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Challenges for the CMS Computing Model in the First Year

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Abstract

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Challenges for the CMS Computing Model in the First Year

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Abstract. CMS is in the process of commissioning a complex detector and a globally distributed computing infrastructure simultaneously. This represents a unique challenge. Even at the beginning there is not sufficient analysis or organized processing resources at CERN alone. In this presentation we discuss the unique computing challenges CMS expects to face during the first year of running and how they influence the baseline computing model decisions. During the early accelerator commissioning periods, CMS will attempt to collect as many events as possible when the beam is on in order to provide adequate early commissioning data. Some of these plans involve overdriving the Tier-0 infrastructure during data collection with recovery when the beam is off. In addition to the larger number of triggered events, there will be pressure in the first year to collect and analyze more complete data formats as the summarized formats mature. The large event formats impact the required storage, bandwidth, and processing capacity across all the computing centers. While the understanding of the detector and the event selections is being improved, there will likely be a larger number of reconstruction passes and skims performed by both central operations and individual users. We discuss how these additional stresses impact the allocation of resources and the changes from the baseline computing model.

1. Introduction

The CMS experiment adopted a distributed Computing Model [1] early on in the program based on a hierarchy of computing Tiers described in the MONARC Project [2]. A variety of factors motivated the distribution including the desire to leverage facility infrastructure, access to additional funding channels, and the desire to better empower the local CMS communities. In the CMS implementation roughly 20% of the computing capacity is located at CERN, while the remaining 80% is distributed. This large decentralized component forces the distributed model to work efficiently from the start of the experiment. There are not sufficient analysis resources located at any one place. Recent operating experiments have achieved a good utilization of widely distributed resources, but have typically succeeded after the detector has been commissioned. Even though there have been many years of preparation in challenges and commissioning exercises, CMS still faces significant technical challenges to commission the computing model during the first year.

One unexpected element facing CMS in the first year is the proposed exceptionally long first run. In the current CERN schedule CMS will begin collecting cosmic events in the summer of 2009 and transition to collecting collision events in October of 2009. The run is planned to continue, with a very short break at Christmas, until late in 2010 after 300pb-1 has been collected. In most previous schedules we had anticipated a significant shutdown during the winter for machine work that would allow the computing program to identify and solve problems observed during the pilot run. The long run is an exceptional opportunity for physics, but is a challenge for commissioning and operations. CMS is examining elements in the computing system to distinguish those that can be relatively easily updated during the run, and therefore can be treated more flexibility, from those that are difficult to update and should be given additional development effort and testing before the run to ensure scaling and performance.

In addition to the long run there are a variety of technical challenges facing the CMS computing infrastructure in the first year of the experiment. Below we will attempt to summary the challenges, starting from the initial running conditions of the machine and working through how the data is distributed and made accessible for analysis.

2. Initial Running Conditions

In the CMS Computing Model[1] there is a baseline trigger rate, which has grown with improved understand since the original detector design, but is specified to allow all elements of the computing infrastructure to keep up with the data taking rate in real time. The system is designed with significant disk buffers at the experiment and in CERN IT, but those buffers were intended to provide contingency for service failures and error conditions. In the design of the Computing Model CMS assumed an accelerator efficiency of 50% that may be unrealistic in the first year of running. In the first year of the program the operational efficiency is likely to be much lower. Current estimates are approximately 20% live time at the beginning. Under these conditions there will be pressure from the experimental community to collect as many events as possible when the beam is on. The interest in the additional data primarily comes from the detector and trigger commissioning efforts. It is possible to overdrive elements of the full data acquisition system and buffer events at defined points, relying on the structure of machine live time to drain the buffers and clear the backlog. In this case the buffers at the detector fill steadily during beam on periods because the network from the detector to CERN IT cannot keep up with the rate. Additionally, the import buffers in CERN IT are used because the reconstruction farm will become backlogged. Since the expected live time of the accelerator is low, the computing system continues to run during the periods without beam to drain the buffers and process the data. This allows more events to be collected during the commissioning phase with beam, but requires a reasonably strenuous program of work to demonstrate that the behaviour of the system is completely understood under the stressed scenarios. CMS is performing a series of tests to ensure the computing system can smoothly recover from filling the buffers and return to normal running conditions promptly for the next beams.

3. Equitably Distributing Data

Once the data is collected, it is divided into streams based on trigger information. The original estimate from the computing model is that 50 streams would be used with a 10% overlap. The current estimate from physics studies is that we will operate with 15-20 data streams at a 20-40% overlap. Each stream will be stored at one custodial Tier-1, though in some cases it may be stored at an additional Tier-1 for better access. Keeping the streams together allows us to prioritize reprocessing of data. A stream can be processed as a whole when an improved calibration is available. Streams of raw data are stored together on a group of tapes, which improves the efficiency to bring the data online. It should be possible to perform most analyses with one single stream, which reduces the number of events a user needs to access when performing an analysis.

Data is sent from CERN to the Tier-1s as soon as the raw data is available in the final format and subscribed to the destination sites. The promptly reconstructed events are subscribed and transferred to Tier-1 sites as the files are available, which is typically between 24 and 48 hours after data collection. The process of replicating data from CERN to the Tier-1s over the optical private network has become quite reliable. Figure 1 shows the replication of data from CERN to Tier-1s during the fall 2008 cosmic running. Even during the collection of cosmic events the transfer rates are approaching the rates expected during collision running.

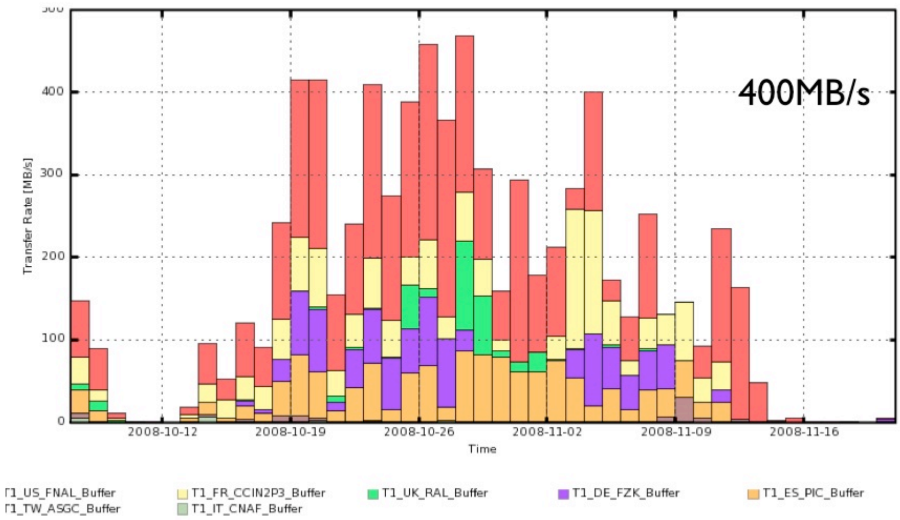

Figure 1: Rate from CERN to Tier-1 Centers during Fall 2008

With the possibility of a particular stream of data residing at a single Tier-1, it is very important that all Tier-1 sites meet our metrics for availability and reliability. A challenge currently facing CMS is that we observe availability of the Tier-1 centers using the VO specific tests that are much lower than the targets from the Worldwide LHC Computing Grid (WLCG)[3]. In order to improve the performance CMS has formed a site readiness task force, who are working with the sites to systematically test each site and improve the availability of the Tier-1s and Tier-2 sites[4].

4. Interactions with Mass Storage

Once samples have been successfully replicated to Tier-1 sites they are stored on tape and served from disk. Given the estimates for the time to process one event and the number of processing cores at a nominal Tier-1 in the Computing Model[1], we can calculate the possible processing rate and the expected IO rate from mass storage. For reconstruction a nominal Tier-1 should be capable of processing 70Hz worth of data with a required IO rate of 100MB/s. This is easily achievable with the available installations. Skimming through the reconstructed datasets uses only 1% of CPU of reconstruction so sparse reading of the file is required to have manageable IO rates.

In order for CMS to make efficient use of the CPUs the files must be predominantly on disk. In the first year nearly all the RAW data should be available on disk, while the simulation samples are expected to be staged from tape for processing and access. Ensuring the files expected to be disk resident are actually on disk and bringing tape resident samples on line remains a challenge facing CMS. The standard protocol for access to mass storage is through the Storage Resource Manager (SRM)[5]. SRM has been a very successfully implemented protocol in the WLCG. SRM provides a consistent interface to a variety of underlying mass storage technologies, it provides good load balancing between the physical hardware systems, and all experiments have been able to achieve high transfer rates. While SRM has interfaces to bring files from tape to disk and to monitor the availability of files, it is not clear that all implementations of SRM scale to the rate needed to support the data management functions needed by CMS. CMS is currently examining how to implement components needed to pre-stage data into the existing data transfer system, PhEDEx[6]. The initial versions of these implementations should be available for testing by the late spring.

5. Data Serving

The Tier-1 sites in the CMS model have some of the most challenging data IO requirements because they are expected to input custodial data from CERN and archive simulation from Tier-2s, while they are serving analysis transfer requests to Tier-2s and performing reprocessing and skimming of data.

In the CMS experiment the Tier-1 centers rather than the Tier-0 serve the majority of the data to the Tier-2 centers for analysis. The data is written once, but it will be read many times so the Tier-1 export rate frequently exceeds the ingest rate. Figure 2, shows an example for Fermilab during the Common Computing Readiness Challenge in the spring of 2008. The data rate into the Tier-1 site peaks at roughly a third of the total rate exported.

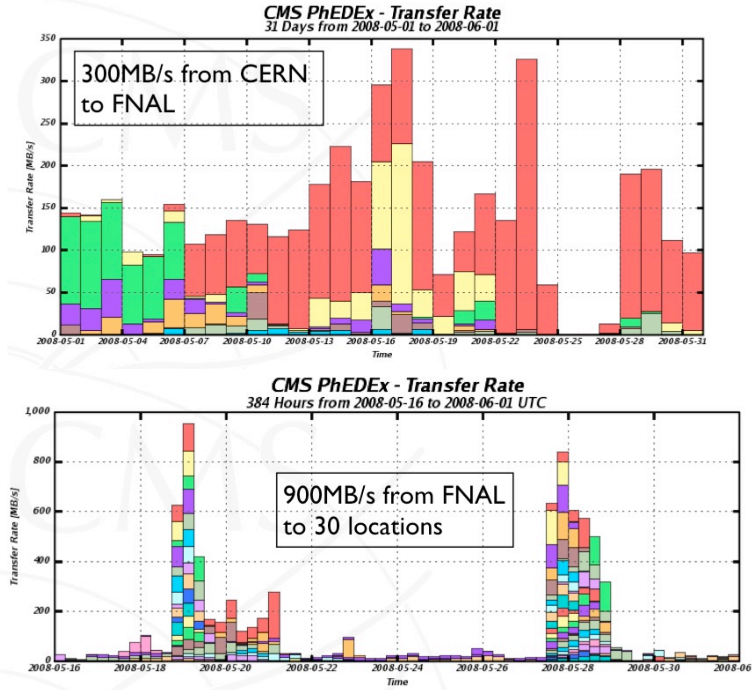

Figure 2: Transfer rates to and from FNAL during CCRC09

In addition to the normal hierarchy of transfers between the tiers as described in the MONARC computing model[2], CMS permits the transfer of data from any Tier-1 to any Tier-2 worldwide. Data is available from at least one Tier-1 site. If an analysis group wants to transfer a sample to a Tier-2 site it is expected to be transferred directly from the source Tier-1 and not forwarded to a regional Tier-1 first. This "full mesh" of transfers improves access to the data, but has required significant computing commissioning effort. This effort in CMS has been the work of the Debugging Data Transfers (DDT) task force[7]. In 2009 CMS has had many examples of achieving the target rates expected in the computing model for both the domestic and international links in the production instance of the data management system. Three particularly good examples in the first quarter of 2009 were the Italian Tier-1 in CNAF to Caltech at greater than 100MB/s for 8 hours, the U.S. Tier-1 in FNAL to Tier-2 GRIF in France at greater than 90MB/s for several days, and the German Tier-1 at FZK to the University of Nebraska at a peak transfer rate of greater than 300MB/s. CMS continues to work at improving the number of permutations in the full mesh of Tier-1 to Tier-2 transfers that achieve the target rate. The ability to efficiently provide access to samples will be critical in efficiently supporting analysis for CMS.

6. Data Access

The CMS computing system has the capacity for very high rate data transfers between Tier-1 and Tier-2 centers in bursts. A nominal Tier-2 in 2008 had 200TB of disk-based storage. Making efficient use of the networking and ensuring the appropriate revision of a dataset is at a location with sufficient processing resources is a challenging data management exercise. The knowledge of the needs of many groups of people is aggregated in the group leaders and not in an automated software system. CMS has attempted to increase the number of people empowered to make data management decisions by dividing the available storage into chunks. The 200TB of Tier-2 storage is divided into 4 logical pieces. At the storage at the Tier-2s increases in 2009 and beyond the allocations to groups and central space will grow.

1. Local Group and User Space: This is roughly 30TB per group currently with an additional 1TB per user that is controlled and managed by the geographically local community.
2. Physics Group Space: 60-90TB of space is allocated to 2-3 physics analysis groups. Representatives from the groups serve as data managers for the space and make subscription and deletion requests. The space for each group will increase with time as datasets grow.
3. Centrally Controlled Space: 30TB (growing to 50TB in 2009) of space is identified at each Tier-2 under the control of CMS centrally. This is used to ensure complete copies of the reconstruction datasets are available across the Tier-2s.
4. Simulation Staging and Temporary Space: 20TB is identified to stage simulation produced at the Tier-2s and other temporary files before they can either be merged or transferred to the permanent home.

CMS is in the process of training users and administrators to manage the storage at the Tier-2s to efficiently support analysis. Even in the current commissioning phase CMS has hundreds of active users and more than 5PB of disk space across the Tier-2s. We expect to utilize the space dynamically and take advantage of the wide area network links to update samples frequently. Shifting to this paradigm involves solving technical challenges as well as engaging a large community of users.

Once data is successfully transferred and available at a Tier-2 facility users access the samples using the CMS Remote Analysis Builder (CRAB)[8]. CRAB shields the underlying complexity of the grid infrastructure from the user community. CRAB has been used by roughly 40% of the CMS members in the last year, which is very broad adoption. We currently see between 30k and 50k job submissions per day, which is roughly one third of the expected rate for collision data. We are actively trying to increase the scale to demonstrate that the analysis resources can be accessed at the design rate.

Currently CMS sees an overall job failure rate of between 10% and 20% for user analysis jobs. These failures come from a variety of sources and work is ongoing to improve the situation. Some fraction of the failures are caused by the underlying grid system, which is being assessed with dedicated scaling tests. Some failures are caused by data integrity problems at the Tier-2 sites. Tier-2s use disk only storage and some data files are lost. CMS has commissioned data integrity checking tools that have improved the situation. Finally some jobs are lost during the stage out of the produced results to user-controlled storage. This is a particularly expensive category of job loss because they waste the largest fraction of resources and fail in the final step. CMS is working with both operational changes to improve the situation and longer term development work to arrive at a more reliable system.

When CMS has collision data the number of users and the amount of activity will increase. We've conducted many challenges to try to ensure the infrastructure will hold up under the heavy load, but we expect the analysis in the first year to be uniquely challenging.

7. Summary

CMS is commissioning a large distributed computing system while commissioning a complex detector. To help ensure the system is functional for analysis from the beginning we have been through a series of challenges and activities, but surprises are certain to appear. The initial run is longer than expected, which is a great opportunity for physics but is a new challenge for operations. Most of the use-cases and access patterns are well understood in theory, but new stress points and failure modes will appear as the system is utilized by thousands of excited physicists. CMS is trying to prepare for the challenges it is sure to face in the first year of collisions at the LHC.

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