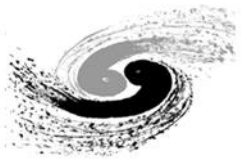

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Scientific Data Transfer System for High Energy Physics HiDTS

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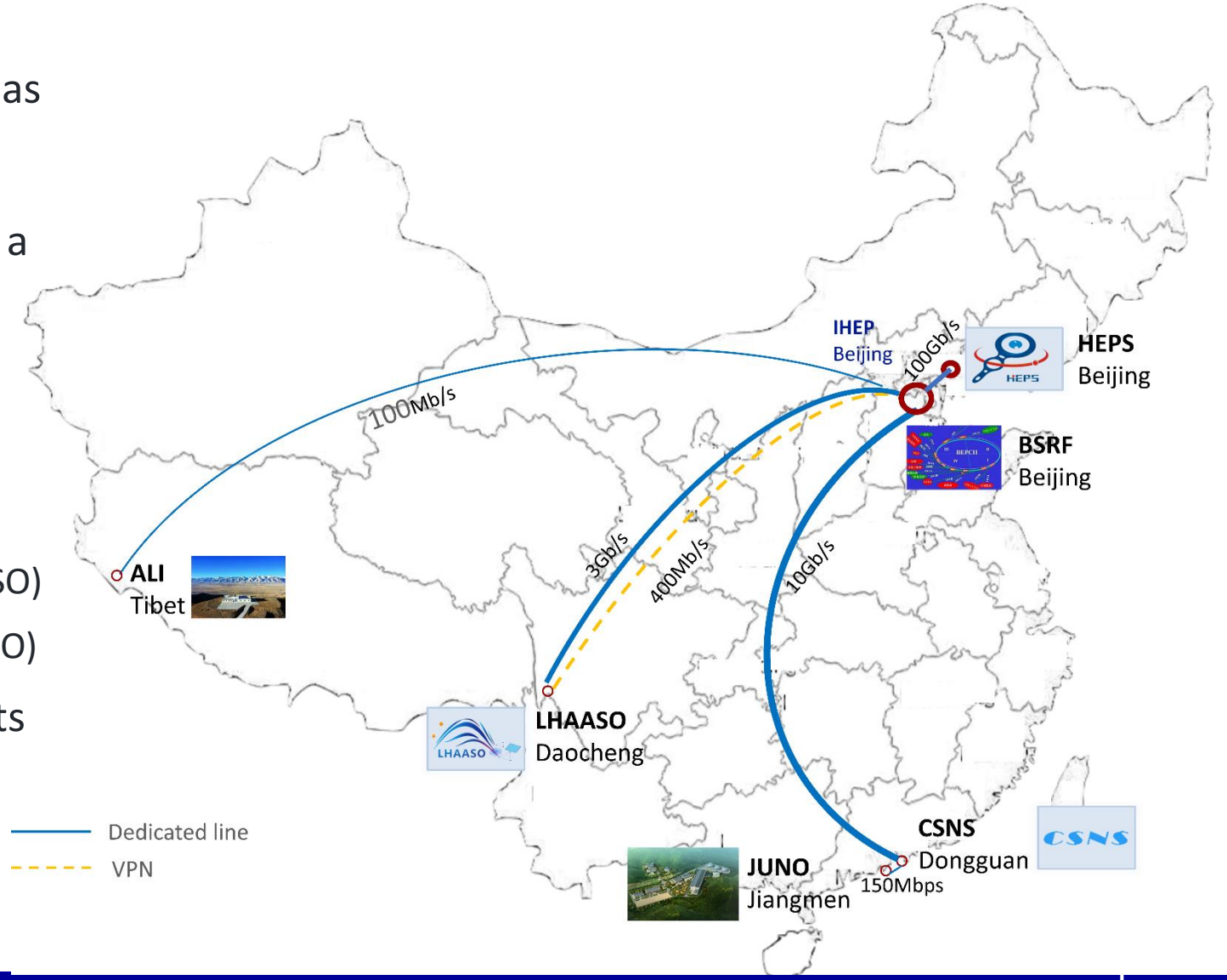
Outline

1. Background of data transfer
2. Challenge of data transfer
3. Technical architecture
4. System functional module.
5. System deployment and application status
6. Summary & Plan

Background of data transfer

- The Institute of High Energy Physics (IHEP) has established multiple large scientific facilities distributed across various locations, generating a large volume of data.
  - Beijing Synchrotron Radiation Facility(BSRF)
  - High Energy Proton Spectrometer(HEPS)
  - Ali CMB Polarization Telescope (AliCPT)
  - Large High Altitude Air Shower Observatory(LHAASO)
  - Jiangmen Underground Neutrino Observatory(JUNO)
- This data requires transfer to IHEP and assists scientists in analyzing experiments in a timely manner.



Challenge of data transfer

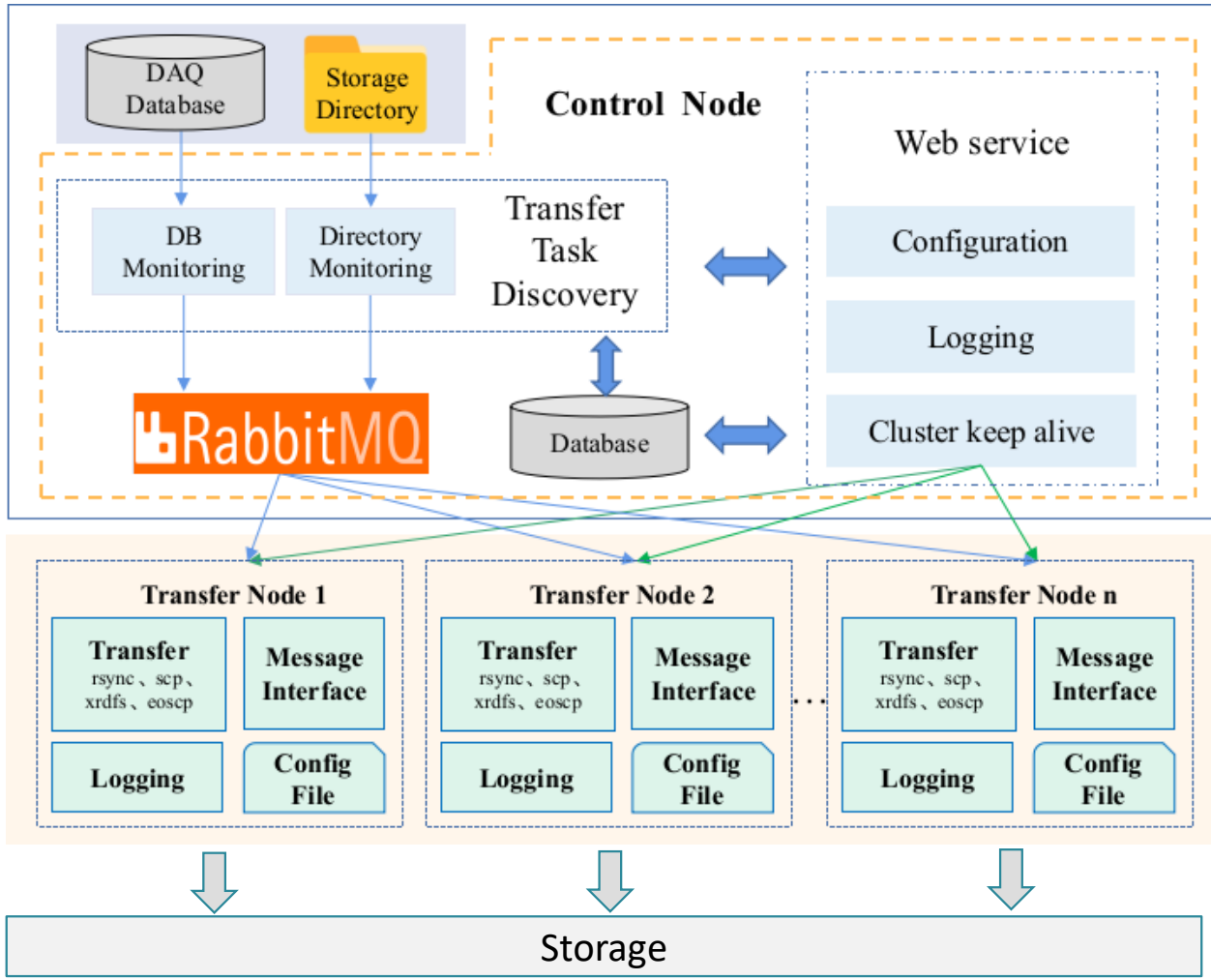
- Huge amount of data transfer Challenge
  - The data volume is rapidly increasing
  - 805.4TB raw data will be produced per day in HEPS
  - 10TB raw data will be produced per day in JUNO
  - 10.2TB raw data is produced per day in LHAASO
- Reliability challenge
  - AliCPT is in high-altitude
    - power outages
    - network disruptions
- Metadata Integrate with other system
  - DOMAS in BSRF and HEPS
  - Rucio in Herd
  - Pipeline in Juno
- Multiple file storage systems in IHEP

Storage System

- Lustre
- EOS
- 9950/9550
- Ceph
- CTA

Technical architecture

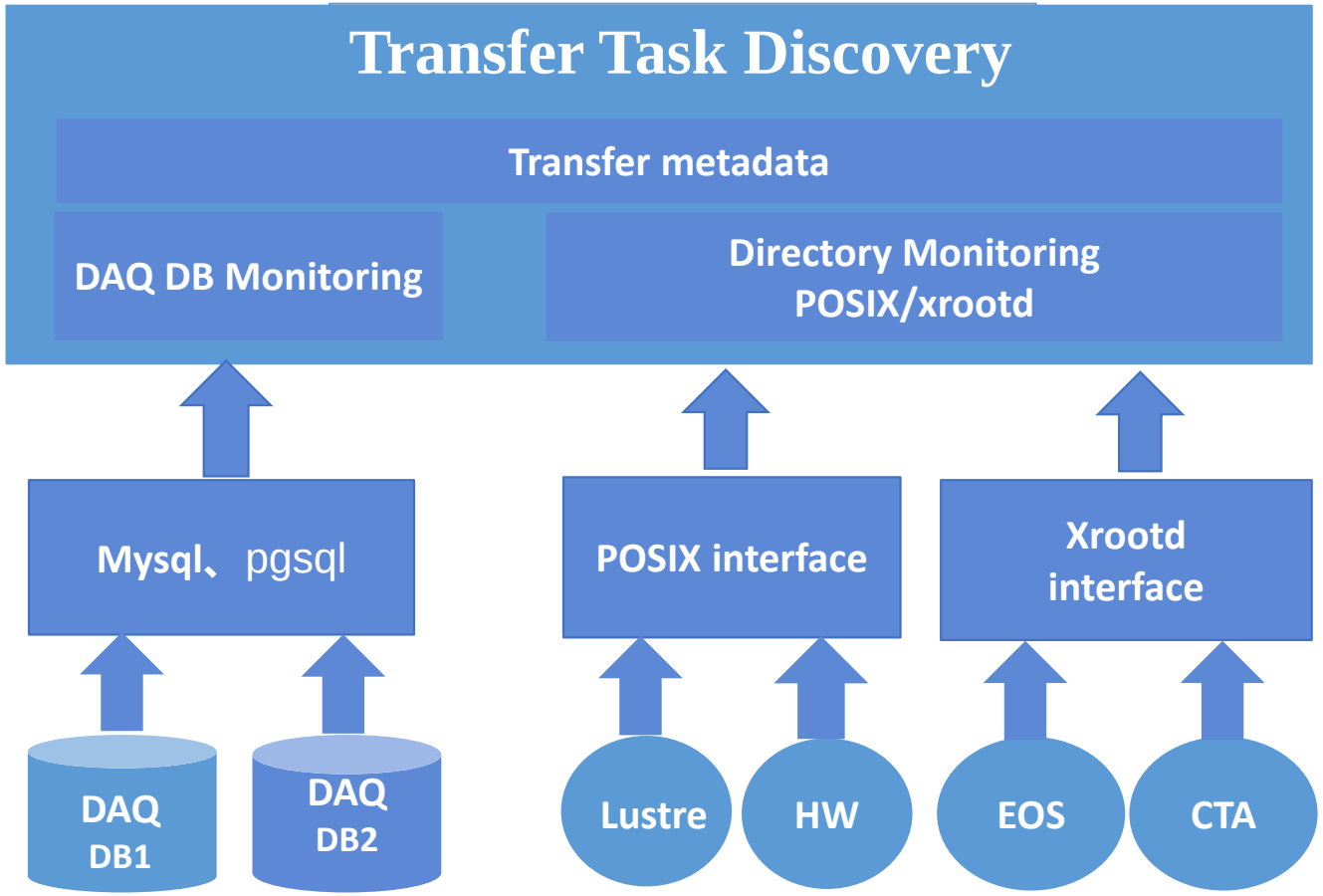
- One control node and multiple transfer nodes
- Control Node
  - Unified web portal for configuration and display
  - Transfer Task Discovery responsible for discovering files
  - RabbitMQ for transfer message buffer
  - Redis for Cluster keep alive management
- Transfer Nodes
  - Transfer Data in different storage
  - Interacting message with other systems
  - File transfer logging
  - Share the same rabbitMQ、Redis、transfer DB and mount the same storage



Transfer Task Discovery

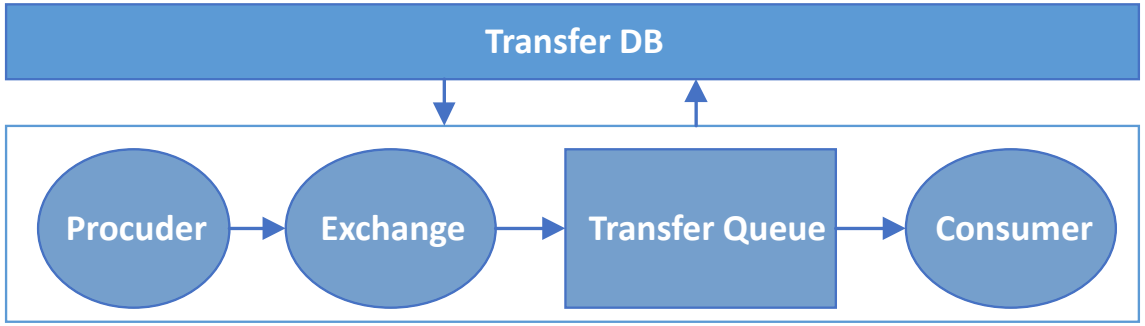
- Monitor transfer files and send messages to the transfer buffer
- Based on web service configuration
- Experiment -> Transfer Task -> DAQ DB monitoring

  -> Directory Monitoring
- DAQ DB monitoring
  - Mysql/Postgresql
  - DAQ DB interface information
- Directory monitoring
  - POSIX/Xrootd
  - Directory information
  - Regex-based matching for directories and files
- We use the last_watched_time as an identifier to discover the newest files

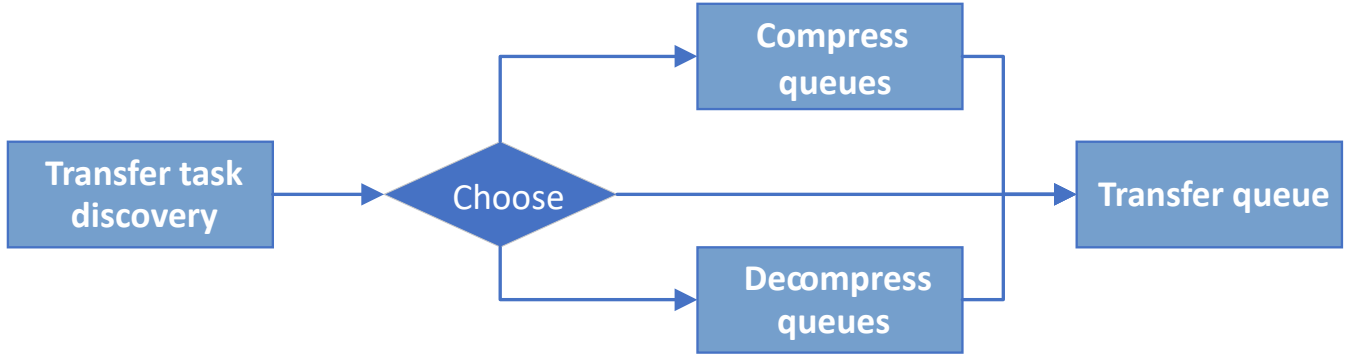


Transfer buffer

- Responsible for managing asynchronous transfer message from transfer task discovery module
- Using RabbitMQ message queue
- Design approach
  - Transfer message queue to decouple the messages
    - Task discovery produce messages to transfer queue.
    - Transfer nodes consume messages from queue
  - File information is stored in the transfer database
  - Compress and decompress messages queues
    - Configure it in web task page
    - Support Compressed data transfer
    - Manage compress and decompress messages



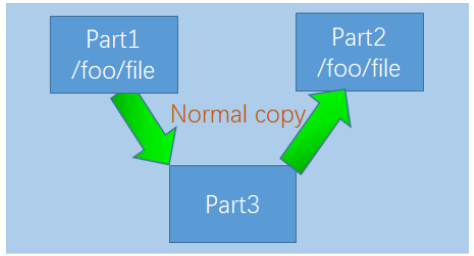
Transfer message queue

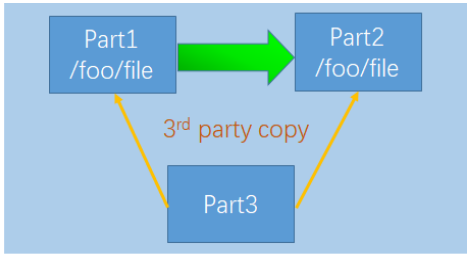


Transfer system queue

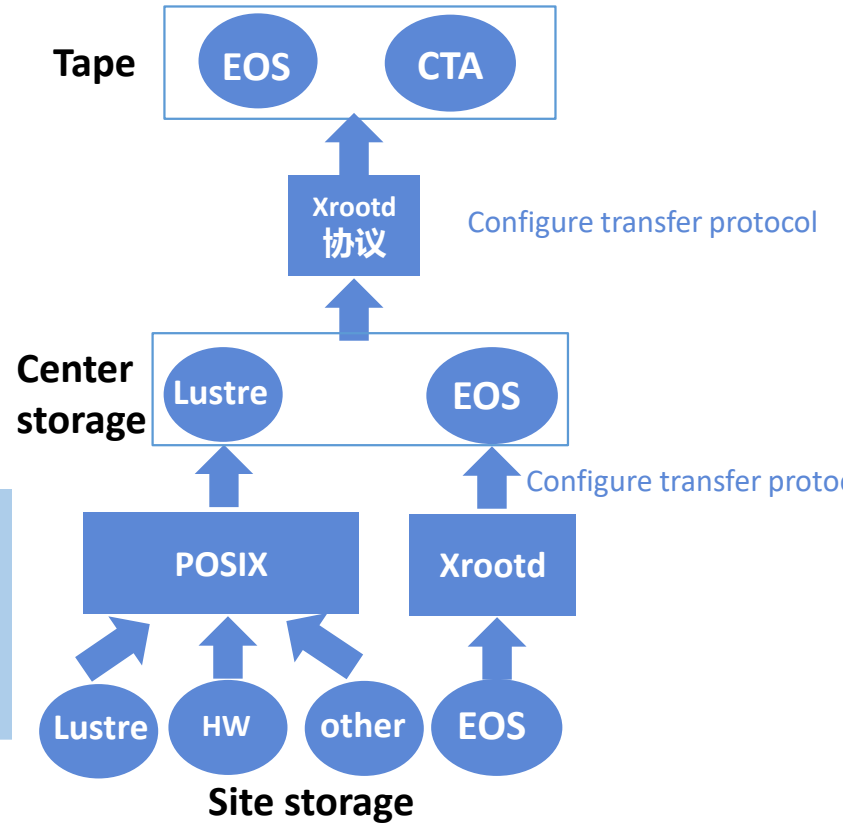
Data transfer

- Consume transfer message from transfer buffer and transfer files.
- support multiple data transfer protocols
  - rsync、scp、eos cp、xrdcp
- High Performance
  - Cluster deployment
  - Multi threads of each transfer node
  - Support Xrootd TPC
- Reliability
  - Checksum verification
  - Automatically retransfer failed file
  - failed files are stored in an failed buffer and retransferred after the issue is resolved
  - Logging and monitoring





Xrootd TPC

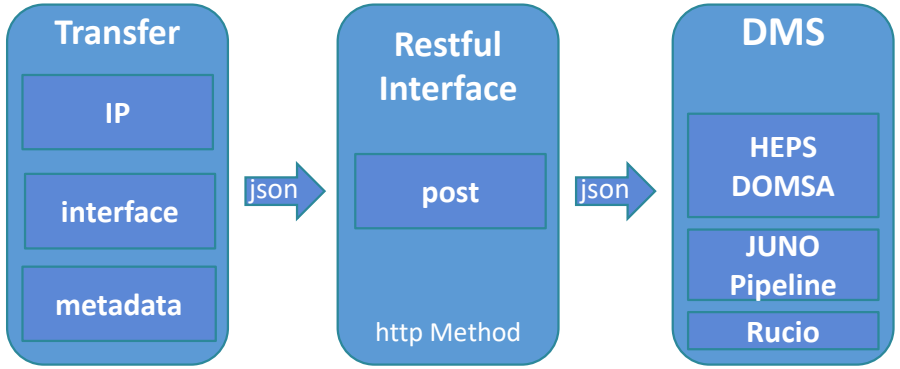


Raw data transfer

Message Interface

- provides Universal interfaces to interact with other systems.
- Generic Design
  - Based on configuration: IP, port, metadata information
  - Metadata is transmitted through RESTful interface
    - Loose coupling: Using standard RESTful
    - Standardization: Interface design based on JSON
    - Compatibility: platform-independent, sending agreed-upon JSON metadata messages
- Reliability Design
  - 5 attempts for message notification
  - Exception message queue, re-sending after server recovery

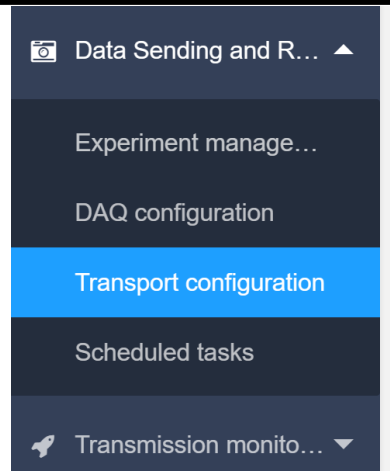
Metadata format to DOMAS

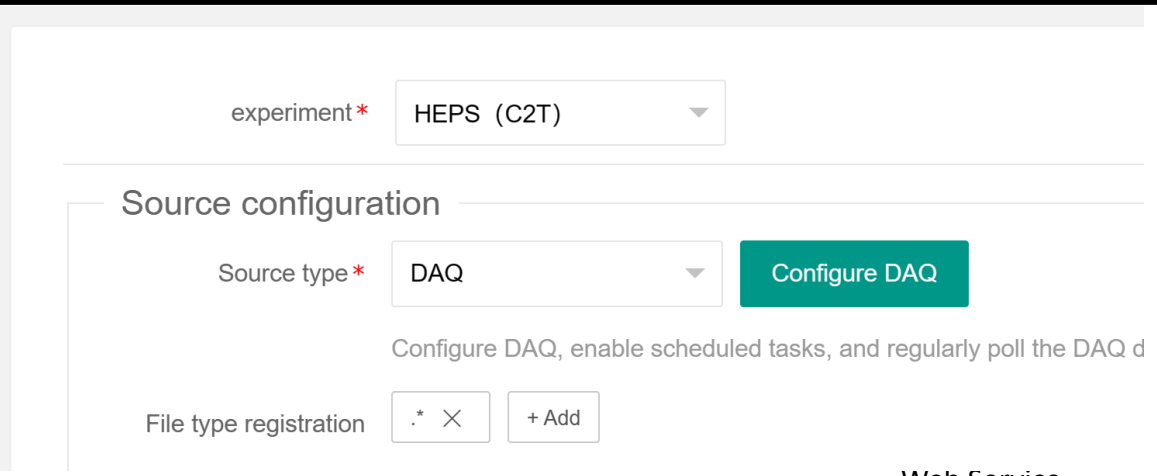


Message interface

Web service and Config

- Web Service
  - Experiment management
  - Transfer tasks management
  - Data Acquisition (DAQ) configuration
  - Scheduled tasks
- Backend configuration（application.yml ）
  - Server
  - Logging
  - Spring Boot
  - MySQL
  - Redis
  - Quartz
  - RabbitMQ





Web Service

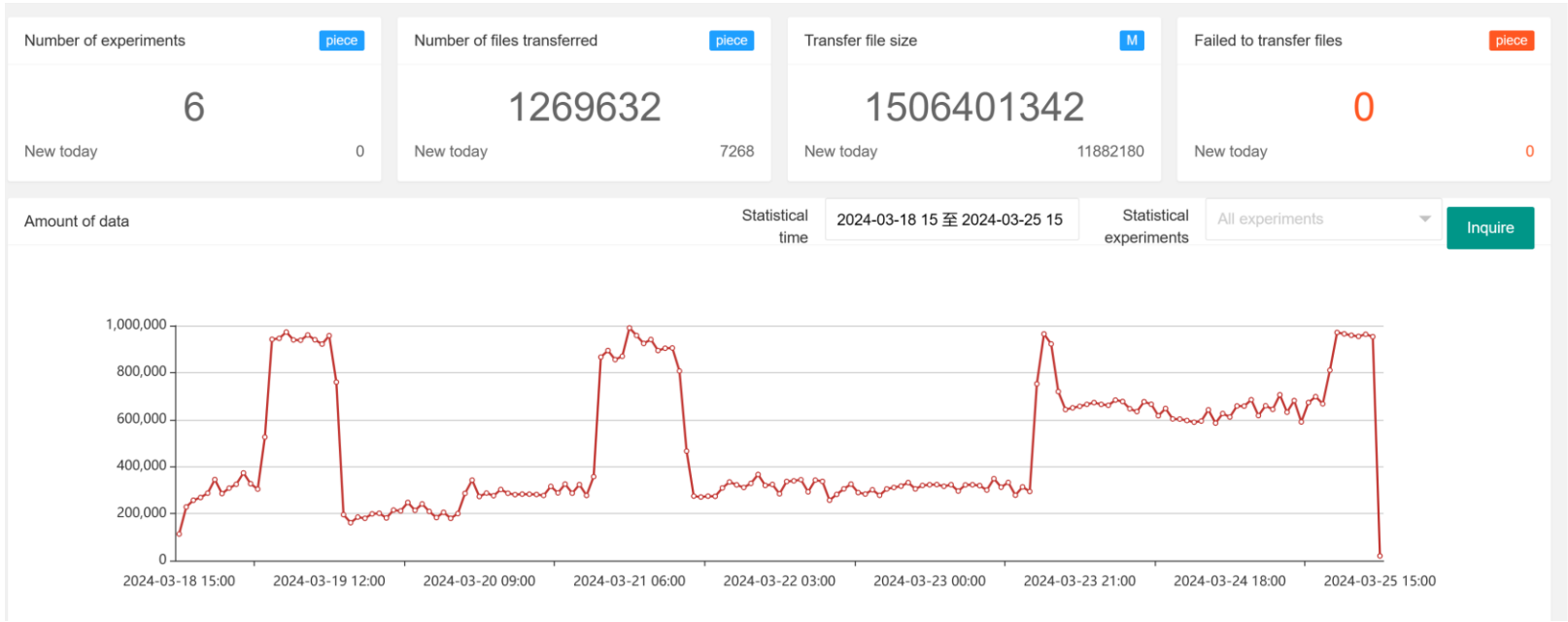
```yaml
##spring相关配置
spring:
  application:
    name: cosmoseye-boot
  profiles:
    active: dev
  messages:
    basename: static/i18n/messages
  main:
    allow-circular-references: true
  web:
    resources:
      static-locations:
      - classpath:/static
      chain:
        enabled: true
        cache: true
        compressed: true
      cache:
        period: 604800
  data:
    web:
      pageable:
        ##layui表格页码数从1开始
        one-indexed-parameters: true
```

Logging and Monitoring

- Logging module
  - The log records the entire lifecycle of data transfer
  - View the logs through the web service.

```
DEBUG 2022.11.30 09:08:05.748 cn.cosmoseye.action.transfer.FileTra... : 开始进行第3次文件传输，处理服务器:192.168.60.162
DEBUG 2022.11.30 09:08:05.944 cn.cosmoseye.ssh.SshServer.send : 开始传输文件：/hepsfs/transfertest/4W1A/2022/20220721test-cw/sample1/sam/sam_89.000.tif，信号文件：无
ERROR 2022.11.30 09:08:36.019 cn.cosmoseye.action.transfer.FileTra... : 文件传输失败
文件不存在：/hepsfs/transfertest/4W1A/2022/20220721test-cw/sample1/sam/sam_89.000.tif
```

- Monitoring Module
  - Monitor the status of data transfers, including statistics..
  - Web-based graphical representation
  - WEB-based list representation
    - Transfer list
    - To be transferred list
    - Failed files list



Dashboard for users

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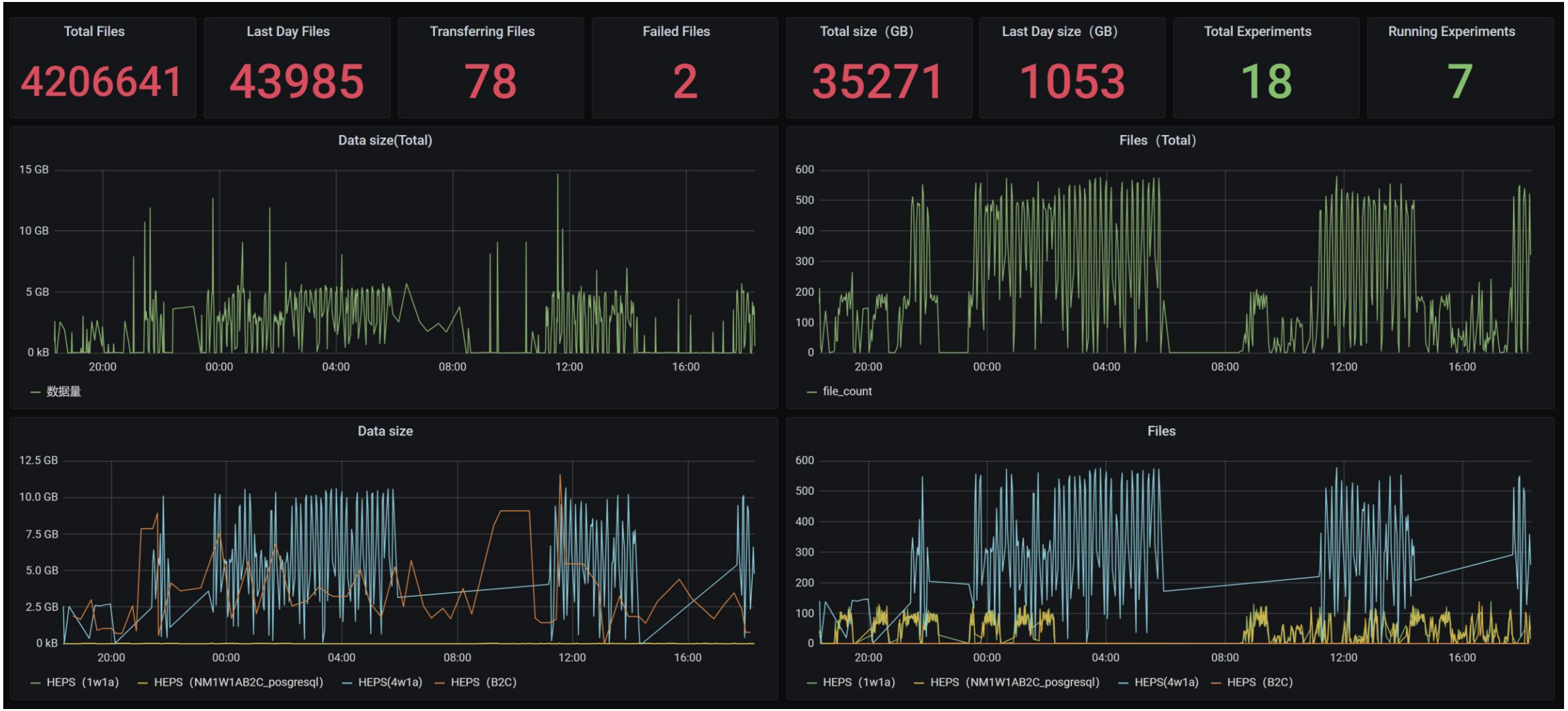
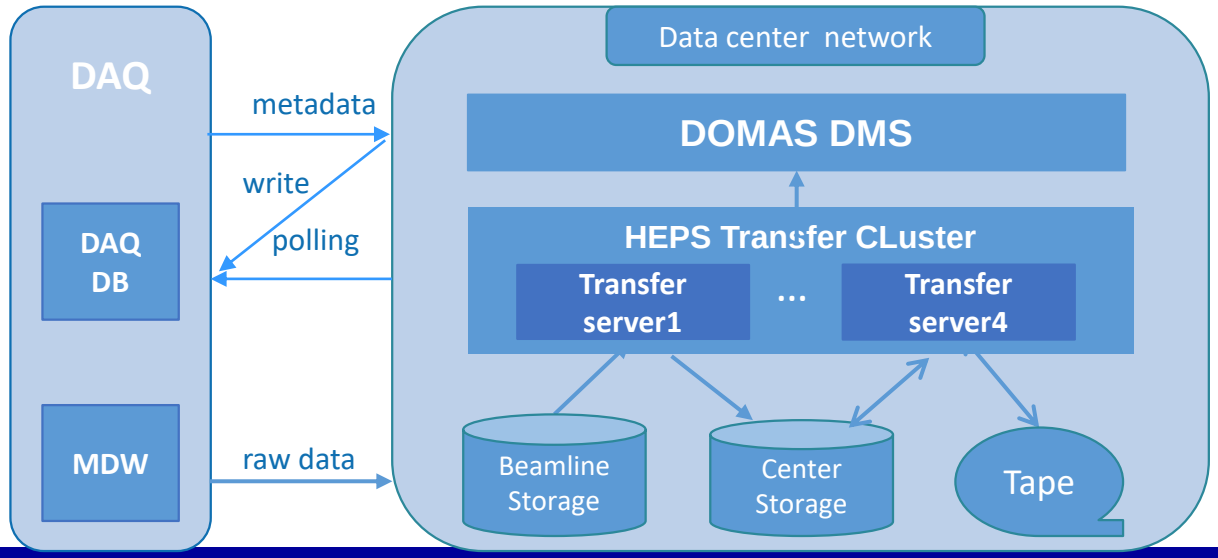


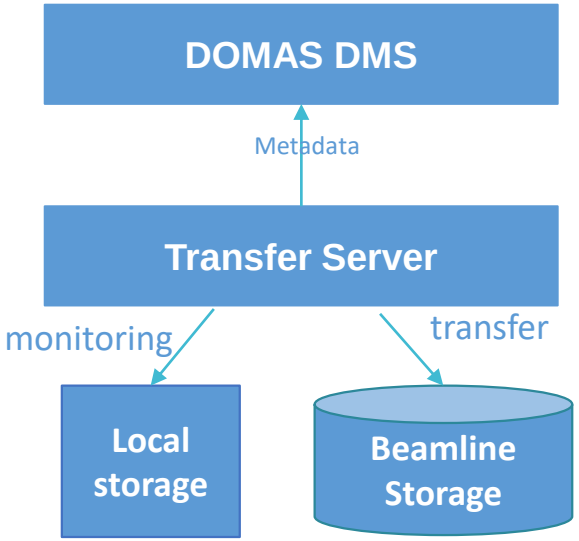
Data transfer at BSRF

- BSRF
  - Beijing Synchrotron Radiation Facility
  - Located in IHEP, Beijing, China
  - 14 beamlines are in operation
- The data transfer at BSRF is for the preparation of HEPS
  - Transfer process : Local storage → Beamline storage → Center storage→ CTA
  - Interacting metadata with DOMAS
  - Multiple storage systems
- Infrastructure status at BSRF
  - Two data transfer servers with 10Gb network cards.
  - 10/25Gbps data center network link

The deployment at BSRF

- Deployed in 4W1B and 3W1 beamline in 2022.06 , 1W1A and 4W1A beamline in 2023.06.
- The optimization we have done.
  - Support transferring File and Directory Access Control Lists (Facl)
  - Configure directory filtering rules for the beamtimeID directory
  - Support data transfer to beamline storage without Mamba（DAQ）
  - According to the beamline station experimental mode, support continuous writing of file transfer
  - Updated the DAQ (Data Acquisition) database from MySQL to PostgreSQL for improved performance





Transfer performance at BSRF

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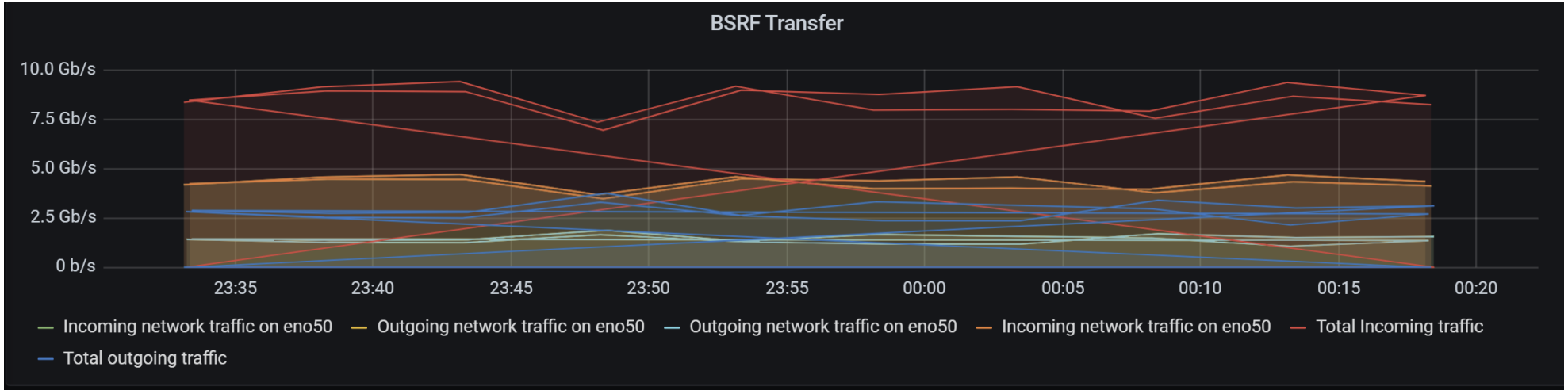
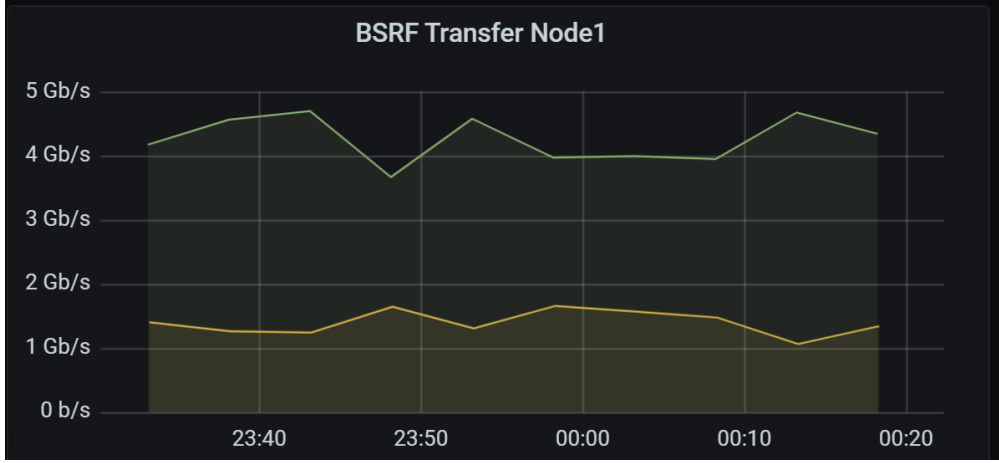
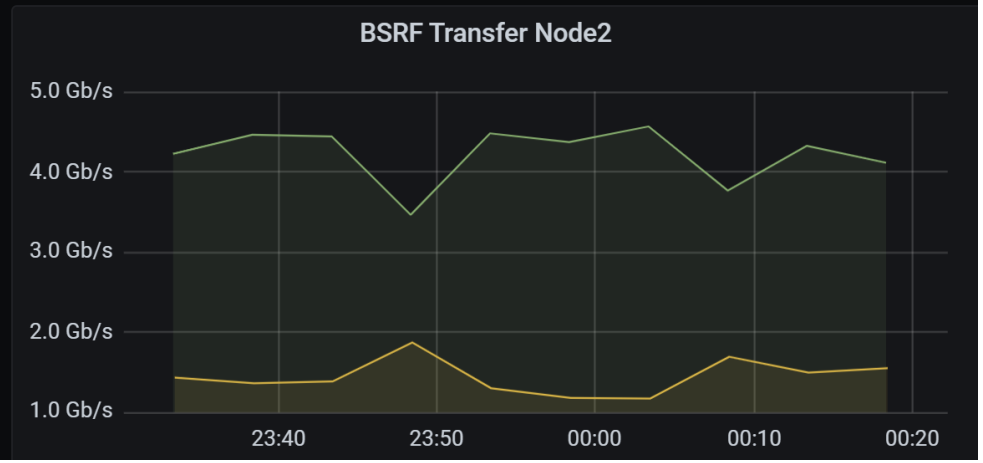
- In the case of sharing a 10Gb bandwidth with other systems, the transfer performance is good, and the total transfer throughput can reach around 9Gb

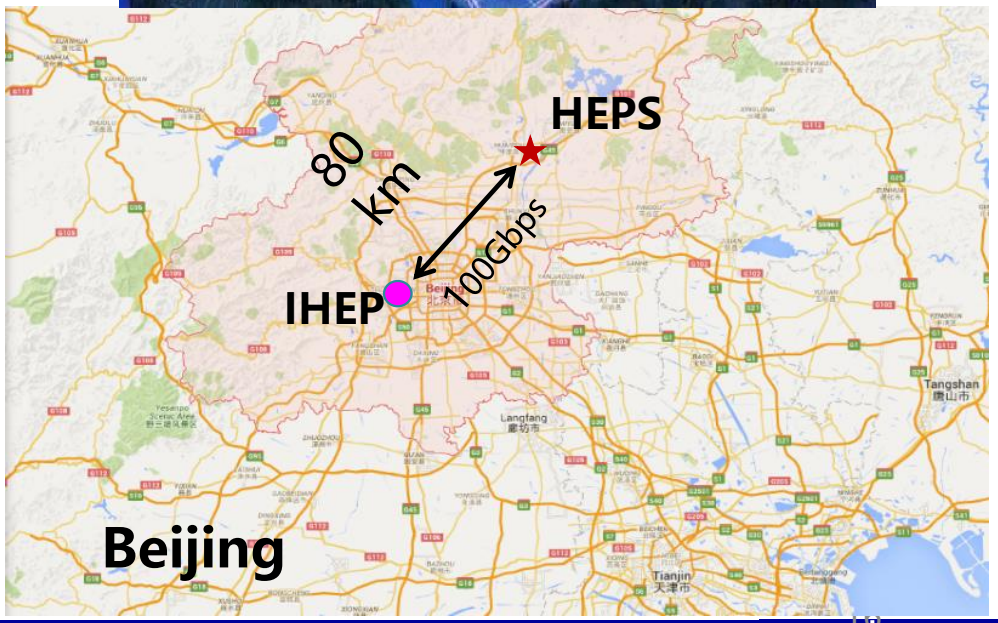






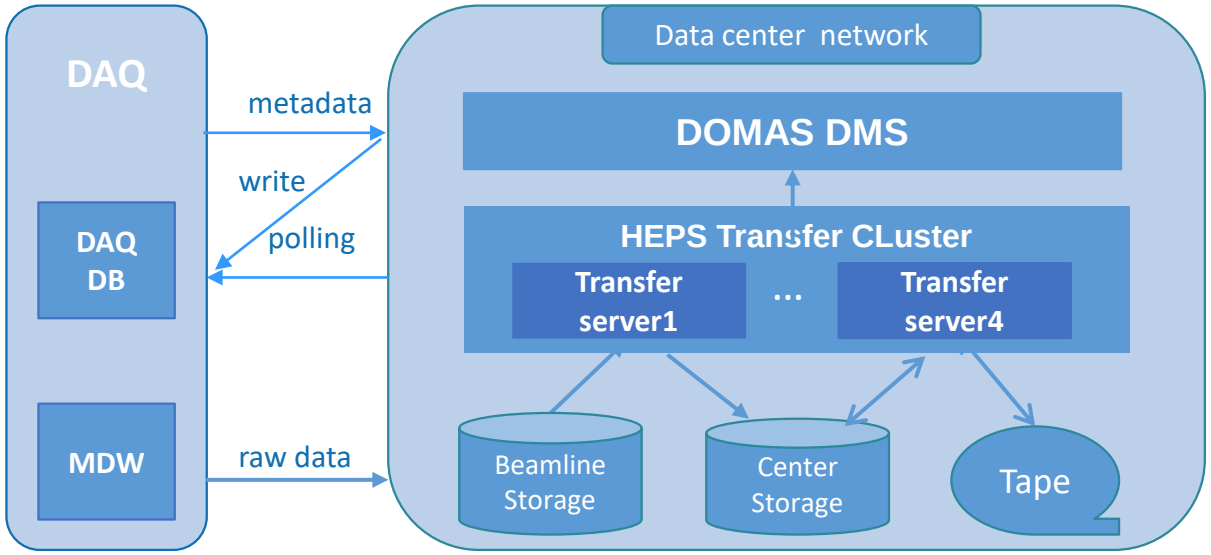
Data transfer at HEPS

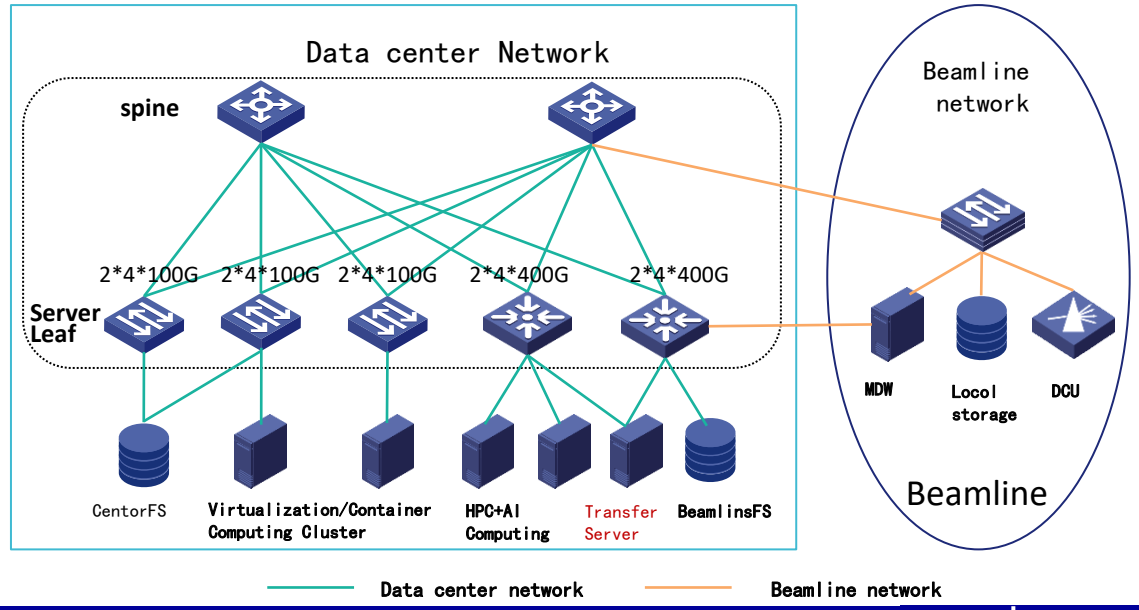
- HEPS
  - High Energy Proton Spectrometer
  - Located in Beijing - about 80KM from IHEP
  - The whole project will be finished in mid-2025
  - 14 public beamlines + 1 optics test beamline in Phase I
- Huge amount of data is a big challenge for data transfer
  - 805.4TB raw data will be produced per day
  - Data needs to be transmitted in a timely manner
- Infrastructure status at HEPS
  - Four data transfer servers with 100Gbps network cards
  - 100Gbps/25Gbps data center network
  - Network support RoCE and Ethernet



The deployment at HEPS

- Deployed at HEPS data center in 2023.09.
  - Deployed four data transfer servers as transfer cluster now
  - The data transfer scheme is the same as BSRF
  - The transfer scheme were tested and work well
  - High performance data transfer will test through data center network next（RoCE and Ethernet）



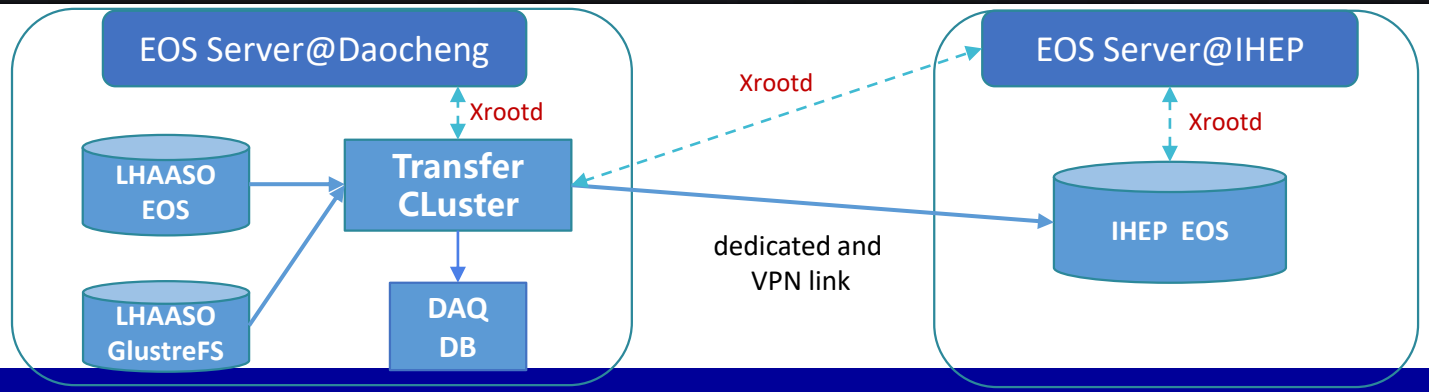


Data transfer at LHAASO

- LHAASO
  - Large High Altitude Air Shower Observatory
  - Located in Daocheng , Sichuan - about 1738KM from IHEP
  - Altitude 4410 meters
- LHAASO is a remote site that has a large amount of data
  - 10.2TB raw data is produced per day now
  - Data needs to be transmitted to IHEP in a timely manner
- Infrastructure status at LHAASO
  - Two data transfer servers with 10Gbps network cards
  - 3Gbps dedicated link and 400Mbps VPN from LHAASO to IHEP
  - Use EOS storage both in LHAASO and IHEP

The deployment at LHAASO

- Deployed in LHAASO
  - Upgraded to HiDTS in 2023.10.
    - Currently two transfer nodes onsite, each with a 10Gb/s network interface.
  - An automatic retransfer Module was deployed
    - Retransfer the files in the transfer failed list every hour
- Transfer performance is good, Continuously and fully utilize the 2G bandwidth before.

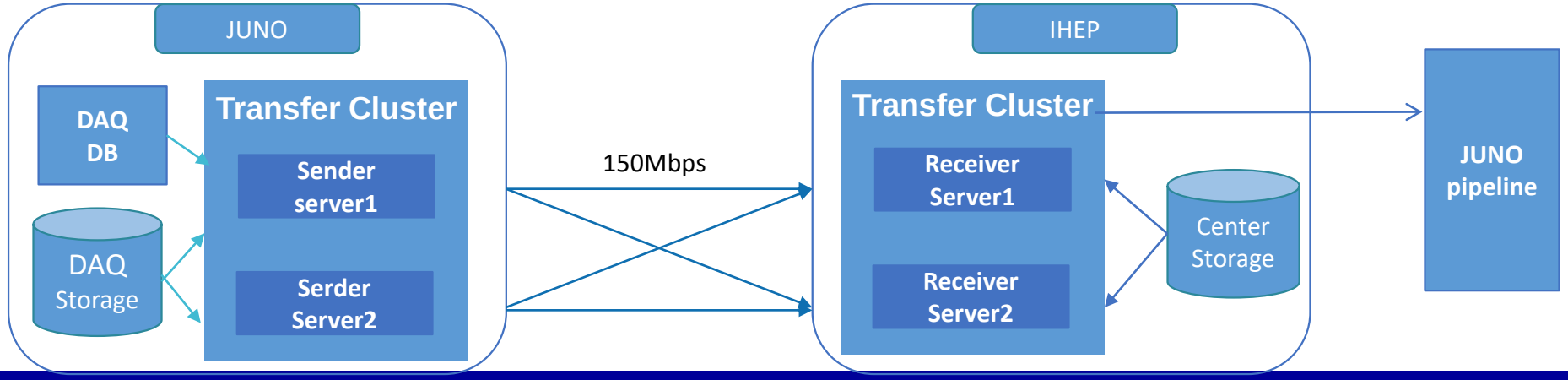


Data transfer at JUNO

- JUNO
  - Jiangmen Underground Neutrino Observatory
  - Located in Jiangmen , Guangdong - about 2000KM from IHEP
  - 700 meters underground
- JUNO is a remote site and has a large amount of data
  - Estimated data volume: 200 files and 10TB per day
  - Data needs to be transmitted in a timely manner
  - Interacting metadata with Pipeline system
- Infrastructure status at JUNO
  - Two data transfer servers with 1Gbps network cards in JUNO
  - Two data transfer servers with 10Gbps network cards in IHEP
  - 150Mbps dedicated link from JUNO to IHEP , 2Gbps in future

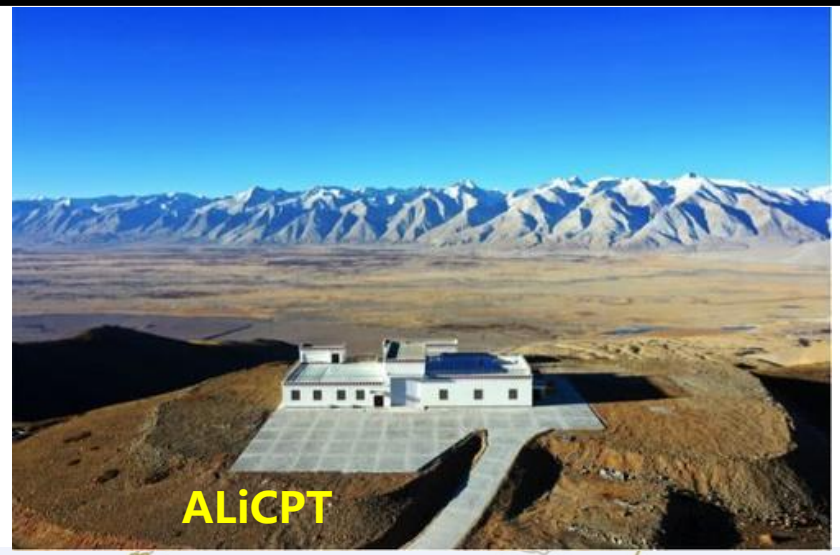
The deployment at JUNO

- The deployment at JUNO follows a similar to the deployment way used in our previous experiments at DayaBay
- Deployment In JUNO
  - Two send server deployed in 2023
  - Transfer data and semaphore file to receiver server buffer
- Deployment In IHEP
  - Two receiver server deployed in 2023
  - Transfer raw data from buffer to JUNO EOS
  - Send metadata Pipeline
- The transfer process has been verified



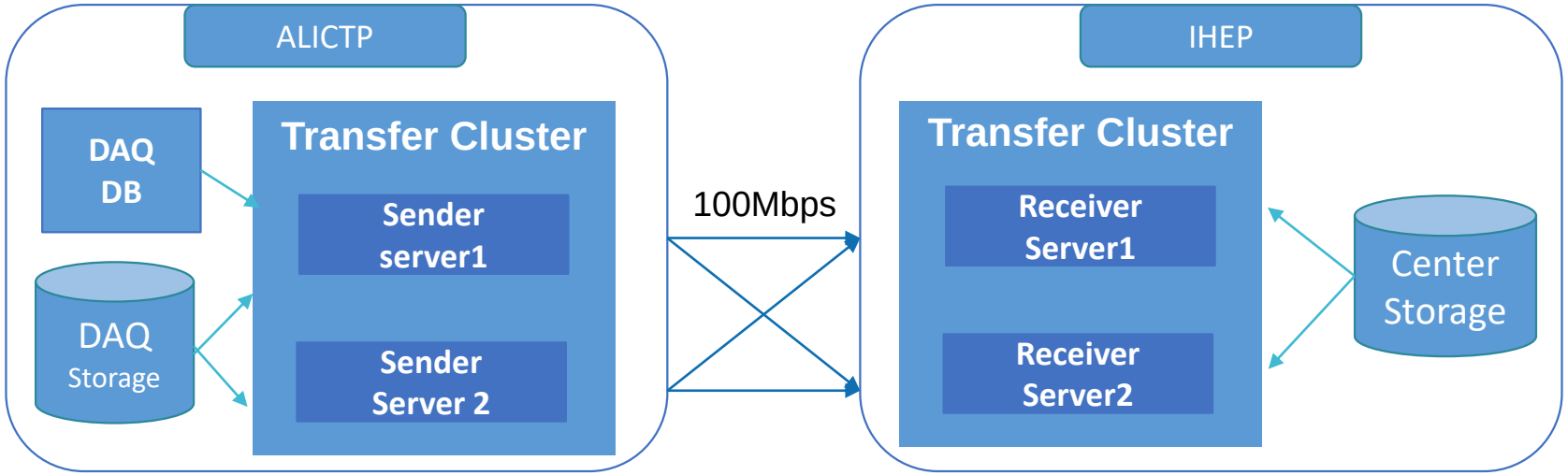
Data transfer at ALICPT

- ALICPT
  - Ali CMB Polarization Telescope
  - Located in Ali , Tibet - about 3000KM from IHEP
  - Altitude 5250 meters
- High reliability challenge due to high-altitude, power outages, and network disruptions.
- Estimated data volume: 150TB/Year
- Infrastructure status at ALICTP
  - Two data transfer servers with 1Gbps network cards in Ali B1
  - Two data transfer servers with 1Gbps network cards in IHEP
  - 100Mbps dedicated link from ALICPT to IHEP.



The deployment at AliCPT

- Deployed in ALiCPT and IHEP
  - We used spade transfer system for testing before
  - Upgraded to HiDTS in 2024.01
- high reliability
  - Two servers both in ALiCPT and IHEP
  - Retransfer for 5 times and automatic retransfer Module was deployed
  - Establish data replicas at Ali B1 site to prevent network interruptions



Summary & Plan

- HiDTS is developed and will be released as open-sourced progressively
- HIDTS is using in BSRF、HEPS、LHAASO、JUNO、ALICTP and NHEPSDC
- Promote the application of HiDTS at SHINE、Herd and multi Storage Center
- It can be integrated into RUCIO as a plugin
- High speed transfer test Based RoCE network in HEPS Data Center
- Keep on Improving reliability and high performance
- Keep on cooperating with other big Scientific facilities and communities

Thank you for your attention!

Comments or suggestions?