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Fault Detection and Diagnosis Software For LHAASO

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Introduction

The Large High Altitude Air Shower Observatory (LHAASO) mainly aims at exploring the origin of high-energy cosmic rays and conducting scientific researches on high energy astrophysical radiation. LHAASO is located 4410 meters above sea level (a.s.l.) on Mt.Haizi in Daocheng County, Sichuan Province, China, and covers an area of 1.36 km². By employing hybrid measurements of extensive air showers (EAS) through the detector arrays, LHAASO achieves unparalleled sensitivity in detecting ultra-high-energy gamma rays and conducting all-sky surveys for very high-energy gamma ray sources. Additionally, it will provide measurements of the energy spectrum of cosmic rays across an exceptionally broad energy range.

Experimentation on a Large Scale
• KM2A: 5195 EDs & 1171 MDs
• WCDA: 3000 PMTs
• WFCTA: 20 Telescopes

Complexity of Online Computing System
• ~170 Computing Nodes
• ~10+400 Switches
• ~200 Software Processes
• ~3GB/s Readout Rate

Requirements for Non-stop Running
• Gamma ray burst
• Unmanned, autonomous control
• ......

Failures are inevitable

Quick diagnosis of the cause of the failure is **key, need a software like...**

Comprehensive Status Detection

Fast Fault Monitoring

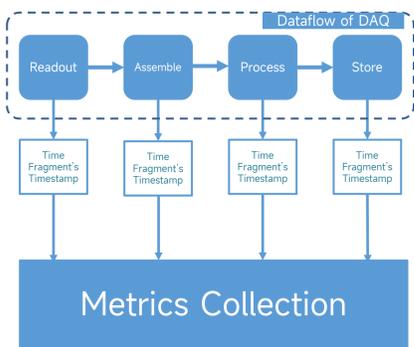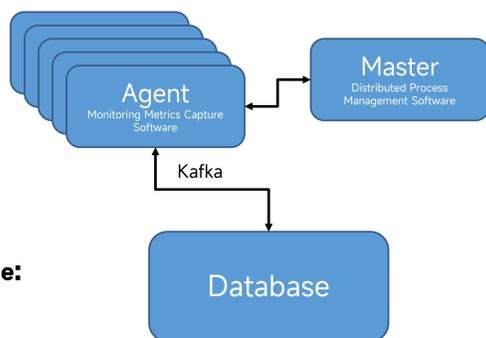Rapid Analysis of Fault Root Causes

Metrics Collection

Agent:
• Quick deployment
• Flexibly deployable
• Modular monitoring design

Master:
• Batch running tool
• Associated with experiment
• Run automatically

klog_online / Dataflow Collect Package:
• C++ dynamic library
• Running the DAQ system
• Collecting performance of time fragment

Agent
Monitoring Metrics Capture Software

Master
Distributed Process Management Software

Kafka

Database

Dataflow of DAQ

Readout → Assemble → Process → Store

Time Fragment's Timestamp

Metrics Collection

ANALYZE PERFORMANCE USING THE TIMESTAMP OF THE TIME FRAGMENT FROM THE DAQ SYSTEM

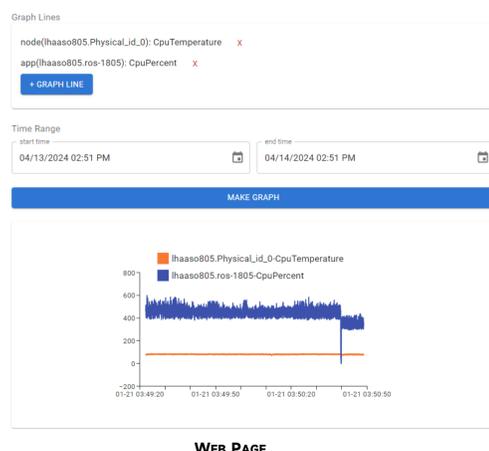| Metrics	Source	Time Interval (Second)
CPU utilization	Software	5
Memory utilization	Software	5
CPU temperature	Computing Node	5
Switch Port Connectivity	Switch	5
Software Performance	Software	-

CONFIGURATION OF METRICS MONITORING

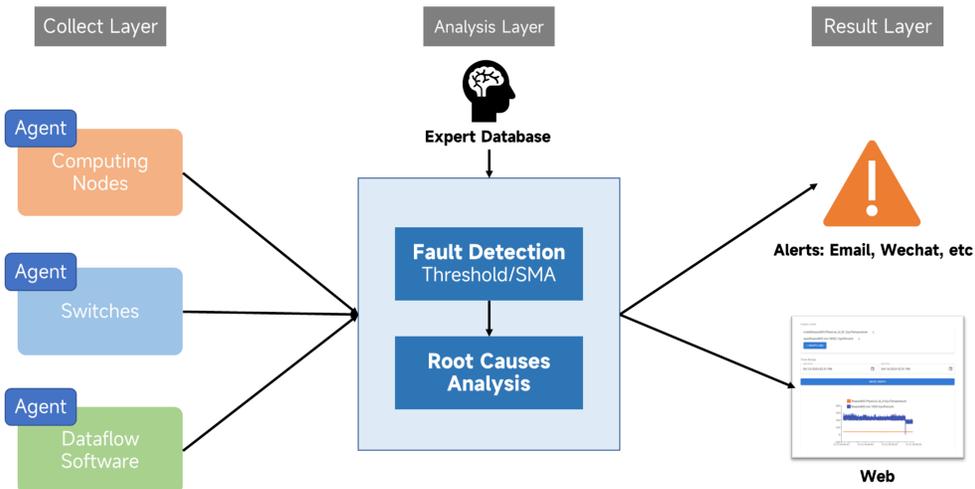## Conclusion

Application on LHAASO Online Computing System
• Improvement of fault monitoring efficiency
• Assist duty personnel to reduce the burden
• Automatic generation of operation reports

Next step:
• Determine whether a fault has occurred based on machine learning methods
• Analyze the root cause of faults based on graph neural networks

Graph Lines

node(lhaaso805.Physical_id_0): CpuTemperature   x

app(lhaaso805.ros-1805): CpuPercent   x

+ GRAPH LINE

Time Range
start time
04/13/2024 02:51 PM

end time
04/14/2024 02:51 PM

MAKE GRAPH

lhaaso805.Physical_id_0-CpuTemperature
lhaaso805.ros-1805-CpuPercent

WEB PAGE

Structure

Collect Layer

Analysis Layer

Result Layer

Agent — Computing Nodes

Agent — Switches

Agent — Dataflow Software

Expert Database

Fault Detection
Threshold/SMA

Root Causes Analysis

Alerts: Email, Wechat, etc

Web

Fault Detection

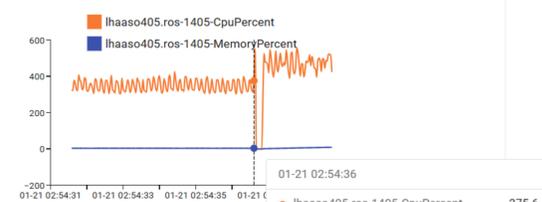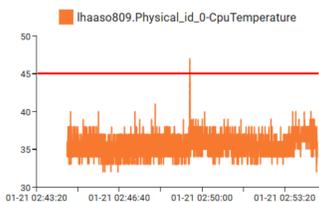| Exception	• Exceeds the standard range • Not yet affected Online Computing System
Fault	• Causes an interruption of Online Computing System • Occurred shortly before the interruption

Based On Threshold
• Setting the upper and lower thresholds
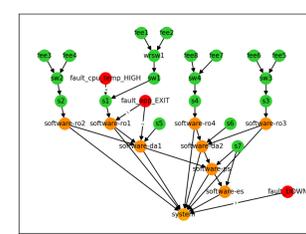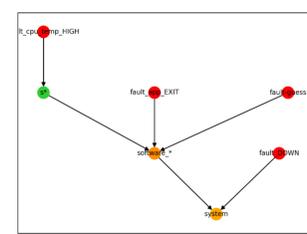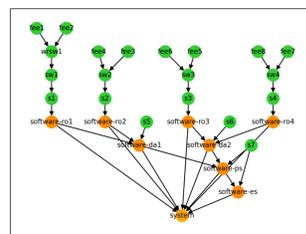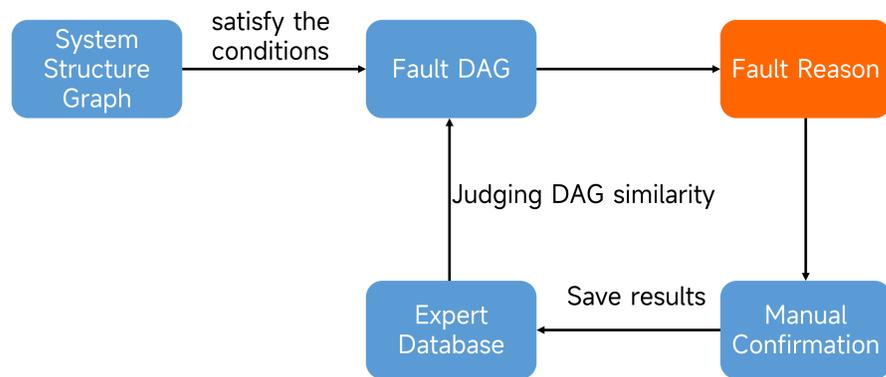• Apply to CPU temperature, memory utilization

Based On Simple Moving Average
• Better representation of data volatility
• Applied to metrics where stability needs to be assured
  • CPU Percent
  • Software Performance
  • …
• $SMA = \frac{\sum_{i=n-L}^{n} x_i}{L}$

lhaaso809.Physical_id_0-CpuTemperature

lhaaso405.ros-1405-CpuPercent
lhaaso405.ros-1405-MemoryPercent

01-21 02:54:36
lhaaso405.ros-1405-CpuPercent   375.6
lhaaso405.ros-1405-MemoryPercent   3.003

Fault Diagnosis

1. Formation of Fault Dependency Graph **Expert** Database by experts
2. Formation of **System Structure Graph** based on system architecture
3. Formation of **Fault DAG** based on System Structure Graph in case of faults
4. Compare with the expert database for **DAG similarity judgment** and get the root cause of the fault.

System Structure Graph → satisfy the conditions → Fault DAG → Fault Reason

Judging DAG similarity

Expert Database ← Save results ← Manual Confirmation

SYSTEM STRUCTURE GRAPH   **FAULT DEPENDENCY GRAPH**   **FAULT DAG**