Keynote

Wireless Industrial IoT: the Next Generation of Industrial Networking

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IARIA ICNS2021 Keynote Talk (virtual)
17th International conference on Networking and Services
May 30th 2021 – June 3rd 2021 – Valencia, Spain

Rute C. Sofia

IIoT Head @ fortiss, Munich, Germany, since 2019

Invited positions:

Invited Associate Professor @ University Lusofona, Lisbon, Portugal, since 2019
Associated researcher @ ISTAR, Instituto Universitário de Lisboa, since 2017

Past positions:

Associate Professor/Senior Researcher, COPELABS/University Lusófona, Lisbon, Portugal

2013-2017: Scientific Director, COPELABS research unit (wireless, IoT, 4G/5G, ICN)
2010-2013: Scientific Director, SITILABS research group (wireless, IoT, 4G/5G, ICN)

- CEO & co-founder, startup Senception Lda (pervasive sensing), Lisbon, 2013-2019
- IAN area leader, INESC TEC, Porto (wireless, QoS, routing), 2007-2010
- Senior Research Scientist, Nokia Siemens Networks GmbH, Munich, 2007
- (high-speed networking, carrier grade Ethernet, IPv6, QoS)
- Senior Researcher, Siemens AG, Munich, Germany (high speed networking, carrier grade Ethernet, IPv6, QoS), 2004-2007
- Senior Researcher, IIS, Bundeswehr Universität, Munich, (QoS, IPv6) – 2004
- WAN Engineer, FCCN, Lisbon, Portugal (Cisco WAN operations), Lisbon, 1998-2003
- Engineer, Grupo Forum, Lisbon, Portugal (NetSys admin), Lisbon, 1995-1998

•Research Interests: IoT; network architectures and protocols; in-network computing
•PhD in Informatics: 2004, University of Lisbon
  •Visiting Scholar (2000-2003), University of Pennsylvania, PA, USA (Roch Guérin, MNLab)
  •Visiting Scholar (2000), Internet Center for Advanced Internet Research (ICAIR), Northwestern University, Evanston, IL, USA
•M.Sc in Informatics: 1999, University of Lisbon
•B.Eng in Informatics: 1995, University of Coimbra (specialization in network and computer architectures)

About fortiss

http://www.fortiss.org

- **Legal form:** non-commercial limited company
- **Foundation:** 2009
- **Shareholders:** Free State of Bavaria (2/3) and Fraunhofer-Gesellschaft (1/3)

2
locations

150
employees

60
current projects

Subjects

What we do research on

Autonomous Systems Blockchain Business Models Human-centered Engineering IIoT Information Management Cognitive Structures Robust AI Machine Learning Human-Robot Interaction Performance Engineering Software and Systems Engineering Safety and Security Service Engineering Decentralized Services Neuro-morphic Computing Requirements Engineering Service Engineering Open Data

Industries

Where we apply our research

Industrial Internet of Things

-Enabling next generation IIoT Applications-

Decentralized Edge Computing	Edge/Fog architectures & service orchestration Reduced latency & increased efficiency Cross-platform interoperability
Real-time System Adaption	Semantic integration of brownfield devices Artificial Intelligence on the edge (Edge AI) Dynamic container orchestration
In-network Computation and Analytics	• In-network processing for control • More flexible infrastructures • Adaptive computation

Aims

- Novel communication & computation architectures for IIoT (OSI Layers 2 to 7)
- Efficiently, robustly, and possibly predictively deploy and orchestrate services
- Seamless computing for decentralized IIoT services

Our Offer

Architecting Edge-Cloud Support

- Open-source edge/server gateways
- Semantic integration of brownfield devices
- Dynamic container orchestration (e.g., Kubernetes, Docker Swarm)

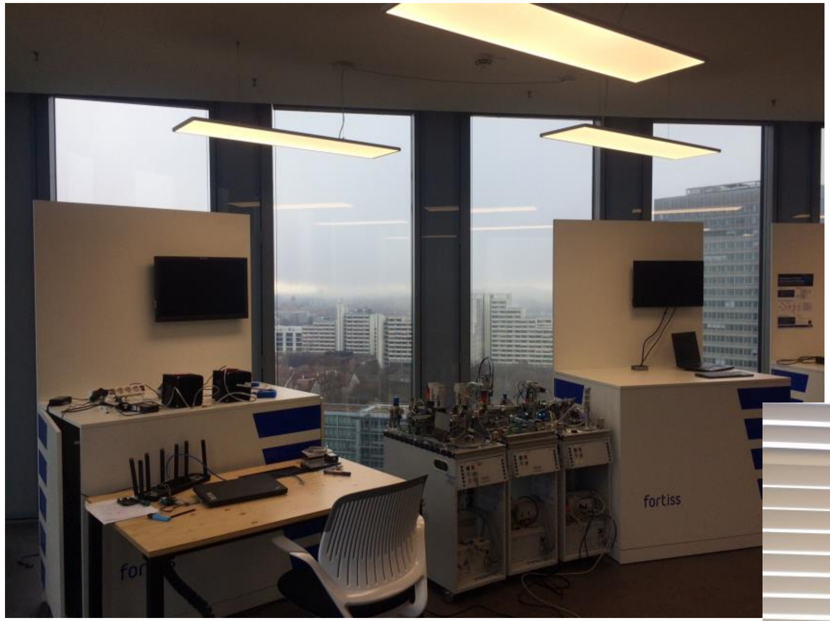
Supporting Intensive IIoT applications

- Performance improvement and analysis of communication protocols (e.g., MQTT Sparkplug, OPC-UA, DDS)
- Adaptation of the infrastructure to better support service decentralisation

Training Aspects

- Hands-on workshops on IIoT
- Technical mentorship on advanced IIoT software

IIoT Lab



Wireless Industrial IoT

The next generation of industrial networking

Motivation

- IIoT applications have strict requirements (e.g., sub-second latency; low jitter, guaranteed bandwidth)
- IIoT infrastructures rely on "Time-sensitive Networking (TSN) to support strict requirements
- IIoT environments are wireless and wired based
  - Wi-Fi6/7 needs tunning to support IIoT applications strict requirements

Aim and Focus

- Determinism support in IIoT wired/wireless (WiFi 6, Wi-Fi 7)
  - Explore wireless mechanisms that can support strict guarantees in wireless (Wi-Fi 6, Wi-Fi 7)
- Backward compatibility with Time Sensitive Networking/Ethernet
  - Traffic profile characterisation
  - Support of tight time synchronisation
  - Support of Time-aware scheduling

Outcome

- Tight Time synchronisation validation based on the wireless Fine Time Measurement (FTM) protocol (IEEE802.11AS-2020)
- Flexible, Time-Aware Scheduling based on the wireless Target Wake Time (TWT) mechanism
- Proof-of-concept demonstrations on the fortiss Industrial IoT Lab

Reliable Wireless Industrial Services

Which Requirements?*

- Wireless Industrial Services Today
  - Sources: IEEE 802.11 Nendica, IEEE 802.11 RTA TIG, IETF DetNet RFC 8578, Avnu Alliance, 5G ACIA 5G for Connected Industries and Automation White Paper, NICT report on wireless use-cases and communication requirements in factories, IEB113 report on TSN and rail metro networks, IETF RAW use-cases, ITU-R report on technical characteristics and operational goals of *Wireless Avionics Intra-communications (WAIC)*
  - Collection of 31 services, grouped into 13 different categories with objective communication KPIs (latency, packet loss, jitter, payload size, etc.)

- Debate on novel industrial wireless services
  - AR/VR Services within flexible factories
  - Decentralized shop-floor communication services
  - Autonomous airbone services
  - Debate on 3 examples of future industrial services; recommendations for wireless integration and specific communication KPIs

*R. Sofia, M. Kovatsch, P. Mendes, Requirements for Reliable Wireless Industrial Services, draft-sofia-raw-industrialreq00

Reliable Wireless Industrial Services

Which Requirements? Examples Today

Use-case	IEEE Nendica	IEEE 802.11 RTA	IETF DetNet	Avnu	5G ACIA	NICT	IEB113	IETF RAW	IIC	ITU-T WAIC
Equipment and processes control	x	x	x	X	X	x		x	X	
Quality supervision	x					x			X	
Factory resource management	x	x				x			X	
Display	x					x				
Human Safety	x					x			X	
Industrial systems	x	x				x			X	
Mobile Robots	x	x		x	X	x			X	
Drove/UAV control		x						x	X	
Power Grid control			x							
Communication based train networks							x			
Mining Industry			x							
Connected Cabin				x						X
Wireless Avionics Intra-communication										X

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Reliable Wireless Industrial Services

Which Requirements?

[R. Sofia, M. Kovatsch, P. Mendes, draft-sofia-raw-industrialreq00]

Collected Requirements

- Reasons for wireless integration
- Considerations for communication requirements
- Latency
- Periodicity - stands for whether or not the data transmission is executed in a periodic fashion
- Cycle, if available
- Transmit data size (data payload) in bytes
- Tolerance to packet loss
- Time synchronisation needs (e.g., requirement for IEEE 1588 synchronisation)
- Node density/number of nodes supported

Example: equipment and Process Control

- Reasons for wireless integration: flexibility of deployment; reconfigurability; mobility; maintenance cost reduction.
- Control of machines and robots services
  - Bounded latency: less than 10 ms.
  - Periodic
  - Transmit data size (bytes): 10-400 (small packets)
  - Tolerance to packet loss: 0.
  - Time synchronisation: IEEE 1588
  - Node density: 1 to 20 (per 20 m x 20 m)
- PLC to PLC communication
  - Bounded latency: 100 us to 50 ms.
  - Transmit data size: 100-700
  - Tolerance to packet loss: 0
  - Time sync: IEEE 1588

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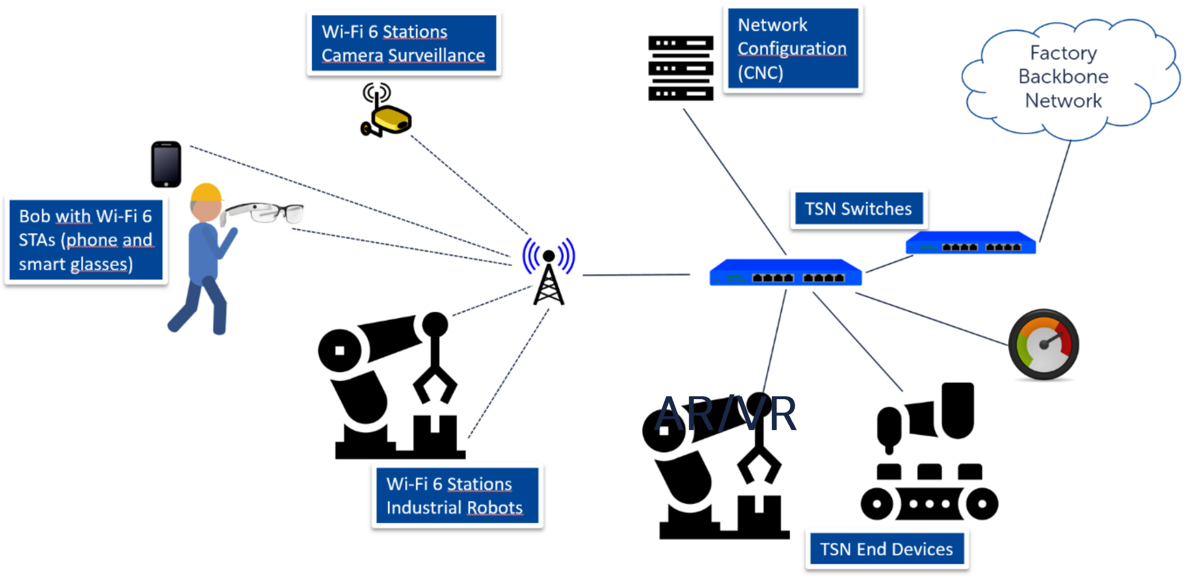
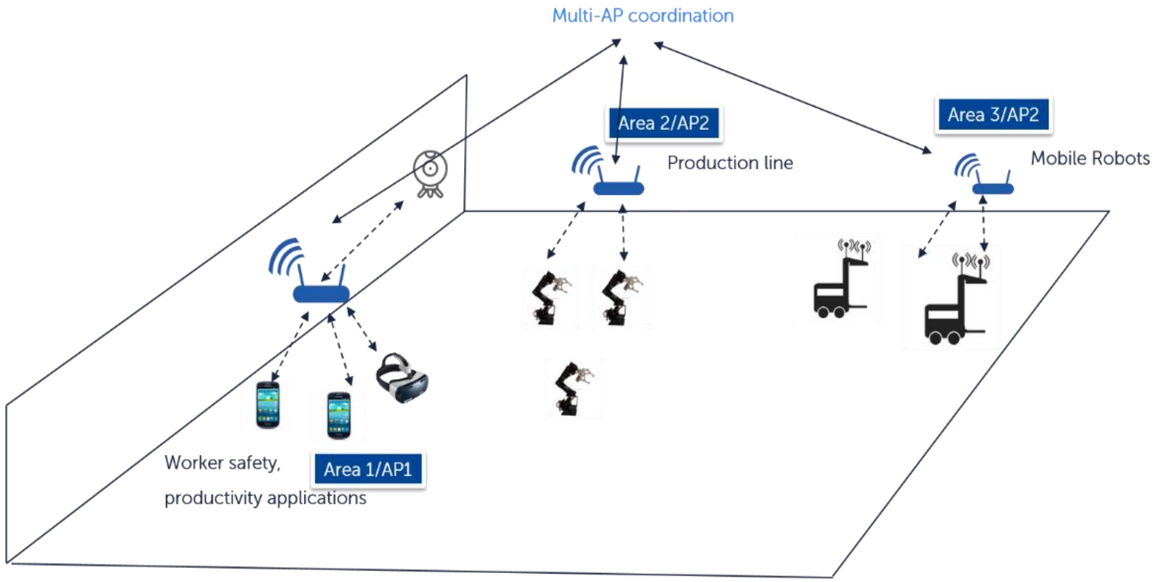
Which Requirements? Future Scenarios*





- AR/VR** for maintenance support
  - Latency: 3-10 milliseconds (ms)
  - Bandwidth, 0.1-2Gbps
  - Data payload, over 4Kbytes

- Decentralised Shop-floor
- Specific KPIs**
  - Latency: 20-40 ms
  - Transmit data size (bytes): 50, VBR**

**AR/VR: Augmented Reality/Virtual Reality
**KPI: Key performance indicator
**VBR: Variable Bit Rate

*R. Sofia, M. Kovatsch, P. Mendes, Requirements for Reliable Wireless Industrial Services, draft-sofia-raw-industrialreq00

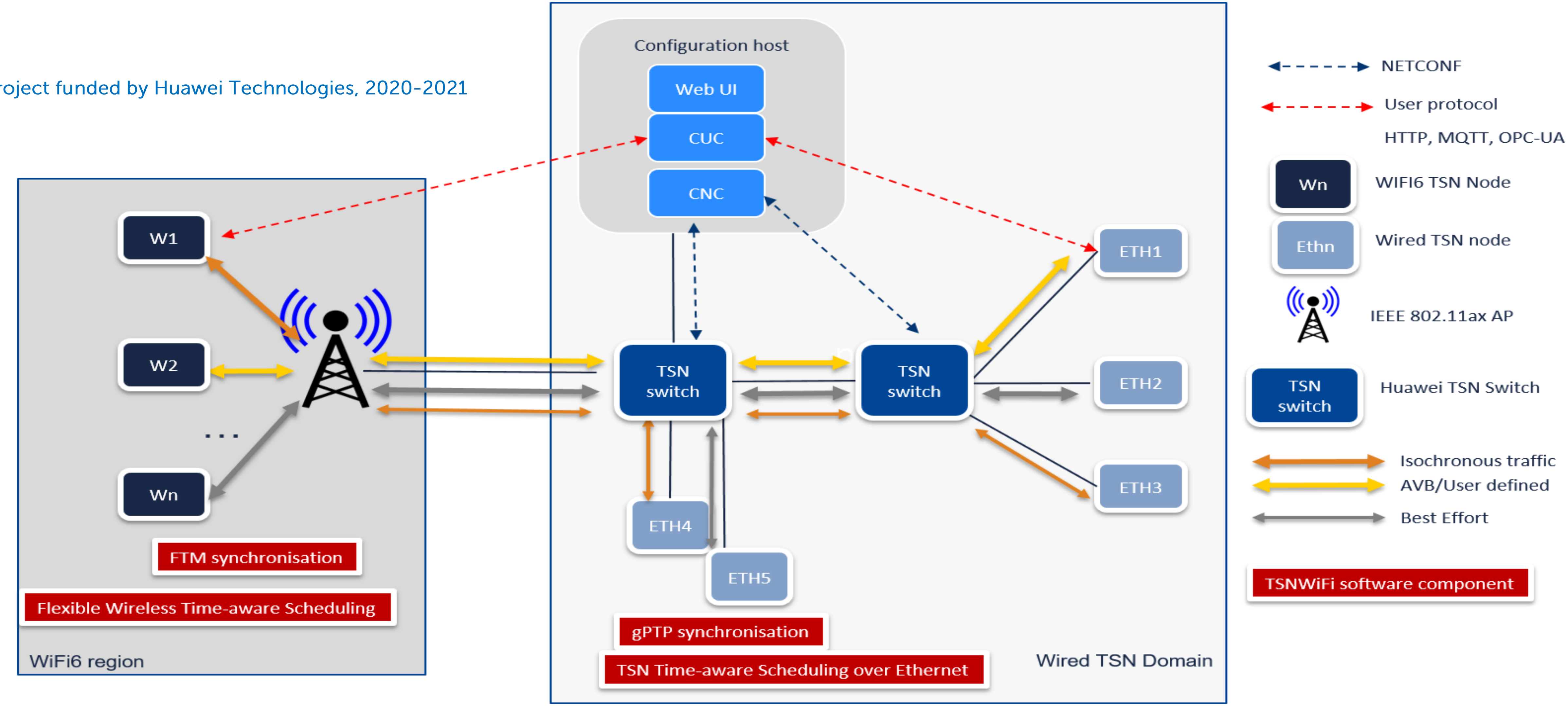
Reliable Wireless Industrial Services
Traffic Profiles, Our Recommendation

Profile	PCP	Delivery Guarantees	Period	Latency	Jitter	Payload (bytes)	Message type	Criticality level
Isochronous control	6	Deadline, latency, zero congestion loss, zero interference	< 2ms	< 50% of the period	Least possible	30-100	Fixed	High
Cyclic control	5	Latency, zero congestion loss	2-20ms	< 90% of the period	n.a.	50-1000	Fixed	High
Network control	7	Bandwidth, latency	50ms-1s	100ms	< period	50-500	Variable	High
Legacy control	4	Bandwidth		n.a.	n.a.		Variable	Medium
Event-based control and Alarms	3	Bounded latency	Acyclic	10ms-50ms (up to 2s for alarms)	No issue	100-1500	Variable	High/Medium
Configuration and Diagnostics	2	Bandwidth, bounded latency	Acyclic	100ms		500-1500	Variable	Medium
Audio/Video	1	Bounded latency, bandwidth	Frame/ sample rate	< 40 ms	n.a.	1000-1500	Variable	Low
Best Effort	0	None	Acyclic	-	n.a	30-1500	Variable	Low

Reliable Wireless Industrial Services

Demonstrator*: https://www.fortiss.org/en/research/projects/detail/tsnwifi

Project funded by Huawei Technologies, 2020-2021

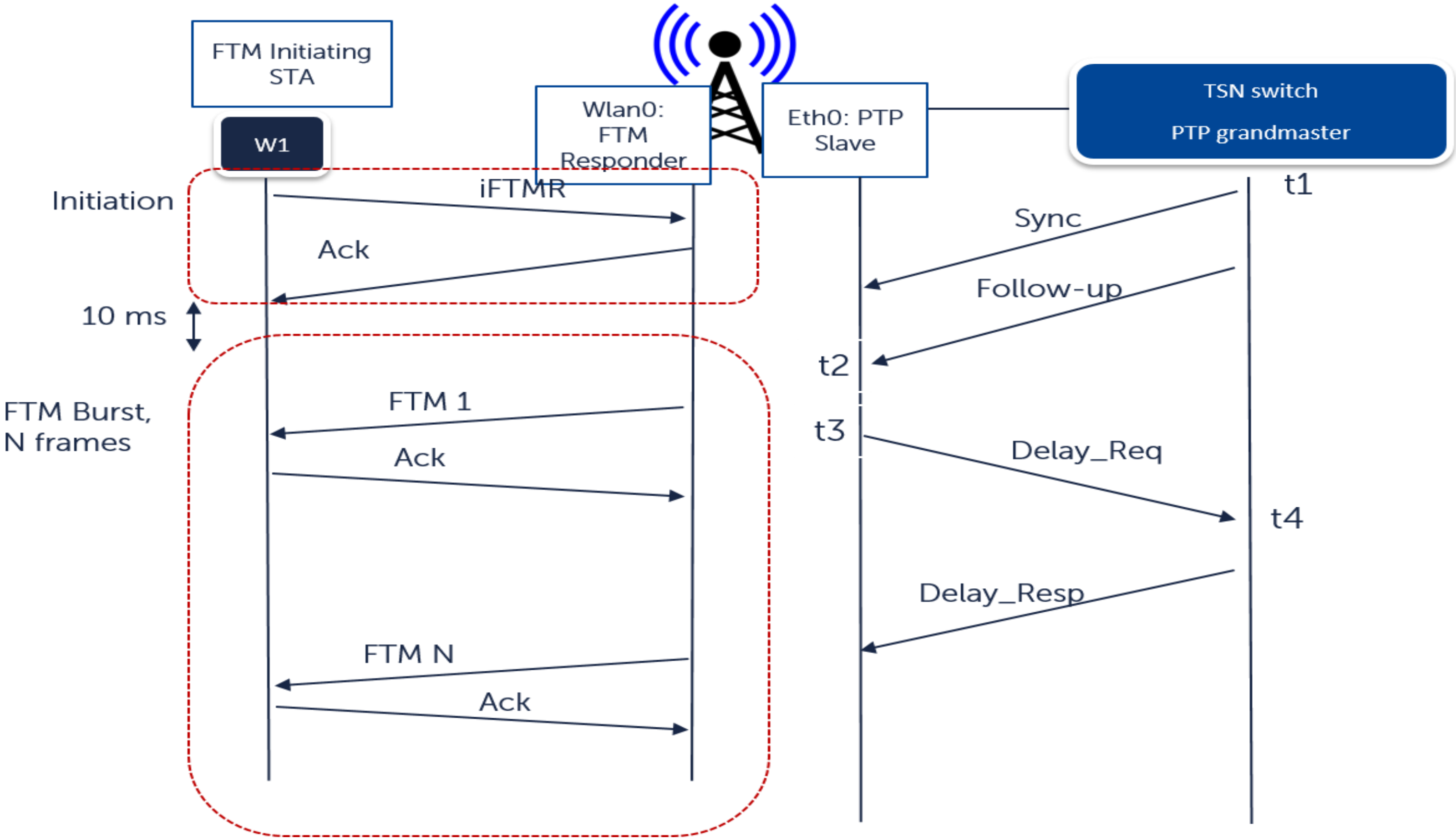


*Sugandh Mohan, Chitiphat C, B. Schneider, Devika Ajith, R. C. Sofia, Matthias Kovatsch. Experimenting with TSN and Wi-Fi 6. Under submission, 2021.

Reliable Wireless Industrial Services

Time Synchronisation Aspects

- Time synchronisation via Fine Time Measurement (FTM) protocol (IEEE802.11AS-2020)
  - Experimental extensions for synchronising AP and wireless stations
  - Wireless region synchronised to PTP via FTM

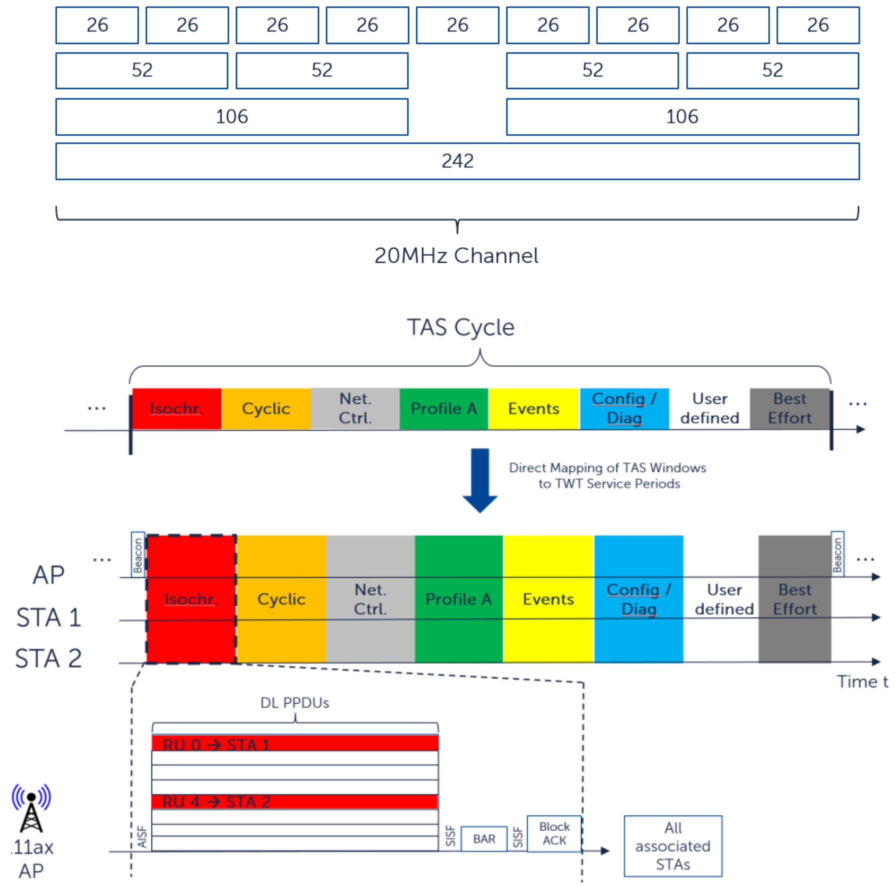


Reliable Wireless Industrial Services

Time-Aware Scheduling*

- Traffic Isolation
  - OFDMA Resource Unit Allocation
  - Provides isolation based on sub-frequencies

- Scheduling based on Target-Wake Time
  - Integrates time-awareness to the wireless exchange
  - Mimics TSN Time-aware Scheduling (TAS)



*B. Schneider, R. Sofia, M. Kovatsch, A Discussion on Supporting Deterministic Behavior in Wireless Industrial Networks, 2021, under submission.
B. Schneider, R. C. Sofia, M. Kovatsch, TAS-based Scheduling for Wireless/Wired TSN Environments, 2021, under submission.

Many thanks.

Any questions?

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