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Additional parameters for a bidirectional TSN communication with a underlying Sub-structure

Contribution Beckhoff Automation

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System structure used in this context

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- A **Machine** has typically a Control Unit and couple of Field Devices
  - Field Devices can have only Inputs or only Outputs or both as process data
  - Smart Devices include a control loop that is controlled by the Control Unit by Set-Points with Feed-Back values from the devices
  - Examples for smarter field devices are drives

- A **Cell** (Line) includes a set of Machines as Executing Devices and a Cell Control Unit
  - Again, a loop structure is required to control the machines

- The roles of the end stations are denoted as control unit and device

Machine internal networks are isolated (physically/logically) from Cell networks
➔ the structuring of both networks are done independently
… different persons, different organizations …

Structure in this context

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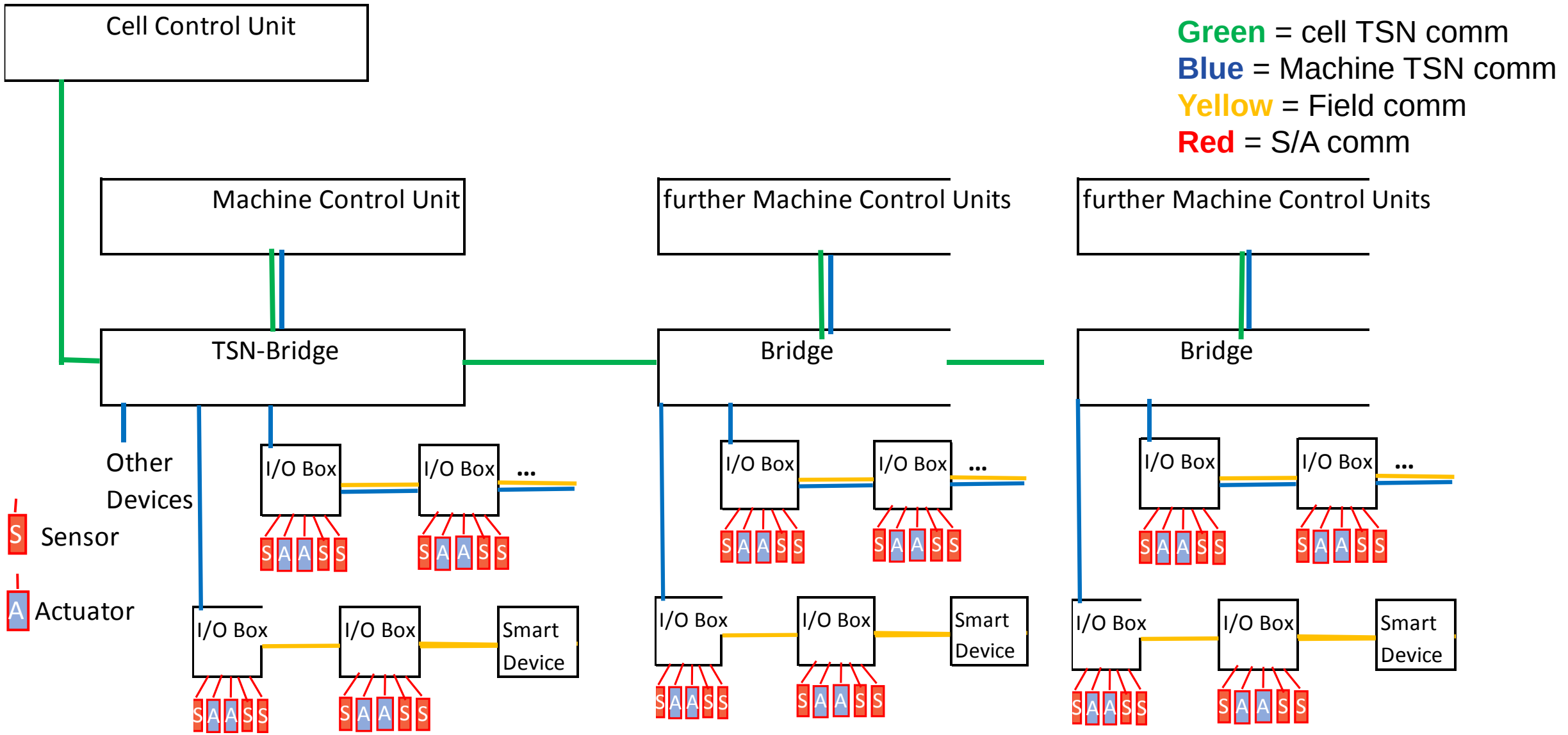

Coordination of communication interaction

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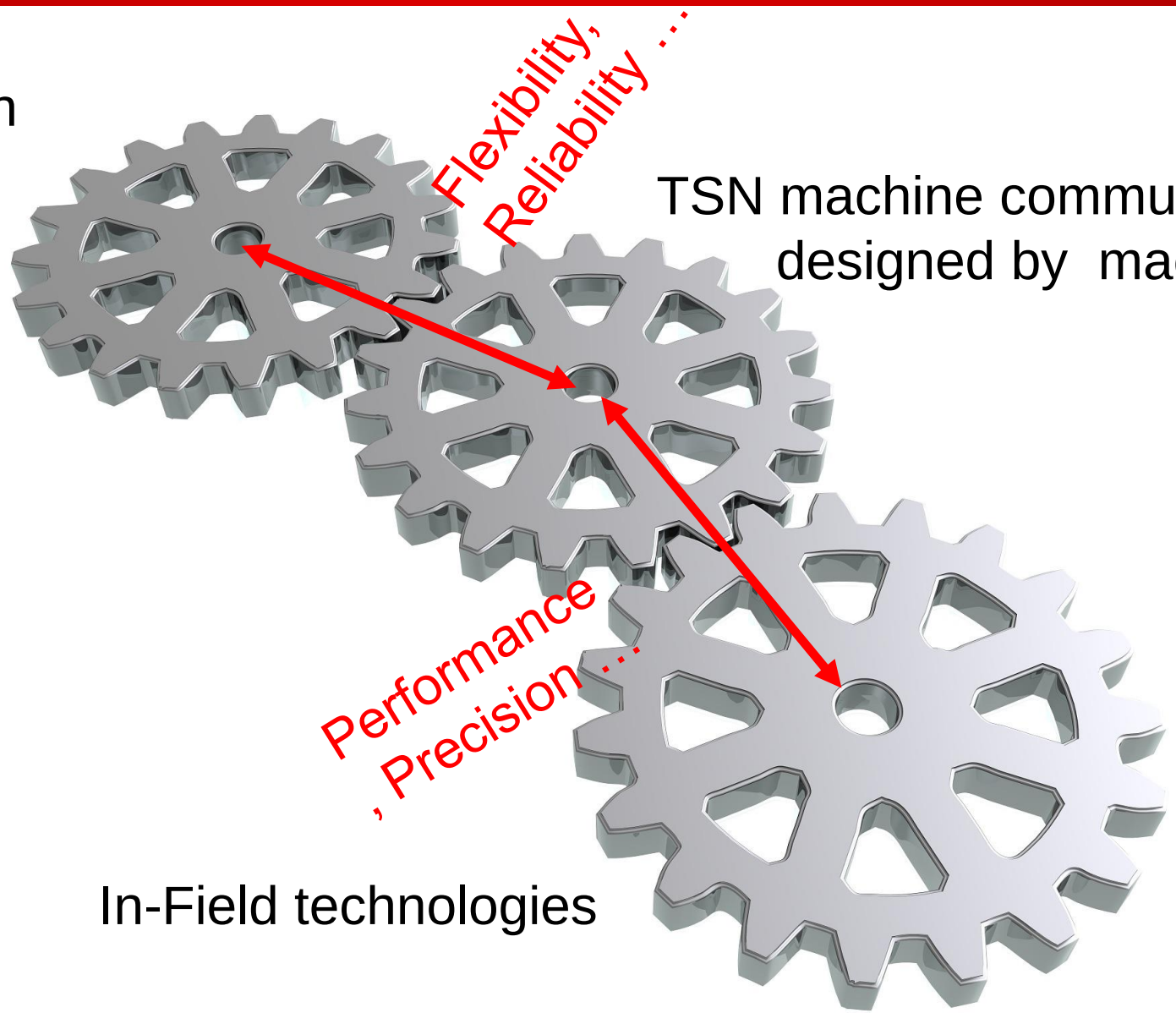
TSN cell communication designed by plant builders



TSN machine communication designed by machine builders

In-Field technologies

Example of embedded machine communication

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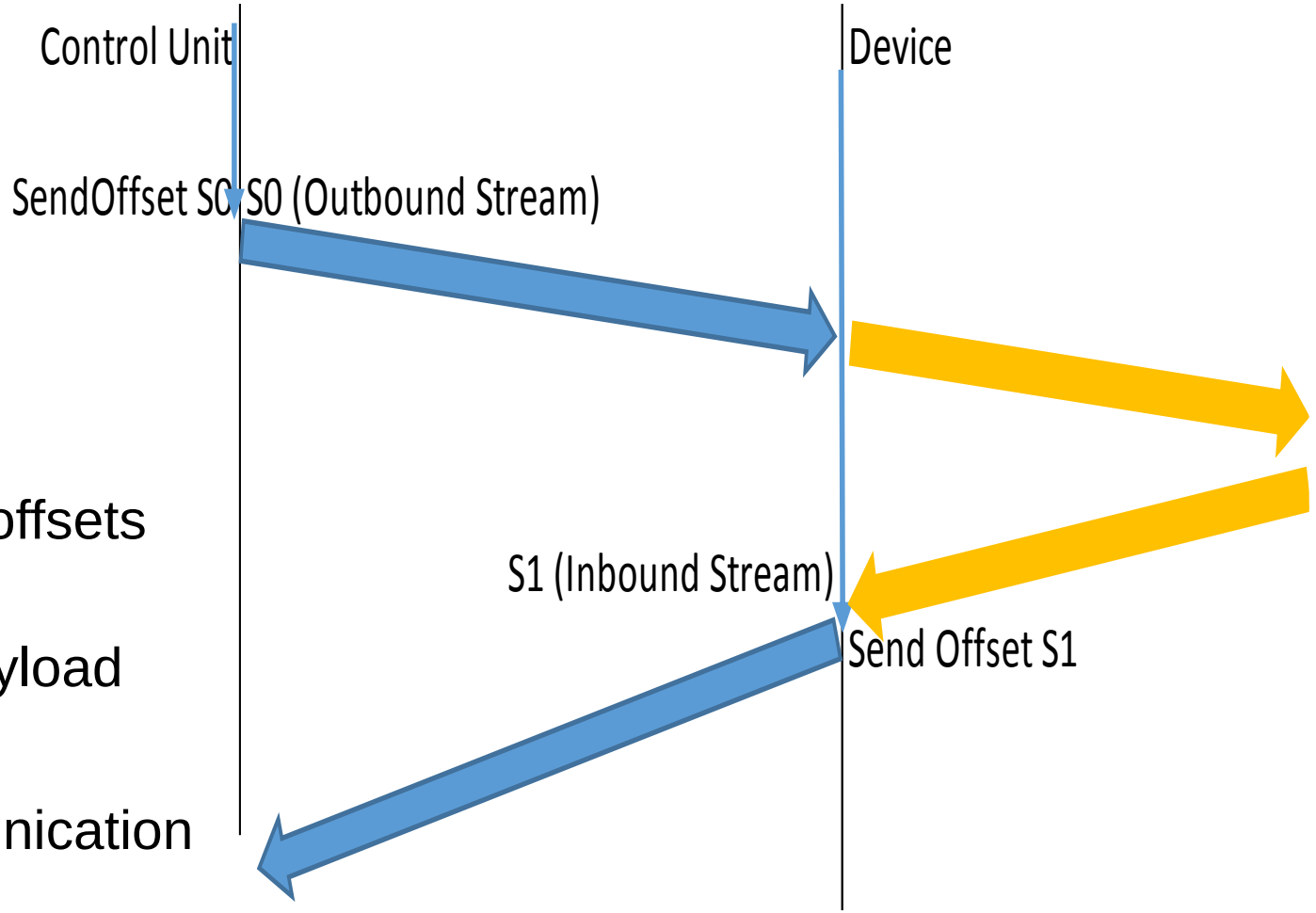
- Blue: bidirectional TSN communication
- Yellow: device/subsystem internal communication
- **There are n Devices (x=1..n)**
- optimized timing requires model of local system reaction
- Criteria shortest S1x arrival time at Control Unit of all Devices x



- The the calculation of stream send offsets requires information related to:
  - Streams S0x and S1x with ist payload
  - Latency of S0x and S1x
  - Device/Subsystem (Sub-)communication

Calculation of sub-communication delay and inbound stream parameter

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- Depends upon Control Unit demands and the Device internal structuring:
  - Device can determine the **latency** of the internal communication
  - Control Unit can determine **the amount and the structure of the data** to be exchanged
  - For simple system structure the formulae
    SubcommDelay = SubcommLatency+RateFactor*StreamPayload+LocalReaction
    - SubcommLatency, LocalReaction can be put together as Device parameter
    - RateFactor is a Device parameter
    - StreamPayload is a Control Unit parameter
  - Can be more complex if latency and payload per local subelement depend upon each other e.g. only a part of payload may be relevant
  - Suggest to use the above performance parameter as default
  - But more enhanced calc schemes should be allowed (OUI specific TLV)
- Inbound stream payload is defined by the Control Unit
- Needs several interactions between Device and Control Unit

Additional parameters for underlying control loops

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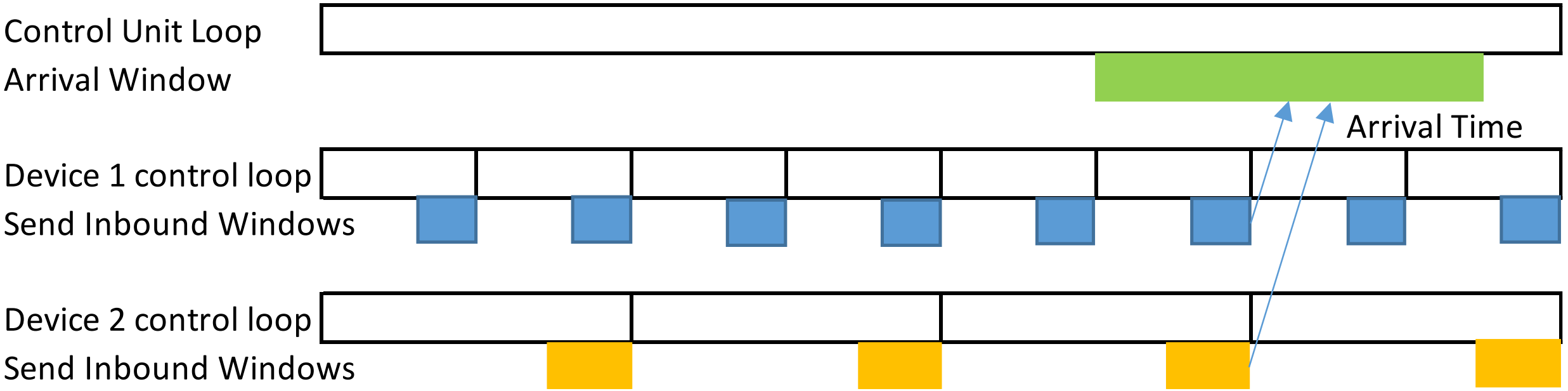
- Underlying control loops run faster! (4 to 8 times)
- Control loops run with a time error and requires a setup time
- The send offset is not a given interval at TSN level but an interval at the control loop
- The internal control loop time shall be an additional parameter and the offsets shall refer to that control loop!



Machine Communication isolated

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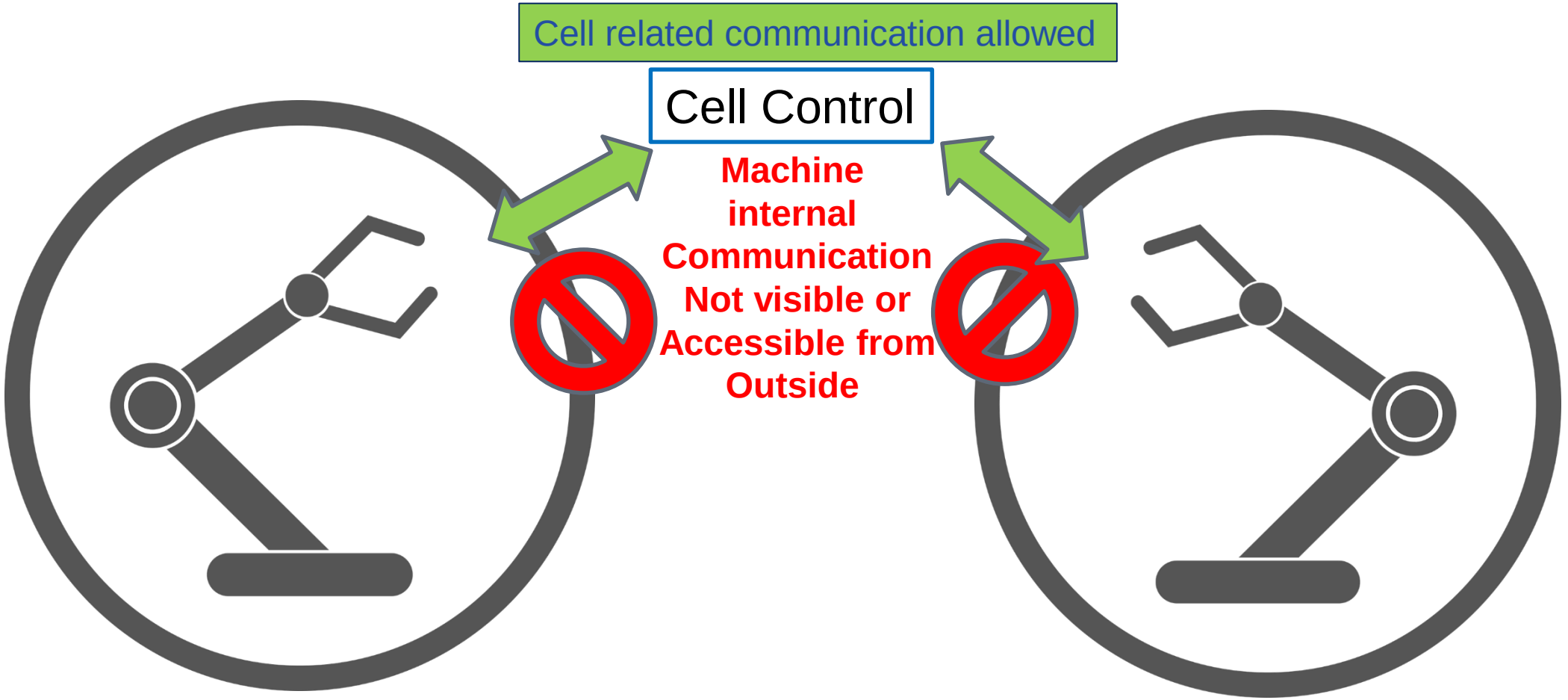

TWINs: Identical machines have identical configurations when shipped

➔**Marking of Machine access ports accordingly:**
block machine internal stream reservation, allow cell access

Channel from cell to machine

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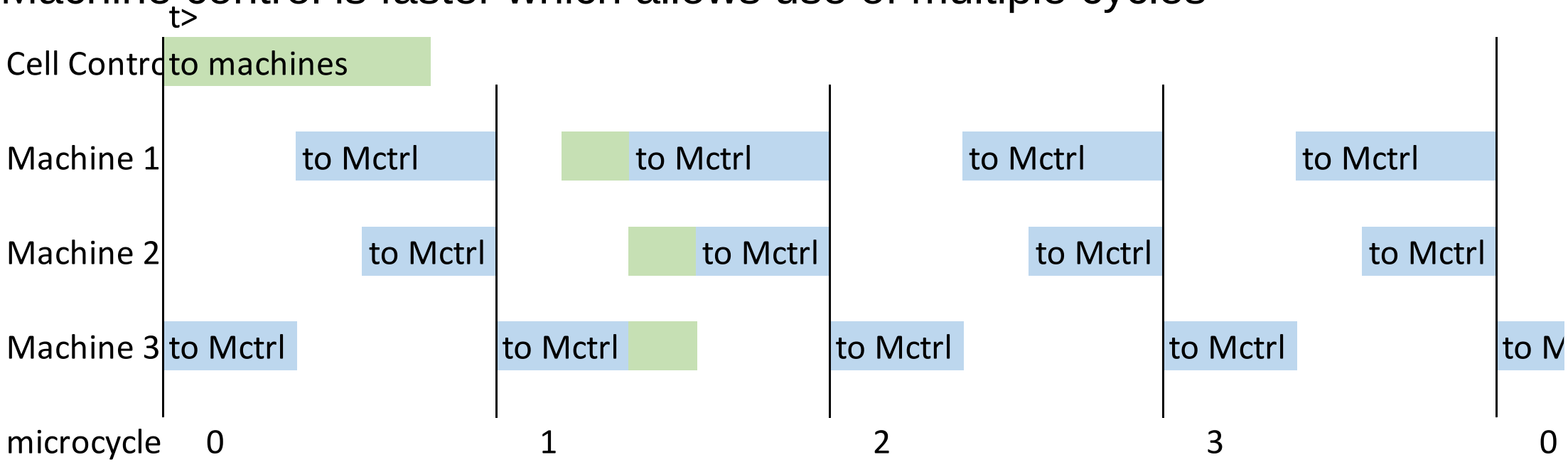
- The machine internal data path can be hardly coordinated with cell communication
- The internal setups of the machines may not allow a common cell schedule
- The communication can be shifted into the next microcycle
- The processing may be located in the next but one cycle
- Machine control is faster which allows use of multiple cycles



Large Synchronization domain

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- An outstanding feature of TSN is the synchronization beyond a single machine.
  - Allows correlation of machine data
  - Reduction of cycle time or more precise machine interactions possible

- Problem in case of failures
  - the local interactions shall be decoupled from sync beyond machine.
  - This could result in a time offset between a machine and the cell level
  - it may be necessary to run temporarily different clocks.

Redundancy at cell level

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- Cell level redundancy is required more frequently
  - machines may be turned on/off while other machines are operational.
- Redundant cell control units may be used.
  - Hot standby ➔multiple streams one of them being active and the other one passive.
    ➔should be supported by the machine internal structures.
  - Cold standby is the more frequent use case with a spare control unit for several cells.
  - cell control tasks may move away from machines to a more suitable place at the factory site. This may require a cell backbone connected in a resilient way (such as a ring or coupled rings)
  - FRER required at ring entry (replicate) and ring exit (eliminate replicates)
  - Initiate