The LHC PC Rack Project

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On behalf of the LHC PC-Rack Study Group
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The LHC PC rack study group

• The LHC PC rack study group started late in 2002
• Initially was LHC PC Rack Cooling Project
• Has since studied other issues with PC racks
• Many people involved from the 4 experiments, PH-ESS and TS
  – Alice: A.Augustinus, S.Philippin.
  – TS-CV: M.Santos.
  – TS-EL: M.Delidais, J. Pierlot, K.Kahle, A.Funken
    • Note this is a low-level activity for essentially all of the above
• We acknowledge the generous support and contributions from others from the experiments and the technical sector.
The cooling problem

- All of the LHC Experiments will have large numbers of PCs in their Trigger/DAQ systems
- Assumption is that these will be “Rack-Mounted” servers (generally mixture of 1U and 4U)
- By late 2002 a solution of water-cooled racks was established for LHC electronics - with vertical air flow
- But PC’s require horizontal (front to back ) air flow
- What does CERN Computer Centre do ?
  - Lots of space so machines not closely packed
  - Lots of air conditioning with high ceilings (so with care can obtain cooling ~2 kW/m^2)
- Looked to IT industry
  - Rapidly increasing power densities were recognised as a problem (Watts/CPU doubling in ~5 years. Density increasing at a similar rate)
  - Almost no installations yet at power density we need
The cooling problem continued

- 1U servers are very compact, **can fit 40 (or more) in a rack**
- Typical dual 1U PC uses ~200W (PSU rated at ~400W), but increasing, so expect 250W (or more)
- Thus require **10-12 kW per rack**
- Power density far too high for air-conditioning
- Best solution found was a water-cooled heat exchanger which could be fixed to the rear door of the rack
  - But only rated at 8 kW
  - Not initially available in Europe *(made to USA specs)*
- Some custom racks for this power were starting to become available - **but expensive and generally much larger**
Cooling with horizontal air flow

- Basic layout as shown
- Rack with \(~40 \times 1U\) PC’s
- Water cooled heat exchanger fitted inside the rear door
Cooling with horizontal air-flow

- Tests run with 30-48 PCs
  - 30 single Xeon 2.4 GHz PCs
  - 18 dual Xeon 2.4 GHz PCs

- Single CPU PCs used ~ 90W
  (at full load - ~60% if CPU idle)
- Dual CPU PCs ~170W
- Power factor typically over 90%
  (ratio W/KV)

- Max power in rack ~5.8 kW
Cooling with horizontal air-flow

- Liebert RackCooler mounted inside rack (Max 8kW)
- Rack sealed with door
  - Holes cut just round fans
- Extensive measurements made
Cooling with horizontal air-flow

• Measure the CPU temperature and power consumption of individual PCs and power consumption of a complete rack
  – under full load
• Measure air temperatures at various positions inside and outside the rack
• Test cooling behaviour in different failure scenarios
  – Fan failure or water flow stop
• Results described in a technical note - published within each experiment
  – ALICE-INT-2004-014
  – ATLAS-DAQ-2004-9
  – CMS-IC-EN-0001
  – LHCb-2004-035 DAQ
Cooling with horizontal air-flow

- PC temperatures reasonably uniform over the whole rack
  - Even though rack taller than cooler

- PC’s slightly cooler with RackCooler than in open rack
  - Improved air flow (~20%)

- Air temperature at outlet ~ as at inlet to rack
Cooling with horizontal air-flow

- At total load of 5.8 kW over 90% of the heat is removed by the cooler
- Failure of the rack-cooler fans or the cooling water led to a gradual rise in temperature - but in worst case only became critical for the CPU temperatures over ~2 hours
Cooling with horizontal air-flow

• Following the measurements, discussed with various companies and an improved version was developed (CIAT)

• ATLAS, CMS and LHCb now have prototype racks with this cooler and ALICE plans to do so
  – Rated at ~10 kW
  – Can be mounted inside or outside rack
  – Dimensioned to fit 600 mm wide racks
  – Requires a rack of height ~2200 mm or more
  – Air is taken from the room and returned at ~ same temperature
    • I.e. not closed circuit
Prototype Racks

- Mounted inside a DELPHI rack for LHCb
Prototype Racks

• Mounted outside a new server rack for ATLAS & CMS
Electrical Issues - 3rd Harmonic

- Measured for several PC’s - *example*: 1U 2.4GHz dual Xeon
- Current 1U PCs with **Active pfc** are not that well corrected
  - In principle can improve - but significant price
- Remove differential trip
- Reinforced neutral (phases add, do not cancel)
  - changes power distribution network + main transformers

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Electrical Issues - continued

- **Harmonic currents:**
  - rate the neutral for same current (or larger) than each phase
  - Include a circuit breaker on the neutral
  - Size the transformer accordingly i.e *1.5-1.7*

- **These precautions, are not free, but may be less than special Active PFC for all PCs.**

- **Comparison with Bat 513 (EDMS 413142)**
  - 3rd Harmonics smaller in Bat 513
    - Towers tend to have better correction (less constraint on size)
    - Greater mix of PC types
    - UPS systems help (although more on in-rush - see below)
  - Experiments do not have farms on UPS - too expensive
  - Currently major upgrade to power and cooling for Bat 513 *(from 0.6 to 2.4 MW)* - but note special harmonic transformers
Electrical Issues - continued

• **In-rush current** *(EDMS 442180)*
  – Measurements made for different PC’s
  – In-rush currents of 40-80 x normal current seen for ~20 ms
    • Some supplies have much lower multiples (“Soft-Start”)

• **How to distribute power to ~40 PC’s in a rack**
  – ATLAS/CMS have 3 phases each at 16 Amps in a rack
  – LHCb has 6 strips each at 10 Amps in a rack
  – Mechanical issue - 0U, where to mount
  – Simple barrette - cost ~10 CHF/PC
    • Inrush current limits number of PCs per barrette
    • Use of D-Curve circuit breakers help *(allow ~x10 current for 0.5s)*
  – **Staggered power-on** - cost ~40 CHF/PC
    • Sockets on a barrette turn on in groups with ~.2s delay between each group
  – **Individual power-on** - cost ~100 CHF/PC
    • Optimal control, but uses more space, greater cost, limited number of suppliers and models (e.g. many have a 1A limit per outlet)
Electrical Issues - continued

• How to remotely reboot PCs
  – Power cycle PC at distribution units
    • But depends of granularity of control in power distribution
  – Use serial connection on PC - if available
  – Boot on LAN signal
Mechanical Issues

- **ATLAS/CMS** propose to use industrial **Server racks**
  - Have flexibility to cope with PC mounting from different manufacturers
  - PC’s mounted on rails supplied with PC
    - 1U PC’s vary considerably in width (+- 5mm) and depth (+- 50mm)
    - Slide rails fixed to the sides, mount front and back at 19 inch centres (Standard electronics racks do not have suitable mounting points for the rear support - cf Server racks do)
  - Racks supplied with Cooler added to rear-door

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Mechanical Issues - continued

- ALICE/LHCb will use recycled LEP racks
  - LHCb use support angle at each side of each server
    - Add custom PTFE block to match the width of PCs
  - Cooler attached to rear-door
- A rack of servers is very heavy - can easily reach 700 kg
- Small peripheral switches have Ethernet ports on front - PCs have Ethernet ports at back
  - Mount back-to-front - cannot see status LED’s from front
  - Or bring cables from front-to-back - wastes at least 1U
Other Issues

• Cooling of switches
  – A lot of the PC racks include small switches
  – Some have front-to-back air-flow
    • But what if switch is mounted from back of the rack?
    • Reverse the fans or what?
  – Many have side-to-side air-flow
    • Do we need additional baffles for adequate cooling?

• Monitoring and control of rack infra-structure
  – DCS systems provides the tools
  – Overall rack power control by DCS
    • How to integrate smart power distribution?
  – No smoke detection inside rack
  – Plan to use internal monitoring of PCs (Fans, temperatures)
  – Integration and correlation of farm fabric software and DCS
Conclusions

• A group has been working to find common solutions for the problems associated with racks of PCs at the LHC experiments.
• A solution has been found to provide \(~10\,\text{kW}\) of cooling with horizontal air-flow and flexibility to be used with various racks
• Study group (with TS) has also studied electrical and mechanical issues
• Continues to meet regularly to compare developments in the prototype farms now being established
Back-up Slides
Use of Blades

• Why not blades
  – Still not mature - but keeping a watch
  – High performance CPU blades are recent development
  – Currently price is more than 1U servers
  – Only clear advantage today is better power supplies and redundancy in cooling
  – For CPU intensive work power efficiency is no better
  – Density can be higher, but cannot use because of power/cooling and weight limits

• However if becomes appropriate to go to Blades
  – Uses 19 inch racks
  – Cooling is still front to back
  – Infra-structure largely unchanged
Server Characteristics

- 1U servers are very compact, can fit 40 (or more) in a rack
- Typical dual 1U PC:
  - Uses ~200W (PSU rated at ~400W), but increasing, so expect 250W (or more)
  - Has large in-rush current (can be ~75 Amps for 20 ms) and significant 3rd Harmonic
  - Weighs 10-15 kg
  - Is cooled by horizontal air-flow, drawn in at front and blown out the back
  - Is ~60-70 cm deep, 1U high (no spare space for support guides), ~42-43 cm wide
  - Is normally supported by slide rails fixed to the sides, which mount front and back at 19 inch centres