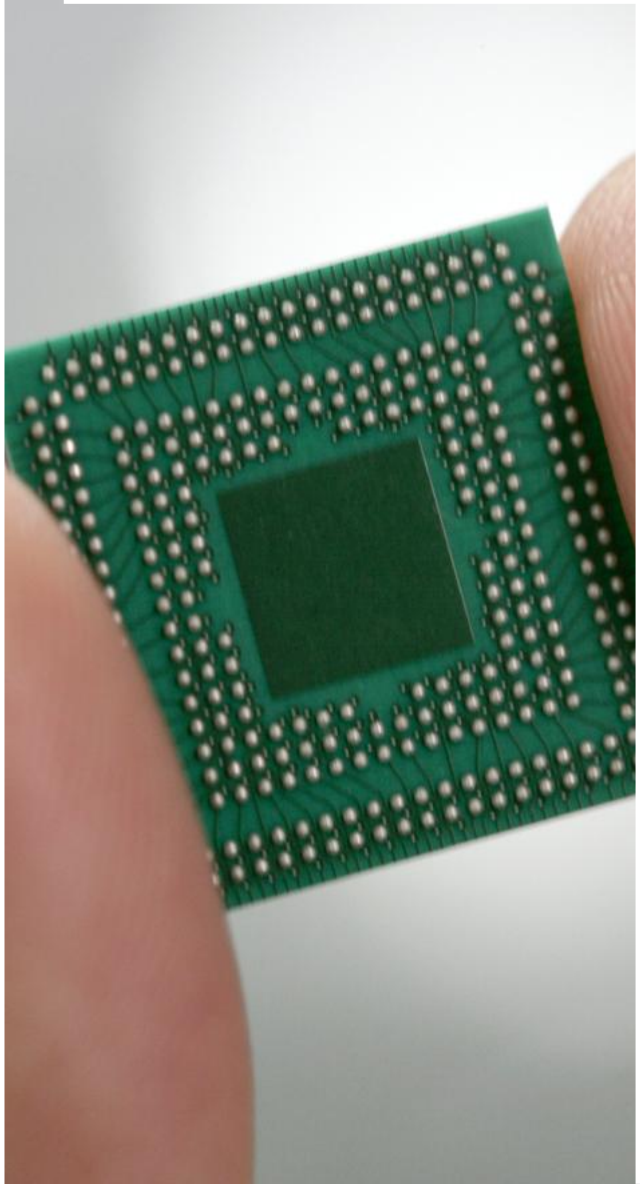

# Industrial Requirements for a Converged Network

January 2013

IEEE 802.3 SG DMLT
Phoenix (AZ)

Albert Tretter, Siemens AG

# Ethernet captures more and more Applications

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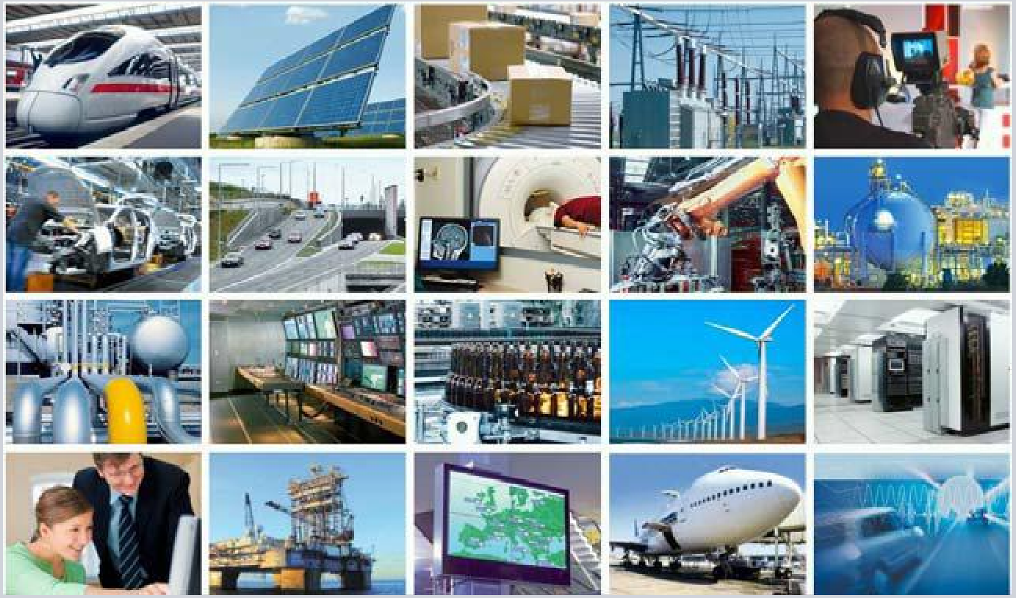
## Traditional Markets

- Industrial Automation
  - Factory Automation
    - e.g. Material handling, Automotive Manufacturing, Transfer lines,
  - Process Automation
    - e.g. Oil, Gas, Chemical / Petrochemical, Food & Beverage
- Energy Automation
  - Power Generation
    - e.g. Fossil Power Plants, Wind Turbines
  - Power Transmission and Distribution
    - e. g. Smart Grid Application
- Building Automation
  - Climate Control
  - Fire Safety



## New Markets

- Avionics
  - Fly-by-Wire, Passenger Experience, etc.
- Railway Systems
  - Train Control
  - Railway Traffic Management Systems
- Medical
  - Patient Imaging,
  - Patient Management

# A bit of History of Industrial Communication

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**1990 to 2000: non Ethernet Solutions dominated the market**

- Profibus, Interbus, Controlnet, Devicenet, ..

**Since 2000 Ethernet based solutions enter the industrial market**

Up to now Ethernet offers not the required real time capabilities (QoS) therefore specific Ethernet solutions appeared on the market, like:

- EtherCAT, Ethernet Powerlink, TCnet, Profinet, ...
- All these solutions contain specific additions or adjustments to the "standard ethernet" in order to provide the required real time capabilities (QoS) for the industrial applications.

➔ **Customers ask for <u>one</u> IEEE802.1/.3 standard based solution**

# Solution: Converged Traffic Environment

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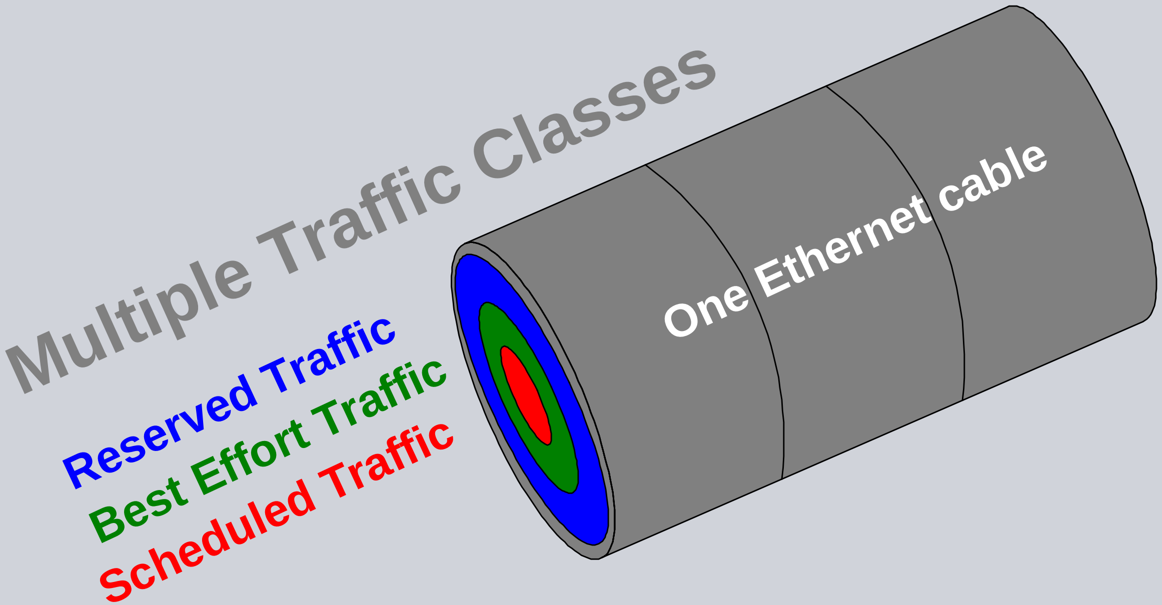


**Customers ask for a solution which:**

- **guarantees minimum latency for Scheduled Traffic and**
- **provides guaranteed bandwidth for Reserved Traffic and**
- **still allows the transfer of Best Effort Traffic**

**on one network**

## Definitions

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**In this presentation the following definitions are use:**

- **Scheduled Traffic:**
  - used for the conveyance of cyclic control data like the input and output values of sensors and actors
- **Reserved Traffic:**
  - used for the conveyance of streams like Audio/Video streams
- **Best Effort Traffic:**
  - used for the conveyance of acyclic data like diagnostic information, access to a WEB server, Firmware Update, ...

# Overview of Industrial Communication Requirements

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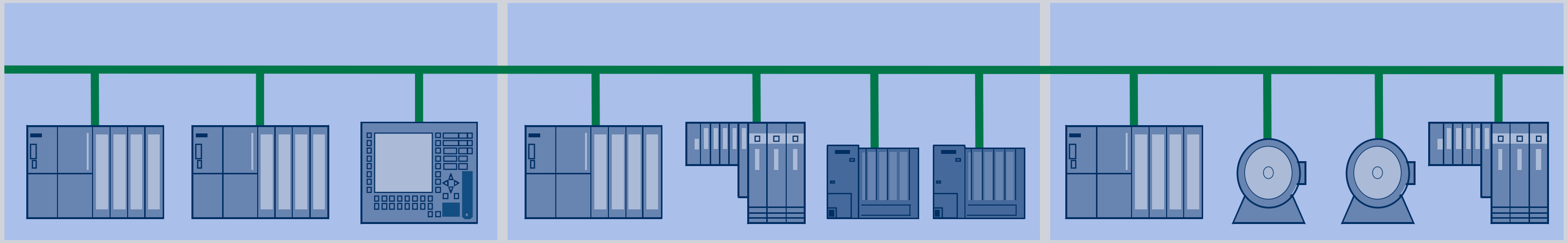
**Process Automation**

**Factory Automation**
**Energy Automation**
**Smart Grid Applications**

**Motion Control**



**Application Cycle or Control Cycle**

100ms ⟷ 31,25µs

**Linkspeeds**

| Process Automation | Motion Control |
|---|---|
| 10GBit/s<br>1GBit/s<br>100MBit/s | 1GBit/s<br>100MBit/s |

**Required Media**

| Process Automation | Motion Control |
|---|---|
| Copper<br>Fiber<br>Wireless | Copper<br>Fiber |

# Examples of Industrial Communication Services

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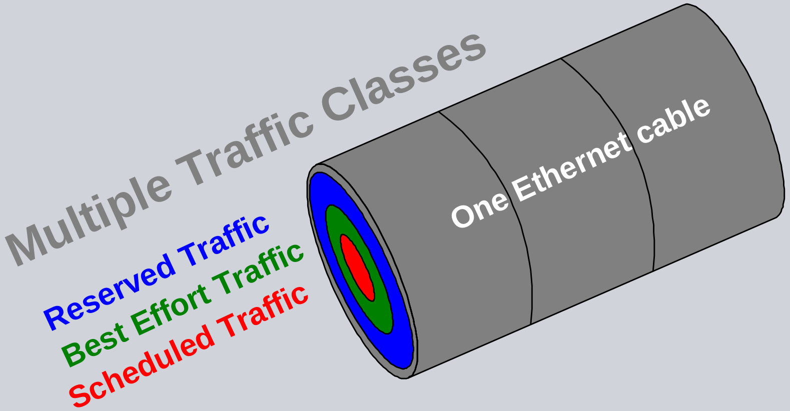
- **Best Effort Traffic**
  - Configuration
  - Diagnostic
  - Web Services
  - Events
- **Reserved Traffic**
  - Real Time Diagnostic (e.g. inspection, identification, tracking, counting and measurement)
  - Vision Systems
- **Scheduled Traffic**
  - General Automation to exchange analog an digital values e.g. manufacturing and process industry
  - Motion Control to exchange typical analog and digital values from actuators and sensors based on synchronized processes
  - Sampled Values (Current and Voltage)




| | Today | | Future: Only one Network: |
|---|---|---|---|
| • Best Effort Traffic: | No guaranteed bandwidth | | Guaranteed bandwidth for Best Effort Traffic |
| • Reserved Traffic: | Separate network | → | Guaranteed QoS for Reserved Traffic |
| • Scheduled Traffic: | Dedicated solutions to guarantee minimum latency, resources and bandwidth and often a separate network for the Best Effort Traffic is necessary | | Standardized solution to guarantee minimum latency, resources and bandwidth for Scheduled Traffic |

# Closed Loop Application based on Scheduled Traffic

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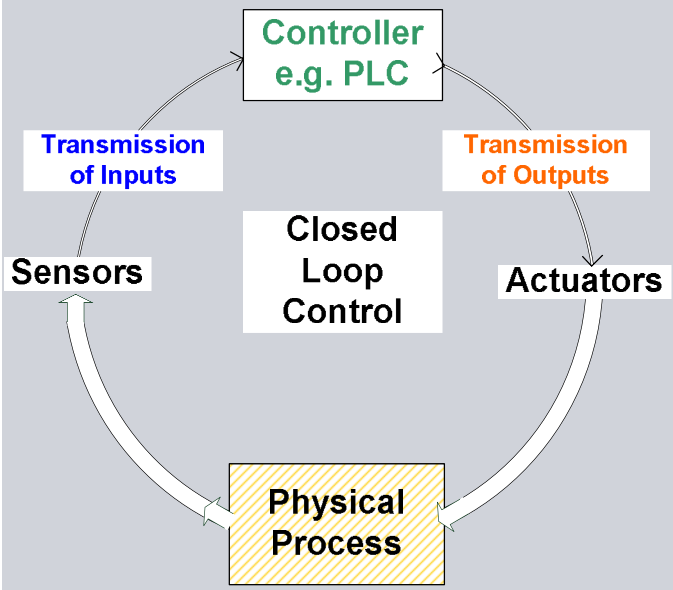
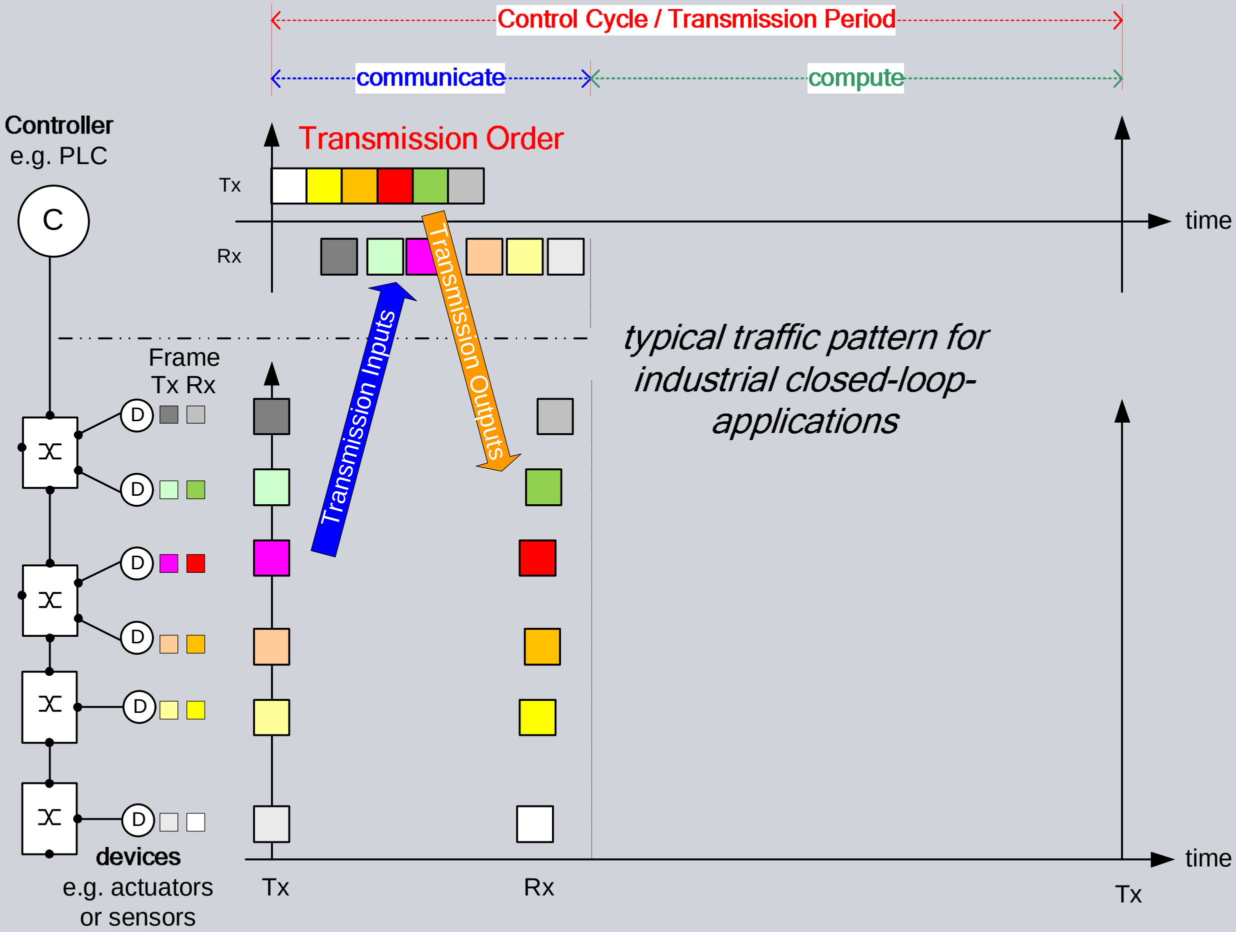
## Closed Loop Application



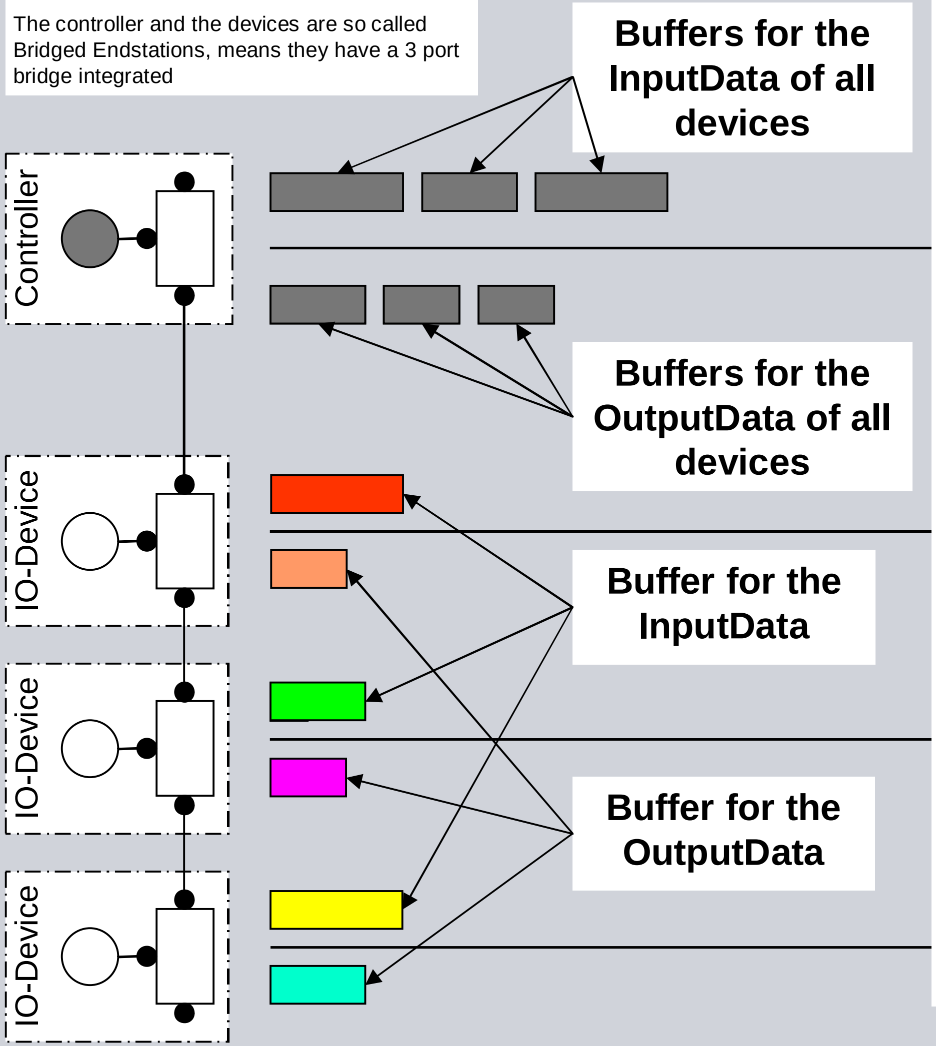

## *Typical traffic pattern for control traffic*



# Model of the cyclic transfer of InputData and OutputData at Industrial Control applications

Note:

The controller and the devices are so called Bridged Endstations, means they have a 3 port bridge integrated




**Behavior of the Buffered Model of the InputData and Output Data at the Controller and Devices:**

InputData:

- The devices update the InputData buffer with the actual values of the InputData in each ControlCycle
- The InputData will be transfered to the controller in each ControlCycle

OutputData:

- The controller updates the OutputData buffer with the actual processed values for the transfer to the devices
- The OutputData will be transfered to the devices in each ControlCycle

General:

- The size of the InputData and OutputData buffers at the controller and devices is configured at startup
- In case of transmission errors the contend of the buffers remains valid and will be used for processing until a defined number of failures occur in one consecutive sequence

# Phase "Communicate":

=> Transfer a copy of the InputData to the controller and
=> Transfer a copy of the OutputData to the devices

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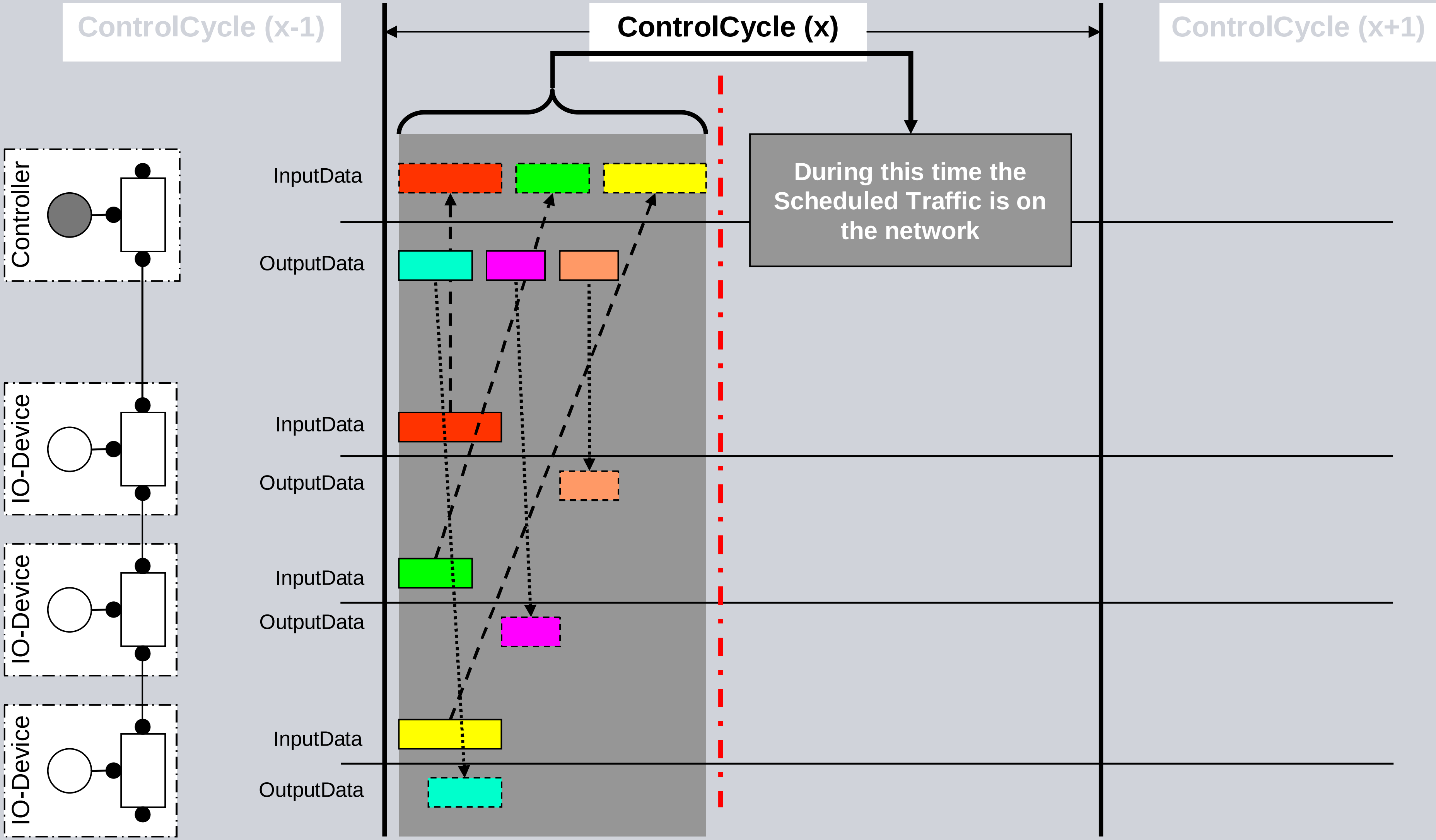

# Phase "Compute":

=> Controller: Process the InputData and calculate new OutputData for the next Cycle

=> Devices: Process the Outputdata and provide new InputData for the next ControlCycle

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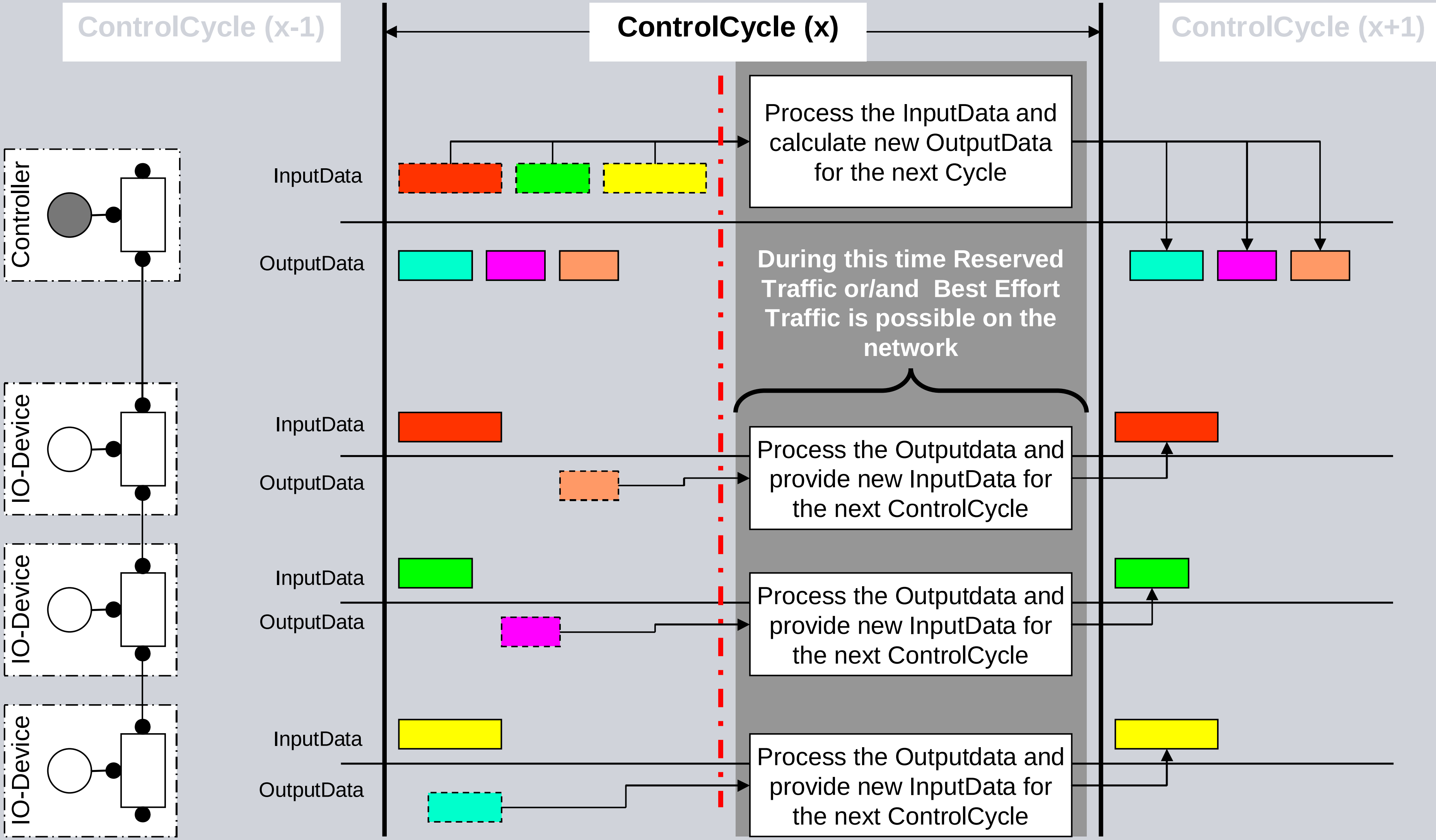

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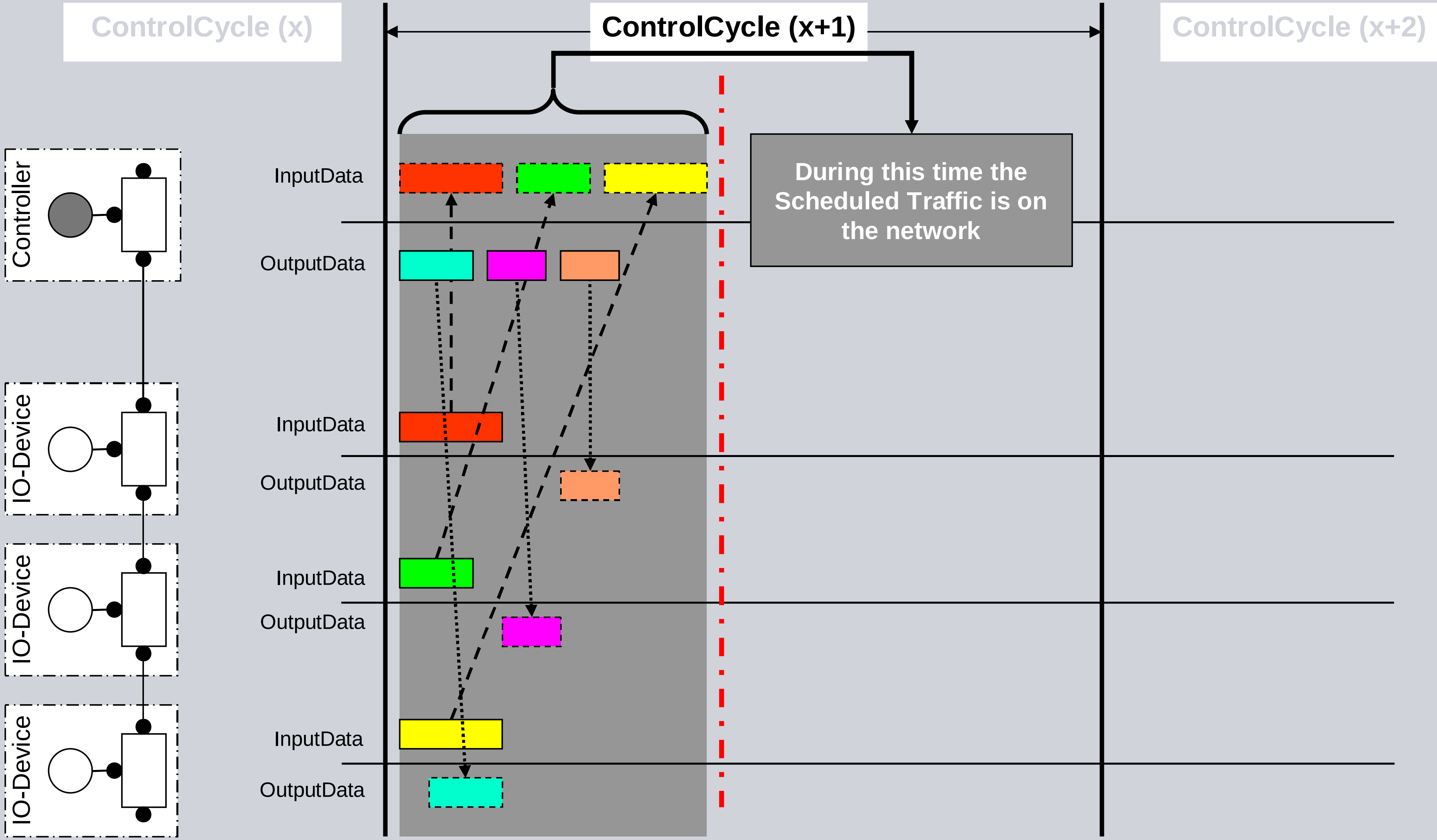

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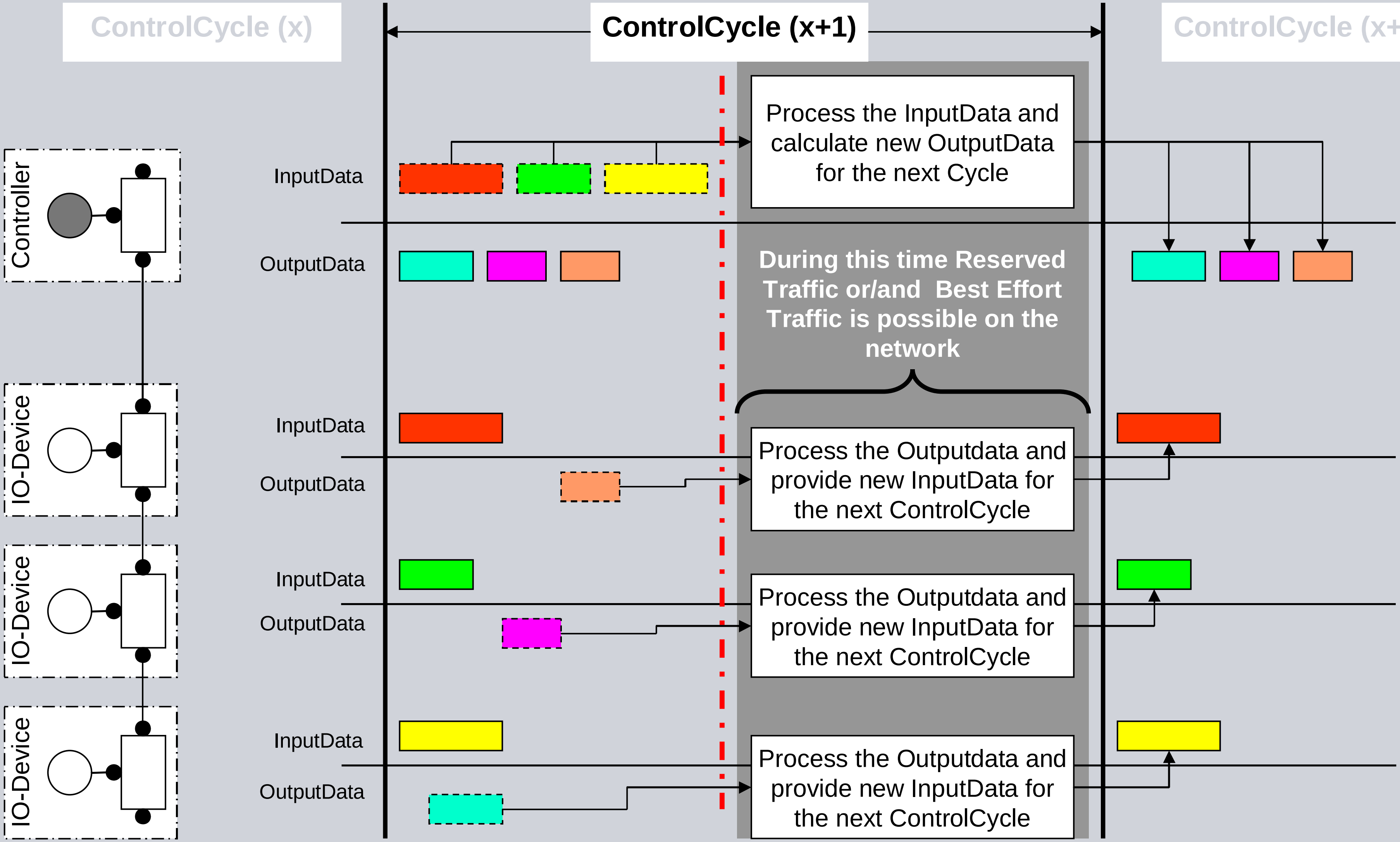

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=> Transfer a copy of the InputData to the controller and
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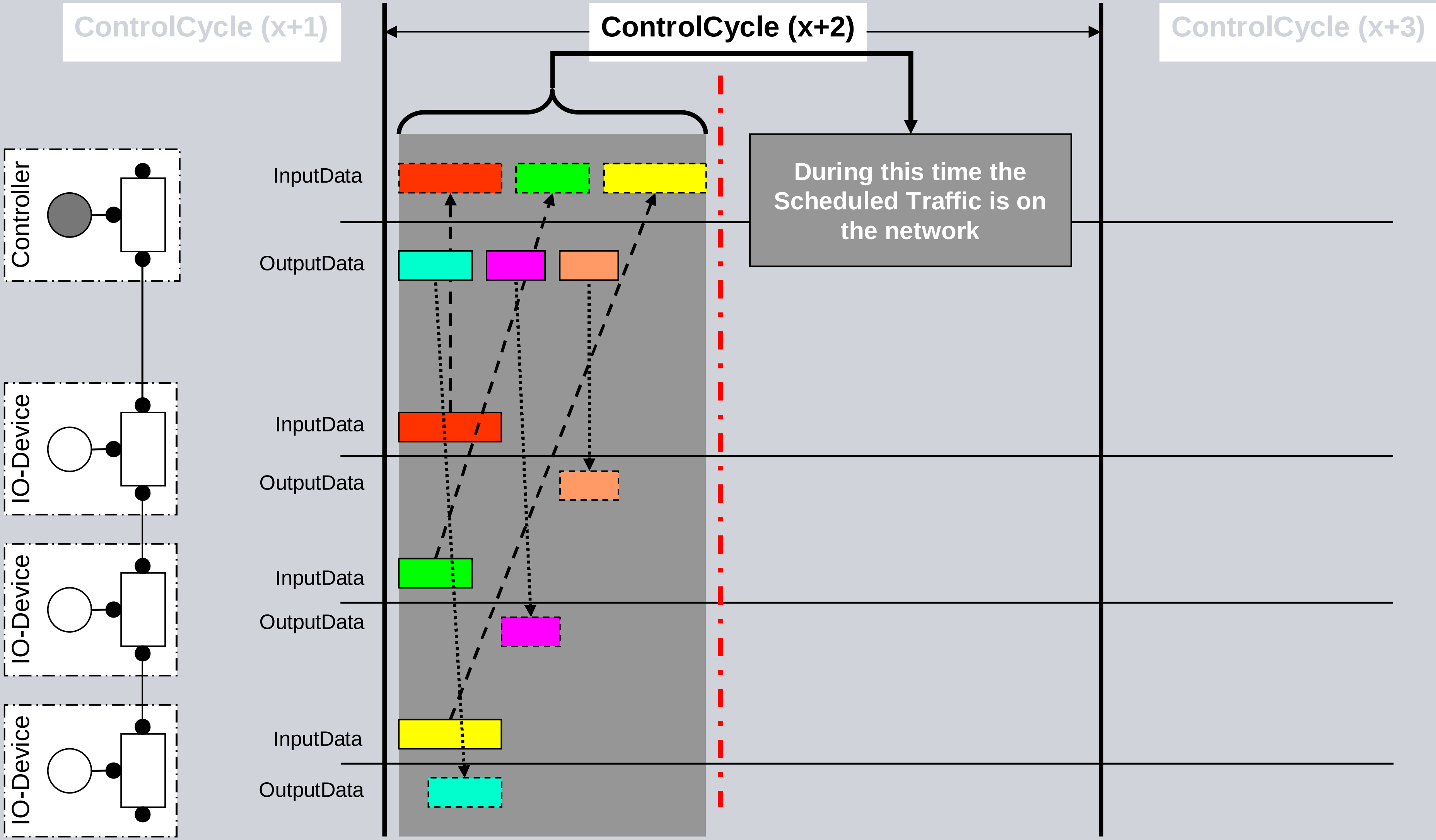

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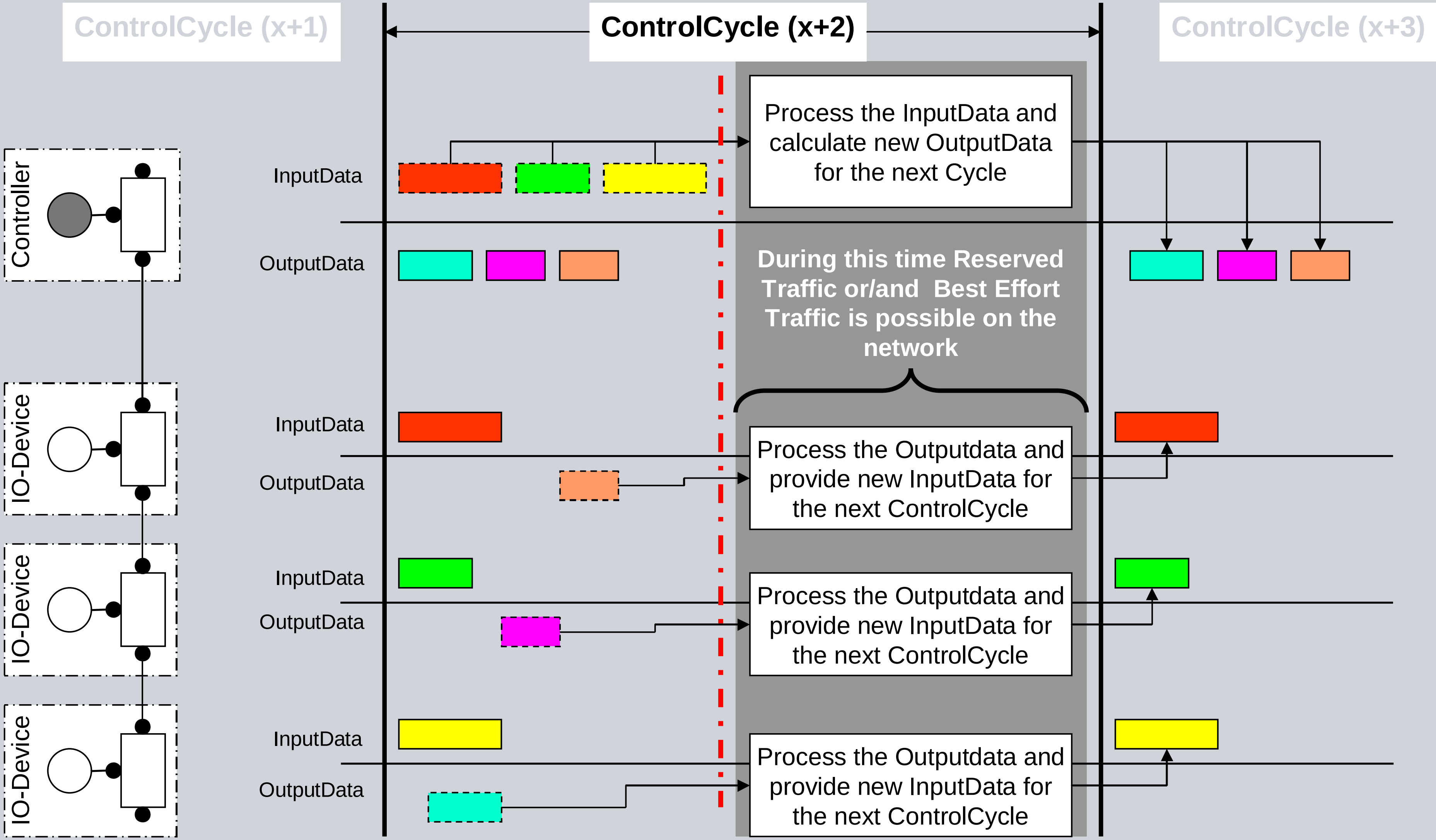

# Requirements for Scheduled Traffic

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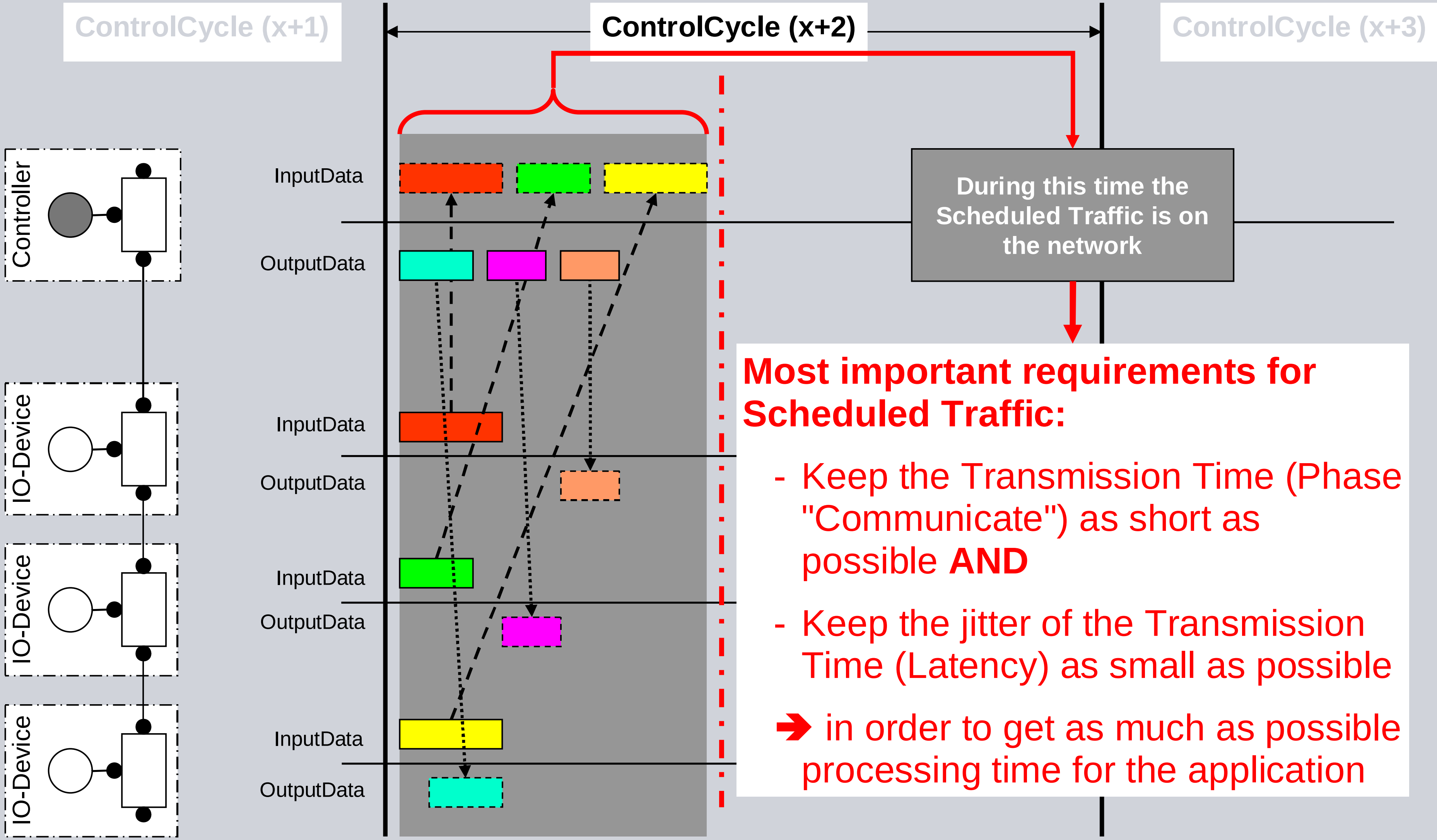


**Most important requirements for Scheduled Traffic:**

- Keep the Transmission Time (Phase "Communicate") as short as possible **AND**
- Keep the jitter of the Transmission Time (Latency) as small as possible

➔ in order to get as much as possible processing time for the application

# Benefits of Minimum Latency for Scheduled Traffic

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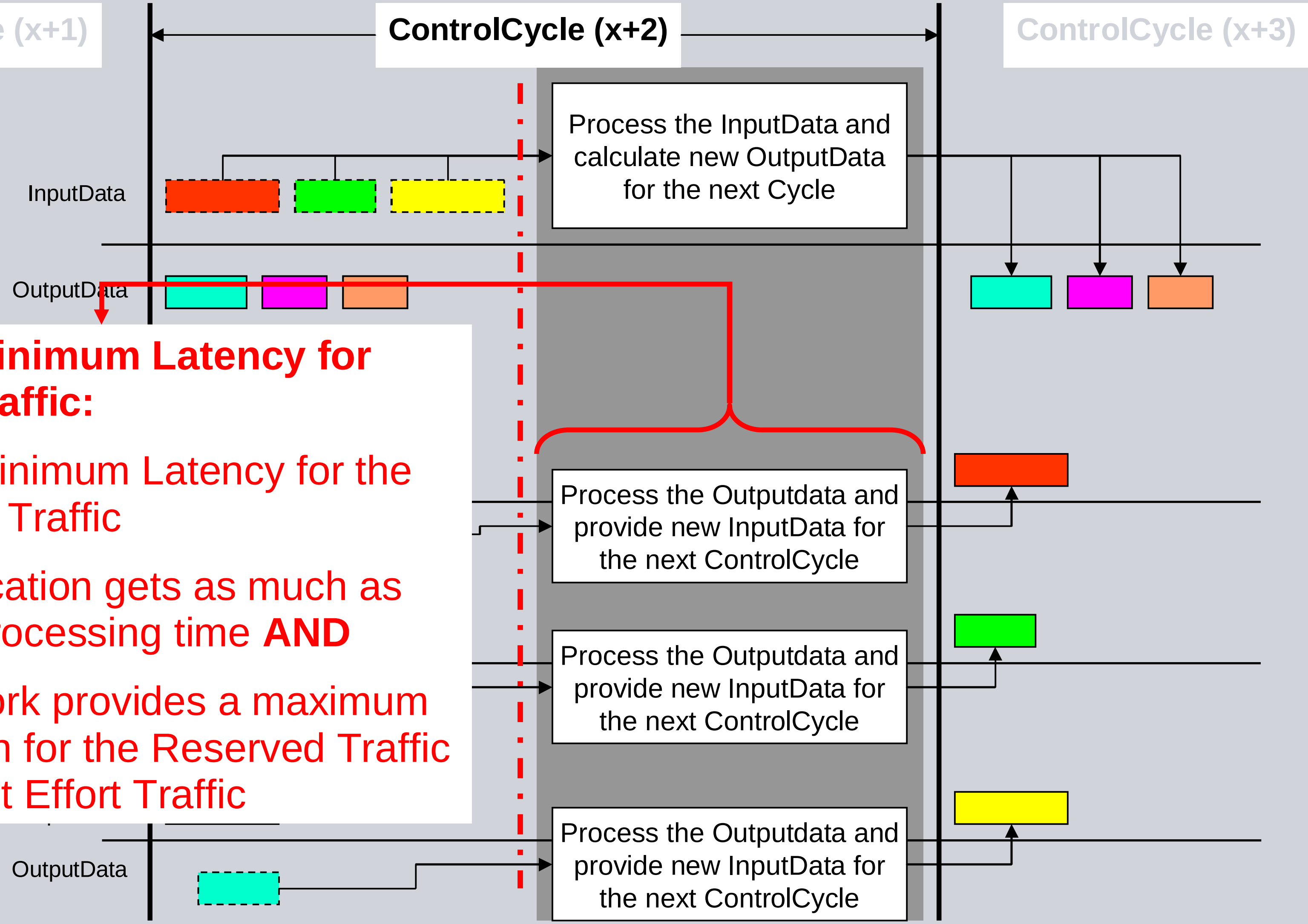


**Benefits of Minimum Latency for Scheduled Traffic:**

- With the minimum Latency for the Scheduled Traffic

➔ the application gets as much as possible processing time **AND**

➔ the network provides a maximum of bandwith for the Reserved Traffic and/or Best Effort Traffic

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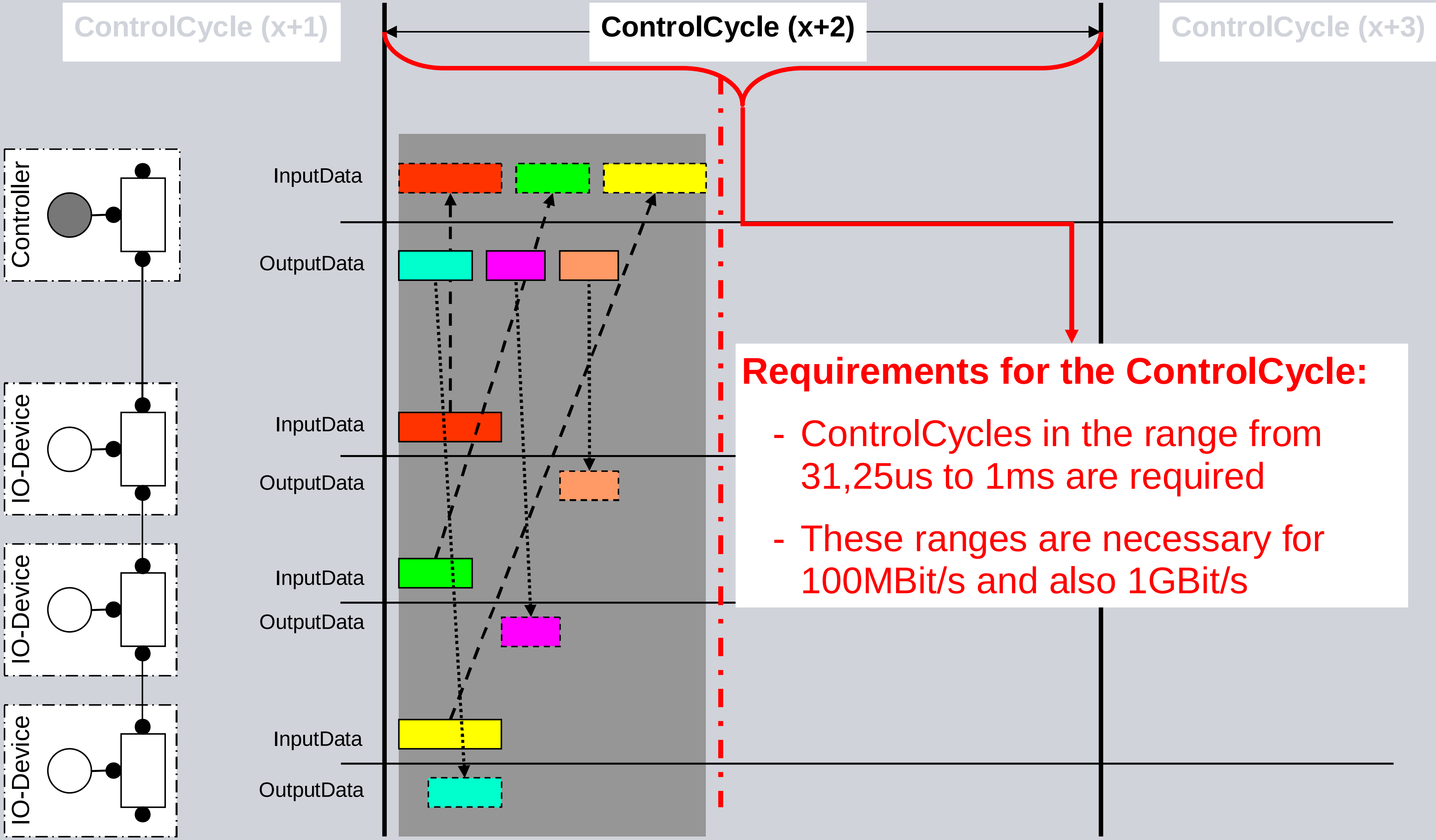
# Requirements for the ControlCycle (Application point of view)




**Requirements for the ControlCycle:**

- ControlCycles in the range from 31,25us to 1ms are required
- These ranges are necessary for 100MBit/s and also 1GBit/s

# Benefits of LOW Latency for Scheduled Traffic

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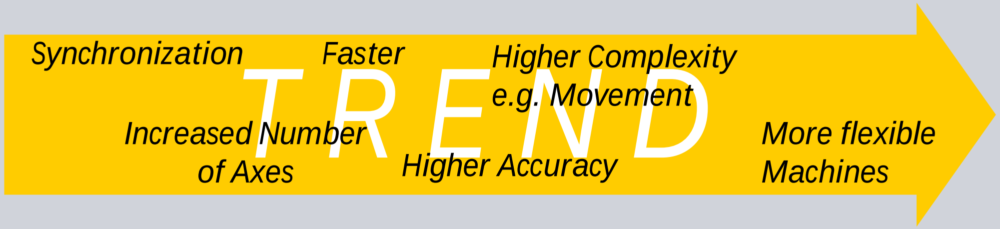
**Reasons for low latency:**

- Increase rate or speed of production
- Increase product quality by increasing product accuracy
- Reduce resources




**=> Minimize Control Cycle**

## Reduce Resources Example (plastic moulding)

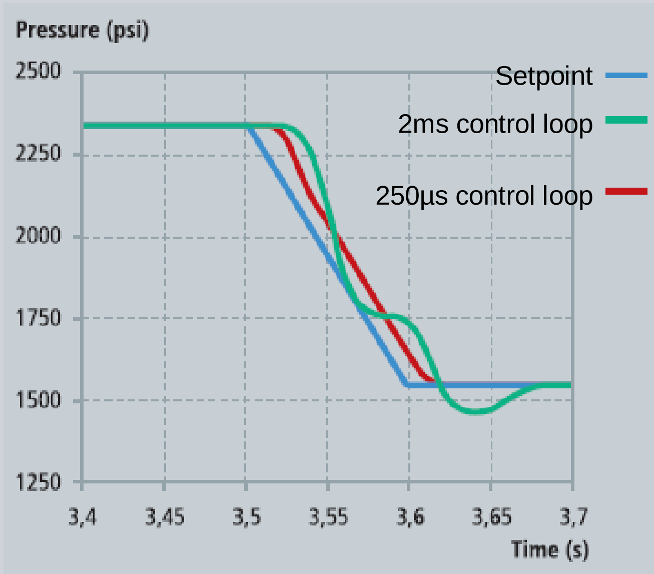
**Control cycle optimization through minimization of the response time and constant dead time is not an end in itself.**

**In addition to enhanced quality, the aim is to save material through reduced wall thickness.**

Example: Plastic cup moulding:

Reduction of cup weigth per part by only 2 grams results in the following savings for the machine user:

- **Cup weight today (g): 22**
- **Cup weight target (g): 20**
- **Parts / year: 54,568,421**
- **Annual material saving (kg): >109,137**
- **Savings per year ($ US): >200,000**



# Industrial Communication Network Topologies

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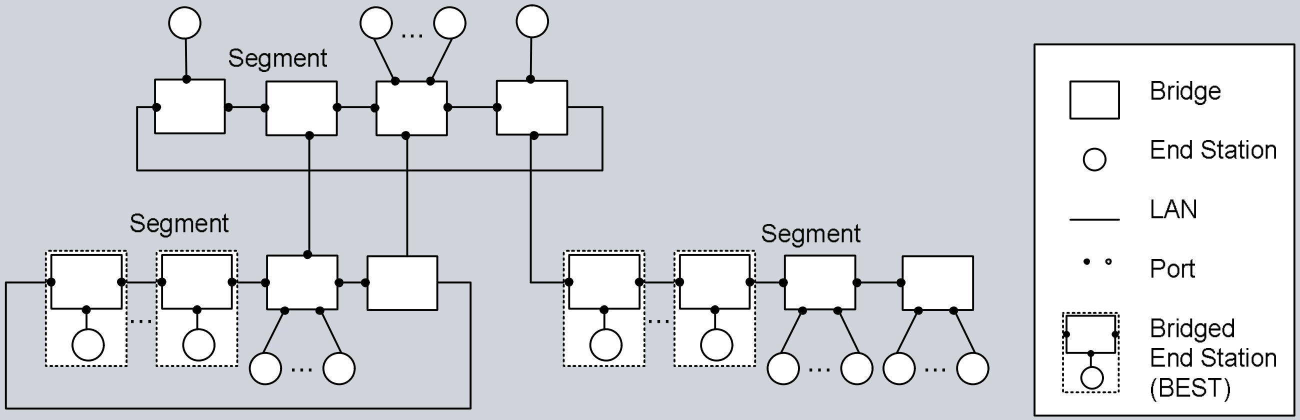
**Network topologies:**

- star
- line
- ring and combinations




## Reasons for line topologies:

- Applications are normally physically distributed in a linear manner , i.e. production lines

- The network is tailored to the application, i.e. line topologies

- To reduce total cost, 2-port-bridges are integrated into the end stations

- Ring topologies are used to provide high availability

- Minimize wiring effort ➔ avoid thick cable harness ➔ cable channel

**Influence of the topology to the QoS of Scheduled Traffic:**

**In line topologies the interference of Scheduled Traffic by Best Effort Traffic increases the latency of the Scheduled Traffic dramatically.**

# Application Example 1: Printing Machine

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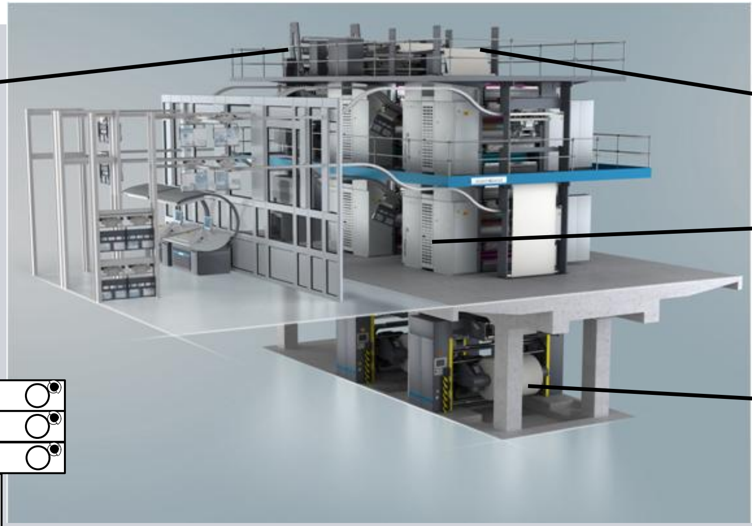
**Finishing Unit**
- Turner Bars
- Folder superstructure
- Folding Unit

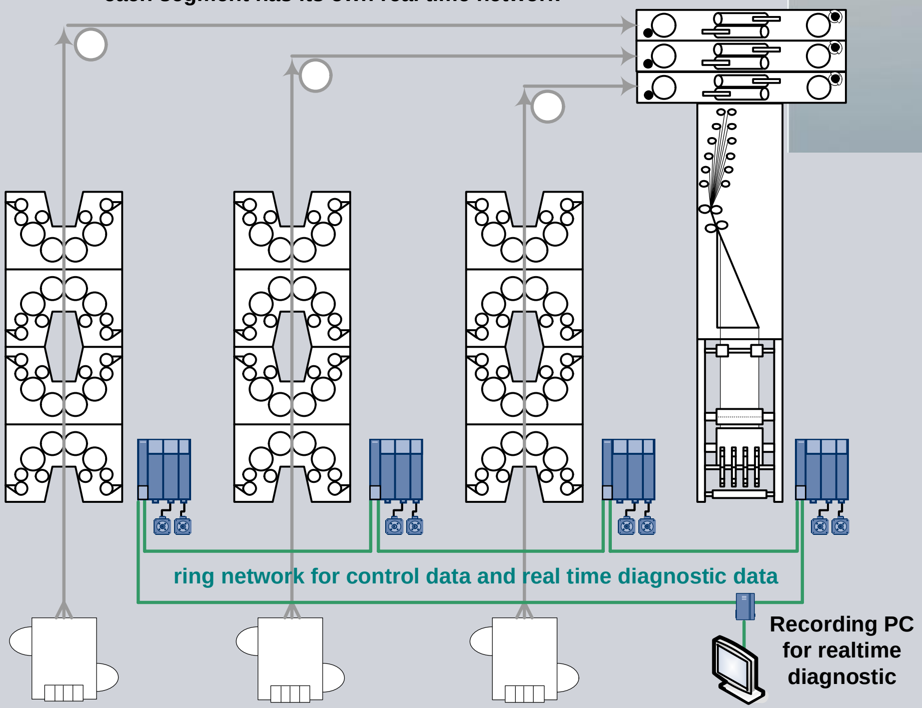


**Guide Rollers**
(to route Paper Webs)

**Printing Unit**

**Reel Stands**
and Paper Rolls

**- multiple printing units per column**
**- up to 10 axes per column**
**- a segment can consist up to 10 column**
**- each segment has its own real time network**




Requirements:

- Transmission Period: 1ms – 125µs, in future 62,5us
- Typical length of control data: 12 – 60 bytes/axis
- Maximum number of axes: up to 100 in one segment
  - up to 1000 axes in huge printing machine
- Topology: daisy chain, ring, comb in combination with star
- High available network – seamless redundancy
- Real time diagnostic for monitoring purposes
  - Payload of AV streams: ~400 bytes
- Payload of Best Effort Traffic : ~1500 bytes

**Future implementations can be more efficient if a converged network is available**

# Application Example 2: Wind Turbine

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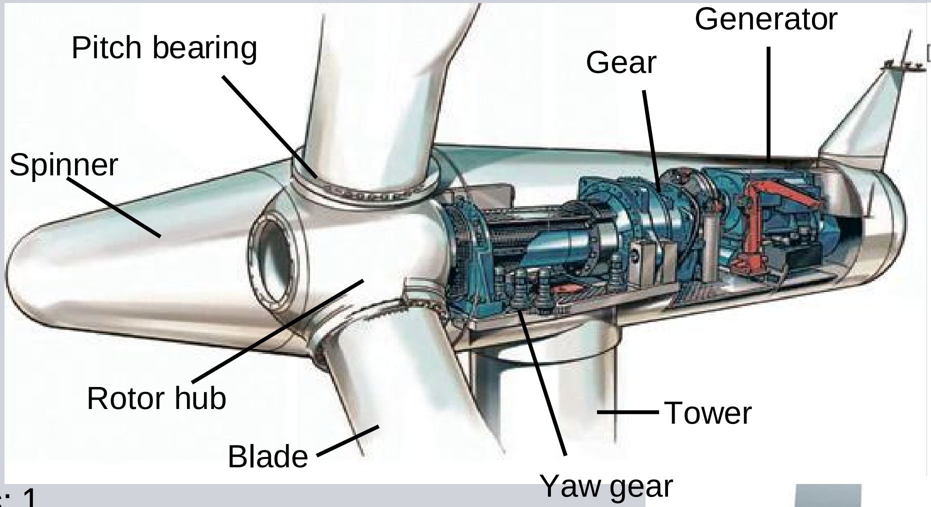
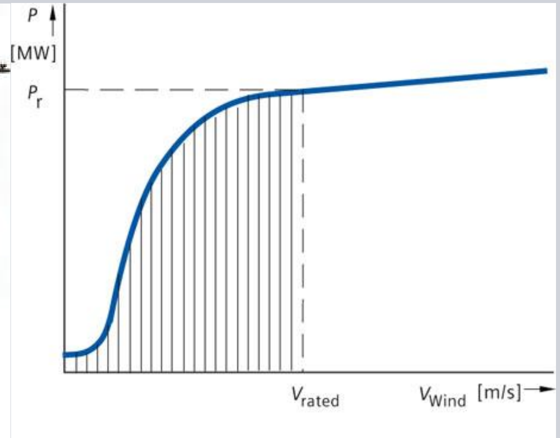
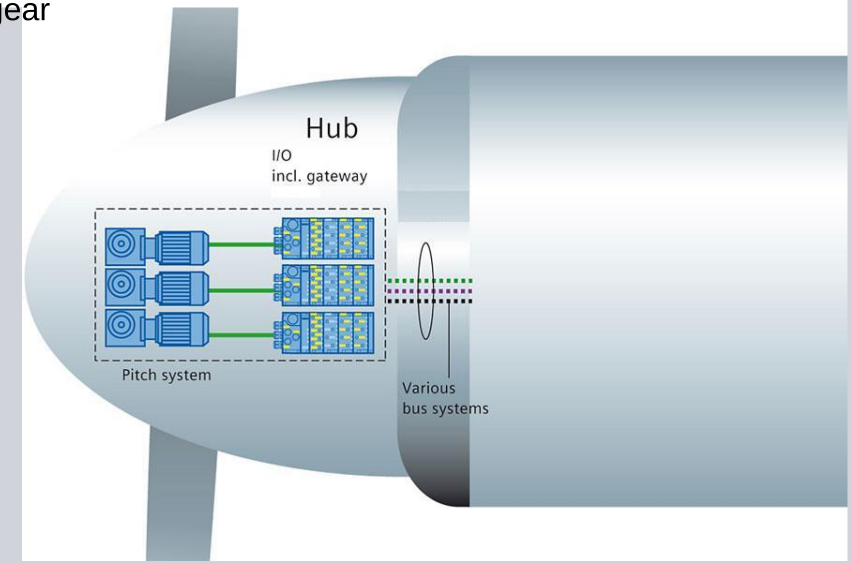


General performance curve of a wind turbine

Requirements:

- Number of controllers: 1
- Number of devices: 8
- Typical length of control data:
  - Input: 40 bytes
  - Output: 40 bytes
- Transmission Period: 125us in future 62,5µs
- Topology: line topology
- Real time diagnostic for monitoring systems (e.g. vibration)
  - Payload of streams: ~400 bytes
- Payload of best effort traffic: ~1500 bytes




**Future implementations can be more efficient if a converged network is available**

## Application Example 2: Substation Automation

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Substation Automation according to IEC 61850 is an integral part in many Smart Grid Initiatives around the world!

Traffic characteristics of Substation Automation according to IEC 61850:

*Scheduled traffic:*

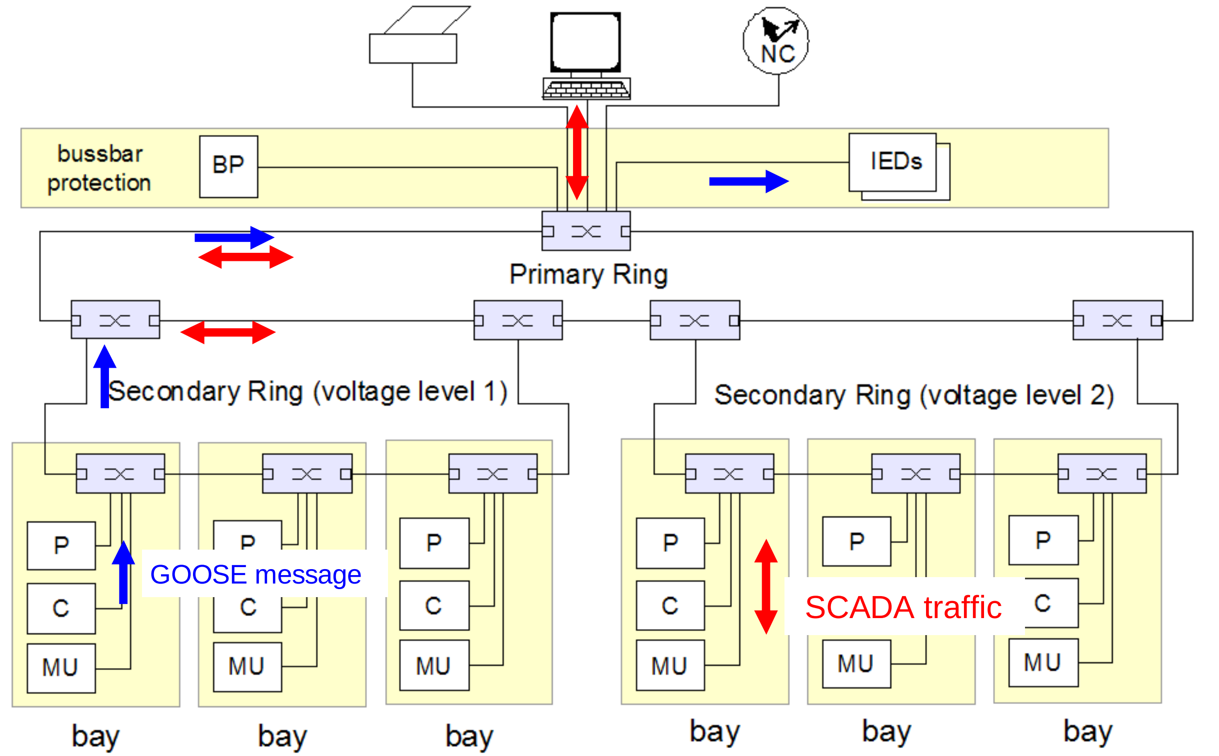
- L2 event trip messages (GOOSE)
- L2 cyclic traffic (Sampled Values)

*Best effort traffic*

- MMS (Manufacturing Messaging Specification) e. g. SCADA File up-/downloads, device configuration, ...

Problem: MMS traffic, like SCADA file up-/downloads increase the latency of scheduled GOOSE and SV traffic

**Future implementation can be more efficient if a converged Network is available**




IED = Intelligent Electronic DeviceM; MU = Merging Unit; P = Protection Relay; BP = Busbar Protection Relay; C = Bay Controller; NC = Network Clock

# Summary: Industrial Requirements for Scheduled Traffic

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**Performance requirements for Scheduled Traffic:**

– Minimum latency: < 1µs @1000MBit/s in case of an empty transmission queue

– Guaranteed latency

– Topology independent

– Typical data size (payload size): 40 - 300 bytes

– Range of transmission period: 31,25µs – 1ms

– Scheduled Traffic has higher priority than Reserved Traffic and Best Effort Traffic

**Preconditions for performance requirements**

– Network topology: star, line, ring and combinations

– Network attributes

- Maximum 64 hops
- Maximum number of nodes (bridged end stations & end stations): 2000
- Maximum cable length: Standard length for Tx and Fx are required
- High available network - seamless redundancy for Scheduled Traffic

– Payload size of Reserved Traffic (e .g diagnostic data): ~400 bytes

– Payload size of Best Effort Traffic: 1500 bytes

* These are our best estimates derived from multiple use cases of the current and future industrial applications.

## Summary: Industrial Requirements for the Physical Layer

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**In Industrial Applications different media types are used and required.**

**Ethernet offers the required physical media like:**

- **100Base-Tx and 1000Base-Tx**
  - used for most applications
- **100Base-Fx and 1000Base-Fiber:**
  - used at harsh EMC environments
  - used to bridge long distances
- **Wireless:**
  - used for mobile devices
- **10GBase-Fx:**
  - used as backbone

## Objectives

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### Objectives for a Converged Network for Industrial Communication:

- No or less configuration - ease of use
- Has to be operational with different link speeds
- Usage of the existing and future IEEE 802.3 Media types
- Connecting existing 802.1/.3 networks to converged networks shall be possible
- Flexibility: Changing the network (e.g. adding new stations, changing the topology) should be possible without influence on the latency of the Scheduled Traffic
- Robustness against miss-configuration
- High available networks are required (as shown in the slide "Substation Automation")
- Efficient usage of the existing bandwidth of the network required
- A converged network should have same transmission performance (e. g. related to the Bit Error Rate) like standard 802.1/.3 networks today

# Thank you for your attention

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