GigaSpaceWire – Gigabit links for SpaceWire Networks

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SpaceWire problems

Demand for:

- Higher data rates, from some hundreds of Mbit/s to Gigabits per second data rates range
- Longer distances – from some meters to dozens of meters, a hundred meters
- Galvanic isolation in a link (optional)
- Real-time operation, QoS, deterministic packet delivery time

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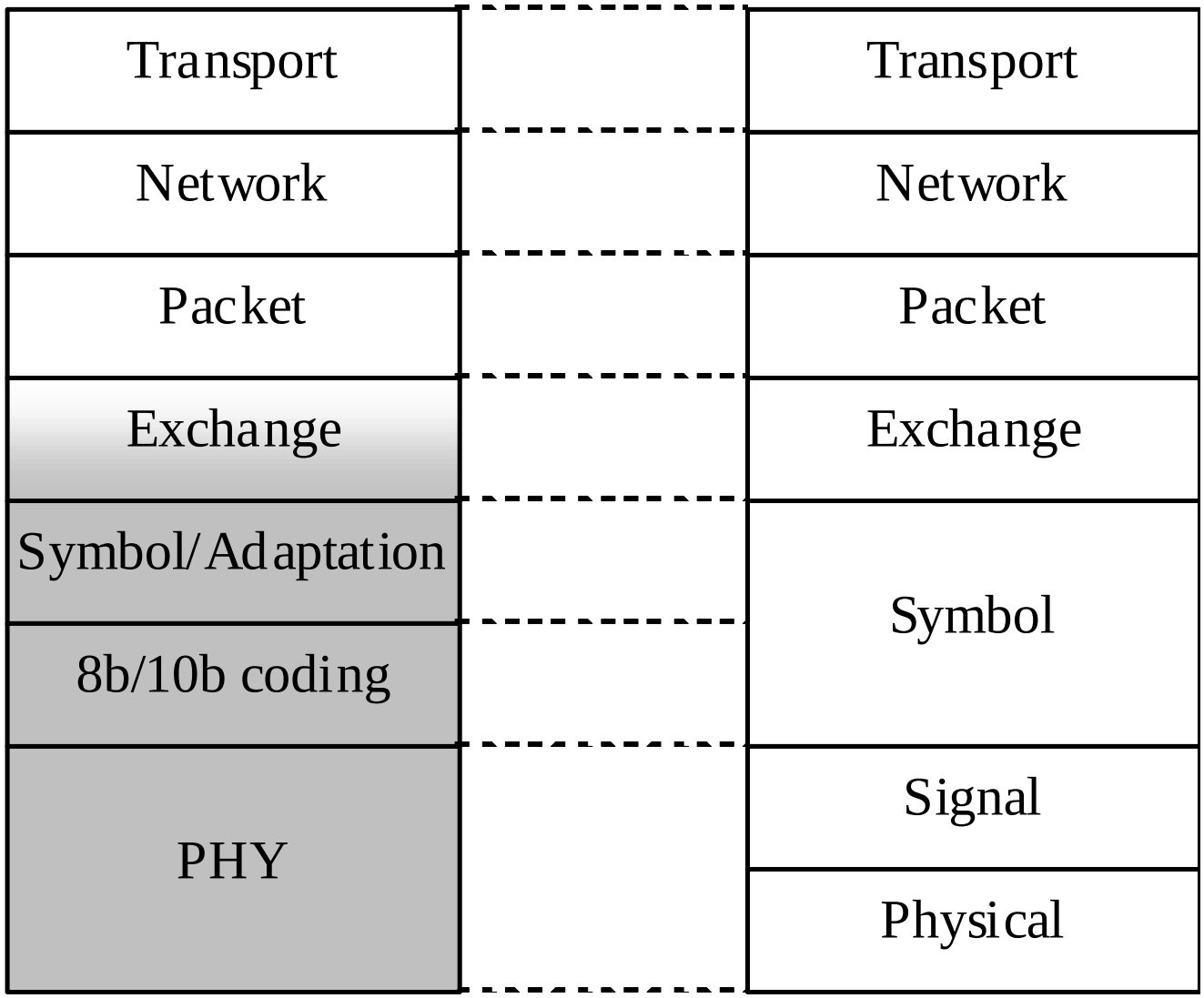
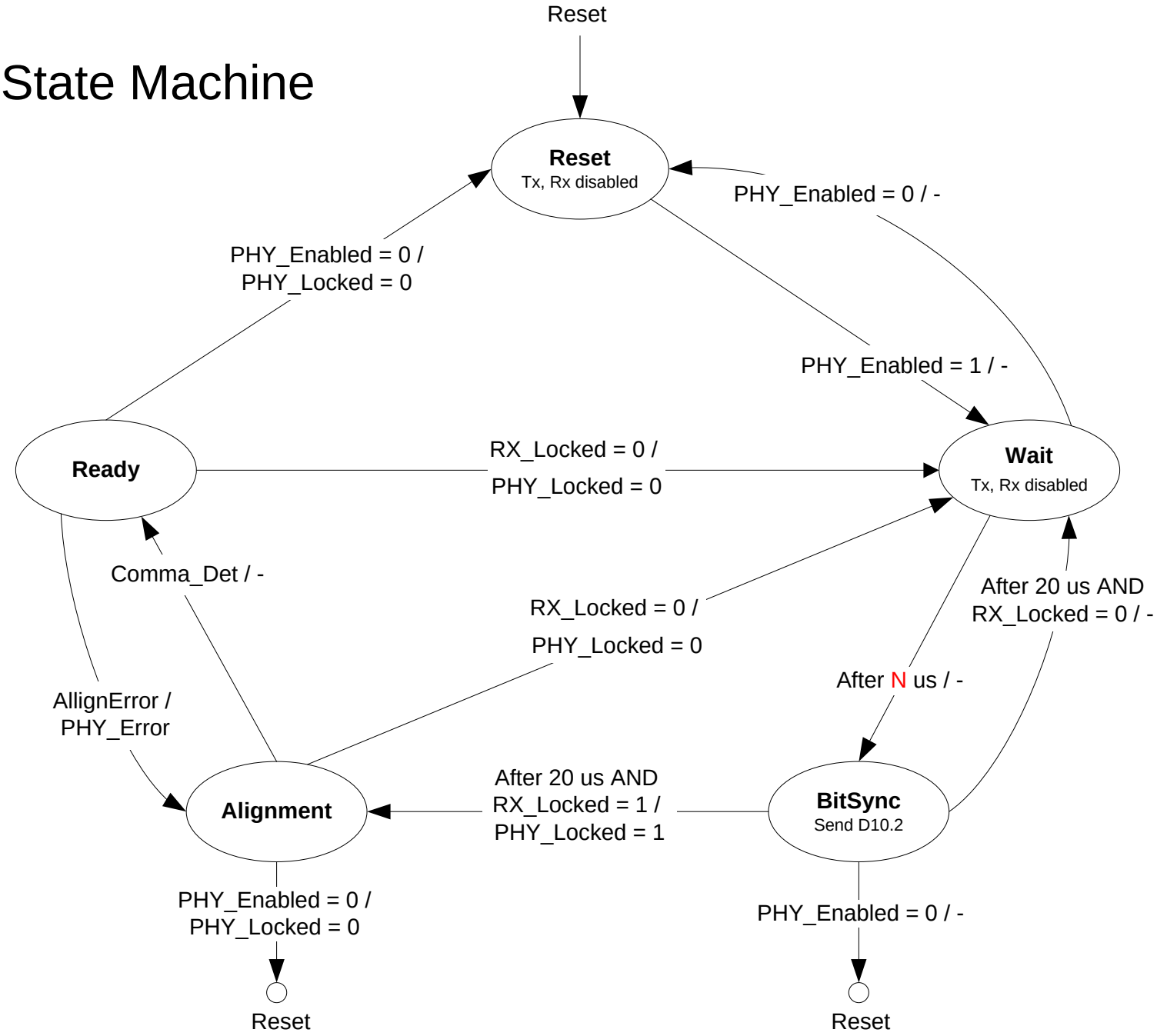
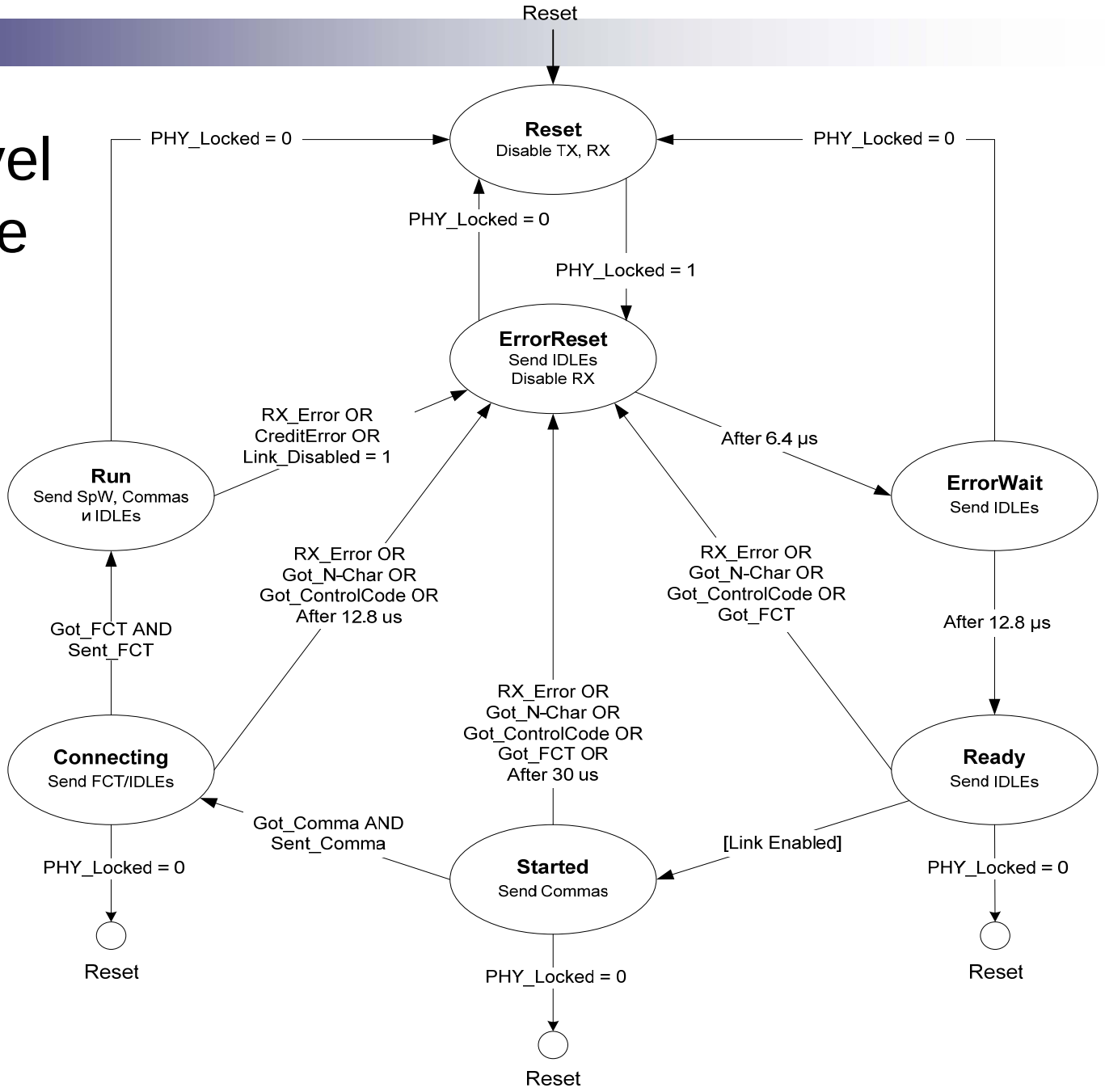
Levels of the Standards



PHY level State Machine

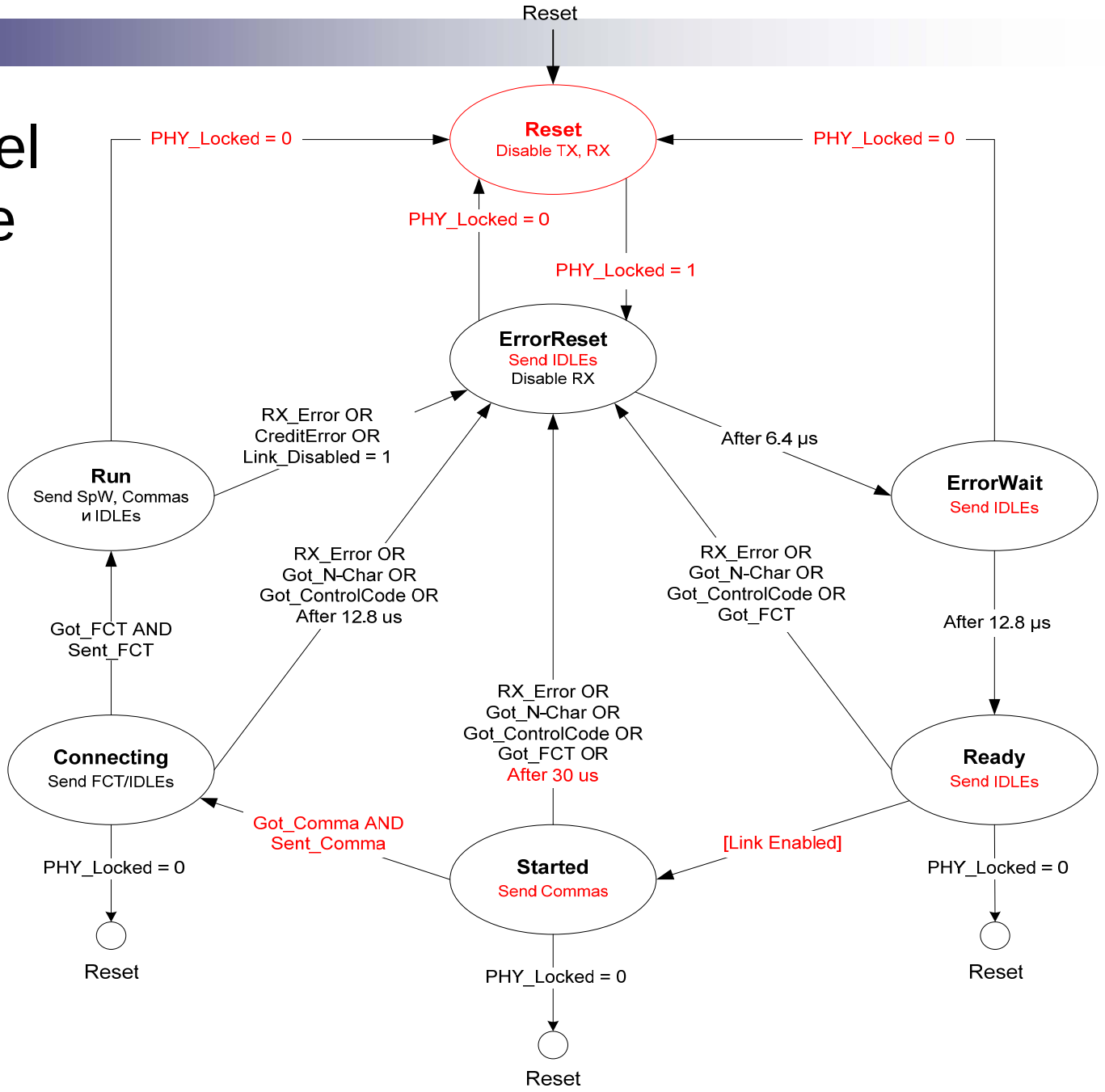


Exchange level State Machine



RX_Error – ошибка рассоединения OR ошибка декодирования
[Link_Enabled] = (NOT Link_Disabled) AND (Link_Start OR (Auto_Start AND Got_Comma))

Exchange level State Machine



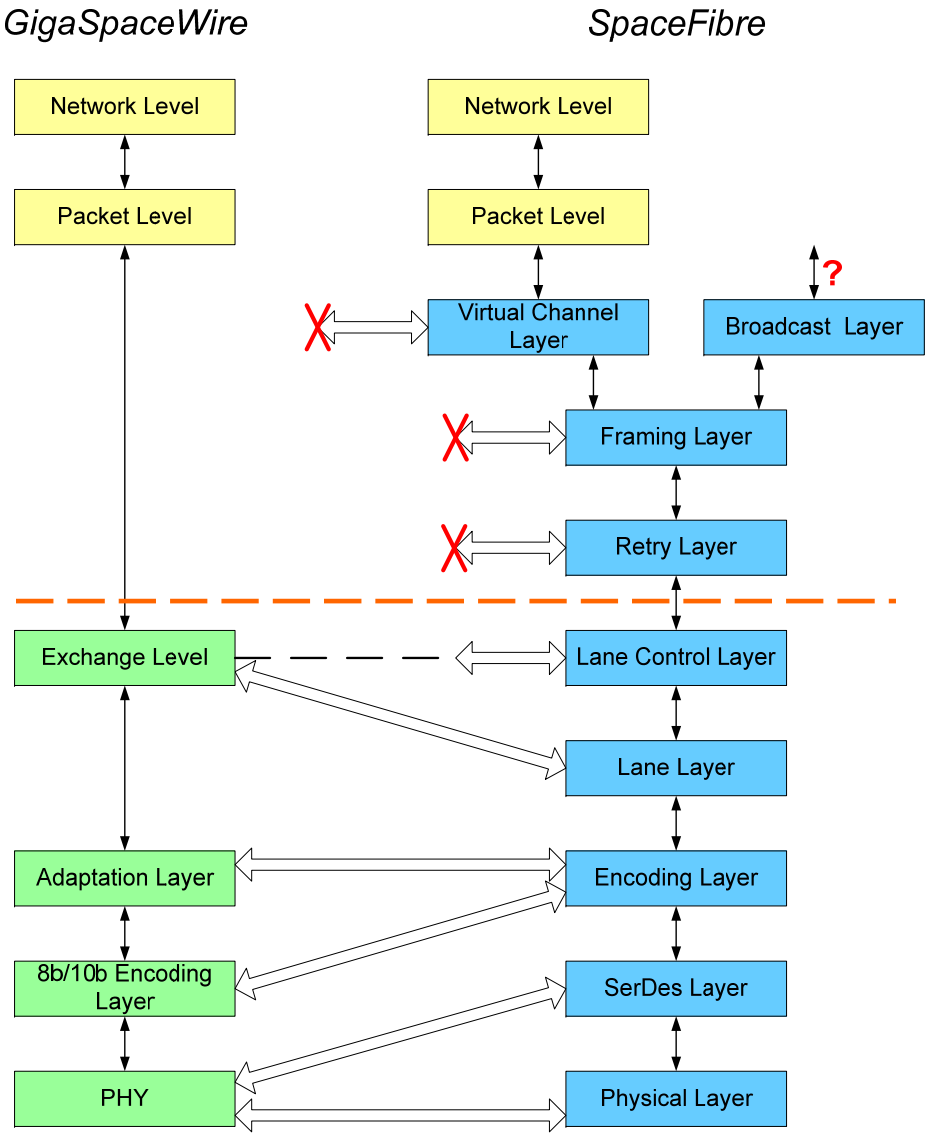
RX_Error = Disconnection error OR Decoder error
[Link_Enabled] = (NOT Link_Disabled) AND (Link_Start OR (Auto_Start AND Got_Comma))

Features

- Every 32 symbols the Comma symbol is sent (for 1 Gbit/s)
- Generated at the Exchange level Disconnection error is based on the Comma symbol
- Disconnection error detection time - 640ns-960ns (for 1 Gbit/s) and is based on the Comma symbol
- Null symbol is not used for starting connection (idle symbol) in the link

GigaSpaceWire and SpaceFibre levels

- GigaSpaceWire and SpaceFibre low layers :
  - Bit synchronization
  - Symbol synchronization
  - Establishment of bidirectional connection over a lane
  - Transmission of a raw data flow over lane using 8b10b encoding
  - Adjustment of data rate difference between transmitter and receiver
  - Error detection and connection recovery after an error
  - Generation of dummy symbols (words) in case of upper layers do not provide data for transmission



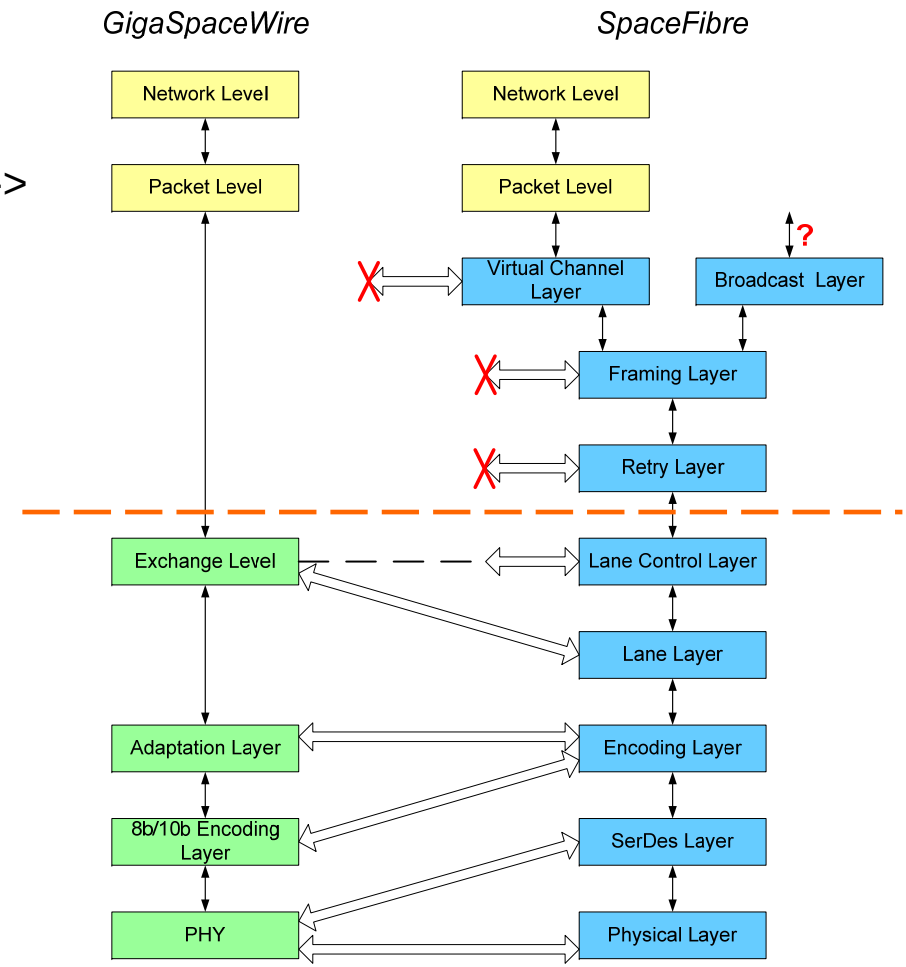
Low layers Interface

- **GigaSpaceWire keeps the SpaceWire Exchange level interface**:
  - N-Chars: Data characters, EOP and EEP
  - Control codes: Time-codes, Interrupt-codes, Interrupt_Acknowledge-codes
  - GigaSpaceWire Exchange level performs codes arbitration of different data flows
  - SpaceWire packet level is transparently implemented over GigaSpaceWire as low layers

- SpaceFibre provides another Lane layer interface:
  - Words: 4 characters, i.e. 32 bits
  - SpaceFibre lane layer does not recognize word type
  - SpaceWire packet level cannot be implemented directly over SpaceFibre low layers

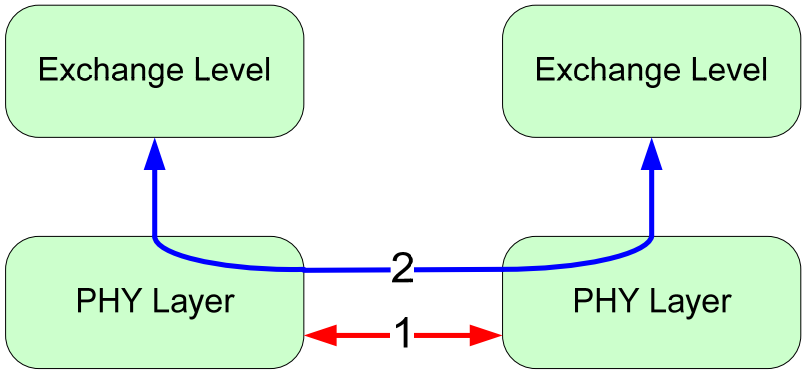
Link state machine

- GigaSpaceWire link state machine:
  - Implemented at the Exchange level
  - Consists of **7** states
  - During handshake always goes through the same sequence of states (ErrorReset->ErrorWait->Ready->Started ->Connected->Run)
  - Easy to implement and debug
- SpaceFibre lane state machine
  - Implemented at the Lane layer
  - Consists of **17** states
  - During handshake may go through different sequences of states. Therefore, one side may finish the handshake while another not yet
  - Seems to be more complicated in implementation and debugging

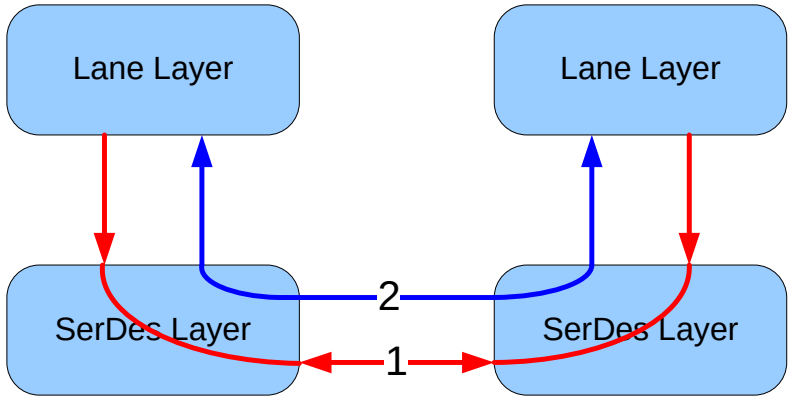


P2P connection establishment

- **GigaSpaceWire** connection:
  - The PHY layer achieve bit synch (step 1)
  - The exchange level establish P2P connection (step 2)
  - Change of PHY does not affect exchange level



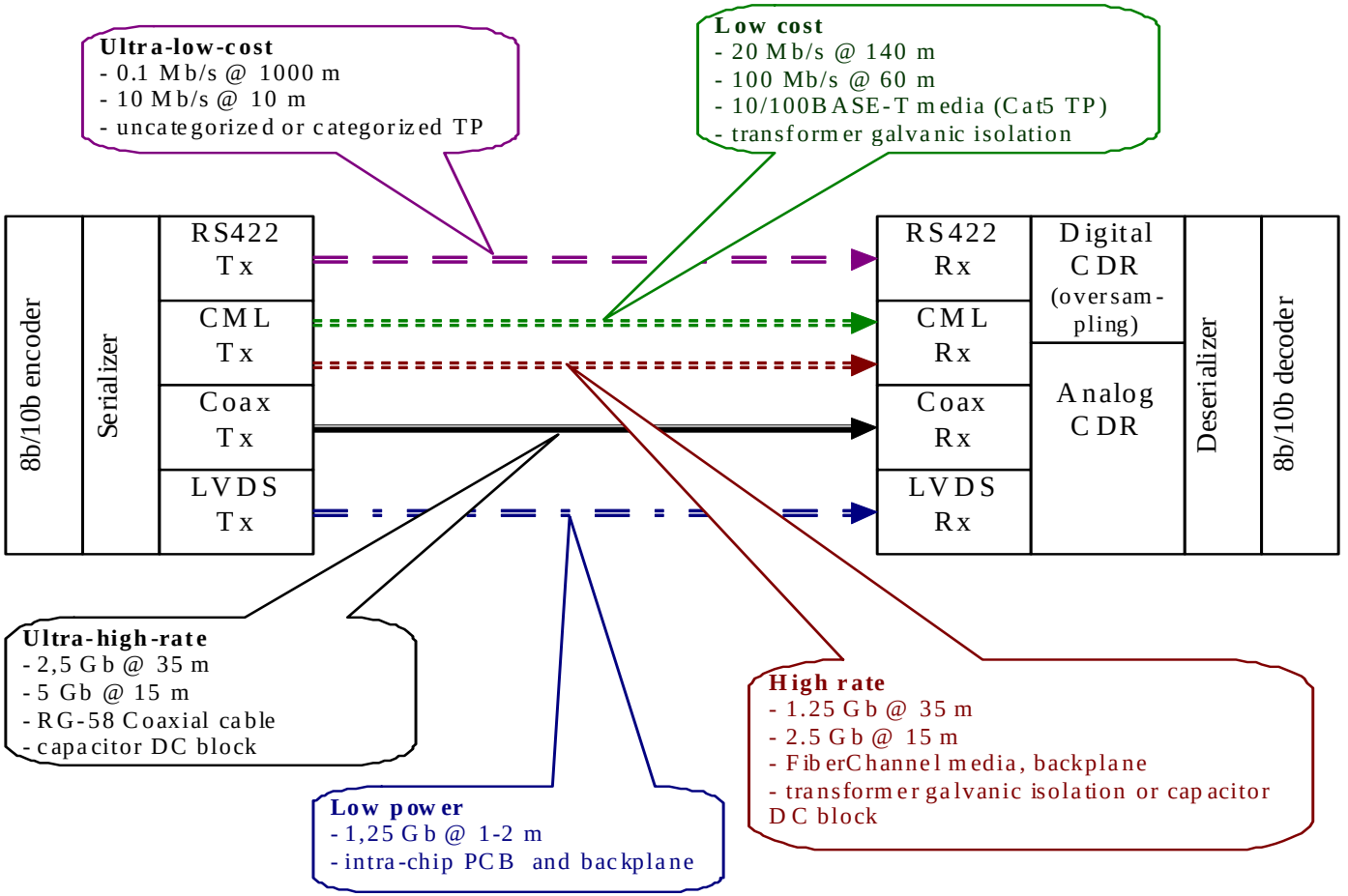
- **SpaceFibre** connection:
  - The lane layer provides the data to establish bit synch at the SerDes layer (step 1)
  - The Lane layer establish P2P connection (step 2)
  - Change of SerDes may affect the Lane layer



Recovery from receiver error

- **GigaSpaceWire** Rx error recovery procedure:
  - Stop user data transmission and reception
  - Move to the ErrorReset state
  - Enter the “exchange of silence” procedure
  - Try to re-establish the connection
  - Does not affect PHY layer
- **SpaceFibre** Rx error recovery procedure:
  - Stop user data transmission and reception
  - Try to recover at the encoding layer in a passive mode
  - Inform the remote end about error, which should send special control words to re-establish the connection at the lane layer
  - Reset **all** low layers (including physical layer)
  - Try to re-establish the connection ***both*** at physical and lane layers

Physical Layer Profiles for GigaSpaceWire



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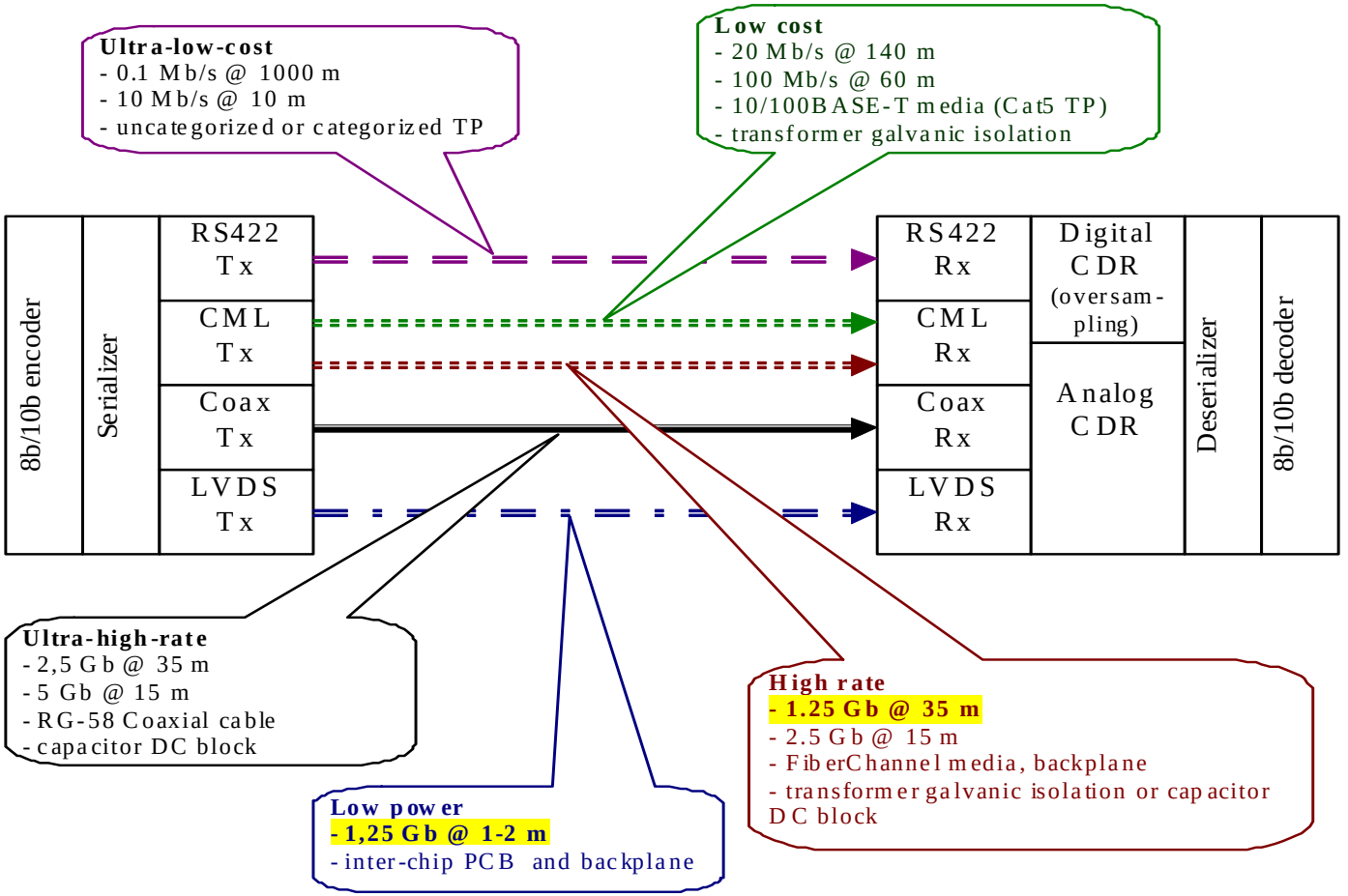
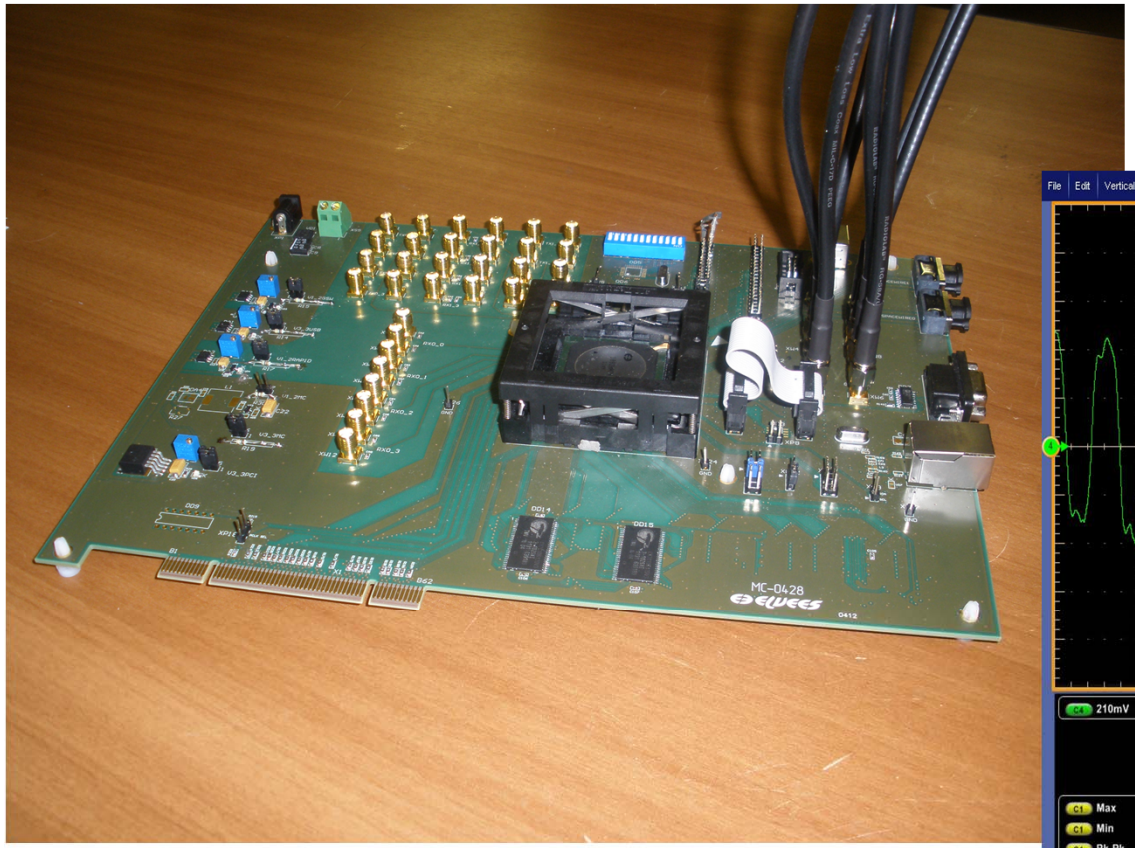
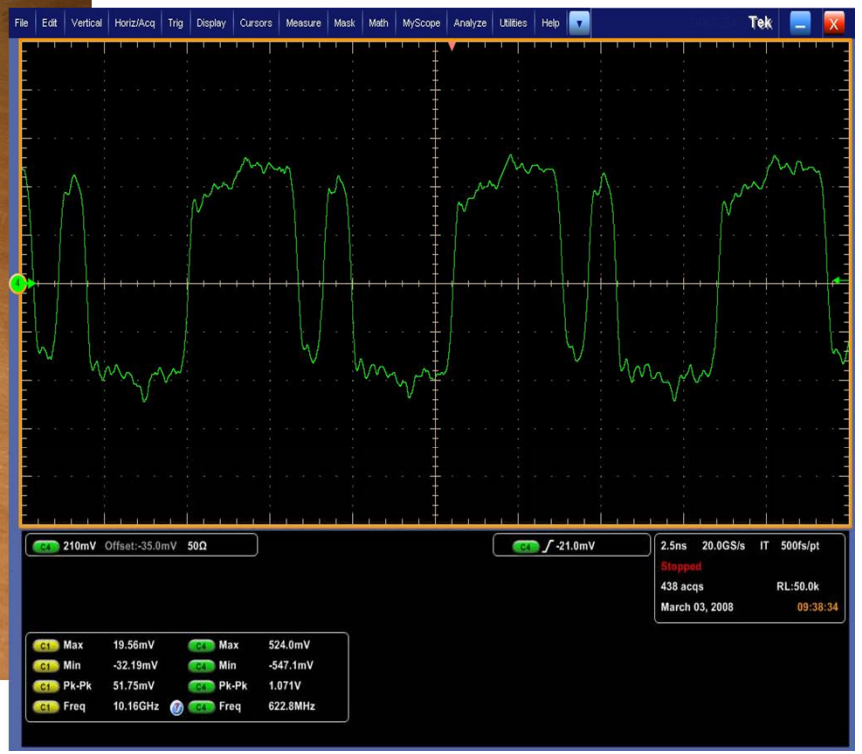


Pilot GigaSpaceWire implementations

- **MC-0428 (*ELVEES*)**
  Heterogeneous multicore processor with SpaceWire and GigaSpaceWire links



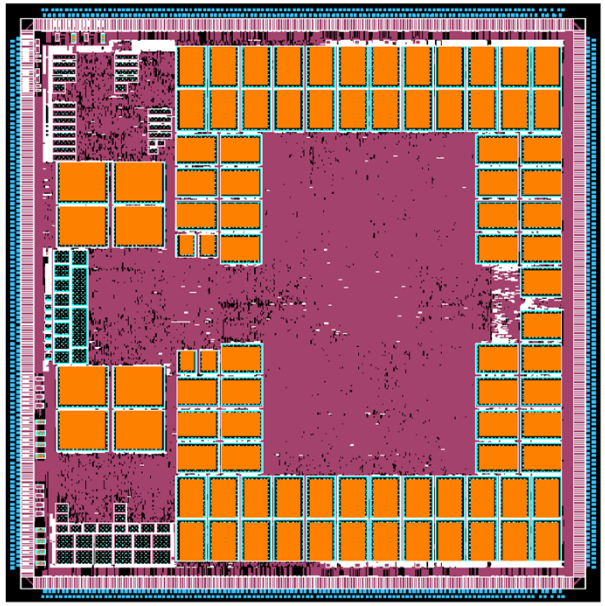


1.25 GHz

MCForce (tm)

MCFlight (tm) Chipset MULTICORE based 5-cores Signal Microprocessor with SpaceWire, GigaSpaceWire (tm) and Serial RapidIO Links

• Architecture – 5-cores heterogeneous SoC includes MIPS32 RISC and four Multicore Floating/fixed-point DSP claster
• CMOS 130 um, 11.7x11.9 mm die
• Clock frequency 300 MHz
• Performance: 9.6 GFLOPs, 38.4 GOPs @int16, 57.6 GOPs @int8
• Two 400 Mbps **SpaceWire** Links
• Two 1,25 Gbps **GigaSpaceWire** Links
• Two 5 Gbps 4-lane Serial RapidIO Links
• DDR, PCI, USB, MFBSP, Ethernet, UART and other peripherials
• Power saving modes
• Maximum Power 3 W.
• MCStudio Software Design Tools: IDE, C/C++ compiler, assembler, linker, simulator, debugger, algorithm libraries);
• Operating Systems: RTOS uOS, LINUX



SWHUB(tm)

MCFlight (tm) Chipset MULTICORE based
Multichannel SpaceWire Concentrator

- CMOS 130 um, 9,8x8,7 mm die
- MIPS32 RISC Core
- Clock frequency 300MHz
- 34 duplex 400 Mbps **SpaceWire** Links
- Two 1.25 Gbps **GigaSpaceWire** Links
- Two 5 Gbps 4-lane Serial RapidIO Links
- Parallel port
- Power saving modes
- Maximum Power 4 W.
- MCStudio Software Design Tools:

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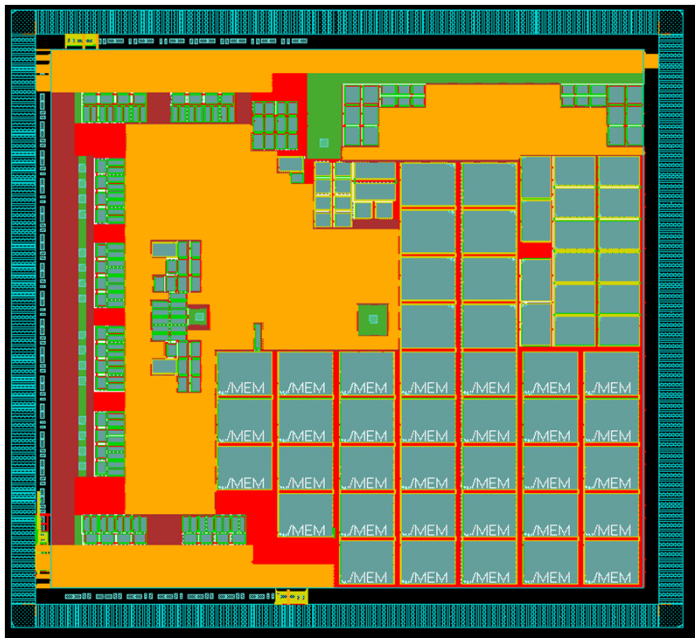
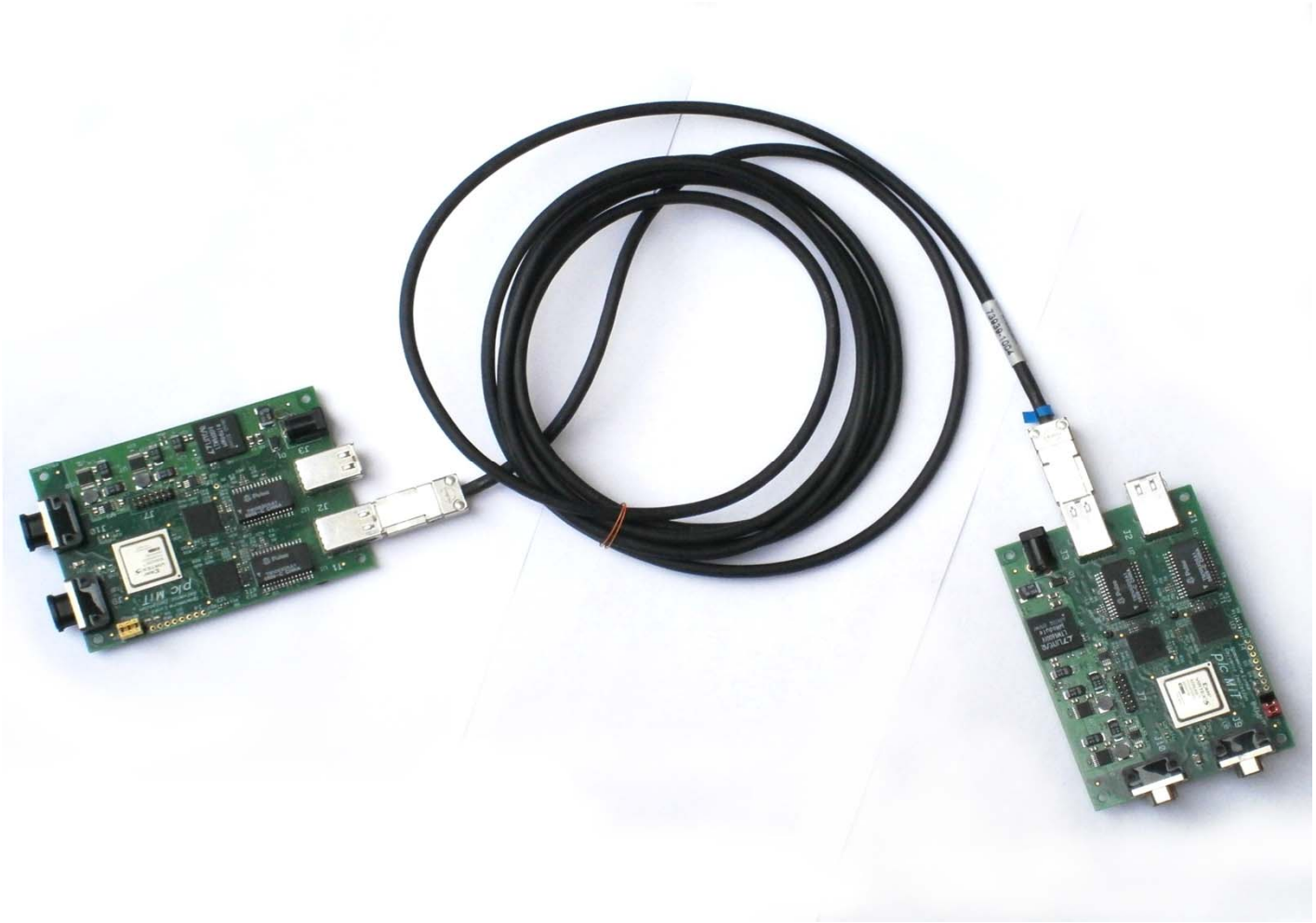
- Operating Systems: RTOS uOS, LINUX



Galvanic isolation set for a SpaceWire link

- **SpW-GiG (*SUAI*)**



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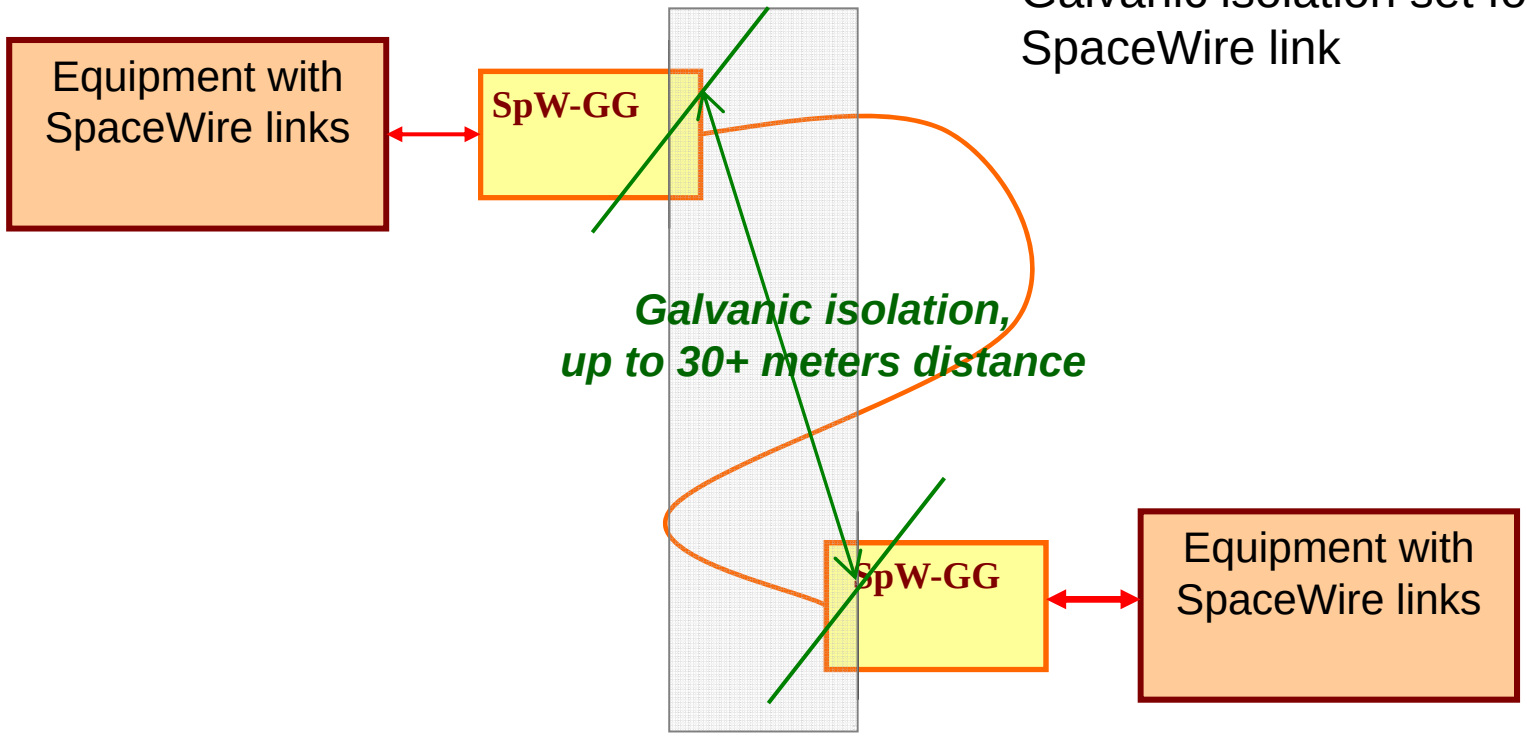


GigaSpaceWire, further developments and prototyping

- Multi-lane links
- Fibre optic
- Other physical level (signals and cabling)

Conclusion

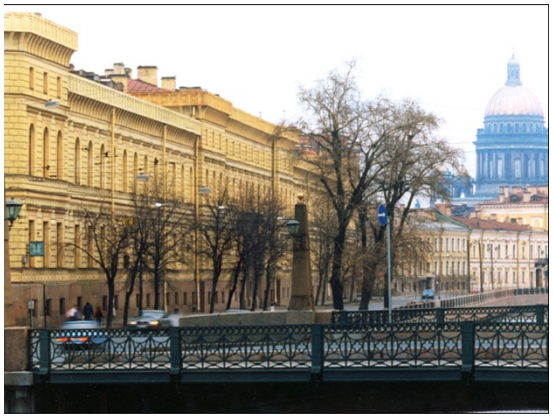
GigaSpaceWire – the today's technology,
pragmatic cost-efficient solution:

- Gigabits per second data rate range
- Longer distances – dozens of meters, hundred meters
- Galvanic isolation in a link (optional)

Also:

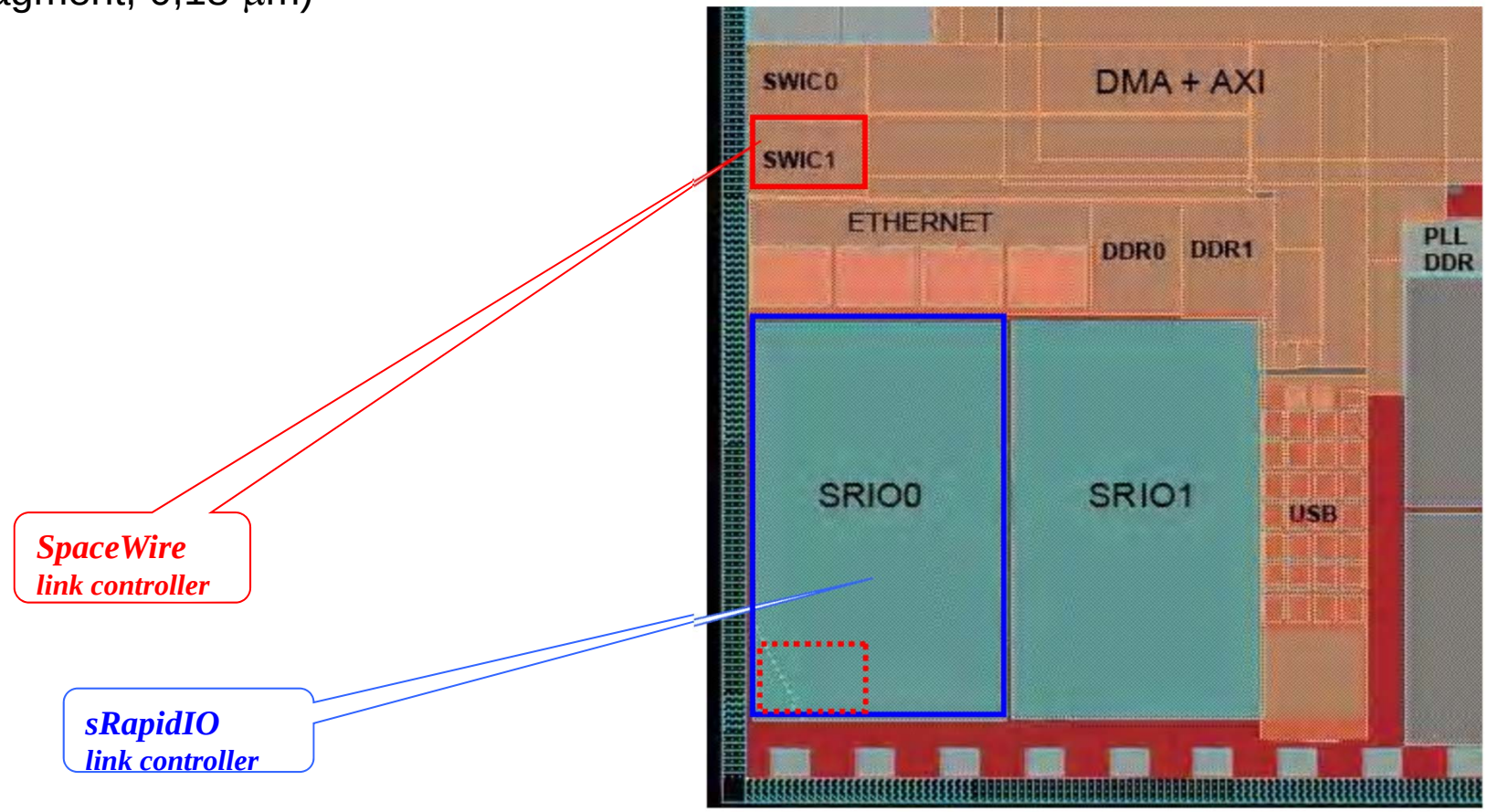
- Simple, straightforward integration in SpaceWire networks
- Simple, compact implementation in chips
- Light weight, 4/2 wire cables (TP/Coax) – lower cabling weight
- Can use a range of proved components for serial links:
  cables, connectors, galvanic isolation components, fibre optics, etc.

Thank you!



SpaceWire and *Serial RapidIO*

at an ASIC floorplan
(fragment, 0,18 μm)



Indication to the remote end about Rx error

- **GigaSpaceWire** uses the “exchange of silence” procedure:
  - An end of the link where an Rx error occurred *does not* send Comma characters for a period more than the disconnection time-out
  - To maintain bit synch at the PHY layer, IDLE characters shall be sent
  - When the disconnection time-out expires, another end of the link detects a disconnection error
- **SpaceFibre** informs the remote end by dedicated lane layer control words
  - To recover from an Rx error without reset, 9 RXERR control words shall be sent
  - To reset all low layers, 32 STANDBY control words shall be sent

PHY error recovery in GigaSpaceWire

- Upon an error detection, the PHY layer stops data transmission and reception and informs upper layers that PHY is unlocked. Upper layers stop data transmission and reception
- The PHY layer enters the “exchange of silence” procedure by disabling the transmitter
- Upon the detection of the disconnection error, the PHY at the remote end informs upper layers and enters the “exchange of silence” too
- After the silence PHY layers at both ends enable the transmitters and start to send special bit sequences, which are required by the receivers to achieve bit synchronization
- When bit synchronization is achieved, this is indicated to the upper layers. These in turn starts receiver error recovery procedure
- PHY layer is fully responsible for bit synchronization. Thus, the upper layers may operate over different PHY layers which require different bit sequences for bit synchronization (e.g. D10.2, commas, etc)

PHY error recovery in SpaceFibre

- Upon an error detection, the serialization layer indicates this to the upper layers
- Upon the indication the encoding layer stops data reception
- Upon the indication the lane layer stops data transmission and reception and starts lane layer recovery procedure, which is equivalent to the warm reset
- After a clearing lane time-out the lane layer starts sending handshake control words intended for bit synchronization, symbol alignment, word synchronization and connection establishment
- Serialization layer is not fully responsible for bit synchronization. So, if a particular SerDes which requires special bit sequence is used, the lane layer shall address this issue

Data rate adjustment

- **GigaSpaceWire** data rate adjustment features:
  - Comma character (i.e. SKIP) shall be sent **every 32 characters**. This rate allows to tolerate the maximum difference between transmitter and receiver rate of 3 per cent of the nominal value
  - Elastic buffer width is 8 bits
- **SpaceFibre** data rate adjustment features:
  - SKIP control word shall be sent **every 5000 words**. This rate allows to tolerate the maximum difference between transmitter and receiver rate of 0.01 per cent of the nominal value. However, it seems to be difficult to implement such low data rate difference
  - Elastic buffer width is 32 bits
- Increase in the elastic buffer size may have significant repercussions:
  - Elastic buffer introduces a delay into data transmission. The more the buffer maximum size, the more the maximum delay
  - Elastic buffer delay becomes even more significant in case of multilaning because the delay may be different for different lanes that shall be tolerated at the multilaning layer
  - Increase in the elastic buffer width leads to more memory requirements, which is especially critical in routers
  - Increase in the memory space assigned for the elastic buffer leads to additional power consumption