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DOCUMENT

SpaceWire-D Requirements and Trade-offs

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1 INTRODUCTION

This technical note provides requirements, baseline considerations and a list of still open trade-offs for the definition of protocols running over SpaceWire networks, intended to provide a deterministic scheme for handling data transfers.

The list of requirements is not meant to be exhaustive nor final as some trade-offs are still to be closed. The main objective of this note is to structure discussions during the SpW WG meeting#16.

The features and protocols aiming at making SpaceWire networks Deterministic are referred to as SpW-D.

A main evolution w.r.t previously mentioned options embedded in SpW-D is the removal of the “Multi-slotting” case as a mean to avoid segmentation. This has been done on the ground of the added complexity introduced by multi-slotting, in particular for fault containment in case of time slot interval violations.

2 REQUIREMENTS AND BASELINE CONSIDERATIONS

2.1 Performance Requirements

SpW-D is intended to provide the means to handle real time traffic on a SpaceWire network with a level of performance compatible with the following range of control loop frequencies:

- 1Hz (Pulse Per Sccond (PPS) driven services)
- 10Hz (AOCS, typically Mil1553 range)
- 100Hz (high-end AOCS, pointing, max Mil1553 capability)
- 1KHz (motor control, Robotics, μ -vibration compensation, fine pointing)

Furthermore, the original characteristics of SpaceWire links in terms of high throughput have to be preserved. This extends as well to qualitative properties such as “simplicity” and low/medium implementation costs (e.g. gate count in an ASIC/FPGA).

SpW-D shall allow the multiplexing of command & control traffic and High Throughput Data Transfers (HTDT) on the same links/network.

SpW-D provides synchronisation properties to a natively asynchronous network.



2.2 Scheduling – Time distribution

The main objective being to schedule data transfers on the network in a deterministic manner (by suppressing, by design, any contention at SpW Router level, every node in a scheduled SpaceWire network has to maintain a Local Clock that is synchronised to a common Master Clock.

The node embedding the current Master Clock shall be the source of time codes broadcasted on the network by SpW Routers.

Time distribution is therefore a core function of SpW-D, and includes the following features:

- CCSDS CUC format compliance.
- Time distribution and node synchronisation mechanism as described for instance in the document “SpaceWire – CCSDS Unsegmented Code Transfer Protocol – 1st of October 2010, Version 1.4, Aeroflex Gaisler). This has the consequence for valid Time Code Periods (TCP) to be a power-of-2 division of 1 s. (see Annex A)
- Local Time is stored and managed by an Elapsed Time counter in every node part of the scheduled network
- Time codes, coded on 6 bits, define a Minor Cycle.
- Major cycles extend the ambiguity period of Minor Cycles to more than a second (see Annex A)

2.3 Selection of Time code frequencies

The Frequency of Time code broadcasting has to be selected according to the following somehow antagonistic needs:

- The frequency has to be high enough to be compatible with the 1 KHz control frequency requirement while allowing multiple control loops to be handled.
- The frequency has to be low enough to maximise efficiency for HTDT while keeping segmentation optional in a range of practical cases.

Proposed Time Code Frequencies

Time Code Frequency	Time Code Period			Minor Cycles per second	Minor Cycle period	
	s	s	μ s (rounded)		s	ms (rounded)
8 KHz	2^{-13}	1/8192	122.1	128	2^{-7}	7.8
4 KHz	2^{-12}	1/4096	244.1	64	2^{-6}	15.6
2 KHz	2^{-11}	1/2048	488.3	32	2^{-5}	31.2
1 KHz	2^{-10}	1/1024	976.6	16	2^{-4}	62.5

2.4 Links speed

The speed of all links in a scheduled network shall be set uniformly to the same frequency.

For the sake of the analysis of the amount of data that can be conveyed in a time code period, the following link frequencies are considered: 2, 10, 20, 50, 100 and 200 MHz. Defining these values do not imply that other values will/cannot be possible.

The following table provides an indication of the available bandwidth by deriving the number of 8-bit data characters (coded on 10 bits) that can be transferred in a Time Code Period.

Link Frequency (MHz)	TC Frequency (KHz)			
	8	4	2	1
2	24	48	96	192
10	122	244	488	976
20	244	488	976	1952
50	611	1222	2444	4888
100	1222	2444	4888	9776
200	2444	4888	9776	19952

It appears from the table that a large span of options will be left to the user.

2.5 Handling of multiple data transfers or transactions in the same time slot

Some combinations between Link and TC Frequencies show that a high amount of data characters can be transferred in one time slot. In order to maximise throughput, multiple data transfers or transactions are allowed to be scheduled in a given time slot provided that:

- Data transfers do not compete for conflicting network resources



- All Data transfers are completed before the next time code is being received (by Initiators, Routers and Targets).

2.6 Type of data transfers

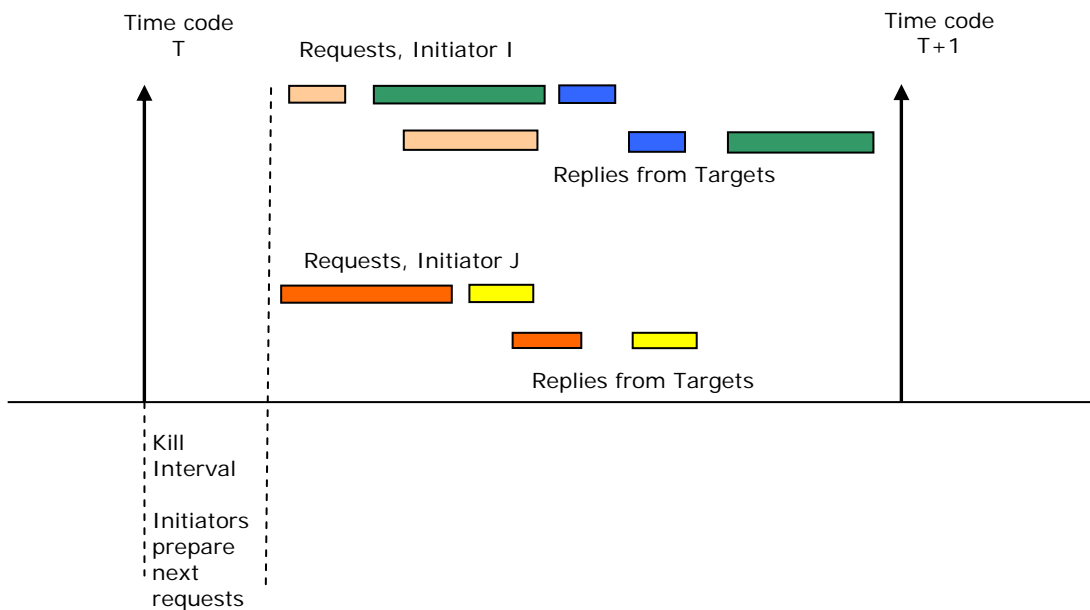
Data transfers authorised include in the general case any (TBC) SpaceWire packet transmissions provided SpW-D scheduling constraints are respected.

Data transfers include native SpW packet transmissions (TBC in particular regarding the addressing mode), transfers related to RMAP transactions or transfers of packets embedding specific protocols.

2.7 Structure of a time slot

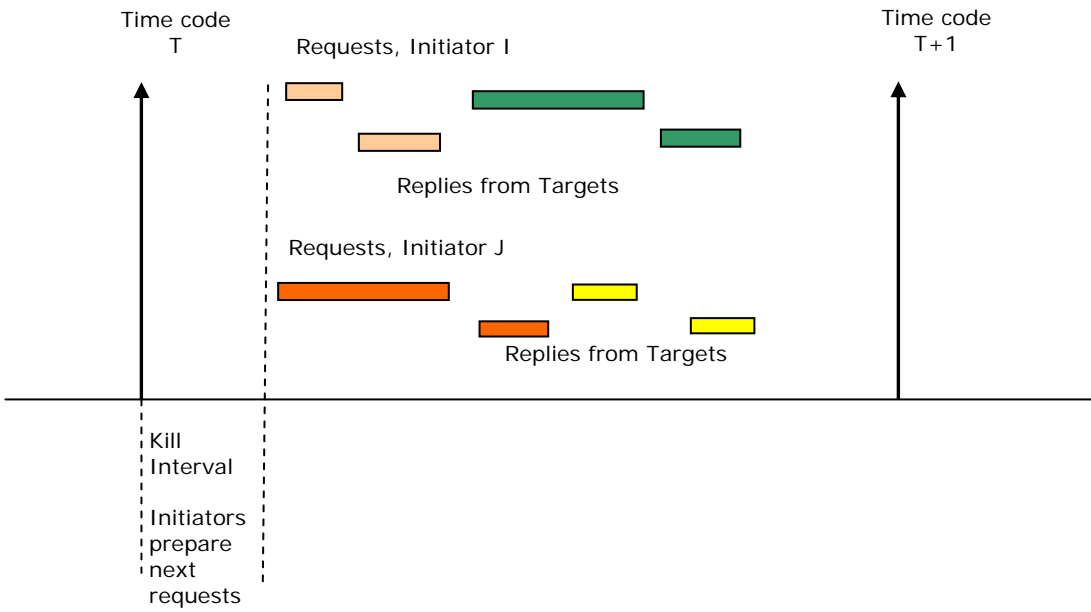
Examples provided here below correspond to RMAP transactions (Request–Reply pairs)

Example A: Posted RMAP Transactions

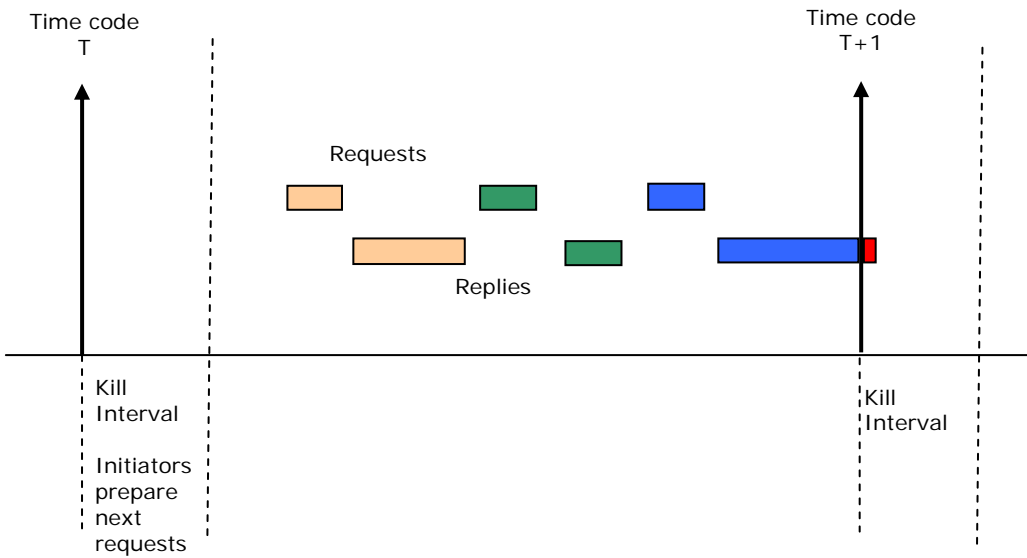




Example B: Sequential RMAP transactions



Example C: RMAP transactions violating time code boundary





2.8 Behaviour in case of transfers or transactions exceeding time code interval boundaries

- If data traffic still exists when a time code is received. Taking RMAP transactions as an example, this would translate in:
 - Initiator and Target detecting the anomaly and stopping/aborting packet transmission
 - Routers detecting the anomaly and flushing/spilling packets
- The time slot period is heading a Kill interval (duration TBC) used:
 - to recover from a detected anomaly
 - to prepare for the next transfers or transactions

2.9 Determinism, integrity and reliability

- Determinism: All data transfers and transactions are:
 - Scheduled, synchronised with time codes
 - Time bound: are executed nominally within one time slot
 - Detected and Killed when exceeding the allocated time slot.
- Strict Determinism :
 - A transaction exceeding the allocated time slot shall not have any impact in the next time slot(s).
- Integrity: Data integrity is provided by SpW, the protocol used for the transfer (when implemented) and/or the application. No specific data integrity is provided by SpW-D per se.
- Reliability: is provided by SpW and the application. No additional reliability is provided by SpW-D (e.g. no retries)

2.10 Channels

Channels are being defined as the network resources needed to perform data transfers in a given time slot, but are not part of SpW-D itself. They can be seen as an abstraction used for the definition of SpW-D schedules potentially used at system and application level.



2.11 Other Features:

- Major cycles management: introduced for cyclic monitoring/commanding with periods above Minor TC cycle durations
- SpW Port Host interfaces shall respect the following constraint:

Packets have to be accepted or discarded or the interface shall allow data to be overwritten. Data transmission cannot be stopped or denied. When data is being overwritten, this shall be notified to the application

- Compatibility with existing devices shall be maximised while defining SpW-D but not at the expense of bending determinism requirements.

3 SUMMARY

SpW-D includes:

- A SpW Network scheduling concept
- The specification of discrete time code periods
- A CUC Time distribution and Synchronisation scheme
- FDIR mechanisms: slot usage monitoring, packet routing timeouts and kill actions when time slot boundaries are violated.

SpW-D schedules deterministically any (TBC) data transfers on SpW networks and in particular:

- RMAP transactions
- Data transfers according to the CCSDS Packet Transfer Protocol
- SpW – CCSDS Unsegmented Code Transfer Protocol packets

SpW-D will allow to support:

- CCSDS SOIS Service implementation (e.g. Packet Transfer Service, Memory Access Service, Device Discovery Service, Test service,)

Open points and Trade-offs

- Allowing any SpW native packet to be transferred, irrespective to the addressing mode (path or logical) or limiting it to specific protocols (e.g. RMAP, CPTP, etc).
- Verifying the need to distinguish between Determinism and Strict Determinism.
- Allowing posted RMAP transactions or only Sequential RMAP transactions
- Defining Schedules in a standardised way, e.g by defining channels
- Defining an optional Segmentation layer



- Elaborating a unified SpW-D Stack representation
- Elaborating on Network monitor function support
- Establishing the compatibility level with existing devices
- Maximising interoperability: scrutinising the existence of options and keep variability to a minimum
- Cross checking the robustness of timing faults containment schemes.

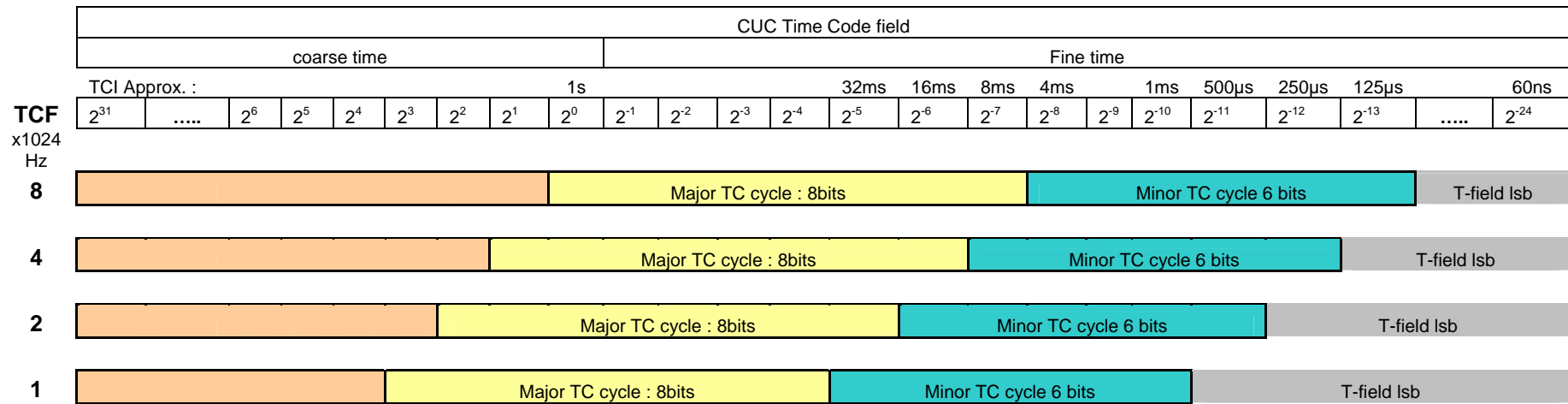


4 ANNEX A SPW-D ELAPSED TIME COUNTER FORMAT

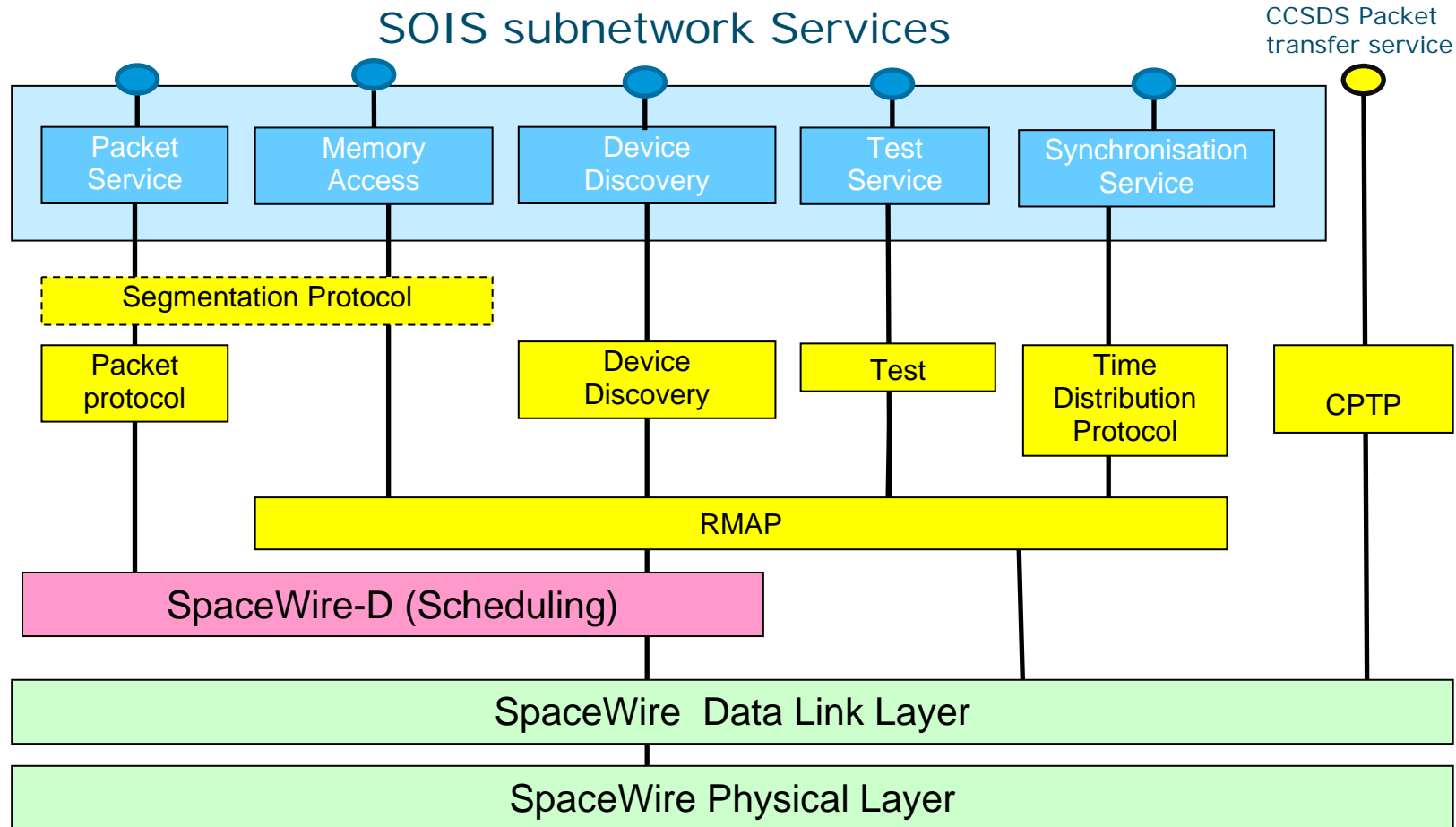
5 ANNEX B SPW-D PROTOCOL STACK



SpW-D Elapsed time counter format



Annex A SpW-D Elapsed time counter format



Annex B : SpW-D Protocol Stack