PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

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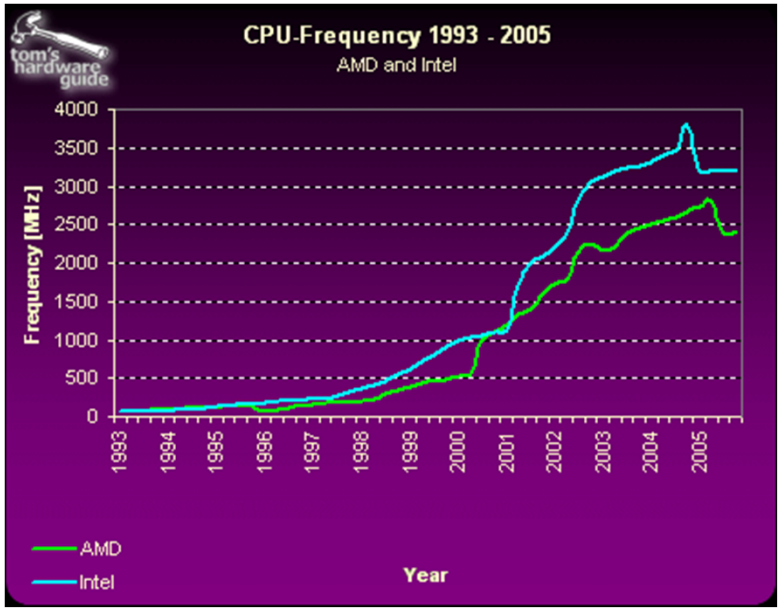
Modern system architectures in embedded systems

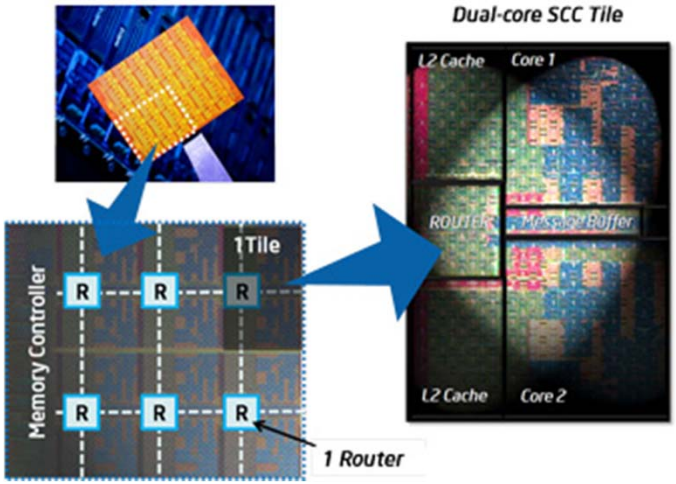
- Outline
  - What is driving the technology?
  - Two most prominent trends
  - How can we take advantage of this?
    - Applications in embedded systems
      - Some being worked on, some imagined
  - Conclusions

- Technology drivers
  - The general IT and telecommunication industry always have their needs for
    - More computing power
    - Most efficient use of the infrastructure
  - Many (but not all) of the technology push comes from there
    - This becomes the technology base for us

- Trend 1: drive towards parallel processing
  - CPU frequencies are not rising any more
  - Speed through parallelization
    - There are a number of variations to this.
    - The most obvious: adding CPU cores

Parallel processing has been around for quite some time, but now we too have to care about it!

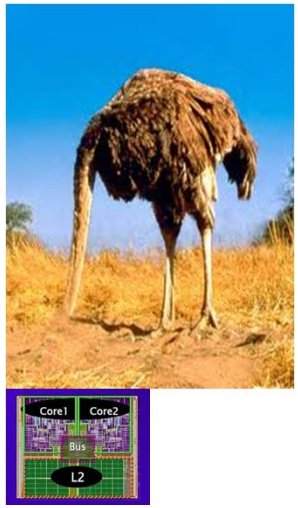




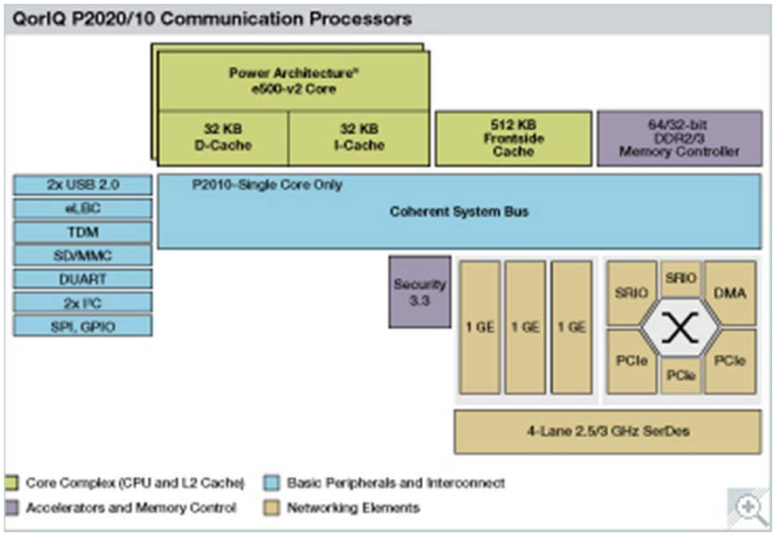
Intel 48-core CPU

- The ultimate in parallel processing:
  - Many talks in this conference have shown the use of FPGAs as computing engines
    - Mathematical operations, DSP, image processing, data reduction to name a few
    - Real applications, not just glue logic
  - Ultimate parallelism to really fine-grained level
  - A few drawbacks, however:
    - Development cycle long
      - Abstraction level of tools is still low
    - Toolsets – at vendor's mercy
      - A full open source toolchain would be great (although not too likely to happen)

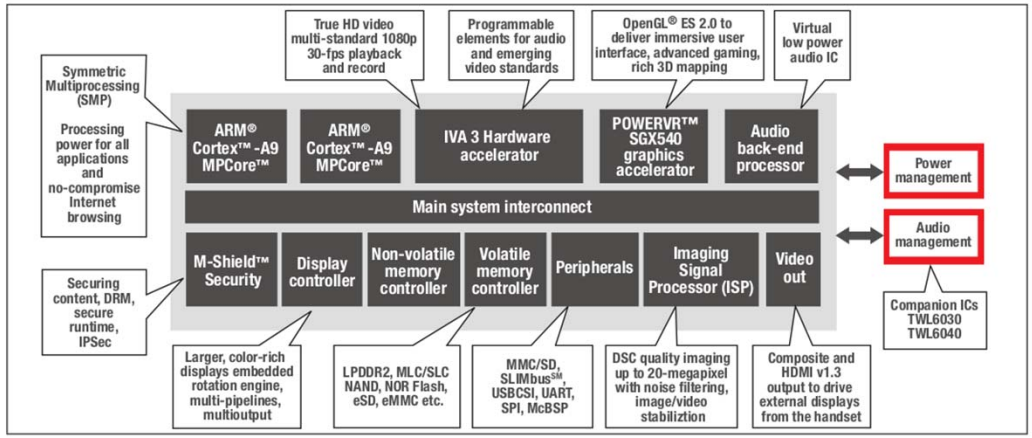
- Parallelism on a coarser level
  - Multi-core CPUs
  - This is datacenter technology but is everywhere
    - Unavoidable, even if one wanted to...
  - Better to study and take advantage of it
  - Has its advantages:
    - Lightweight (relatively)
      - Faster development cycle
      - Mainstream OS support
  - But is not without a catch:
    - Real-time systems have to be looked at closely
    - Timing behaviour, deadlocks,...
      - Very little attention so far
        - » Some contributions in this conference



- Multi-core variants
  - Homogenous
    - Many identical processors
  - Heterogenous
    - Diverse cores (DSP, GPU)
    - Can be very interesting for embedded applications
  - Task partitioning important
    - OS & library support



Freescale QorIQ



OMAP44x block diagram

TI OMAP

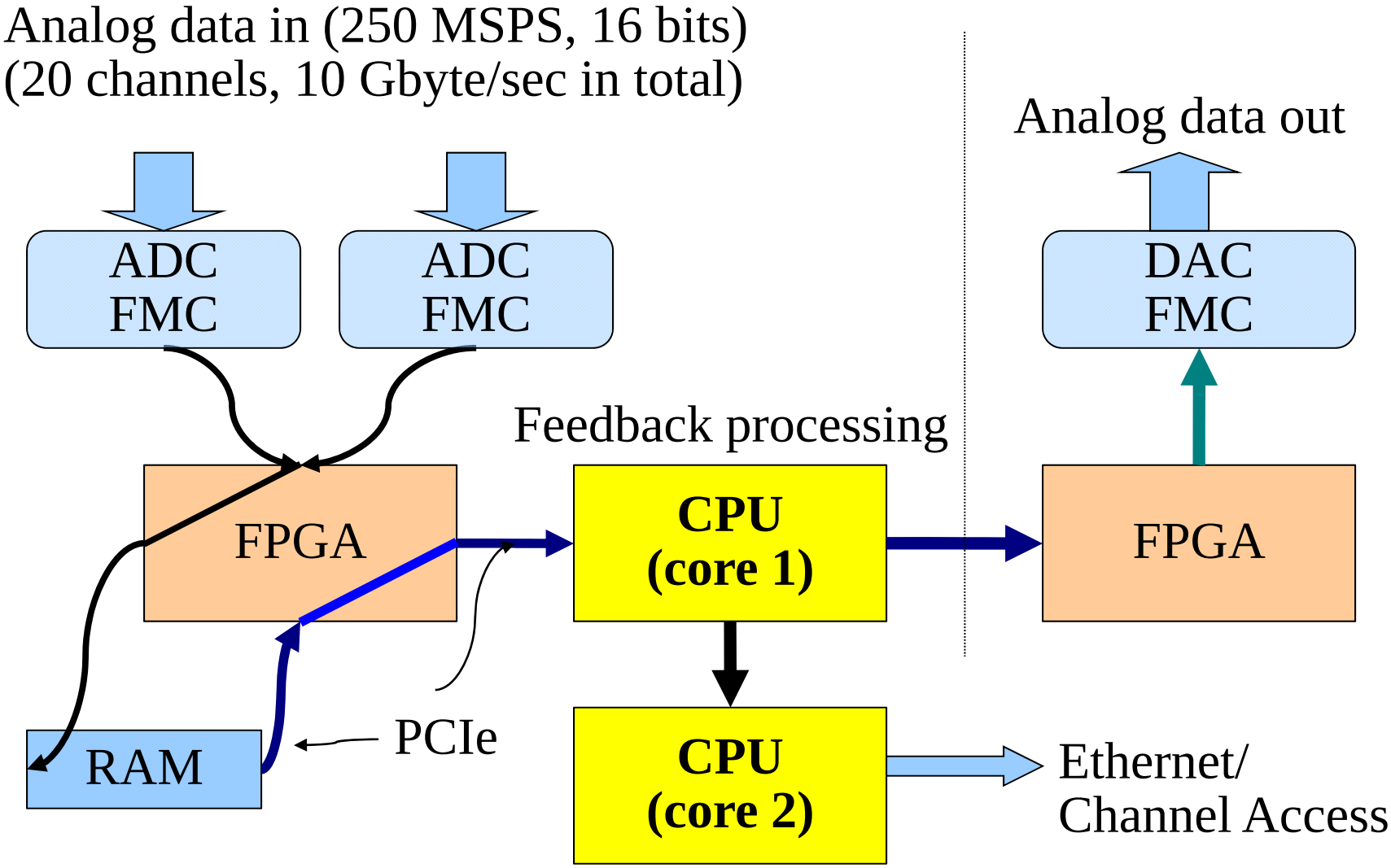
- Interconnects (fast serial links)
  - Needed (also) for efficient parallelism
    - Multi-drop bus scales badly with multicore
    - Point-to-point, data plane
    - Also message passing
  - Serial links are everywhere
    - Ethernet & PCI express are the dominant protocols
    - Custom protocols sometimes needed but are a challenge for integration
  - Mastering these technologies is essential
    - Needed to take advantage of parallelism
    - Makes the whole scene interesting

- Trend 2: Virtualization
  - another datacenter trend
  - Efficient use of hardware
    - Reduce number of idling CPUs
  - Even more pressing needs:
    - Maintenance
      - Fewer servers to look after
    - Management
      - Start, stop, move servers around (high availability)
    - Cooling, etc. infrastructure
    - This all applies to embedded systems, too!
      - Or, at least could apply

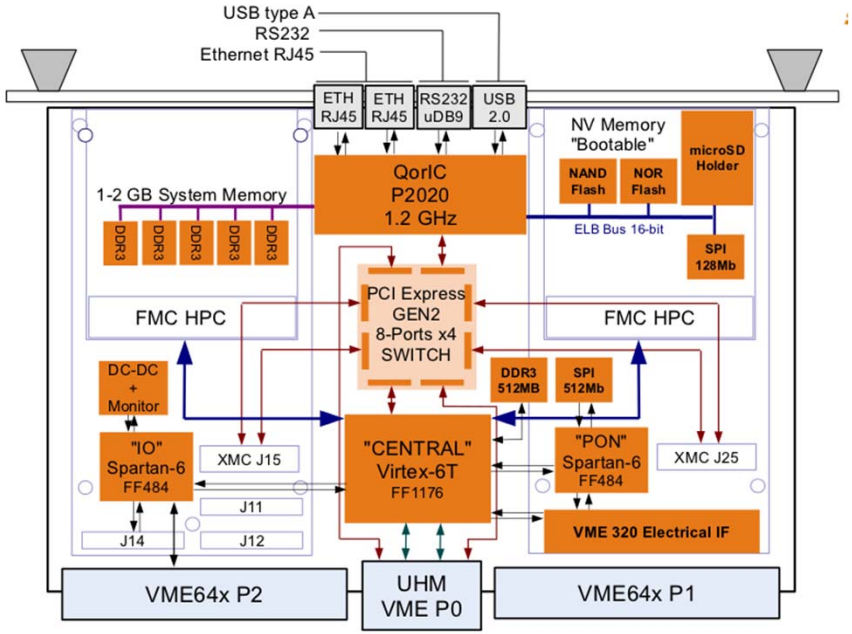
- Support for parallelism has not been the main driver for virtualization but it is needed to take advantage of multicore parallelism
  - Symmetric multiprocessing does not scale well to very large number of cores
  - Could open up interesting possibilities (examples later)
  - Speciality: I/O Virtualization
    - Hardware implementation of hypervisor function
    - Guest OS gets direct access to hardware
    - Removes bottlenecks due to software intervention
    - Part of general trend to move virtualization support to hardware

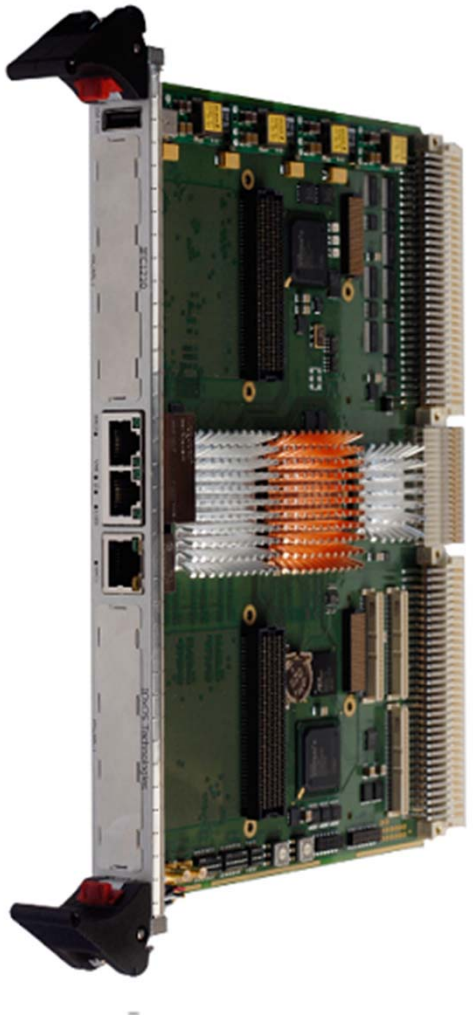
- Three selected applications
  - To illustrate how these things may affect us
  - Real and imaginary
    - None of these is in real use yet – some of them may never be

- Applications (1)
  - Data streaming and processing in a fast (local) feedback system (LLRF)
    - demonstrates
      - Parallelization
      - Use of fast interconnects
      - Use of multi-core separate functions
  - We (Controls & Low-level RF groups at PSI) are actually working on this
    - First prototypes expected early next year


Analog data in (250 MSPS, 16 bits)
(20 channels, 10 Gbyte/sec in total)
Analog data out
ADC
FMC
ADC
FMC
DAC
FMC
Feedback processing
FPGA
CPU
(core 1)
FPGA
RAM
PCIe
CPU
(core 2)
Ethernet/
Channel Access

This is real... our new platform: IFC_1210





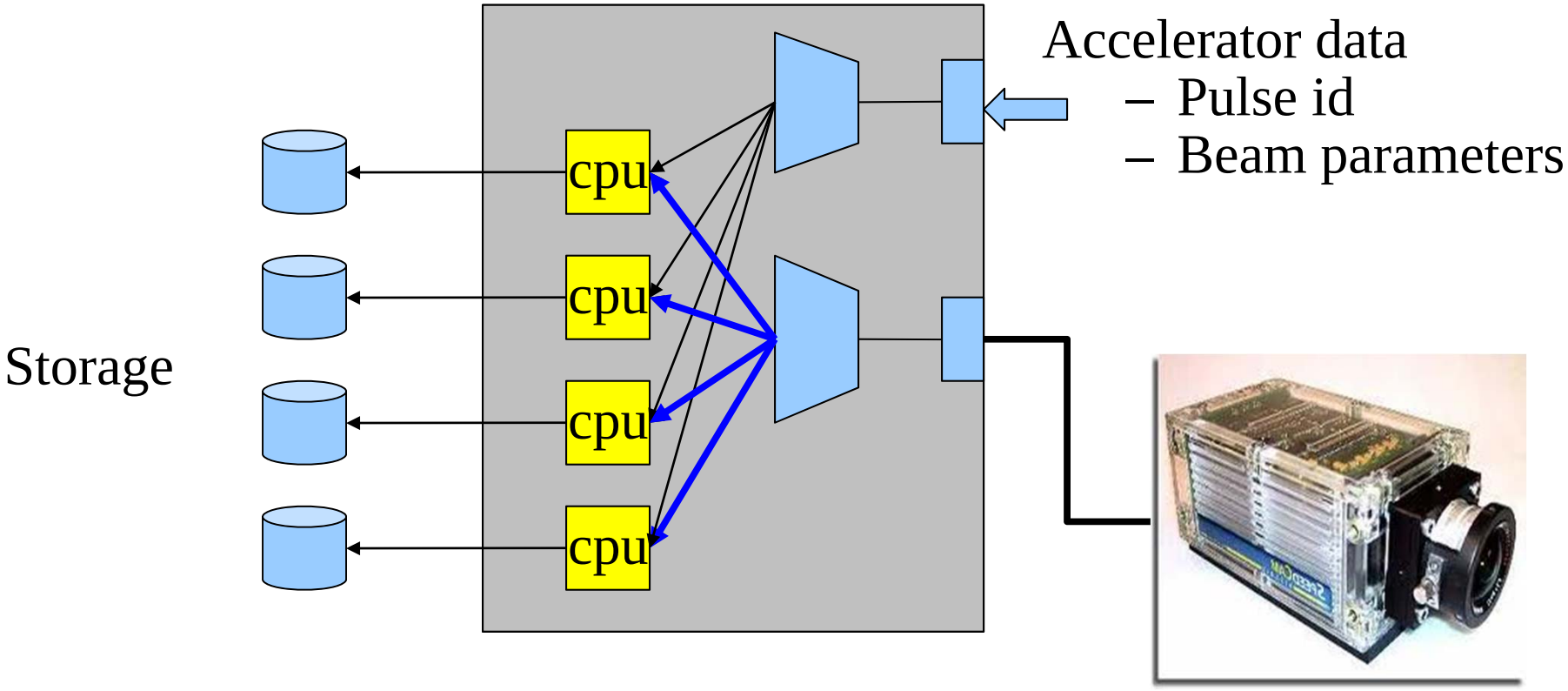
IOxOS SA & PSI co-development

- Plugs in a normal VME64x crate
- PCI express (two 4x lanes) & GTX serial links through P0
- Dual FMC (XMC,PMC) carrier
- Details see www.ioxos.ch

- Applications
  - Striping data acquisition
  - Fast (imaging) detector and (image) processing
    - Parallelism with multiple cores
    - Serial interconnects
    - Use of I/O virtualization for load sharing
      - » Improves efficiency
    - (imaginary- we might do this but are not doing at the moment)

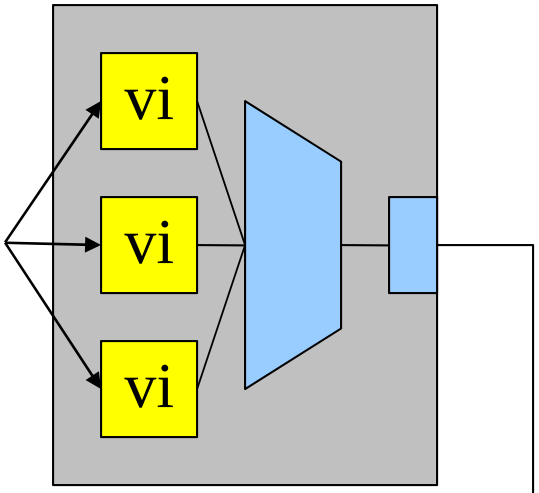
Multicore server processing large volume data

- Too fast for a single core
- Data striped, processed and stored to disk
- Merge with e.g. pulse number (X-ray FEL)



- Applications: centralize I/O processing
  - Virtualization of front-end I/O
  - Maintainability
    - System updates
    - CPU power allocation
  - Totally changes the landscape...
  - Frontend equipment can be made thin
    - Cooling, power, monitoring
    - No CPU mandatory
    - Imagination is the limit...

Virtual system (IOC) images



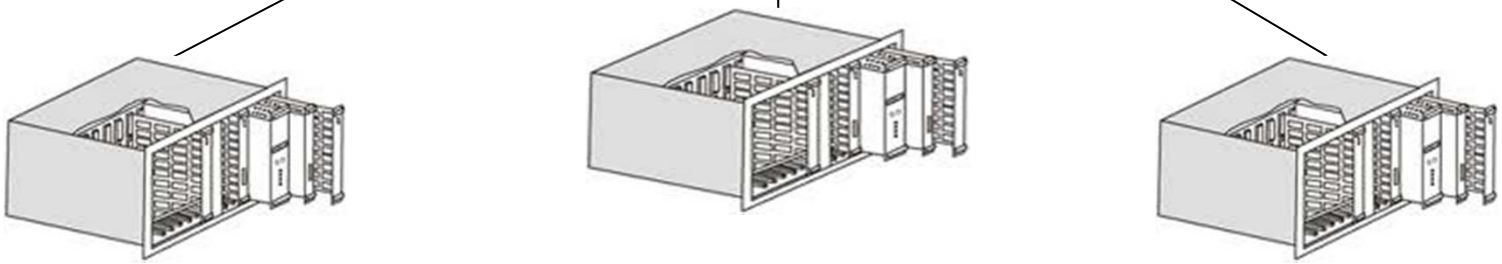
Processing servers can be remote

- Even real-time
- Processing power can be allocated where needed
- Redundancy

(hardware still has to replaced on-site when broken)

Long-distance links (PCI express)

PCIe switch



I/O systems (VME/cPCIe/xTCA/...)

- Conclusions
  - Trends hit us, if we want it or not
    - Mastering the technologies is important
    - parallelism
    - Interconnect protocol is the key to integration
  - These trends can (and will) change how we do things
    - Thats what keeps us busy... and why this is a great field to be in!

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Thank you for your attention!