



TSN Influences on ODVA Technologies

Steve Zuponcic, Mark Hantel, Rudy Klecka, Paul Didier
Rockwell Automation, Cisco Systems

February 22, 2017

Presentation Overview

- Introduction
- Definition of Terms
- Standards Overview
- The Bigger Picture: System based Network Configuration and Commissioning
- Avnu Alliance
- Industrial Use Case
- Scope and Timing
- IETF
- ODVA Distributed Motion & Time Synchronization SIG

Definition of Terms

- **CNC:** Centralized Network Configuration policy engine. The controller that receives all network and policy requirements and calculates both the network calculus as well as the schedule for the network.
- **CUC:** Centralized User Configuration entity. Provides the CNC with network loading and timing requirements necessary for successful management of traffic across any given connection. In an industrial system, the CUC is most likely associated with the PLC programming software for offline configuration, or, with the PLC during runtime. It is in these components where network information is already known.
- **Scheduled Traffic:** Traffic that is managed via the 802.1Qbv specification which defines a time-based shaper for bounding both latency and variations in data delivery.
- **Rate-constrained traffic:** All traffic that uses traditional quality of service (QoS) methods of prioritization and that is not scheduled traffic.
- **Best effort traffic:** Traffic that does not have any guarantees that data is delivered nor is given a QoS level or specific priority.
- **Network Calculus:** The mathematics for calculating network loading and for modeling the network characteristics given payloads, maximum latencies per stream, and requested packet intervals.
- **RPI:** Requested Packet Interval. This is the requested sampling frequency for data exchange across a connection.

- Time Sensitive Networking (TSN) refers to a set of standards that are being driven and developed by the IEEE 802.1 Time Sensitive Networking Task Group.
- The TSN standards and technologies represent approximately 20 new projects that contribute to the IEEE-802.1 portfolio of standards. There is not simply one standard that is being launched but many that could have impact on the way that traffic may be managed in the future.
- This presentation provides an overview on TSN technologies, the influencing bodies that are shaping its implementation and direction, and addresses key issues and concerns relative to existing ODVA technologies.

IEEE 802.1 TSN Standard List

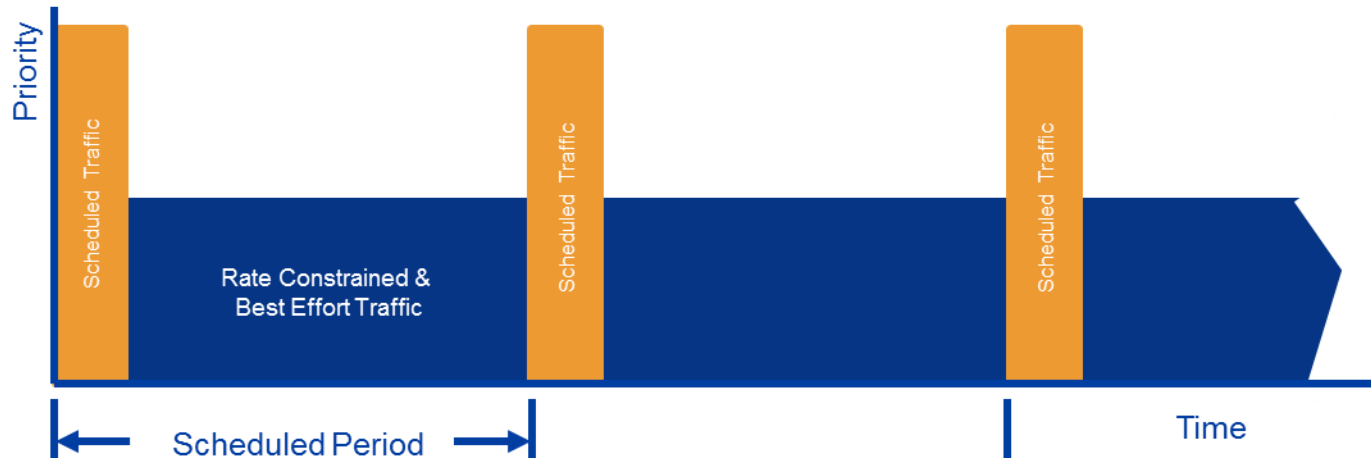
- **Published Standards**
 - 802.1AS-2011 – Timing and Synchronization
 - 802.1Qat-2010 – Stream Reservation Protocol
 - 802.1Qav-2009 – Forwarding and Queuing for Time Sensitive Streams
 - 802.1BA-2011 – Audio Video Bridging Systems
 - 802.1Qbu & 802.3br – Frame Preemption
 - 802.1Qbv – Enhancements for Scheduled Traffic
- **Standards at Final Ballot**
 - 802.1CB – Frame Replication and Elimination for Reliability
 - 802.1Qci – Per Stream Filtering and Policing
 - 802.1Qch – Cyclic Queuing and Forwarding
- **Standards in Progress**
 - 802.1AS-REV – Time Sync Enhancements including Time Redundancy
 - 802.1Qca – Path Control and Reservation
 - 802.1Qcc – Stream Reservation Protocol Enhancements
 - 802.1CM – Fronthaul Specification
- **Standards under Consideration**
 - 802.1Qcr - Asynchronous Traffic Shaping. [Urgency Based Scheduler]
 - 802.1CS - Updated MRP++ Reservation Protocol [LRP]

Scheduled Ethernet

- TSN technologies create new Layer 2 services and new prioritization mechanisms
- Significant work in the TSN standards and compliance organizations is focused on 802.1Qbv, or scheduled Ethernet.
 - Tight, predictable control of multiple traffic streams
 - Absolute management of traffic timing can facilitate modeling and simulation of the network
 - Allows for an offline design workflow prior to acquisition of hardware or commissioning in the field
- However, scheduled traffic is now the highest priority traffic on the wire
 - Can override traffic that had previously been given the highest priority under traditional QoS rules
 - Challenge is to create mechanisms that allow for the “blending” of existing technologies and products within a new, scheduled, environment

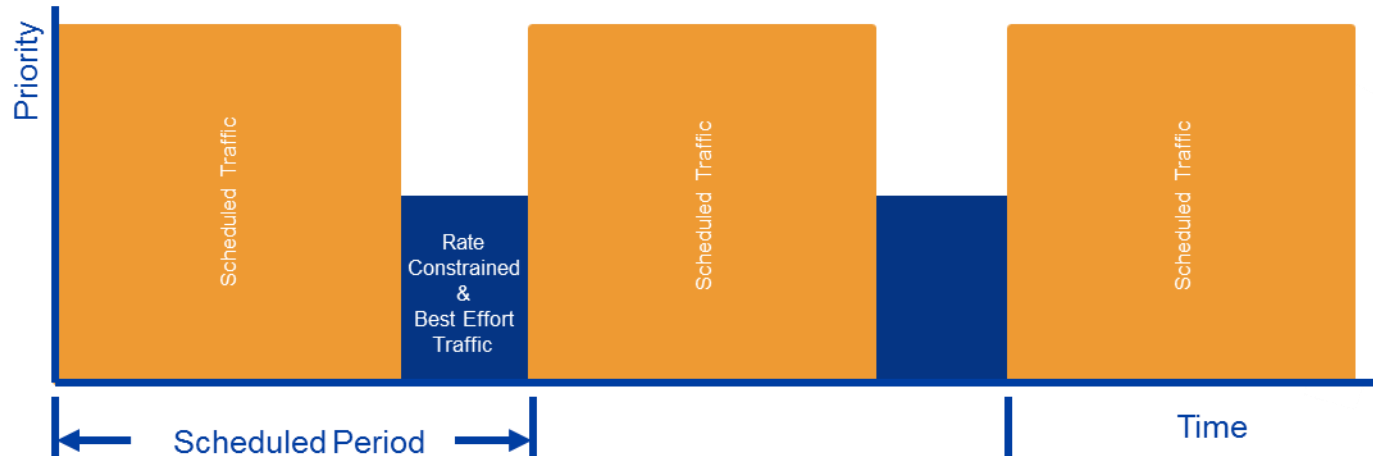
Scheduled Ethernet

- Scheduled traffic is given highest priority above all else
- Today's implementation of CIP traffic, would fall into the "rate constrained" or "best effort" category
- On a lightly loaded system, rate constrained traffic can coexist with scheduled traffic



Scheduled Ethernet

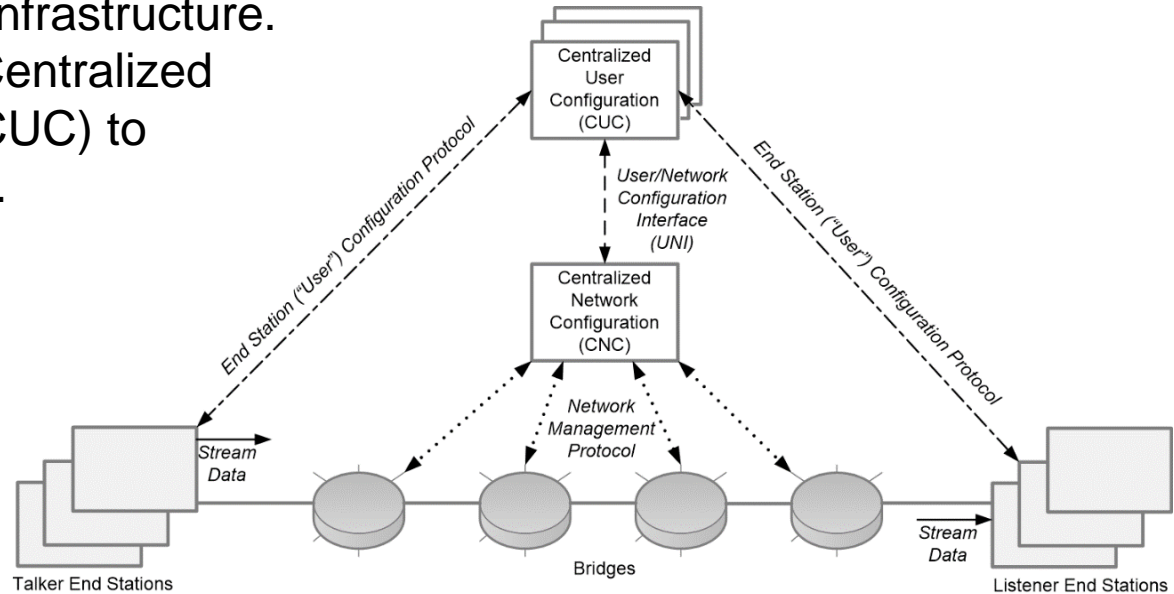
- On a heavily loaded system, where scheduled traffic has a high “duty cycle” within any given frame, CIP traffic is given less time on the wire.
- Is this a problem?
 - It depends on the application



System Based Network Configuration

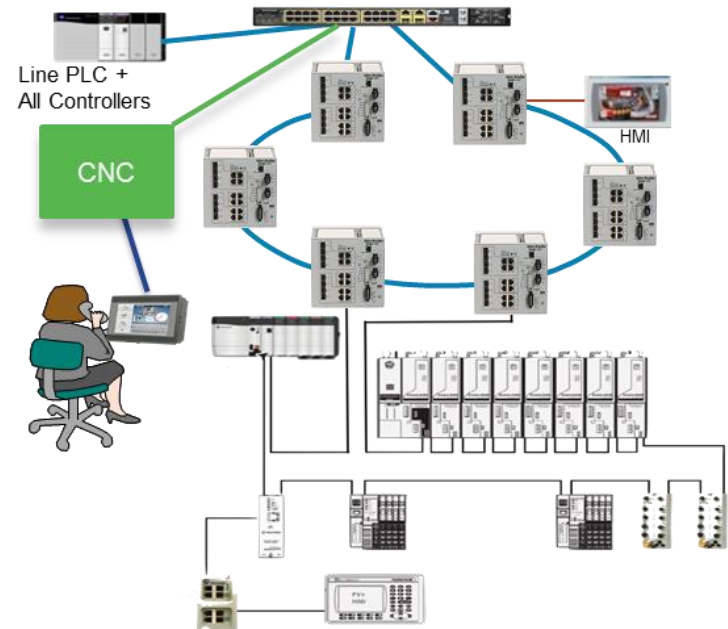
- A core precept of the TSN value proposition is that all network communications are managed so that there is a guarantee for performance and for data delivery.
 - If all streams are defined, payloads are known, RPI's are determined, and maximum data delivery latencies are provided, system network calculations can determine if successful operation of the network is achievable
 - All devices need to participate in traffic planning by publishing to, or notifying, a Centralized Network Configuration (CNC) engine of their traffic requirements for the connections involved.
 - Integration of 802.1Qcc, Stream Reservation Protocol Enhancements, allows components in the system to publish their traffic requirements to the CNC.

- In this diagram, the CNC function has the role of configuring the infrastructure.
- It communicates with the Centralized User Configuration tools (CUC) to receive stream information.
- In an industrial system, the CUC is most likely part of the PLC programming software for offline configuration, or, a part of the PLC during runtime.



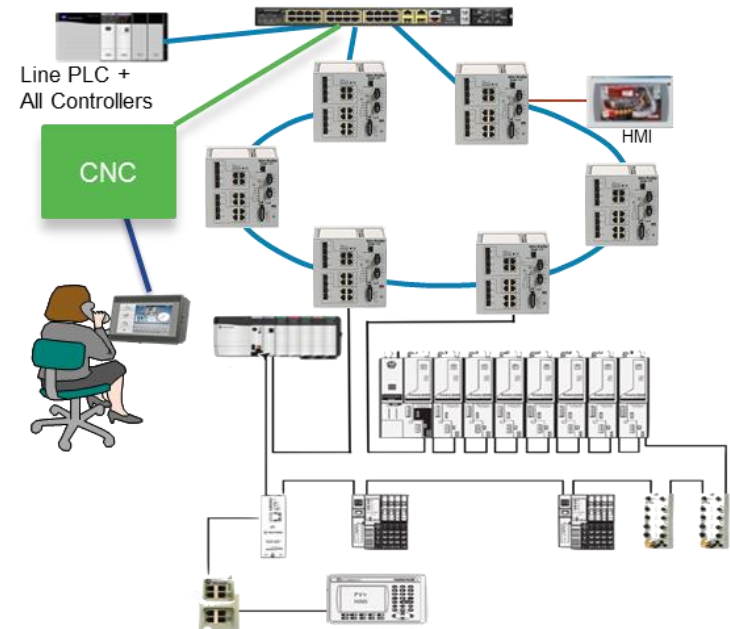
Policy based prioritization

- System level configuration allows for control of both the network and the application
- Policies provide prioritization for traffic that is deemed important in the application
 - Telephone system different than motion system
- Policy information may be provided at a system level by the user through the CNC
- CNC is given all information necessary to configure the network for proper stream management
 - Payload, RPIs, latency, required schedules, policy information, etc.



Policy based prioritization

- Per policy, it's possible that unscheduled traffic may be more important than scheduled traffic *in the application*
 - For example: Motion > VOIP
- The CNC must solve and configure for successful operation of the application given all existing constraints
 - If not solvable – return an error to user for reconfiguration of the network
- Policy based prioritization is counter-balance against data delivery mechanisms on the wire
 - Provides “fairness on the wire”



CNC for scheduled and unscheduled traffic configuration

- CNC policy engine configures network based on policies as well as capabilities and constraints of the infrastructure and devices its configuring
- Two calculating engines can be a part of the CNC policy engine
 - Scheduling Engine (SE)
 - Network Calculus Engine (NCE)
- CNC can manage either scheduled traffic, rate constrained, or both, to provide proper management of the system.

- The Avnu Alliance consists of over 60 member companies and is the certifying body responsible for developing interoperability specifications for TSN standards
- Major markets represented by today's membership include:
 - Pro Audio/Video
 - Smart Auto
 - Industrial
 - Consumer



Industrial Market Segment in Avnu

- The industrial market segment is relatively new to the Avnu organization
- Work has begun to develop industrial profiles and certification standards
 - Convergence a challenge with multiple existing technologies and standards in place
 - One example: Multiple time profiles exist demanding a convergence strategy
 - Avnu certifies on 802.1AS; ODVA has IEEE-1588 default profile; there is also a power profile and existing peer-to-peer TC profiles
 - The industrial market has a very large installed base
- The Avnu Alliance has released its first revision of an industrial “Theory of Operation” document which describes the baseline, foundational, technologies that reflect today’s version of TSN
- This document will evolve as industrial profiles become clearer and will be used to help define industrial conformance standards.

Industrial Control Overview

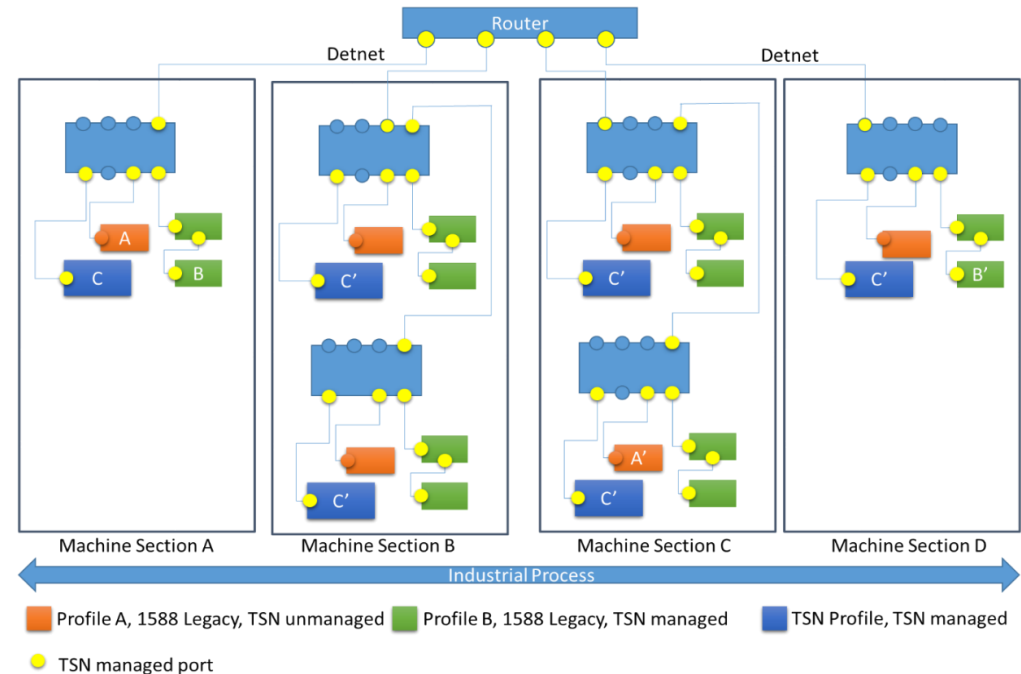
- Modern industrial networks combine the disciplines of both information technology (IT) and operational technology (OT) to meet the requirements of industrial applications.
- The industrial control networking legacy is long established
 - Multiple industrial technology standards
 - Multiple vendor-specific, proprietary technologies.
 - Not motivated toward convergence
- TSN demands a holistic approach and a system view
 - All vendors, technologies and products must participate on a shared wire
 - Network requirements must be published for proper planning and configuration in the system
 - Lack of participation results in lack of service and lack of resources on the network

Industrial Use Case

- The following characteristics define the industrial use case:
 - Different sections of machines are manufactured by various OEMs
 - Machine sections are delivered to the end site and integrated to create an entire industrial process at the end site
 - The end user may have N manufacturing sites around the globe
 - There are X machines per site
 - Equipment is functionally segmented through the use of VLANs, but IP Addressing schemes may be reused via Network Address Translation (NAT)
 - Each machine IP addressing scheme is identical to the other machines that are like it
 - The entire manufacturing facility uses the same understanding of absolute time or “wall clock time”
 - Events on the production floor may be correlated against events in other manufacturing areas or in the business systems
 - The following disparities may exist
 - Different clock technologies (CIP Sync, 802.1AS)
 - Different implementations of TSN technologies (Scheduling, QoS)

Industrial Use Case

- Various technologies are mixed and will need to coexist
 - Different standards
 - Older and newer generations
- Device A in Section may talk to Device A' in Section C
- Product B in Section A may communicate to product B' in Section D
- Products C in Section A may communicate to C' in other sections
- Communications may occur within layer 2, or across layer 3
- Switches may act as time bridges



Scope and Timing

- This use case is typical for a very wide range of industrial applications.
- Illustrates the need for solutions at layer 2 (switching), layer 3 (routing), and for time bridging functions.
 - Layer 2 is covered by IEEE and they have provided a solution that is complete enough to implement today.
 - Layer 3 is covered by IETF. They have purposefully lagged behind IEEE and more technology needs to be developed for a comprehensive solution.
 - Time bridging functions are not specified by any standards community to date. These can be standardized or proprietary.

- The Internet Engineering Task Force (IETF) is responsible for Layer 3 solutions.
- They have formed a group known as “DetNet” to study and provide Layer 3 scalability to TSN
- This work is not complete at the time of this presentation.

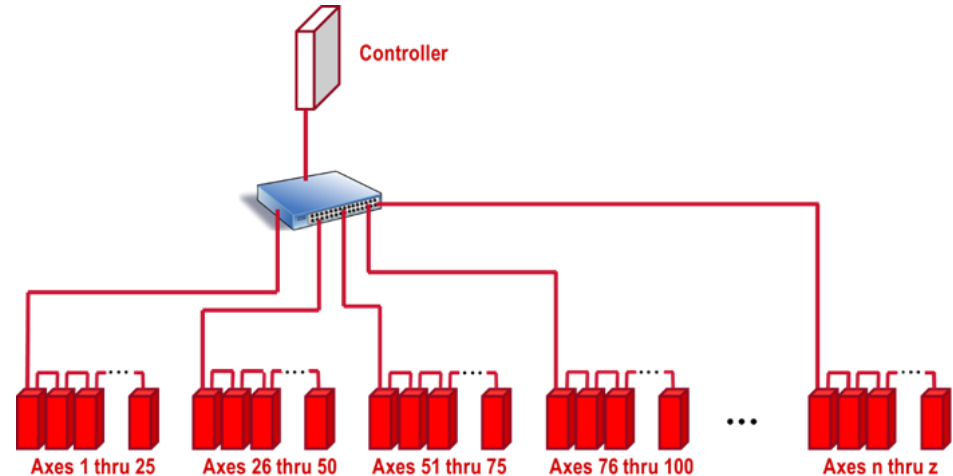


ODVA Distributed Motion and Time Synchronization SIG

- In November of 2015, the ODVA Distributed Motion SIG changed its name to the Distributed Motion and Time Synchronization SIG (DM & TS SIG) in order to respond to the market's movement toward Time Sensitive Networking Technologies
- The primary focus and priority for the DM & TS SIG with regard to TSN is to develop approaches and migration mechanisms that minimize impact of TSN integration on current product designs and existing installations.
- The SIG focused on the following areas as a starting point:
 - Gigabit Ethernet
 - Frame Preemption (IEEE 802.1Qbu & 802.3br)
 - Stream Reservation Protocols (IEEE.802.1 Qcc) and related technologies

Application analysis reveals benefits of Gigabit Ethernet

- For raw performance, wire speed far outweighs contributions from either preemption or scheduling alone.
- Analysis of motion application shows significant increase in number of total axes served by increasing wire speed vs. preemption or scheduling



	No TSN Functions	Preemption Enabled	Scheduling Enabled
100 MBit/s	17 Axes	35 Axes	37 Axes
1 GBit/s	411 Axes	430 Axes	432 Axes

Preemption and Scheduling

- However, preemption and scheduling both help to reduce latency of higher priority traffic behind large packets of lower priority

	100 Mbit/s	1 Gbit/s
1518 bytes (w/o preemption)	123 microseconds	12.3 microseconds
124 bytes (w/ preemption)	~10 microseconds	1.0 microseconds
0 bytes (scheduled traffic)	0.0 microseconds	0.0 microseconds

- The following conclusions can be made:
 - Wide deployment of gigabit technologies gives the single greatest benefit.
 - Preemption can significantly help a rate constrained network
 - Scheduling has similar benefits with respect to latency when 802.1 Qbv is used

Rate Constrained and Scheduled Traffic Coexistence

- Despite the performance benefits presented in the application analysis above for Gigabit Ethernet and preemption, the market is slowly moving toward adoption of the IEEE-802.1 Qbv technologies (scheduled Ethernet)
 - The mathematics for controlling traffic and for modeling and simulating entire networks is simplified by virtue of predetermined timetables for critical streams
 - Network simulation tools can now provide predictable models that allow network designers to know well ahead of commissioning whether their system will be successful or not.

Coexistence with Scheduled Traffic

- QoS prioritized traffic (i.e. EtherNet/IP) can coexist fairly with scheduled traffic through several methods
 - By using a CNC that supports both the scheduling engine as well as the network calculus engine
 - Through inclusion of policy based prioritization algorithms that account for both application priority as well as traffic requirements
 - By adopting 802.1Qcc stream reservation protocols that allow for products to publish their requirements to the CNC
 - This is a baseline requirement for ODVA products to coexist with scheduled traffic in the future

Time Gateway

- CIP Sync and 802.1AS are ways of solving the same problem; they both bring sub-microsecond time accuracy to a network
- Since each profile of 1588 is based on high accuracy time, a transfer function could be used to convert between each profile.
- This conversion could be done at a layer 2 bridge level, at a device level, or in a converter box.
- The ideal solution would be that each port of a layer 2 bridge could be configured to support each time profile for compatibility

- Ethernet is changing due to the ongoing work on TSN in IEEE, IETF and Avnu.
- ODVA is working to adapt to these changes through the Distributed Motion and Time Synchronization SIG. Focus areas for the SIG are:
 - Continued development and promotion of Gigabit Ethernet
 - Inclusion of IEEE 802.1Qbu & 802.3br for frame preemption
 - Integration of IEEE 802.1 Qcc and other stream reservation services for publication of network requirements to the CNC
 - Definition, development, and promotion of time gateways to allow for bridging of various time domains and time profiles (E.g., 802.1AS to CIP Sync's IEEE-1588 default profile)



THANK YOU