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Modern system architectures in embedded systems

ICALEPCS 2011
• 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!
• 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

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

Feedback processing

FPGA

CPU (core 1)

CPU (core 2)

RAM

PCle

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)

Accelerator data
- Pulse id
- Beam parameters
• 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

Long-distance links (PCI express)

PCIe switch

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)

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
  - That’s what keeps us busy... and why this is a great field to be in!
Thank you for your attention!