NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DATA ANALYTICS STORAGE SYSTEM (DASS) FOR NASA'S LARGE-SCALE CLIMATE DATA ANALYTICS

DANIEL DUFFY
(DANIEL.Q.DUFFY@NASA.GOV)
HIGH PERFORMANCE COMPUTING LEAD
NASA CENTER FOR CLIMATE SIMULATIONS

NOVEMBER 10, 2016

Data Analytics Storage System (DASS)

Climate and weather models take in relatively small amounts of input data and generate extremely large data sets. These models require high performance solutions that are tightly integrated to enable a single model run over many computing systems. Once the data is generated, researchers must then analyze the large volumes of data and turn it back into small amounts of data from which knowledge of the model and processes is extracted. While these analytics require large amounts of data, they can typically be run in inherently parallel ways that do not require tightly integrated solutions.

The NASA Center for Climate Simulation (NCCS) has been evolving its systems and services towards an environment in which these two competing sets of requirements (high-resolution modeling and data analytics) can coexist. By combining our knowledge of high performance computing and analyzing the emerging commodity solutions around "Big Data", the NCCS has created the Data Analytics Storage System (DASS) that will combine high-performance computing and storage services in a single system to serve both traditional and emerging data analytics. This architecture was presented at the 17^{th} Workshop of High Performance Computing in Meteorology in Reading, UK[1].

The DASS hardware is a traditional set of servers and storage built out of commodity components. The system is architected to be able to scale both horizontally (compute and bandwidth) and vertically (storage capacity). The DASS will be at the center of the NCCS environment and will house strategic model and observational data sets in a write-once, read/compute-many environment. The initial capacity of the system is almost 16 petabytes of storage divide up evenly across 22 storage servers. The system has a total of 792 processor cores for a peak computing capacity of over 32 teraflops. This is roughly the equivalent to the total compute capacity of the NCCS just 6 to 7 years ago!

While the hardware is largely commodity based, the uniqueness of the system comes in the software stack, which is being designed to serve both traditional analytics and the Hadoop ecosystem. To enable traditional analytics, the NCCS is using the IBM GPFS high performance file system, which provides a POSIX interface to data stored in the DASS. Users will have the ability to run traditional python scripts, IDL, Matlab, C, and Fortran code on scientific data. Layered on top of the GPFS file system is a connector that allows for the use of the Hadoop ecosystem on top of a shared parallel file system. Users can then have the ability to run MapReduce and Spark jobs on the same hardware being used for traditional analytics.

However, the Hadoop ecosystem was not designed to be able to natively ingest structured scientific data sets stored in formats such as NetCDF. Therefore, data accessed through Hadoop needs to be sequenced into <key, value> pairs to be useful. Given that the data sets are petabytes in size, the creation of a second copy of data in a different format is an untenable solution. To solve this, the NCCS has created a custom Spatiotemporal Indexing Approach (SIA) that uses the knowledge of the natively stored, structured scientific data to create a custom index for Hadoop queries.[2]

This unique combination of software (GPFS, Hadoop, and SIA) allows for large NetCDF data sets to be copied into a POSIX file system and indexed for use by Hadoop applications without sequencing or making additional copies of the data. Rather than move the data to the application, this hardware and software architecture allows for the data analytics application to be moved into close proximity to where the data is stored.[3] Hadoop MapReduce and Spark applications will be passed down into the DASS to run on the GPFS storage servers. The SIA index allows for extremely efficient indexing in order to maximize the data locality of queries and minimize data movement. By enabling the Hadoop ecosystem, the NCCS is also very interested in exploring the use of this architecture for deep learning applications, and the computational capacity of the DASS provides a unique opportunity to apply machine learning to climate and weather data.

In addition to embedded analytics within a compute/storage fabric, the DASS is also positioned within the NCCS environment to serve data out to other systems, including the ADAPT high performance analytics science cloud. The DASS will serve data out to the virtual machines within ADAPT to continue to supply the traditional methods for analytics. In addition, ADAPT will be able to leverage the embedded analytics within the DASS to call MapReduce, Spark, and other big data applications. ADAPT could then be used to create new services and enable new interfaces to data and analytics built around application programming interfaces and web services. The vision is for users to access the data and compute within the DASS environment through notebook type interfaces, thereby truly enabling users to submit large-scale, knowledge-based queries that are computed within the NCCS environment and provide only the output back to the requester.

References:

[1] http://www.ecmwf.int/sites/default/files/elibrary/2016/16790-emerging-cyber-infrastructure-nasas-large-scale-climate-data-analytics.pdf

[2] ***A spatiotemporal indexing approach for efficient processing of big array-based climate data with MapReduce***, Zhenlong Lia, Fei Hua, John L. Schnase, Daniel Q. Duffy, Tsengdar Lee, Michael K. Bowen and Chaowei Yang, International Journal of Geographical Information Science, 2016, http://dx.doi.org/10.1080/13658816.2015.1131830.

[3] ***Climate Analytics as a Service***, John. L. Schnase, Daniel Q. Duffy, Mark A. McInerney, W. Phillip Webster, and Tsengdar J. Lee, Proceedings of the 2014 conference on Big Data from Space (BiDS'14), Frascati, Italy, 12–14 November 2014, doi: 10.2788/1823.