Three-Tier High-Performance Computing Environment

Baker Hughes

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Abstract— The Baker Hughes high-performance computing environment is deploying a three-tier approach to providing technical computing resources as an alternative to typical high-performance computing. Baker Hughes uses a complete spectrum of computer resources that break from the standards of high-density, dedicated resources. This environment is intended to provide a more flexible and efficient approach that is responsive to business needs. The design has been proven in production systems in the United States and the Russian Federation since the second quarter of 2010 with multiple proprietary and in-house scientific applications. This paper will discuss a computing infrastructure that Baker Hughes has built to better adapt to meet changing requirements in high-performance computing.

Keywords - HPC, dedicated resources, desktop scavenging, cloud computing, scientific computing, case study

Baker Hughes is an oilfield services company that operates in more than 90 countries and has more than 50,000 employees [1]. It is one of the largest oilfield services companies in the world. Baker Hughes provides a full range of services for the oil and gas business including directional drilling, drill bits, perforating services, fluid systems, well logging, data analysis, completion, production and transportation solutions, pressure pumping services, et al.

Baker Hughes has a global network of research, development, and testing facilities with number of research sites in different geomarkets. One of the largest centers is the Houston Technology Center, located in Houston, USA, and the Novosibirsk Technology Center, located in Novosibirsk, Russia,

Almost each scientific project requires theoretical and numerical modeling, and thus software and hardware to perform this modeling. That is the area of expertise for Baker Hughes' High Performance Computing (HPC) team.

The HPC team is charged with developing a new paradigm for technical computing that shifts the emphasis from a strict traditional definition of HPC to a more generalized approach to providing computational resources to the business.

The goal of the HPC team at Baker Hughes is to build and characterize a flexible heterogeneous computing infrastructure that can provide appropriate resources for given problems and adapt to meet changing requirements [1]. The HPC group has designed and developed an enterprise architecture for the HPC infrastructure that makes available HPC resources at our disposal and uses technologies that allow server machines in data centers to be dynamically deployed based on resources. The addition of power management allows inclusion of nontraditional computer assets into HPC using specific computers with predictable usage as contingent HPC nodes [2, 3].

The principal infrastructure consists of three tiers: dedicated, opportunistic and on-demand, each designated for specific methods [4]. The real innovation in the three tier model is creating 'compute tasks' that can be run on any of the tiers without recoding.

The dedicated tier is an array of high-CPU, high-memory servers that can provide massive total compute power linked into clusters with fast interconnects. This tier is used mainly for applications that require dedicated uninterrupted access to hardware while benefitting from parallelization.

The opportunistic tier is basically desktop scavenging, which makes use of idle compute assets such as desktops and redundant servers, usually at night. Using Wake on LAN (WOL) technology, these computers can be powered on or off as needed. This is a green and cost-saving solution, suitable for short run time applications with small footprints.

The on-demand tier uses the cloud. It can be very helpful to leverage massive external HPC when there is unexpected resource demand or peak compute loads.

DOI: 10.5176_2010-2283_1.4.106

I. DEDICATED RESOURCES

The dedicated tier is a 'traditional' array of high-CPU, high-memory servers that can provide massive total compute power joint into clusters with fast interconnects. This is used mainly for applications that require dedicated, uninterrupted access to hardware and/or benefit from parallelization. Also using dedicated resources are the 3d-party computer-aided engineering (CAE) software that requires a lot of memory and with long runtime, and high-priority computations, such as interpretation of field data.

The following includes the current structure of dedicated resources:

- Computational nodes
  - Windows-based
  - Linux-based
  - Solaris-based
  - Dual-boot
- Visualization nodes,
  - Windows-based
  - Linux-based
- GPGPU computational nodes

Computational nodes are managed by the Moab Adaptive Computing resource manager, the scheduler on the Linux side, and the Microsoft Windows® HPC server 2008 R2 on Windows side, which offer a variety of interactive options. Jobs can be submitted and controlled through scripts, graphical user interface (GUI) for Windows, and Web interface.

II. OPPORTUNISTIC RESOURCES

The opportunistic tier is basically desktop scavenging – use of idle compute assets such as desktops and redundant servers. It was first developed in-house at the Baker Hughes Novosibirsk Technology Center. After successful results, it was decided that a third-party resource management solution called UnivaUD GridMP would be used. This solution is controllable by the user, which is secure and supports all common workstation architectures.

The operations with the service are basically the same as with dedicated hardware. For example, users input a job and submit it to the scheduler on the server through the command line, Web interface or the script. The scheduler then distributes it to some workstation node with client installed.

The HPC team worked with the packaging team to distribute Grid MP to the client through the HP OpenView Radia software system (the standard software deployment system).

This solution is suitable for short run time applications with small footprints and for applications that benefit from distribution.

It is also a cost saving and green solution. Baker Hughes recently became one of the Top 10 Green IT companies. [5] The opportunistic tier is one of the components in this success.

III. ON DEMAND RESOURCES

The basic idea of the on demand resources tier is that with dedicated and opportunistic tiers of HPC resources (described above) the maximum estimated capacity of whole resources is provided and depicted as green line in figure 1. The actual utilization chart is depicted by the red line. Typically, it's expected that utilization is less than capacity; however, in this case, all users have resources for their computation needs.

But consider an urgent need case when users request more resources than total capacity of internal HPC resources. For example, in the case of an urgent field support task that affects the company business instantly or possibly the end-of-year rush, when everybody is preparing their reports. How should users be provided with the resources they need? It's impossible and unprofitable to purchase and deploy new servers instantly because these new servers may be idle most of the time. The best solution for the case described above would be cloud computing.

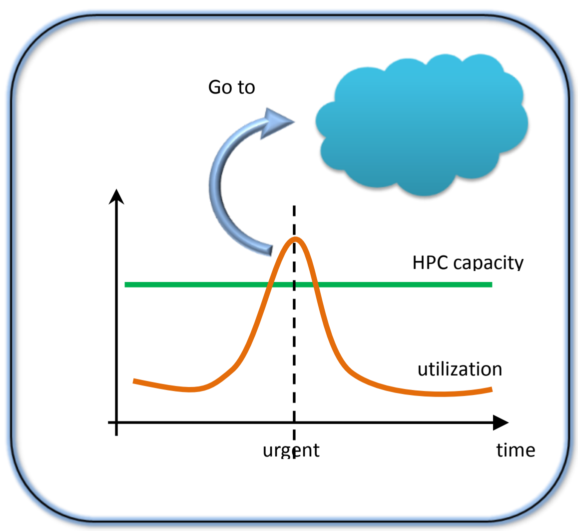

Figure 1. Principle utilization chart of HPC resources

Another reason to use cloud computing is because it quickly addresses urgent needs by instantly increasing the computer power. To optimize drilling and wellbore integrity, scientists and engineers run simulations that approximate reservoir and fluid-flow conditions. These simulations can be composed of more than 500,000 complex calculations and can take up to nine months to complete. The challenge was to reduce the amount of time it takes to process a simulation, without the costly expense of adding more on-premises servers.

Although nine months is not an unheard of length of time for results from these types of simulations, there was a need to accelerate the outcomes in order to be more responsive to the needs of scientists and engineers. Because the fluid-flow simulations are approximations, scientists can take the results, make adjustments to the input parameters, run the simulation again, and retrieve even more accurate results. Therefore, by accelerating the calculation time, scientists and engineers would have the option of getting either faster results or more accurate results by adjusting and running simulations again.

One consideration was to add more physical servers to the HPC infrastructure to accelerate delivery of simulation outcomes to scientists and engineers; however, building additional physical or virtual high-performance server clusters would cost hundreds of thousands of dollars. Leasing servers would be less expensive than purchasing, but would still be too costly, especially when taking into account the cost to maintain and manage the additional support infrastructure.

In addition to the cost associated with adding more servers to the existing infrastructure, simply adding more servers would not be an optimum use of computing resources. Since the extra computing power is only needed sporadically when running large simulations, the additional infrastructure would sit idle otherwise.

Instead of a replacement solution for the existing HPC infrastructure, we wanted an on-demand computing solution that could be used when existing resources were being used for other processes or because faster results were needed.

After surveying the landscape of cloud services providers, Microsoft® Windows Azure cloud platform was chosen as the solution for simulators and CPU-intensive processes. It was a success story for Baker Hughes company [6]. Windows Azure is the development, service hosting, and service management environment for the Windows Azure platform, which is hosted through Microsoft data centers. It provides a cloud operating system that serves as a runtime for the applications and provides a set of services that allows development, management and hosting of applications off-premises. All Azure Services and applications run on Windows Azure. Windows Azure provides the cloud-based solution for the on demand tier.

One way to put applications into the Windows Azure cloud is to write a custom wrapper for the .NET framework with a minimal amount of code. Another way to interact with the Windows Azure is to use HPC Pack 2008 R2 software that is used to control the dedicated tier of Windows-based resources. It also has capabilities to allocate cloud resources and submit jobs with the same interface as for dedicated resources. It is possible to join Azure nodes to the enterprise domain, making it easy to deploy applications and its data to the cloud and return the results back. Another option is to deploy a custom virtual image to the Azure node that already contains all needed applications.

IV. TUBEFLOW SIMULATOR

One of Baker Hughes' in-house R&D applications is the "TubeFlow" simulator that approximates drilling fluid-flow conditions while drilling [7]. The TubeFlow is a computer program for modeling fully developed laminar and turbulent flows of Newtonian and non-Newtonian fluids in an annular channel with eccentricity and rotating inner and outer cylinders; based on finite volume method. Baker Hughes uses TubeFlow to compute the flow of drilling fluid between borehole casing and rotating drillstring. Before providing a field engineer with the "instant" result of simulation, a database must be created that serves as an interpolation grid. This requires a huge number of individual calculations that run concurrently with the run time of one calculation being from 30 minutes to several hours. Due to its low memory requirements, small input/output data size and compatibility with all recent Windows versions, this application is suitable for all three tiers and was successfully implemented with this strategy. This implementation accelerated the calculation time, enabling scientists and engineers the option of receiving either faster results or more accurate results by adjusting and running simulations repeatedly.

Windows clusters of the dedicated tier use Microsoft Windows HPC Server 2008 R2 OS because it can be managed from client workstations with the Windows HPC Pack. The API of this pack allows writing JavaScript and Visual Basic scripts to submit the batch of jobs at once. Typically one batch of TubeFlow computations add about 75,000 jobs to the queue.

Most of current user workstations are installed with Windows® XP, which makes them compatible with TubeFlow computations. These are submitted to the opportunistic tier queue from the client workstation with the set of scripts. After the end of computations the results are stored on the Grid MP server and can be downloaded. Flexible settings allow setting the time of computations on the workstations and other restrictions. Workstation users also have control over the Grid MP client activity.

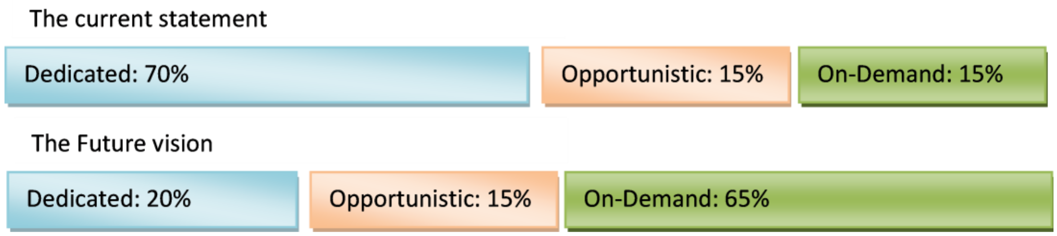

Figure 2. The current statement and the future vision of the HPC environment in terms of tiers ratio

As aforementioned, the interactions with the cloud can be made the same way as with dedicated resources. The script to submit the jobs to the cloud is basically the same as for the dedicated tier, with slight modifications. With the modified script, scientists can choose to either submit parameter sets to the existing HPC clusters, or if they need the results faster or if other computing resources are unavailable, the parameter sets to the cloud can be submitted for computation.

With the TubeFlow simulator, the importance of on the on demand tier is that it gives the ability to refine the interpolation grid very quickly. When researchers find a lack of data in a grid area that has been populate with new values, the HPC environment can quickly provide them with any reasonable number of concurrent computations.

V. The Future of Corporative HPC at Baker Hughes

We are hopeful that the Microsoft HPC server will eventually provide the opportunity to work with all three tiers under one scheduler if the target application is the Windows application.

Right now it's possible to join any Windows 7 desktop to the HPC Server 2008 R2 cluster as a workstation node. Therefore, dedicated and opportunistic tiers can be combined under the one scheduler after the full transition of user desktops to Windows 7 is complete.

In the HPC Server 2008 R2 SP2 Microsoft develops the work with so called Azure compute nodes. It's possible to establish a special node template that provides a user with the ability to raise any number of Azure virtual machines that can serve as cluster compute nodes. Users can submit the job on the Azure node via the same scheduler. Other features of SP2 are the HPC job portal, which lets cluster users submit and monitor jobs from a Web portal and provides the ability to run MPI jobs on Windows® Azure.

A further development of the cloud computing idea is what can be called a "virtual research center." Baker Hughes is in the process of opening new research centers that will require computation power for scientific research. Instead of deploying local server facilities with the necessary cooling, power and hardware, it is possible to use cloud computing. In the simplest case, all that would be needed for local workstations would be Internet access. For the long term, however, it is recommended to have a local server as a "headnode" and database of the jobs. The limitations would be the size of input/output files and licensing regulations for third-party CAD/CAE software.

According to our expectations, the future HPC needs will be primarily covered by on demand (cloud) components with quotas that are expected to increase (Fig. 2).

VI. Conclusion

This discussion described a three-tier strategy that moves Baker Hughes to the cutting edge of using new techniques to solve business problems and brings efficiency in computer assets. The infrastructure is easy for scientists to use and can handle all types of computations: large FEA computations that last for weeks, massive parallel computations, such as molecular dynamics, and batches of small computations, such as TubeFlow described above.

Acknowledgment

Baker Hughes thanks Microsoft® for providing all required info about the Windows Azure platform and for active support during the deployment.

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BIOGRAPHIES

Nikita Tropin received a master's degree in mathematics and mechanics at the Novosibirsk State University, Russia in 2009. He is presently working as a HPC project leader at the Novosibirsk Technology Center of Baker Hughes. His research interests are in the area of high-performance computing, parallel computing, computational fluid dynamics and molecular dynamics.

Egor Vtorushin graduated from the Novosibirsk State University, Russia. He received a Ph.D. degree in the field of mechanics of solids from the Lavrentyev Institute of Hydrodynamics, Russia in 2006. Egor Vtorushin joined Baker Hughes in 2008 as a scientist and has been working on the adaptation of various geophysical and mechanical numerical problems of high-performance computing. His research interests also include computational fracture and solid mechanics, rigid body dynamics and parallel computing.

Tom Gardosik has been with Baker Hughes for 14 years. During that time he has worked as System Integrator as the High-Performance Computing Group Team Lead, and currently as Enterprise Solution Architect for High-Performance Computing.

In this and previous prositions, Tom has been responsble for on-site system installations in the UK, Spain, Australia, Russia, Norway and China.
Tom received a bachelor's of sciences degree from the University of Maryland in 1977.