CONVERGENCE COMPUTER-COMMUNICATION METHODS FOR ADVANCED HIGH-PERFORMANCE CONTROL SYSTEM

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Abstract

Convergence computer and communication technologies are moving to high-performance modular system architectures on the base of high-speed switched interconnections. Multi-core processors become more perspective way to high-performance system, and tradition parallel bus system architectures are extended by higher speed serial switched interconnections. New with serial switch system interconnect are analysed. Compact modular system on the base of passive 3-4 slots PCI bas with Fast switch network interconnection are described as example of modern effective scalable control system solution, which can be compatible extended to advanced system architecture on the base of new technologies.

NETWORK BASED SYSTEM ARCHITECTURES

The tradition bus architectures are too slow for fast graphics and an additional accelerated graphical port (AGP) was introduced. PMC mezzanine sub-modules for PCI modules as additional function extensions inside modules were developed as industrial standard. Some applications are also significant consumers of high-speed interconnects such as DVI, SATA and 10Gbit Ethernet; and 2D/3D image processing in Physics and medicine creates huge demands on systems for capturing, collect and interpreting information. Parallel data processing, modeling, simulation, and image processing in real time are compute and communication intensive. A revolutionized approach is required to decide all today's problems. System Area Network (SAN) architectures were developed on the base of Serial Interconnect for high-performance data processing and mass storage access. Among modular computer systems PCI bus and VME bus architectures with passive backplane are most popular in control industry today. Many applications like image processing, biological, 2 PCI-X slots allow a maximum clock rate of 100 MHz, and 4 slots would drop down to 6 MHz. PCI architecture was adopted for telecom industry as compact PCI (cPCI) with maximum data throughput from 133 MB/s then moving to 533 MB/s. New Standards Industrial Specifications (PICMG, VITA) include PCIe, cPCIe, InfiniBand and 10 GE.

Serial cPCI Express Interface

Serial PCI Express (PCIe) is transparent on physical layer to application software, and programs written for traditional PCI devices can run on PCIe devices. Data is transferred via high-speed, point-to-point serial links know as lanes. PCI and PCIe can be used together in the Hybrid system. Each lane comprises a pair of differential conductors with 250 MB/s pro direction: one pair is used for data transmission, other - for receiving. These lanes can be bundled to a maximum of 32 lanes per channel (up to 16 GB/s in both directions). PCIe bandwidth is scalable. The common lane configurations are x1 ("by 1"), x4, x8 and x16. The bandwidth available is proportional to the number of lanes. Typical 64-bit PCI-X bus uses 127 signal pins on multiple board layers versus x4 PCIe slot that provides twice as much bandwidth and requires 15 signal pins. PCIe replaces shared bus with a shared switch. But centralized control of PCIe switch should be changed in future by ASI (Advanced Serial Interconnect) as symmetrical Switch Interconnection like Network. Compact PCI Express (cPCIe) supports bus structures with 4 - 16 lanes per channel enabling data transfers up to 4 GB/s, which bi-directional, doubling the 250 MB/s data throughput to 500 MB/s. If cPCIe board cannot administer all available lanes of the board, then the unused lanes will be automatically deactivated during initialization. Remaining from cPCI is the power connector for the PSU and the slot for parallel-bussed peripheral modules (PICMG 2.0).

VME/VXP Compatible Extension

There are a few reasons for parallel VME bus compatible extension: 1) Interrupts over ASI is not best decision for RT-systems. 2) Arbitration between peer-to-peer or tightly coupled processors is similar as interrupt. VITA is aimed to increase VMEbus performance, while maintaining backword capability. The key efforts are: faster parallel bus (VITA 1.5); multi-Gigabit switched serial interconnects (VITA 41 and 46) and new mezzanine cards (VITA 42). The first VME bus renaissance was being the 2eSST protocol, which implemented with chips from Tundra and Thales, enables bus to run at 320 MB/s (an 8x bus performance of VME64's).

VITA 41.x (VSX) family of specifications is VMEbus extensions for serial switched technology. VXS (VITA 41.0) defines physical features that enable high-speed serial links in a VMEbus –compatible system with the addition of high-speed connector to the VME64x board in the P0/J0 position. The VXS backplane currently has Infiniband (VITA 41.1), RapidI/O (VITA 41.2), Gigabit Ethernet (VITA 41.3) and PCI Express (VITA 41.4) protocol layer. Serial VITA 46 (VPX) replaces all the DIN connectors on VME module by high-speed connectors supporting signaling rates up to 6.25 Gbit/s.

There are a series of standards, including VITA 46 (VPX) and VITA 48 (VPX RDI). VITA 46 standard provides 4 switch fabric ports of 10 Gbit/s each.

The specification expands users I/O PCI Express. VSO was developed specification for enhanced design (VITA 48.x), electronic cooling (VITA 50), reliability predictions (VITA 51), lead-free practices (VITA52), technical management (VITA 53) and other requirements. New compact VPX 3U modules are concurrent of cPCI 3U modules. At the heart of VPX is a high-speed backplane 7-row MultiGiga 2 connector (signal rates up to 6.25 Gbit/s), developed by Tyco. It provides a effective way of allowing VMEbus users to leverage the performance of the high-speed switched fabrics such as StarFabric, RapidIO and user I/O or fabric connections from XMC (VITA 42) mezzanine to the backplane.

Infiniband System Architecture

The InfiniBand specification defines the interconnect architecture that can pull together all I/O and memory subsystems for next generation servers, HPC and Control. It is industry standard technology that advances I/O connectivity for high performance computing clusters, breaking through the bandwidth and limitations of the PCI bus by migrating from the traditional shared bus architecture into switched fabric architecture, where two or more nodes are connected to one another through the fabric. The architecture is based on a serial switched fabric defining link bandwidths 2.5 - 30 Gbits/sec, resolves the scalability, expandability, and fault tolerance limitations of the shared bus.

InfiniBand switch fabric, consisting of a single switch or a collection of switches and routers, was developed as a System Interconnect platform for modern servers, Data Centers, SAN, HPC, storage subsystems. Server clusters and grids, linked with high-speed interconnect, creates intensive compute power solutions. With it's scalability and efficiency small and large clusters scale up to thousands of nodes. With 20 Gb/s node-to-node and 60Gb/s switch-to-switch solutions available, and a roadmap to 120 Gb/s, Infiniband Adapter 10Gb/s matches Gigabit Ethernet pricing. High speed Channel Adapters (HCA) can support multiple end-points that can provide dedicated granular QoS and security services to virtual servers, storage and Control.

Gigabit Ethernet

10 Gigabit Ethernet (10GE) is popular approach to update ProfiNet Industry Network based on Fast Ethernet (FE) for modern Control Systems application. Tradition Star Topology is not the best for Redundant Industry Control Network Topology becouse of possible traffic collapse. Redundant Structure with RING topology is best decision for industrial Control Systems, where some connections can be under reconfiguration in case of some errors. Reconfiguration Time should be as small as possible. Today some companies produce industry switch with 2 GE ports only (MOXA), but full industrial GE Switches will be developed and provided in next year for Control Systems. Next generation specification for 100GE switches are under investigation as newe standard.

ADVANCED MODULAR SYSTEMS

Advanced Telecom Computing Architecture (ATCA) base specification defines the form factors, core backplane fabric connectivity, power, cooling, management interfaces, and the electromechanical specification of the carrier board (the existing IEC 60297 Eurocard).

ATCA

ATCA compared with existing TCA backbone systems, is faster, fault-tolerant switch fabric, system management, hot swap and modular format. The carrier can be a simple passive board, SBC or Switch. The backplane has become the core of interconnection between each of the modules. Data have to be switched and transferred at multi-gigabit speed and designer must consider connectors as part of the signal transmission line and take care of impedance, delay, skew, and crosstalk. Cable interconnects to the backplane and Mezzanine Card connectors become the system infrastructure. Differential signaling requires 2 separate lines for each lower signal voltage, but it offers greater isolation from noise.

Differential pair signals must arrive at their destination at the same time. Since characteristic impedance is a function of geometry and materials, each of these variations can alter the impedance and generate reflections. PICMG 3.x specification series define how to map a specific switching interconnect technology onto the physical framework. PICMG 3.1 defines the mapping of Ethernet and Fibre Channel (FC), PICMG 3.2 defines Infiniband, PICMG 3.3 - StarFabric, PICMG 3.4 - PCI Express, and PICMG 3.5 - RapidI/O.

Micro TCA

Micro TCA (2006) was developed as a new advanced compact modular system standard based on mezzanine format AMC modules, which could be used in advanced low-cost compact modular systems with own backplane. Systems are modularized in a compact, highly integrated fashion as Computer-On-Module (COM) or System-On-Module (SOM) concepts.

Compact AMC modules is deigned to meet the carrier needs of reliability, availability, and service ability. Target interfaces are High-speed AMC, which optimized for targeted interfaces like PCIe, ASI and Gigabit Ethernet. An AMC design key is hot swap.*AMC.0* – is common specification (mechanics, management, power, thermal, and interconnect). *AMS.1* - specification defines the implementation of PCIe and ASI; *AMC.2* - Ethernet interfaces; *AMC.3* - storage interfaces such as FC. Micro

AMC architecture supports a number of transfer protocols with different bandwidths. The same compact AMC modules can be installed in Micro and on big boards for scalable ATCA systems.

MODULAR DAQ-CONTROL SYSTEM

Compact DAQ and Control Systems with GE Switch interconnection with Embedded SBC and DSP-based modules and Scalable Integrated Switched Architecture (SISA) are proposed and discussed as example of GE Switched systems with compact modular RT-systems. Problems of Data Acquisition, Monitoring and Control in Industry and Experimental Area are connected with general problems of signal registration, event selection and registration for analysis. Monitoring recognizes events, which can be abnormal signals, reflecting risk state of some equipment. Periodical Signal Event Recognition is based on minimum or maximum limits of input signals or special signal form analysis. Signal recognition and registration algorithms can be developed for special control in software in the same system by professional users.

Terminal station (TS) is effective (performance/cost) compact modular system with passive 3-slots PCI bus for SBC and DSP-based measurement/control modules. Such TS was embedded in box with font-end electronics for signal conditioning and used as autonomous RT-system. Multi channel analog I/O is used for simulating signals by software modeling for test of all input channels as real event signals. Module dimensions is 185x122 mm, power is 5V (1.8A).

Distributed System (DS) for signal registration and complex events analysis is based on GE network switch and connected to some distributed objects. All TS nodes work as RT-systems. Required numbers of TS can be used for complex event registration and analysis.

Supervisor station (SS) can be used as central node for control, visualization and signal generation (like TS with number 0). Collection of real and simulated events in server can be used as knowledge base for future prediction critical state and optimal control of objects. In this case simulated events should be registering in the same instrumentation systems as monitoring events.

Supervisor station is used for control, modeling and simulating event in autonomous mode or can send signals to selected TS with any number (not 0). Embedded modeling and simulating signals help in testing special new algorithm for optimal control in the same environments.

Modeling and Simulating of object signals can be done in each node parallel with monitoring by SS-node. Registered signals can be collected in central node (file server, DB) and with real signals can be used for analysis. Additional simulating functions of TS and SS-nodes are system testing with input signals produced by internal TS generator or by external precision generator.

Integrated Wired and Wireless subnets can be used as effective platforms for System Area Network for Desk and Mobile Computer connections and for IP-phone communications for personal inside the same System

RESUME.

1. New switched modular systems include 10G Ethernet (IEEE 802.3ak – CX4), serial attached SCSI (SAS), Serial ATA2 (SATA-2) and InfiniBand and use the same compact modules fro small and extended modular system
2. Compact modular Terminal Station including passive 3 slot PCI bus with DSP-based Control-Measurement Modules and Supervisor Station with Server at other side, interconnected by GE Switch is effective concept for scalable system development, which can be upgrade to PCIe compatible nodes and 10GE switch.
3. Advanced Modular System Architecture can be based on the same standard modules for big scalable systems and future micro systems.