Cloud-based Distributed Computing System for LHAASO

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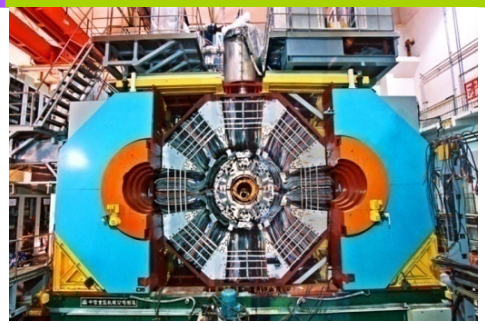
Outline

- Scientific Computing in IHEP
- Overview of LHAASO experiment
- Computing Requirements and Challenge of LHAASO
- Cloud-based Distributed Computing Solution
- Summary

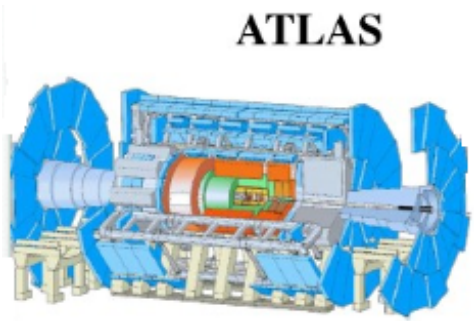
Scientific Computing in IHEP

- BEPCII & BESIII
  - ~10PB data
- LHAASO
  - Start taking data in 2018,6PB/year
- DayaBay
  - 200TB/year, >2PB data
- JUNO
  - Begin taking data in 2020, 2PB/year
- HXMT,CSNS, CMS, ATLAS, LHCb experiments on LHC,HEPS



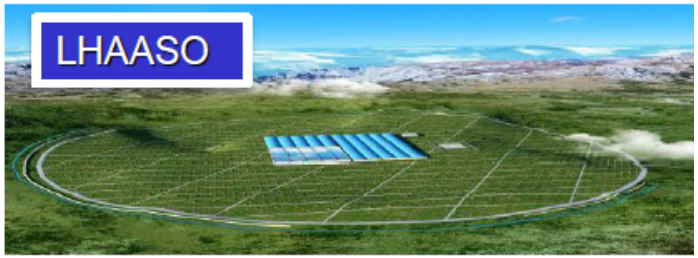
Daya Bay 13

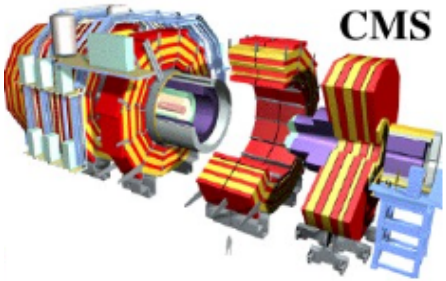
DYB (Daya Bay Reactor Neutrino Experiment)



JUNO

JUNO (Jiangmen Underground Neutrino Observatory)

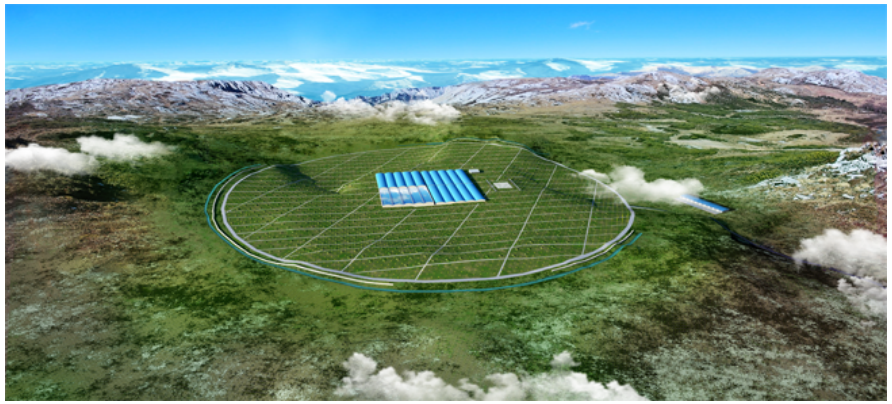




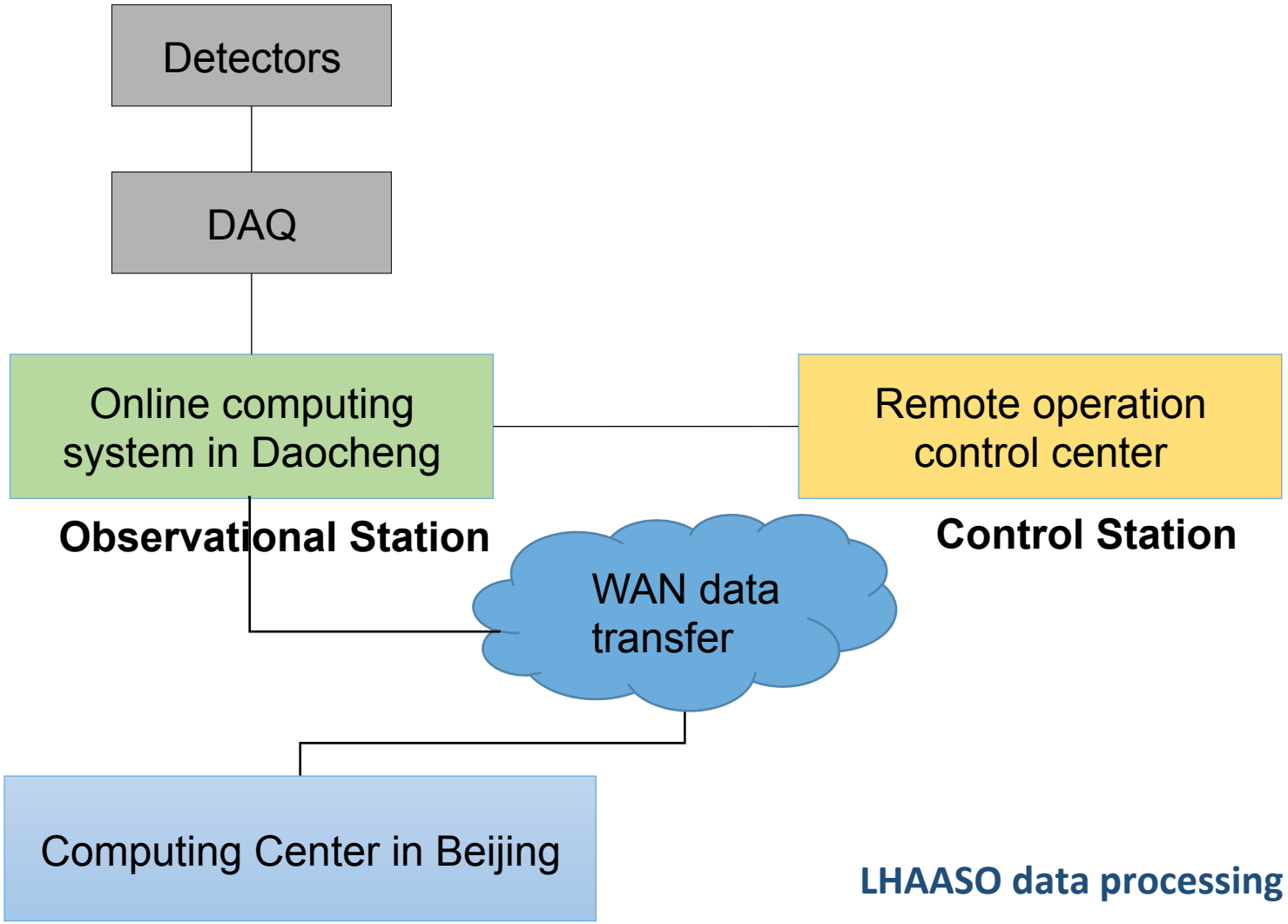
LHCb

LHAASO

- **Large High Altitude Air Shower Observatory**
  - Located in Daocheng, Sichuan province (at the altitude of 4410 m)
  - Expected to be the most sensitive project to study the problems in Galactic cosmic ray physics
  - Start to take data in 2018
  - ~6PB/year
- **Computing Requirements**
  - >100000 CPU cores
  - Disk Storage: ~20PB
  - Tape storage:, 120PB(6PB*10*2) two replication for 10 years
  - Dedicated network between IHEP and DaoCheng: 2.5Gpbs, 2PB to be transferred annual



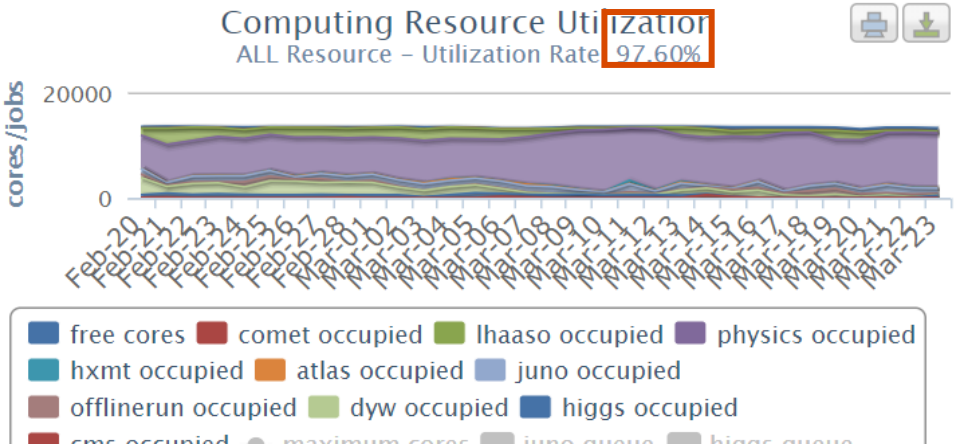
LHAASO data processing platform



LHAASO data processing platform

Motivation

- IHEP provides the computing service for BESIII, Dayabay, JUNO, LHAASO, CMS,Atlas and LHCb experiment
  - ~15000 CPU cores, 88 GPU cards, +15PB disk storage, 9.18PB tape storage
- The computing resources of the existing single data are under pressure
  - A large number of jobs are always queued



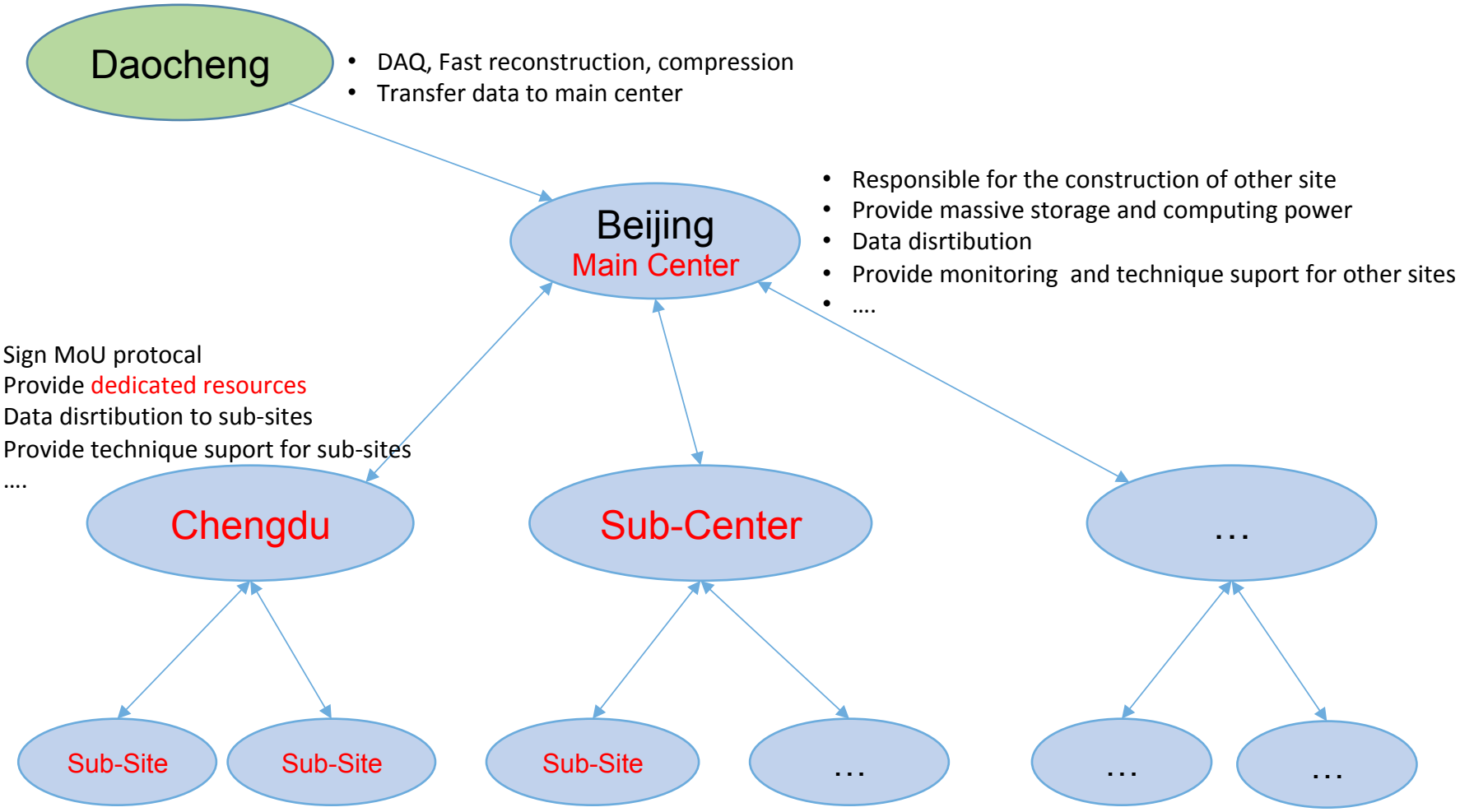
The overall resource utility keeps up to 95%+

- To meet the requirement of huge amount of storage and computing power, we need to integrate distributed heterogeneous resources to expand computing scale

Motivation & Challenges

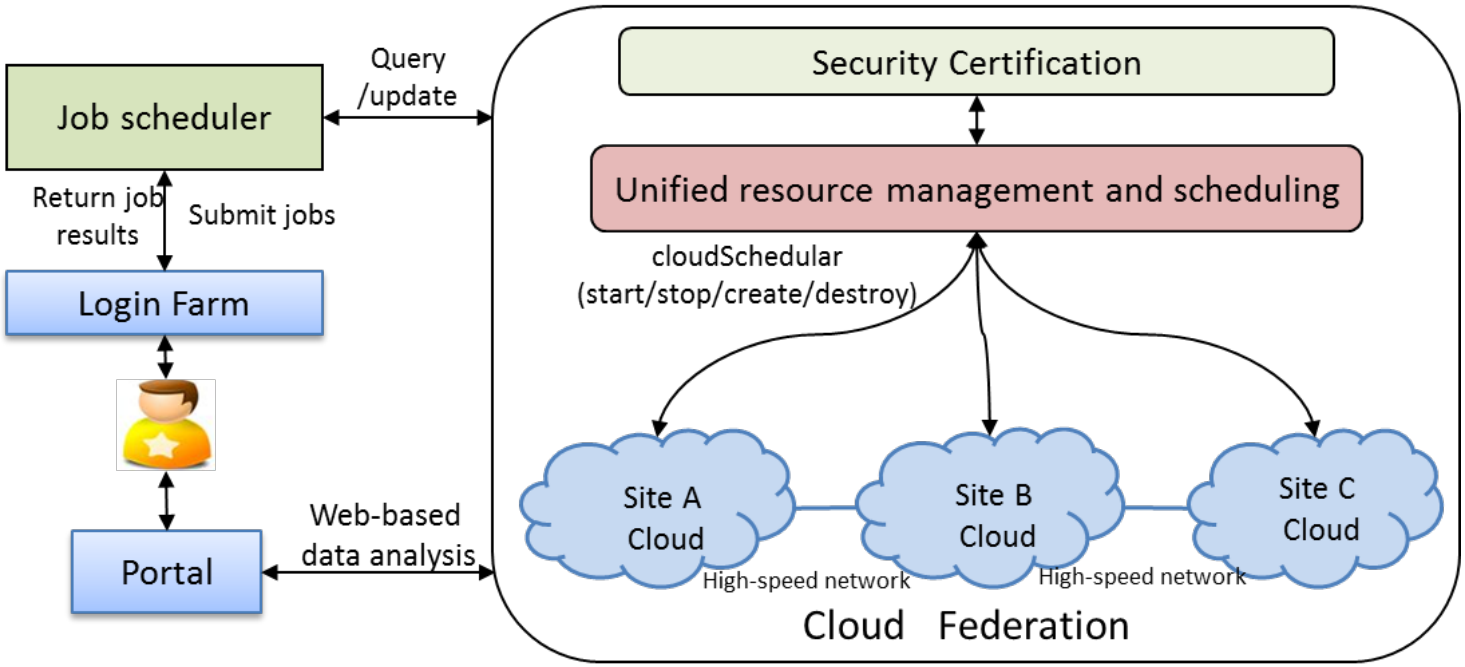
- The dedicate computing resources for LHAASO are distributed, located in Beijing, Daocheng and Chengdu
- Resource integration promotes resource sharing and improve the contribution of LHAASO cooperation groups
- HEP experiments using cross-border resources are troubled with some issues
  - High operation and maintenance costs
  - Computing system instability of remote sites
  - Operation and maintenance ability is poor
  - Shortage of experienced administrators
- We introduce virtualization and cloud computing technologies into LHAASO computing system
  - Use virtualization technology to hide the underling details
  - Make sure the system availability and stability
  - Significantly reduce the maintenance cost

Shcema: LHAASO Distributed Computing system



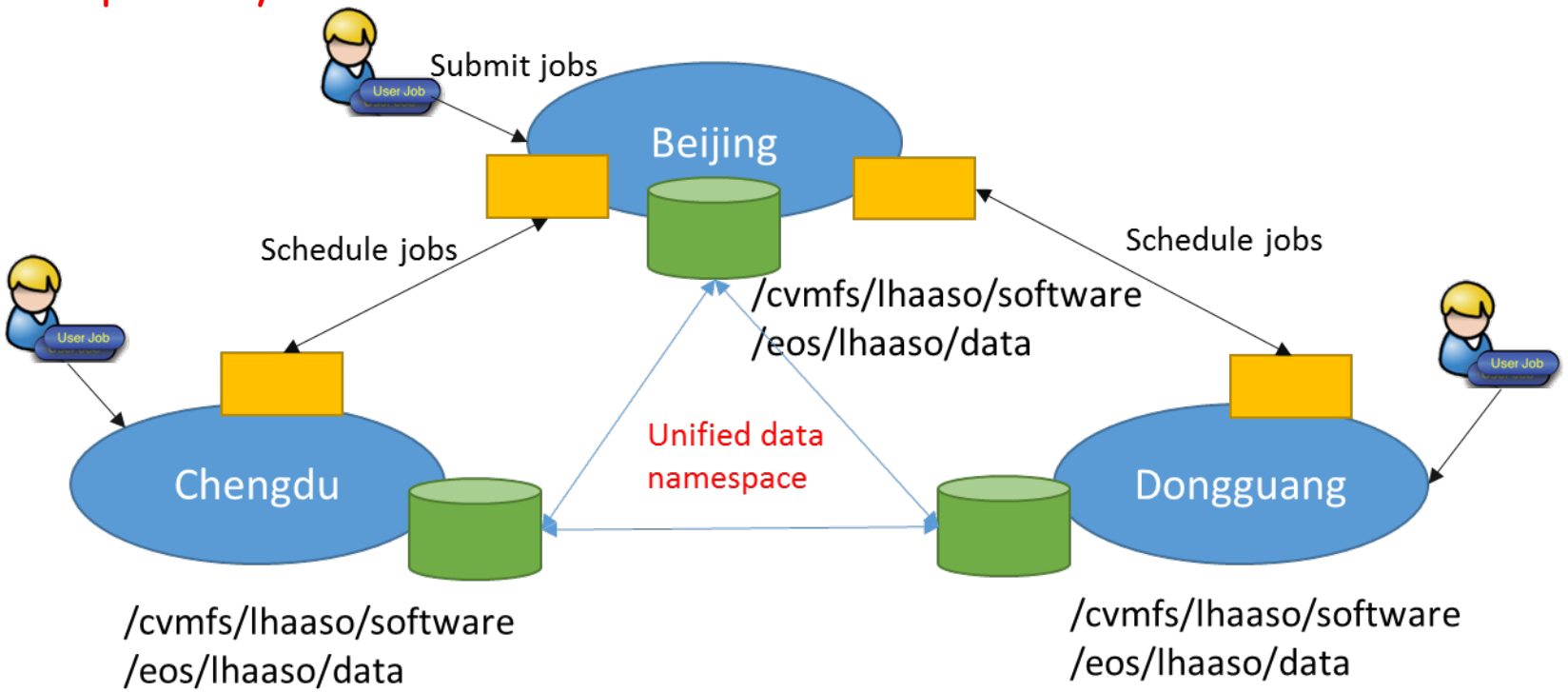
Architecture

- Key points
  - Unified distributed resource management
  - To schedule jobs across regions transparently
  - Dynamic resource provision to meet the peak demand
  - Distributed monitoring and automated deployment
  - Security certification



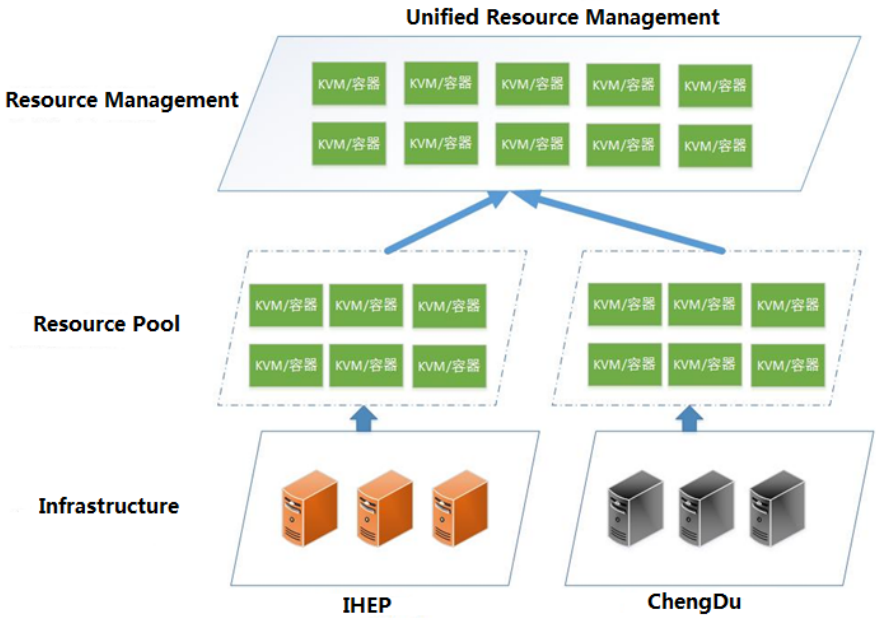
Features

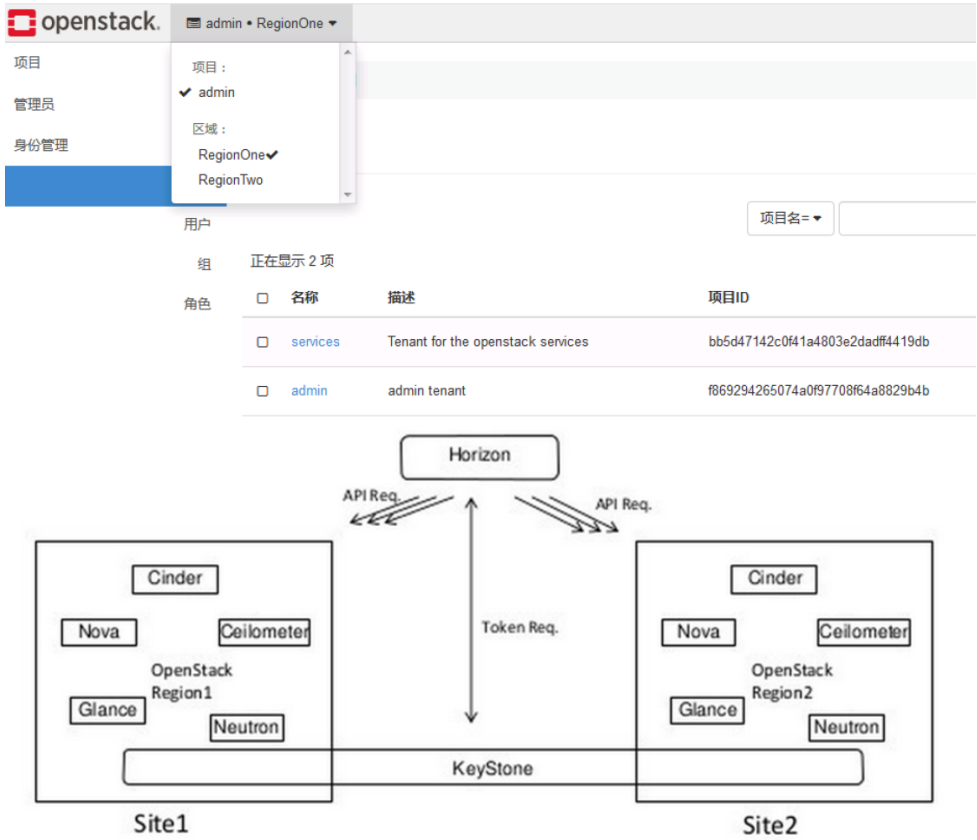
- Based cloud computing models to achieve unified management across regions
- Remote operation and maintenance
- Unified data namespace and support remote data access
- When the local site is busy, the jobs can be allocated to remote sites transparently



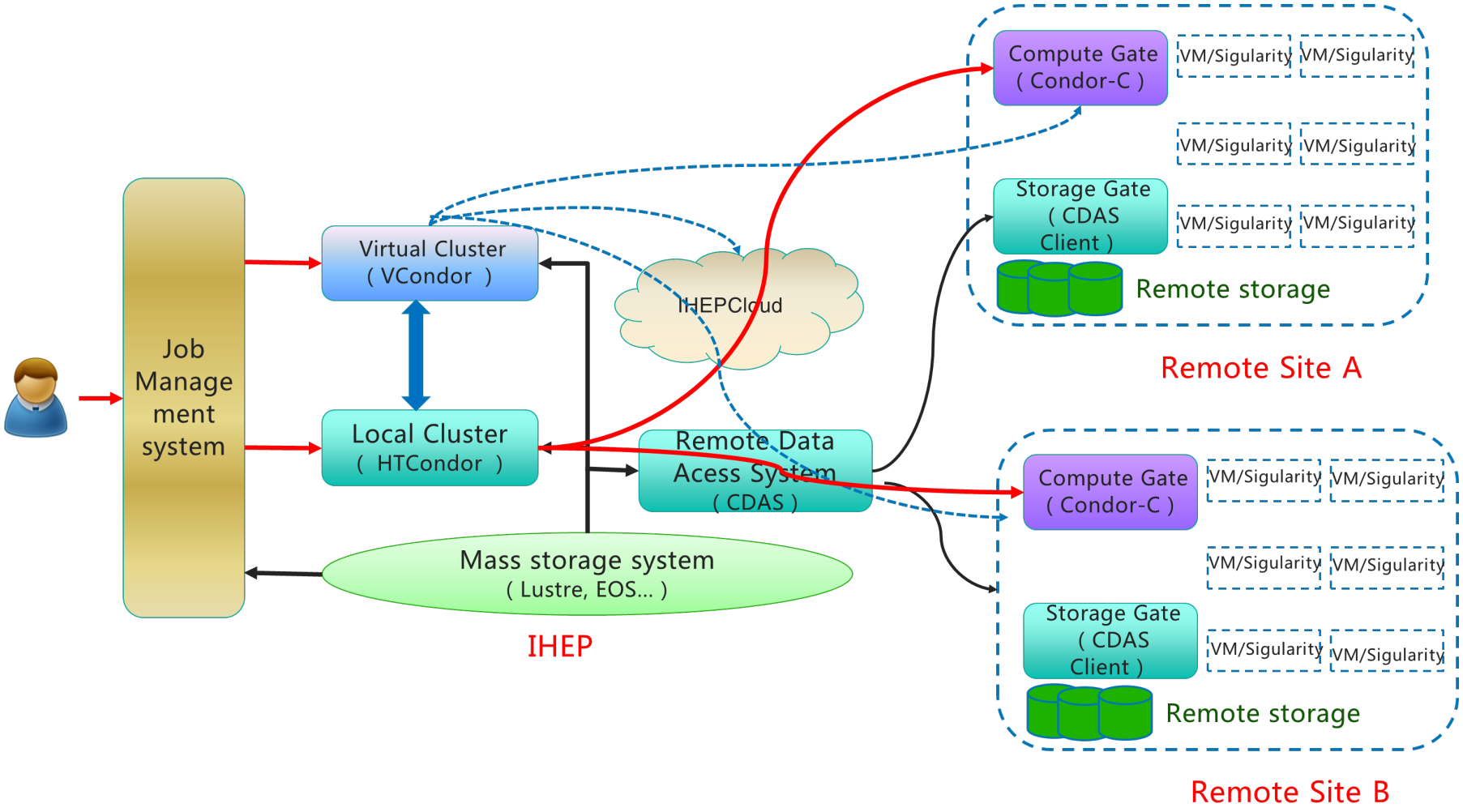
Unified Resource Management

- Based on Openstack and HTCondor
- Adopted Multi-region to manage the resources across domain
- A prototype is located in Beijing, Chengdu and Dongguang





Job Schedular

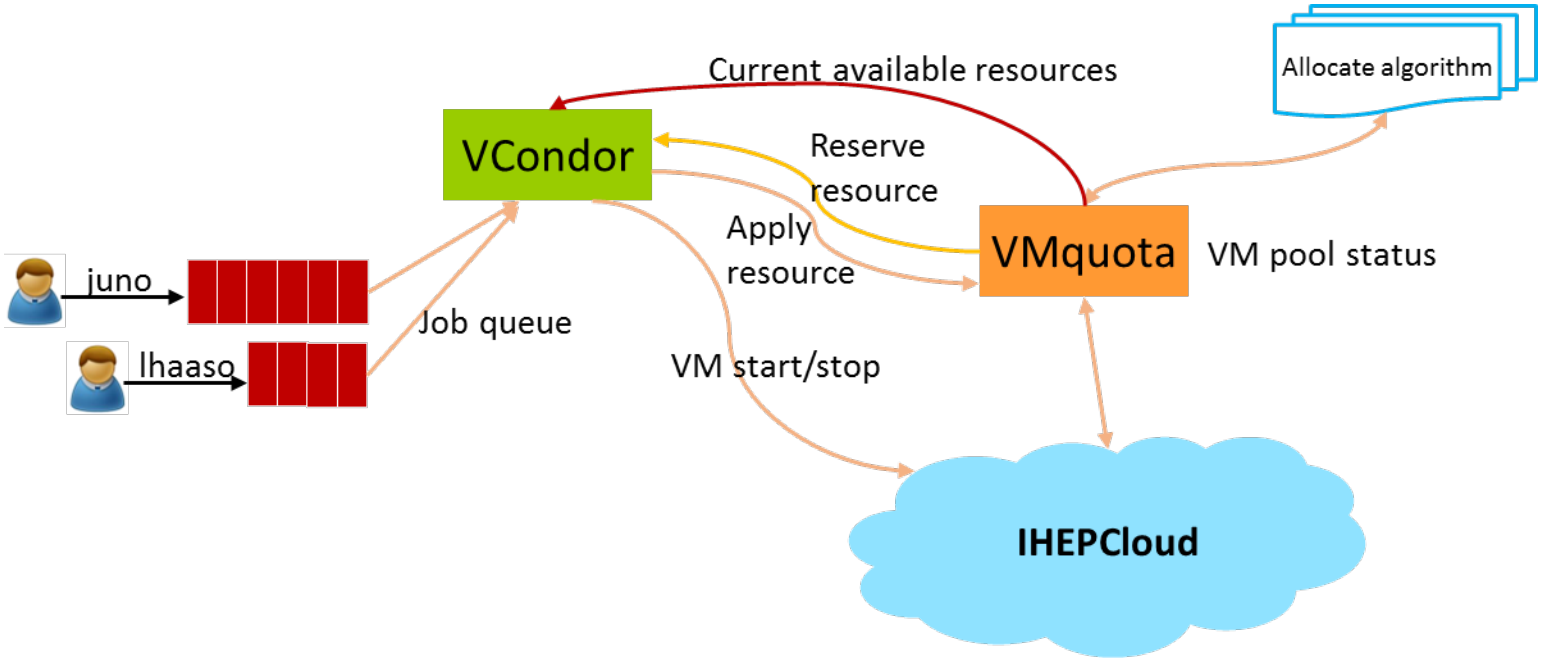


Job Scheduling(2)

- Job Management system
  - Design the a toolkit(submit/query/delete) based on HTCondor
  - hep_sub/hep_rm/hep_q
- Schedule job to remote via “Condor-C” model
  - Job in queue could be transformed to remote cluster via Condor-C
- Dynamic resource provision
  - Developed Vcondor
  - Remote control Vms dynamically
- User management
  - All the users uses AFS account managed by IHEP
  - Submit jobs from Login farm in IHEP
- IHEP Virtual Cluster
  - ~1000CPU cores
  - Resource provision dynamically to meet peak demand
  - Improve resource sharing between different experiments
  - Based on IHEPCloud(a private cloud)

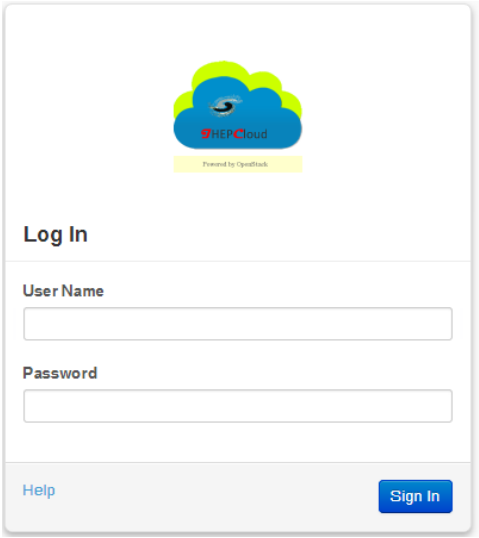
CloudScheduler-Vcondor

- VCondor is a cloud scheduler providing elastic resource allocation service based on HTCondor
- Take fine-grained resource allocation to schedule tasks instead of taking nodes.
- Design flexible allocating policy to provisioning VMs dynamically, considering job types, system load and cluster real-time status.



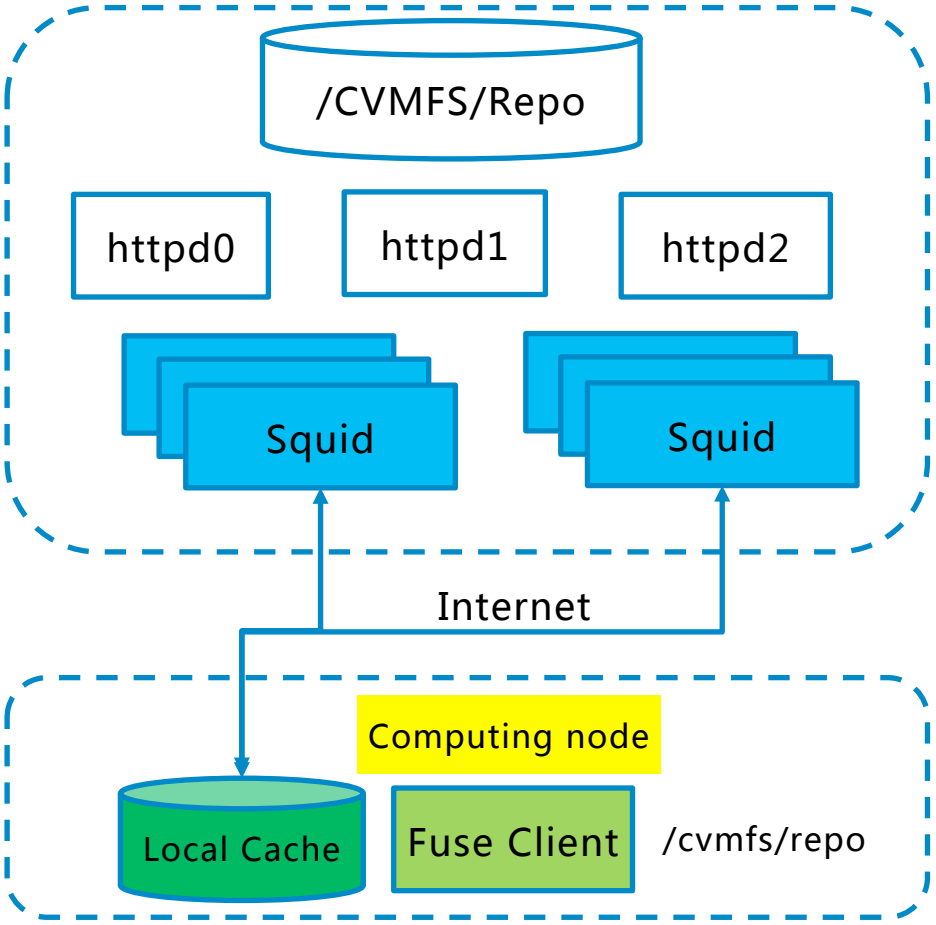
IHEPCloud

- ~2000 CPU cores
- A private Iaas platform aiming to provide a self-service cloud platform for users and IHEP scientific computing
- SSO authentication: Any user who has IHEP email account (>1000 users, ~107 active users)
- Three use scenario
  - User self-Service virtual machine platform
    - User register and destroy VM on-demand
  - Virtual Computing Cluster
    - Job will be allocated to virtual queue automatically when physical queue is busy
  - Distributed computing system
    - Work as a cloud site: Dirac call cloud API to start or stop virtual work nodes



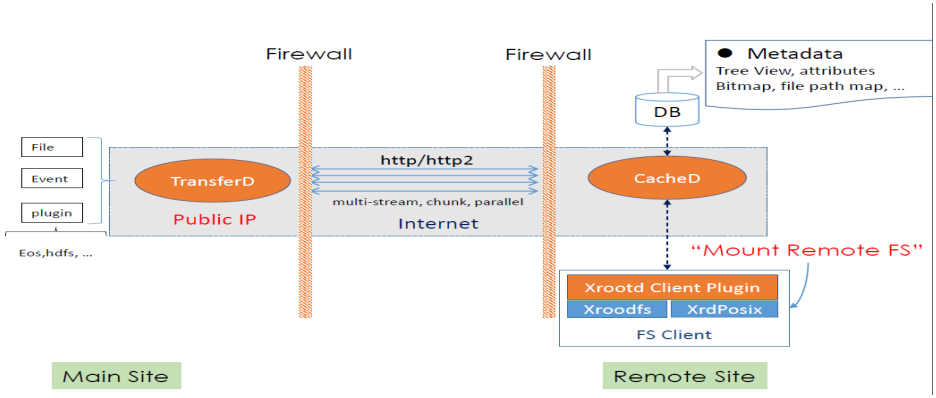
Data access in distributed computing system

- Software
  - Physical library(Boss, Gaudi), common software(gcc),etc
  - Version consistent among distributed sites
- Experiment Data
- Solution
  - AFS
  - CVMFS
  - CDAS: Event-based data access system (Developed by IHEP)
  - EOS geo replica

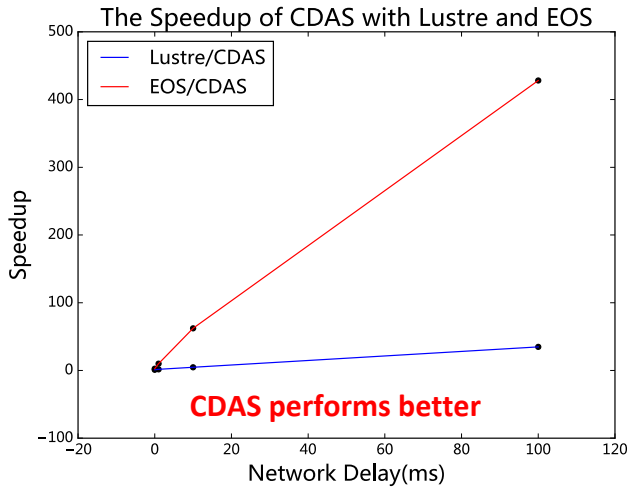


Data access in distributed computing system

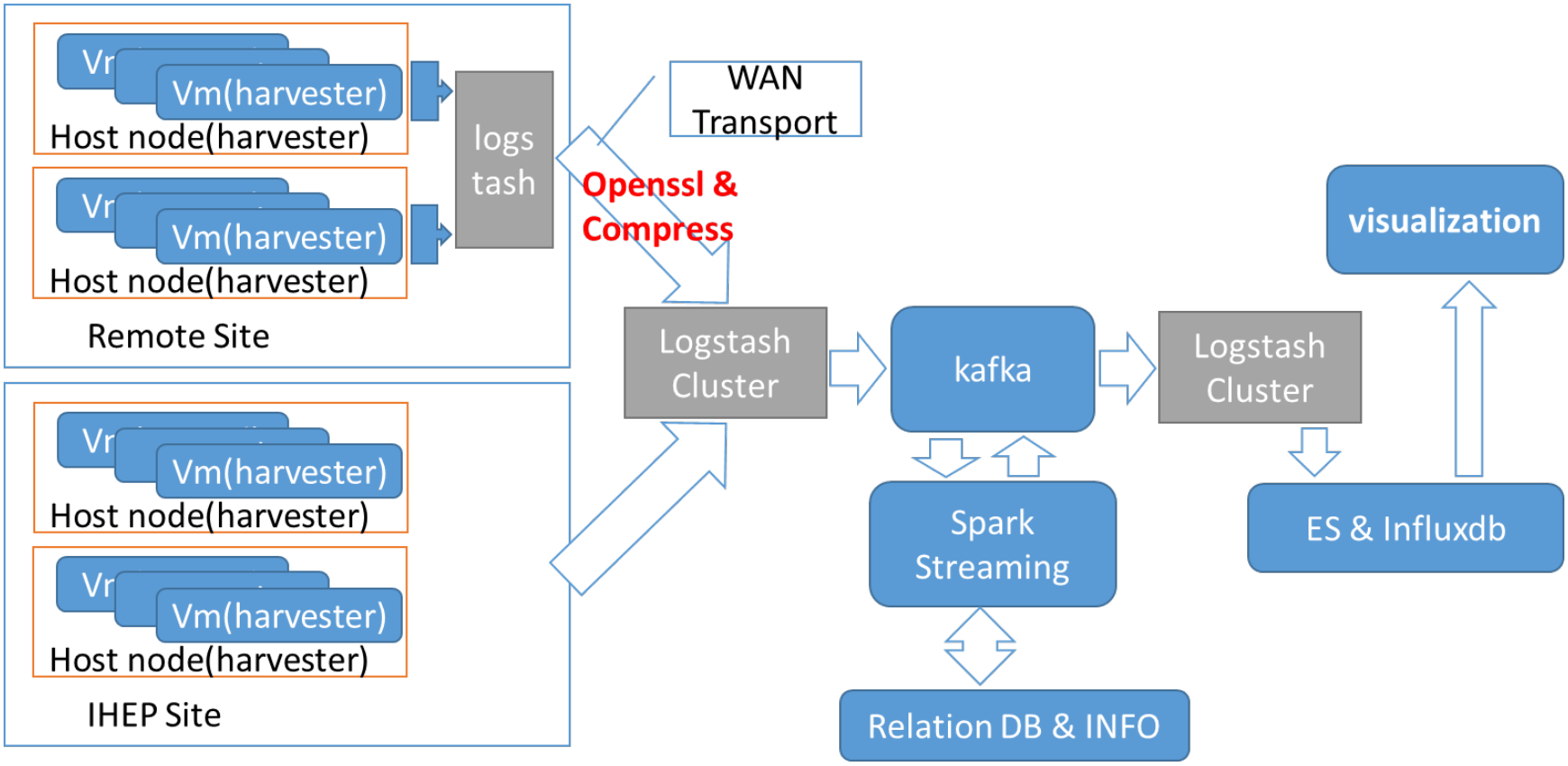
- CDAS system
  - Unified namespace
  - Use HTTP protocol to go through firewall。
  - Deployed in Beijing and Daocheng
  - CDAS performs better in WAN compared with Lustre and Eos
- EOS replica by geotag
  - Data access prefer to local replication



Network Delay (ms)	Lustre	EOS	CDAS
0	79.85	30.12	77.36
1	45.93	7.26	72.71
10	13.87	1.03	64.02
100	1.49	0.12	51.38

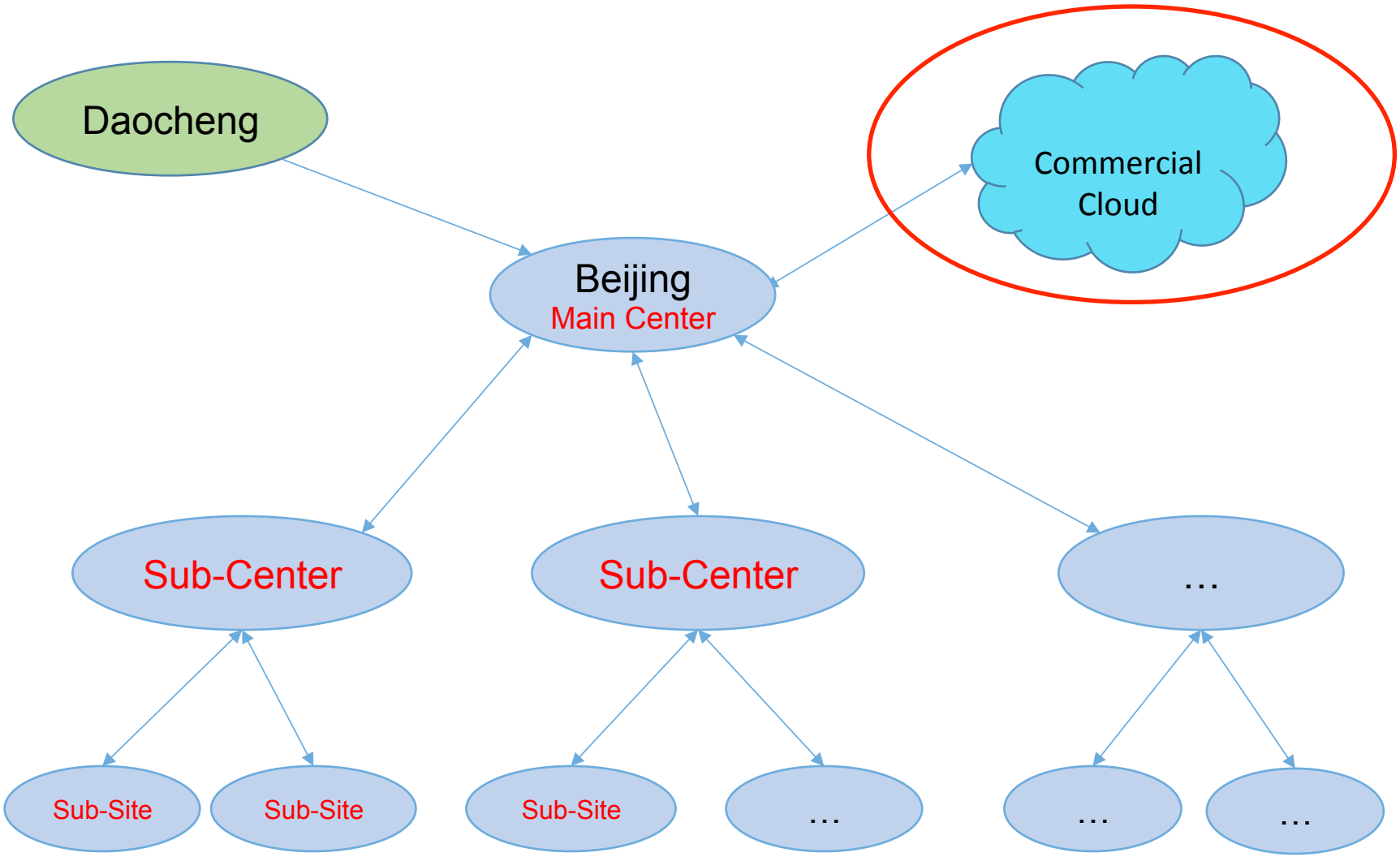


Distributed Monitoring



- Remote site monitoring data compression and encryption transmission
- The virtual machine and host monitor can display together
- Real-time streaming data processing

Shcema: LHAASO Distributed Computing system



Evaluation on Alibaba Cloud

- Expand the Vcondor to remote control Vms
  - Modular designed
  - Called the Alibaba Cloud API to create/start/stop/delete VMs
- CPU benchmark(The performance is optimistic)

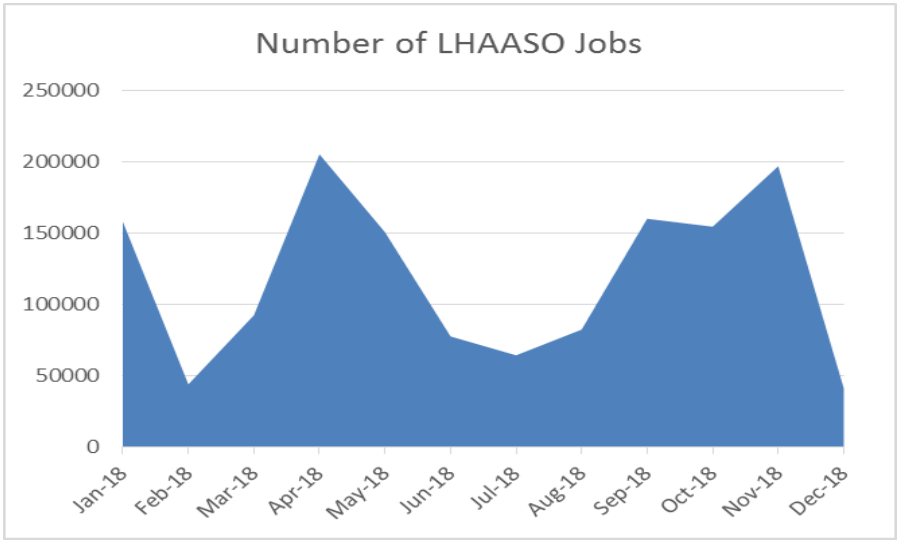
	2 CPU 4GB	2CPU 8GB	4CPU 8G	4CPU 16GB	8CPU 16GB
Alibaba Cloud	32.84	51.96	96.95	96.26	110.45
Equal	4 CPU cores Intel Xeon E5420 @ 2.50GHz	4CPU cores Intel Xeon E5620 @ 2.40GHz	6CPU cores Intel Xeon X5650 @ 2.66GHz		

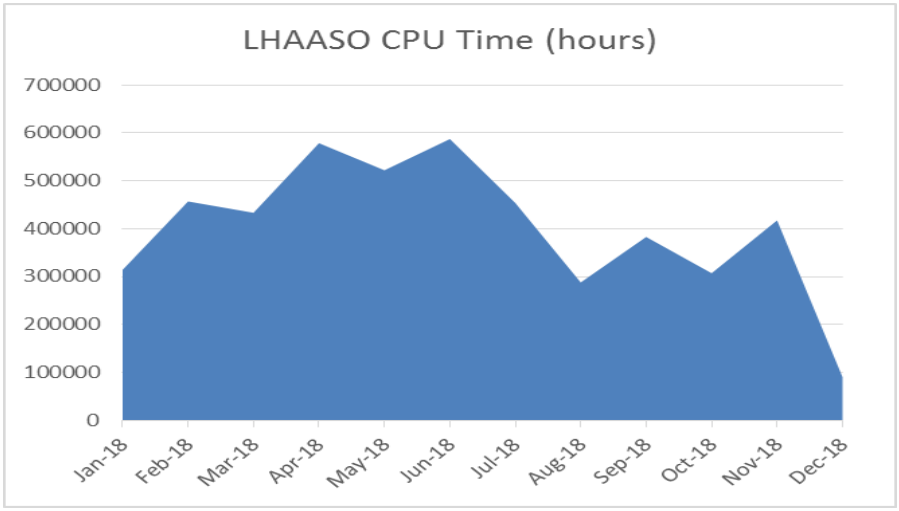
Test results shows the job efficiency running in Alibaba Cloud is equal to our local cluster

Some tests achieve better performance in Alibaba Cloud especially when the local farm is busy

Running status

- The cloud-based computing system became in production in September, 2014
  - Local cloud cluster:~1000 CPU cores.
  - ~30,000 jobs, 250,000 CPU hours in average one week
  - In 2018, total number of jobs completed: 1,425,181 occupancy CPU hours: 48,33,227 CPU hours
- The remote site: Daocheng is in production
  - 576 CPU cores, 139TB
- Some other sites are being integrated
  - ChengDu, Dongguang

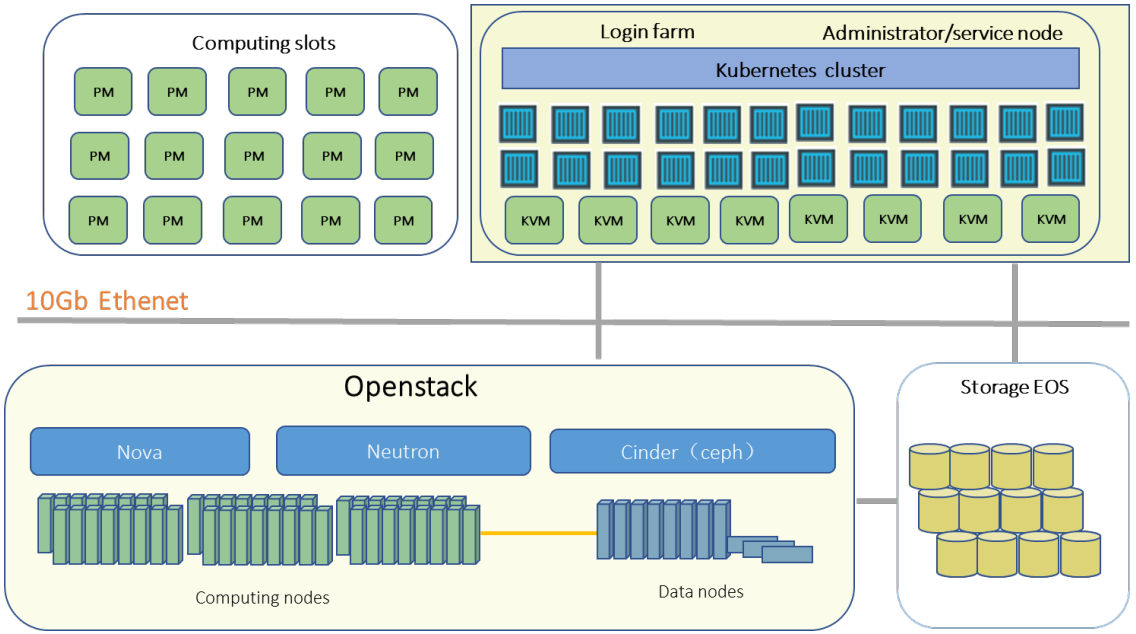




Daocheng Site

- Located in Daocheng(at the altitude of 4410 m), Sichuan Province
- 576 CPU cores, 139TB EOS storage
- Deployment with virtualization and cloud technologies (KVM, docker…)
  - Reduce operation and maintenance costs
  - Docker-based deployment for Login farm and administrate nodes
  - Job scheduled by HTCondor

More details: Container activities in IHEP. Wei Zheng



Activities on GPU virtualization

- Plan to introduce HPC service on Cloud
  - For GPU application, we deploy singularity in the cloud or HPC clusters
  - GPU provisioning in cloud for developers to access powerful computing resources
- Evaluation on vGPU is under going
  - KVM attached the vgpu
  - Testing on the vGPU graphic processing

```
[root@gpu020 ~]# nvidia-smi vgpu
Fri Feb 22 17:42:26 2019
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 410.91                 Driver Version: 410.91                    |
|---------------------------------+------------------------------+------------+
| GPU  Name                       | Bus-Id                       | GPU-Util   |
|      vGPU ID     Name           | VM ID     VM Name            | vGPU-Util  |
|=================================+==============================+============|
|   0  Tesla V100-SXM2-32GB       | 00000000:1C:00.0             |   0%       |
+---------------------------------+------------------------------+------------+
|   1  Tesla V100-SXM2-32GB       | 00000000:1D:00.0             |   0%       |
+---------------------------------+------------------------------+------------+
|   2  Tesla V100-SXM2-32GB       | 00000000:1E:00.0             |   0%       |
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|   3  Tesla V100-SXM2-32GB       | 00000000:1F:00.0             |   0%       |
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|   4  Tesla V100-SXM2-32GB       | 00000000:B3:00.0             |   0%       |
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|   5  Tesla V100-SXM2-32GB       | 00000000:B4:00.0             |   0%       |
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|   6  Tesla V100-SXM2-32GB       | 00000000:B5:00.0             |   0%       |
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|   7  Tesla V100-SXM2-32GB       | 00000000:B6:00.0             |   0%       |
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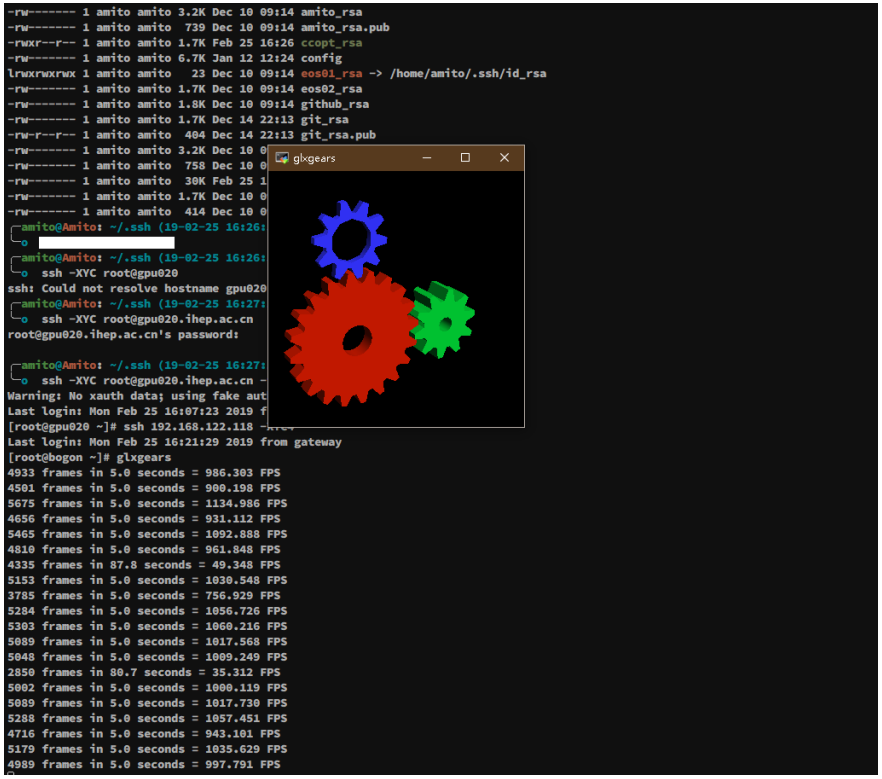

Summary

- Virtualization and cloud computing technologies were adopted to support LHAASO experiment successfully
  - Using Openstack and HTCondor to integrate remote heterogeneous resources to expand computing scale
  - Activities in container
- Easy to integrate more resources with this solution
  - More collaborated sites
  - Commercial cloud
- Activities are in progress
  - GPU virtualization
  - Web-based data analysis
  - Data management and share in distributed computing system
  - Distributed Monitoring and analysis

Thank you