SpaceWire Standard
Problems and Evolution Lines.
Experience of implementation and application

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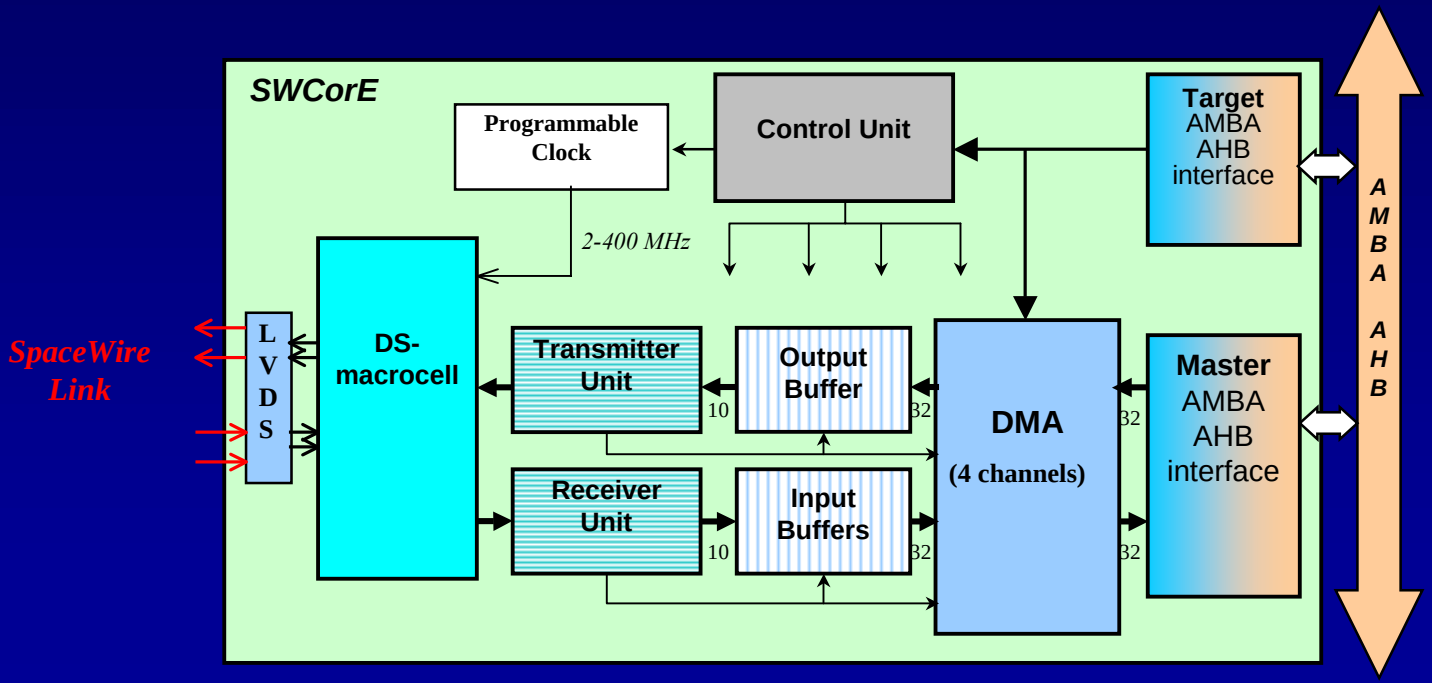
SpaceWire features, problems and proposals

- **SpaceWire links and bit rates**
  - Adaptable link rate
  - Higher bit rates for limited distances
  - Links striping
  - Conductivity isolation problem
- **Packets and Frames**
  - Byte credit in frames, information transfer in packets
  - Multi-byte words assembling/disassembling
  - Unpacketized data stream
- **Distributed parallel processing support**
  - Sections of the SpaceWire channel and its effective throughput
  - Routing in SpaceWire interconnection
- **SpaceWire outside Space applications**

SWCorE™

SpaceWire NIC IP-core for AMBA AHB bus



SpaceWire links and bit rates

1. Adaptable link rate
2. Higher bit rates for limited distances
3. Links striping
4. Conductivity isolation problem

SpaceWire links and bit
Adaptable link rate

- Embedded in the SpaceWire link synchronisation scheme
- One of the SpaceWire standard advantages
- SpaceWire standard gives a smooth bit rate scale

It gives a way for full exploitation of the SpaceWire throughput potential

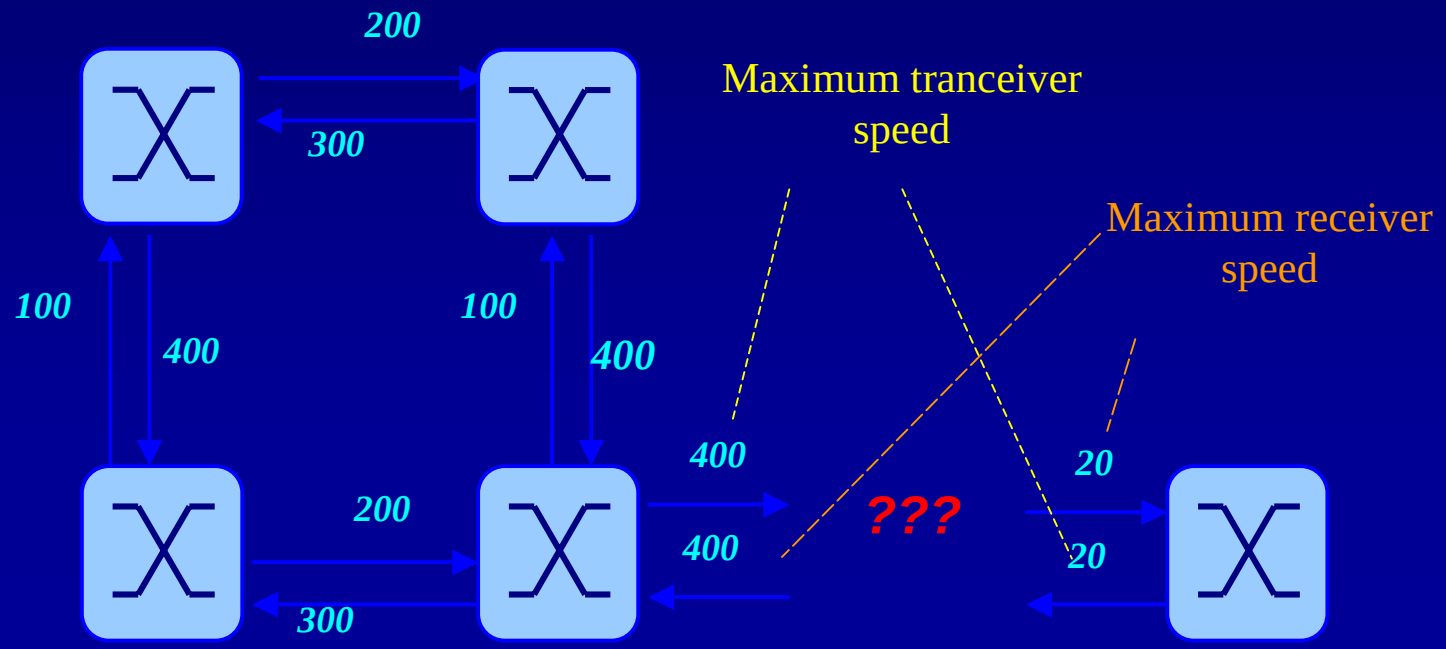
- to scale down the bit rate smoothly, when top bit rates are a problem
- to have heterogeneous bit rates in a SpaceWire interconnection
- to attach dynamically new devices to the interconnection

SpaceWire links and bit rates

Bit rates matching in a SpaceWire link

The problem:

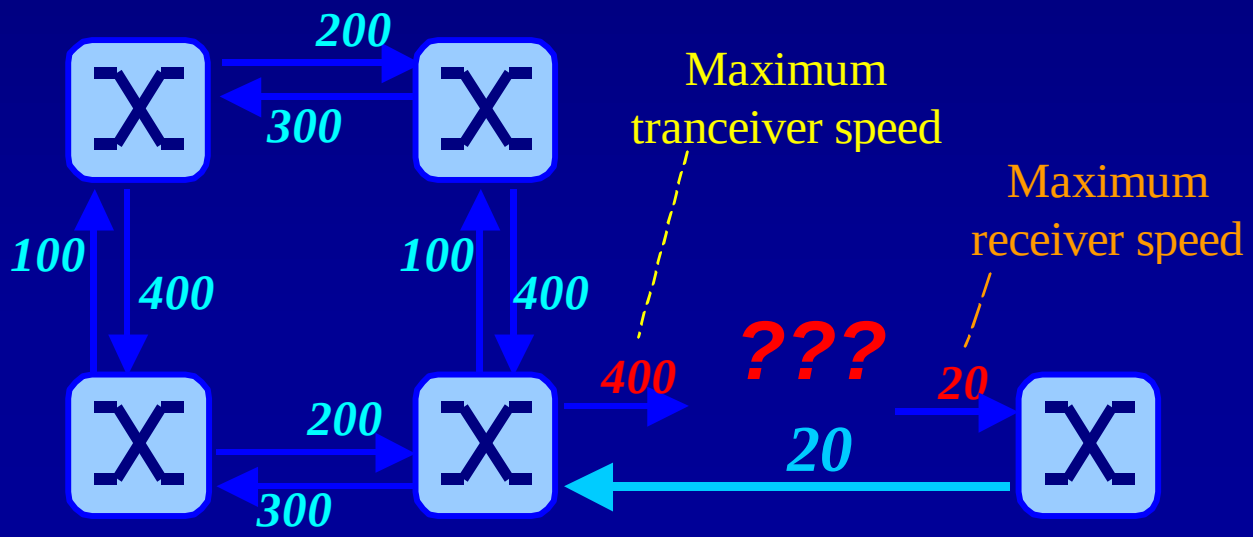
A bit rate adaptation procedure between adjacent devices is not defined by the SpaceWire standard.



SpaceWire links and bit rates

Duplex link bit rates matching procedure is left out of the protocol

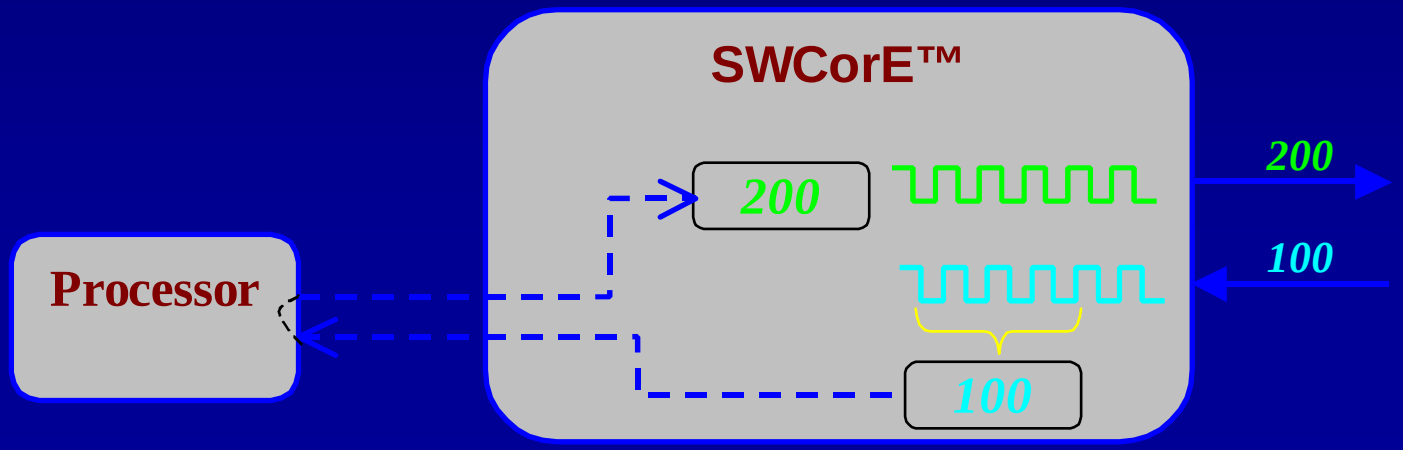
- SpaceWire standard admits different rates of input and output bit streams in the same device.
- A low rate transmitter will force a high-rate partner to receive data on its low rates.
- A high-rate transmitter can work, at the same time, on its upper speed, which the low rate partner can't process at all.



Software bit rate matching

Bit rate matching at the system software level.

- A hardware support in a SpaceWire link block
- Facilities to count and read the incoming frequency in the SWCorE™ IP-core.



SpaceWire links and bit rates

Next SpaceWire standard release should include a duplex link rate matching procedure

- A bit-rate matching procedure should be standardised, to ensure interconnection of independently designed systems
- Should a bit rate matching procedure be a software or a hardware implemented ? -- May be a practical design question
- Hardware implementation in a SpaceWire IP-core can make the bit rate matching a regular procedure in the course of SpaceWire interconnection operation.

2. Higher bit rates for limited distances

Next generation SpaceWire links with Gbit/s rates are in claimed plans

What else can we do within DS-coding technology of the first generation SpaceWire standard ?

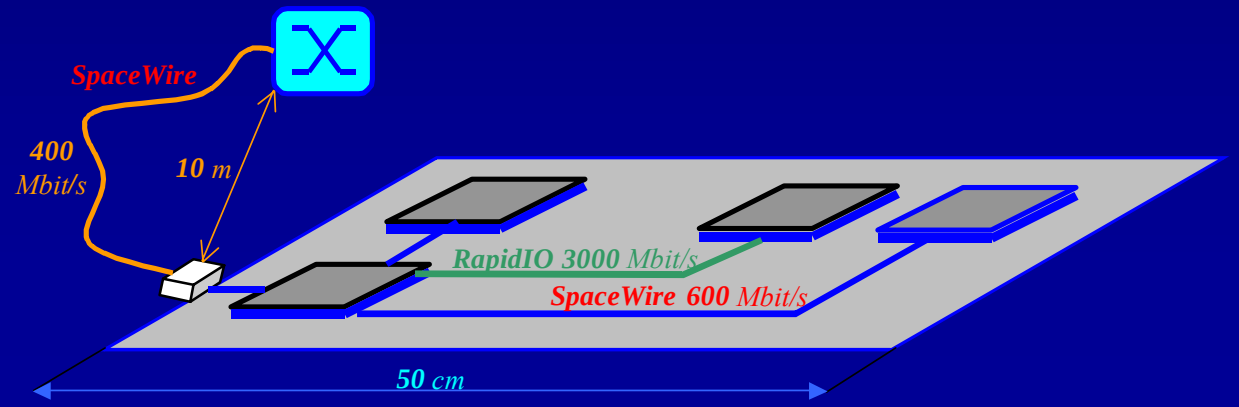
Natural constraints in SpaceWire cable length, e.g. for

- Small- and micro-satellites (<< 10 m)
- SpaceWire chips within multichip boards, in boxes with backplanes

Can we use these facts to push the SpaceWire link bit rates up?

Higher SpaceWire bit rates for shorter links

- Define a set of SpaceWire link length limits with correspondent pick bit rates
- (Serial RapidIO is an expamle – up to 50 cm, up to 2 connectors and PCB conductors between them, etc.).
- Investigate, what rates could be achieved under such conditions (600 Mbaud?)

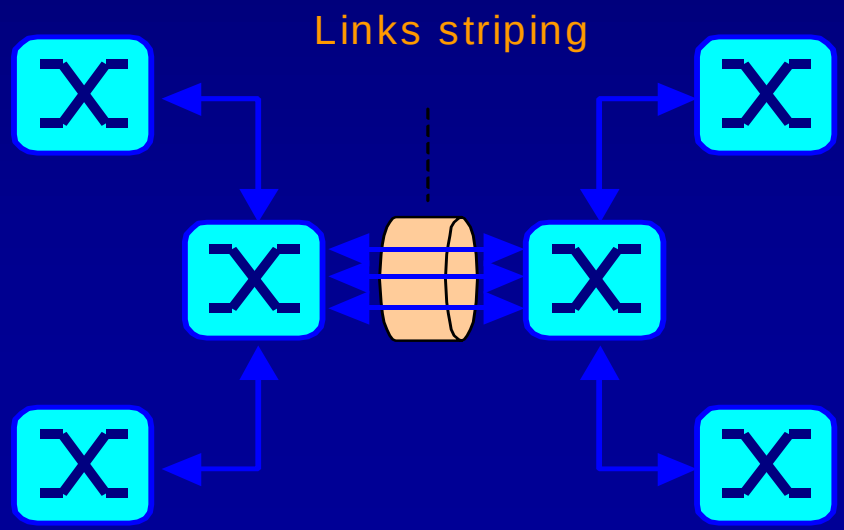


Higher SpaceWire bit rates for shorter links

A length/bit-rates curve in the next SpaceWire standard revision

Links striping

- Improves ***throughput*** by parallelising information stream over several links
- Reduces ***latency*** of a packet delivery
  (against using parallel links to transmit sequence of packets, which improves link throughput, but not reduces packet delivery latency)



SpaceWire links and bit rates

Links striping

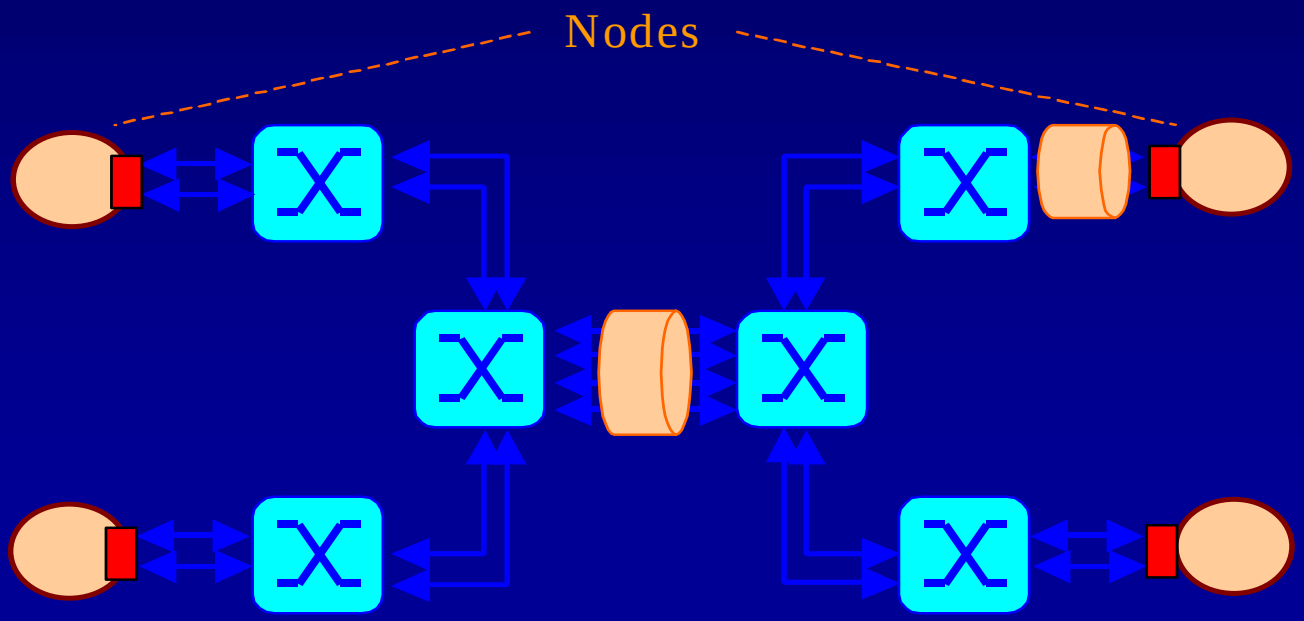
Group adaptive routing parallelize information flow over several SpaceWire links

Limitations:

- - Group adaptive routing is defined only for switches, not for nodes
- - Does not parallelize a packet transmission, does not reduce the packet latency

Links striping

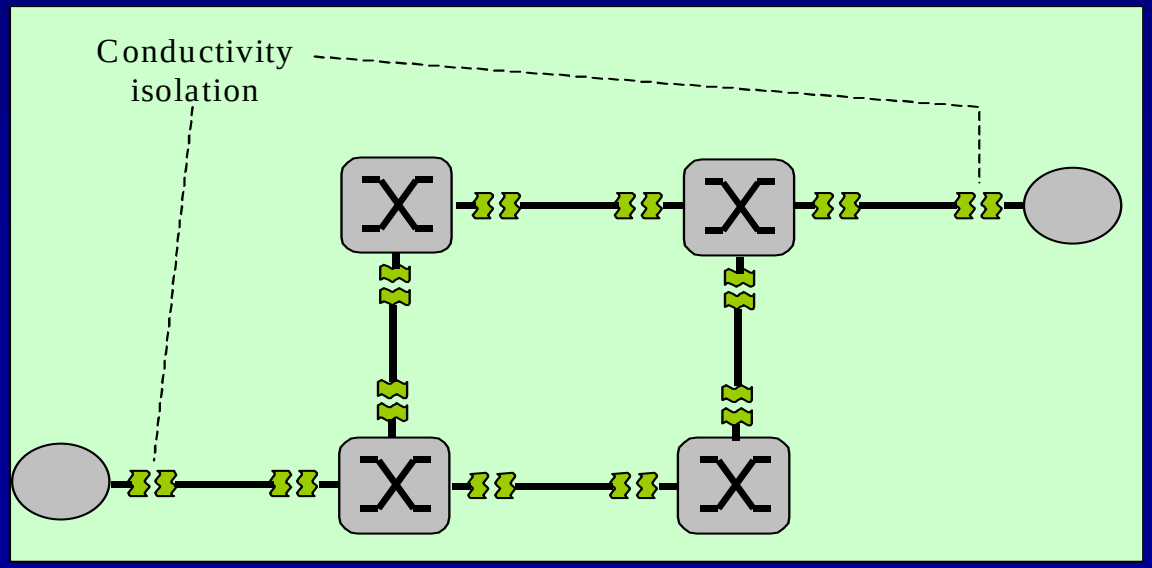
- An example - the FibreChannel standard (FC-3 layer) defines striping as a common service
- SpaceWire Links striping could be defined as a SpaceWire standardized feature



Conductivity isolation problem

- In many spacecraft and avionics applications the conductivity isolation is one of the primary requirements
- Absence of a conductivity isolation in SpaceWire – a serious obstacle for its wider acceptance by aerospace and hazard environment markets.

Reasonable to develop a SpaceWire standard extension with conductively isolated links, a variant of the Signal level.



Packets and Frames

1. Byte credit in frames, information transfer in packets
2. Multi-byte words assembling/disassembling
3. Unpacketized data stream

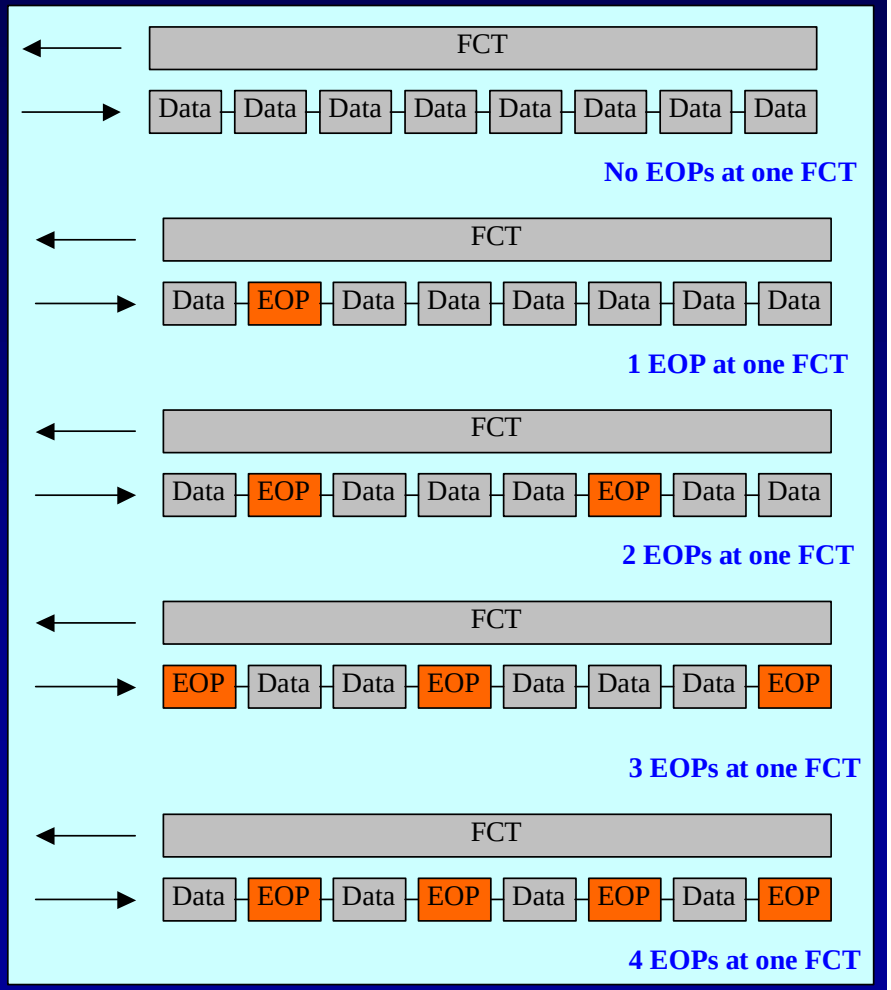
Packets and Frames

Byte credit in frames, information transfer in packets

- Poor correspondence between Exchange & Network levels (inherited from transputer links).
- Flow control at the Exchange level – in 8-byte credit frames. Information transfer is defined in packets.
- Packet size is free in the standard and is not co-ordinated with the credit frame size in any way.

Packets and Frames
Byte credit in frames, information transfer in packets

Multiple situations in buffering information flow inside a SpaceWire link block, in information exchange with the main memory of the node



Packets and Frames
Byte credit in frames, information transfer in packets

It may be reasonable

- To set some rules for a packet size in the SpaceWire standard,
- Correlate the packet size with Exchange level features and implementation issues in modern processing nodes.
- For instance, it may defined, that packet size should be adjusted by 32-bit (4-byte) words boarders.

Packets and Frames

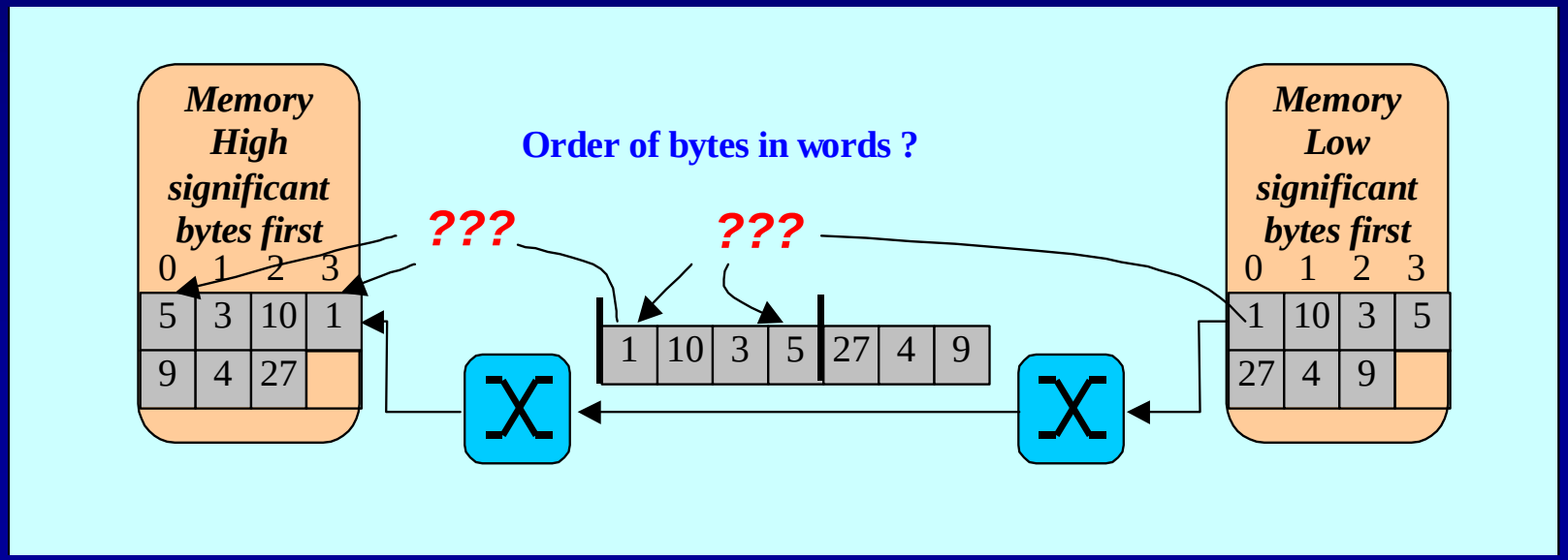
Multi-byte words assembling/disassembling

- SpaceWire standard defines information flow in bytes
- Sources of information to be transmitted, as well as recipients of incoming information flow, are processing nodes.
- Modern processors work with multi-byte words, main memory of a node is usually organised in words (32-bit/4-byte. 64-bit/8-byte)
- Serialising memory words into a sequence of bytes for the SpaceWire packets transfer, packaging incoming stream of bytes into main memory words.

Packets and Frames
Multi-byte words assembling/disassembling

SpaceWire link controllers in nodes implement some order of assembling/disassembling word into bytes.

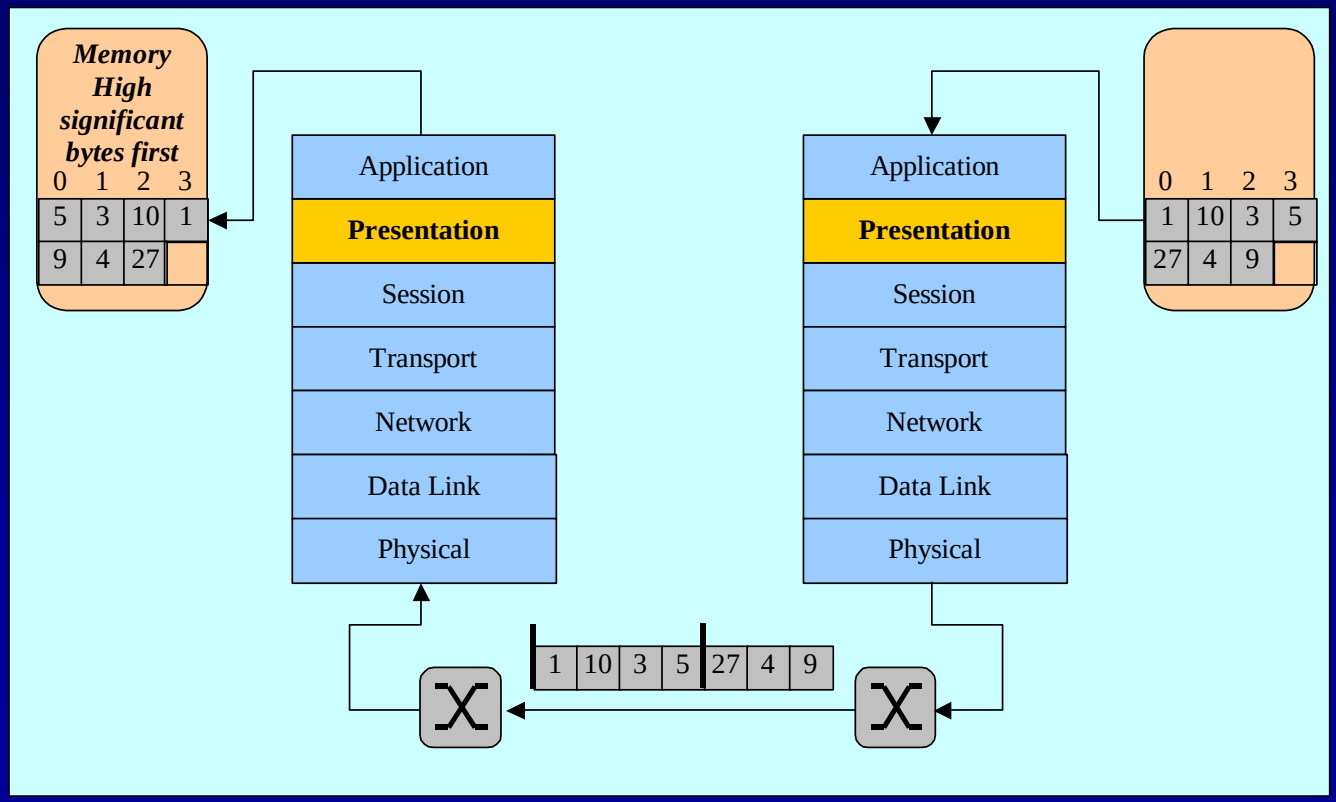
Who would ensure, that they follow the same assembling/disassembling rules ?



Packets and Frames

Multi-byte words assembling/disassembling

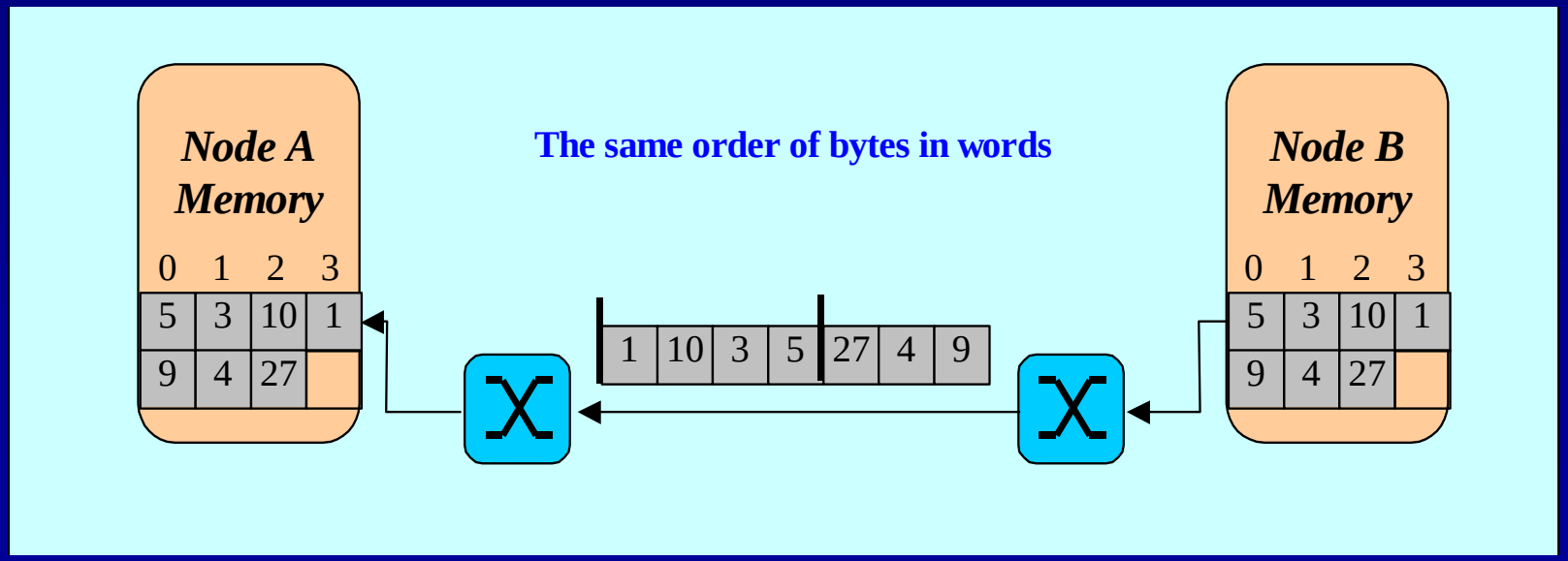
In conventional layered structure of a protocol stack, e.g. in ***OSI***, the problem is positioned at the Presentation layer.



Packets and Frames

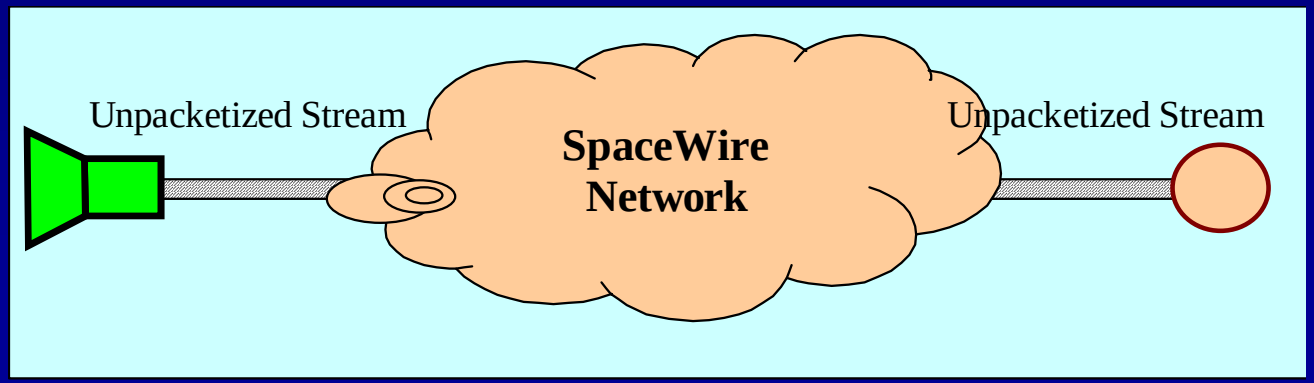
Multi-byte words assembling/disassembling

- Due to high SpaceWire link rates, node memory words assembling/disassembling into a sequence of bytes is hardware implemented
- It should be done in uniform manner by all SpaceWire links implementations.
- For compatibility, it is necessary to standardize multi-byte words assembling/disassembling into a flow of bytes in a SpaceWire link.



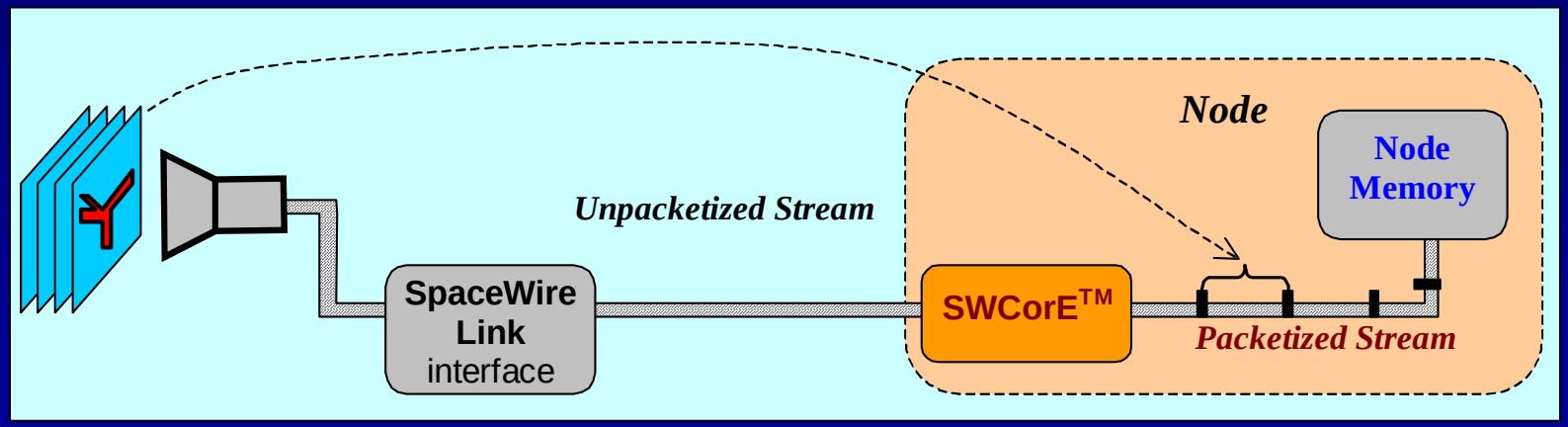
Unpacketized data stream

- The SpaceWire standard does not set any limitations on packet size.
- SpaceWire receiver can run into receiving unlimited number of Nchar without an End-of-packet character, has to process this situation
- This feature can be used for unpacketized data stream processing (e.g. raw radar digital signal stream)



Packets and Frames
Unpacketized data stream processing

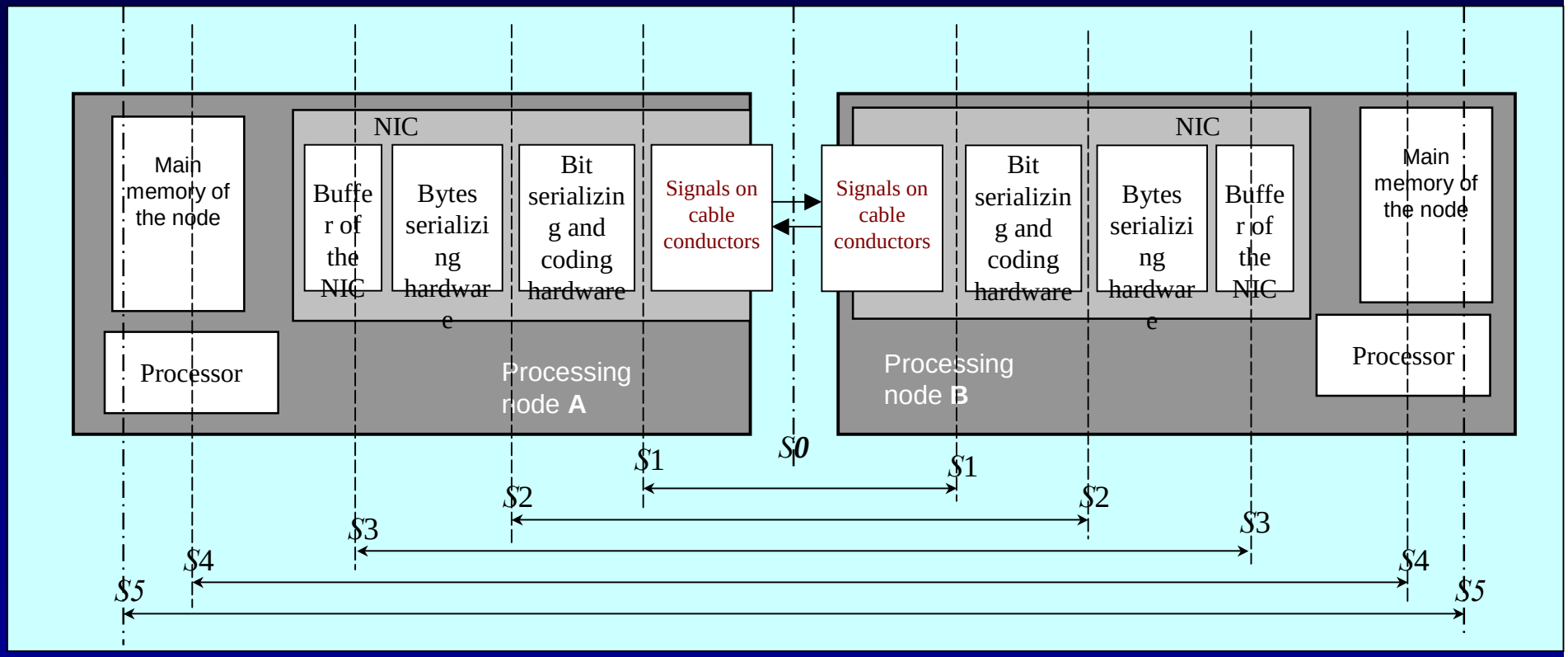
- Framing and packaging of unpacketized input flow of Nchar into packets in the SWCorE™



Distributed parallel processing support

1. Sections of the SpaceWire channel and its effective throughput
2. Routing in SpaceWire interconnection

Sections of the SpaceWire channel and its effective throughput



- Section S0 – Signals on physical cable lines. (2 - 400 Mbaud)
- Section S1 – DS-coded Bit stream
- Section S2 – Net stream of packet bytes
- Section S3 – A packet in the NIC's buffer
- Section S4 – A packet (framed part of a message) in the main memory of the node
- Section S5 – A message from the application, running in the node A, to the application in node B.

Effective throughput of a SpaceWire channel

- NIC (Network Interface Controller) characteristics and system software architecture may influence effective throughput for message passing between applications more than the bit rates of the physical link.
- SWCorE™ implements NIC for the SpaceWire link
- Full rate hardware implementation for parsing Sections S0 – S1 – S2 – S3.
- the SWCorE Extended support by For S3 to S4 4-channel DMA, hardware formed and processed packet descriptors.
- Chained DMA operation support for transition S4 to S5 – disassembling and framing a message into a sequence of packets and assembling message from sequence of packets on receipt.

Further improvement of effective throughput at the Sections S5-S5

- General issues of node communications architecture and system software organisation.
- A source of message passing request is an application process.
- Efficient implementation of message transfer requires more intellectual NIC and new system software architecture.
- The Virtual Interface Architecture (VIA) is an example

VIA NIC for SpaceWire Interconnections

The NIC VIA is responsible for transfer a message from/to memory space of an application:

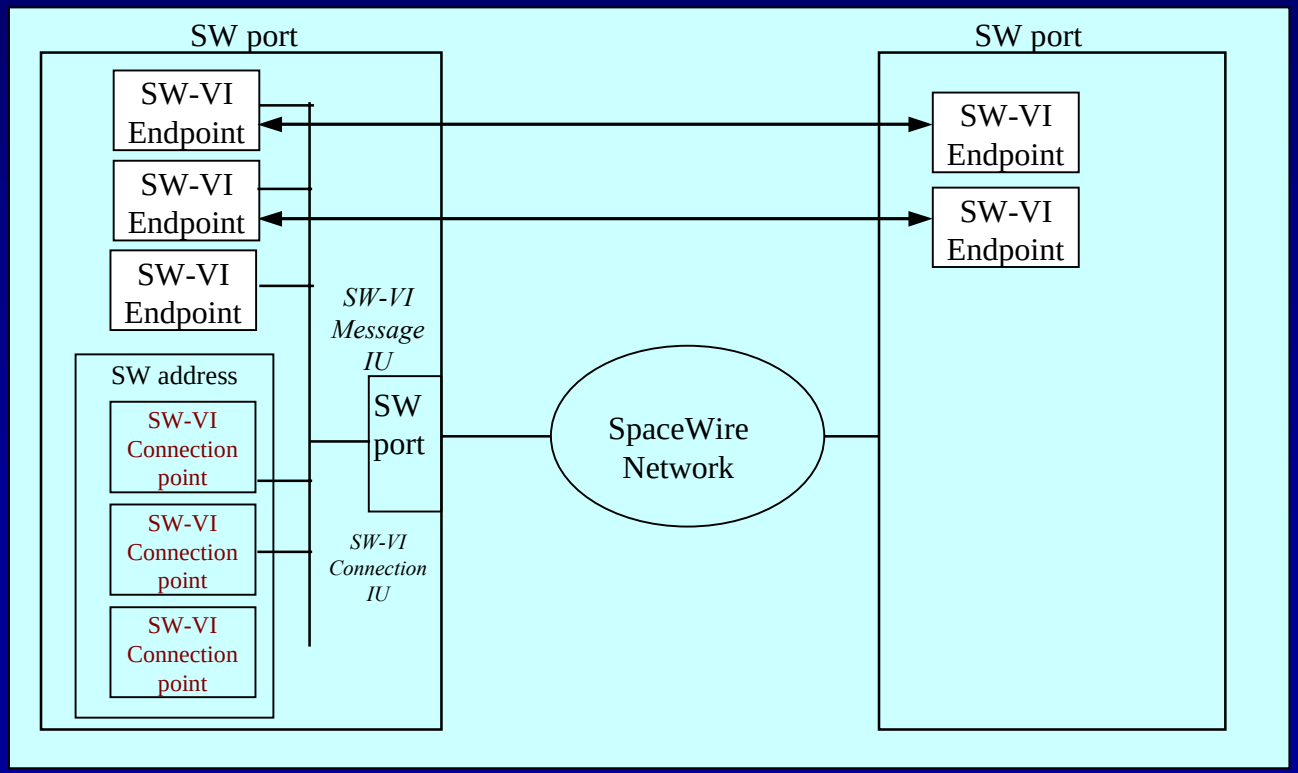
NIC implements Section S5-S4 path without node processor intervention : takes a message from main memory, slices it into fragments, frames them into packets, sends over high-rate interface, and informs application of message transfer completion.

VIA NIC will rise effective Section S5-S5 throughput, decrease message delivery latency and node processor overheads,

SW-VI specification development

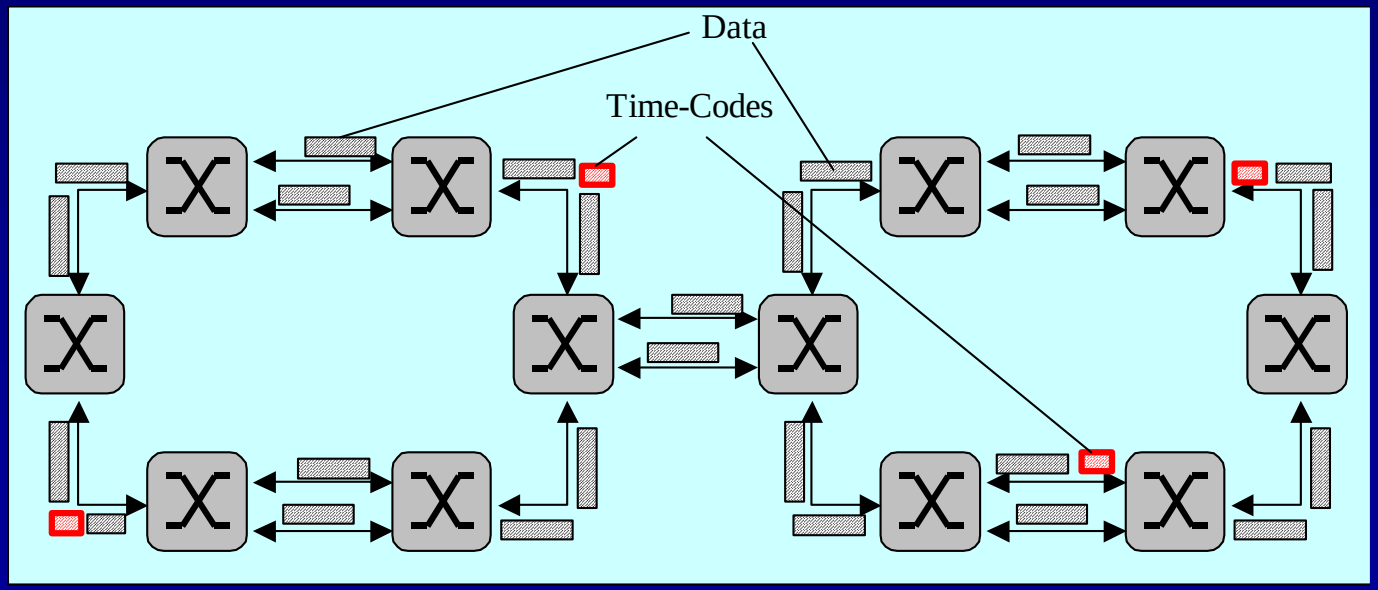
The VIA specification complements high-speed interconnection standards.

- SpaceWire defines interfaces and protocols for node NICs interconnection
- VIA specifies interaction of a NIC with the core part of the processing node: processor, memory and software.



Routing in SpaceWire interconnections

- Routing facilities are important features for distributed processing support
- Time-code distribution is embedded deep in the SpaceWire levels stack – an advantage for Real-Time distributed processing!



More system functions for distributed real-time computations

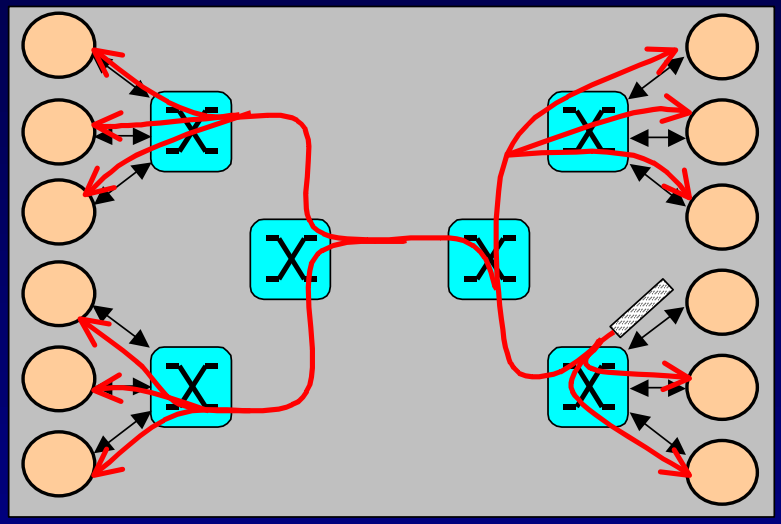
- Extend system functions list for efficient support of distributed real-time computations.
- Introduction of some more system codes at the Symbol level.
- Examples:
  - distributed interrupts;
  - heart-beat markers for fault-tolerant configurations.
- Extended system codes distribution support in SpaceWire routing mechanisms.

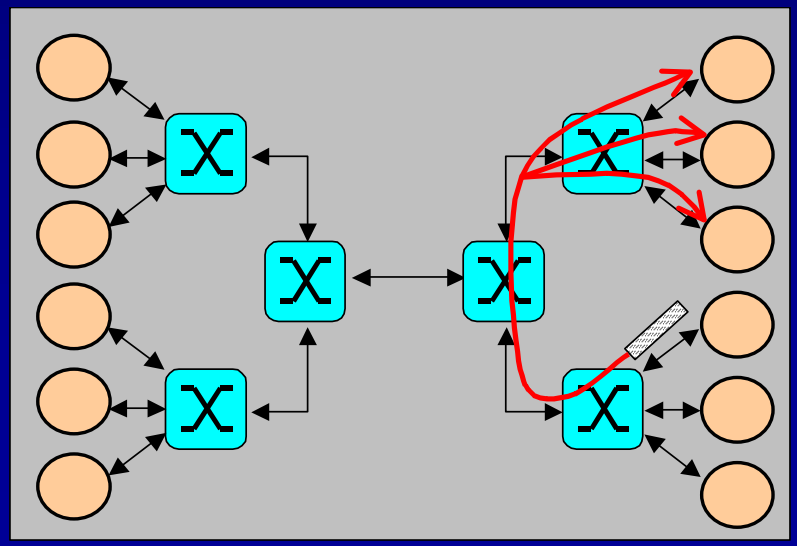
Cycling problem for broadcast system codes

- Solved for time-codes
- Open problem for other system codes
- Can be solved in broader context of broadcasting/multicasting in SpaceWire routing

Broadcast/multicast modes in SpaceWire interconnections

- Important for distributed processing system functions and applications





•Limited broadcast/multicast modes of packets transfer (from a switch to its adjacent processing nodes) in current SpaceWire standard

Broadcast/multicast modes in SpaceWire interconnections

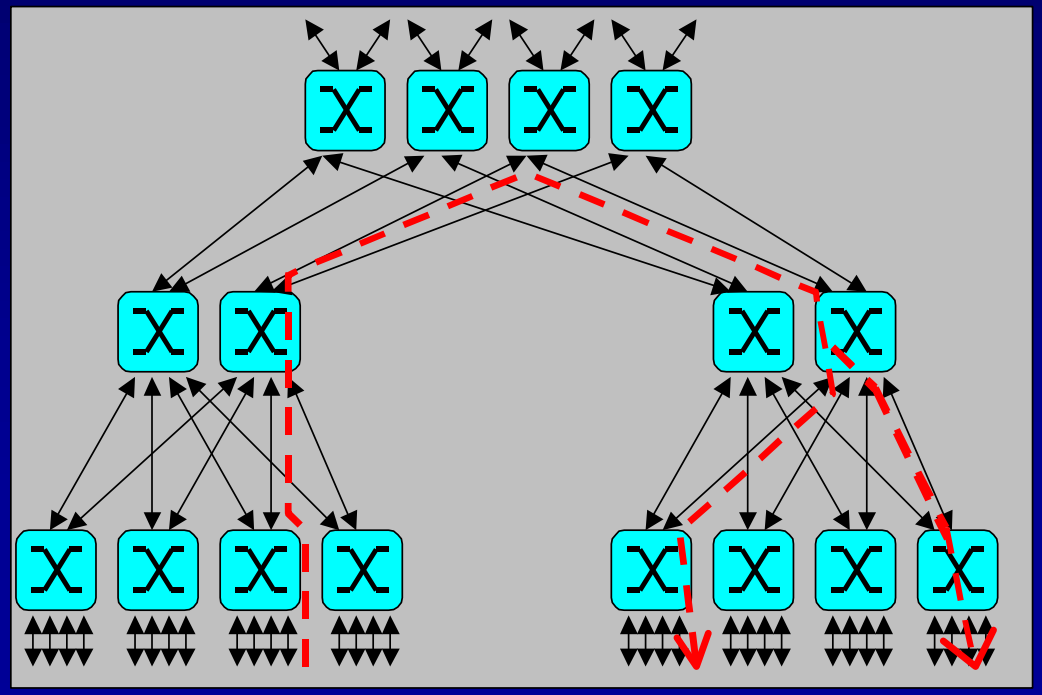
A tendency to exclude broadcast/multicast

Broadcast/multicast modes should be in the SpaceWire

- Broadcasting implementation by individual packets delivery is inefficient and time consuming
- Broadcast/multicast implementation problems follow from unlimited SpaceWire interconnection structures
- Introduce reasonable constraints on SpaceWire interconnections topologies
- Hold redundant links for fault-tolerance by hierarchical interconnection schemes

Example: RACE interconnections

- Routers with 2 links “Up” and 4 links “Down”
- Broadcast/multicast packets distribution:
  a packet going from upper level can be broadcasted ***only*** to “Down” links



SpaceWire outside Space applications

- Feasibility of any modern technology is governed by its quantity production and application
- Necessary to move SpaceWire technology to wider market
- Avionics is a natural candidate
- Industrial and telecommunication applications
- Not so fine, but more feasible cabling, connectors, etc. should be defined in the SpaceWire standard also

Conclusion

1. **SpaceWire is a prospective high-rate interconnection technology**
2. **Some revisions for the next SpaceWire standard release:**
   - Links striping
   - Packet size rules
   - Feasible cabling, connectors, etc. for SpaceWire usability outside Space systems
   - Standardization of multi-byte words assembling/disassembling into a flow of bytes
   - Extended system functions list for distributed real-time computations support

Conclusion

3. Further developments in SpaceWire technologies:

- Higher bit rates for limited distances
- Gigabit range SpaceWire links
- A variant of the Signal level with conductively isolated links
- Duplex link rate matching procedure
- SW-VI specification development
- Broadcast/multicast modes
- Transport layer
- SpaceWire standard conformance test bench