WR deployment and operation at LHAASO

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Outline

- LHAASO introduction
- WR timing system for LHAASO
- Deployment status
- Running status
- Summary
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2. WR timing system for LHAASO
3. Deployment status
4. Running status
5. Summary
Large High Altitude Air Shower Observatory

- 29°21’ 27.6” N, 100°08’ 19.6” E
- 4410 m a.s.l.
- Full operation since 2021-June.
- Chinese National Major Science and Technology Infrastructure

• YaDing airport
Detect the air shower generated by cosmic rays

Main goals:
- VHE gamma sky survey & Monitor (100 GeV-1 PeV)
- Gamma ray spectrum measurement
- Cosmic rays (10 TeV-10 PeV) detect

Other goals:
- Dark matter
- Counterparts of neutrinos, …
- Sunstorm & IMF (interplanetary magnetic field)
- Particle physics
UHE gamma-ray

- measured the spectrum of the Crab Nebula at the highest-energy end up to 1.1 PeV
- 12 UHE gamma-ray sources discovered

https://www.nature.com/articles/s41586-021-03498-z
Detector array

- **EDA** – Electron (Electromagnetic particle) Detector Array
- **MDA** - Muon Detector Array
- **WCDA** - Water Cherenkov Detector Array
- **WFCTA** - Wide Field-of-view Cherenkov Telescope Array
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Timing system for LHAASO

- Time stamps of all nodes to be aligned,
- Distribute synchronous ADC sample clock
- Cable delay compensation
- Data throughput, online monitor
- Reliable, low cost, suitable for outdoor use

Precision: <0.5ns (rms)
Structure of Timing system

1# Elec_HUT

GM

WRS-L1
x3

WRS-L2
x30

WRS

~600m

WRS

~600m

WRS

~600m

Detector
elec.
X 6800

Distributed in field

Computer Room

DAQ
SERVER

Computer Room
WR in detector

- WRPc intergraded inside the detector electronics
  - Save the cost for additional connector and FPGA
  - Simplify the interface and protocol
  - Calibration required when the detector logic changes
  - Additional constrains added for the project
WRS-FL

- Improved heat dissipation, without FAN
- Improved device temp. range to -20 ~ 70
- Improved low jitter clock circuit
- Improved kernel board placement
- Optical Management port for fiber connection
- 18 WR ports with light guide
- Software/Firmware compatible with standard WRS-18

https://www.ohwr.org/projects/wrs-fl-hw/wiki
WRS-FL
Mass production for LHAASO

550 WRS-FL produced, 500 installed in field
WR in the field

- WR nodes are embedded inside the detector
- Photoelectric composite cables used for detector
  - 220V AC power + 3 fiber (1 used, 2 spare)
- 4-core fiber from L3 WRS to 1#HUT
  - 1 used for WR Uplink (port1)
  - 1 used for Management
  - 2 spare
WR in 1#HUT

Cable tray for inter-connection

SYS rack  MNG rack  ODF rack

Cable tray

WRS-A  WRS-B
Outline

LHAASO introduction
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Running status
Summary
LHAASO is running while construction
- 30 nodes, ¼ array, ½ array, ¾ array, full array
- WR switch produced/installed in batches

WR network supports both the timing and data collection

Very Flexible and expandable

Online monitor of WR timing system with Zabbix

Many issues found and solved (partly)
Zabbix monitor

Dashboard overall status

Devices with problem

Monitor: WRS sync status, packet flow of WRS port, RTT, temperature, etc..
WRS RTT monitor

RTT mean: 5.96us
daily change: 500ps

Maintain work undergoing

Unexpected Power-off

RTT of "km2a-3-4AP4"
Temperature monitor

✓ year modulation

✓ temperature changes in a day

Meteorological temperature
High temperature after snow

- High temperature warning recorded after the snow
- Same situation for almost all WRS
- The FPGA can reach 100°C
- Temp. changes over 60°C in a day

The sunlight reflection of snow
Thermal reflective film

Thermal reflective film pasted

4.27

5.28
WRS as switch

- The packet switch performance of WRS is not powerful
  - The routing table is handled by software code
  - The routing table limits the scale of the network
  - Static RTU may be modified if repeated MAC exists in the network
  - MAC learning still needs improvements
    - Repeated HASH mapping cause conflict that drops package.
    - CPU overload
  - Broadcasting of unrecognized MAC
    - Even in VLAN, introduce extra flow.

- Many of them are normal behavior, some are known bugs
- Project is moving forward, we can not wait for updates
- Our solution: Extreme conservative static RTU
  - Static RTU
    - the MAC of each port for each WRS should be added “manually” to its RTU
    - Otherwise it can not be seen, nor access.
  - MAC learning forbidden

- Not ideal, quite stupid, bus suitable for LHAASO.
  - The structure of Cosmic observatory is quite stable
  - only customized detector electronics with MAC address pre-assigned are expected in the WR network
  - Less intelligence are acceptable in LHAASO network.
Known bugs

- Bugs are only known until suffer from it

Static RTU rules are removed if frames with a given MAC arrive on another port

To reproduce:
add a static rule to another port than the device with a given MAC is connected
rtu_stat add 22:33:09:1e:5a:d5:S 0

CPU load when redundant MACs (or loads of new MAC addresses to learn)

Consider whether we can somehow limit the load of CPU (frequency of learning requests) in two situations:

- redundant MACs on different ports (see issue https://www.ohwr.org/project/wr-switch-sw/issues/201)
- burst of new MACs to learn

This possibly needs some intelligent mechanism in HDL...
- Broadcast packets is heavy burden to the network and WRS
- Static RTU with no MAC learning can avoid any auxiliary network packets
  - 99% of packets transmitted inside the network are generated by the detector electronics.
  - The packet flow of uplink and downlink fits the number from detector
Summary

- LHAASO is a powerful cosmic observatory
  - Large detector array
  - Fully operational since June, 2021

- WR based timing network
  - Provides time/frequency for all detector
  - Provides data transmission network

- WRS customized for the LHAASO
  - Fan-less with improved heat dissipation
  - Optical manage port

- LHAASO WR network is fully installed and operational
  - Over 500 WRS installed
  - Continues operation since the first ¼ array to full array
  - Very nice installation and operation experience

- Many issues have been solved
- Long-term operation with more physical outcome are expected
THANK YOU