SpW-D preliminary Protocol Implementation & Analysis

Parameter Identification and Trade-Off

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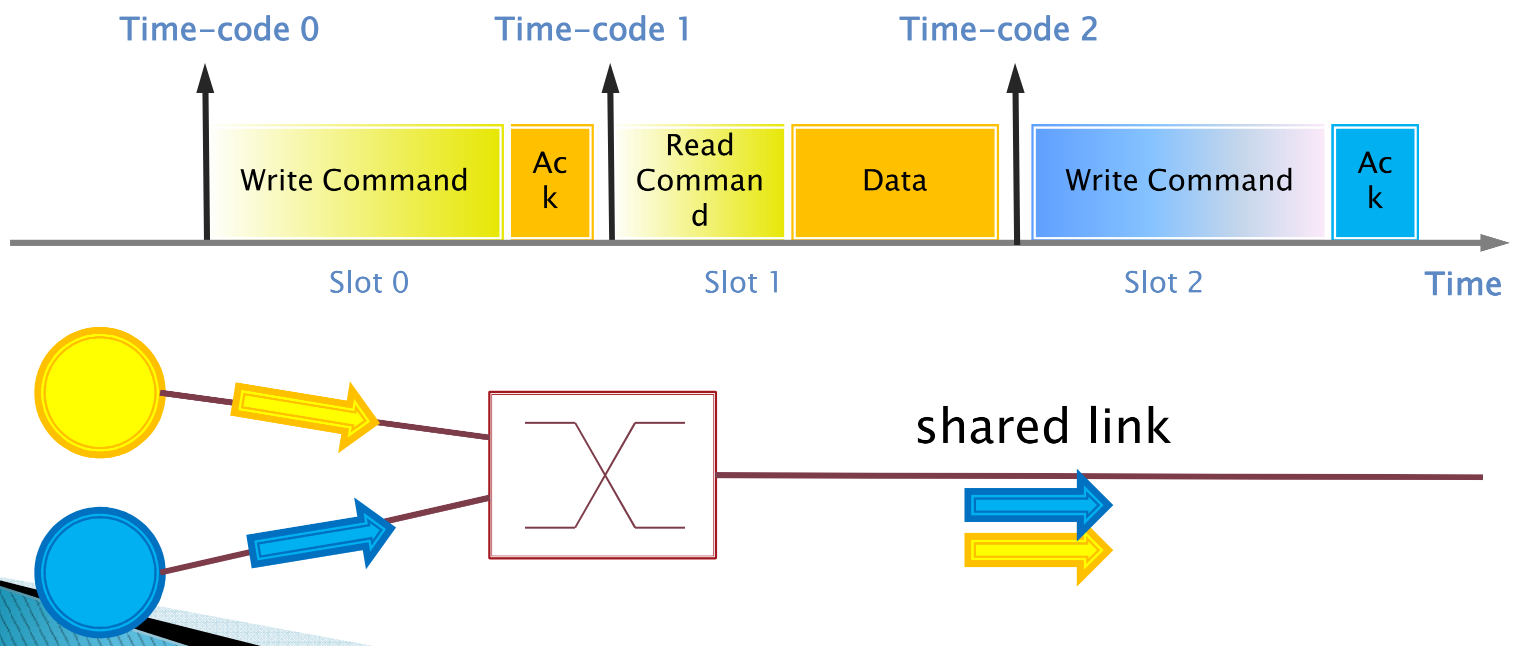
Draft presentation

SpW-D Objectives

- Provide guaranteed/deterministic latency and throughput, with:
  - High data rate for Payload Data
  - Low latency for Command and Control operations.
- Reuse existing SpaceWire devices and protocols
- Make it efficient
- Make it simple

SpW-D Overview

- SpW-D provides deterministic packet delivery to SpaceWire networks using time-slots and RMAP transactions
- Time-slots are equally spaced in time, in which a single RMAP transaction can take place.



SpW-D Advantatges

- Why RMAP? An RMAP transaction allows to **read or write** to an address space (**memory or FIFO**) located in a remote unit using SpaceWire links. It implements **acknowledgments**.

- Why scheduling? Deterministic behaviour provides **guaranteed** maximum **latency** for control messages and **bandwidth** allocation for payload data.

With scheduling... There is NO congestion!

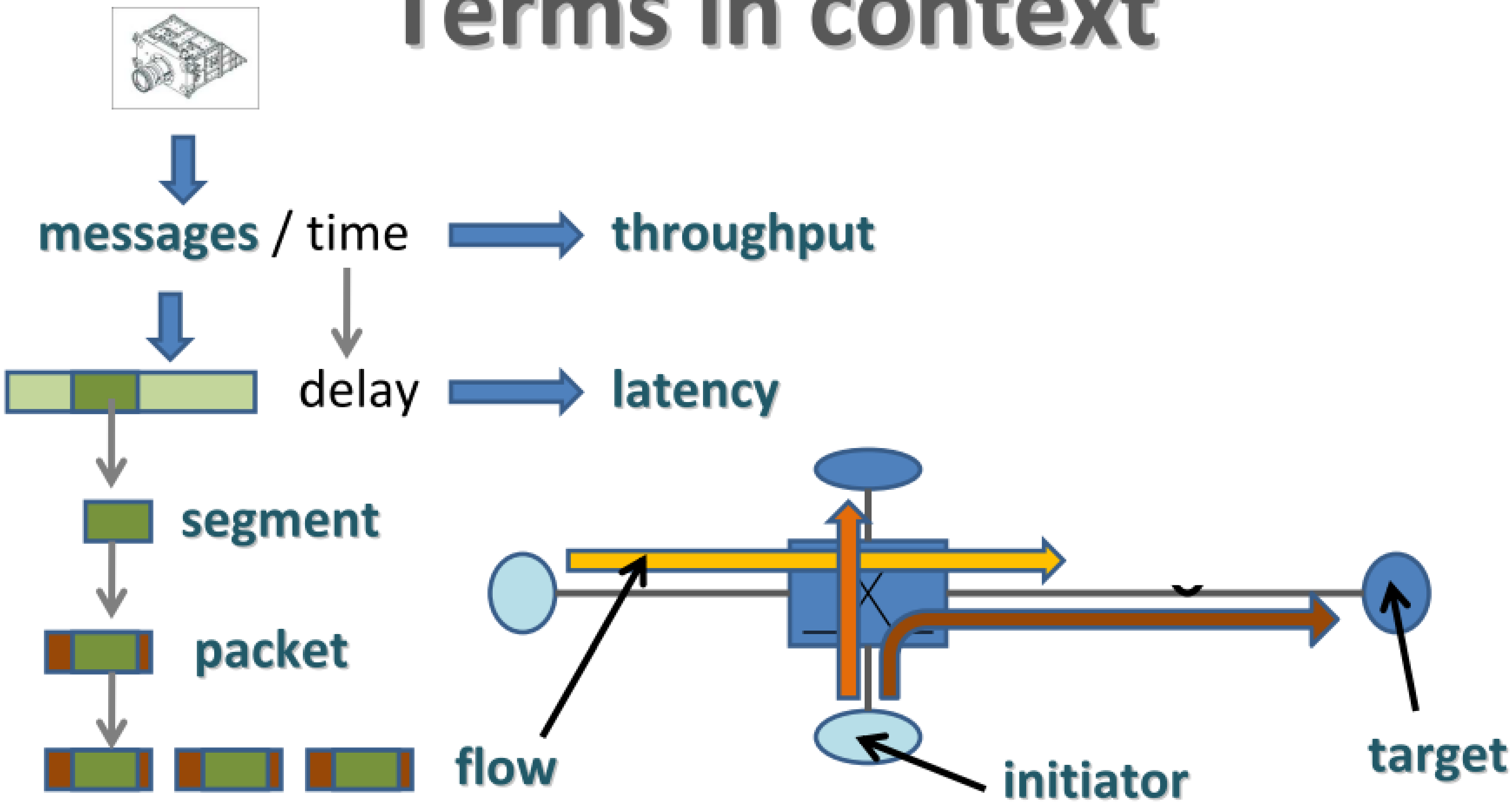
SpW-D performance and parameters

- Performance depends on the following parameters:
  1. Link speed
  2. Slot period
  3. Maximum data length of the RMAP packet

- Link utilization determines the efficiency of the protocol and is a function of the previous parametres.

- Network latency and processing time of SpW-D devices determine if a set of parameters are valid

Terms in context



Link speed

- The higher the link speed the higher the performance of SpW-D
  - The maximum link speed determines the maximum performance of SpW-D
- So, if we want to set the parameters for maximum performance we should set them based on the maximum link speed (200 Mbit/s)
  - Lower link speeds can be accomodated using multi-slot scheduling (multiple consecutive slots for a single RMAP transaction)
    - One transaction in 2 consecutive slots for 100Mbit/s devices
    - One transaction in 4 consecutive slots for 50Mbit/s devices

Slot period

- The slot period must be unique in the network
- The lower the slot period the lower the latency
  - Target: less than 150µs slot period, 5.4ms epoch
- The minimum slot period is constrained by the protocol header, the network latency and the processing time.
  (15-20µs @ 200Mbit/s)
- The slot period should be suitable to be use for global timing synchronization
    - For example, 1 second divided by the slot period could be a power of two:

Why segmentation?

- Trade off of the data length field in the RMAP packet:
  - A small data length increase the protocol overhead due to the protocol header and rmap transaction network and processing delay.
  - Big data lengths increase the slot period and therefore, the latency.
- High data rate traffic characteristics:
  - Use big packets to achieve better processing efficieny
  - Requires long slot periods and increase the latency
    - High data rate packets of 4Kbyte requires >150μs
  - It can support small slot periods if we use multi-sloting, but this increase the latency of other messages tha use the same link(s).
- Segmentation is required if we want to send payload packets without increasing the latency of other data flows.
  - Maximum segment size = RMAP maximum data length

Maximum segment size

- A small segment size increase the protocol overhead
  - Due to the protocol header and rmap transaction network and processing delay.

- A bigger segment size is inneficient if the user packets are small, BUT:
  - Small packets are usually command and control messages, that are not as common as payload data segments (high data rate messages).
  - A bigger segment allows to guarantee that a command and control is sent in a single segment.
    - The latency of a control message is then the latency of a single segment

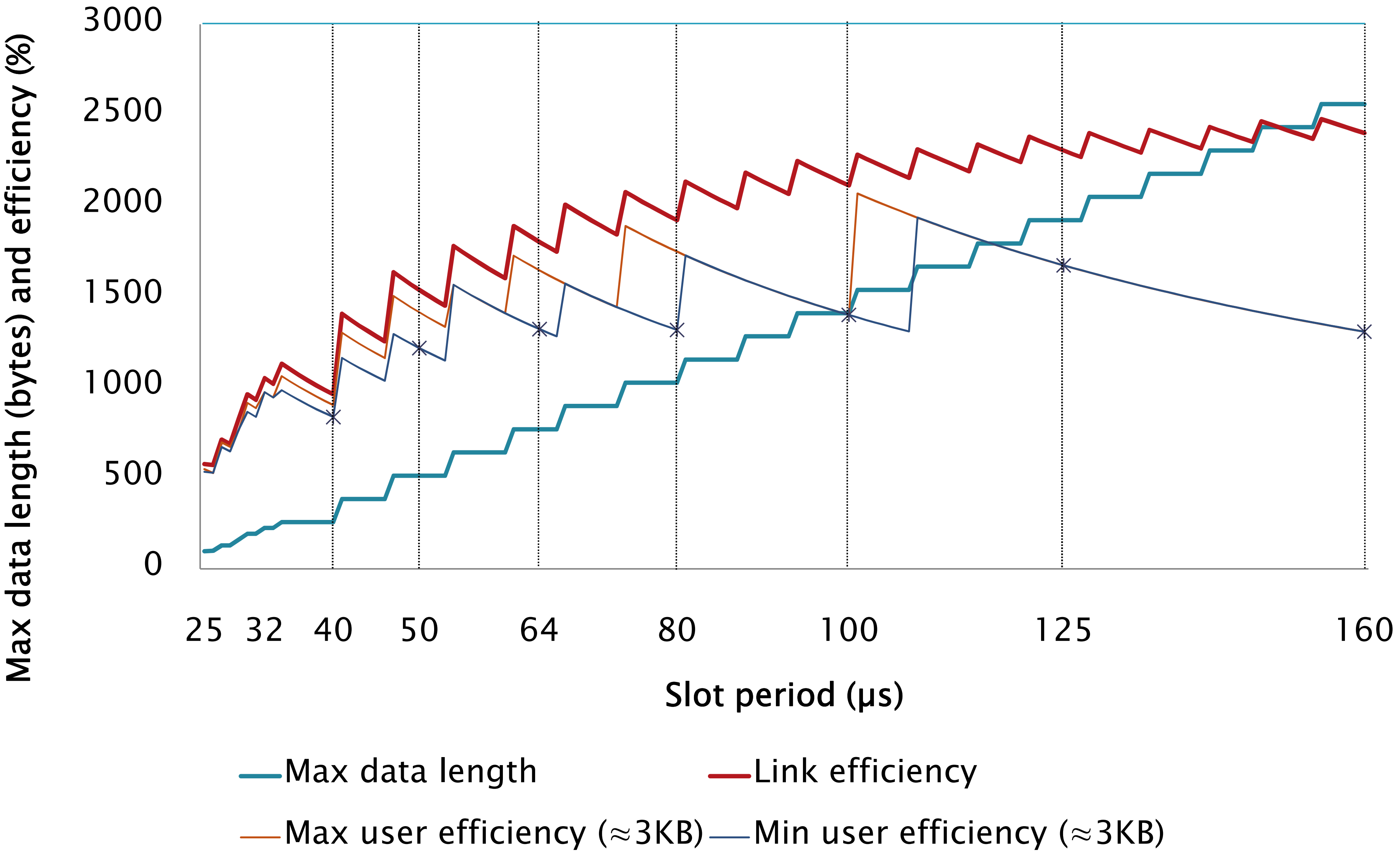
- If payload mesage size is a multiple of segment size the efficiency is maximized.

  Payload message size is usually a multiple of a power of 2

Segment size should be big enough to accomodate any low latency message
Segment size should be a multiple of 128 or 256

Example of a trade off plot

- Methodology and assumptions
  - Segment size is the maximum allowed by the slot period
  - Segment size is a multiple of 128 bytes
  - Link efficiency is based on the ratio between SpW-D user data rate and SpW user data rate.
    - Assumes segments are always filled with user data
  - User data rate efficiency takes into account the fact that the segments are not always filled with user data
    - Max user data rate efficiency: use the ratio (10%) between command and control packets (100bytes) and data packets (3Kbytes).
    - Min user data rate efficiency: data packets of 3Kbytes+1



Longer slot periods increase the latency of low latency messages but do not always improve the actual data rate of high data rate messages of around 3Kbytes

Trade off results

Slot period	Max segment size	Link efficiency	Max user data rate efficiency	Min user data rate efficiency
40	256	32%	30%	28%
50	512	51%	47%	41%
61	768	63%	57%	46%
64	768	60%	55%	44%
80	1024	64%	58%	44%
100	1408	70%	46%	46%

The best compromise latency/throughput/timing synchronization/source buffering space, is 61μs slot period with 768 bytes segment size.

The maximum data rate possible is 100Mbps. Higher data rates can be achieved with multi-slots (up to 130Mbit/s)

SpW-D Channel concept within a node

- A channel (or virtual channel) wraps a single RMAP message configuration with the allocated slots for this message. It also provides the sending status and error reporting.

- Multiple channels can be active at the same time. This means that they are sending segments of multiple long messages.
  - This increases the global throughput when they are using different slots.
  - If multiple channels are allocated to the same slot, the highest priority one (usually associated to command and control) will be send first.

SpW-D Channel concept (2)

- A channel does not send the first or the next segment of a message if the host indicates that there is no data available
  - Data available status can be changed at any time to support sporadic asynchronous messages or data coming from a FIFO interface.

- SpW-D checks the channel with the lowest number first, to see if there is data available and if it is allowed to send in the current timeslot.
  - If not selected, it will check the next channel with increasing numbering.

SpW-D Channels example

priority ↓

Channel	type	Segments to send per epoch	slots	Destination	Data ready
Ch0	Control	M0-1	0,2,4	A	No
Ch1	Data	M1-1, M1-2	0,2,4	A	Yes
Ch2	Data	M2-1, M2-2	1,3	B	Yes

Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	
M1-1	M2-1	M0-1	M2-2	M1-2	

↑ At this instant Host wants to send control message, sets data ready (Ch0) = yes

SpW-D Channel Advantatges

- Implements a priority scheme that removes the need to allocate slots for sporadic messages.
  - Only the throughput they require must be taking into account.
- Allows to send segments of messages going to different destinations concurrently, without having to wait for the first one to finish before sending the next message.
  - Slots for the second destination are not wasted while sending to the first destination.
- It does not add complexity to the basic SpW-D implementation if segmentation is required.

Segmentation

- The targets needs to identify if a RMAP packet is a segment of a message (Big RMAP packet) and if it is the start or the end segment.

- Two bits required (to be implemented in the Transaction ID field of RMAP packet)
  - First/start segment flag
  - Last/end segment flag

- When single segment both bits are set
- When middle segment both bits are cleared.
    - If first segment follows a middle segment then the last message received must be considered incomplete (equivalent to EEP)

Error detection

- Time-Code error: set when a Time-Code is received too early or too late (or it has been lost)

- Per each channel the following conditions are defined:

  - TX error: set when the RMAP command header is invalid or there is a bus error. Disables the corresponding channel.

  - TX congestion: set when a RMAP packet is still being send at the beginning of the next slot.

  - RX error: set when the RMAP reply is not received or when it has been received with an error code. Disables the corresponding channel.

  - Late reply: A reply has been received after the end of the slot but before the deadline set for this channel.

Late RMAP reply allowed

- If there is an error in the network, temporarily network congestion can affect any channel of the network
  - The routers take time to spill the packet(s) that are using the malfunction link or device. This time could be higher than the duration of a timeslot
  - Channels that are using working links or devices should not be disabled even if they experiment contention

- It may be better to flag that there has been temporally congestion than to disable the affected channel (avoid error propagation)
  - An RMAP reply is considered valid if it has been received after a programmable number of slots.

Sequence number

- A sequence number must be used for
  - Matching a RMAP reply with the corresponding RMAP command
  - If the increment bit of RMAP is not always set (i.e remote writing to a FIFO interface), the RMAP target needs to know if the current segment received is out of order.
    - If multiple channels are used, there must be an independent sequence number per channel

- The sequence number is stored in the transaction ID field of an RMAP command and it is incremented per segment sent.

Transaction ID

- One byte of the transaction ID field is reserved to be used by SpW-D
  - The other byte can be used by the user and it is . application dependent.
    - RMAP standard states that the transaction ID field is optionally provided to the destination Host.
- Formatting of SpW-D transaction ID byte
  - Option 1: SpW-D does NOT support the non increment address option of the RMAP standard

Start Seg (1 bit)	End Seg (1 bit)	Sequence number (6bits)

  - Option 2: SpW-D supports the non increment address option of the RMAP standard

Start Seg (1 bit)	End Seg (1 bit)	Channel number (5bits)	Sequence number (1 bit)

Send and wait scheme requires a single bit

Error recovery

- Retry mechanism
  - Retry must be done in the next slot allocated to the same channel.
    - Retry is not performed unless it is indicated by the host or the network manager by clearing the error condition.

- Automatic enabling a channel when previous channel number got an error.
  - Allows to set a channel that will be used to send a notification message to the network manager if another channel fails.
  - Allows to set an automatic retry using another path or to another destination.