UNI
Requirements from Industrial Automation (IA)

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Goal of this contribution

- Consensus on the timeliness parameters of UNI
  - Stream request/ response

Agenda

- Industrial automation requirements
  - Quick recap
- Flexible vs. fixed stream schedule
- Stream request and response requirements
  - Considering feedback and comments (from previous contribution)
- Proposed UNI (focus on timeliness aspects)
  - Comparison of required and existing parameters

Industrial Automation (IA) Requirements

Quick recap

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Recap: IA requirements

Converged network supporting Plug & Produce

- Need for incremental network configuration and resource allocation
- Bridge and end station components need to inform about their available resources
- Application engineering independent of network engineering

Recap: IA requirements

Wide range required by applications

- Expected IA system

2* PLCs	1000 Devices
1024 Talkers	**16** Talkers
25µs to 4s (10^{-6} to 10^{0}) Cycle length	**25µs to 4s** (10^{-6} to 10^{0}) Cycle length
64 to 2000 (octets) Frame size	**64 to 2000** (octets) Frame size
65.536 (octets) Total sent data	**3.072** (octets) Total sent data
1024 Listeners	**16** Listeners
65.536 (octets) Total received data	**3.072** (octets) Total received data

large range

large amount

*Representative number of PLCs, not maximum

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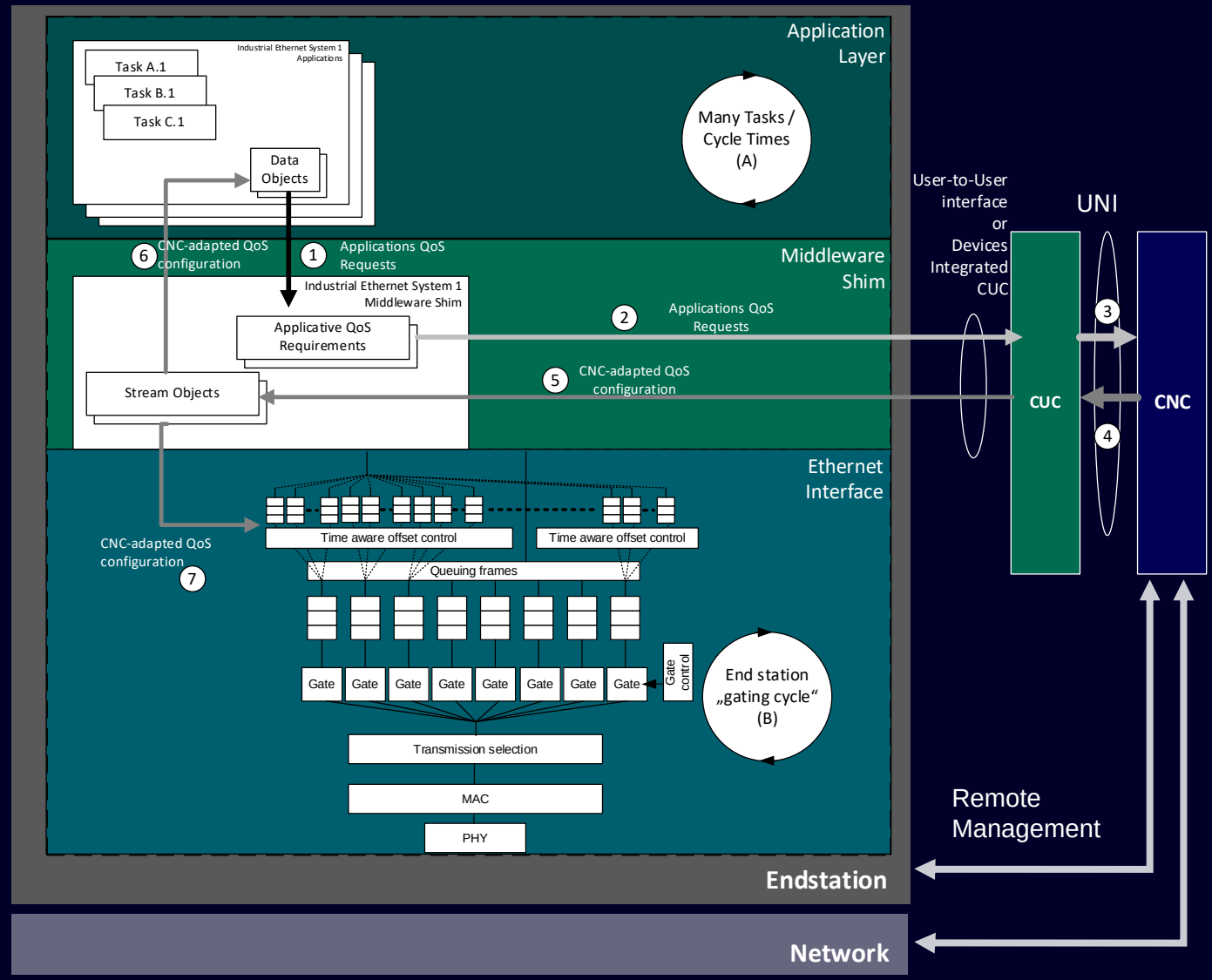
Recap: Industrial Application

- Communication requirements from IA application layer
  - Data objects (application and communication relations)
- Middleware (CUC part of middleware)
  - Translates application layer requirements into stream requirements
  - Sends Stream requests to CNC via UNI
- CNC responses to middleware via UNI
  - Setup comm based on stream responses
- CNC establishes stream using remote management



Extracted from IEC/IEEE 60802 D1.3

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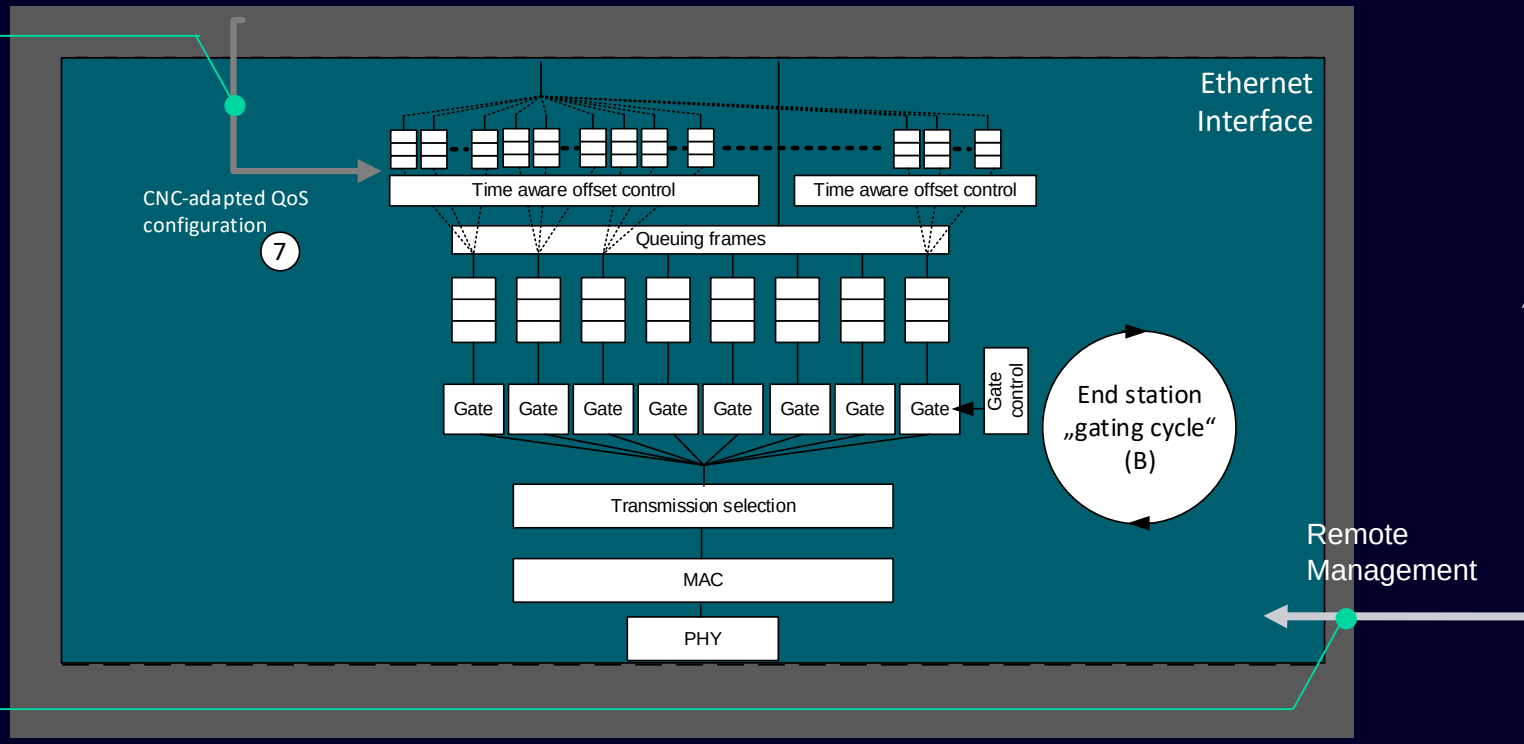
Recap: Ethernet Interface as per IEC/IEEE 60802

Time Aware Offset Control

- Stream(stream group)-based queue
- Talker added by application layer



Gate Control (Qbv)

- Priority-based queue
- Triggered by gating control list

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Recap: Frame injection

Based on reduction ratio concept

- Common base-cycle
  - Qbv gating cycle
- Stream interval expressed by reduction ratio
  - power of 2 multiple of gating cycles

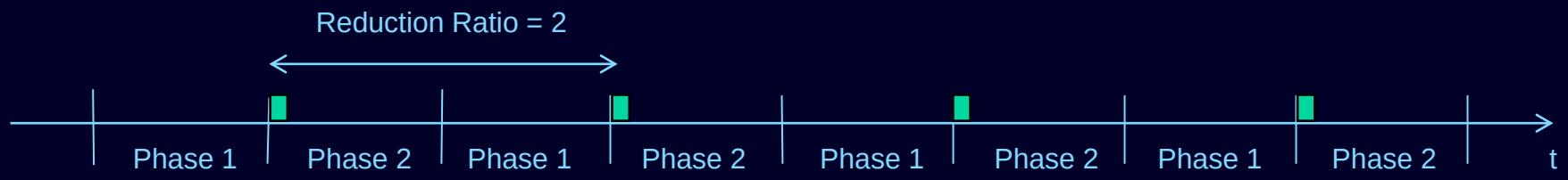
Facilitates implementation

End station centric representation

- Common gating cycle behavior
  - Defined once
- Individual gating cycle behavior defined for each phase
  - Constrained scope (per phase)

Phase: identifies out of a set of gating cycles (w.r.t reduction ratio) the one in which the transmission of a stream starts.

For a stream with RR=n, max number of phases=n



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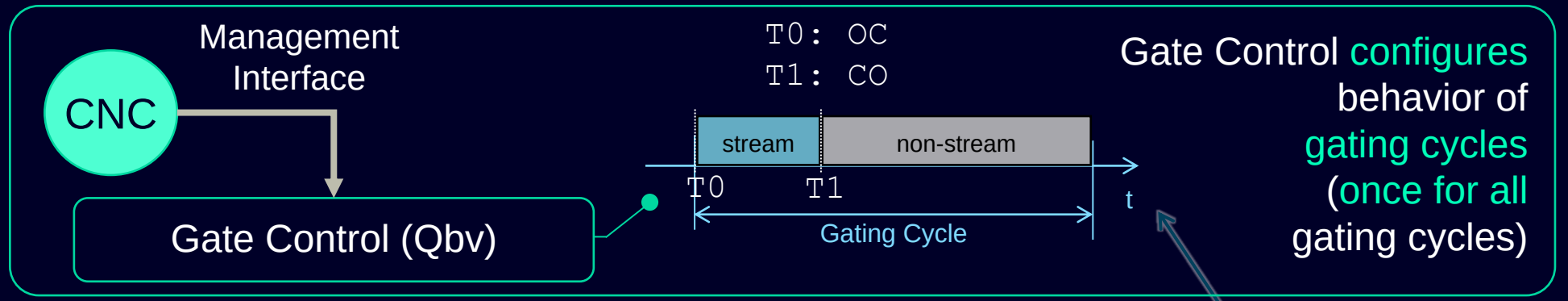
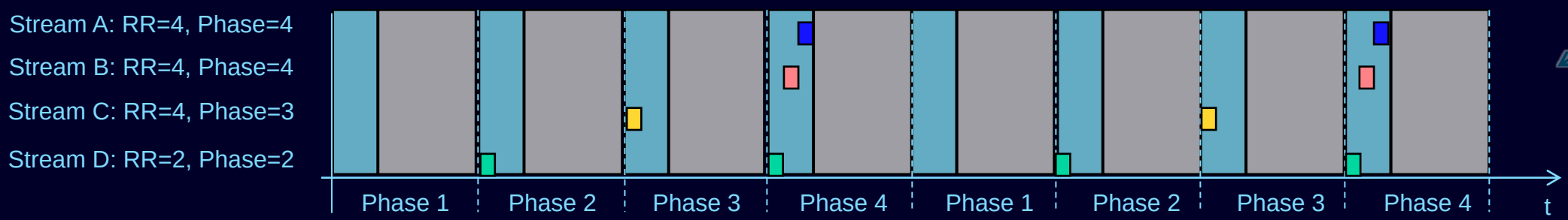
Recap: Frame injection (cont'd)



Gate Control configures behavior of gating cycles (once for all gating cycles)



"wire view" after gate control

Time Aware Offset Control assigns streams to gating cycles by means of phases (per stream response)

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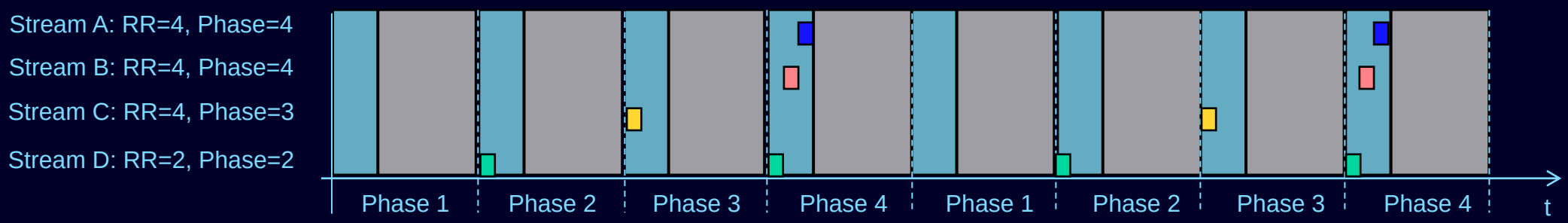

Time Aware Offset Control
assigns streams to gating cycles
by means of phases
(per stream response)

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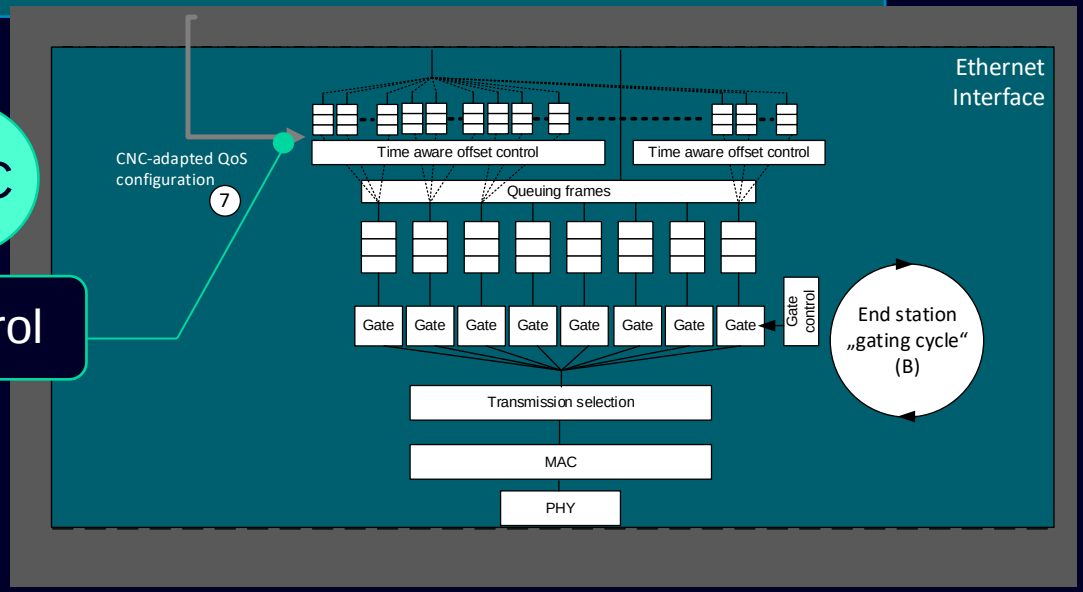
Recap: Frame injection (cont'd)

Transmission of frames in same gating cycle (phase)

- As burst ordered by priority (gate control)
- Then ordered by reduction ratio
- Then by sort-in position
  - For instance
    - after:



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Need for flexible stream scheduling

Flexible vs. fixed scheduling

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Motivation

Current Qdj does not cope with these requirements

1. Converged network supporting Plug & Produce
   1. Need for incremental network configuration and resource allocation
   2. Application engineering independent of network engineering

2. Wide range required by applications
   1. Large range, large amounts

This contribution addresses

- Means for flexible stream scheduling (resource allocation)

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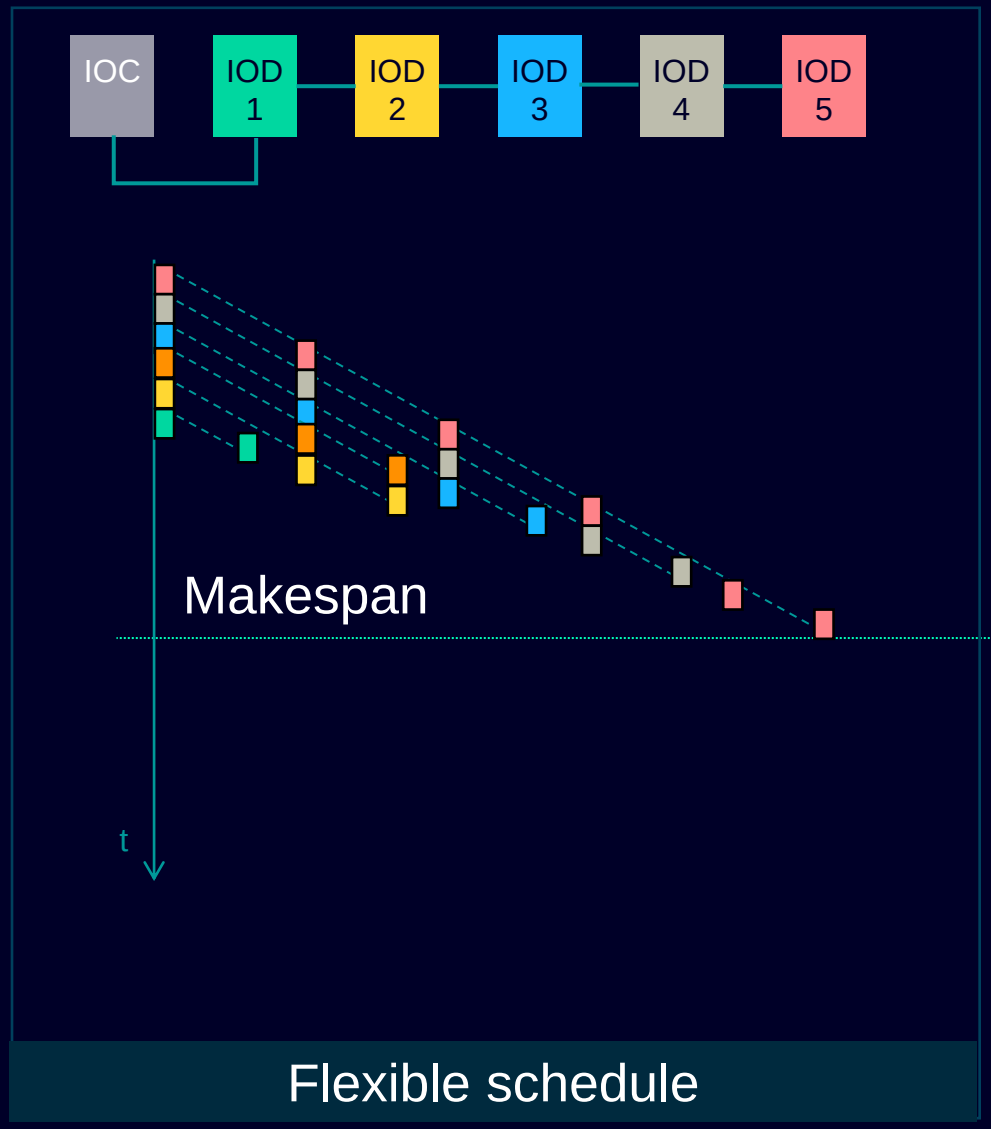
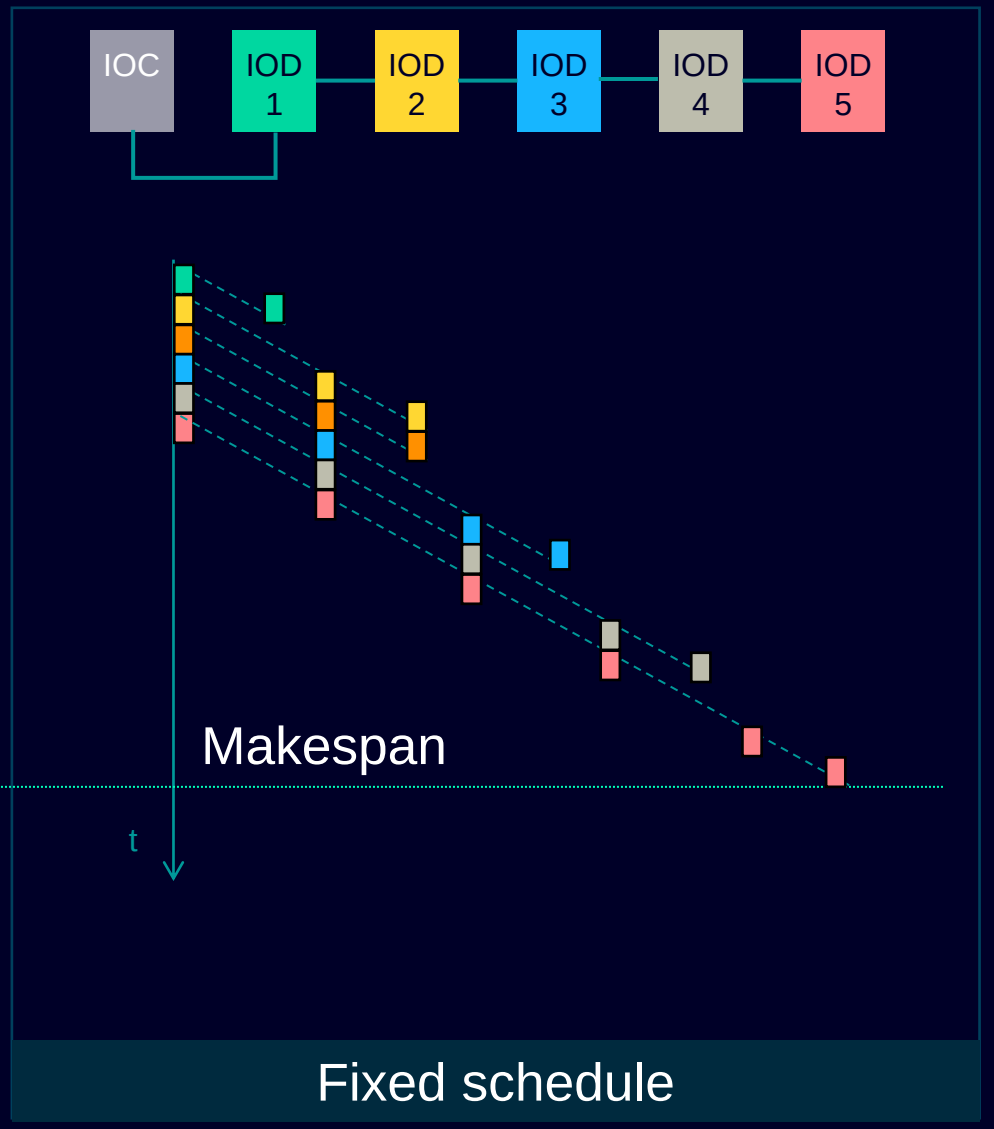
Flexible schedule allows for lower makespan than fixed schedule



Flexible schedule



Fixed schedule

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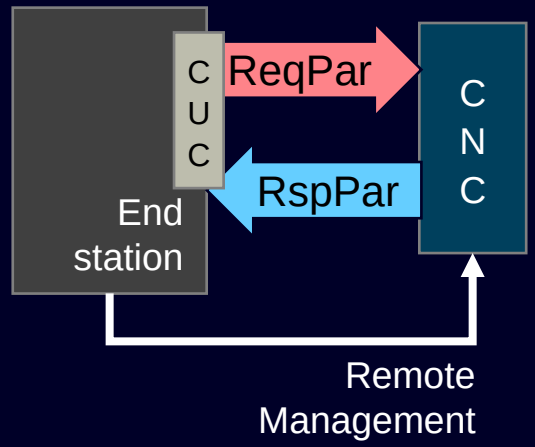
Current Qdj (presented in Qcc)

Qdj stream request parameters

1. Tspec
   1. Interval
   2. MaxFramesPerInterval
   3. MaxFrameSize
   4. TransmissionSelection
   5. TimeAware
      1. EarliestTransmitOffset
      2. LatestTransmitOffset
      3. Jitter
2. UserToNetworkRequirements
   1. NumSeamlessTrees
   2. MaxLatency



Qdj stream response parameters

1. StatusInfo
2. AccumulatedLatency
3. InterfaceConfiguration
   1. …
   2. TimeAwareOffset

After a stream is established, shifting its transmission time is not possible

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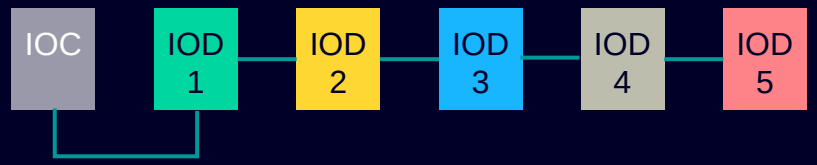
Importance of flexible scheduling: an example



Assumption

- 1 IOC, 5 IODs
- Line topology
- IODs powered in the same order as their IDs
- Streams requested as soon as IOD is connected*
- Streams
  - Talker = IOC, Listener = one IOD
  - Interval = 30 [time units]
  - Frame size = 1 [time unit]
  - Deadline = 15 [time units]

*one exception

Required flexibility (Plug & Produce)

- All stream requests cannot be sent as a batch

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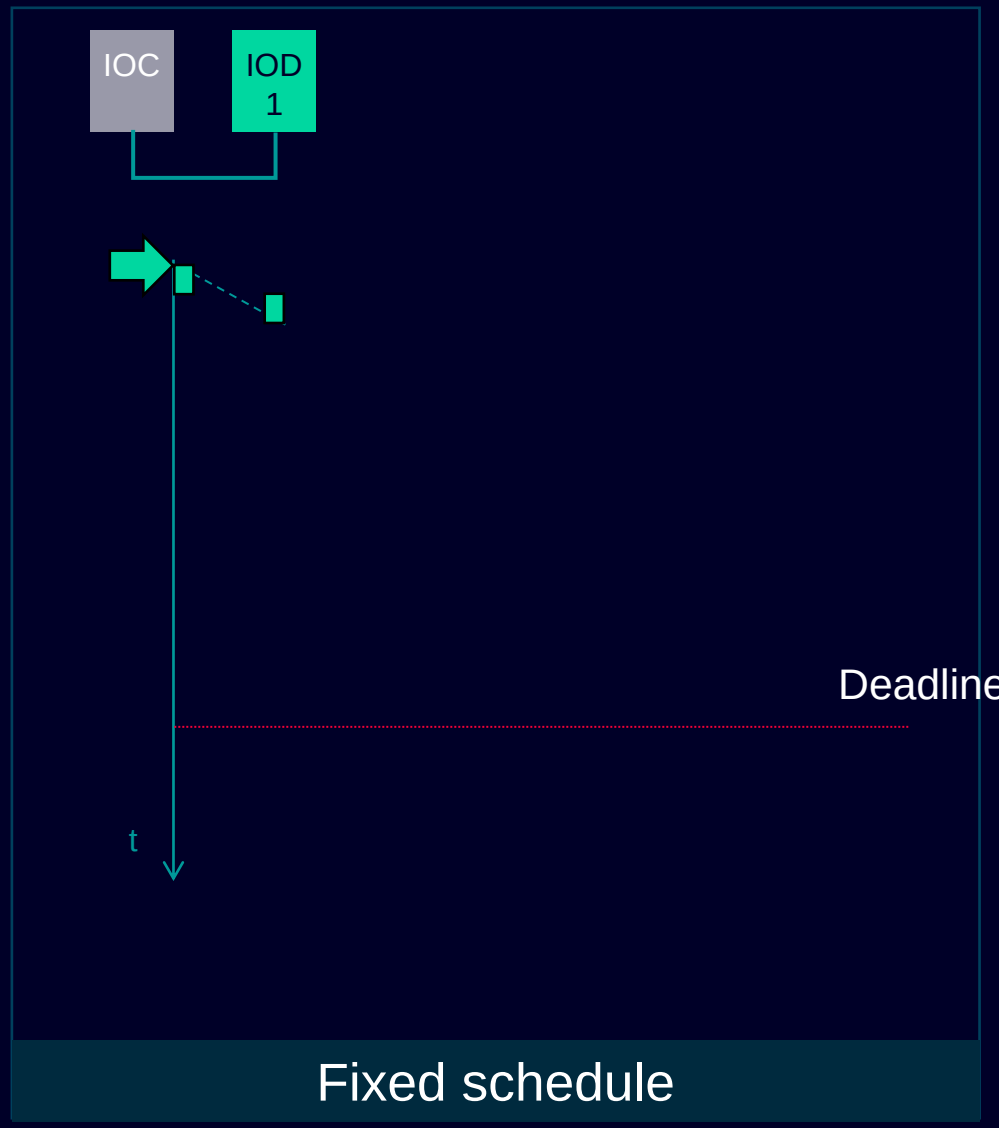
Fixed schedule example



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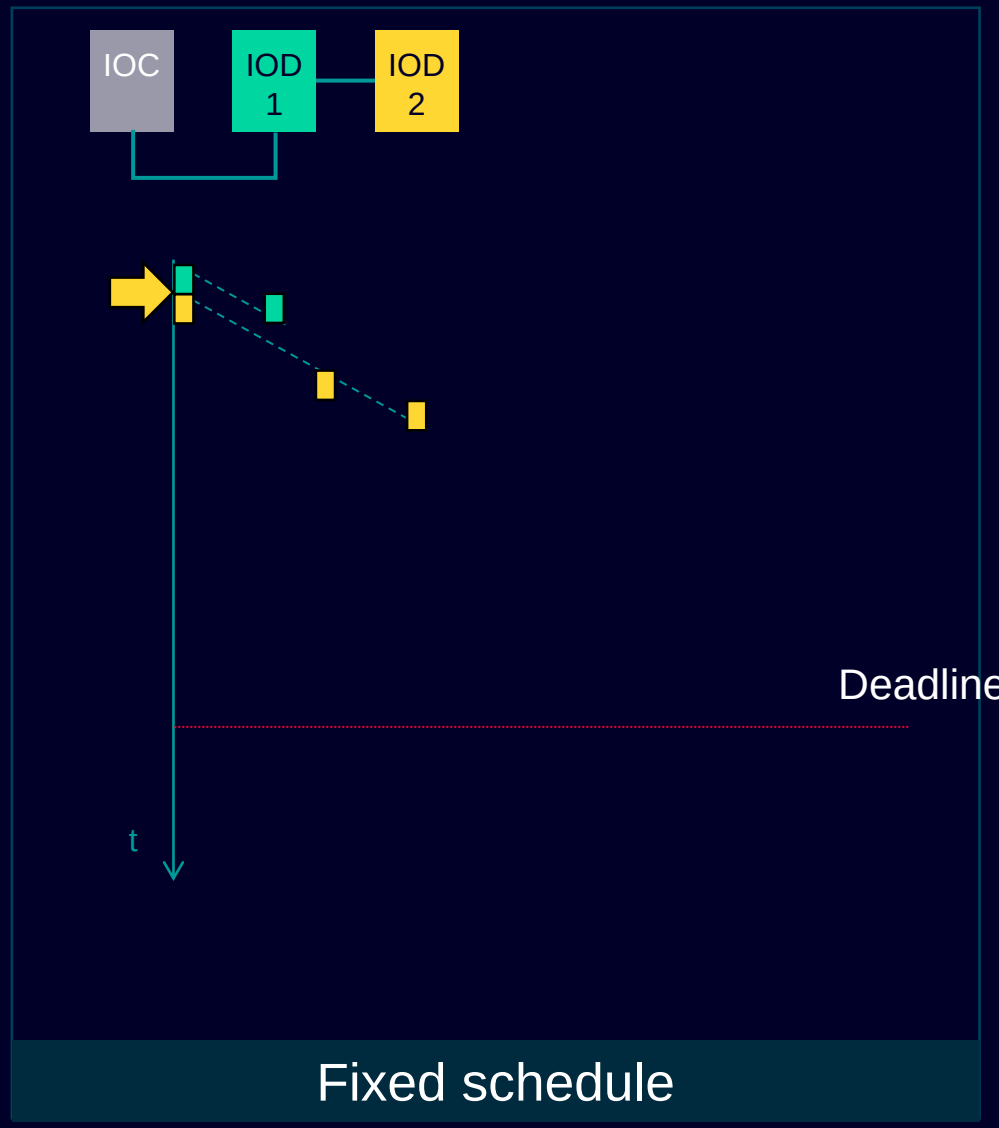
Fixed schedule example



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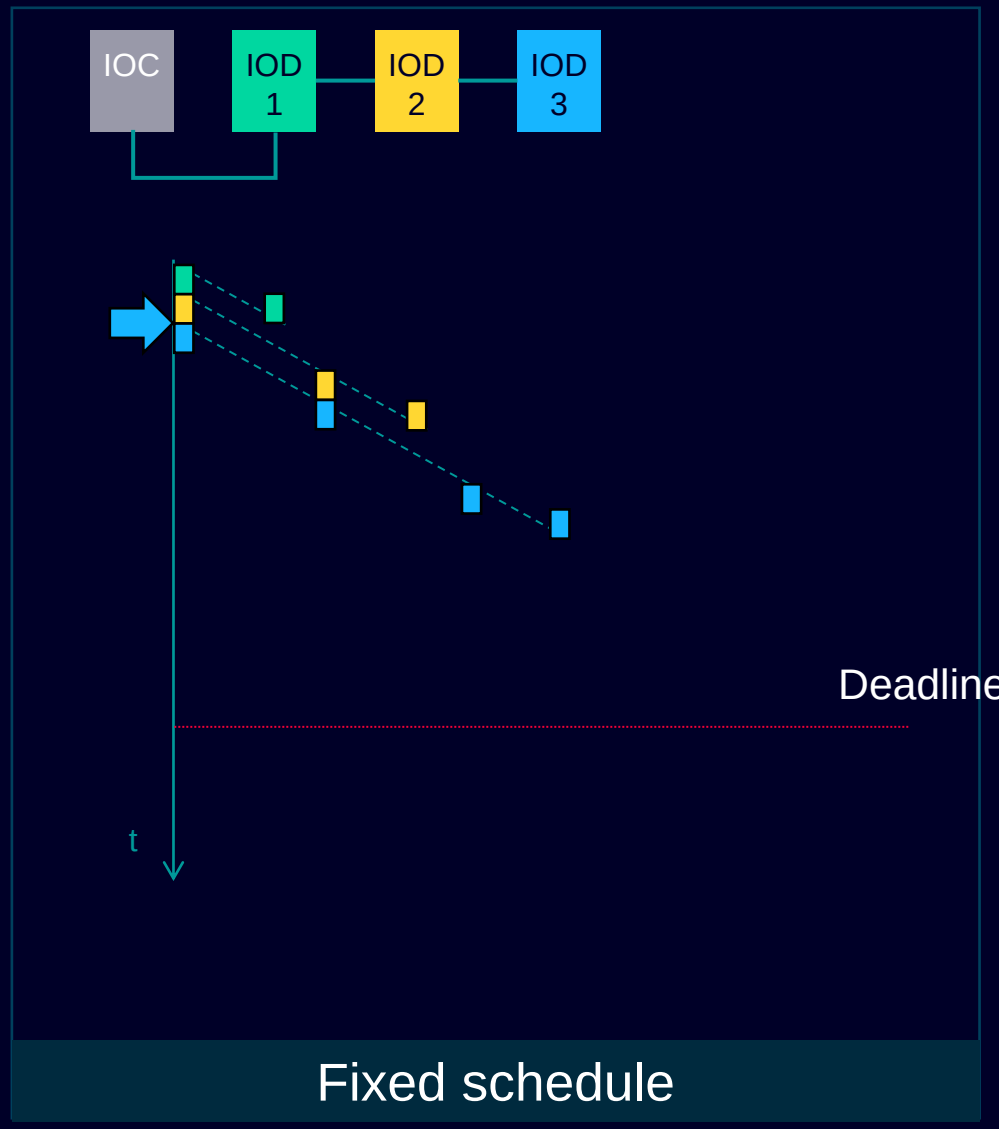
Fixed schedule example



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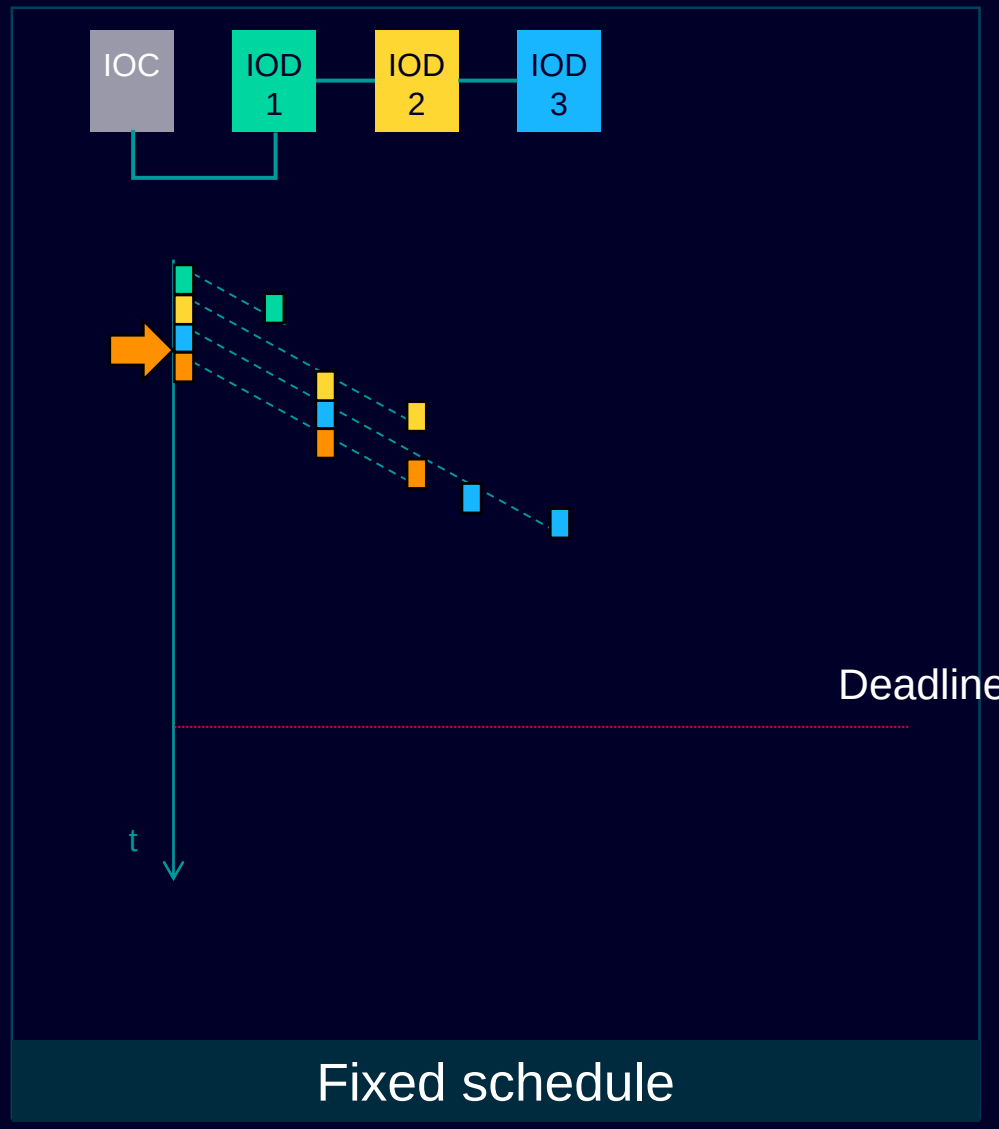
Fixed schedule example



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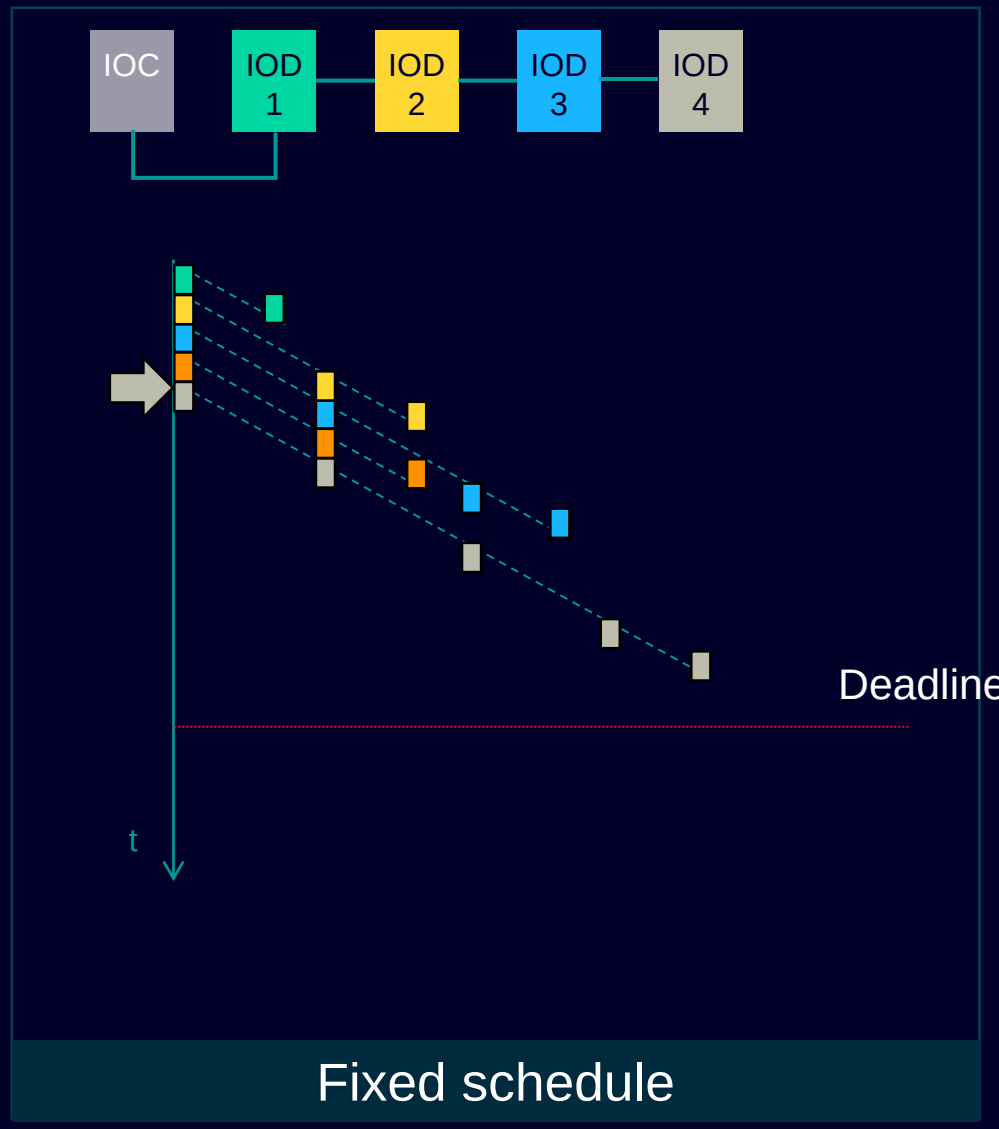
Fixed schedule example



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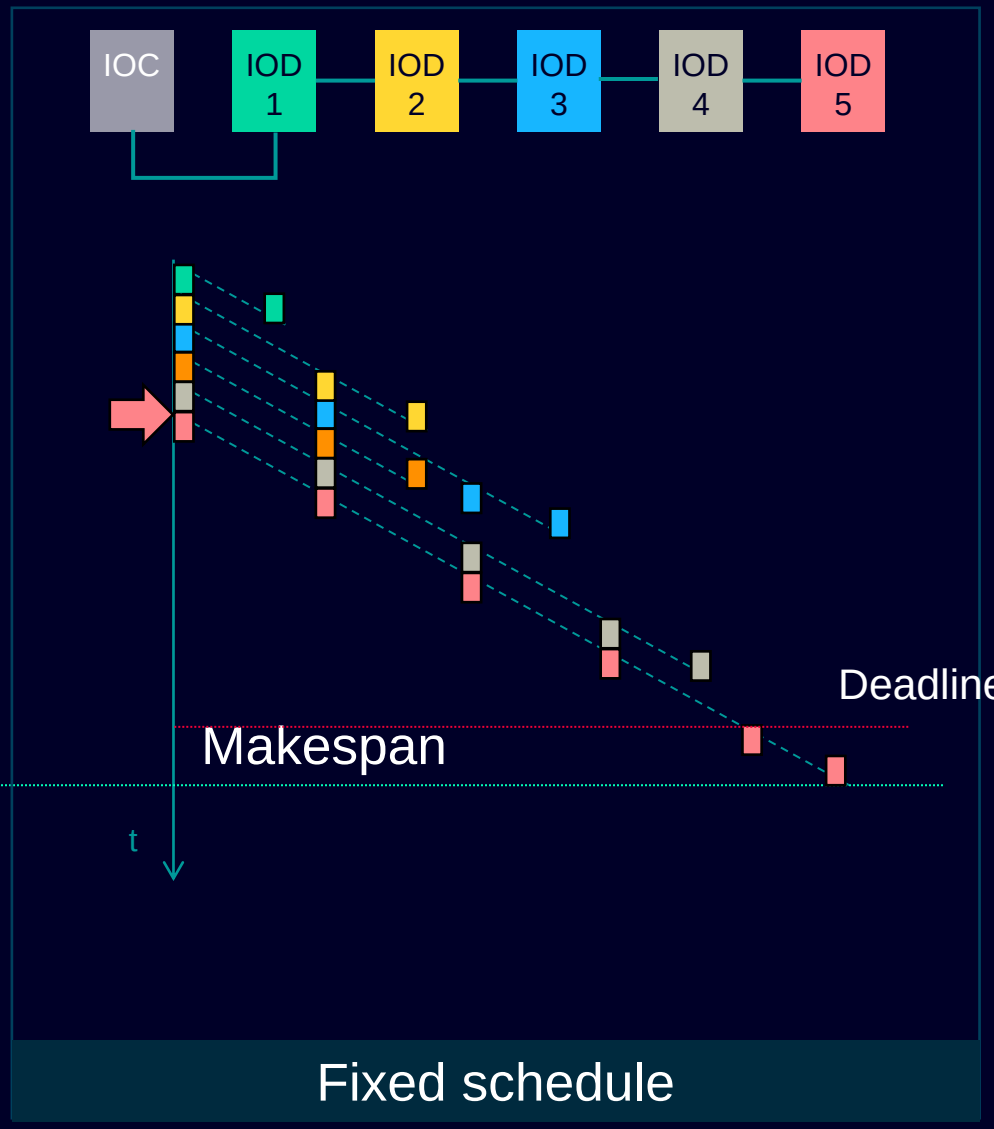
Fixed schedule example



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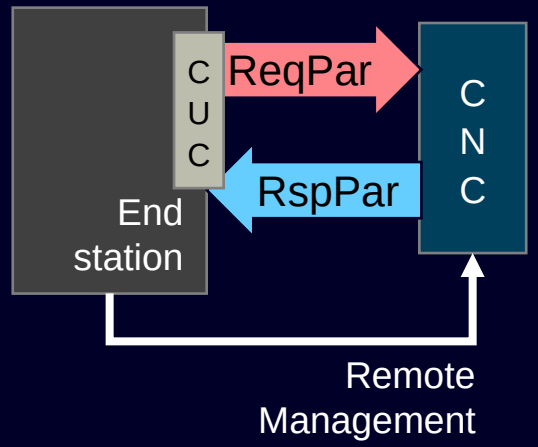
Proposal to Qdj

Proposed stream request parameters

1. Update interval
2. Communication deadline
3. Maximum frame size



Proposed stream response parameters

1. Phase
   1. Start of selected gating cycle
2. Sort-in position
   1. Flexible ordering within a gating cycle

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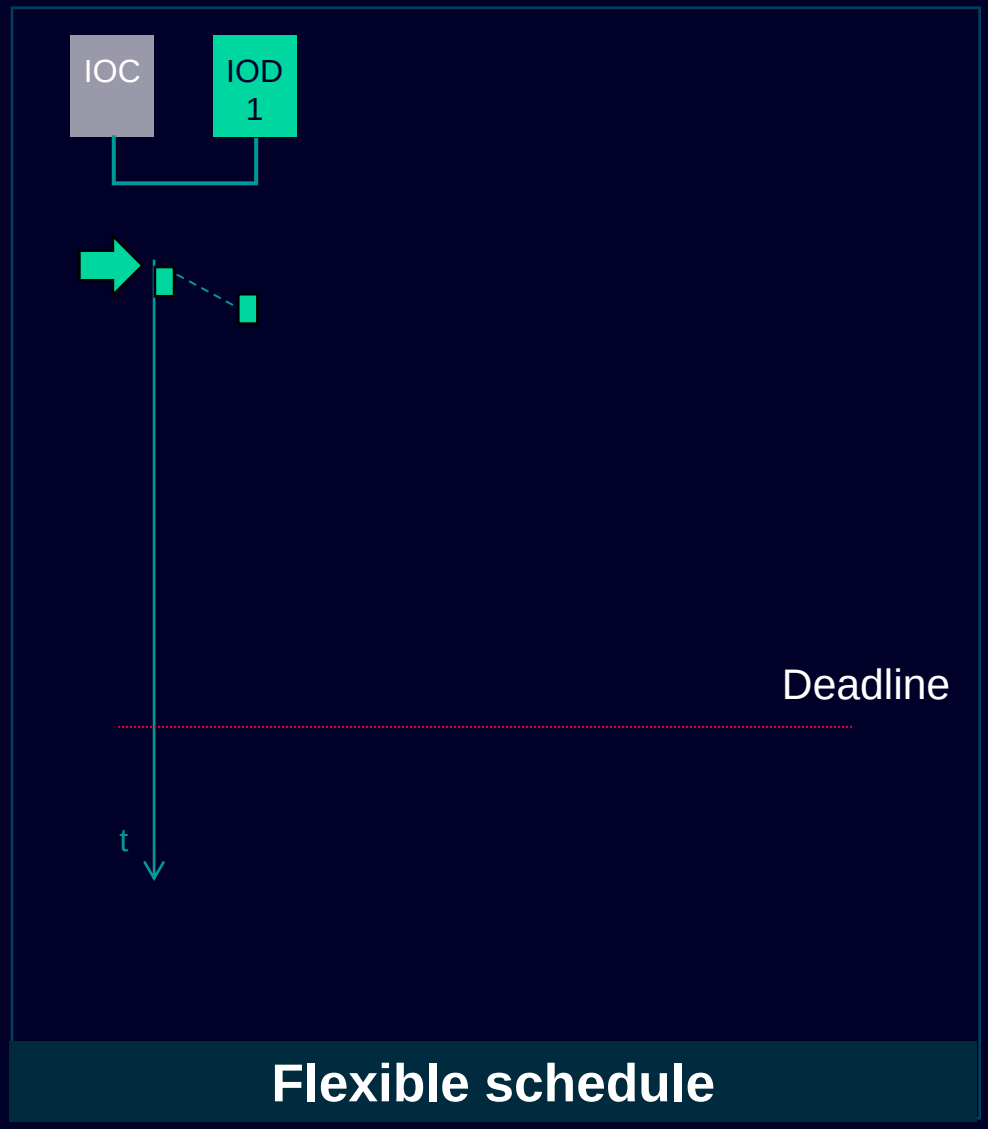
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD1

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = 0
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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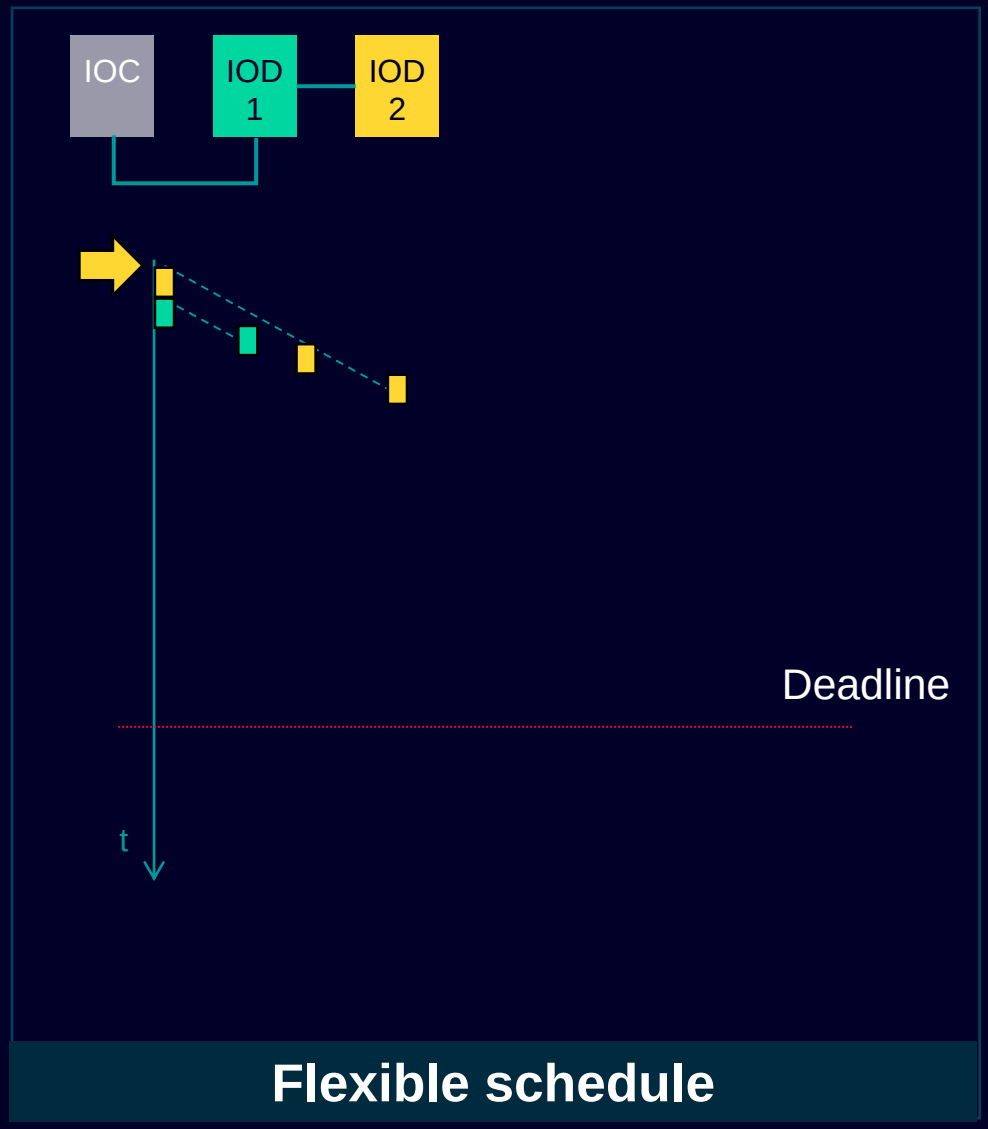
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD2

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = 0
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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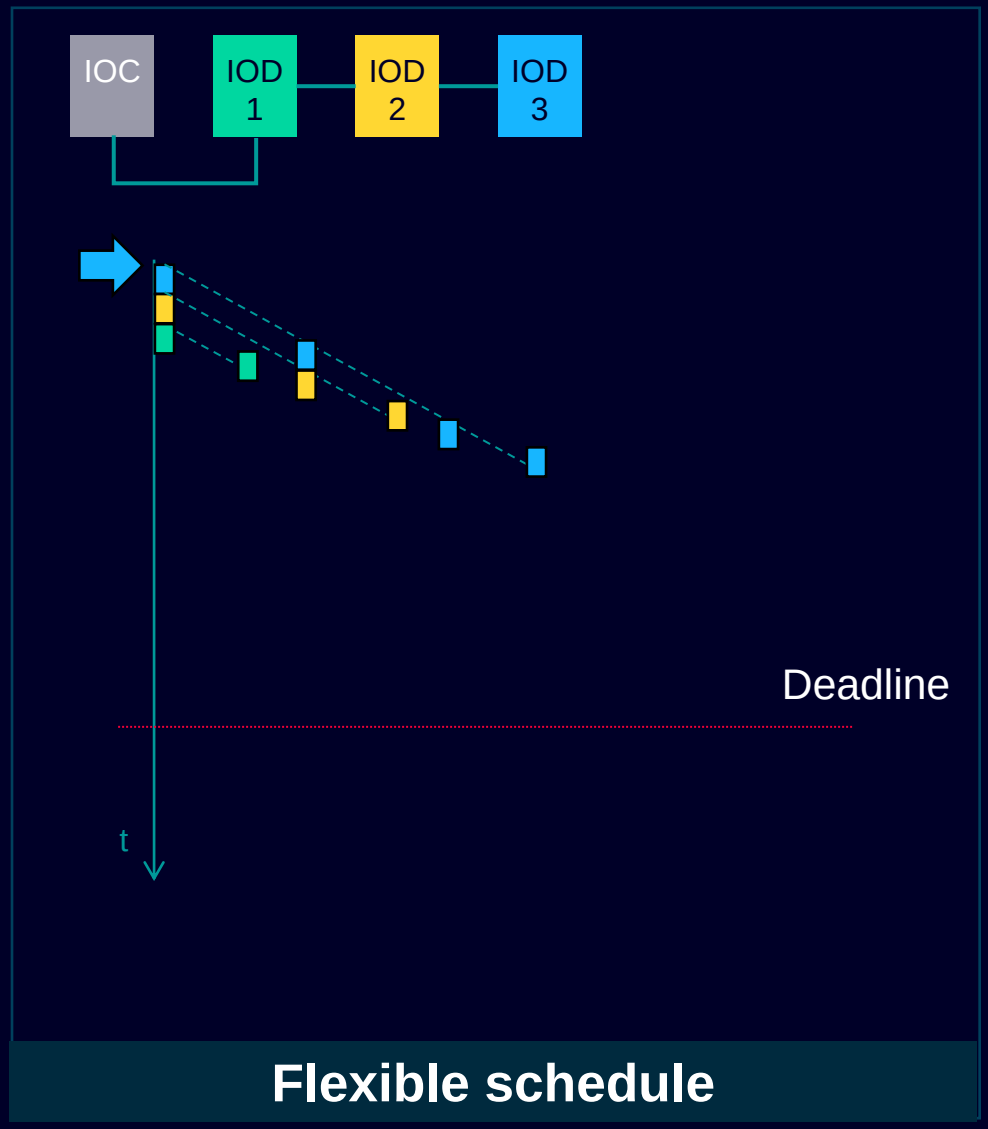
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD3

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = 0
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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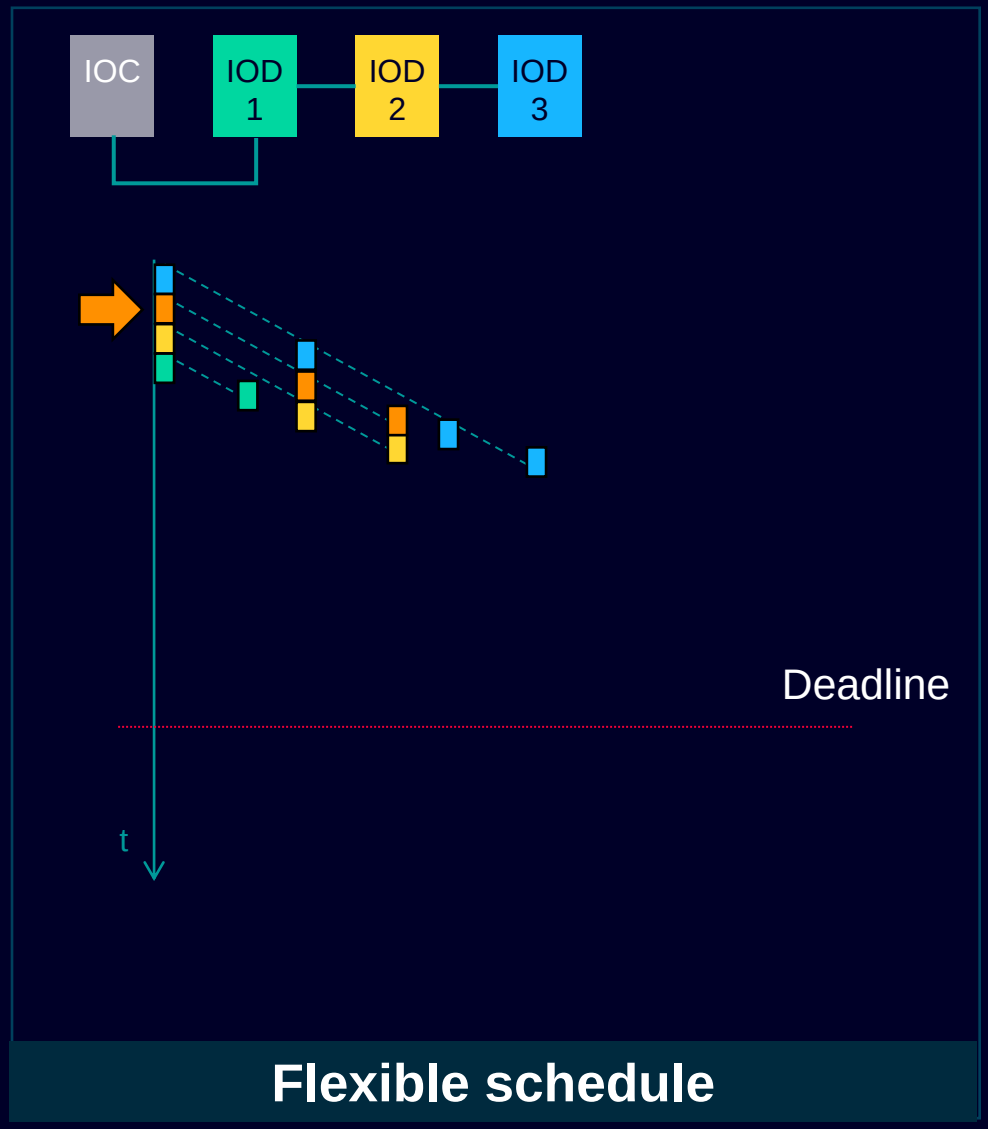
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD2

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = after
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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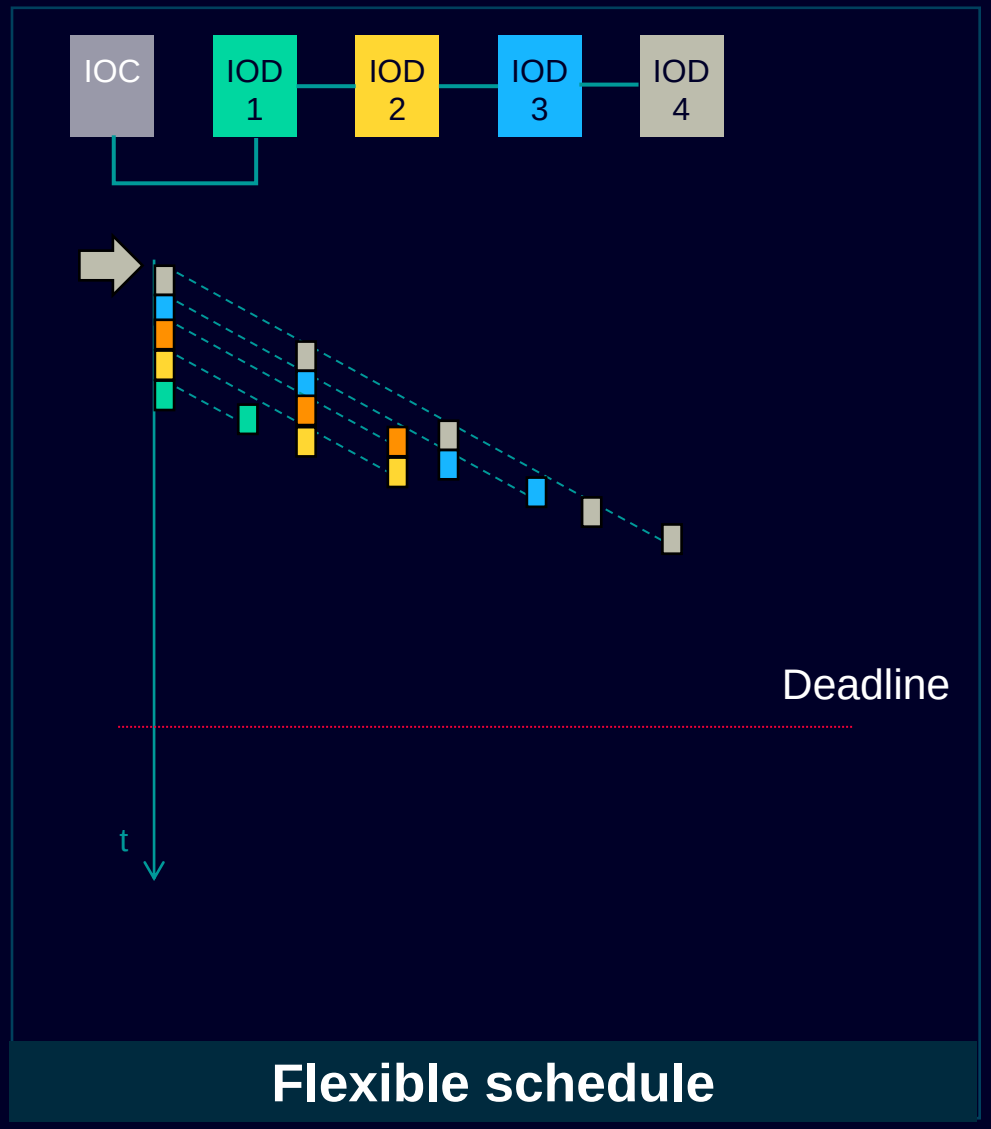
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD4

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = 0
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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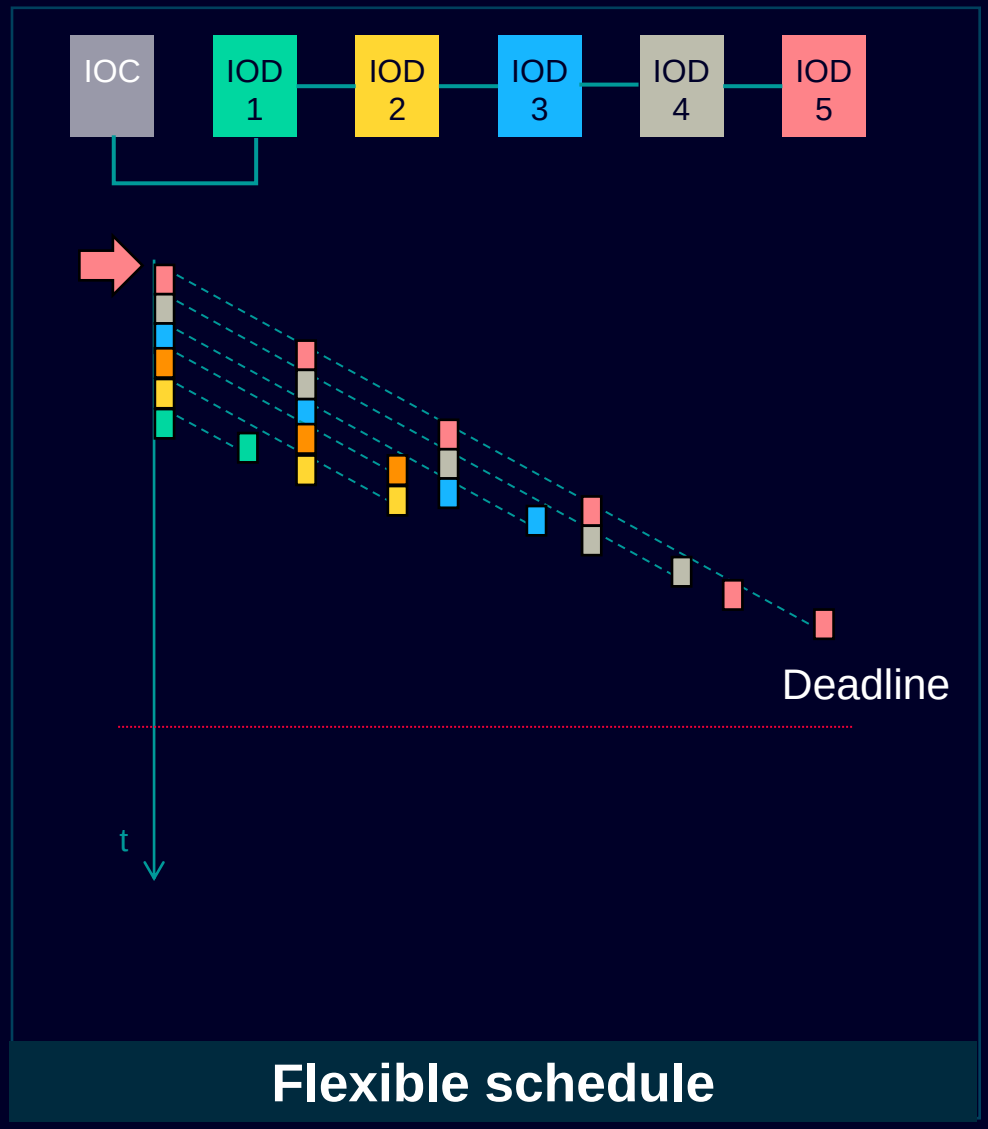
Flexible schedule example



- Proposed stream request parameters
  1. Update interval = 30
  2. Communication deadline = 15
  3. Maximum frame size = 1
  4. Talker = IOC, Listener = IOD5

Proposed stream response parameters

1. Phase = 1
   1. Start of selected gating cycle
2. Sort-in position = 0
   1. Flexible ordering within a gating cycle

Remote management

1. Gating cycle = 30

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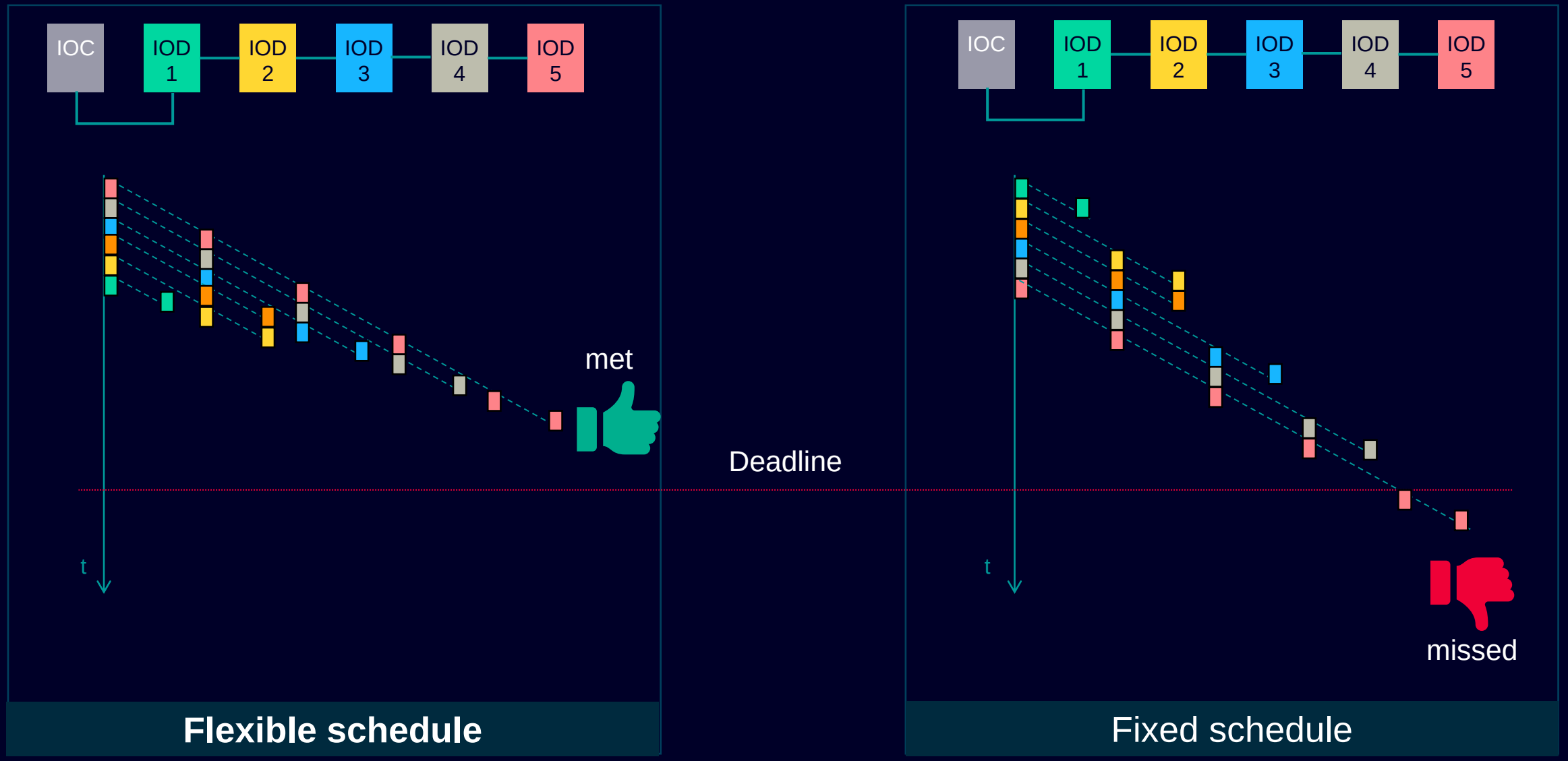
Flexible allows for lower makespan than fixed schedule



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Stream Request & Response

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Note on stream traffic types in IEEE/IEC 60802

- Isochronous
  - Transmission in sync with network and task
- Cyclic synchronous
  - Transmission in sync with network
- Cyclic asynchronous
  - Transmission in sync with network is optional

Examples in this contribution

- Isochronous

UNI parameters presented in this contribution

- covers all three types

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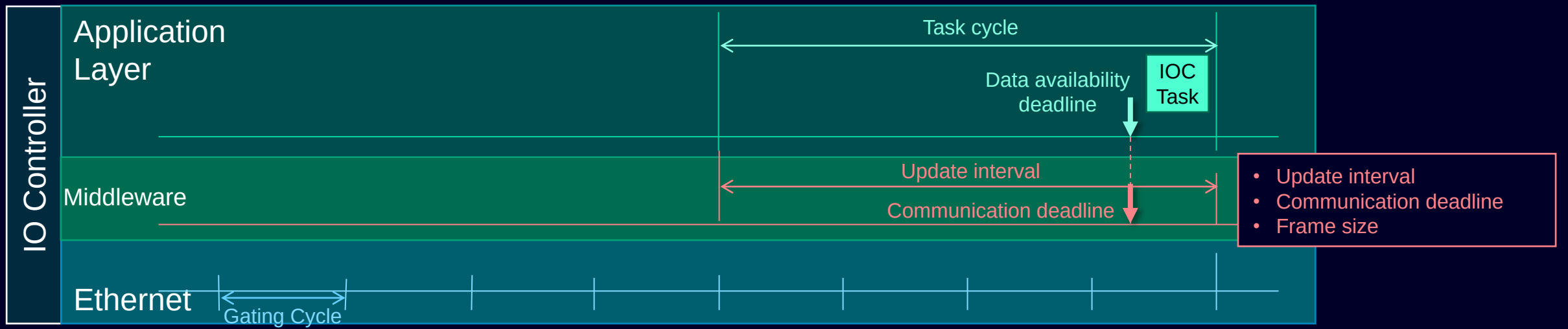
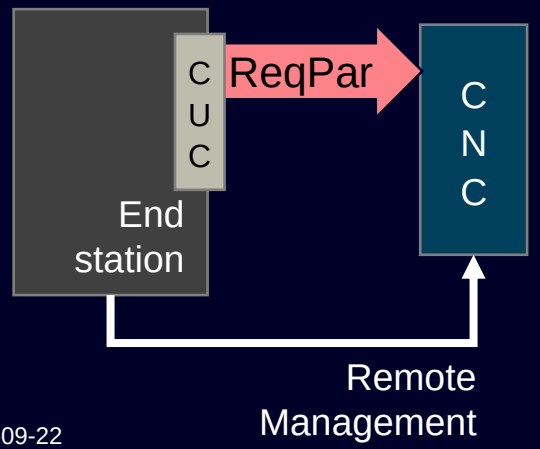
Stream request & response parameters



Stream request parameters

1. Update interval
2. Communication deadline
3. Frame size
4. …



Further stream properties

- Traffic class
  - ISO, CYC-S, CYC-A, …
- Redundancy
- Source, Sink
- …

Deferred to a future contribution

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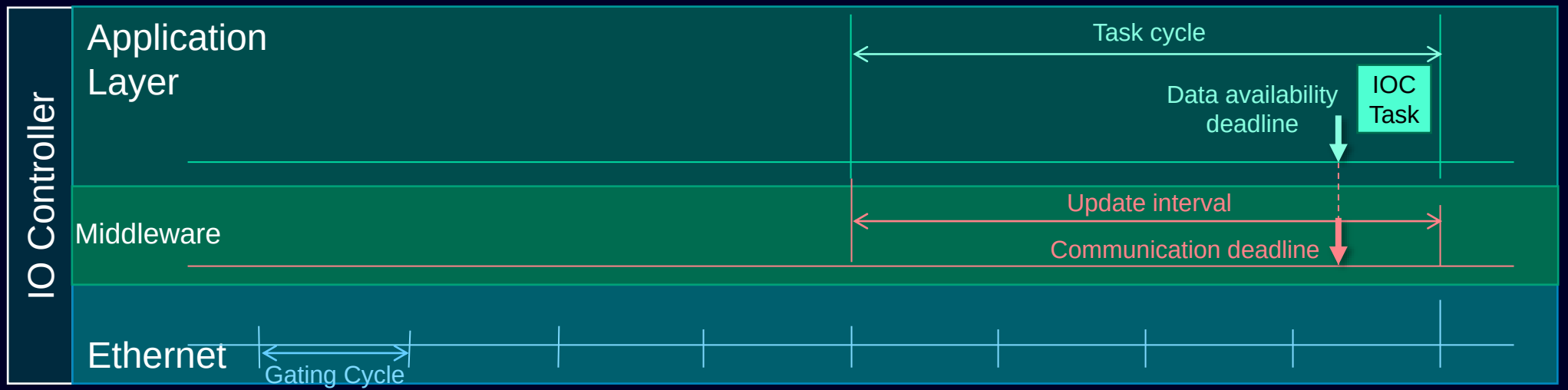
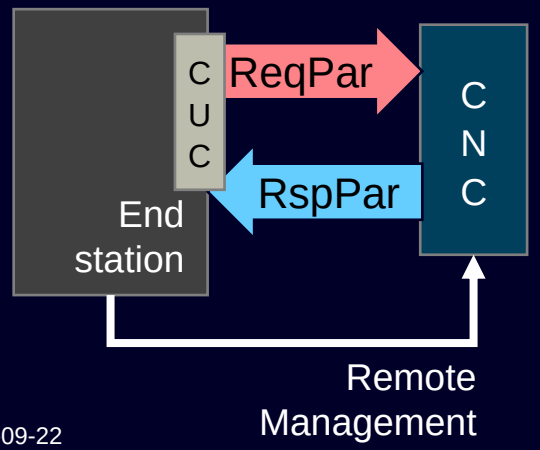
Stream request & response parameters



Stream request parameters

1. Update interval
2. Communication deadline
3. Frame size



Stream response parameters

1. Phase
2. Sort-in position
3. …

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User/Network Interface: Proposed parameters

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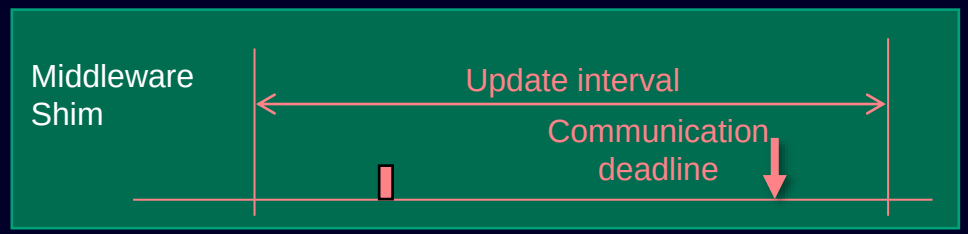
Stream Request over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream request parameters

1. Update interval
2. Communication deadline
3. Frame size



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Stream Request over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream request parameters

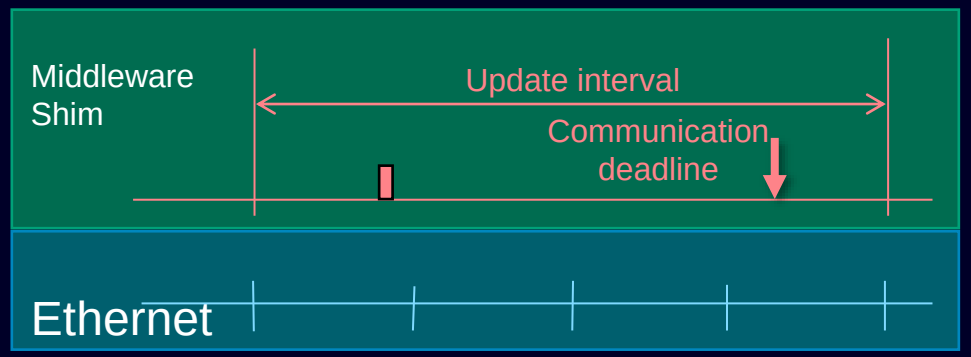
1. Update interval
2. Communication deadline
3. Frame size

Existing: TrafficSpecification.Interval (802.1 Qcc-2018 46.2.3.5.1)

Interval

- a sliding window of time, OR
- window of time aligned with the time epoch that is synchronized on the network

NOTE: The (length of each) Interval shall be an integer multiple of the gating cycle.



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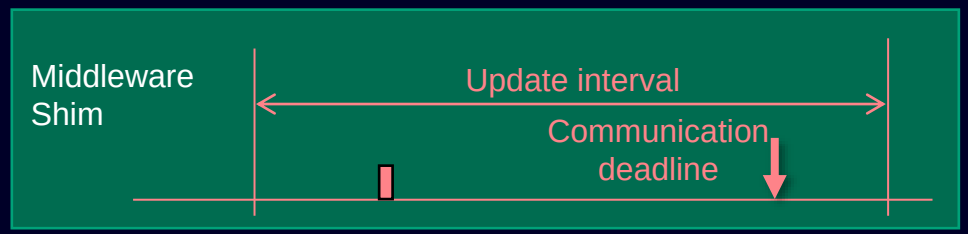
Stream Request over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream request parameters

1. Update interval
2. Communication deadline
3. Frame size

NOTE: this definition addresses issues similar to those addressed in dj-ademaj-MaxLatency-contribution-0521-v01, e.g. preemptable frames and semantic of deadline.



New: CommunicationDeadline

- Not latency as per IEEE 802.1Q (clause 3)
- Not the same as MaxLatency (802.1 Qcc-2018 46.2.3.6) with TSpecTimeAware present
- Deadline requirement origins at application
  - Complete data is available to the application
    - Complete arrival of preempted frames

Communication deadline specifies the latest point in time at which the last symbol of the FCS of the frame of interest shall pass the reference plane marking the boundary between the network media and PHY.

The reference point in time for the communication deadline (sometimes also referred to as “first point”) is the start of the Interval.

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Stream Request over UNI: timeliness related parameters

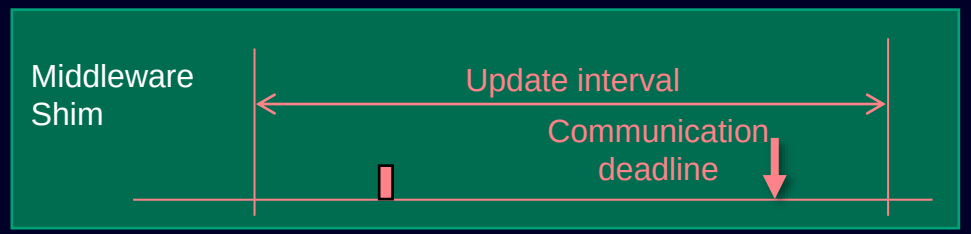
New parameter
Existing parameter
Extend existing

Stream request parameters

1. Update interval
2. Communication deadline
3. Frame size

Existing: TrafficSpecification (802.1 Qcc-2018 46.2.3.5)

MaxFrameSize



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Stream Request over UNI: timeliness parameters

Presented	Existing	Comment
Update interval	Tspec.Interval	Matches presented requirement Note: The start and the length of the intervals shall be aligned with the gating cycles
	Tspec.MaxFrPerInterval	1
MaxFrameSize	Tspec.MaxFrameSize	Matches presented requirement
	~~Tspec.TransmSelection~~	Deferred to a future contribution. (rather as ETH IF capability via remote management)
	Tspec.TimeAware.Earliest-/LatestTransmitOffset	Needed only if per frame time aware transmit. Otherwise ignored, e.g. 0/0
	~~Tspec.TimeAware.Jitter~~	Deferred to a future contribution. (rather as ETH IF capability via remote management)
	Us2NwReq.NumSeamlessTrees	Deferred to a future contribution
	~~Us2NwReq.MaxLatency~~	Not required
Communication deadline		

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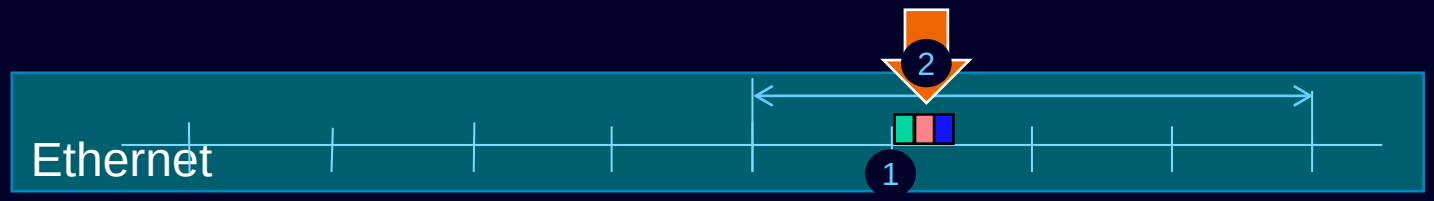
Stream Response over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream response parameters

1. Phase
2. Sort-in position



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Stream Response over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream response parameters

1. Phase
2. Sort-in position

Existing: TimeAwareOffset (802.1Qcc 46.2.5.3.5)

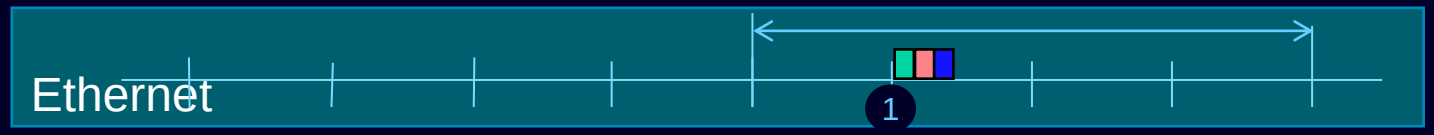
"TimeAwareOffset specifies the offset that the Talker shall use for transmit.

…

The value is expressed as nanoseconds after the start of the Talker's Interval."

Textual contribution to account for this extension must describe:

- If frames scheduled (injected) per burst: TimeAwareOffset indicates the start time of the gating cycle in which the stream is transmitted. Thus, this value shall be a multiple of the gating cycle.
- If frames scheduled (injected) per frame: : TimeAwareOffset indicates the start time when the frame is transmitted.



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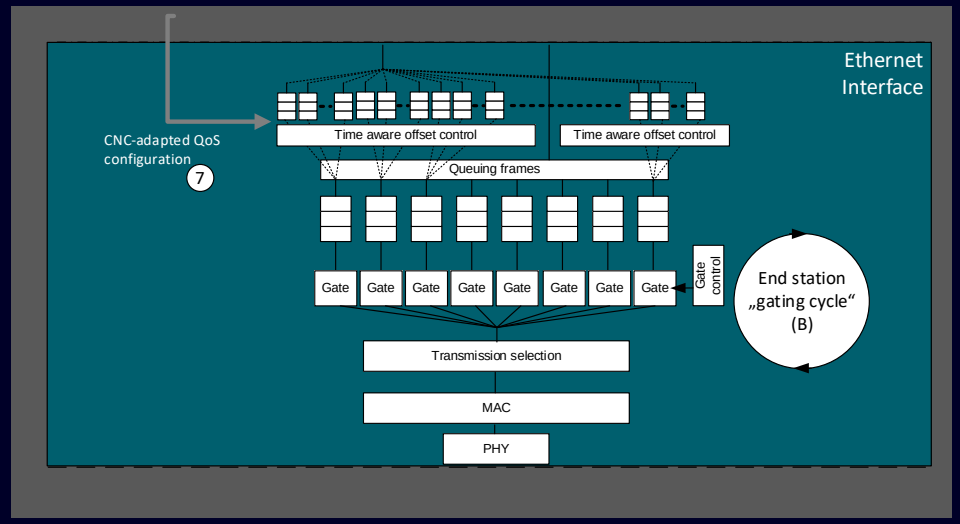
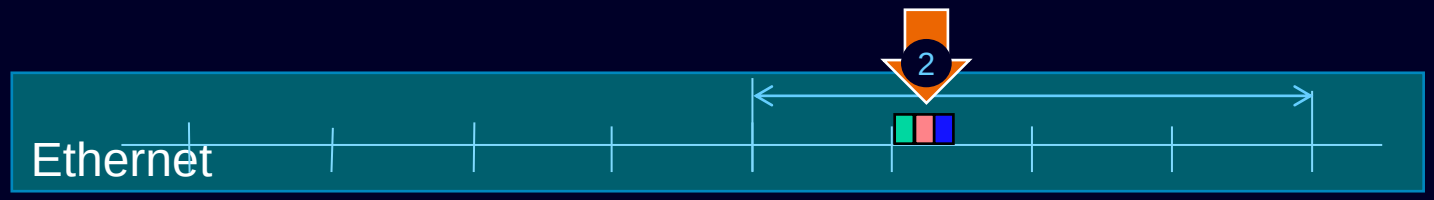
Stream Response over UNI: timeliness related parameters

New parameter
Existing parameter
Extend existing

Stream response parameters

1. Phase
2. Sort-in position





New: Sort-in position

SortInPosition specifies the sorting order of streams per traffic class and interval for a given gating cycle.

This can be implemented, for example, by grouping streams with same traffic class, Interval and scheduled phase in each Time Aware Offset Control queue. In such implementation, SortInPosition defines the transmission order of streams within each group.

To allow for simple incremental scheduling implementation, this parameter could represent a pointer to its predecessor stream.

For instance: after:

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Stream Response over UNI: timeliness related parameters

Presented	Existing	Comment
Sort-in position	None	This is a new parameter
Phase	InterfaceConfiguration.TimeAwareOffset	Matches presented requirement principle. Requires textual contribution
	InterfaceConfiguration.IEEE802-MacAddresses	Deferred to a future contribution
	InterfaceConfiguration.IEEE802-VlanTag	Deferred to a future contribution
	InterfaceConfiguration.IPv4-tuple	Deferred to a future contribution
	InterfaceConfiguration.IPv6-tuple	Deferred to a future contribution

Summary

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Summary

IA needs support for

- Converged networks
- Plug & Produce

Which in turn requires

- Flexible network configuration
- Flexible resource allocation

Current Qdj does not support flexible scheduling

Summary

This contribution presented

- Means for flexible scheduling
- Required timeliness parameters

Questions ?

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