A Sample Selection for an Industrial Profile of TSN (with contributions)

Version 1.0

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Impetus

- This presentation was developed at the request of several 60802 members and provides background for a few task group ballot comments.
- It provides a selection of TSN and Ethernet features for inclusion in the profile
- The presentation references the profile D1.0, use cases v13, and the example selection presentation given in Hiroshima by Guenter Steindl
  - http://www.ieee802.org/1/files/public/docs2018/60802-industrial-use-cases-0918-v13.pdf
  - http://www.ieee802.org/1/files/public/docs2019/60802-Steindl-ExampleSelections-0119-v02.pdf
- This presentation is relevant if the reformatting proposed by Janos Farkas in http://www.ieee802.org/1/files/public/docs2019/60802-farkas-d1-0-ballot-comment-support-steps-1-and-2-trk-0219-v01.pdf is adopted though the section numbers may change.

Opening Question

- Is TSN only for high end applications?

Opening Answer

- The expected answer is “no”.
- Basis for this answer: The use cases and their requirements should be supported from v13 of the use case document; unless purposefully excluded by the 60802 working group.
- Applications for Time Sensitive Networks vary between a small microcontroller based system (Use case 3) with a couple sensors to applications with thousands of axes of motion (Use Case 16).
- The trend of this group according to 60802 D1.0 seems to be pointing towards being able to support all applications with every infrastructure device.

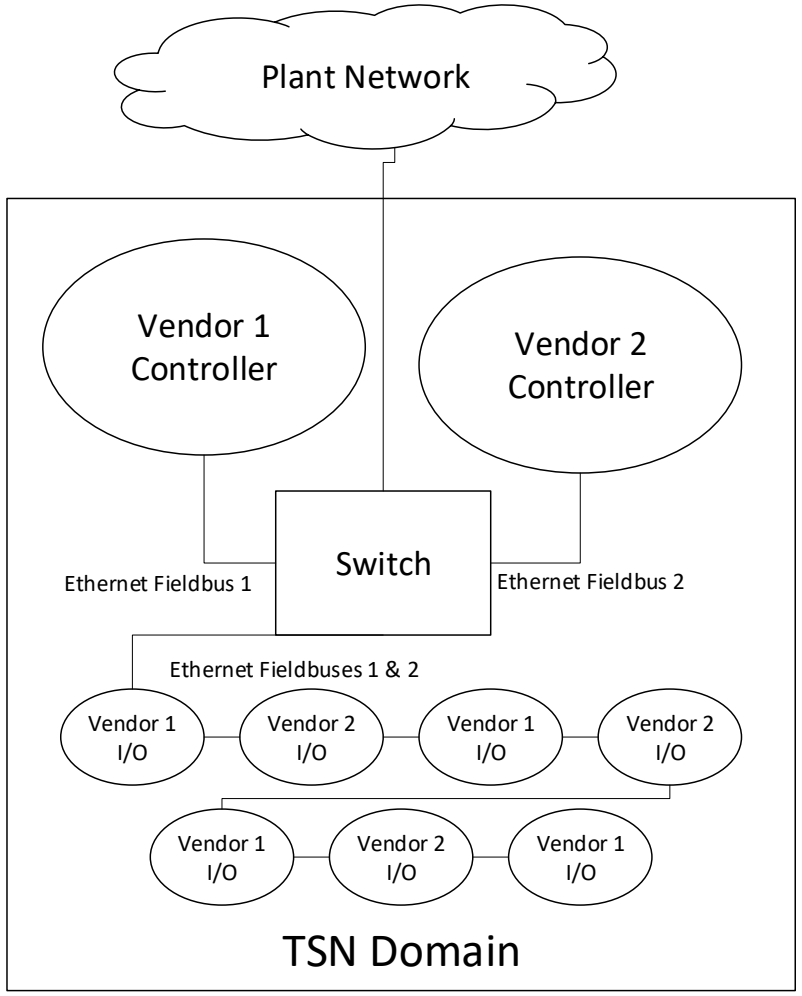
TSN Infrastructure Complexity

- Specifying TSN Infrastructure to be a one-size-fits-all solution means infrastructure components will have complexity many applications don't need.
- This does not mean multiple profiles are the only option, though multiple profiles may be the right option. A single profile can be written such that it accommodates scalability.
- The data sheet approach, centralized or fully distributed TSN management and network calculus can enable a scalable approach to implementing TSN infrastructure.
- 60802 needs to provide **a guarantee that the network can meet the needs of all applications running over it all the time, and must have a reasonable path to adoption.**

A Suggested Approach

- Focus the profile on being flexible enough such that infrastructure can meet the needs of customer applications rather than specifying all infrastructure must meet the needs of all applications.
- This can be accomplished either by creating multiple profiles, or by creating one profile with optional components and places to define where those options can be implemented.

A Sample Lower End TSN Application Featuring Coexistence on the Wire



This is an implementation of use case 3

A selection of TSN “Tools in the Toolbox” to support the Lower End Application

- Network Management Engines implemented in the controllers (PLCs), one is primary for the TSN domain
- Gigabit Network
- Non-Isochronous Application
- Fewer than 512 streams
- Management & Information Streams to other TSN domains implemented
- Only 4 QoS queues on embedded bridges
- Time Aware Shaping not necessary at gigabit operation
- 802.1AS-REV implemented for timestamping of events
- TSN Domain protection against unauthorized streams/devices
- Network Management Engine validates that neither synchronized network access nor preemption are needed to meet the application requirements, therefore:
  - Synchronized to a Local Timescale
  - Preemption not available on all infrastructure

A sample High End Customer TSN Application

2.5.10 Use case 16: Vast number of connected stations

Some industrial applications need a massive amount of connected stations like

- Car production sites
- Postal, Parcel and Airport Logistics
- …

Examples for “Airport Logistics”:

- Incheon International Airport, South Korea
- Guangzhou Baiyun International Airport, China
- London Heathrow Airport, United Kingdom
- Dubai International Airport, UAE
- …

Dubai International Airport, UAE
Technical Data:

- 100 km conveyor length
- 222 check-in counters
- car park check-in facilities
- Max. tray speed: 7.5 m/s
- 49 make-up carousels
- 14 baggage claim carousels
- 24 transfer laterals
- Storage for 9,800 Early Bags
- Employing 48 inline screening
- Max. 8-stories rack system
- 10,500 ton steel
- 234 PLC’s
- 16,500 geared drives
- [xxxx digital IOs]

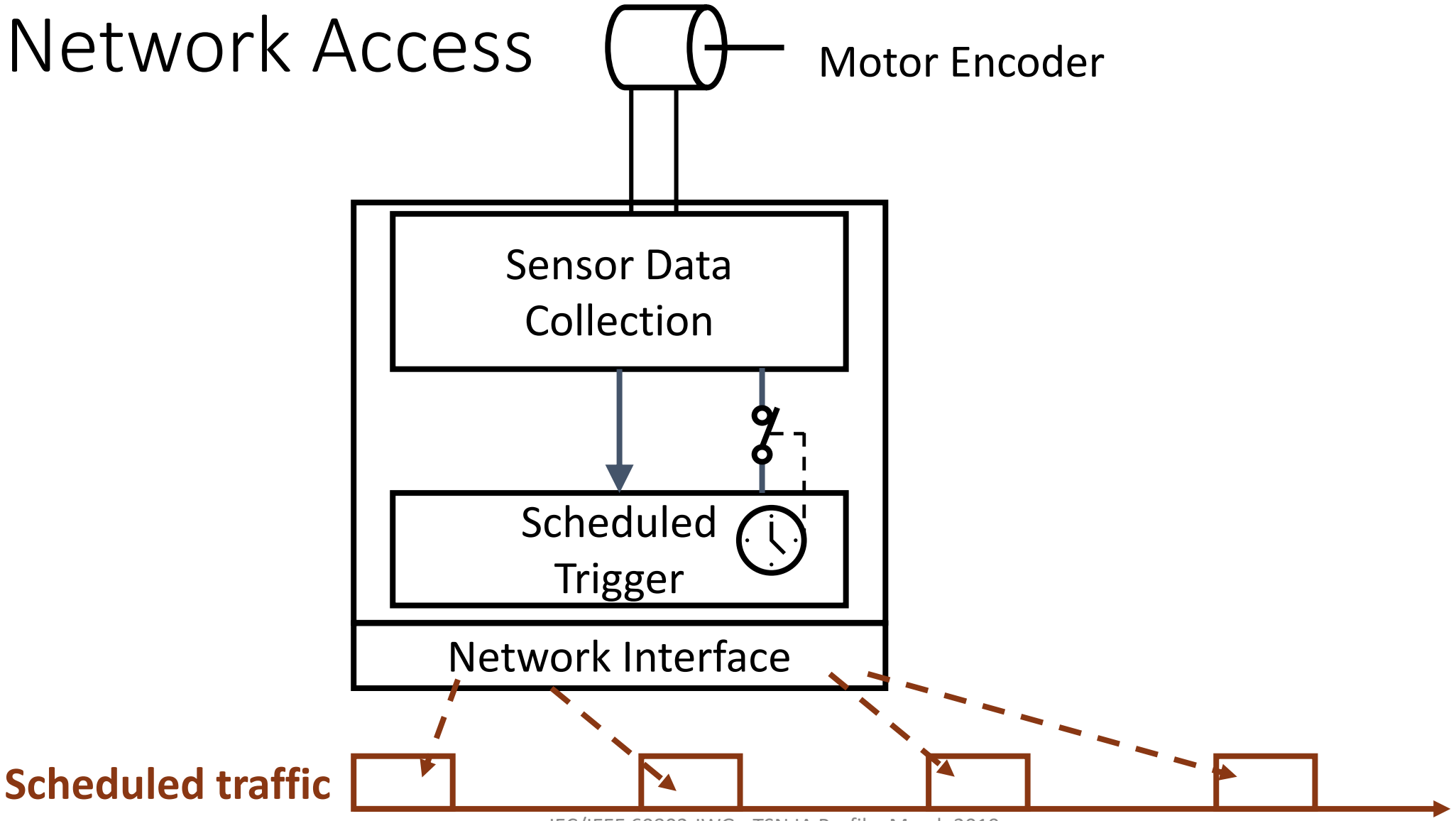
A selection of TSN “Tools in the Toolbox” to support the High End Application

- Vast number of stations will be broken down into multiple TSN domains & layer 2 broadcast domains along logical boundaries
- Network Management Engines can be implemented in controllers (PLCs) or a stand alone device, one is selected for each TSN domain
- Gigabit Network
- Isochronous Applications
- Thousands of streams
- Management & Information Streams to other TSN domains implemented
- 8 QoS queues on bridges, though some small limited device TSN domains may find 4 acceptable
- Time Aware Shaping not necessary at gigabit operation
- 802.1AS-REV implemented for isochronous applications and sequence-of-events
- TSN Domain protection against unauthorized streams/devices
- Network Management Engine validates application by synchronizing network access throughout all end stations. Some small limited device TSN domains may find that synchronized network access is not necessary.
- Bridges generally support and have preemption enabled. Some small limited device TSN domains may not find preemption necessary.

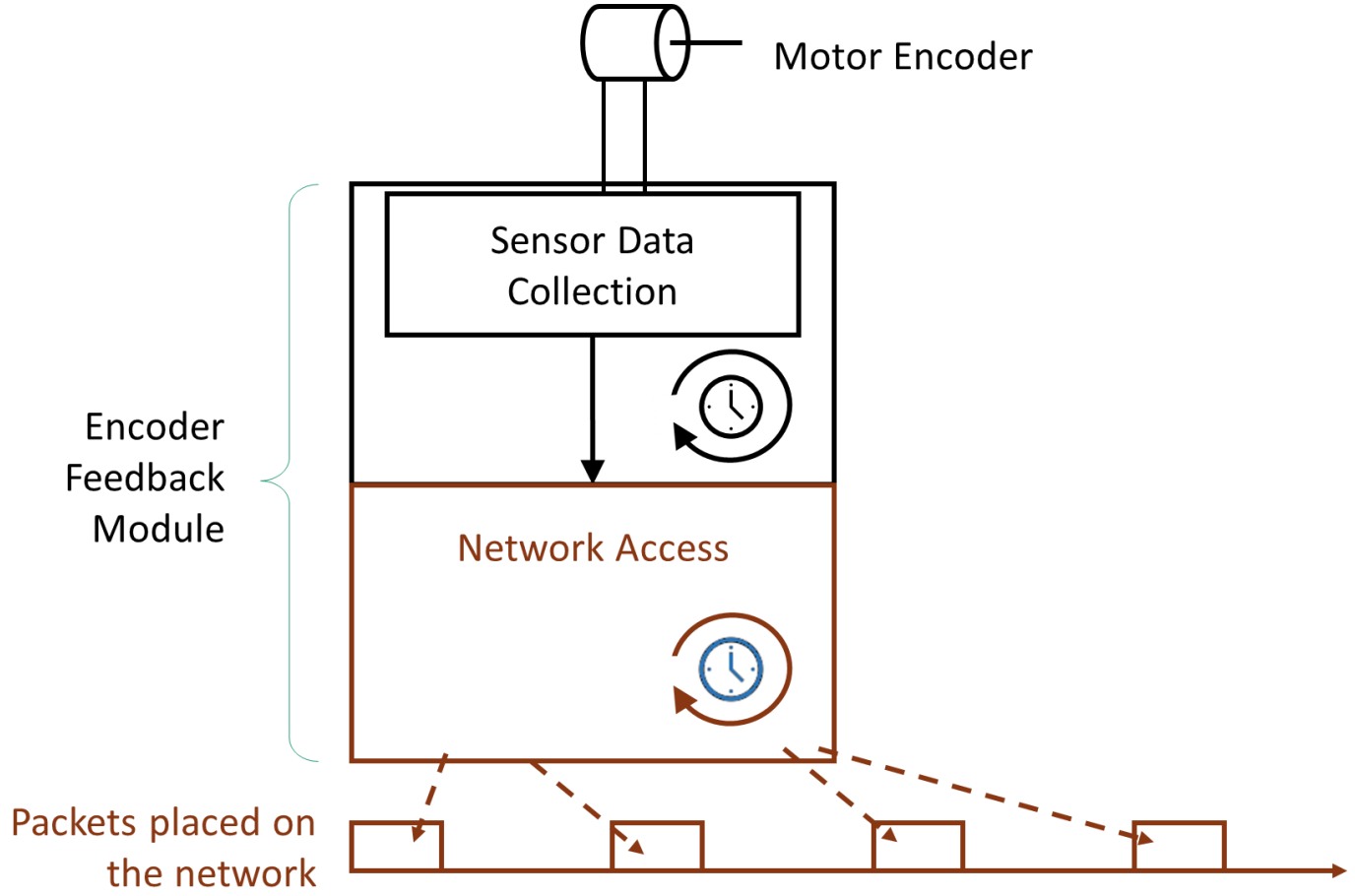
Synchronizing Network Access to Working Clock

- This concept is based on the profile draft 1.0 and “Example Selection” presentation by Guenter Steindl
- In essence, the concept as currently understood can be explained as traffic lights on highway on-ramps
- If network access is controlled in times of congestion, guaranteed latencies can be provided to applications
- The advantage of this concept as compared to scheduling the network via Qbv is that the precision of this schedule can vary greatly with the needs of the supported applications.
- There are many details still to be defined regarding this concept.

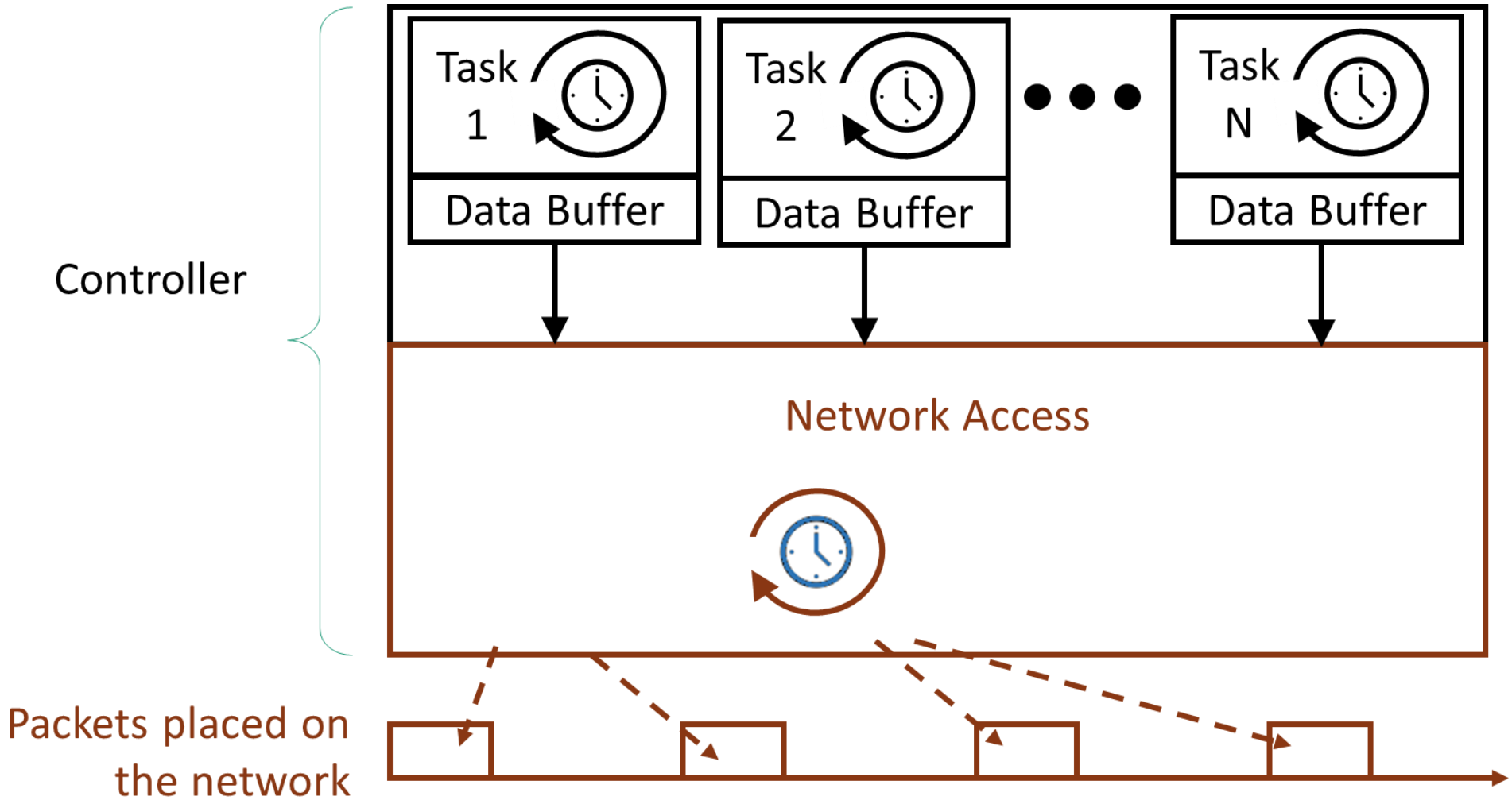
Isochronous Application with Synchronized Network Access



Non-Isochronous Application with Synchronized Network Access



Multiple Applications with Synchronized Network Access



Proposed Changes to 60802 D1.0

- Suggest making preemption optional
- Suggest making the minimum number of QoS Queues 4, with 8 recommended
- Suggest additional background information to support Section 4.1

Proposed Additional Background Information

- Section 4.1 jumps into a lot of detail without sufficient background information.
- Terms are currently undefined and not understood by new readers.
- The network access synchronization to working clock concept needs to be defined in more detail.
- The following are slides that can be copied into the draft if the group agrees to provide sufficient background information

Proposed Definitions for Section 3.1 of 60802 D1.0, Part 1

TSN Domain

The current definition is “quantity of commonly managed industrial automation devices”. This is technically accurate, but not precise enough. Suggest changing to:

A set of stations (end stations and/or Bridges), their Ports, and the attached individual LAN’s that transmit Time-Sensitive Streams using TSN standards which include Transmission Selection Algorithms, Preemption, Time Synchronization and Enhancements for Scheduled Traffic and that share a common management mechanism (or “policy engine”).

Note 1 to entry: It is an administrative decision to group these devices.

Network Access

The action of placing frames on the network or of collecting frames from the network. Any controlling element is capable of generating data for placement onto the network or utilizing the data that is collected from the network. However, the act of generating the data or utilizing the data is separate from actually placing the data on the wire or collecting it from the wire.

Proposed Changes to Section 3.1 of 60802 D1.0, Part 2

Working Clock

The clock in any given TSN domain against which network access, infrastructure components, devices, or applications may be synchronized.

Multiple events triggered by the working clock are synchronized based on the common notion of time they derive from the working clock.

Local clock

The local oscillator onboard any device that requires processor execution. This clock may or may not be synchronized to the working clock depending upon application requirements. Absence of a working clock assumes local clock control.

Isochronous Application

An application that is synchronized to the same working clock that is synchronizing network access.

Proposed replacement in Section 4.1 of 60802 D1.0

- The following slides are proposed to replace:

~~Applications may or may not be synchronized to the Network Access depending on the application requirements. Applications which are synchronized to Network Access are called "isochronous applications". Applications which are not synchronized to Network Access are called "non-isochronous applications".~~

~~Network Access shall be synchronized to a common working clock or to a local timescale.~~

~~Network / Bridges may or may not be synchronized to a common working clock depending on whether the Enhancements for Scheduled Traffic (IEEE 802.1Q-2018) are applied.~~

Proposed Section 4.1, Part 1

- Applications need to have a common understanding of time if they need to synchronize and sequence events. This may be used for things such as synchronizing multiple axes of motion, or for timestamping sensor inputs. The working clock enables a common understanding of time. If an application doesn't need to have a common understanding of time, it may be executing based on its own oscillator which would be known as a local timescale.
- The working clock will be synchronized throughout a network using a profile of the Precision Time Protocol (PTP). While bridges must propagate the working clock, the bridging function will only synchronize transmission according to the working clock if Enhancements for Scheduled Traffic (IEEE 802.1Q-2018) is enabled.
- While many time sensitive applications may be implemented on an industrial automation system, two applications require minimized latency and known delivery windows. The first is known as isochronous applications and the second is non-isochronous applications.
- Isochronous applications are typically used for motion control and can have application cycle times as low as 31.25uS. Isochronous applications must align the application cycle with the working clock. Non-isochronous applications are commonly cyclic traffic (I/O), alarms and events, network control and more with nominal update rates of 1ms and above. Non-isochronous applications may align the application cycle with the working clock.

Proposed Section 4.1, Part 2

- Meeting the latency requirements of all applications can be accomplished in multiple ways. Some of those methods are:
  1. Define and test all possible application combinations
  2. Overprovisioning the network
  3. Providing scheduled time slots for each application to transmit on the network
  4. Preempting lower priority traffic
  5. Reserving time on the network for certain traffic classes
  6. Synchronizing network access
  7. Simulating the traffic ahead of time
- This profile of TSN uses methods 4-7.

Proposed Section 4.1, Part 3

- Preemption can decrease overall latency of high priority traffic by stopping a lower priority frame mid-transmission on a predetermined boundary (64 bytes by default), interspersing the high priority traffic, then resuming the lower priority traffic when complete.
- Reserving time on the network for certain traffic types can be done through the implementation of Enhancements for Scheduled Traffic (802.1Q-2018). A network cycle needs to be defined for this to work. The network cycle is a multiple period of the applications that are traversing the network. Once that cycle time is defined, a portion of that cycle can be reserved for transmission of those traffic types.
- When a single application is implemented on a network, that application is responsible for sequencing the entire industrial automation system. The application can ensure the network will be able to meet all latency requirements through internal sequencing. When multiple applications share the same network, those applications need to validate that the network will always meet their latency requirements. A function which simulates network performance can compute which TSN components are necessary to meet the application requirements. One component is synchronizing Network Access. This is a method for coordinating transmission of all the traffic that shares a TSN domain to validate all application requirements can be met while increasing utilization.

Timing

- The Guenter Steindl “Example Selection” Presentation showed a timing model with 4 time domains. It is assumed these are running simultaneously.
- Many applications may only need one time domains with the working clock, especially if the working clock is based on TAI time from a GPS source.
- Working clock redundancy via “cold standby” (having multiple grandmasters on each time domain) works today and should be supported.

Conclusion

- The 60802 specification should allow all application requirements to be met either through multiple profiles or a profile with multiple options.
- Network access scheduling has distinct advantages over Qbv, and should be included, but more work is needed here.
- All applications don’t need preemption, it should be optional.
- All applications don’t need 8 QoS queues, for constrained applications 4 are plenty.
- All applications don’t need infrastructure support of 512 streams.
- All applications don’t need “hot standby” working clocks.

Thank you!