ESA-EOP needs for SpaceFibre

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- Product needs and priorities
  - IP cores, components, standards
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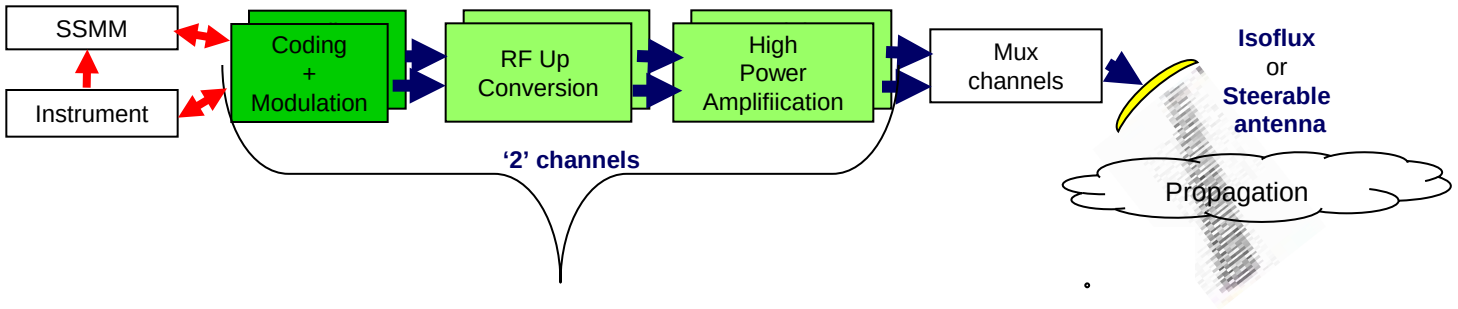
  - Comparable to ECSS-E-ST-50-12C ? (or not?)
- Conclusions

This presentation represents an attempt to express the view of those who have to select SpaceFibre for future EO missions

Increasing data rates in Earth Observation

- Instruments generating higher data rate: Examples
  - next generation SAR with Dig.BeamForming: 8.7 Gb/s
  - multi-spectral imagers (multi Gb/s)

- Higher downlink capabilities (under development)
  - Optical InterSatellite to EDRS (European Data Relay Satellite)
  - K-band data downlink (25.5 to 27 GHz => 4 times more Bw than X-band)



Example of Variable Coding Modulation (VCM)

Scheme (Modul-Code)	Es/No (FER 1E-08)	(η) = Effic. (info_bit/ symbol)	Data rate (Mb/s) @ 500 Mbaud
QPSK- 1/2	1.150	0.994	494
QPSK- 3/5	2.380	1.194	593
QPSK- 2/3	3.250	1.328	**660**
QPSK- 3/4	4.180	1.494	742
QPSK- 4/5	4.750	1.594	792
QPSK- 5/6	5.250	1.662	825
QPSK- 8/9	6.350	1.774	881
QPSK- 9/10	6.570	1.796	892
8PSK-3/5	5.65	1.791	889
8PSK-2/3	6.77	1.993	989
8PSK-3/4	8.06	2.241	1,113
8PSK-5/6	9.50	2.493	1,238
8PSK-8/9	10.84	2.661	1,321
8PSK-9/10	11.13	2.694	1,338
16APSK-2/3	9.00	2.657	1,319
16APSK-3/4	10.20	2.988	1,484
16APSK-4/5	11.00	3.188	1,583
16APSK-5/6	11.60	3.323	1,650
16APSK-8/9	12.90	3.548	1,762
16APSK-9/10	13.10	3.592	1,784
32APSK- 3/4	12.73	3.735	1,855
32APSK- 4/5	13.64	3.985	1,979
32APSK- 5/6	14.28	4.154	2,063
32APSK- 8/9	15.69	4.435	2,202
32APSK- 9/10	16.05	4.490	2,230

é

for low elevation (horizon) Wet Season

for high elevation (zenith) Dry Season

ê

- **RF chain is the same** for a given symbol rate
- about **15 dB** difference in Es/No (plus the back-off)
- Efficiency (η) and data rates factor between **1 and 4.5**
- Peak data rate **2.23 Gb/s per channel** -> (2 channels 4.46 Gb/s)
- Modulator informs SSMM about data rate

- Two Standards: **DVB-S2** and **CCSDS131.2-O-1**
  - common modulation and performance (energy ; spectral eff.), but different complexity
  - Coding is different (LDPC in DVB & SCCC in CCSDS)

Flexibility is ideal to compensate for 'propagation' 'elevation angle' and seasonal variations

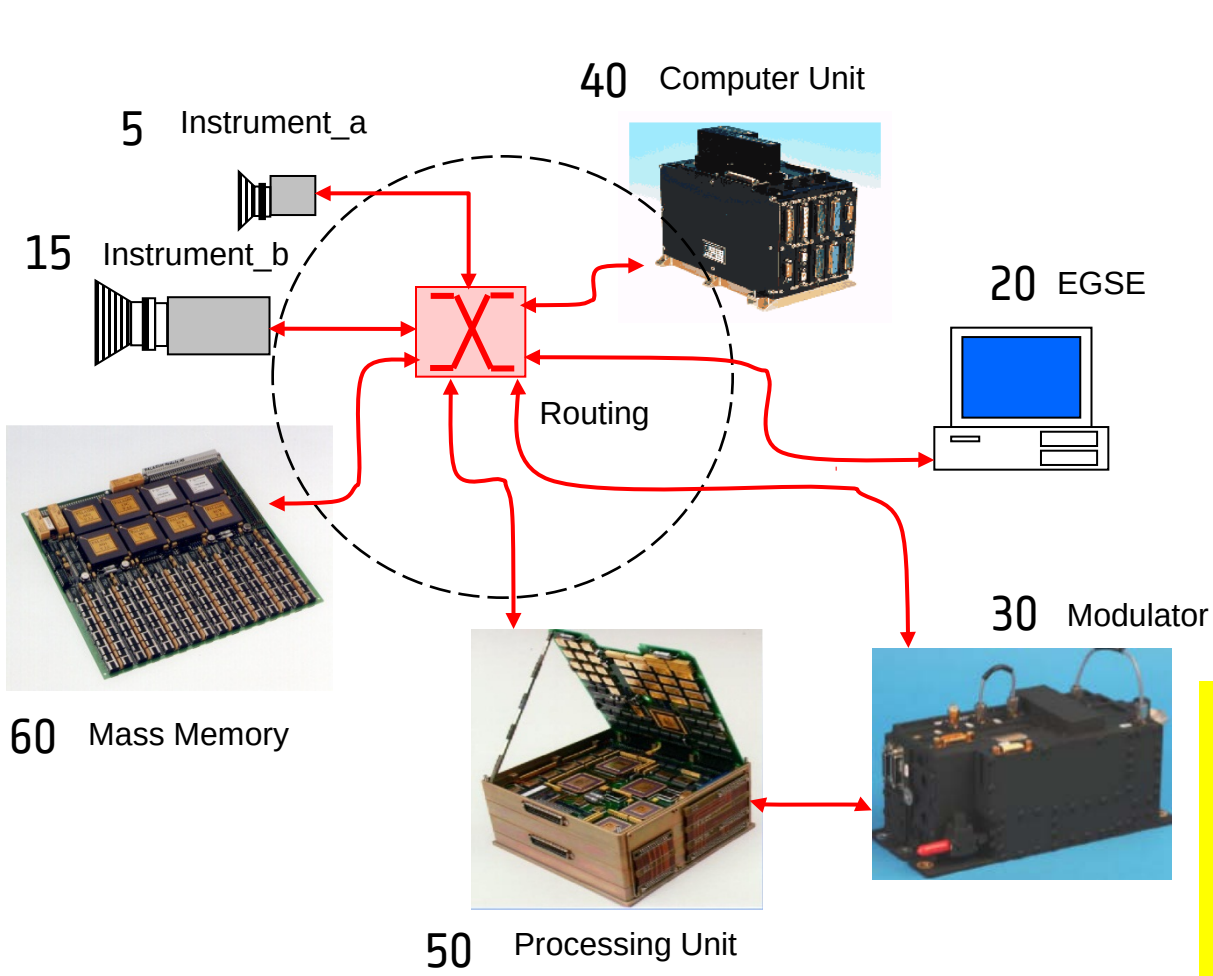
Modulation_order * coding_eff.
= $\log_2(32) * 9/10 = 4.5$

Need for full products, standards, and priorities

- Products:
  - CoDec IP cores => to ensure miniaturisation and adoption by everyone
  - components (non proprietary and non-ITAR sensitive)
    - Digital part (with codec IP core + additional functionality)
    - Analogue (also cables, connectors, drivers, etc.)
  - Supporting Standards
    - for CoDec
    - Upper layer protocols

- Timely for project & Scaleable : applicable to CoDec, components, Stds
  - start simple (for first projects)
  - build up gradually

Flexibility for very diverse architectures



LEAST COMMON MULTIPLE (LCM)

5:	Instrument_a
5*3:	Instrument_b
5*2*2:	EGSE
5*2*3	Modulator
5*2*2*2	Computer unit
5*2*5	Processing unit
5*2*2*3	Mass Memory

Least Common Multiple (LCM) : Coder / Decoder (CoDec)

ECSS-E-ST-50-12C
31 July 2008

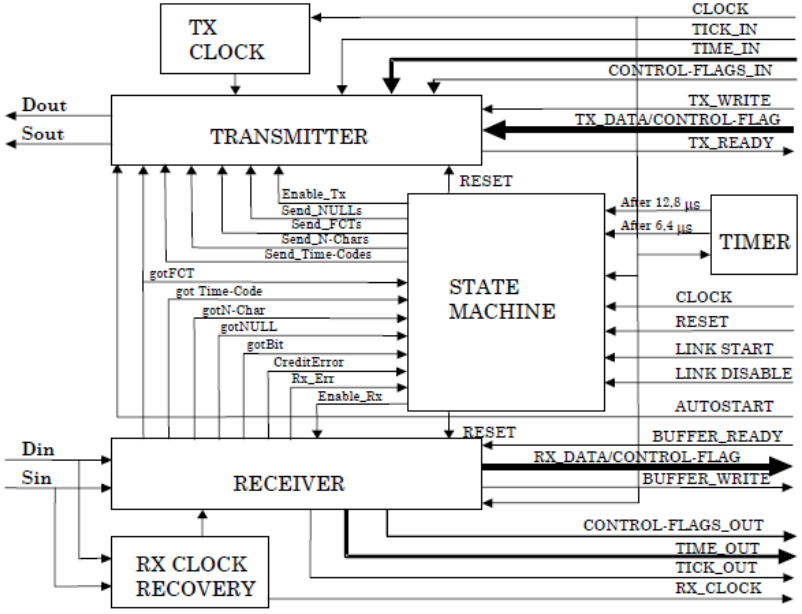
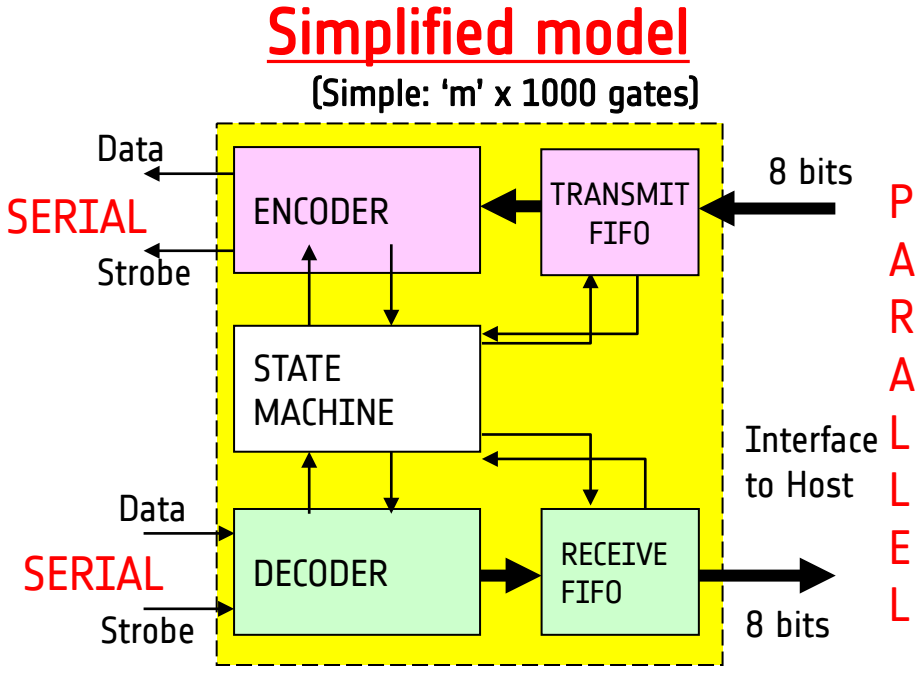


Figure 8-1: Example SpaceWire link interface block diagram

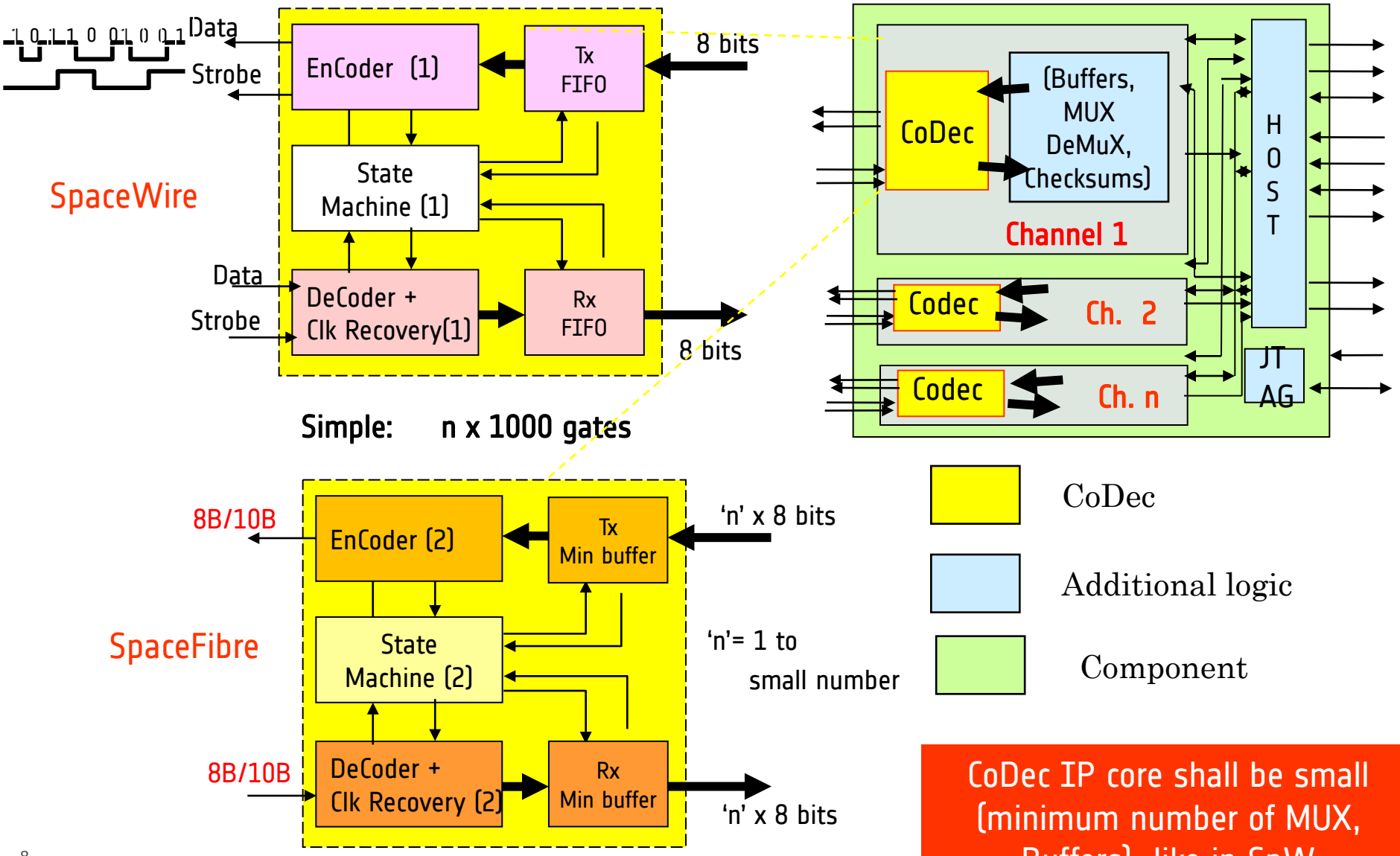


CoDec is the ENABLER:

- Compatibility challenge is on the SERIAL side
- LCM for PARALLEL side: 'n' times 8 bits (in SpaceWire: 'n' is 1)
  - good interface to make it scaleable with MUX/buffers in upper layers

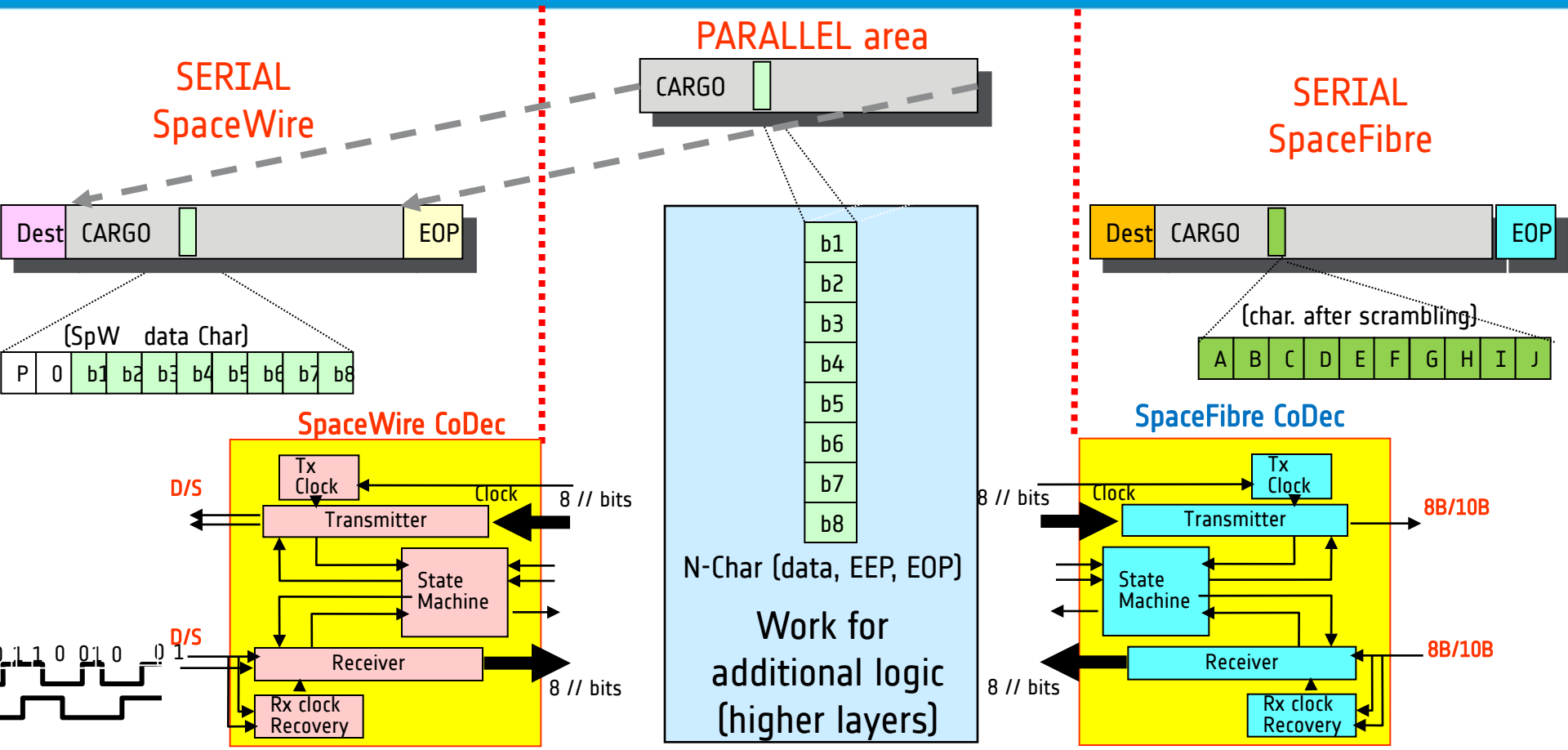
Coder / Decoder (CoDec) IP Core

Full component



CoDec IP core shall be small (minimum number of MUX, Buffers) like in SpW

Common Packet (SpW – SpF)



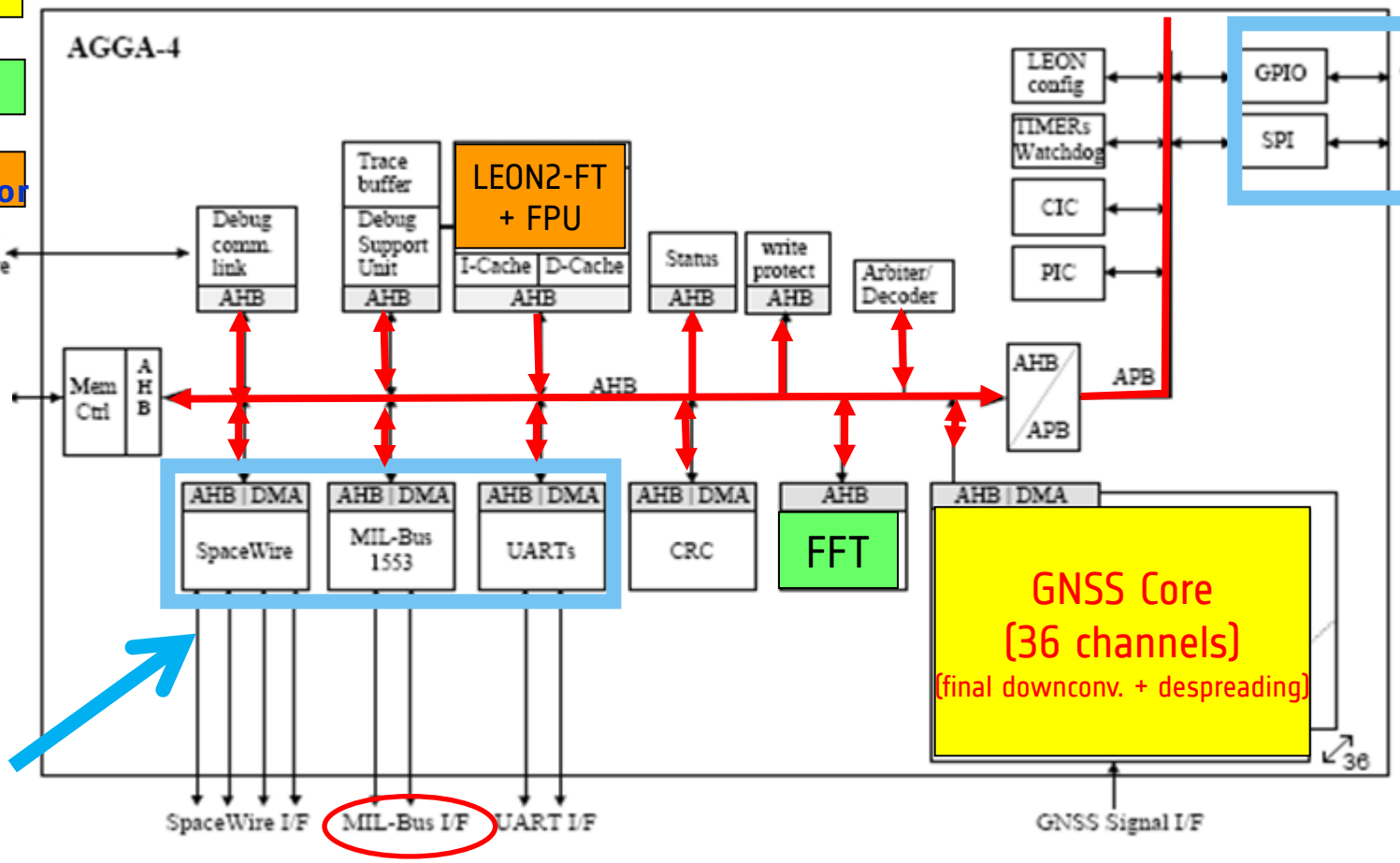
Common for SpaceWire - SpaceFibre

- Both provide serial to 8 bit conversion ports -> routing can be very similar
- Same packet structure with EOP (but not necessarily with the same packet length)
- Layers on top of Packet can be common

Why SpW characters in section 5.3.2 of SpaceFibre DRAFT Std ?

Advanced GPS-Galileo ASIC (AGGA-4)
(1st prototypes manufactured 1Q-2012 ; 6 Mgates)

- GNSS module
- FFT module
- LEON µ-processor
- external I/F
- AMBA I/F
- DMA I/F

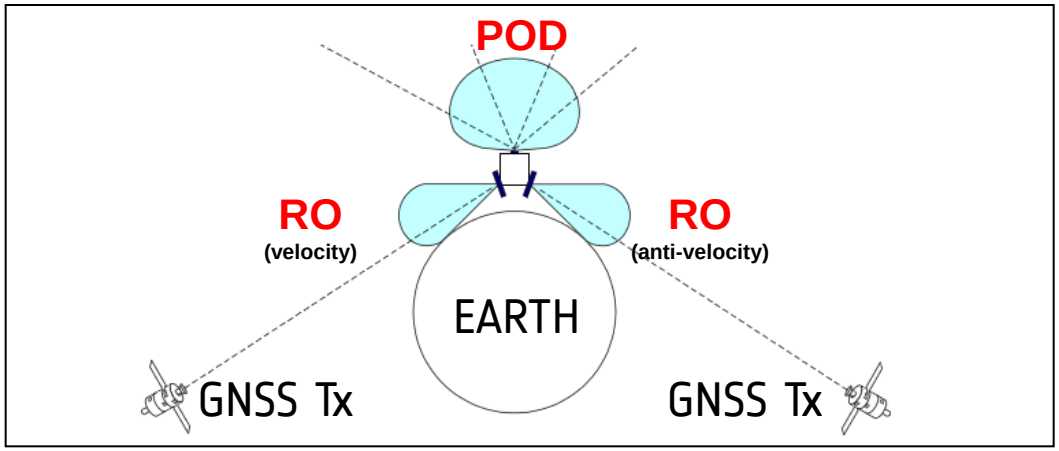


Modules with
4 SpaceWire
(2% of chip gates)

Message: I/F is not the primary objective of the ASIC
Simple IP core to be made available to ASIC designers
1553 was the last interface added (one project wanted this for TT&C)

Radio Occultation Instrument

(for MetOp-SG , launch 2019)

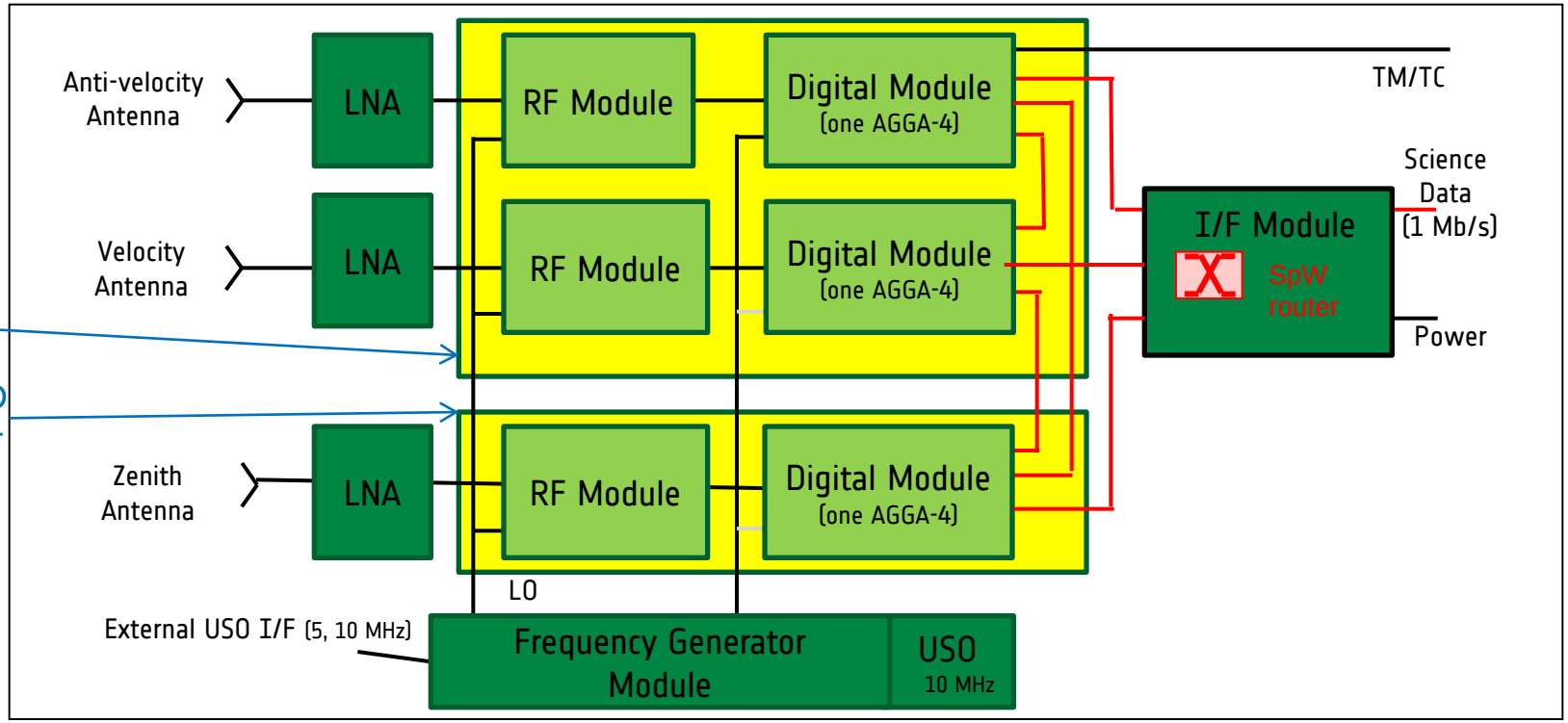


- 4 SpaceWire links per AGGA-4 device
  - directly between boards
  - also through router

SIMILAR NEED for SPACEFIBRE ?
(probably)

RO part of Receiver

Navigation/POD part of Receiver



IEEE 1355 (published in 1995)

IEEE Std for Heterogenous InterConnect (HIC) Low-cost, Low-Latency Scalable Serial Interconnect for parallel system Construction

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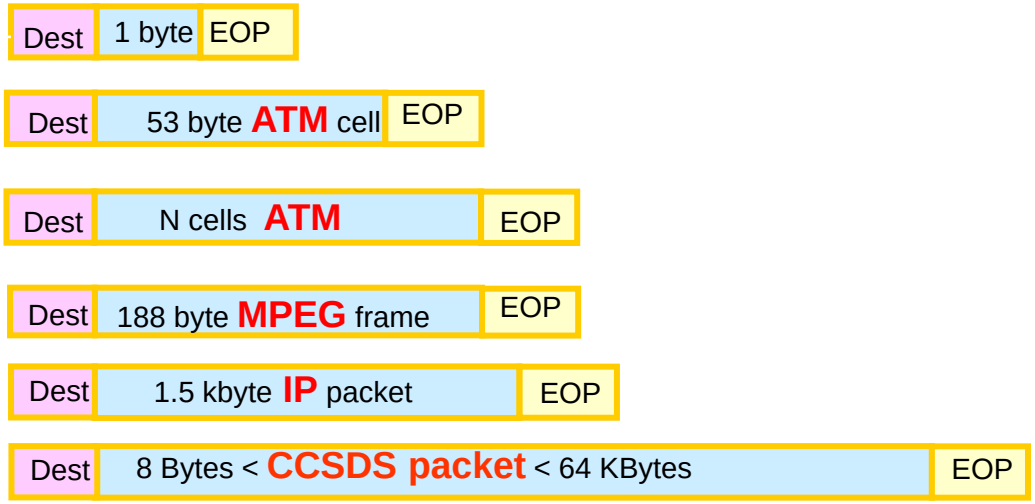
SpW predecessor

Kind of SpaceFibre

Common Packet is centric (regardless of CoDec)



9.2 Packet format

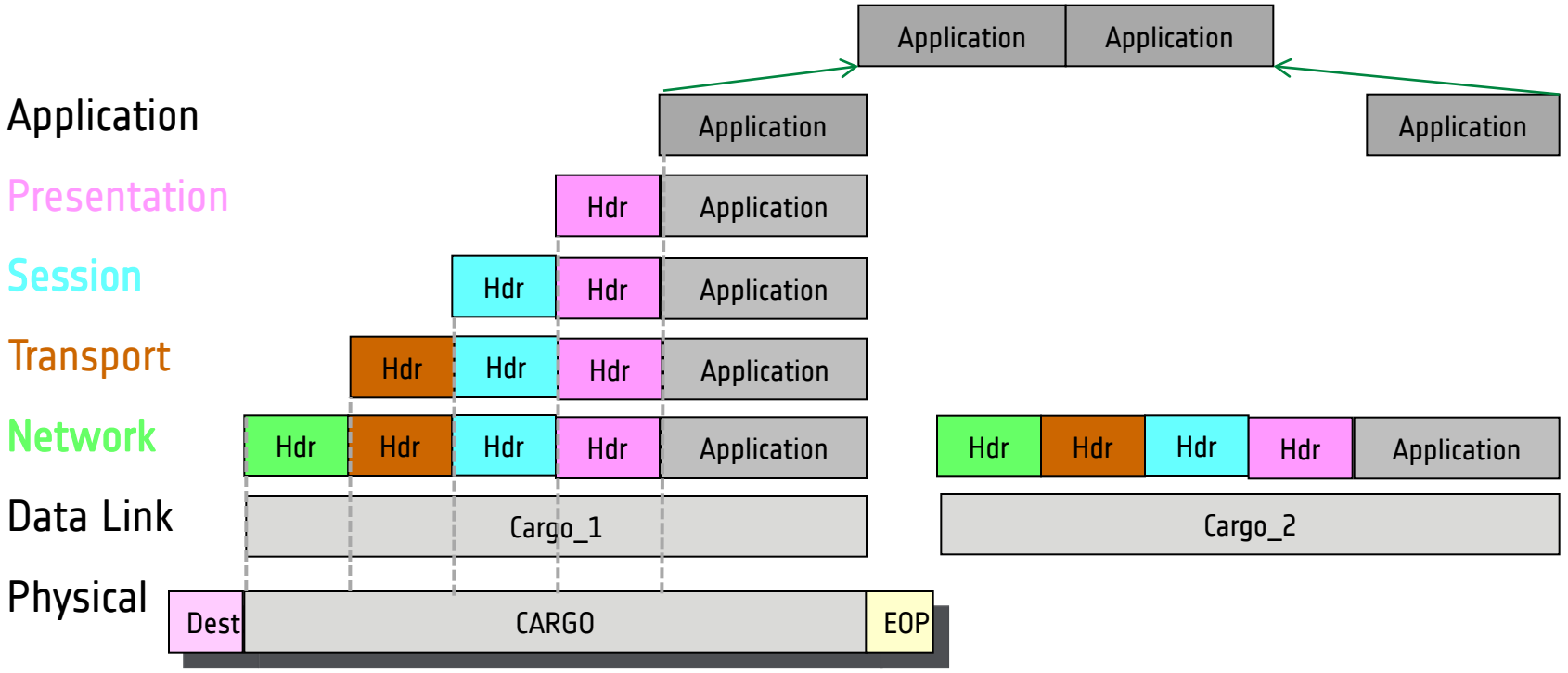
A packet consists of a destination followed by a payload, and is delimited by an end_of_packet marker: <DEST><PAYLOAD>< End_Of_Packet>

Questions:

- why the SpF draft Std has a FRAMING layer and not a PACKET layer ?
- Can we merge them ?

OSI model (ISO-7498)

OSI model (ISO-7498): Each layer has its header
Packets/frames come together again at higher layers (mainly application)



Remarks:

- 'frames, frame retry, CRCs, Virtual Channels' are not specific of SpaceFibre (also applicable to SpaceWire)
- they may need to be in hardware (for performance), but not inside, the CoDec
- could we have packet content (frames, CRCs, VCs, etc) in a standard for higher layers?

Packet is very flexible

Example: http://essp.larc.nasa.gov/EV-I/pdf_files/CII_Hosted_Payload_Guidelines_Final.pdf

CII SpaceWire Packet

SpW Logical Address	Cargo						ExP
	Protocol ID (0x02)	CCSDS					
		Reserved (0x00)	Type Code	Header	Data	CRC	
1 byte	1 byte	1 byte	1 byte	15 bytes	0–236 bytes	1 byte	4 bits
	9–255 bytes						

Specification Legend

- SpaceWire (ECSS-E-ST-50-12C)
- SpaceWire Protocol Identification (ECSS-E-ST-50-51C)
- SpaceWire – CCSDS Packet Transfer Protocol (ECSS-E-ST-50-53C)
- GOES-R Reliable Data Delivery Protocol (417-R-RPT-0050; uses CRC only)
- Packet specific data (e.g. time, position, commands, telemetry, science data)

Figure 16-1: CII SpaceWire Packet

CRC

CII SpaceWire Command Message Packet

SpW Logical Address	Cargo						ExP
	Protocol ID (0x02)	CCSDS					
		Reserved (0x00)	Type (0x04)	Header	Data	CRC	
1 byte	1 byte	1 byte	1 byte	15 bytes	3–236 bytes	1 byte	4 bits
	22–255 bytes						

Figure 16-7: CII Command Message Packet

Assuming SpaceWire:
Critical on-Board messages
(e.g. kb/s TC and TC-ACK)
are done in SW by application

Table 16-1: CII Message Types

Type Code	Message Type	Data Path
0x02	Spacecraft Status Message	Spacecraft to Instrument
0x04	Command	Spacecraft to Instrument
0x08	Command Acknowledgement	Instrument to Spacecraft
0x10	Instrument Telemetry	Instrument to Spacecraft
0x20	Instrument Science Data	Instrument to Spacecraft

Possible to send TC thru Gb/s bi-directional infrastructure ? (realistic ?)
Do we need RETRY in HW ? Can it be done at packet level (SW) ?

SpaceFibre specifications

Least Common Multiple
Physical Layer + CoDec

Packet
TBD somewhere here

above packet
not specific to SpaceFibre

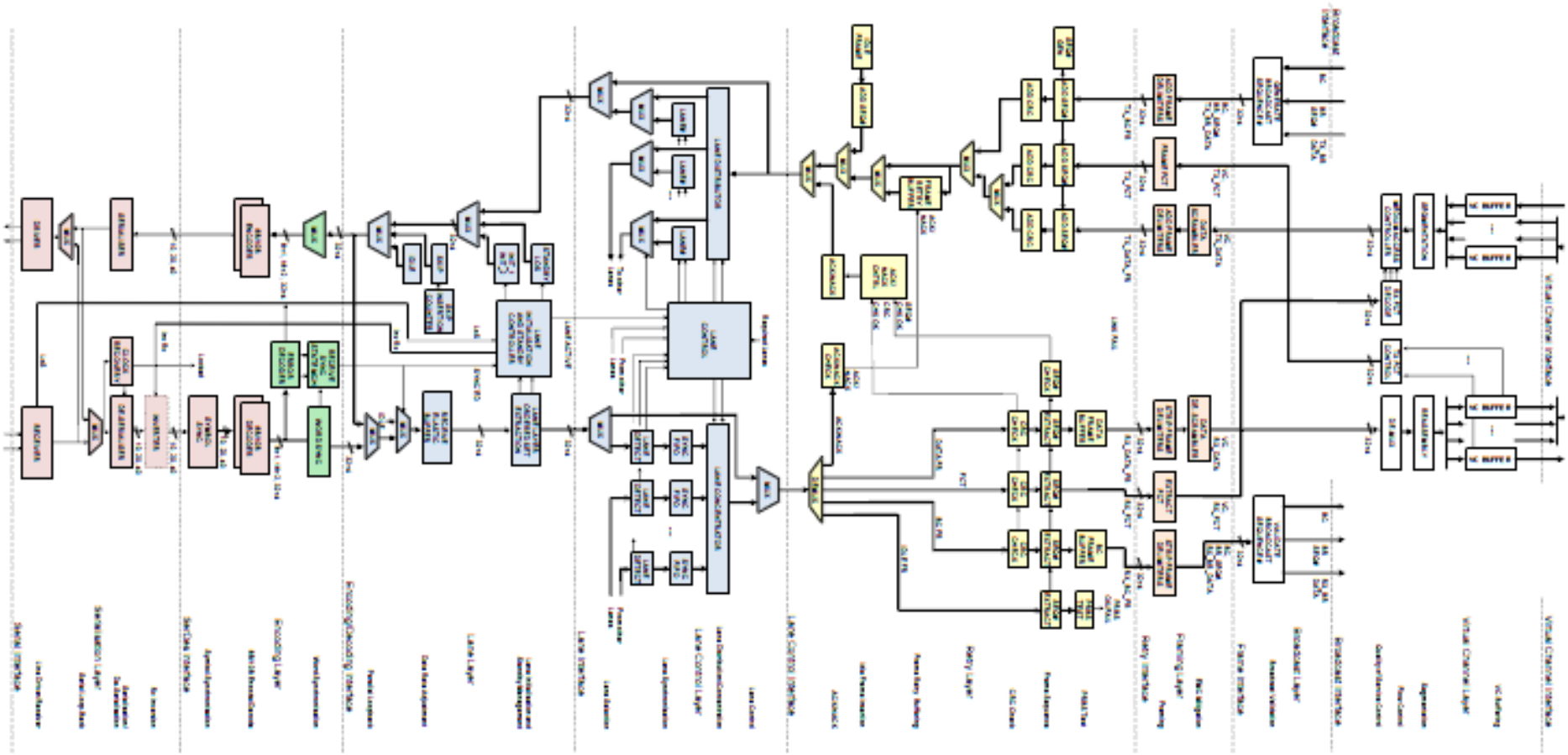


Figure 4.2 SpaceFibre CODEC Conceptual Architecture

Physical Layer to be defined as soon as possible

ECSS-E-ST-50-12C
31 July 2008

2 Normative references

The following normative documents contain provisions which, through

ECSS-S-ST-00-01	ECSS system — Glossary of terms
ECSS-Q-ST-70-08	Space product assurance — Manual soldering of high-reliability electrical connections
ECSS-Q-ST-70-26	Space product assurance — Crimping of high-reliability electrical connections
ANSI/TIA/EIA-644	1995 Telecommunications Industry Association, "Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits", March 1996
ESCC 3401/071	Connectors, Electrical, Rectangular, Microminiature, Solder Buckert Contacts with EMI Backshell, based on type MDM
ESCC 3902/003	Cable, "Spacewire", Round, Quad usi… Cables, Flexible, –200 to +180 °C

5.12.2.3 Single-ended Electrical Connectors
a. TBA
5.12.2.4 SpaceFibre Electrical Cables
a. TBA
5.12.2.5 Differential Electrical Connectors
a. TBA
5.12.2.6 Differential Electrical Cables
a. TBA

5.12.3 Fibre optic driver and receiver
5.12.3.1 Fibre Optic Driver and Receiver
a. TBA
5.12.3.2 Fibre Optic Connectors
a. TBA
5.12.3.3 Fibre Optic Cables
a. TBA

Where is the definition of :
What cable, connector, driver ?
CML ?
8b/10b
SERDES and (K28.1, K28.2, D08.1, D15.1 ?)

ECSS-E-ST-50-XXX
Draft D: 29th February 2012

2 Normative references

The following normative documents contain provisions which, through

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-E-ST-50-12C	Space engineering - SpaceWire - Links, nodes, routers and networks
ECSS-E-ST-50-51	Space engineering - SpaceWire protocol identification
ECSS-E-ST-50-52	Space engineering – Remote Memory Access Protocol

The current SpaceFibre standard

SpaceWire and SpaceFibre have the same network (and P2P) topology:
=> The Standards should be more symmetrical (see proposal in next slide)

SpaceFiber DRAFT (29/02/2012)	SpaceWire ECSS-E-ST-50-12C	Comments
Virtual channels (including QoS)	Not specified	Common
Broadcast message (including FDIR)	Not specified	
No network layer	Network layer	
No Packet layer	Packet	Convergence here
Framing	Not specified	
Retry	Not specified	
Lane control	Not specified	
Lane	Exchange	Important for CODEC
Encoding/Decoding	Character, Exchange,	
Serialisation	Character, Exchange	
Physical (Very undefined)	Physical , Signal (LVDS based)	Fundamental for performance / reliability

Priority for ESA-EOP

1) Consolidated layers up to packet level
   Major concern about Physical layer

2) Demonstration of performance (> 2 Gb/s) and reliability (EMC, BER) asap

3) Get full products (IP core, components) asap
   - ITAR-non-sensitive, avoid proprietary
   - full TLK2711 back-compatibility not required

To achieve the objectives in not too long time, options with alternatives could be removed or simplified *(least common multiple* approach*):*

Examples:	Alternatives
Parallel lanes	Multiple links
Retry in HW	Retry of packets (more SW Ctrl in application)

Proposed break down of standards

TBD name of Standard (common SpF - SpW)
Virtual channels (including QoS)
Broadcast message (including FDIR)
Data Framing (TBC) (excl. scrambling)

Packet Content layers

Leave what is common in SpW-SpF in a different standard,
and demonstrate it first with SpaceWire

SpaceFiber DRAFT (29/02/2012)	SpaceWire	
Network	Network layer	Common (TBC)
Packet (new)	Packet	Common (TBC)
Framing (excl. scrambling)	Not specified	TBC
Retry (optional or out , TBC)	Not specified	TBD
Lane	Exchange	No lane control
Encoding/Decoding (incl. scrambling)	Character, Exchange,	
Serialisation		
Physical (To be defined asap)	Physical , Signal (LVDS based)	

ESA-EOP priority for SpaceFibre Standard

- consolidate it up to Packet Layer (including Physical Layer)
- Upper layers (e.g. packet content) should NOT impose unnecessary complexity on lower layers
  - Could we have a 'light' (subset of layers) version ?

Related issues / questions

- Terminology to be cleaned up: consistency needed (standard also for those not in these meetings)
  - Frame vs Packets
  - definition of CoDec (which layers)
  - Applicable documents, relationship with other Stds (e.g. upper layers)
  - SpaceWire characters (e.g. NULLs) in SpaceFibre spec (5.3.2) do not make sense. (probaby editing point)

- Keep SpaceFibre simple
  - need also for using SpaceFibre (lower layers) alone (without SpaceWire) in simple terminals (without QoS, FDIR) and possibly at low speed too
  - **one lane** (> 2 Gb/s) would already be a major breakthorugh
  - re-try at Gb/s : (not fully understood)
    - e.g. BER and complexity of HW?, SW alternatives?, only within link?, when to use it? risk to hinder determinism ?

Conclusions / Recommendations

- There is a real need (very soon) for > Gb/s in just one link -> SpaceFibre
- Technology Products:
  - SpaceFibre Coder/Decoder IP core (ENABLER)
    - Keep it simple (Least Common Multiple - LCM)
      - get it developed and adopted fast, facilitate integration in ICs
    - Scalable interfaces (the upper layers could be integrated later, only where needed)
  - Components for the whole link
    - Digital part (with LCM codec IP core + additional functionality)
    - Analogue part (also cables, connectors, drivers, etc.)
      - characterize performance (speed, BER, EMC) asap
    - Start with the simplest applications (LCM)
- Supporting Standards
  - SpaceFibre Std needs to be more symmetric to SpaceWire
    - Packet level should be addressed
    - Simplify : align with LCM SpaceFibre CoDec + complete Physical layer
  - New Std for upper layers with common issues with SpaceWire