Present a series of contributions to help **closing the gaps** between current **Qdj** and the **industry requirements**

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System Architect
Industrial Communication

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Communication Requirements for Industrial Automation

why (and how) User/Network Interface must be modified

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Agenda

- Industrial automation requirements
  - System level
  - End station level
  - Network level (out of scope of this contribution)

- Stream request and response requirements

- Proposed UNI parameters
  - Timeliness aspects
  - Other aspects in future contributions

System level:
Plug & Produce

Dynamics and converged network

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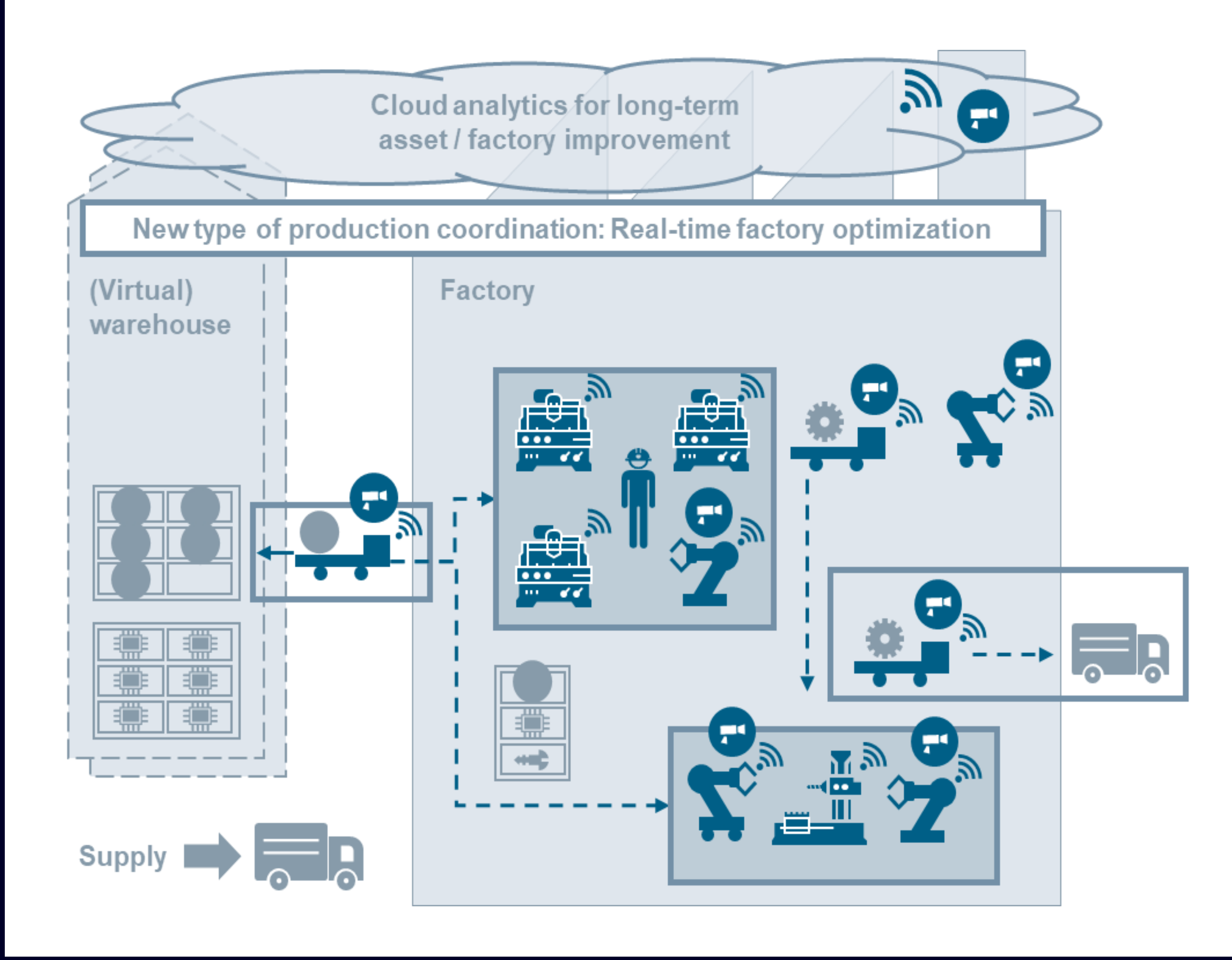
Plug & produce

Machines (network parties)

- added and/or removed without additional network engineering steps

- Incremental network configuration needed
  - Applications request network resources
  - If request is granted, new applications communicate over existing network
    - New streams established
    - Old streams still work
  - Stream removal possible
    - Releasing no longer needed resources

Incremental network configuration and resource allocation



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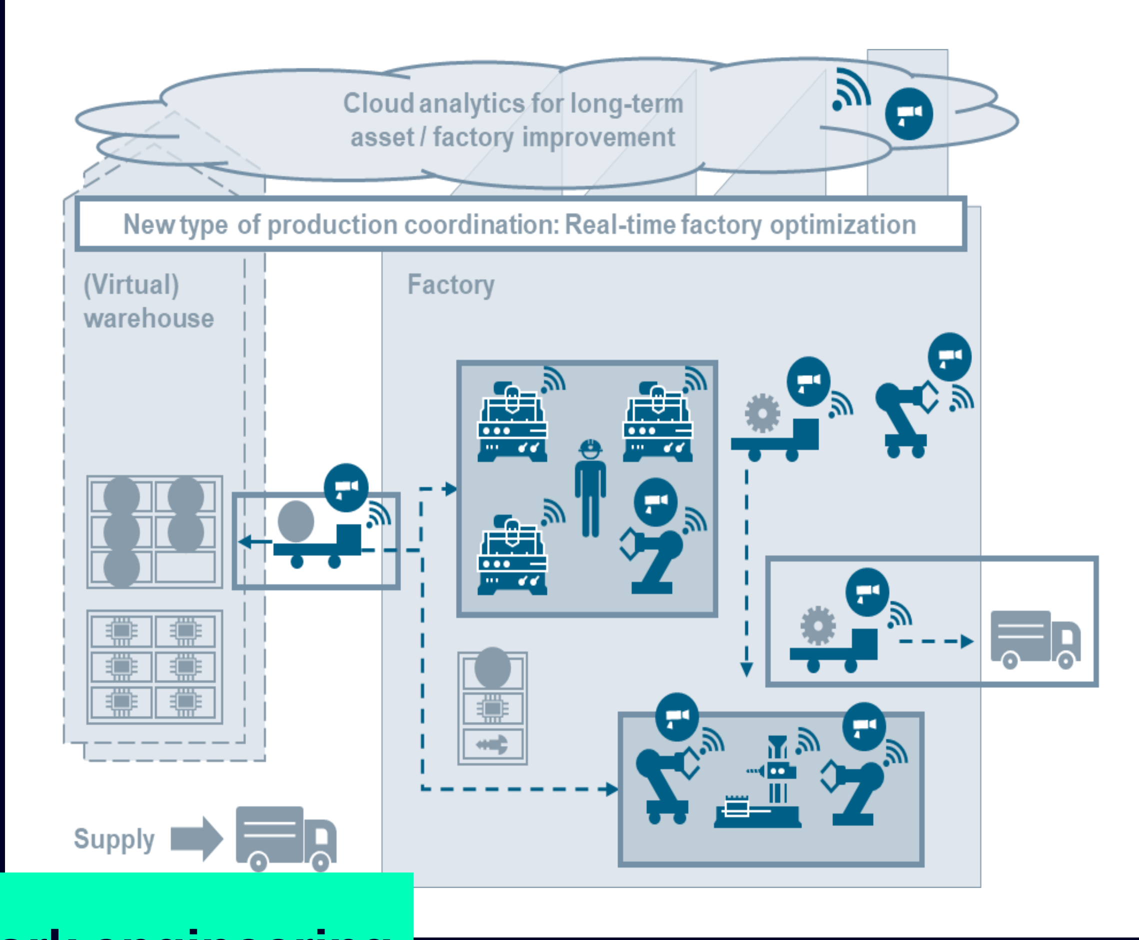
Converged network supporting Plug & produce

Application engineering

- Functionality
- Timeliness requirements
  - Including communication

Independent of network knowledge

- Shaper agnostic
- MAC addresses unknown
- …



Application engineering independent of network engineering

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End Station (ES) level:
ES Model

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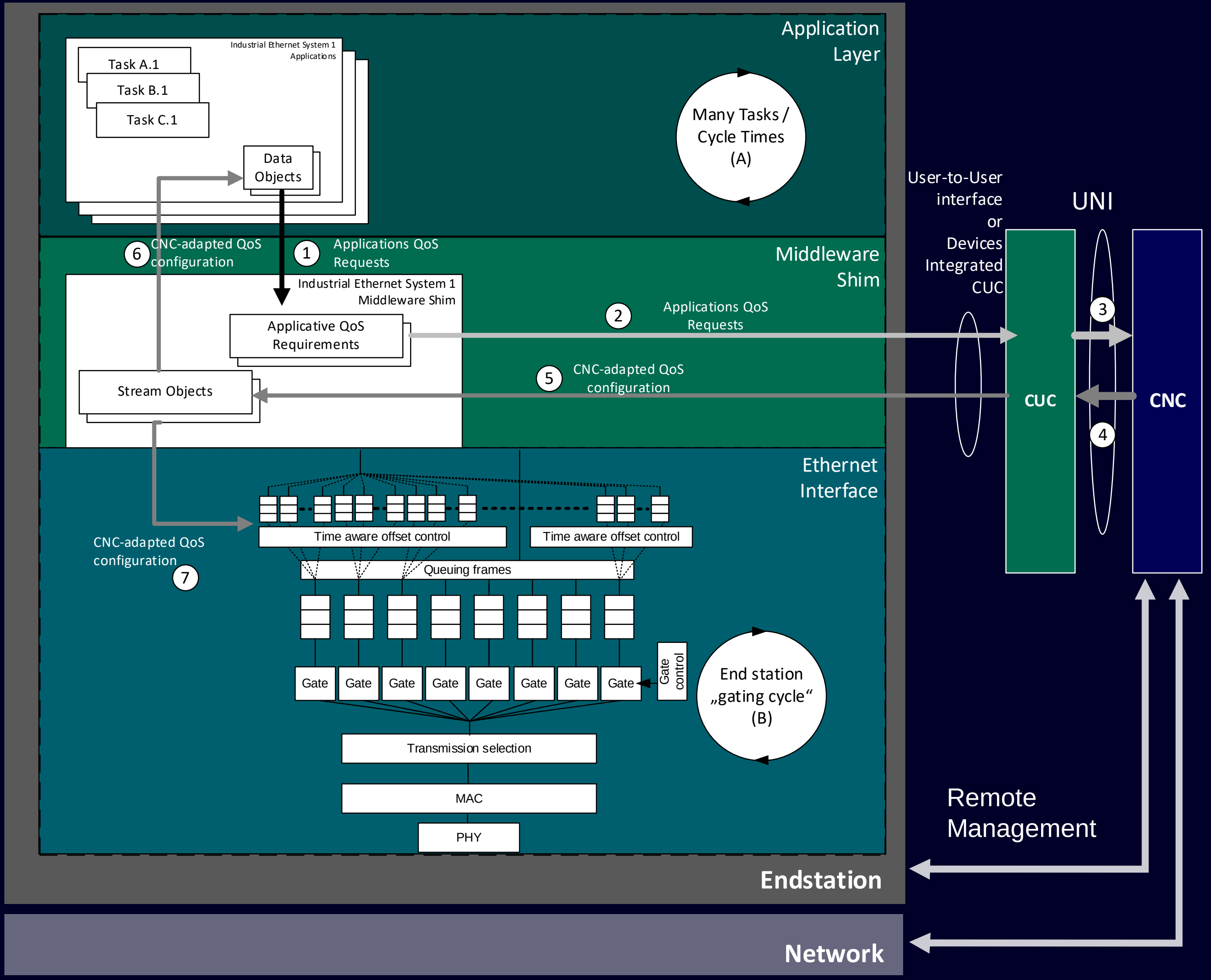
End station by IEEE/IEC 60802

- Communication requirements from IA application
  - Data objects (application and communication relations)

- ES 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 60802-Steindl-Clause4-0121-v17-clean.pdf (Contributions 21-05-SantaFe)

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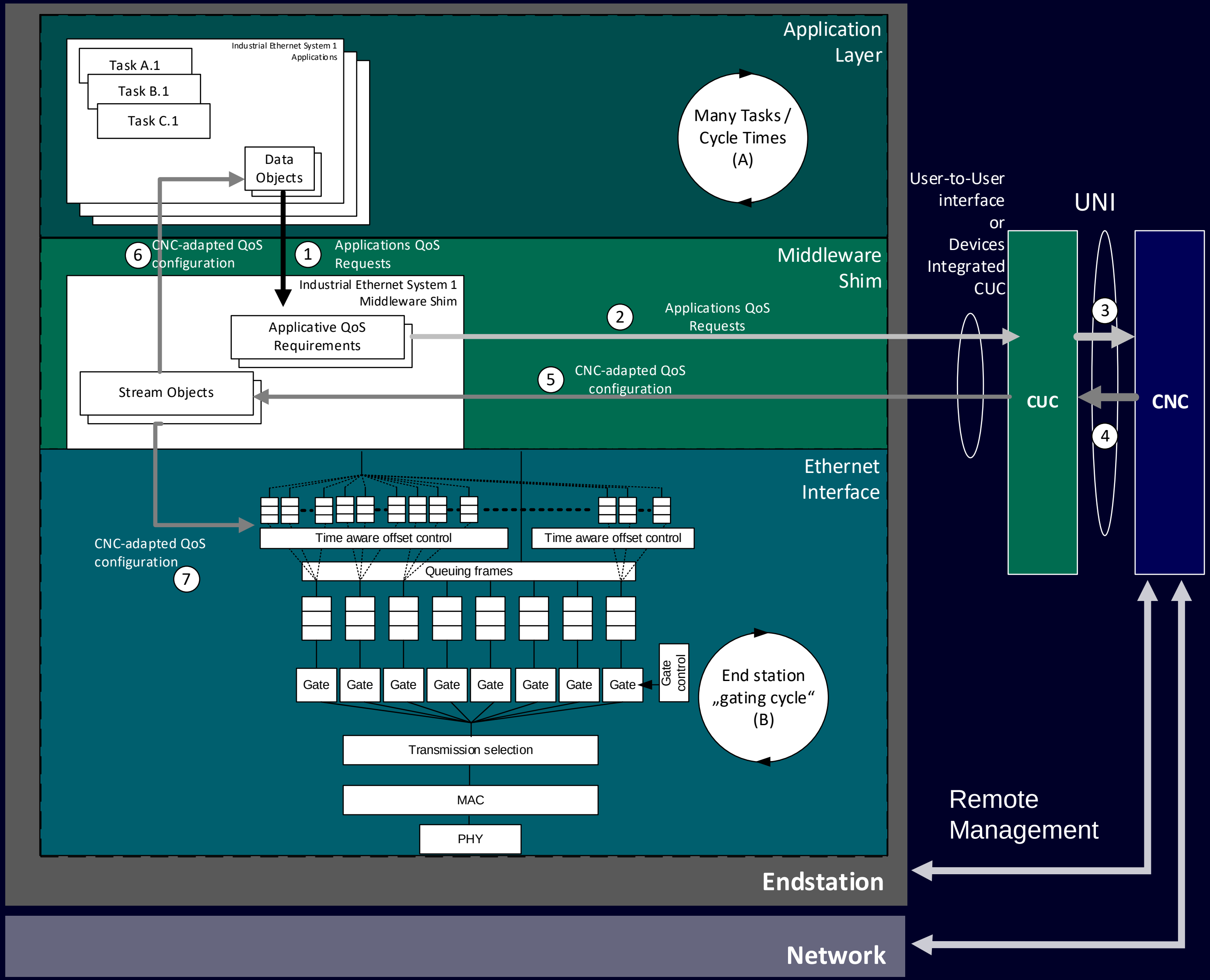
End station by IEEE/IEC 60802

- End station capabilities discovered by CNC via remote management



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(Contributions 21-05-SantaFe)

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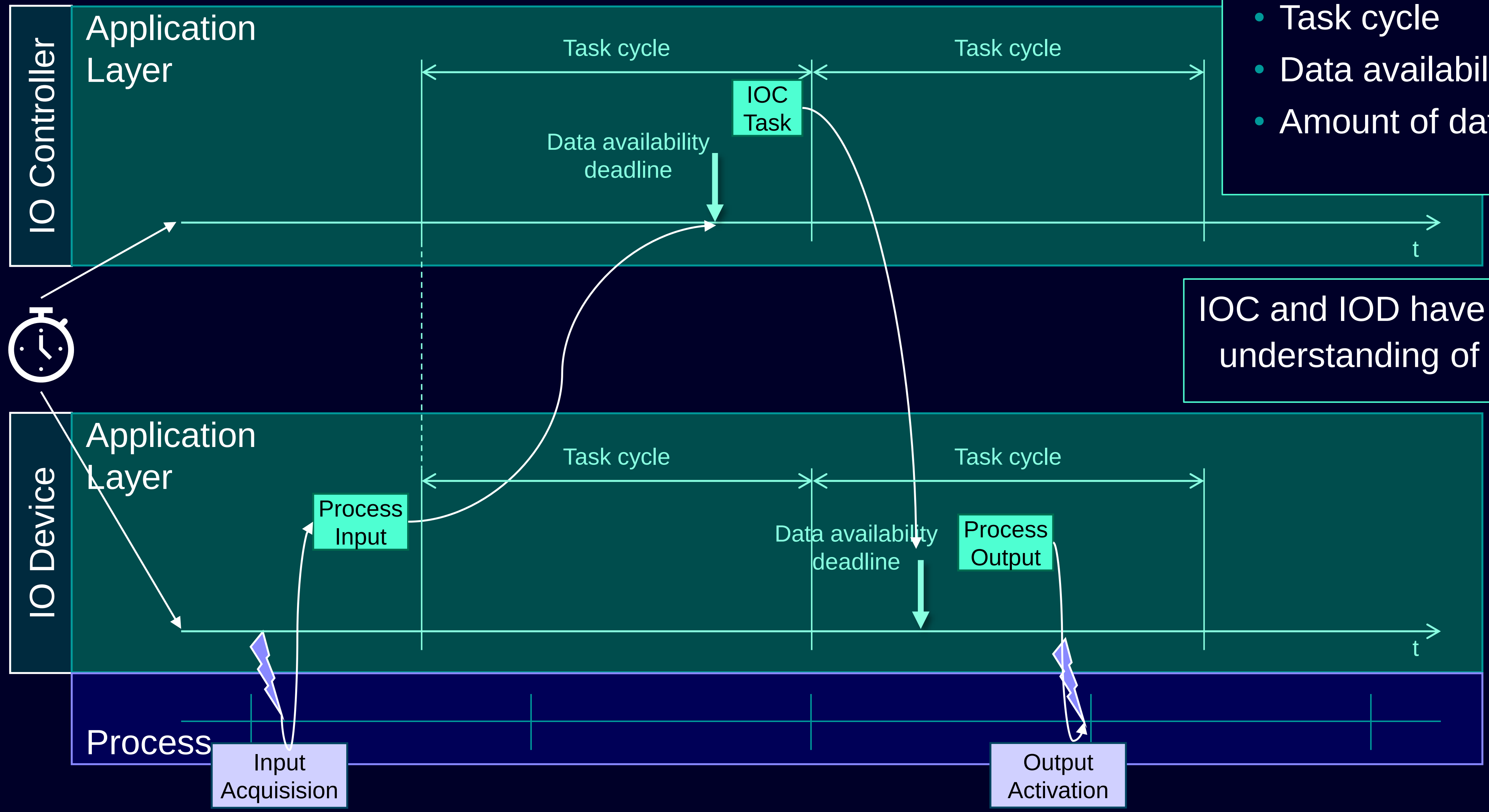
ES Model: Application Layer

Application Layer: Simplified view of communication for isochronous tasks



Task

- Task cycle
- Data availability deadline
- Amount of data to send

IOC and IOD have the same understanding of task cycle

Wide range required by applications

25µs to 4s Cycle length
(10^{-9} to 10^{0})

64 to 2000 Frame size
(octets)

large range

512 Talkers *1
512 Listeners *1
1000 Devices
> 9k Streams *2

large amount

*1 per IOC
*2 C2D and C2C, with 8 PLCs

ES Model: Middleware Shim

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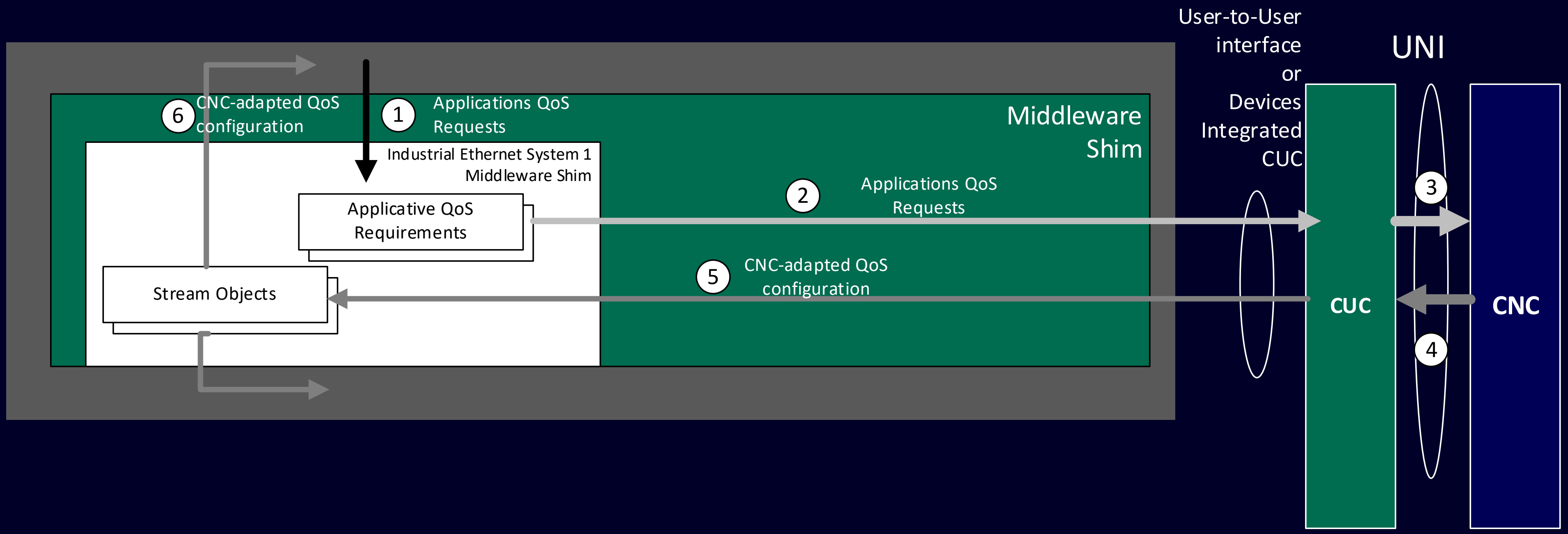
Tasks of middleware (relevant for UNI)

Manage stream requests

- Translates application layer requirements into stream requirements

Setup end station communication



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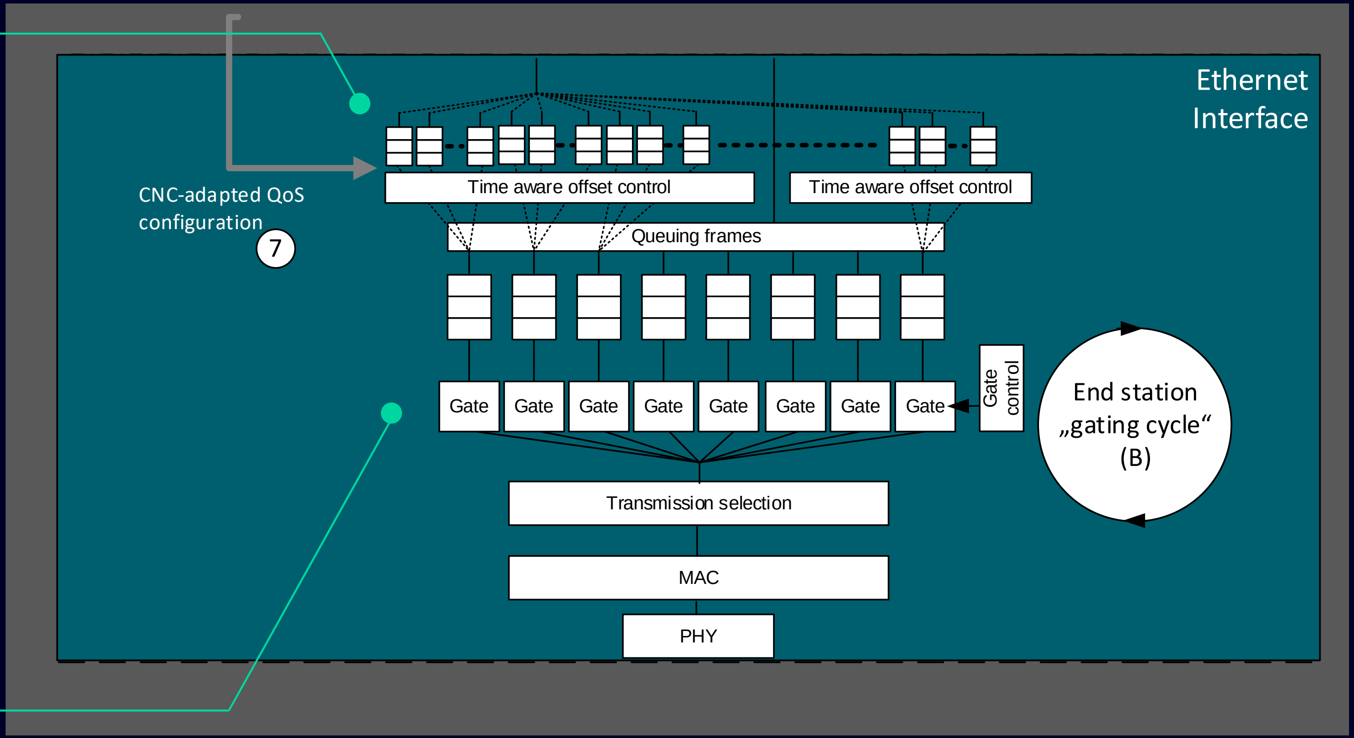
ES Model: Ethernet Interface

Ethernet Interface as per IEEE/IEC 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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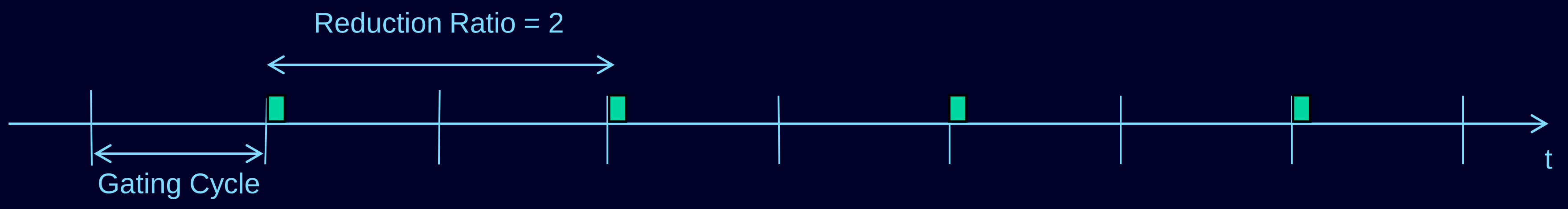
Frame injection: reduction ratio concept

Based on reduction ratio concept

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



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Frame injection: reduction ratio concept

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

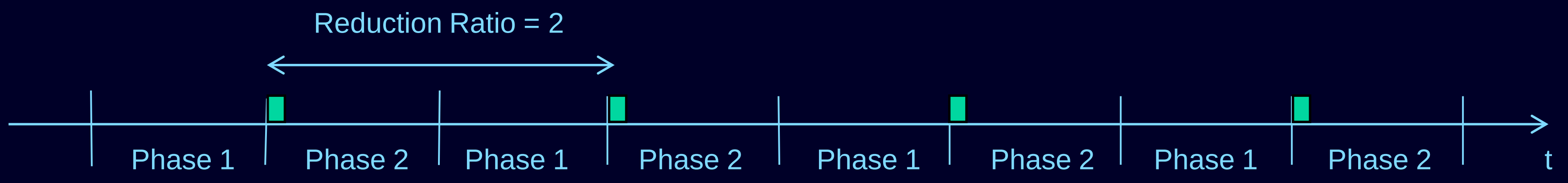
End station centric representation

- 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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Frame injection: reduction ratio concept

CNC

Management Interface

Gate Control (Qbv)

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
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CNC

UNI

Time Aware Offset Control

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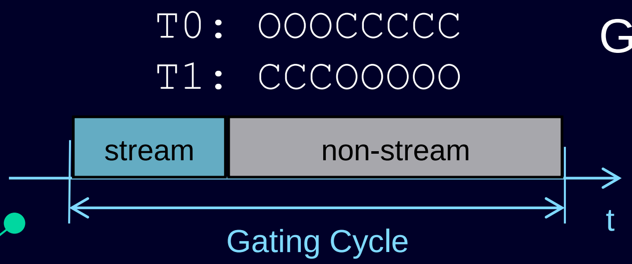
Frame injection

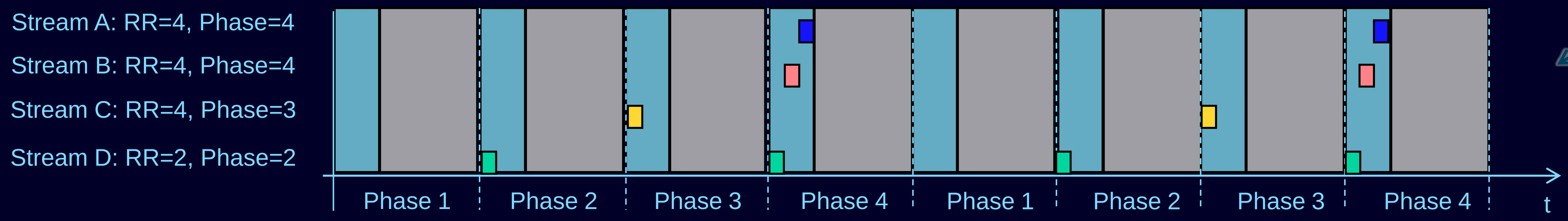
CNC

Management Interface

Gate Control (Qbv)



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)

CNC

UNI

Time Aware Offset Control

Phase 1

Phase 2

Phase 3

Phase 4

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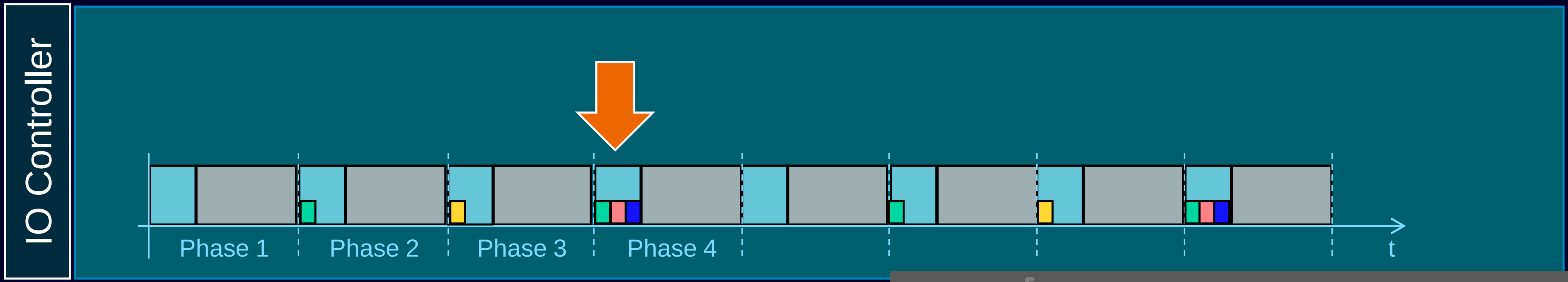
Frame injection



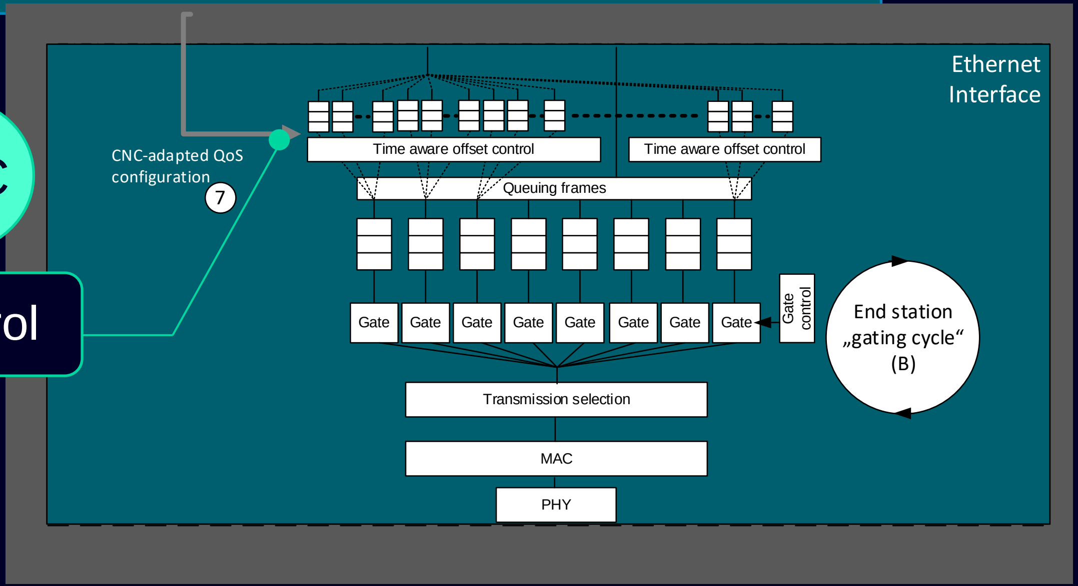
Transmission of frames in same gating cycle (phase)

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

UNI

CNC

Time Aware Offset Control



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Reduction ratio concept

This solution favors

- Dynamic stream requests
- Predictability
  - Defined transmission order of streams per gating cycle
- Lower dispatching complexity

over

- Optimal network utilization

25µs to 4s (10^{-9} to 10^{0})	Cycle length
512	Talkers *1

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Stream Request & Response

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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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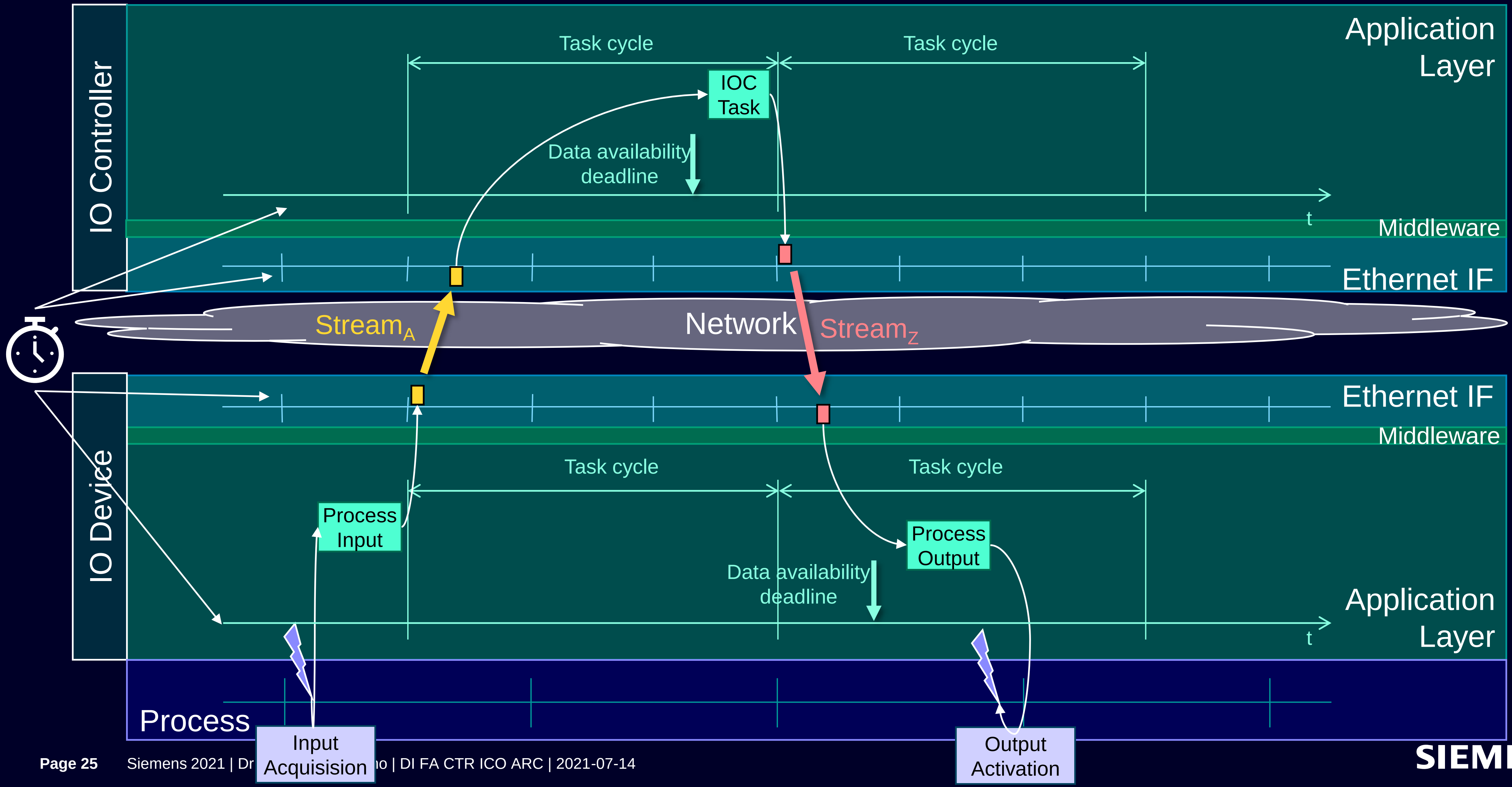
Stream timeliness: One IO-Controller, one IO-Device, isochronous tasks



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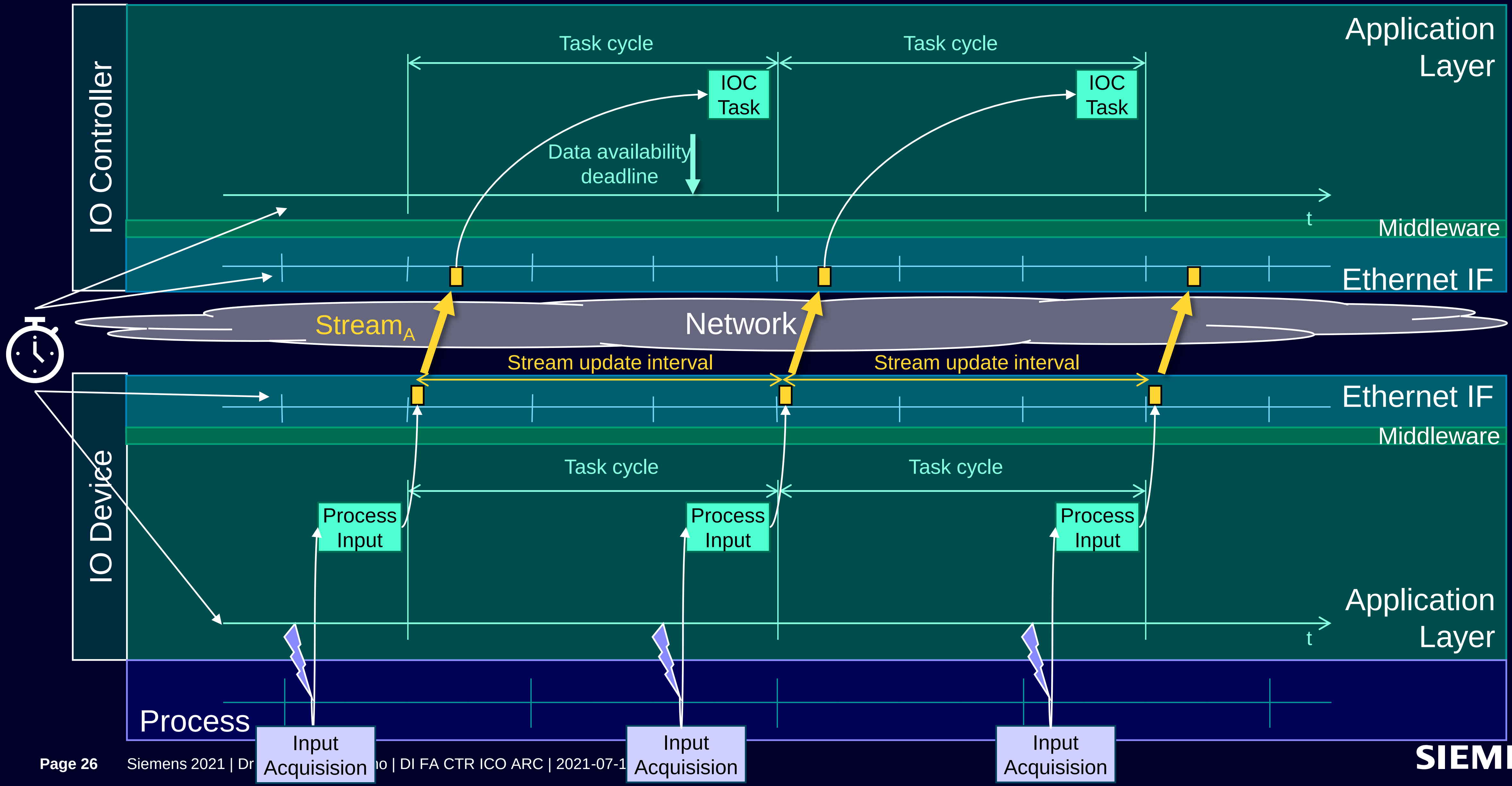
Stream timeliness: One IO-Controller, one IO-Device, isochronous tasks



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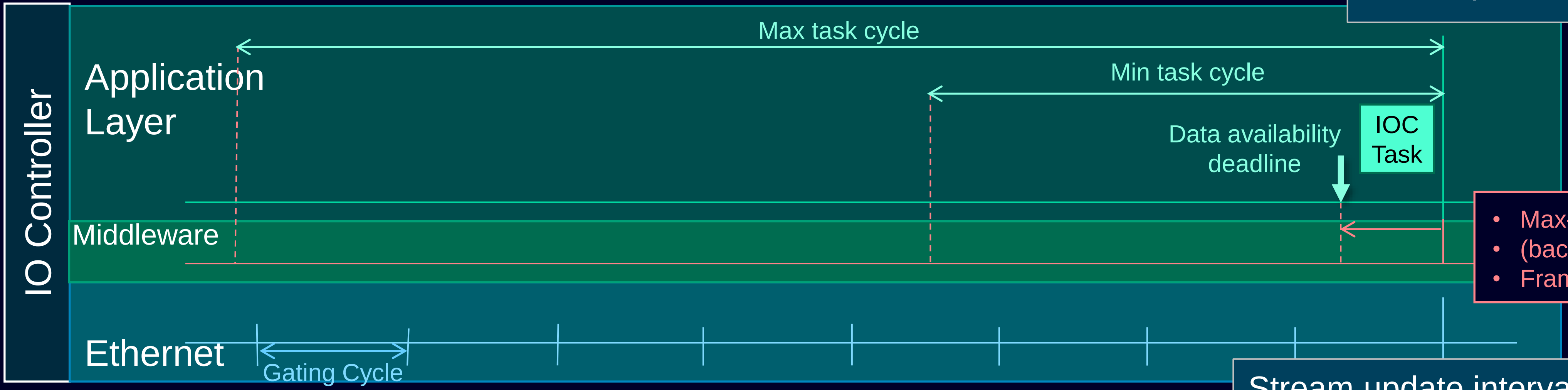
Stream request & response parameters

Application engineering
- independent of network

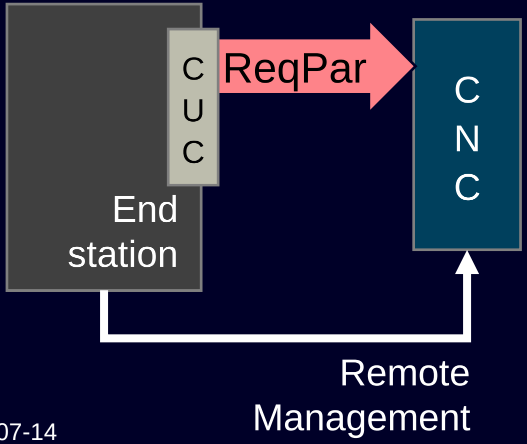


- Max-,Min update interval
- (backwards) Comm deadline
- Frame size

Stream update interval
- power of 2 multiple of gating cycle

Stream request parameters

1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …



Further stream properties
- Traffic class
  - ISO, CYC-S, CYC-A, …
- Redundancy
- Source, Sinks
- …

Not addressed in this contribution

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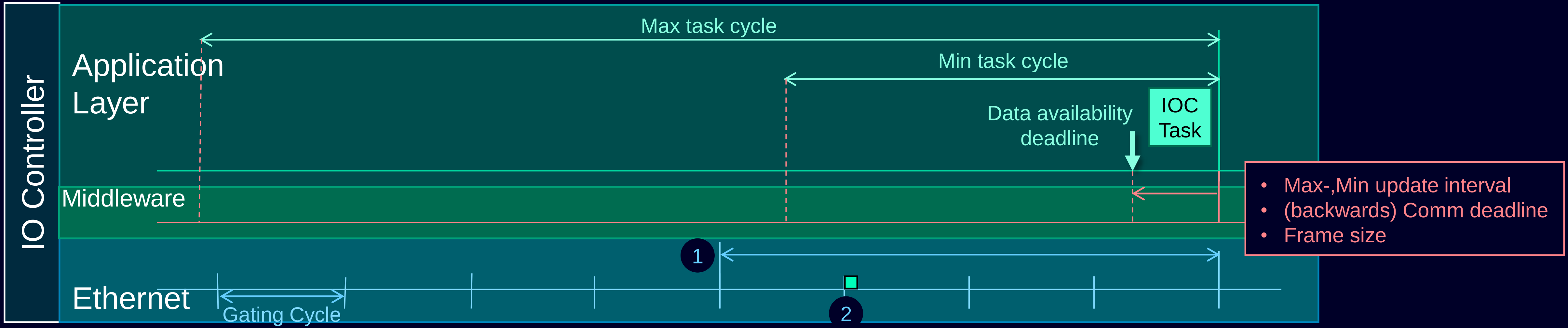
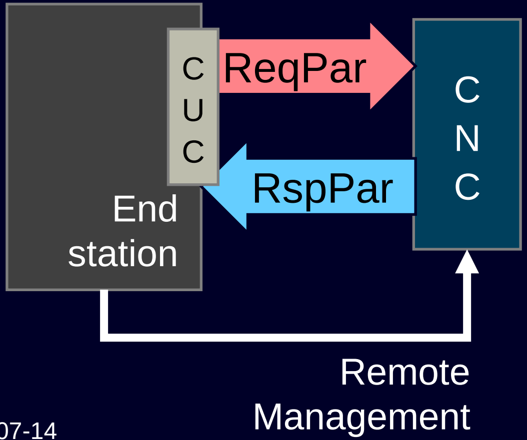
Stream timeliness: One IO-Controller, one IO-Device, isochronous tasks



Stream request parameters

1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …



Stream response parameters

1. Computed update interval
2. Phase
3. Sequence identifier
4. …

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User/Network Interface: Proposed parameters

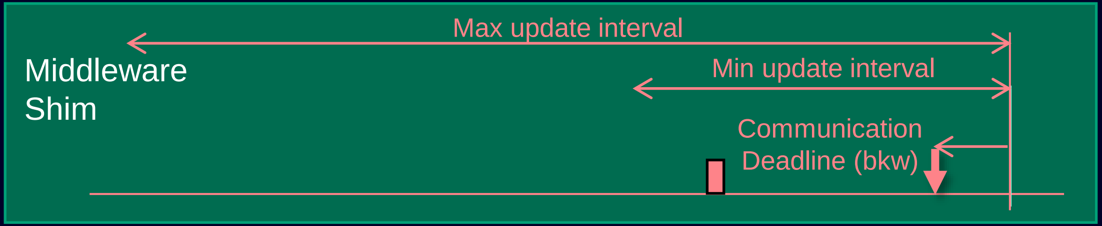
Stream Request over UNI: timeliness related parameters

New parameter

Existing parameter

Stream request parameters

1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …



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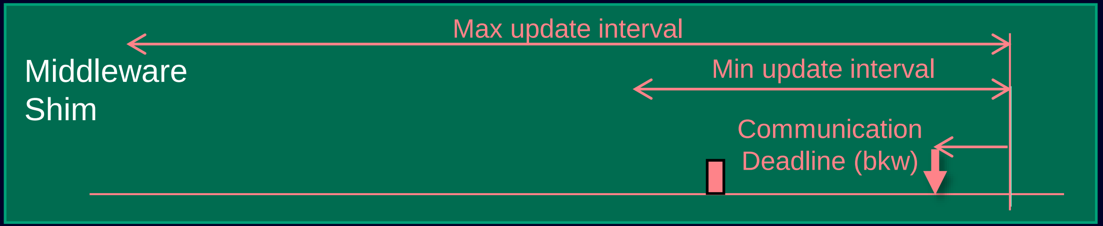
Stream Request over UNI: timeliness related parameters

New parameter

Existing parameter

Stream request parameters

1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …



New: Minimum and Maximum Update Interval

specify the minimum and maximum update interval of time in which the traffic specification cannot be exceeded. The traffic specification is specified by MaxFramesPerInterval=1 and MaxFrameSize.

Note that definition of interval is very similar to the one in Qcc: TrafficSpecification Interval (46.2.3.5.1)

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Stream Request over UNI: timeliness related parameters

New parameter

Existing parameter

Stream request parameters

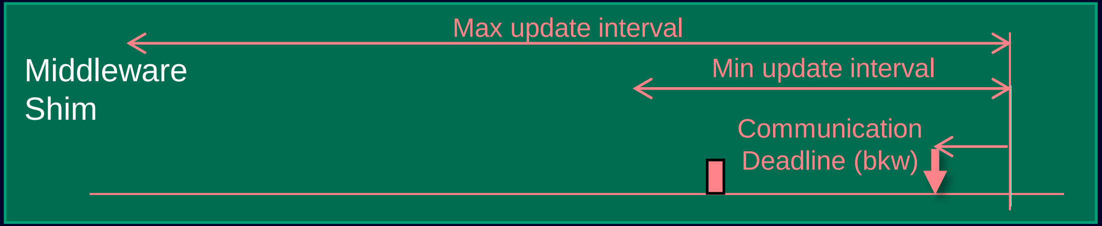
1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …

New: Backwards Communication Deadline

Latest arrival time at the listener(s) of this stream.

This value should be specified 'backwards', i.e. :

- the 'first point' is the end of the update interval.
- the 'second point' is at the reference plane at the Listener marking the boundary between the network media and PHY.



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Stream Request over UNI: timeliness related parameters

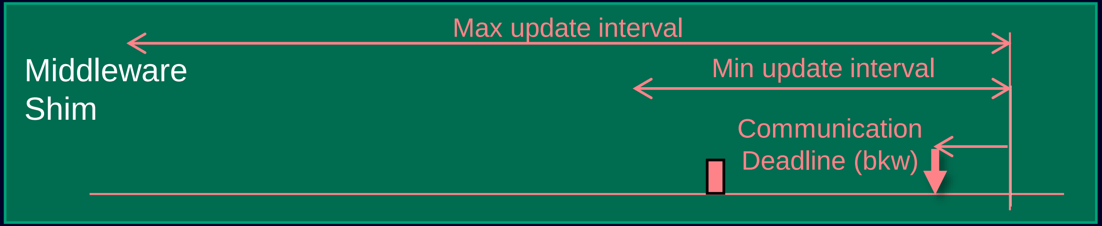
New parameter

Existing parameter

Stream request parameters

1. Min-,MaxUpdateInterval
2. (backwards) Communication deadline
3. Frame size
4. …

Existing: TrafficSpecification.MaxFrameSize



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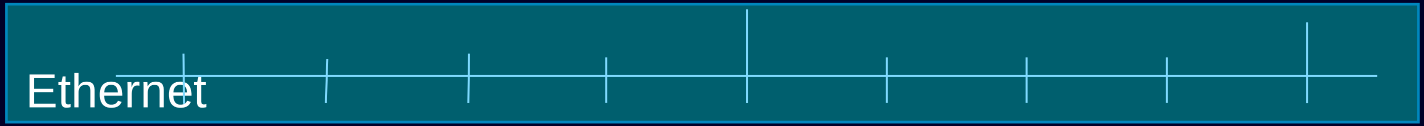
Stream Response over UNI: timeliness related parameters

New parameter

Existing parameter

Stream response parameters

1. Calculated update interval
2. Transmission phase offset
3. Sequence identifier
4. …



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New parameter

Existing parameter

Stream Response over UNI: timeliness related parameters

New: Calculated update interval

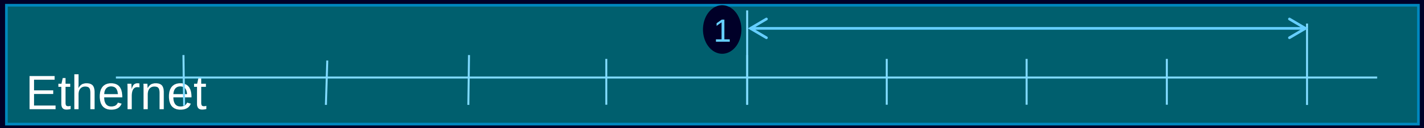
Value between provided min und max update interval

Is a result from CNC, not a requirement from CUC

Note that definition of interval is very similar to the one in Qcc: TrafficSpecification Interval (46.2.3.5.1)

Stream response parameters

1. Calculated update interval
2. Transmission phase offset
3. Sequence identifier
4. …



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New parameter

Existing parameter

Stream Response over UNI: timeliness related parameters

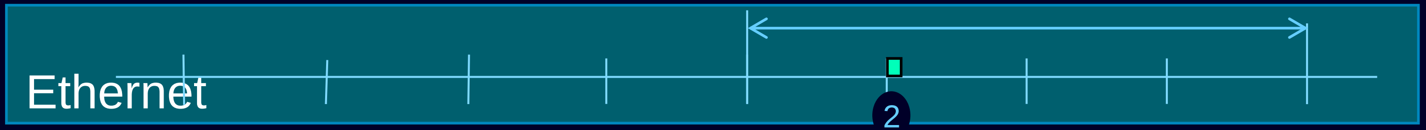
New: Transmission phase offset

Per burst: offset to indicate the start time of the gating cycle in which the stream is transmitted. Reference point is the start of the planned update interval.

Per frame: offset to indicate the start time when the frame is transmitted. Reference point is the start of the planned update interval.

Stream response parameters

1. Calculated update interval
2. Transmission phase offset
3. Sequence identifier
4. …



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Stream Response over UNI: timeliness related parameters

New parameter

Existing parameter

New: Sequence identifier

Sequence identifier defines a tie-break rule to decide the transmission order of streams planned to be sent as burst in:

- Same gating cycle
- With same priority
- With same reduction ratio

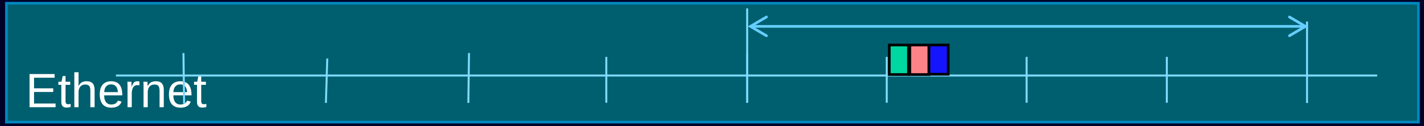
To allow for simple incremental scheduling implementation, this parameter represents a pointer to the previously sent stream.

For instance:

after:

Stream response parameters

1. Calculated update interval
2. Transmission phase offset
3. Sequence identifier
4. …



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Summary

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Summary

Goal: allow for Qdj to fulfill the industry requirements

This contribution shows that currently Qdj does not cover all industry requirements

This contribution focused at UNI and presented

- main timeliness issues
- first modification proposals

Next contributions

- address comments from this contribution
- present further industry related issues at UNI and propose respective Qdj modifications, e.g.
  - Stream ID management by CNC
  - Network agnostic representation of
    - Source and sink
    - Stream traffic type
  - Multiple CUCs
- present textual contributions to Qdj

Questions ?

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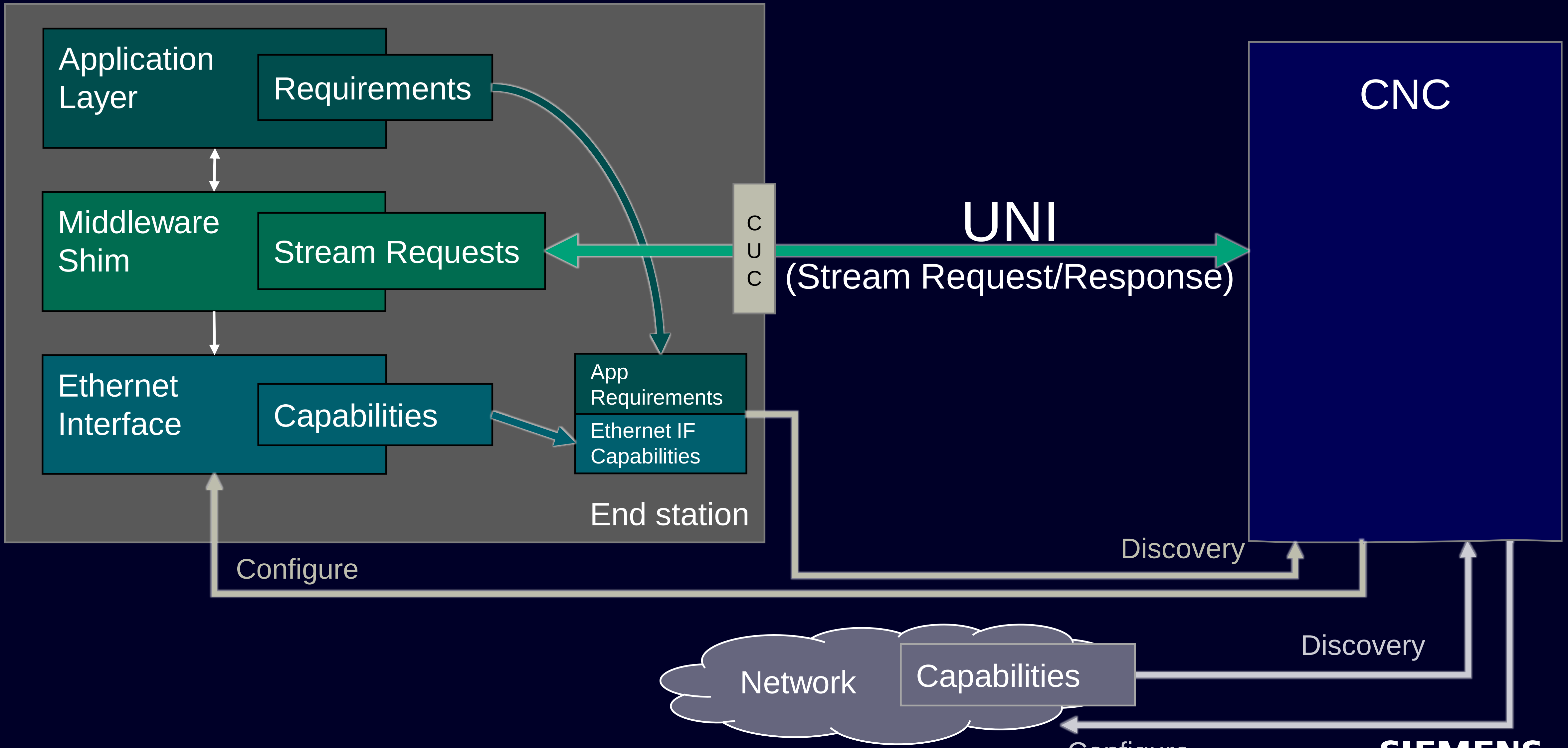
End station and its interactions with CNC by IEEE/IEC 60802



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Stream traffic types and requirements

	Stream traffic type		
	Isochronous	**Cyclic synchronous**	**Cyclic Asynchronous**
Periodic	Yes	Yes	Yes
Transmission in sync with network	Yes	Yes	Optional
Transmission in sync with task (application layer)	Yes	No	No
Tolerance to frame loss due to congestion	No	No	No
Timeliness	Deadline (w.r.t. task cycle, i.e.the start of gating cycle in which update interval starts)	Max latency (w.r.t. start of gating cycle in which the stream is sent).	Max latency (w.r.t. start of gating cycle in which the stream is sent).

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