Data Links and Networks in Space Applications – SpaceWire usage

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SUMMARY

- On-board data communications context
  - Space Systems Constraints and Requirements
  - Data Processing Functions and Trends
  - Trade-offs
  - Data processing architectures
- Usage of SpaceWire in space applications
  - Current usage of high speed data links
  - Advanced data processing architecture studies
  - Issues for best usage of SpaceWire networks
- Conclusion

DATA COMMUNICATIONS CONTEXT
Space Systems Constraints

- Harsh environment
  - Radiations | Vibrations | Shocks | Thermal effects…
    - Induces high costs for development and qualification programs
  - Mission and phase dependant (launch | Low Earth Orbit | Geostationary | Deep space…)
  - Limited resources in space for embedded electronics
    - Communication Link
      - Availability and delays of ground/spacecraft communications
      - This induces on-board data-handling support functions (data compression, storage, retrieval, autonomous monitoring and control…)
    - Power budget is strictly limited (electrical and propulsion)
    - Mass and volume needs to be minimized (launch cost, life-time…)

Reduced choice of electronic components and available technologies

Need for concentrating the development efforts on a limited set of standardized and perennial solutions

DATA COMMUNICATIONS CONTEXT
Space Systems Requirements

- Mission dependant systems requirements
  - Command and Control
  - Failure Detection Isolation and Recovery
  - Performances of spacecrafts bus and instruments
  - Reliability
  - Availability
  - Safety
  - Operational and maintenance requirements
  - Qualification levels

Various range of requirements induces numerous specific solutions for the Data Processing Systems architecture and products

Need for flexible generic architectures based on a limited set of common HW and SW building blocks

DATA COMMUNICATIONS CONTEXT
Data processing functions and trends

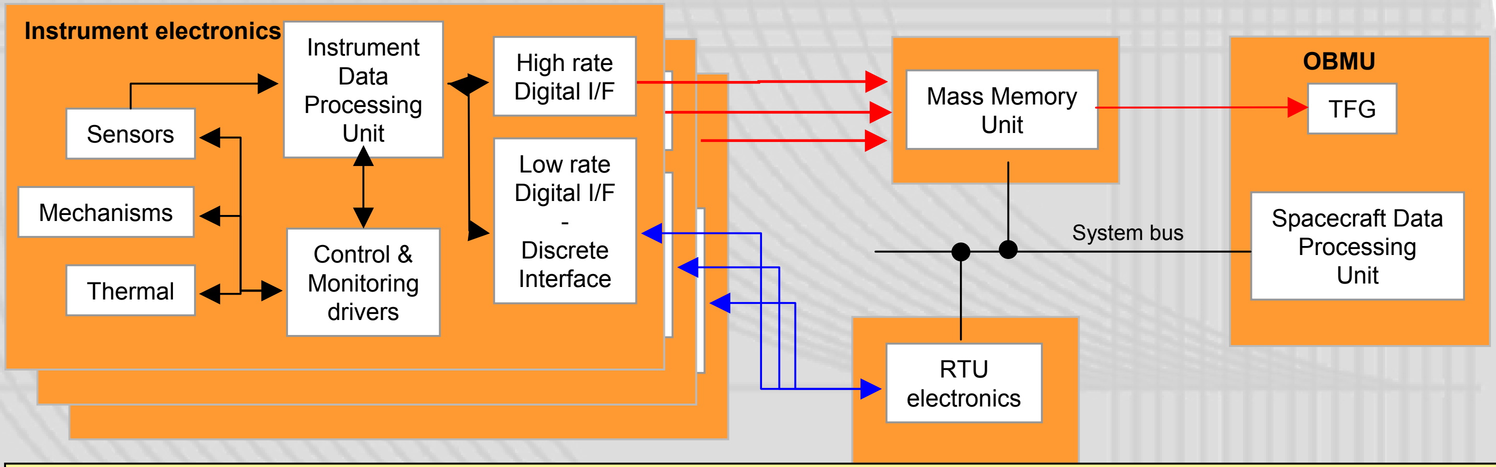
- P/L Science data cannot be downlinked at acquisition rate
  - Increasing need for high performance on-board data processing (e.g. compression, formatting, filtering…)
  - Increasing need for high capacity on board data storage
- Several independent instruments on a same spacecraft
  - With high rate data links
  - With low rate command and control
- Telecommunication data switching requires higher performance dynamic control (for e.g. telephone, internet…)
- Growing need for on-board intelligence (AOCS, camera, radar, robotics, navigation…) resulting in data rate increase
- TM/TC and on-board data require increased security functions

DATA COMMUNICATIONS CONTEXT
Trade-offs

- Critical trade-off in the implementation of space systems
  - Technologies adaptation to environmental constraints
  - Quality of payload data
  - On-board processing performance
  - Data transmission delays and synchronisation of distant units
  - Redundancies of elements and data links
  - Power consumption, Overall Weight/length of cables
  - Overall cost …
- Efficiency of the data links solutions depend on the systems priorities and of the nature of the transmitted data
  - This results in several types of data links
    - Command and control buses (OBDH, 1553, Can)
    - Point to point serial data links (RS232, RS422, 1355, SpaceWire,…)
    - Discrete dedicated interfaces (Direct commands, sensor acquisition…)

DATA COMMUNICATIONS CONTEXT
Typical data processing architecture

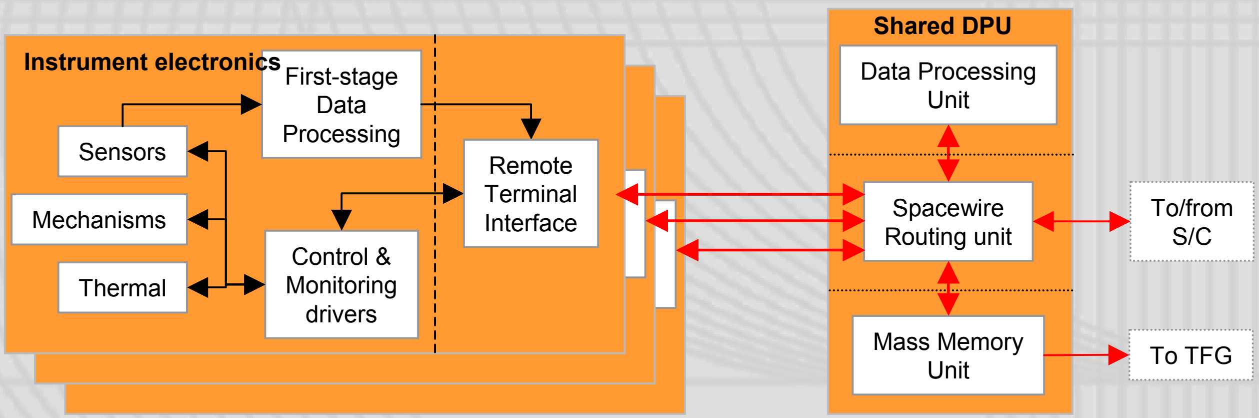
- Typical resulting on-board data processing architecture
  - Independent instruments data processing units
  - Direct interfaces to Mass Memory for high rate data storage
  - Instrument control through system bus and Remote Terminal Units (RTU)
  - Several types of data links adapted to communication needs



Compromise between system requirement, available technology and signals characteristics

DATA COMMUNICATIONS CONTEXT
Alternate data processing architecture

- Dedicated to improve the system budget issues:
  - Lower number of nodes and links variants
  - Share of common functions/resources
  - Instrument connected to SpaceWire Network through Remote Terminal Interface (RTI)



SpaceWire Networks could be an element for improvement of future on-board data processing architecture and overall budgets

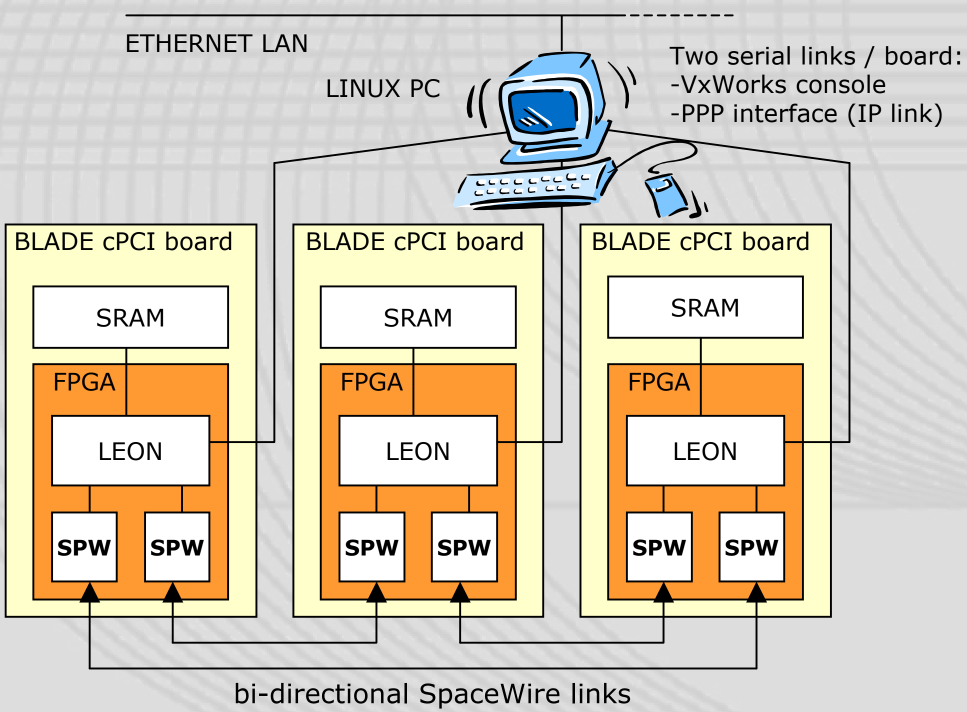
USAGE OF SPACEWIRE IN SPACE APPLICATIONS
Current usage of high speed data links

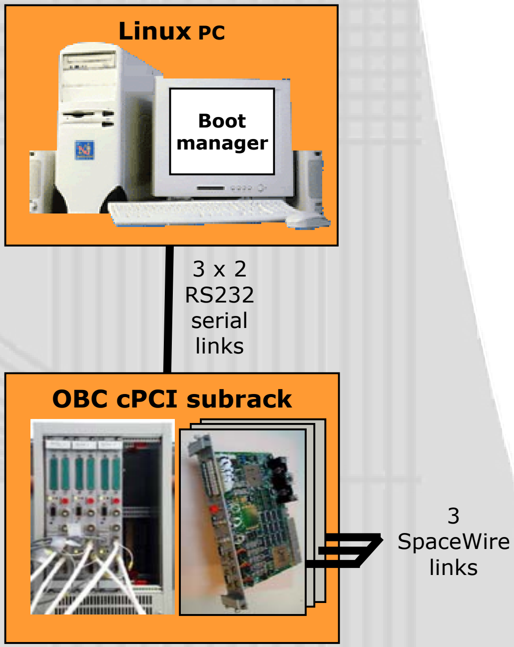
- 1355 links used in several spacecrafts such as
  - Science data to Mass Memory (Cryosat, Rosetta, Mex/Vex)
  - For telecom signal dynamic switching (Inmarsat4)
- Other High data rate links used for Gbits performance requirements (Pleiades, TerraSAR-X)
- Also used as OBC ground test interface for software instrumentation (Pleiades, TerraSAR-X)
- SpaceWire used in most studies on future data processing architecture and Leon SoC prototypes
  - ESA studies (e.g SCoC and the A3M demonstrator, A3SysDef, Gamma, Disco…)
  - National agencies and EADS-Astrium internal projects (ALF3, Unionics, MAEVA,…)

DATA PROCESSING ARCHITECTURE STUDIES

Avionics Advanced Architecture and Modules (A3M)

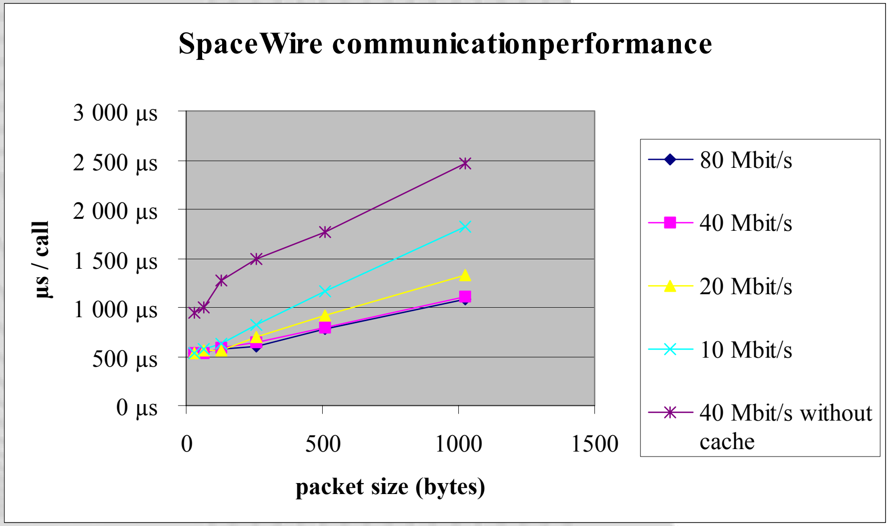
- The A3M architecture includes fault tolerance mechanisms
  - Demonstrator includes three Spacecraft Controller on a Chip
  - Bi-directional SpaceWire links used for inter-node data synchronisation





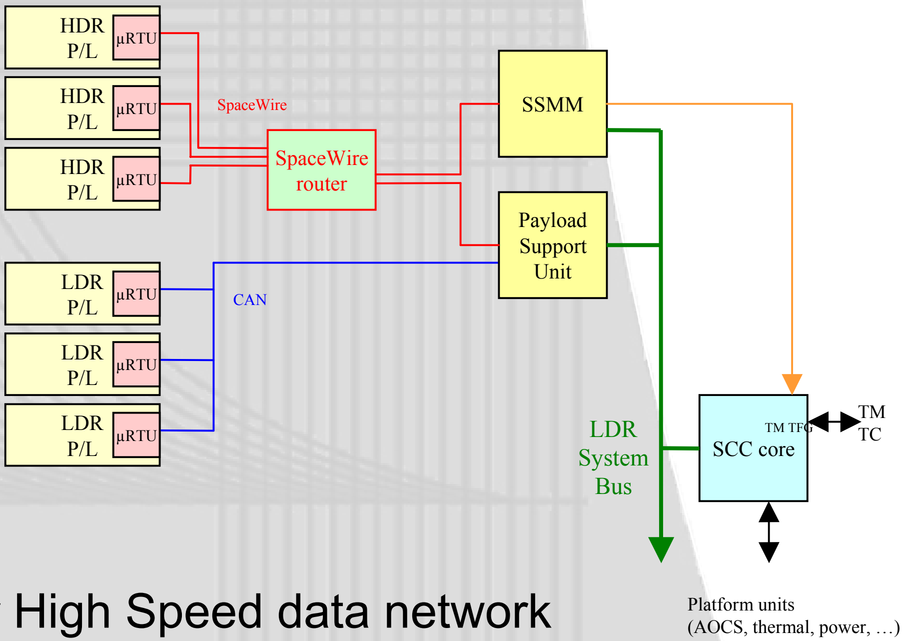
DATA PROCESSING ARCHITECTURE STUDIES
Avionics Advanced Architecture and Modules (A3M)

- The A3M study conclusions on SpaceWire
  - Very efficient for inter-processor communication :
    - With intelligent controllers, very high data rate can be achieved from memory to memory
    - Efficient implementation of protocols atop SpaceWire requires to limit the number of SW layers
    - The software must take into account the flow control mechanism in order to avoid overload propagation from one processor to the others
    - Communication time is generally small compared to the processing time required to manage a message.



DATA PROCESSING ARCHITECTURE STUDIES
Aurora Avionics Architecture System Definition (A3SysDef)

- Definition of a generic functional architecture for planetary exploration missions
- High speed data-links between standard functional units
- Trade-off performed between:
  - PacketWire (10 Mbps, LVDS)
  - SpaceWire (200 Mbps, LVDS)
  - GIGABIT SpaceWire (1 Gbps, LVDS or optical)
  - Ethernet 100baseT (100 Mbps, 1,5 Vpp)
  - IEEE-1394 (400 Mbps, 265 mVpp)
  - USB 2.0 (480 Mbps, 3.3 Vpp)
  - PCI express (up to 2500 Mbps, 0,5 Vpp)

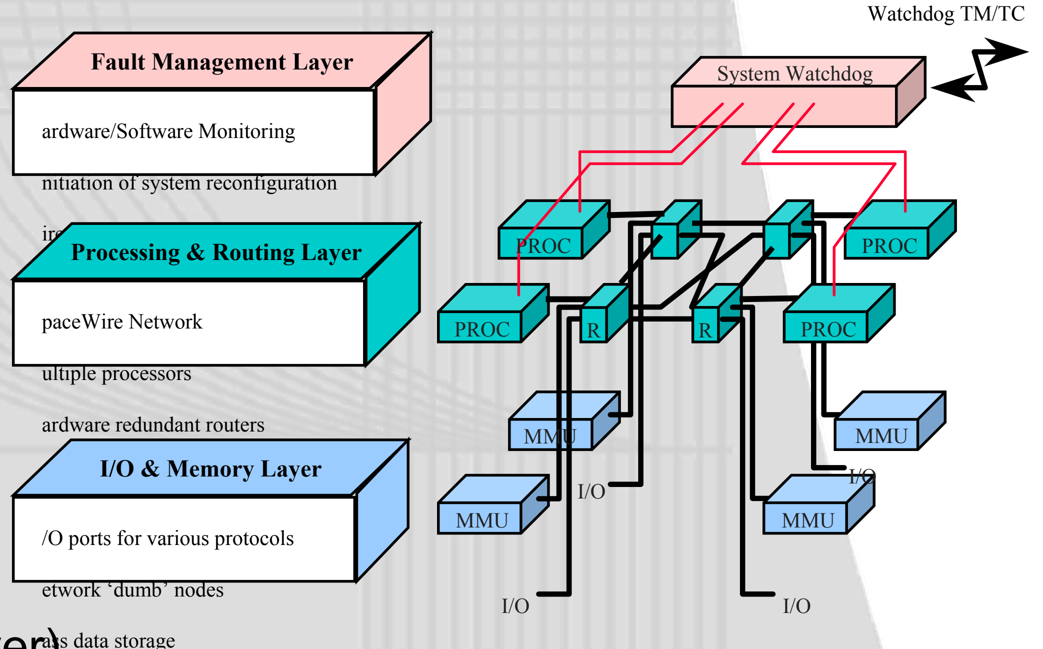


✓ Conclusion : SpaceWire is selected for High Speed data network between on-board building blocks

EADS ASTRIUM

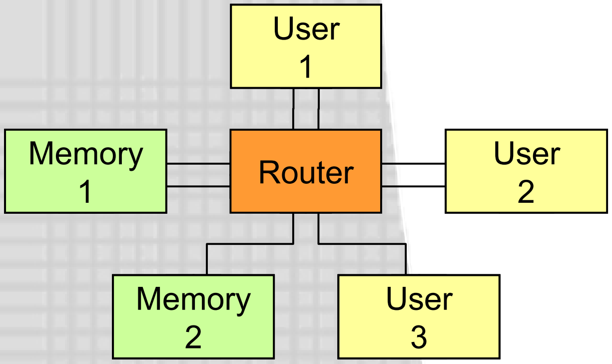
DATA COMMUNICATIONS CONTEXT UNIONICS

- Advanced architecture dedicated for High-performance on-board distributed processing
- Modular and scalable architecture on SpaceWire network
- Specialized building blocks including:
  - Processor nodes
  - SpaceWire Routers
  - Mass Memory nodes
  - System Watchdog
- Demonstrator developed
- Further works planned
  - FDIR consolidation
  - Processing node on Leon2
  - Consolidation of SW modules
  - Case study implementation and evaluation (ExoMars Rover)

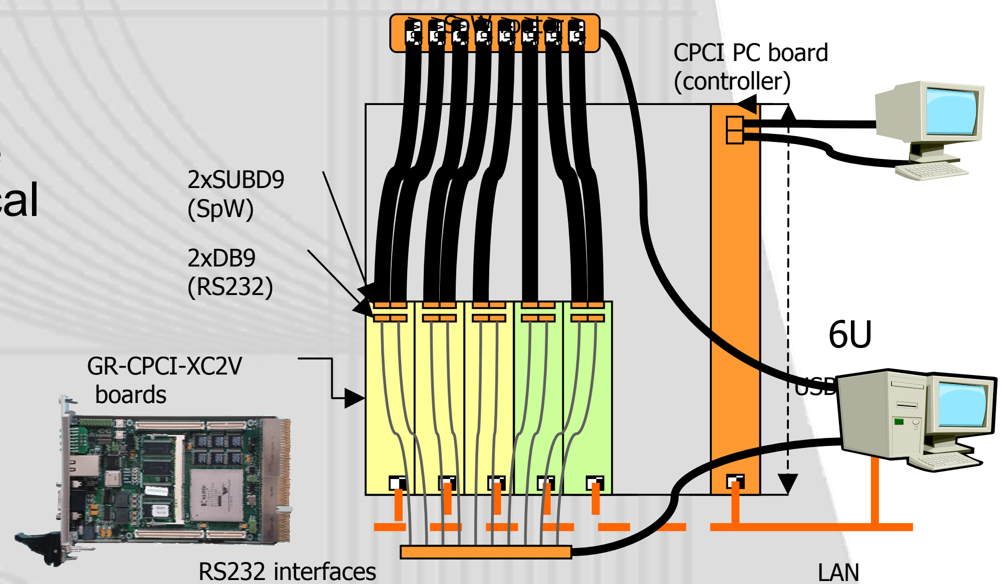


DATA PROCESSING ARCHITECTURE STUDIES

Generic Architecture for Mass Memory Access (Gamma)



- Distributed architecture for data storage management.
  - Several memory users (Calculators, instruments, …)
  - Several memory modules (and technologies)
    - Manage concurrent data accesses
    - Protect transactions
    - Ensure data consistency
- Demonstrator on a representative environment based on five identical commercial FPGA boards.
  - Use of SpaceWire network:
    - 40 Mbps at first,
      80 Mbps and more expected.
    - 2 SpaceWire interfaces per board to test concurrent accesses.



USAGE OF SPACEWIRE IN SPACE APPLICATIONS
Issues for best usage of SpaceWire networks

- Availability of SpaceWire Network building blocks elements
  - Space qualified components and IP's for integration in SoC's
  - Ground support software/hardware
    - adapters to ground networks (usb, ethernet…), Traffic monitor/simulator, network administration SW, simulation…
- On-board Software issues
  - Communication services / SOIS – HW/SW interface
  - Support of application distribution and resource sharing
- FDIR issues:
  - Failure modes of network building blocks (Routers, RTI's)
  - Support of Broadcast and Multicast modes
  - Support of time/memory data partitioning
- Detailed evaluation of properties for SpaceWire networks (latency, propagation time, data security…)

USAGE OF SPACEWIRE IN SPACE APPLICATIONS
Conclusion

- SpaceWire/ECSS-E50-12 supports the need for high performance data processing on future spacecrafts
  - To be recommended for any point-to-point high speed links under 200 Mbps
    - A higher data rate implementation (for instance through other physical media) would increase the usability domain
  - Viewed as a future solution toward more generic payload data processing systems through on-board data networks
    - Optimising on-board resources and performances
    - Some issues require consolidation (FDIR, communication services, development of SW and HW components, development tools)
  - Could also be extended to the whole data processing system (eg. for small vehicles, robotics…)