INDUSTRIAL INTERNET OF THINGS (IIOT)

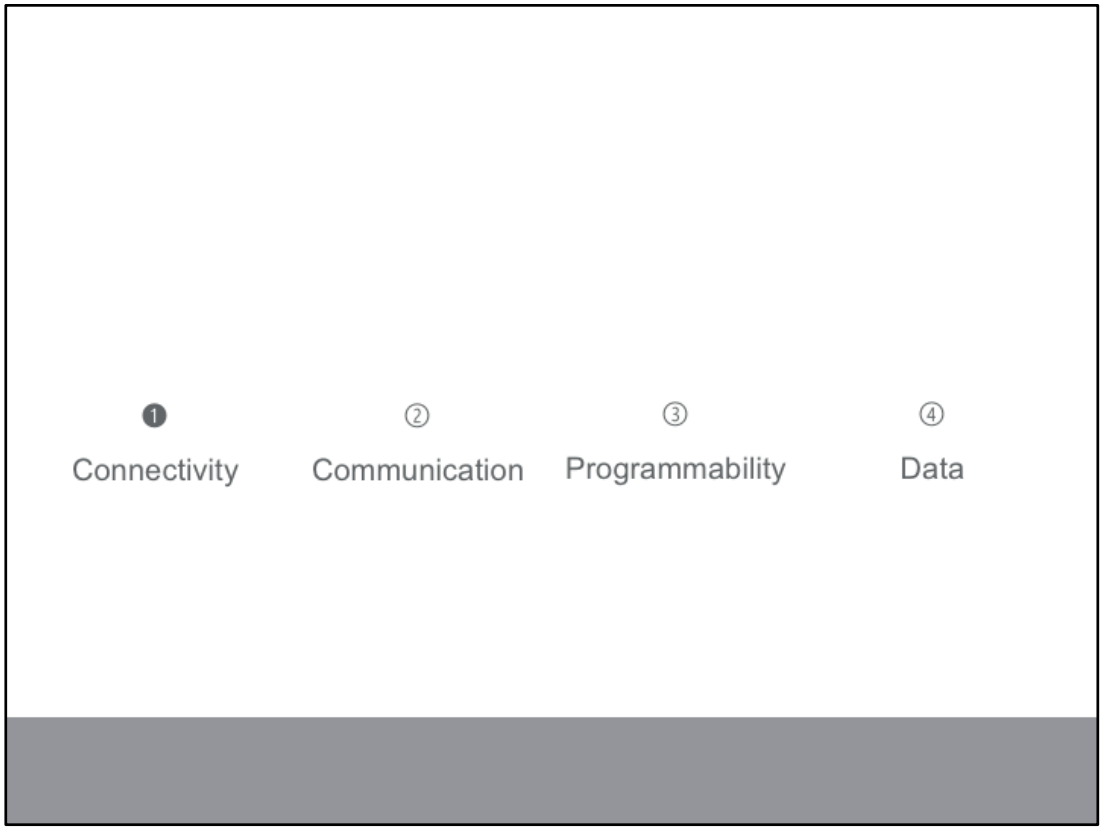
PART 3: CONNECTIVITY (3)

AV Lecture in Summer Term 2018
Dr.-Ing. Alexander **Willner**, Oliver Keil, Zahoor Ahmed

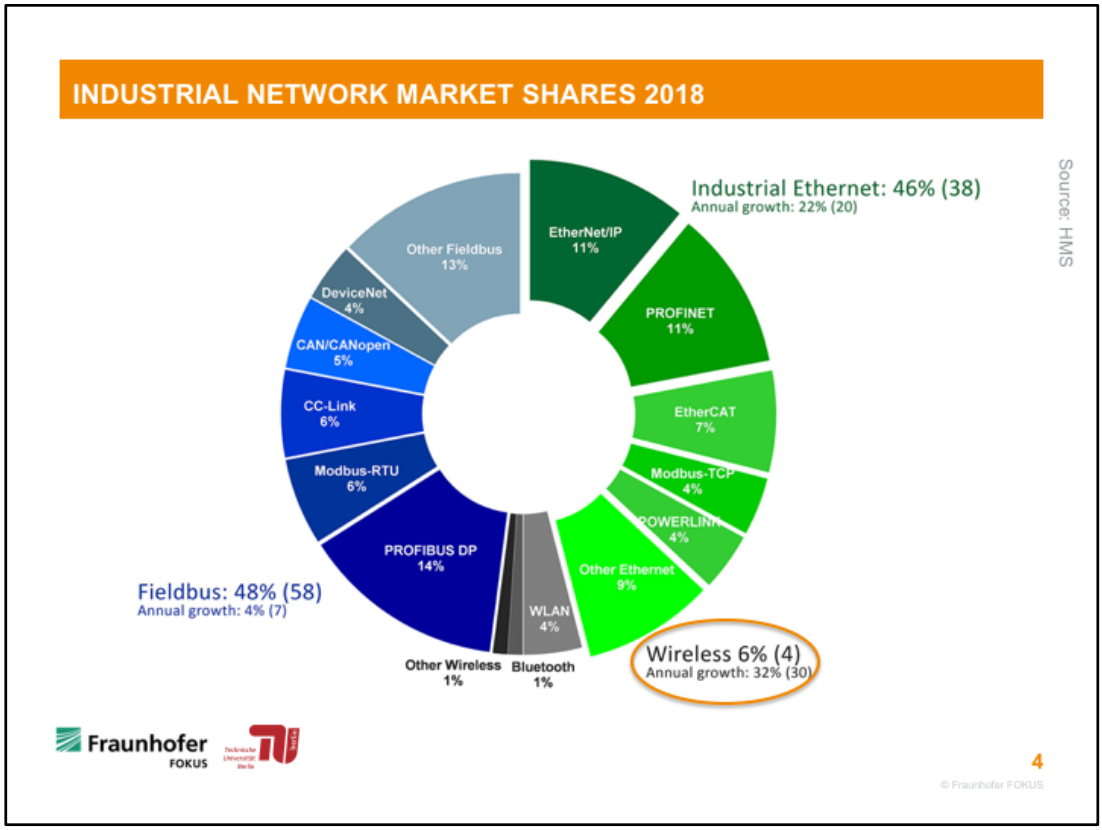
We'll start **at 14:15pm**

THE LAST LECTURE

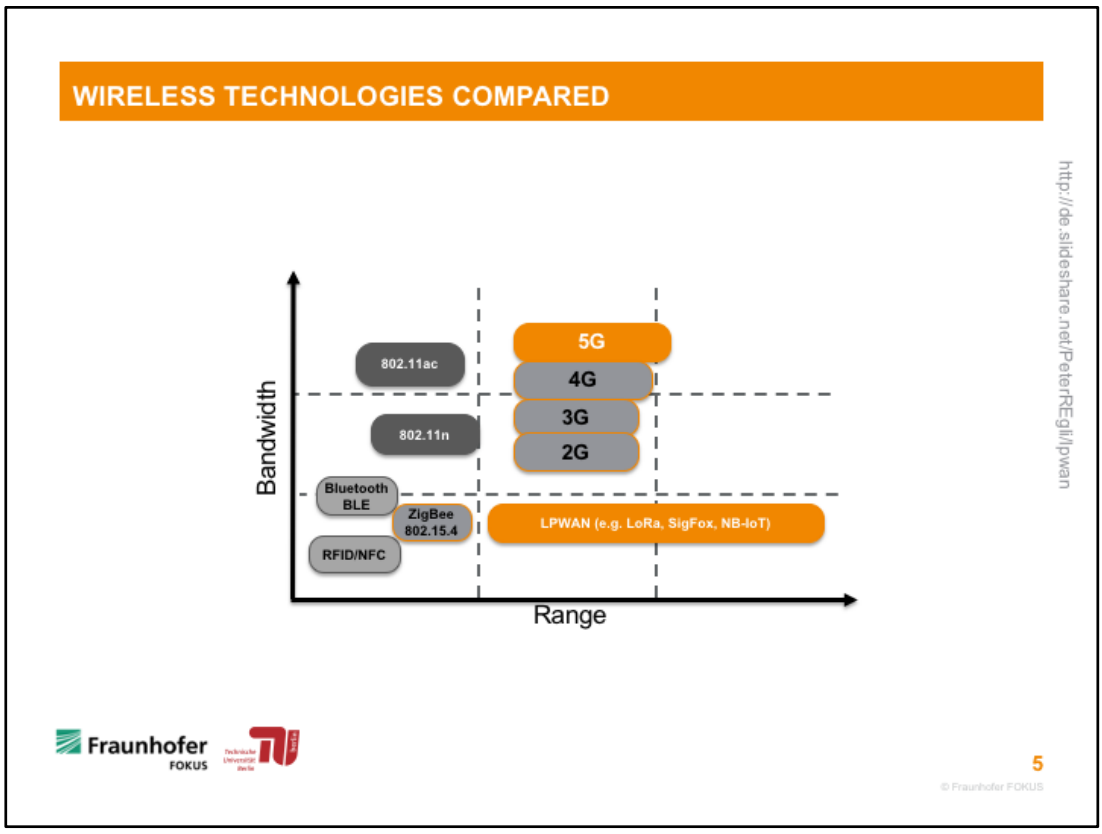
5 Minutes



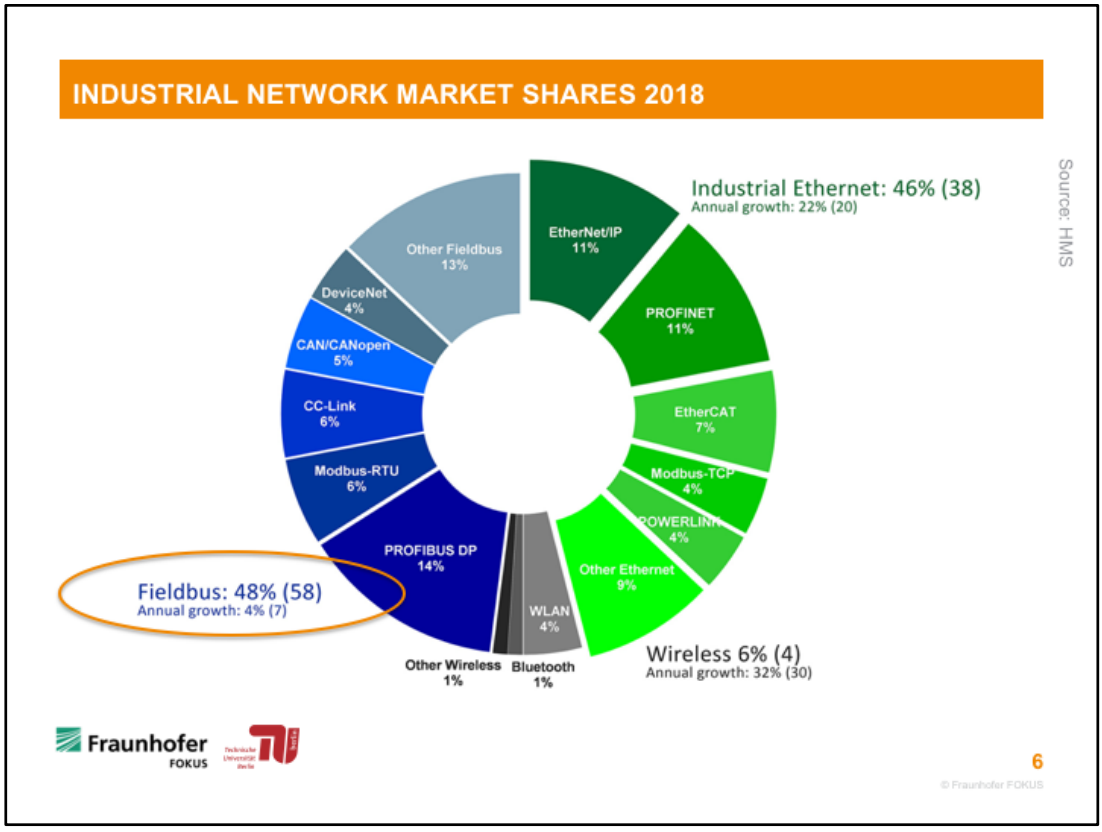
- This lecture is divided into 4 different areas
- (Really) last time to talk about the first one



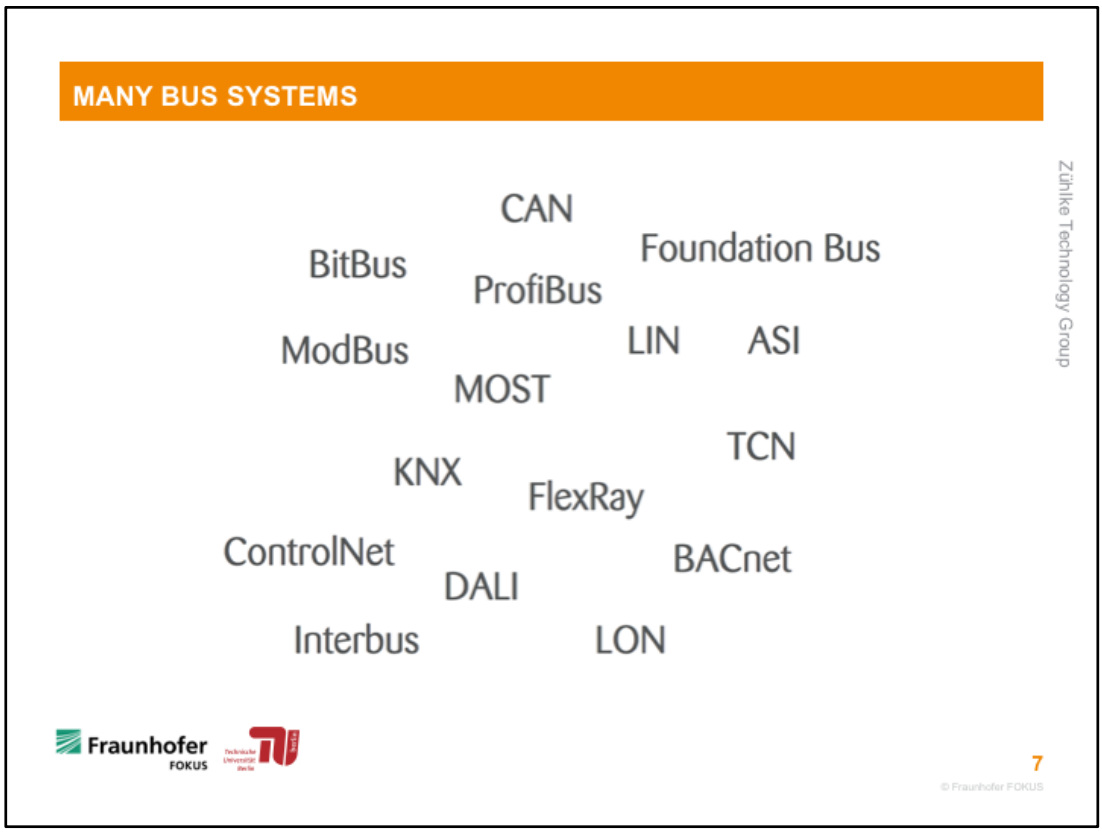
- Due to specific communication requirements, specialized connectivity technologies are being used in the factory.
- We talked about the different wireless communication technologies



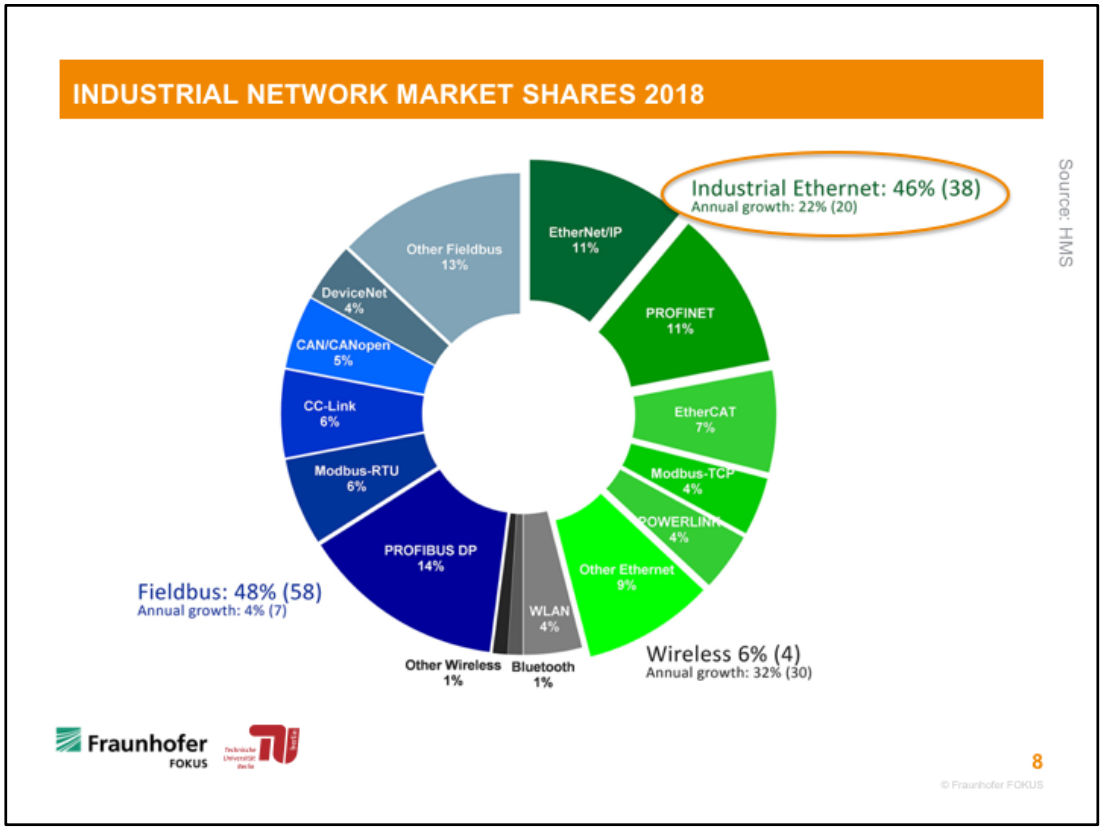
- Differentiation of technologies based on their range
- Important metrics
    - Bandwidth
    - Range
    - Licensed vs. unlicensed band



- We then moved over and talked about field bus systems

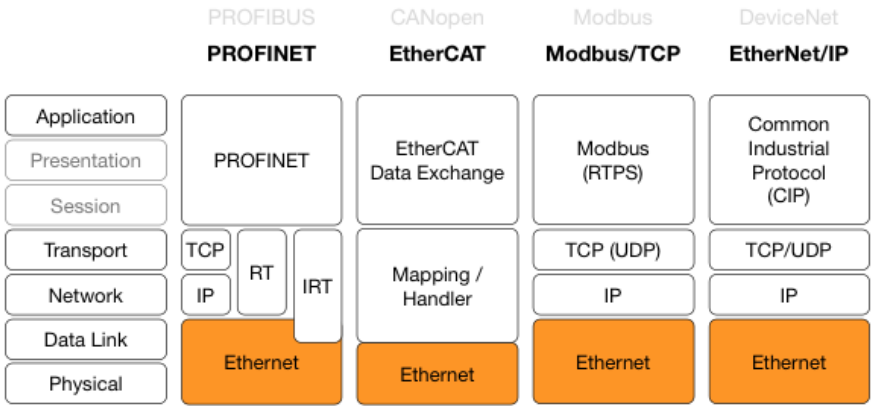


- We have covered a number of field bus systems



- Next we talked about Industrial Ethernet techologies

FIELDBUS → INDUSTRIAL ETHERNET



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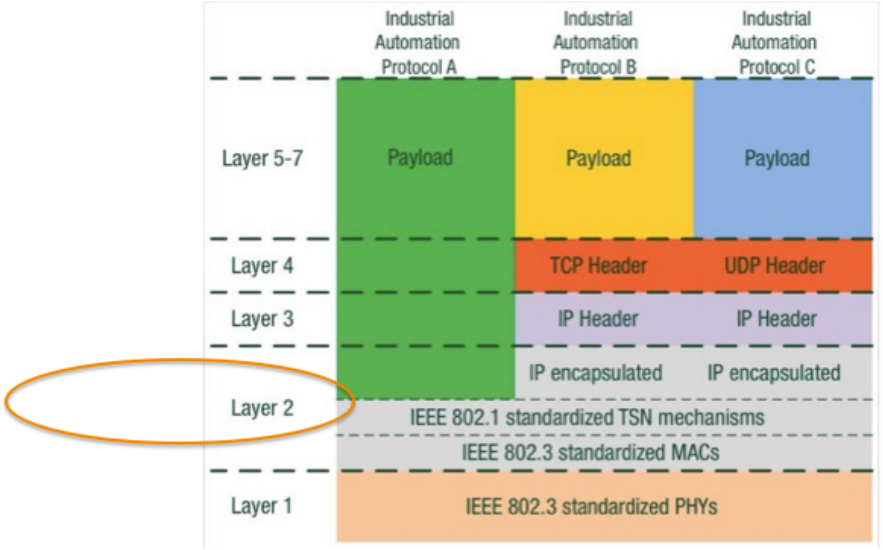
- Same physical connectors
- Similar MAC protocols
- Depending on the real-time requirements, modification of the data link layer

IEEE TSN: A SET OF LAYER 2 RELATED STANDARDS



Source: AutomationWorld

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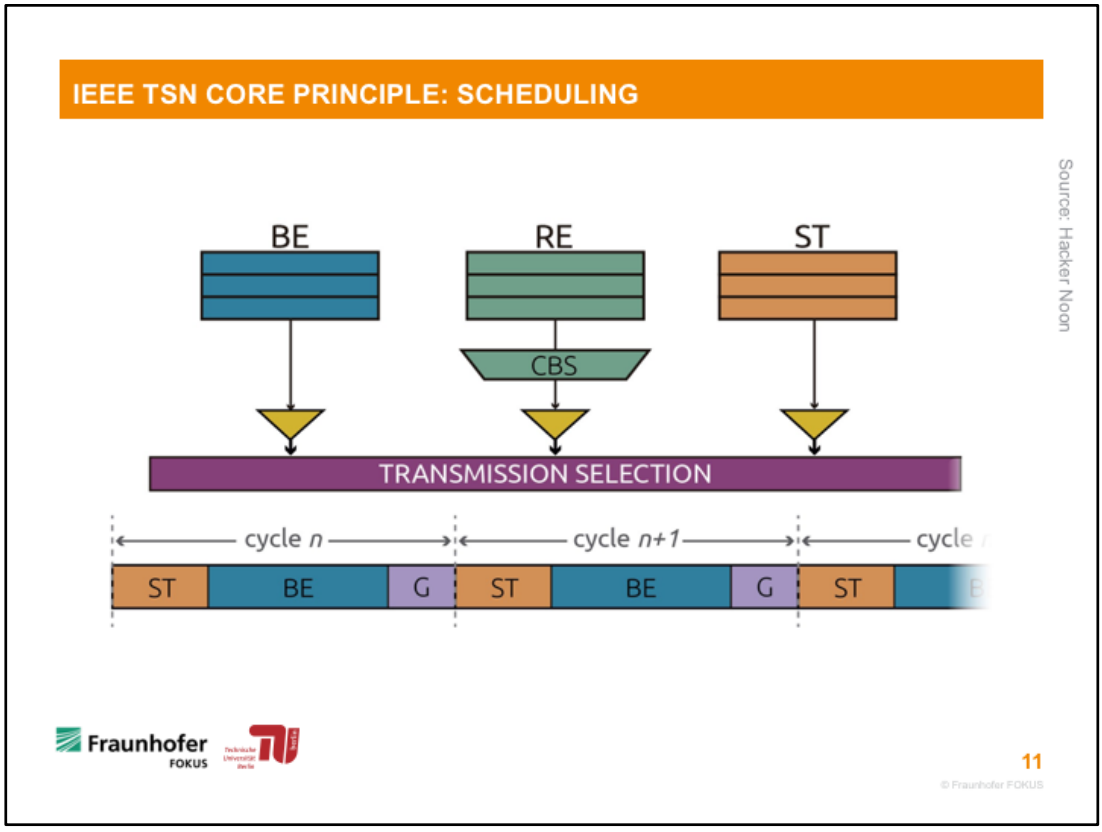
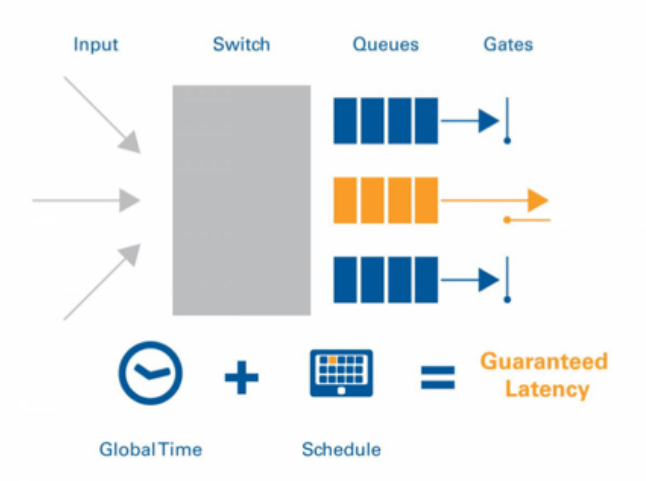
- Next step are the IEEE TSN standards (it‘s NOT a single standard)



- First core principle: scheduling

IEEE TSN CORE PRINCIPLE: GLOBAL TIME



source: EBV

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- Second core principle: global time

THE LAST LECTURE

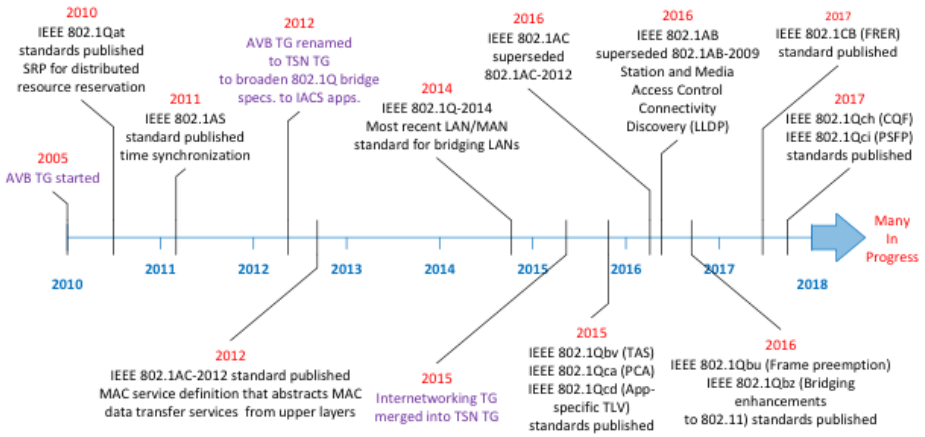
Questions?

INDUSTRIAL ETHERNET TECHNOLOGIES (2)

25 minutes

- Continuation of last lecture

IEEE TSN MILESTONES



Source: A. Nasrallah et al.: Ultra-Low Latency (ULL) Networks: A Comprehensive Survey Covering the IEEE TSN Standard and Related ULL Research, March 2018.

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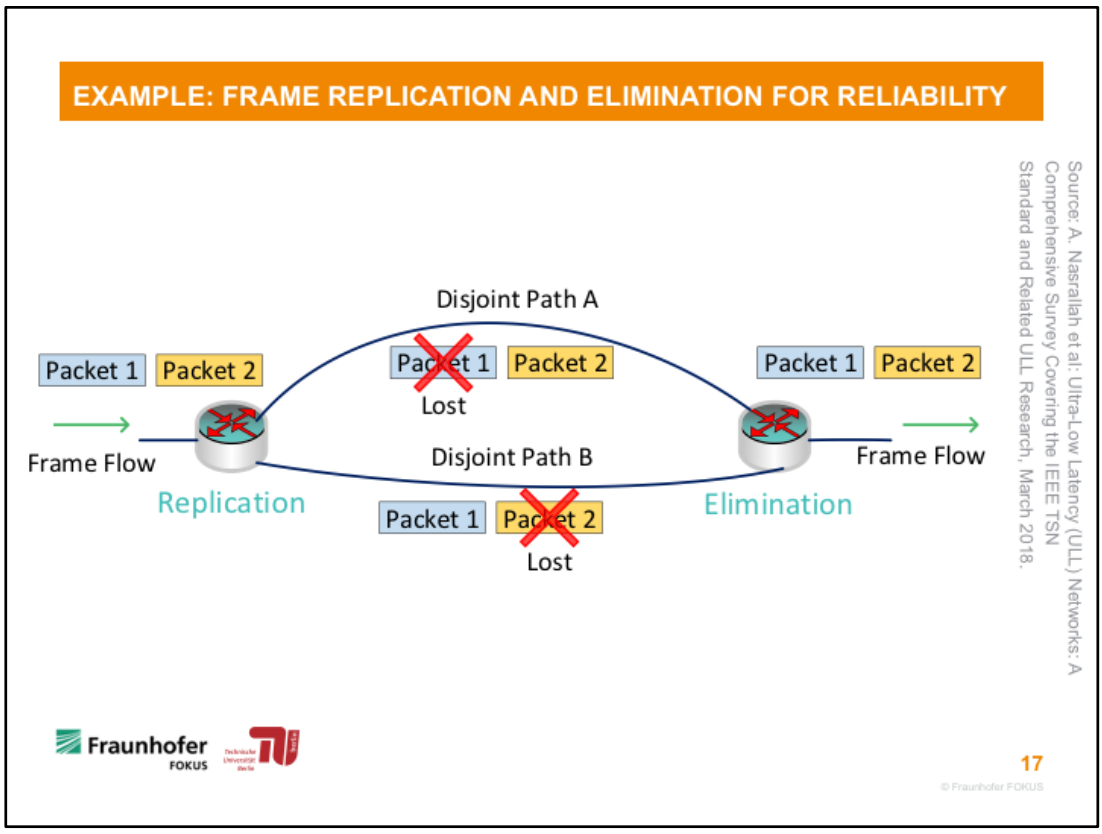
- Milestones for shifting from AVB to TSN

TSN/AVB STANDARDS OVERVIEW

Standard	Group	Title	Status	Last updated
IEEE 802.1Qbu	**Forwarding and Queuing**	**Frame preemption**	**Published**	**August 30, 2016**
IEEE 802.1Qbv	**Forwarding and Queuing**	**Enhancements for Scheduled Traffic**	**Published**	**March 18, 2016**
IEEE 802.1Qca	**Stream Reservation (SRP)**	**Path Control and Reservation**	**Published**	**March 11, 2016**
IEEE 802.1Qch	**Forwarding and Queuing**	**Cyclic Queuing and Forwarding**	**Published**	**June 28, 2017**
IEEE 802.1Qci	**Forwarding and Queuing**	**Per-Stream Filtering and Policing**	**Published**	**September 28, 2017**
IEEE 802.1CB	**Stream Reservation (SRP)**	**Seamless Redundancy**	**Published**	**September 28, 2017**
IEEE 802.1AS-Rev	Timing and Synchronization	Timing and Synchronization for Time-Sensitive Applications	Draft 5.0	June 12, 2017
IEEE 802.1Qcc	Stream Reservation (SRP)	Enhancements and Performance Improvements	Draft 1.1	September 1, 2016
IEEE 802.1CM	Vertical	Time-Sensitive Networking for Fronthaul	Draft 0.5	October 15, 2016
IEEE 802.1Qcr	Forwarding and Queuing	Asynchronous Traffic Shaping	PAR approved	June 30, 2016
IEEE 802.1CS	Stream Reservation	Local Registration Protocol	PAR	
…	…	…	…	…

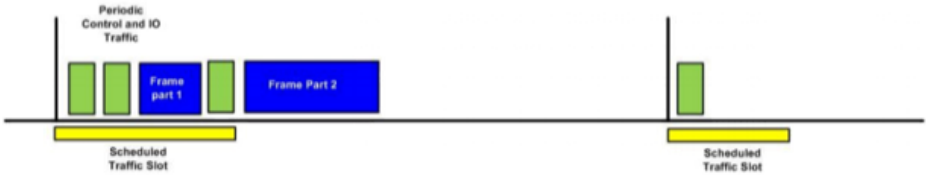
- A number of different standards, drafts and Project Authorization Request (PAR)
- IEEE 802.1Qbu → preemption of Ethernet frames, see example
- IEEE 802.1Qbv → forwarding process that supports scheduled traffic
- IEEE 802.1Qca → stream reservation
- IEEE 802.1Qch → queuing
- IEEE 802.1Qci → stream policy
- IEEE 802.1CB → frame replication, e.g. for a backup path
- IEEE 802.1AS-Rev → see Precision Time Protocol, but via layer 2
- IEEE 802.1Qcc → stream reservation, see example
- Actually, depending on the source, there are a number of related drafts relasted to the TSN task group



- IEEE TSN P802.1CB - (FRER)
- E.g. using multiple physical cables to have a backup if one cable breaks

EXAMPLE: FRAME PREEMPTION

(a) Non-Critical Frame interruption



(b) Frame Preemption

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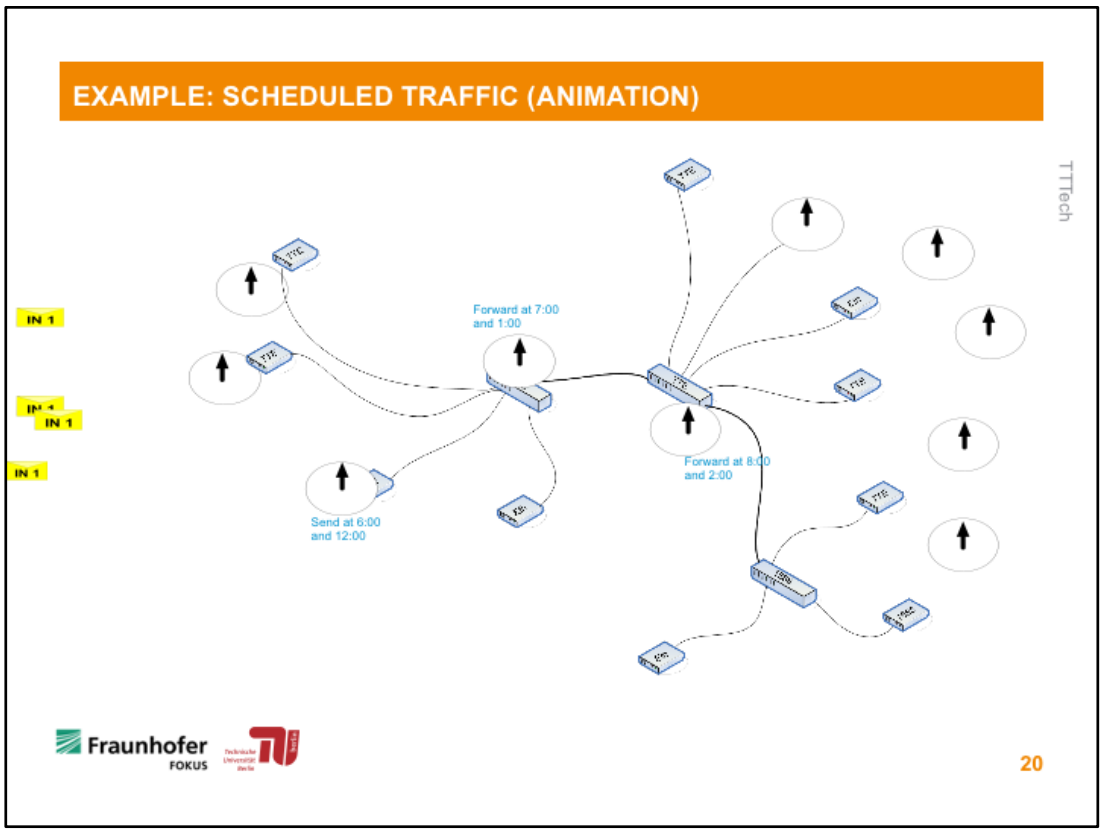
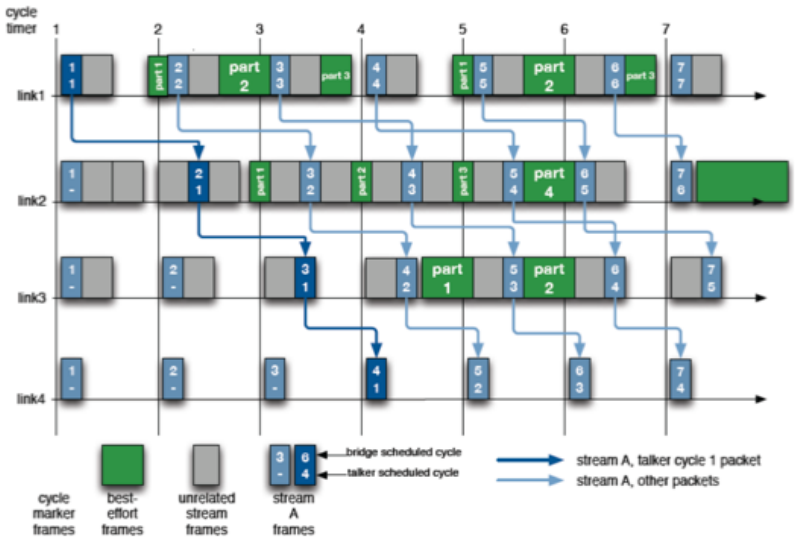
- Preemptive task scheduling known from modern operating systems
- Yellow = scheduled slot
- Green = scheduled traffic
- Blue = best effort frame
- IEEE 802.1CB
- (a) hard real-time requirements not met



- Animation of globally synchronized scheduled slots for sending and forwarding packets

EXAMPLE: SCHEDULED TRAFFIC



TSN Primer

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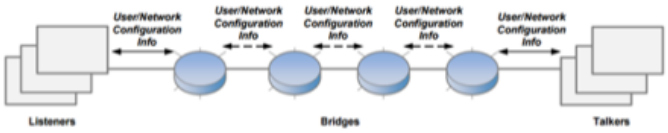
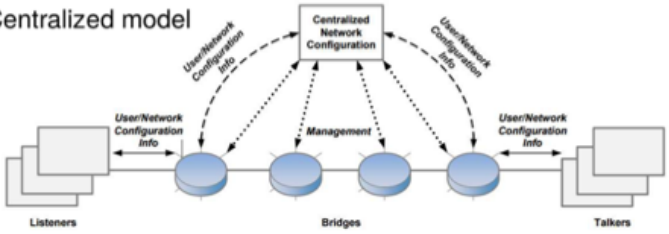
- We see the scheduling of packets of streams along with best effort traffic
- Dark blue: stream 1
- Light blue: stream 2
- Gray: other stream
- Green: best effort
- Vertical: 4 different links (first = talker, rest = bridges)
- Horizontal: 7 schedule cyles

IEEE TSN CORE PRINCIPLE: RESERVATION

- Fully distributed model



- Centralized model



Source: IEEE P802.1Qcc Draft 0.5

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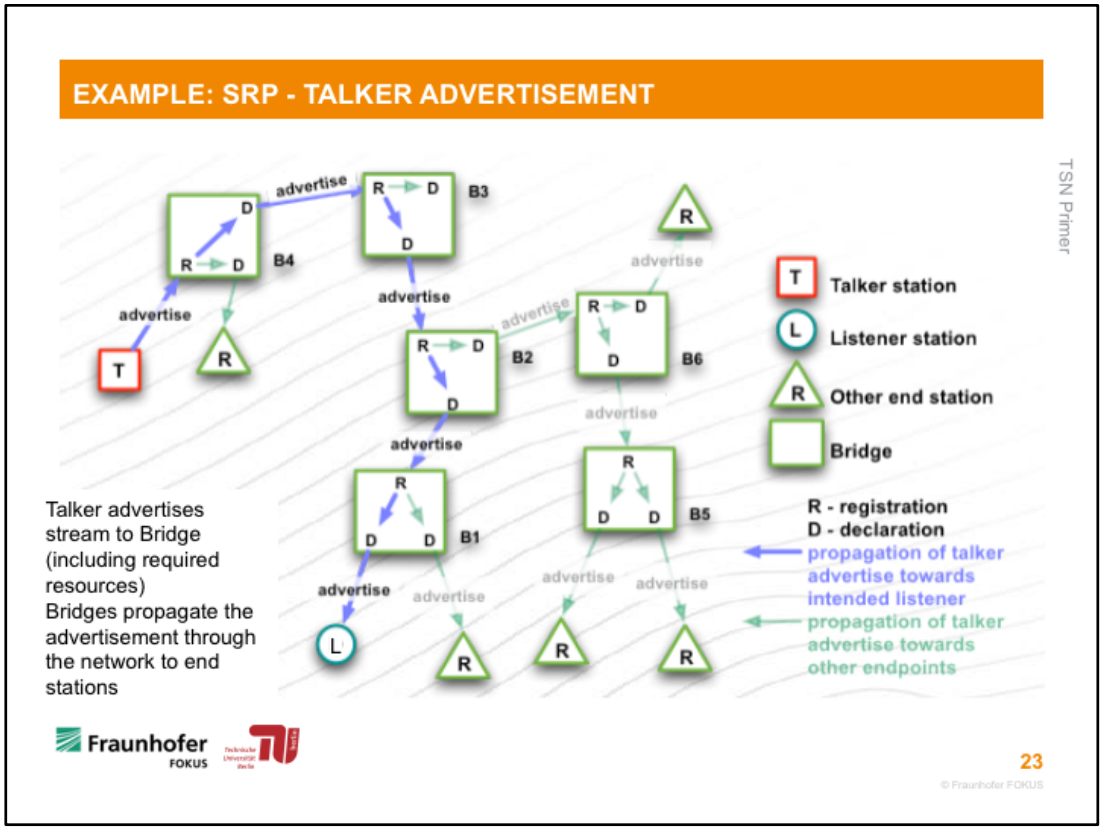
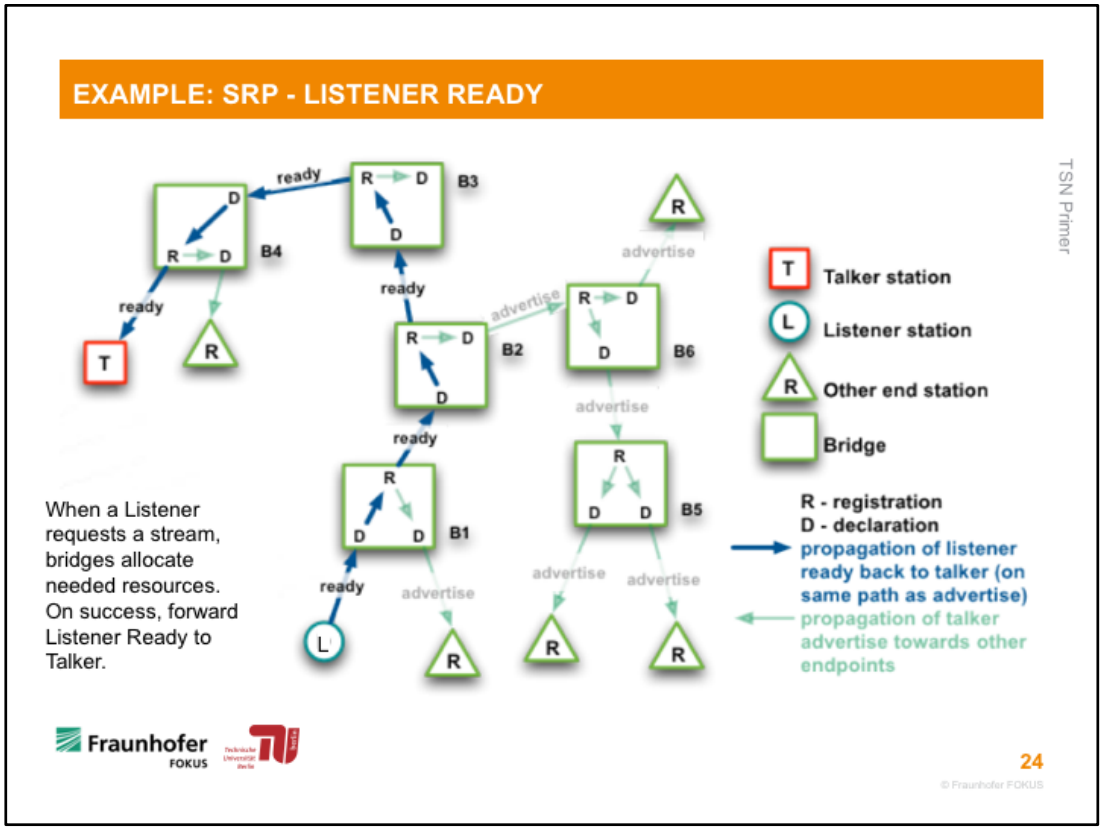
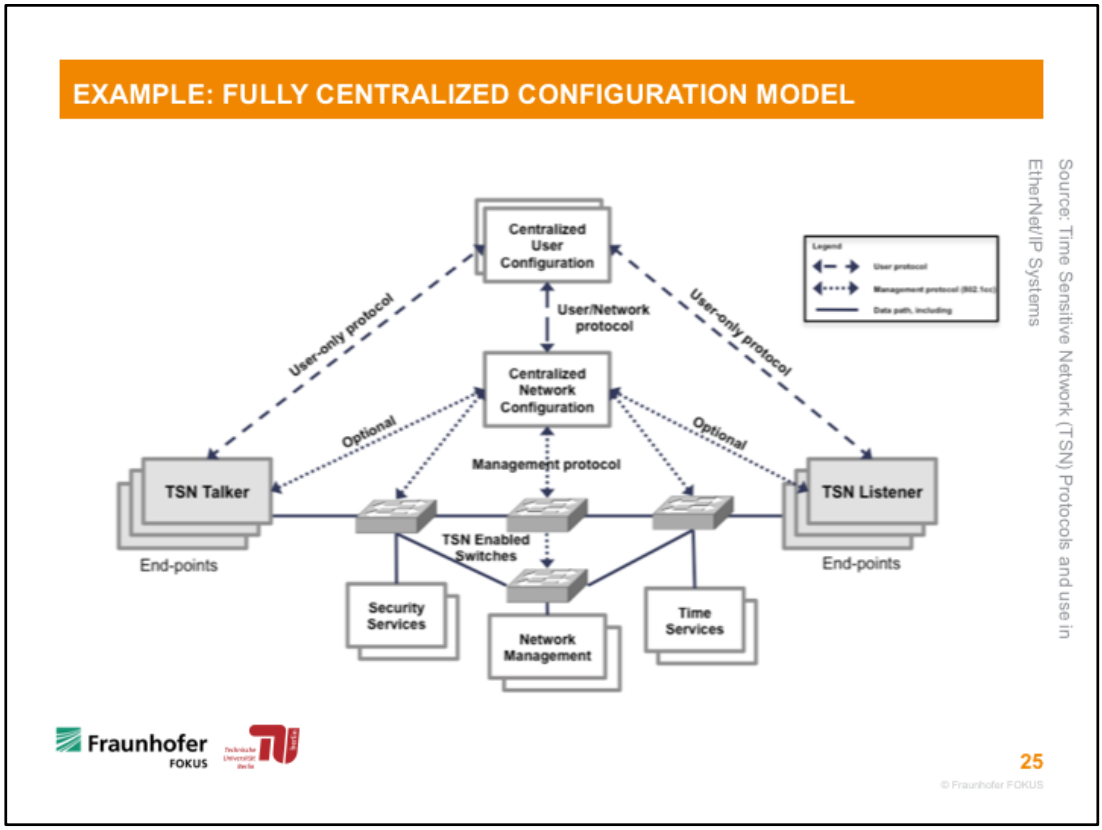
- To meet TSN requirements IEEE 802.1 TSN TG defines new configuration models, i.e. IEEE 802.1Qcc (Stream Reservation)
- TSN require dynamic configuration based on application requirements
- Basically two different models for network configuration
- Distributed
    - Using the Stream Reservation Protocol (SRP), a bridged network can be configured in a distributed, plug-and-play manner
- Centralized
    - To compute network paths and transmission schedules, a CNC needs to understand the network's physical topology. The Link Layer Discovery Protocol (LLDP) is the most common protocol.



- Step 1: Talker Advertisement
- Talker = Acts as stream source and advertises the stream
- Listener = Acts as stream destination and “books” the advertised stream
- Domain = A set of talkers, listeners, and bridges that support the resource requirements
- Reservation = A (reserved) path that provides the requested resource requirements
- **Stream Reservation class**: A traffic class whose bandwidth can be reserved for traffic time-sensitive Streams using the Stream Reservation Protocol (SRP). A priority value is associated with each SR class. SR classes are denoted by consecutive letters of the alphabet, starting with A and continuing for up to seven classes.



- Step 2: Propagation back to talker



- **Centralized Network Configuration (CNC):** A centralized component that configures network resources on behalf of TSN applications (users).
- **Centralized User Configuration (CUC):** A centralized component that discovers and configures application (user) resources in end stations. A CUC exchanges information with a CNC in order to configure TSN features on behalf of its end stations.
- Workflow
    - Talkers and Listeners communicate their stream quality of service requirements to a Centralized User Configuration (CUC) entity using an end-station specific configuration protocol.
    - The CUC communicates stream quality of service requirements, on behalf of all Talker/Listener groups for its associated application, to a Centralized Network Configuration (CNC) entity using a User/Network
    - The CNC performs necessary calculations to meet stream quality of service requirements in the bridged network, including calculating transmission schedules, determining data paths, etc.
    - If the CNC can satisfy the end stations' stream quality of service requirements, it configures the bridges, Talkers and Listeners

INDUSTRIAL ETHERNET TECHNOLOGIES (2)

Questions?