaneously on-premises.
3. The third option is somewhat like a race car; if users need extra power and capacity beyond the abilities of their local machine or internal farm, they can hit the turbo boosters by simply clicking a button and transitioning to Clarity Cloud. Unlike the local machine or internal farm, the user is not responsible for maintaining the hardware resources. The Cadence team manages the Clarity Cloud infrastructure, instead.
Figure 13 shows the flow for the new Clarity Cloud approach.

![Diagram of Clarity Cloud flow](image)

The user simply goes to the computer resources setup window and selects the Clarity on Cloud option, chooses the number of CPUs needed for the simulation, and clicks OK. The design file resides on the local computer, and when the user is connected to the network, the simulation data files are zipped, encrypted, and uploaded in the background to the Amazon Web Services (AWS) site maintained by Cadence. The files are then un-zipped and Clarity 3D Solver run. When the simulation is complete, the results automatically download to the local machine for viewing. The user does not need to copy the local files onto the server—Clarity Cloud does this automatically. To run a complete simulation, the user only needs to select Clarity on Cloud, select the number of cores, and hit OK, Clarity Cloud does the rest.

Designers or a customer’s IT teams don’t need to provision the cloud and set up the Clarity 3D Solver and they need not worry about handling licenses and the security of their data. Cadence has a pre-installed multi-tenant Clarity environment already set up and waiting for the user. Under the hood, all the information required is packaged and transparently and securely moved to Cadence CloudBurst™ and dispatched onto multiple machines. The results are then pulled back to the design cockpit, and the design data is deleted from the cloud. Designers can go straight to analyzing their results.

Most aspects of the cloud are positive; one pushback is the security of the design data when using the Clarity 3D Solver in the cloud. However, the Clarity Cloud solution is highly secure. Clarity Cloud leverages the ISO/IEC 27001:2003-certified CloudBurst, which follows CIS-defined security best practices and CSA recommended controls. An additional security layer performs the penetration test, network and endpoint security, threat monitoring, vulnerability management, and security information and event management (SIEM). This CloudBurst infrastructure also meets the very strict security requirements of the foundries, before they release their IP and PDKs to the Clarity 3D Solver Cloud environment.

Finally, Clarity Cloud only communicates simulation data, not the design data, to/from the cloud; it is encrypted in transit and at rest using the latest transport layer security (TLS) protocols and deleted after the analysis is complete.
Conclusion

Clarity 3D Solver is a state-of-the-art full-wave 3D EM analysis technology that provides unbounded capacity and up to 10X faster performance than legacy solutions. The tool is very easy to deploy from the desktop and provides straightforward, secure, and scalable EM analysis of complex systems. Now available in the cloud, the new Clarity 3D Solver Cloud is safe, secure, and cost efficient, using a simple hybrid approach with on-premises setup and cloud simulation. It is no longer necessary to wait for resources; designers now have instant access to affordable cloud computing for even the most complex simulations.

References

2. Laptop simulation video