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Analysis of the Transport Protocol Requirements for the SpaceWire On-board Networks of Russian Spacecrafts

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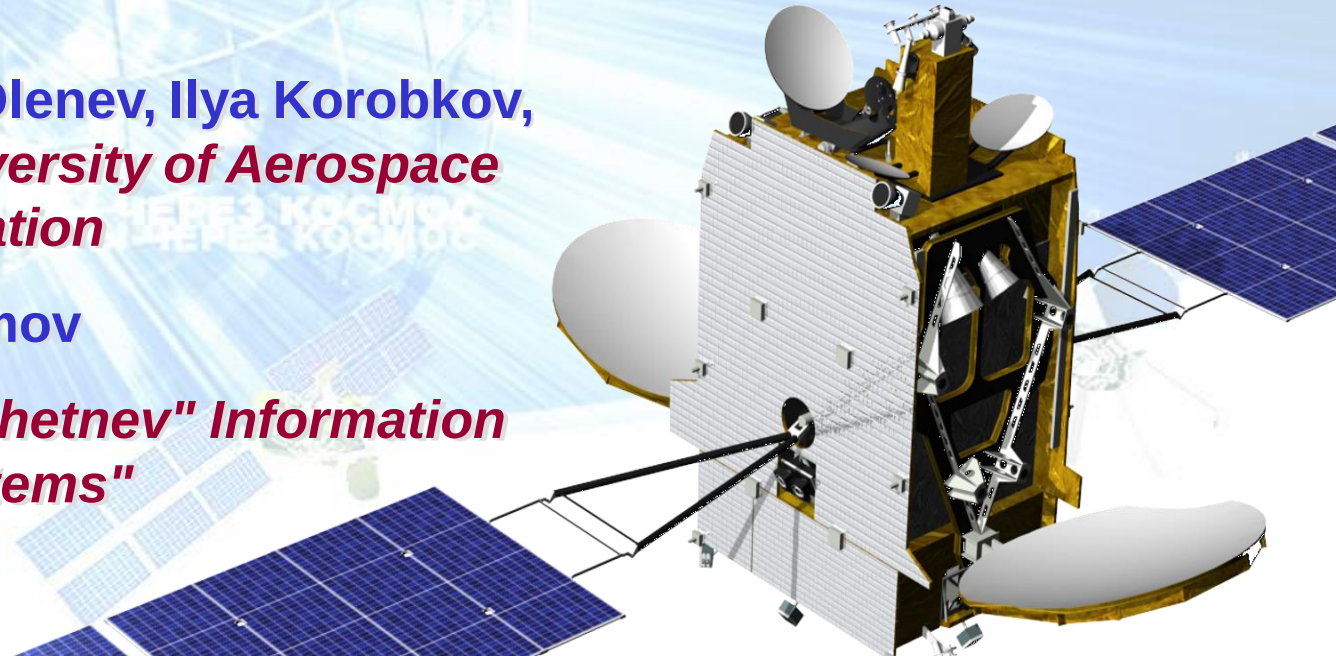

SpaceWire standard

- SpaceWire is a data-handling network for spacecraft which combines simple, low-cost implementation, with high performance and architectural flexibility.
- SpaceWire is a network technology which does not provide transport layer services.
- Current Russian space industry demands a Transport protocol running over SpaceWire which will provide
  - reliability
  - guaranteed services
  - determinism

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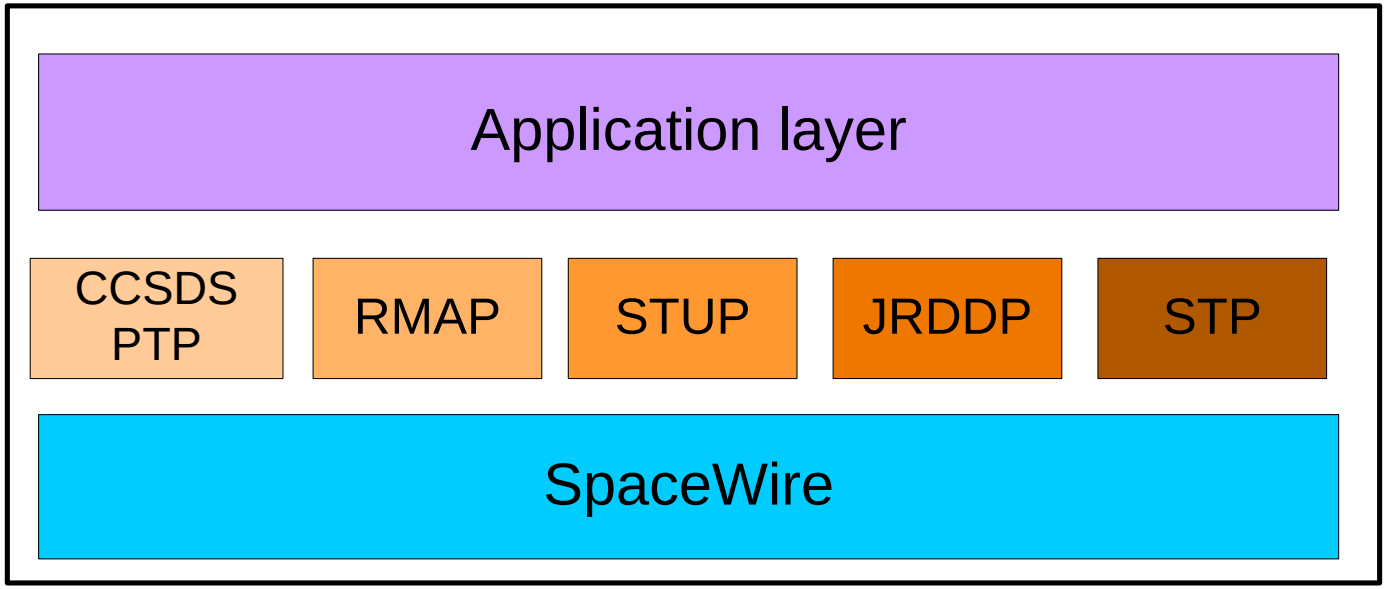
Transport Protocols for SpaceWire



Transport protocols intended to operate over SpaceWire:

- Remote Memory Access Protocol
- CCSDS Packet Transfer Protocol
- Serial Transport Universal Protocol
- Joint Reliable Data Delivery Protocol
- Streaming Transfer Protocol

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Remote Memory Access Protocol

Primary purposes

- To configure SpaceWire switches, setting their operating parameters and routing table information.
- To monitor the status of switches and nodes
- To set application configuration registers, to read status information and to read from or write data to memory in the unit for simple SpaceWire units without an embedded processor

General Features

- connectionless transport protocol;
- supports path, logical and regional addressing;
- write commands
  - acknowledged or not acknowledged,
  - verified and not verified;
- provides a means of reading and writing of data into the memory by just one command (read-modify-write command);
- no timeouts;
- no flow control.

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CCSDS Packet Transfer Protocol

- **Primary purposes**
  - to encapsulate a CCSDS Space Packet into a SpaceWire packet
  - to transfer it from an initiator to a target across a SpaceWire network and extract it from the SpaceWire packet and pass it to a target user application.
  - CCSDS PTP does not provide any means for ensuring delivery of the packet nor is it responsible for the contents of the packet.
- **General Features**
  - connectionless protocol
  - data transfer request by the user at any time
  - variable or fixed packet length
    - minimal – 7 bytes
    - maximal – 65542 bytes
  - unidirectional data transfer without acknowledgments
  - no data retransmission mechanism
  - no packet verification
  - no guaranteed quality of service

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Serial Transfer Universal Protocol

- **Primary purposes**
  - data transfer over the SpaceWire network
- **General Features**
  - connectionless protocol
  - easy to implement protocol (minimized complexity)
  - 2 types of commands:
    - write
    - read
  - no mechanisms for guaranteed quality of service

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Joint Reliable Data Delivery Protocol

- **Primary purposes**
  - reliable data transmission over SpaceWire network
  - packet delivery services to one or more higher-level host application processes
- **General Features**
  - connection-oriented protocol
  - multiple logical connections
  - reliable data delivery
  - detection of missing packets
  - out-of-sequence packet reordering
  - buffer fragmentation and reassembly

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Streaming Transport Protocol

- **Primary purposes**
  - streaming data transmission over SpaceWire network
  - simultaneous transmission of multiple coherent data flows
- **General Features**
  - connection-oriented protocol;
  - reliable handshake for connection establishment and teardown (*3-way handshake*);
  - asymmetric connection (*from slave to host device*);
  - multi-streaming (*up to 65535 connections*);
  - fixed length of transmitted data;
  - periodical data transfer in specified time period;
  - data delivery without acknowledgements and retransmission;
  - data flow control.

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Protocol Comparison

Feature	RMAP	PTP	STUP	JRDDP	STP
Multiple applications	-	-	-	√	√
Data flows of different priorities	-	-	-	√	-
Data flow control	-	-	-	√	√
Configuration flexibility	√	-	-	-	-
Transport connection establishment	-	-	-	√	√
Segmentation	-	-	-	√	-
Data correctness check	√	-	√	√	√
Data sequence check	-	-	-	√	-
Scheduling	-	-	-	-	-
Data retransmission	-	-	-	√	-
Acknowledgements	√	-	-	√	-

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Transport Protocol General Requirements

- *Requirements have been elaborated in collaboration with JSC "Academician M.F. Reshetnev" Information Satellite Systems"*
- **Transport Interface**
  - General data flows passing from the Application layer:
    - control commands;
    - application process messages;
    - time codes;
    - interrupt codes and interrupt acknowledge codes.
- **Segmentation**
  - Segmentation of large messages should be performed on the Application layer.
  - The target segments with the additional service information should be passed from the Application layer to the Transport layer.

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Transport Protocol General Requirements

Data flows and priorities

- The data flows should have the following precedence:
  - Control commands – the highest;
  - Urgent messages (in the transmission order from the Application layer);
  - Common messages (in the transmission order from the Application layer) – the lowest.

Buffering on the transmitter side

- Transport protocol should comprise a separate logical buffer for each data flow priority.

Quality of Service

- Transport protocol should provide an additional fault detection level over the SpaceWire connection by means of the following mechanisms:
  - CRC checksum
  - packet sequence numbers
  - acknowledgements of the successful packet receipt
  - detection of lost packets by timeouts.

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Quality of Service

Data Flow	Length	Intensity	Latency	QoS	Priority	Ack
Control commands	16 bits	≥ 1 ms	≤ 0,5 ms	priority, scheduling	1	√
Urgent messages	4 bytes 1 Kbyte 64 Kbytes	≥0,2 ms ≥5 ms ≥250 ms	≤ 0,25 ms ≤ 0,5 ms ≤ 40 ms	priority, scheduling, guaranteed	2	√
Common messages	4 bytes 1 Kbyte 64 Kbytes	≥0,2 ms ≥5 ms ≥250 ms	≤ 1 ms ≤ 1 ms ≤ 80 ms	priority, scheduling, guaranteed, best effort	3	√ / -
Time codes	6 bits	≥ 60 s	≤ 0,1 ms	priority	0	-
Interrupts, interrupt acknowledges	5+1 bits	≥ 5 ms	≤ 0,1 ms	priority	0	√ / -

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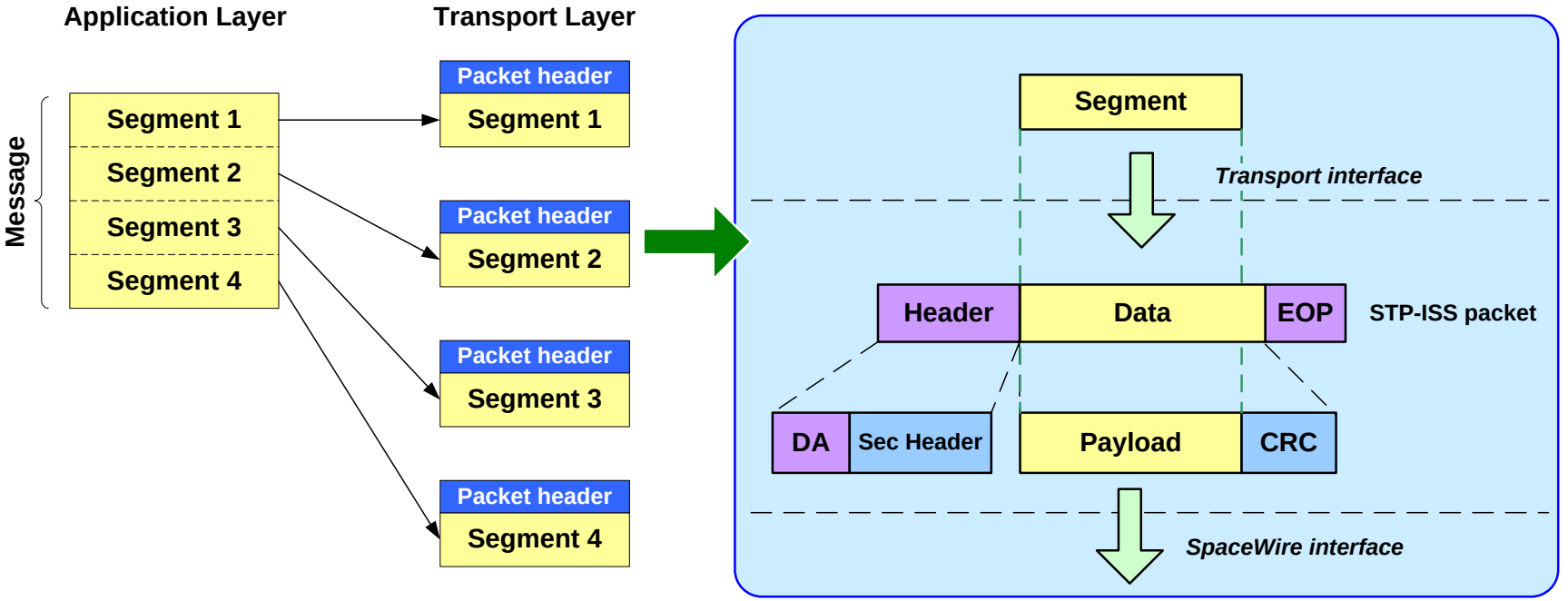
Solutions : Segmentation and formatting



- The incoming messages should be divided into segments on the Application layer
- A special field for a secondary header holding segment number and an end of message flag
- CRC-8:
  - packet header,
  - acknowledge packets
  - control command packets
- CRC-16 for STP-ISS packet's data field. The maximum data field length is 2048 bytes.

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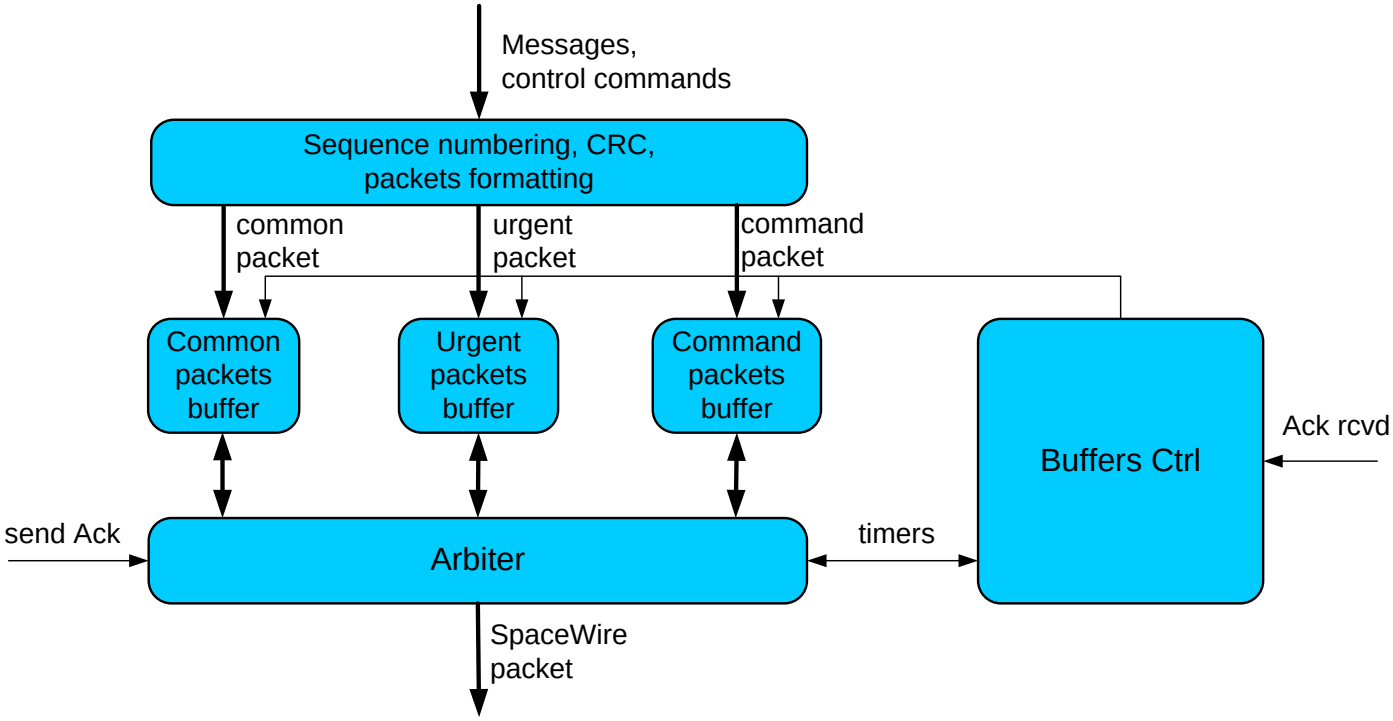
Solutions : Buffering

- Buffers for each type of the incoming messages:
  - control commands buffer
  - urgent messages buffer
  - common messages buffer
- Sequence numbering for each packet
- Lifetime timer for setting packet's actuality
- Indication about successful or unsuccessful packet delivery



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Solutions : Interfaces

Control codes interface

- A separate interface for time-codes, interrupt codes and interrupt-acknowledge codes

Configuration interface

- Configuration parameters should be set during the device configuration stage
- Possible configuration parameters:
  - Guaranteed data delivery on/off
  - Scheduling on/off
  - Lifetime timers
  - Retry timers

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Solutions : Quality of Service

- Quality of service types:
  - priority transmission
  - guaranteed data delivery
  - scheduling
  - best effort
- Priority levels
  - Acknowledgment packets
  - Control command packets
  - Resent control command packets
  - Urgent message packets
  - Resent urgent message packets
  - Resent common message packets
  - Common message packets
- Retry timeouts for enabling the possibility of packet resending

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Thank you!