

OPC DAY FINLAND 2019

6.-7.11.2019 @ EXPO AND CONVENTION CENTRE MESSUKESKUS HELSINKI
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TSN and its Configuration Deep Dive into the Challenge of Complexity

Ben Schneider

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Time-Sensitive Networking (TSN)

What is TSN?

IEEE Standard-Extension for Ethernet

- Determinism
- Real-time
- Vendor independent
- Convergent network

Layers of the ISO OSI model

7 Application	OPC UA Client-Server		OPC UA Pub-Sub
6 Presentation	UA Binary	UA XML	UADP
5 Session	UA TCP	HTTP(S)	
4 Transport	TCP		UDP
3 Network	IP		
2 Data Link	Ethernet + TSN		
1 Physical	...		

Time-Sensitive Networking (TSN)

What is TSN?

IEEE Standard-Extension for Ethernet

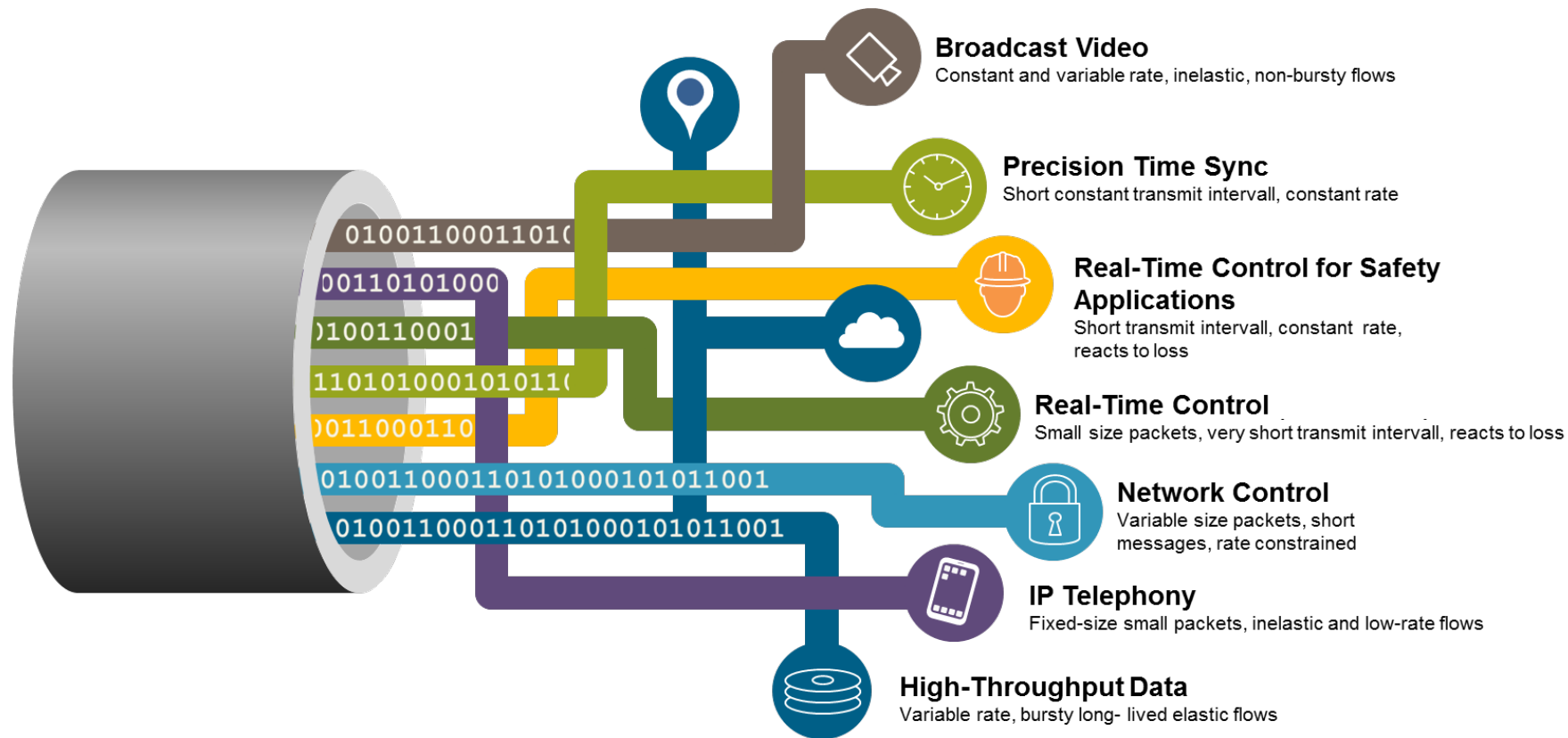
- Determinism
- Real-time
- Vendor independent
- Convergent network

What is TSN not?

- No application protocol, but standard Ethernet
- No fieldbus, but infrastructure for Ethernet-based protocols (OPC UA, Ethernet Powerlink, EtherNet/IP, ..)

Convergent Network

Combination of Traffic with Different Requirements on the same Cable



Source: https://www.automatiosseura.fi/site/assets/files/1661/dominik_rohrmus_lni_4_0.pdf

Complexity of IEEE 802.1 TSN – An Incomplete List

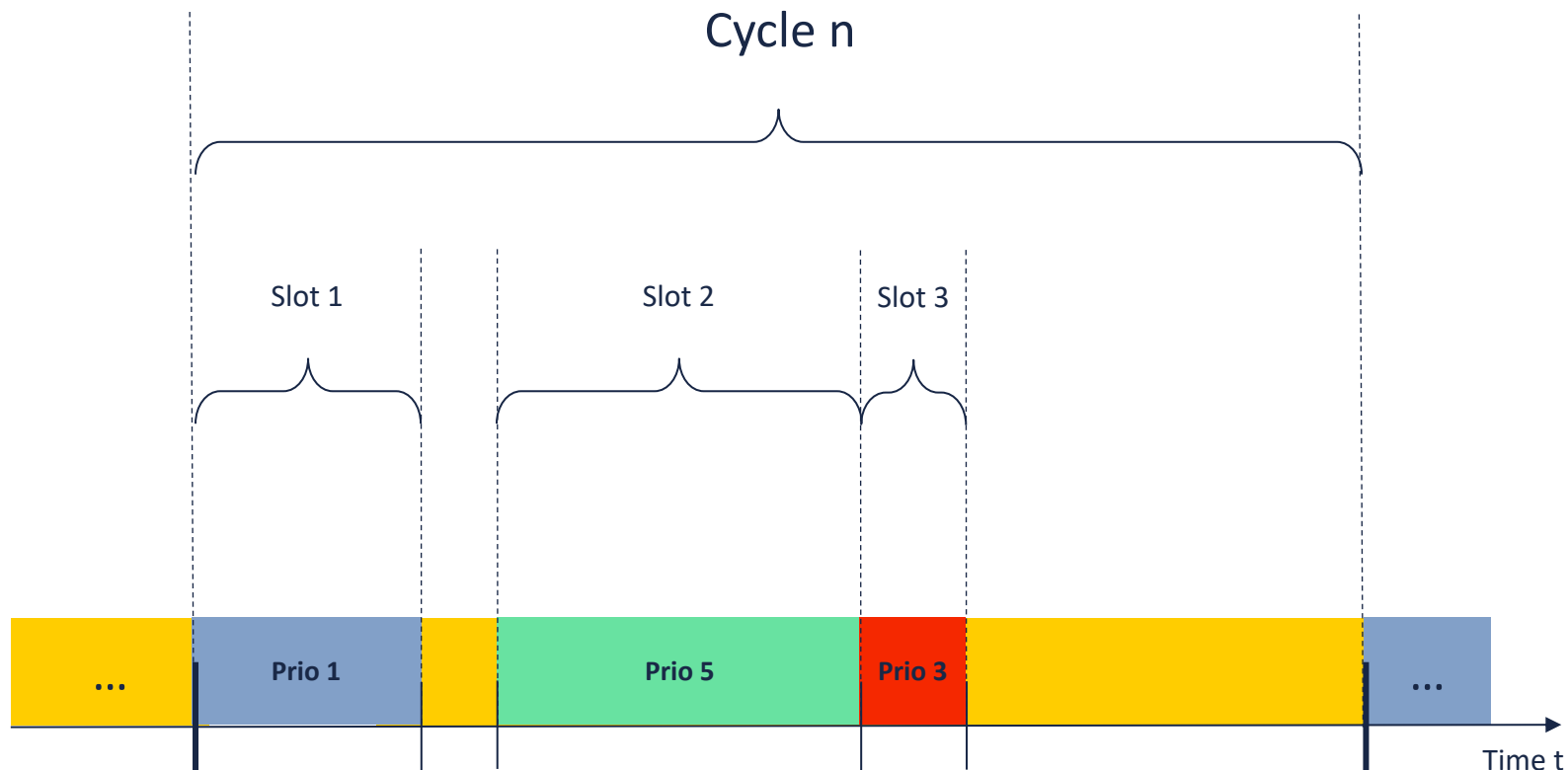
Standard	Title	Status	
IEEE 802.1Qbv	Scheduled Traffic	P	Scheduling Mechanisms
IEEE 802.1Qbu	Frame Preemption	P	
IEEE 802.1Qch	Cyclic Queueing and Forwarding	P	
IEEE 802.1Qcr	Asynchronous Traffic Shaping	T	
IEEE 802.1Qca	Path Control	P	Reliability
IEEE 802.1Qci	Per-Stream Filtering and Policing	P	
IEEE 802.1CB	Frame Replication and Elimination	P	
IEEE 802.1CBdb	Extended Stream Identification	T	
IEEE 802.1AS-Rev	Time Synchronization and Redundancy	S	Time Synchronization
IEEE 802.1AS	Time Synchronization	P	
IEEE 802.1Qat	Stream Reservation Protocol	P	Network Management
IEEE 802.1Qcc	TSN Configuration	P	
IEEE 802.1Qcp	YANG Data Model	P	
IEEE 802.1Qcw	YANG Data Models for Qbv, Qbu, Qci	T	
IEEE 802.1ABcu	YANG Data Model for LLDP	T	
IEEE 802.1CBcv	YANG Data Model for CB	-	
IEEE 802.1CS	Link-local Reservation Protocol	T	
IEEE 802.1DF	TSN Profile for Service Provider Networks	-	Industrial Profiles
IEEE 802.1DG	TSN Profile for Automotive	-	
IEC / IEEE 60802	TSN Profile for Industrial Automation	-	
...			

“Building Blocks”:

different
standards
for different
use cases

- = no Draft vote
T = TSN TG ballot
W = 802.1 WG ballot
S = Sponsor Ballot
P = Published

Time Aware Shaper (IEEE 802.1Qbv)

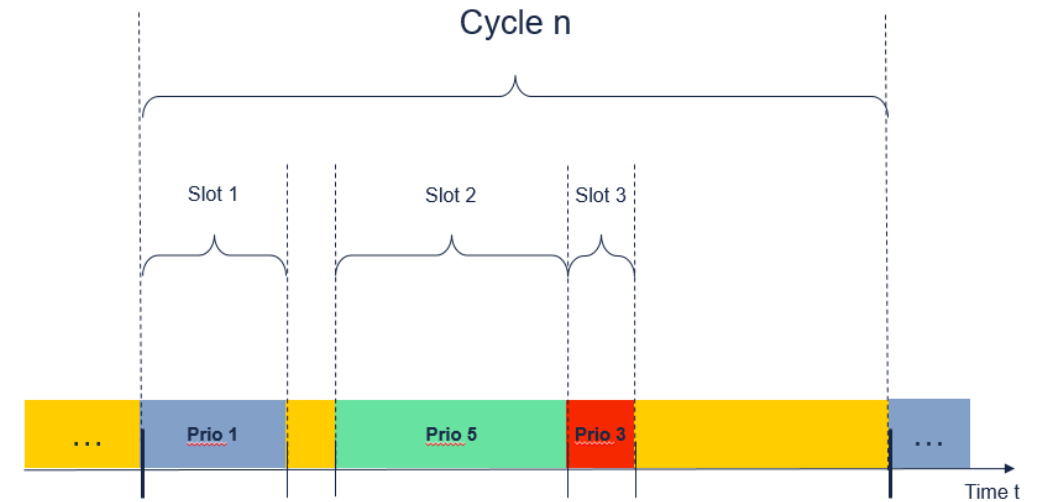
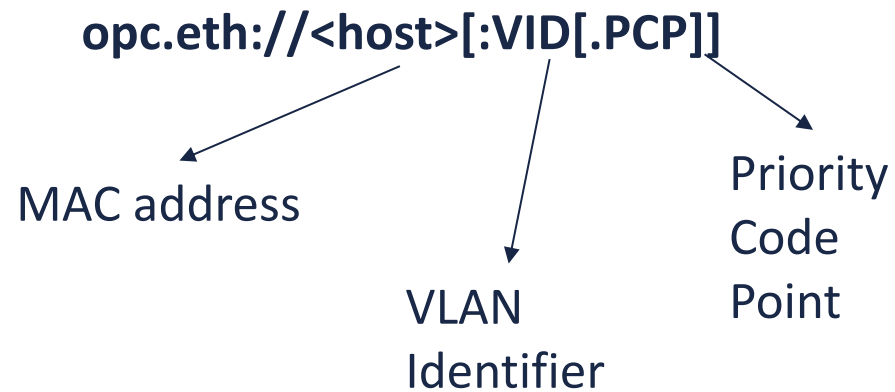


Time-triggered approach:

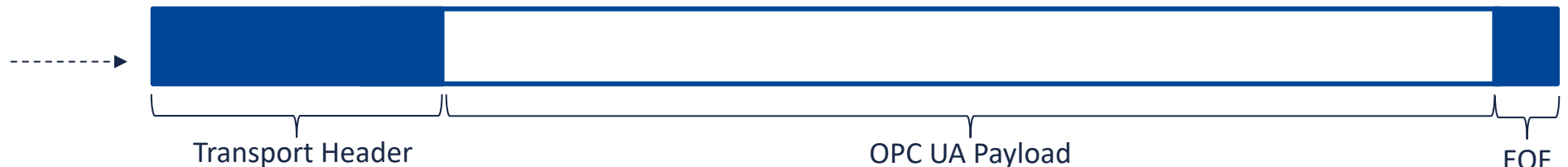
- Divide bandwidth in periodic cycles of equal length
- Reserve slots based on priority of streams

Example: OPC UA PubSub over TSN

Ethernet Protocol Bindings defined OPC UA Part 14: PubSub



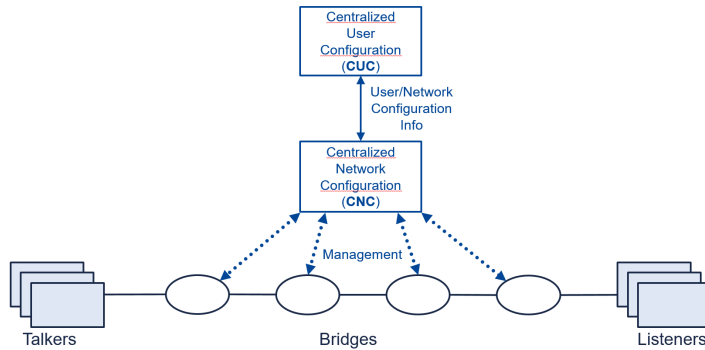
PubSubConnection
Object



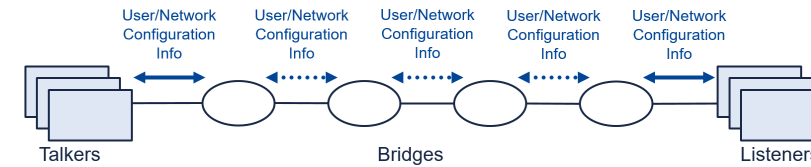
TSN Configuration Approaches

According to IEEE 802.1Qcc

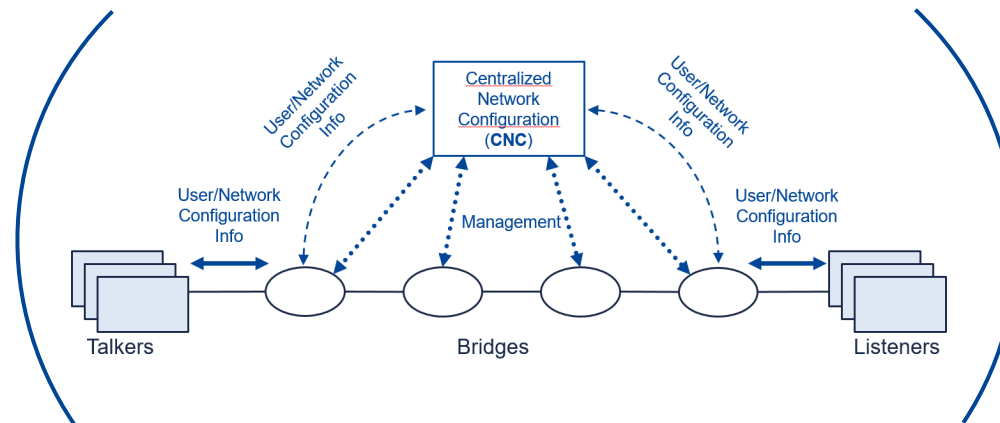
Centralized



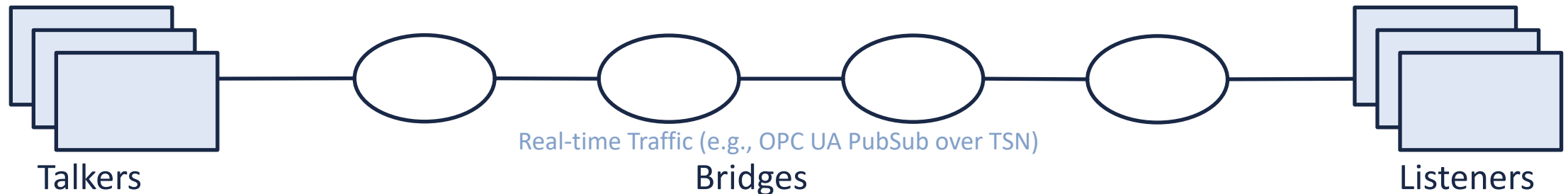
Distributed



Hybrid

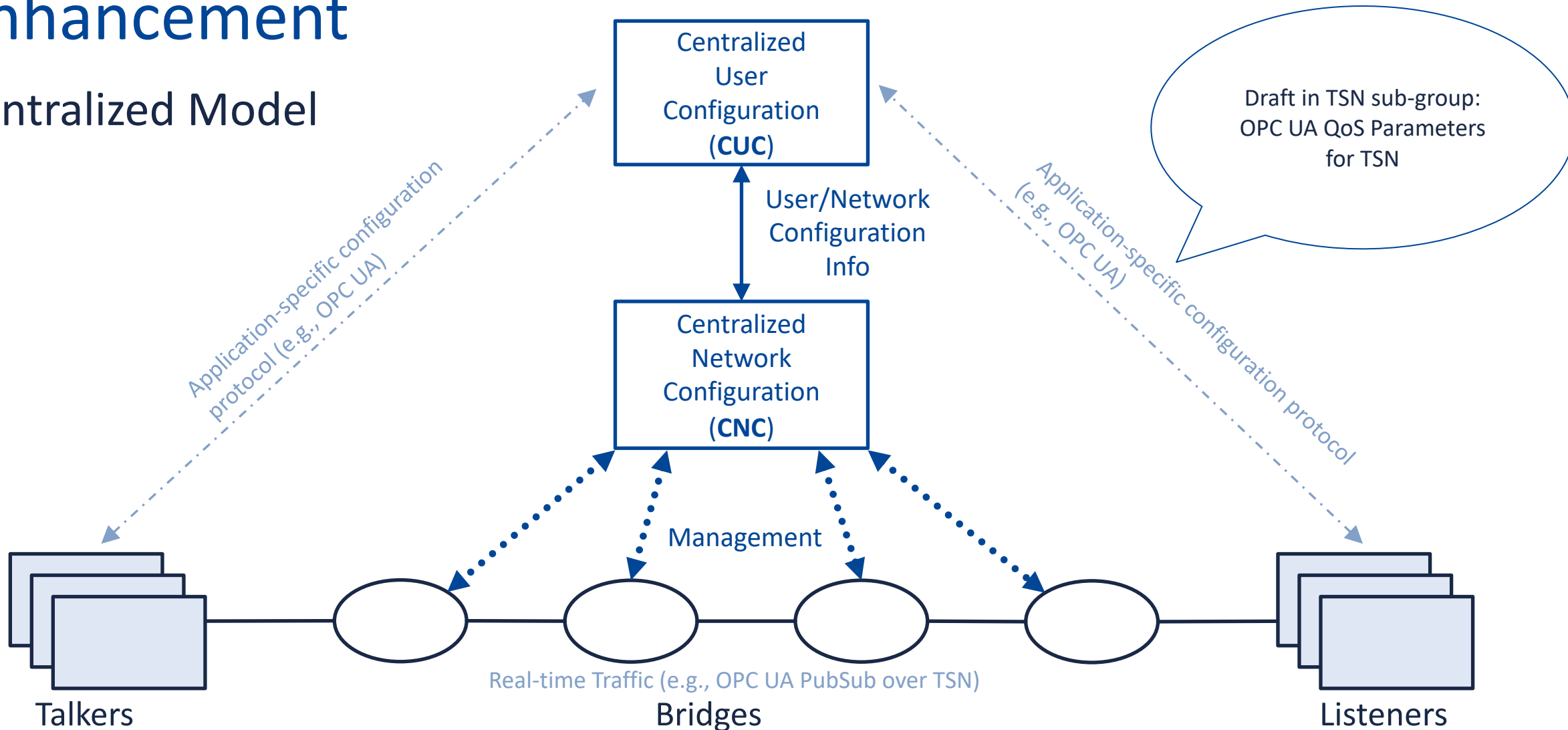


IEEE 802.1Qcc – Stream Reservation Protocol Enhancement



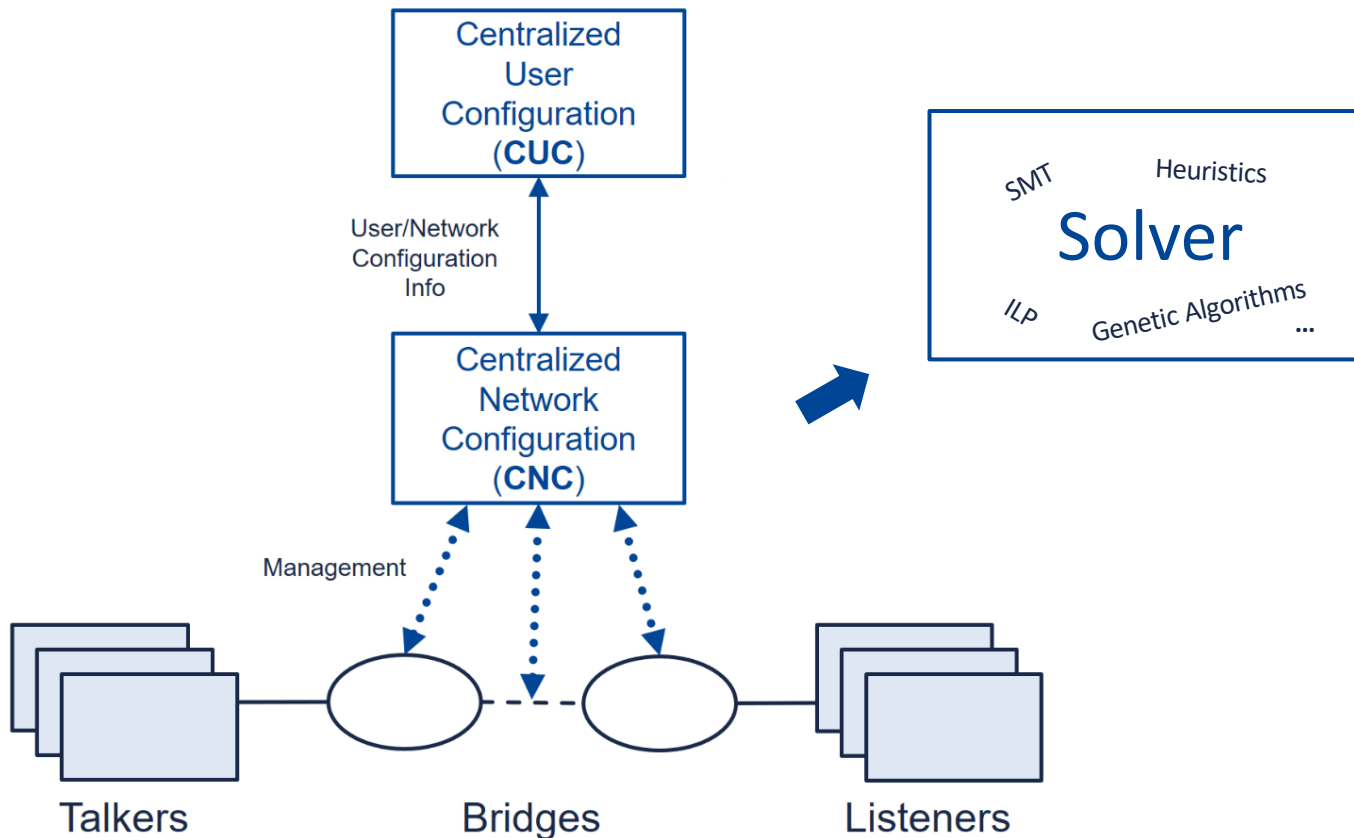
IEEE 802.1Qcc – Stream Reservation Protocol Enhancement

Centralized Model



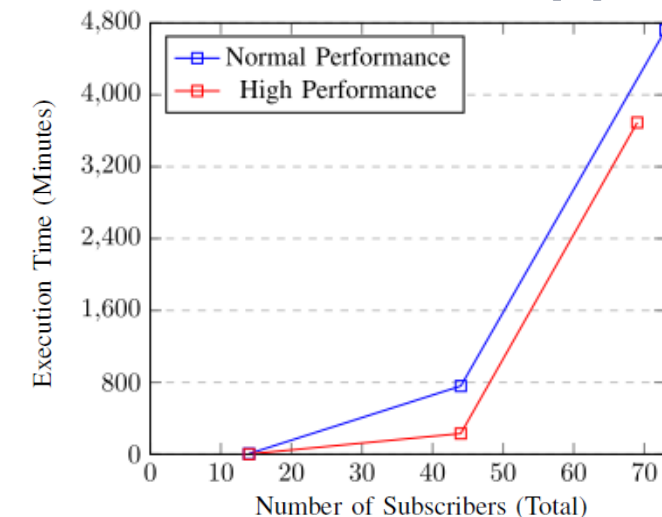
Challenges of Central Configuration

Scalability



Scheduling the Time Aware Shaper
is an NP-Complete Problem

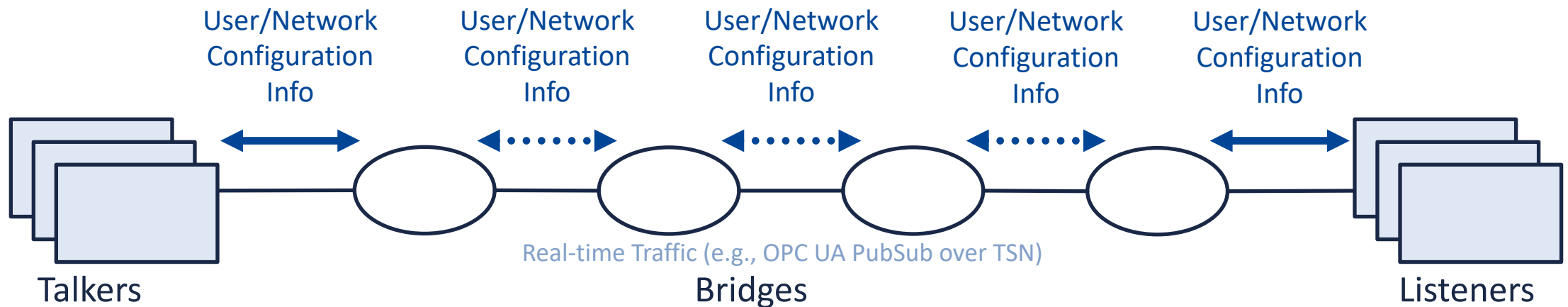
Solvers with Exponential
Execution Time [1]



[1] Aellison Santos, Ben Schneider, Vivek Nigam; TSNSCHED: Automated Schedule Generation for Time Sensitive Networking @ FMCAD 2019 in San José

IEEE 802.1Qcc – Stream Reservation Protocol Enhancement

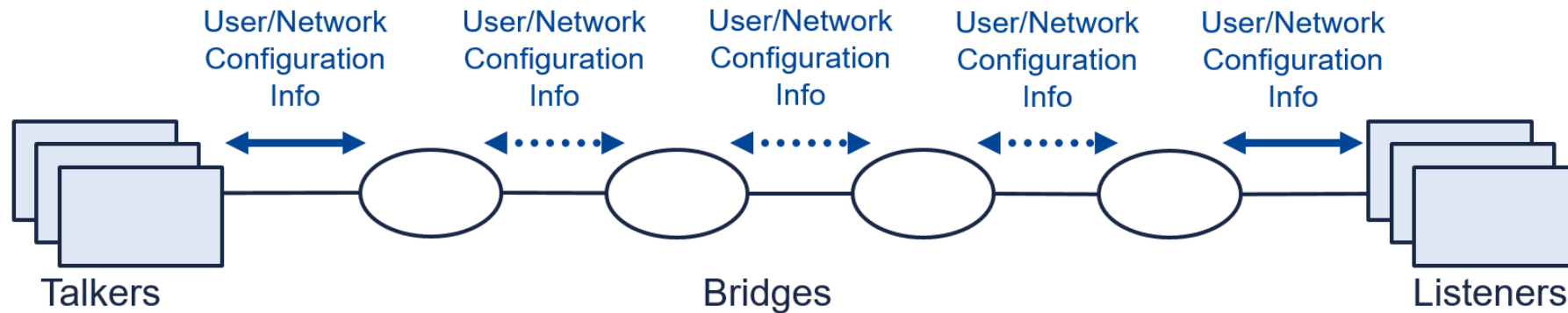
Distributed Model



Challenges of Distributed Configuration

Scope of configuration limited to individual devices

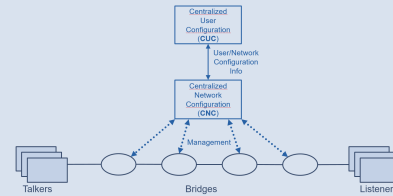
- Optimization challenging
- Diagnosis challenging
- Currently limited to the line topology with number of hops



Centralized vs. Distributed Configuration

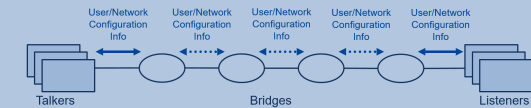
A Comparison

Centralized Configuration



- Scalability issue: exponential execution time of Solvers
- Rather static, but highly optimized
- Dedicated configuration infrastructure
- Diagnosis: quick validation of a solution

Distributed Configuration



- Scalability issue: conflicts on large networks difficult to resolve
- Highly dynamic, but optimization difficult
- No extra infrastructure
- Diagnosis: error reporting challenging



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- TSN makes OPC UA **real-time** capable
- Complexity for TSN configuration caused by the **convergent network**
- Centralized and distributed approach face **scalability** issues
- **Distributed** approach is highly **dynamic** (Plug-and-Play)
- **Centralized** approach is capable of high **optimization**

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Thank you!



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