Network Resiliency Implementation in the ATLAS TDAQ System

Stefan Stancu

Outline

- TDAQ system block diagram
- Networks and protocols
 - ☆ Global view
 - ☆ Control network
 - ☆ Front/Back-End network
- Operational issues
- Conclusions

TDAQ system block diagram

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Global view – routers

- 3 networks, 5 routers
 - ☆ Ethernet + IP
 - ☆ ~2000 computers, ~100 edge switches
- OSPF (Open Shortest Path First) in-between routers
 - ☆ redistribute connected
 - ☆ black-hole prefixes assigned to TDAQ
 - ☆ Links
 - ✱ In-between Control routers and from Control to “outside” → high speed (10GE+)
 - ✱ From the Control to Front/Back-End are auxiliary (used for management purposes) → Low speed (GE)
- Interface with Outside – static for easy/complete decoupling:
 - ☆ Dormant back-up (no load balancing)
 - ✱ Outside: TDAQ prefixes are routed on the primary and backup (with higher cost) links
 - ✱ Inside: two default gateways – primary and backup (with higher cost)
 - ☆ Primary link simulated failure → not perceived by user/application level
 - ✱ no real failure experienced to date

Control network - VRRP

- Inter-router link runs OSPF (“redistributes connected”)
 - ☆ Two trunked 10GE lines
- R1,R2 provide:
 - ☆ subnet 1 to sw1
 - ☆ subnet 2 to sw2
- VRRP (Virtual Router Redundancy Protocol) operation:
 - ☆ SubnetX → VRRP instance X:
 - ✱ One MAC (vrrp_macX) and one IP (vrrp_ipX) for the virtual router
 - ✱ Physical routers hand-shake and elect:
 - a master router (R1) → implements the virtual router
 - a backup router (R2) → dormant while the master is active
 - ☆ R1—sw2 link fails
 - ✱ R1—R2 handshake on subnet 2 fails (as R1 is not reachable through sw2)
 - ✱ R2 no longer sees a master so it becomes the master itself, implementing the virtual router (with vrrp_mac2, and vrrp_ip2)
 - ✱ Hosts in Rack2 continue to talk to the virtual router, unaware of the physical change
- A single VRRP instance provides redundancy but no load balancing
 - ☆ Two VRRP instances per subnet (R1 master in one instance, R2 master in the other one) could provide load balancing
 - ✱ However this causes asymmetric traffic (potential flooding on sw1, sw2)
 - ✱ To be avoided if bandwidth is not an issue

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- Practical issues
 - ☆ Tested prior to deployment
 - ☆ With proxy ARP enabled the following happens when host a host from rack 2 (host_r2) wants to talk outside subnet 2:

arp who-has host_x_IP tell host_r2_IP
arp reply host_x_IP is-at vrrp_mac2 # correct
arp reply host_x_IP is-at R2_phys_mac2 # spurious

- ☆ Depending on which ARP reply is received first (can be assumed to be random), the host will
 - ✱ either behave correctly (correct ARP received first)
 - ✱ or will use the “backup” router R2 (spurious ARP received first)
- ☆ Undesired behaviour because:
 - ✱ Traffic through R2 is asymmetric (return comes through R1) flooding can occur on sw2 depending on its mac-address-aging settings
 - ✱ Uncontrolled load balancing
 - ✱ Will not be detected on a test which only disables one swX primary link to R1
- ☆ Deployed in production only after the issue was fixed by the manufacturer

- If possible thoroughly test before deployment.

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Control network –high throughput servers

- High throughput needed on ~70 infrastructure and monitoring servers
- “Standard” options:
 - ☆ **Edge switch and VRRP with 10G up-links**
 - ✱ Two points of failure (switch and server interface)
 - ☆ Edge switch and VRRP with 10G up-links + bonding on the server
 - ✱ Linux bonding in ‘active-backup’ on the server can provide good redundancy
 - ✱ One point of failure (switch)
 - ☆ Two edge switch and VRRP with 10G up-links + bonding on the server
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 - ✱ No single point of failure
 - ✱ NOTE: STP is required in the subnet in order to break the loops created by the two switches (each one with 2 up-links)
- Direct router connections
 - ☆ Linux bonding in “active-backup”: primary link connected to R1, back-up one to R2
 - ☆ Not enough:
 - ✱ example: failure of sw1 primary up-link renders the servers unreachable for Rack1
 - ☆ Use VLAN interfaces on the routers and interconnect them (emulate a rack level switch)
 - ✱ the already existing high speed trunk used by OSPF can be shared by virtually any number of VLANs (tagged)
- Production experience
 - ☆ Deployed for:
 - ✱ all (most) critical servers
 - ✱ the NetApp FAS3100 storage units used system wide (user accounts, etc)
 - ☆ Sample failure while running:
 - ✱ a server interface going down and then re-negotiation to a lower speed
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FrontEnd TDAQ network

- High throughput, low latency
- Two vertical slices (fan out at the ROS level)
- Geographical location:
 - ☆ ROSs and ros-swX are underground
 - ☆ Cores and Trigger/EB farms are at the surface
- ROSs to Cores > 100M → fibre
 - ☆ Original design: fibre ports on the ROSs PCs
 - ☆ Once 10G affordable → Concentrate with GE copper underground and use 10G to feed the cores at the surface
 - ✱ One up-link failure renders <10 ROSs interfaces invisible
 - ✱ A ros-swX switch failure renders <20 ROSs interfaces invisible (at most one interface per ROSs)
- Use two VLANs (one per slice) and deploy a MST (Multiple Spanning Tree) instances for each VLAN (one per slice)
 - ☆ provides both load balancing and redundancy:
 - ✱ full lines are active
 - ✱ dotted lines are disabled (back-up)
- Production experience
 - ☆ Fibre cleaning
 - ✱ Fibre giving CRC errors
 - ✱ Disable it → traffic goes on the alternate (back-up) path (~200 ms downtime)
 - ✱ Clean the fibre
 - ☆ ~0.04% loss rate on two up-links (impact on data taking)
 - ✱ Caused by double bit error in SRAM on the line-card
 - Switch syslog issued “NOTICE” messages
 - ✱ Network monitoring does not show drops, not straightforward to troubleshoot
 - ✱ Disabled the problematic links , and continue running on the back-up links

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- Use two VLANs (one per slice) and deploy a MST (Multiple Spanning Tree) instances for each VLAN (one per slice)
 - ☆ provides both load balancing and redundancy:
 - ✱ full lines are active
 - ✱ dotted lines are disabled (back-up)
- Production experience
 - ☆ Fibre cleaning
 - ✱ Fibre giving CRC errors
 - ✱ Disable it → traffic goes on the alternate (back-up) path (~200 ms downtime)
 - ✱ Clean the fibre
 - ☆ ~0.04% loss rate on two up-links (impact on data taking)
 - ✱ Caused by double bit error in SRAM on the line-card
 - Switch syslog issued “NOTICE” messages
 - ✱ Network monitoring does not show drops, not straightforward to troubleshoot
 - ✱ Disabled the problematic links , and continue running on the back-up links

FrontEnd TDAQ network

- High throughput, low latency
- Two vertical slices (fan out at the ROS level)
- Geographical location:
 - ☆ ROSs and ros-swX are underground
 - ☆ Cores and Trigger/EB farms are at the surface
- ROSs to Cores > 100M → fibre
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BackEnd network

- Routed network (layer 3)
 - ☆ one subnet for SFIs/SFOs
 - ☆ one subnet for each Trigger farm
- 802.3ad LAG (Link Aggregation, a.k.a. trunking)
 - ☆ used on most SFIs, SFOs and a most Trigger farm switches up-links
 - ✱ dictated by bandwidth requirements
 - ☆ typically trunks made up of two copper GE ports
 - ✱ provides built-in redundancy
 - ✱ if a link goes down (link down) the remaining active ones are transparently used
 - ☆ on the Core router, LAGs are distributed on multiple line-cards to increase availability
 - ☆ load balancing
 - ✱ 802.3ad stipulates order preservation, but this comes at the cost of imperfect load balancing
 - ✱ Linux bonding and some networking devices offer load balancing modes with “perfect” balancing, at the cost of reordering frames
 - ✱ Full events (~>2Mbyte) are transferred in the network
 - Good load balancing (with out-of-order frames) offers better performance for this particular case.
- Production experience
 - ☆ partial failure of a 12 ports module (each port is a member of a separate LAG – paired with another 12 ports module)
 - ✱ receive OK, but send corrupted frames
 - ✱ corresponding links are active so they are used as part of the LAGs
 - ✱ ~50% frame loss in one direction -> LAGs are unusable
 - ☆ Provides good redundancy against complete failures, yet vulnerable to incomplete ones.

Miscellaneous operational issues

- Link autonegotiation
 - ☆ Standard (IEEE 802.3ab)
 - ☆ At power-up, consistently experienced sporadic autonegotiation failures
 - ✱ links at 10Mbit/s, 100Mbit/s, or even inconsistent speeds/duplex on the two ends
 - ✱ Preponderantly on a set of machines with bonded interfaces, but not only
 - ☆ Various solutions tried out
 - ✱ No result: cables tested, replaced and re-tested
 - ✱ Successful: advertise only 1000 Mbit/s during autonegotiation on the PC side, and try to bring the link up several times in case of failure
 - practical workaround, but the cause of the problem remains unknown
- Proxy ARP rate limitation
 - ☆ proxy ARP was initially deployed in the Control network (simplifies end-host management)
 - ☆ Rare and random connection failures experienced for an information server (receiving data from ~1500 clients at the same time)
 - ✱ problem traced down to be caused by a limitation in the rate of ARPs that can be proxied by the router.
 - ✱ This was a legitimate DoS protection
 - ☆ Gave up on using proxy-ARP, and things work smoothly since
- Flooding on ROS data switches
 - ☆ Message hand-shake between all applications at “prepare for run”
 - ☆ after ~1h stable beams and the trigger is “turned” on (1000 processors suddenly talk to ~150 ROSs)
 - ✱ packet loss is observed on the ROS switches
 - ☆ Limited rate or “large” latency for re-learning the MAC addresses of the processors
 - ✱ flooding unnecessarily multiplies the already high rate of frames
 - ✱ buffer overflows in the corresponding switches, and subsequent warnings (due to late replies)
 - ☆ Solution: mac-address-aging time increased to a safe value, so that the “prepare for run” message exchange persistently populates the MAC address tables.

Conclusions

- Large system with heterogeneous demands (control, Front/Back-End)
- Deployed different flavours of protocols meant at increasing resiliency:
 - ☆ layer 2: trunking (including bonding on hosts), MST (load balancing)
 - ☆ layer 3: OSPF, VRRP (no load balancing in current implementation)
- Real life failures are not text-book failures
 - ☆ very few total failures experienced
 - ☆ partial failures proved to be more frequent
 - ✱ since some functionality is preserved, the redundancy protocols may be fooled into using a malfunctioning link.
 - ☆ foreseeing redundancy reduces down-time, but there is no guarantee that it will always work.
- As the system increased in size, unexpected scaling problems rose to surface (e.g. proxy ARP rate limitation)