Reliable Low Latency Wireless Communication Enabling Industrial Mobile Control and Safety Applications

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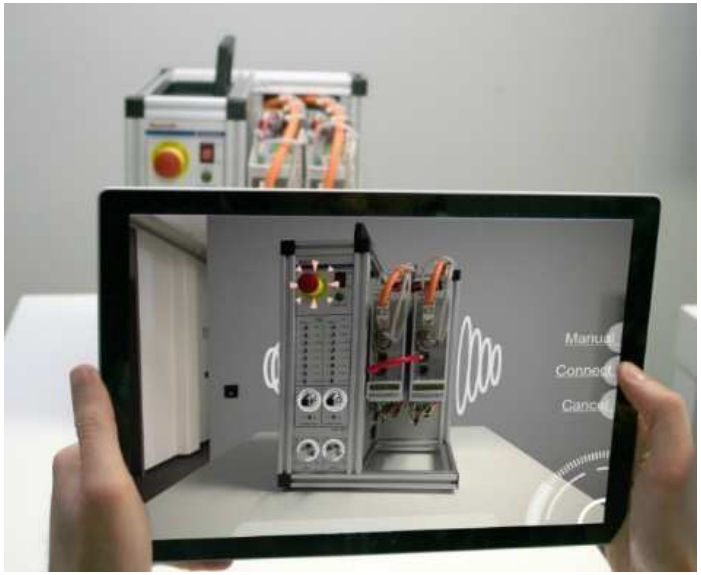
Outline

- Industrial HMI Applications
  - Augmented Reality
  - Mobile Control
- Requirements
- Radio Interface
- Conclusion

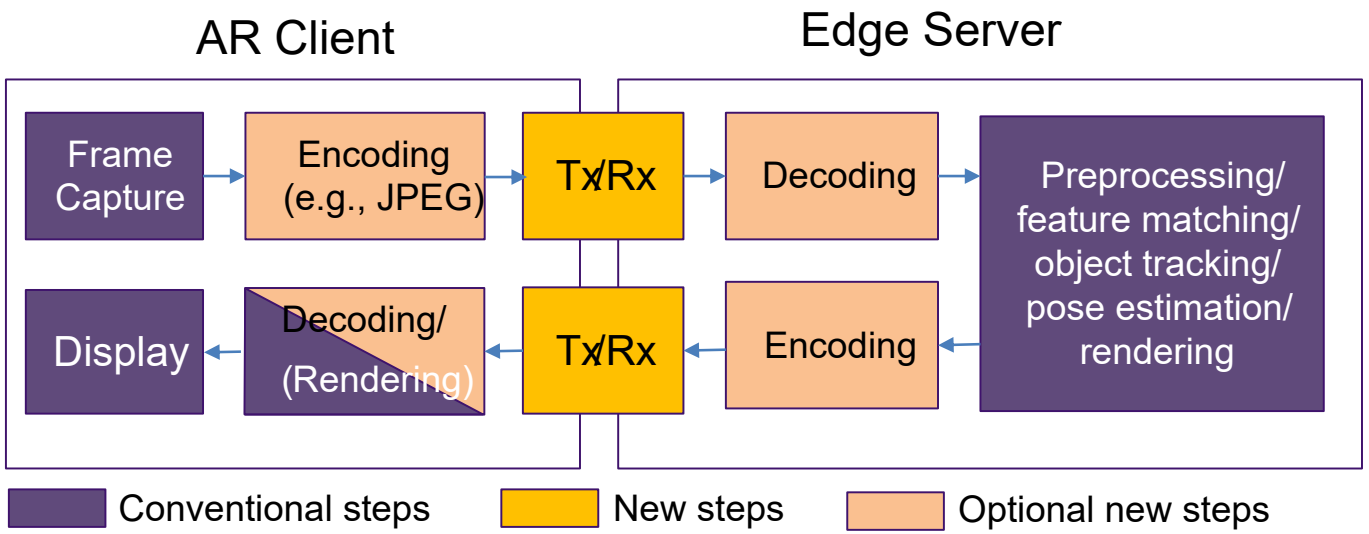
Augmented Reality

- Augmentation of life pictures
  - Navigation
  - Life documentation
  - Assistance
- Requirements
  - Motion-to-Photon latency < 20ms
  - Costs, size and weight constraints
  - Use by multiple collaborating users simultaneously



AR: Edge Computing

- Benefits of AR and MEC:
  - Offloading — enabling AR for resource-constrained devices
  - AR as a service
  - Server-side rendering of complex 3D models
  - Enabler for collaborative and context-sensitive AR

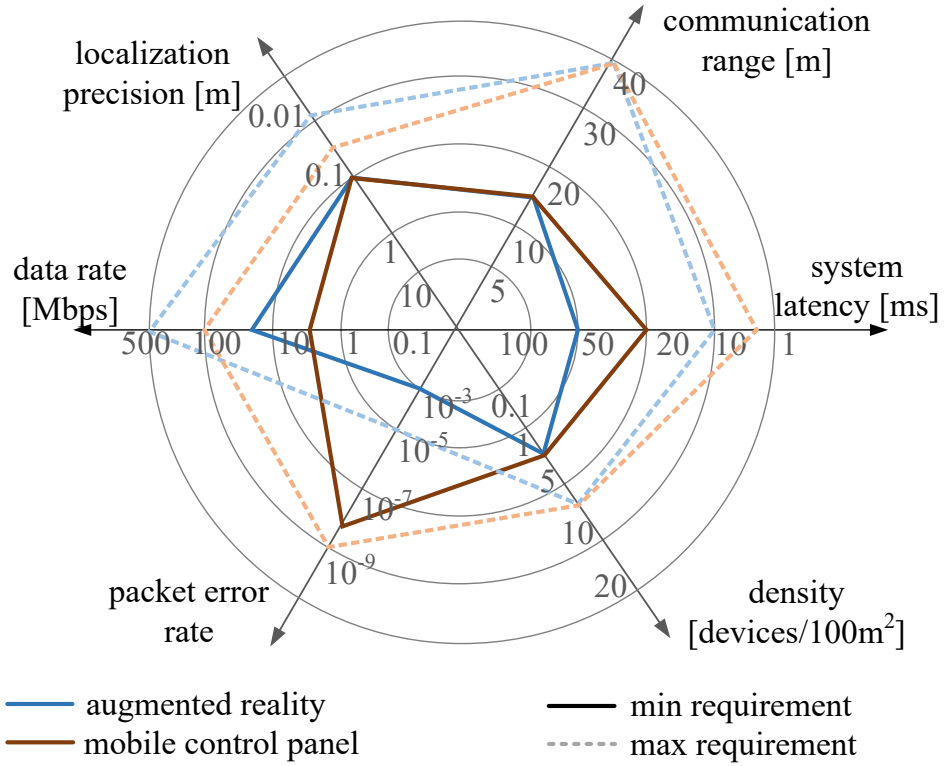


Mobile Control

- Control applications
  - Machines
  - Robots
- High requirements on safety
  - Emergency stop,
  - Safety-Protocols: PROFISafe, . . .
- “Sign-of-Life”-Packets
  - Watchdog: 5 – 30 ms
  - PER: 10^{-8}
- Safety-Zone-Concept
  - Precise localization

Requirements

- Augmented Reality
  - Low latency
  - High data rate
  - Visual localization
- Mobile Control
  - High reliability
  - Real-time
  - Radio localization
- General
  - Security
  - Flexibility
  - Scalability

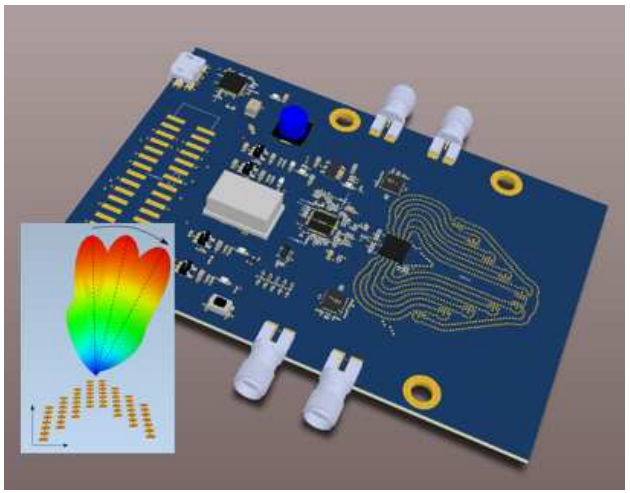


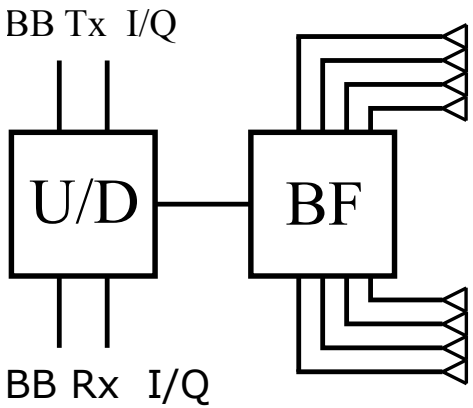
Radio Interface

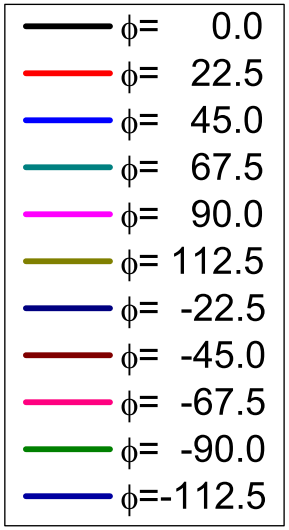
- 60 GHz communication
  - High data rates
  - Precise localisation
- Agile Multiband Approach
  - 2.4 GHz, 5 GHz and 60 GHz
  - Reliability
- Flexible Waveform
  - OOB emission reduction
  - Increase in spectral efficiency
- Channel Access
  - Hybrid MAC approach
  - Traffic prioritisation and scheduling
- Localisation
  - Time-of-Flight approach
  - Integration with communication

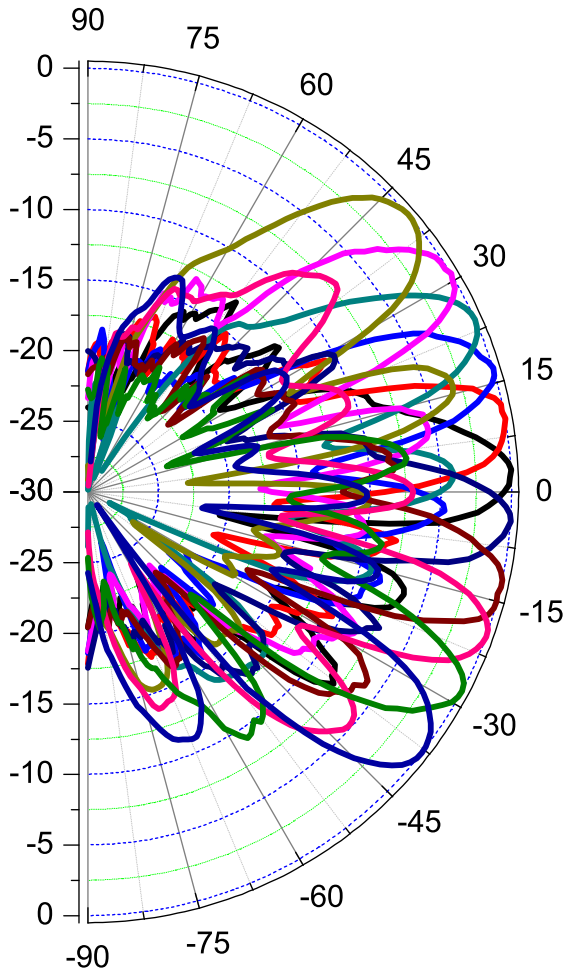
60 GHz System

- Analog front-end with 8 channel beamforming
- 130 nm SiGe:C BiCMOS technology



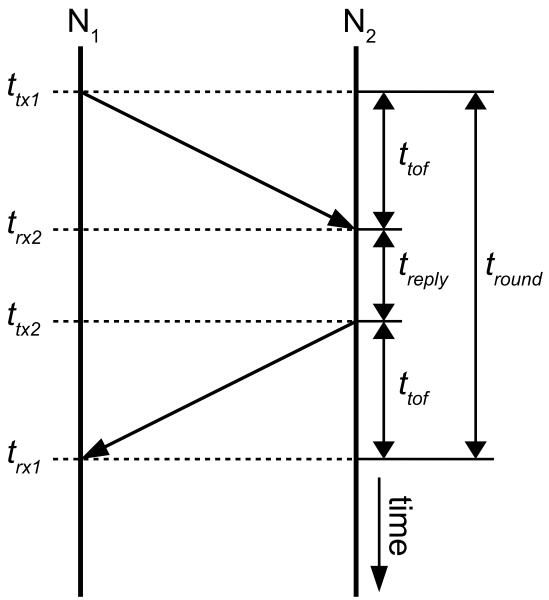


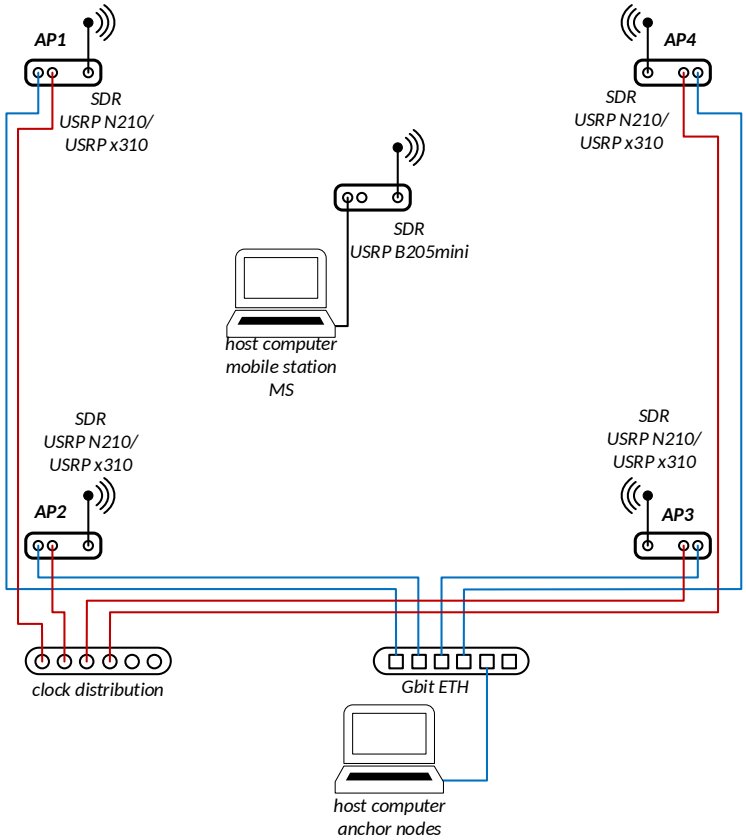




Localisation

- Two way ranging
- Precise localisation
  - Below 1 m with 50 MHz bandwidth
  - Below 10 cm with 1.7 GHz bandwidth

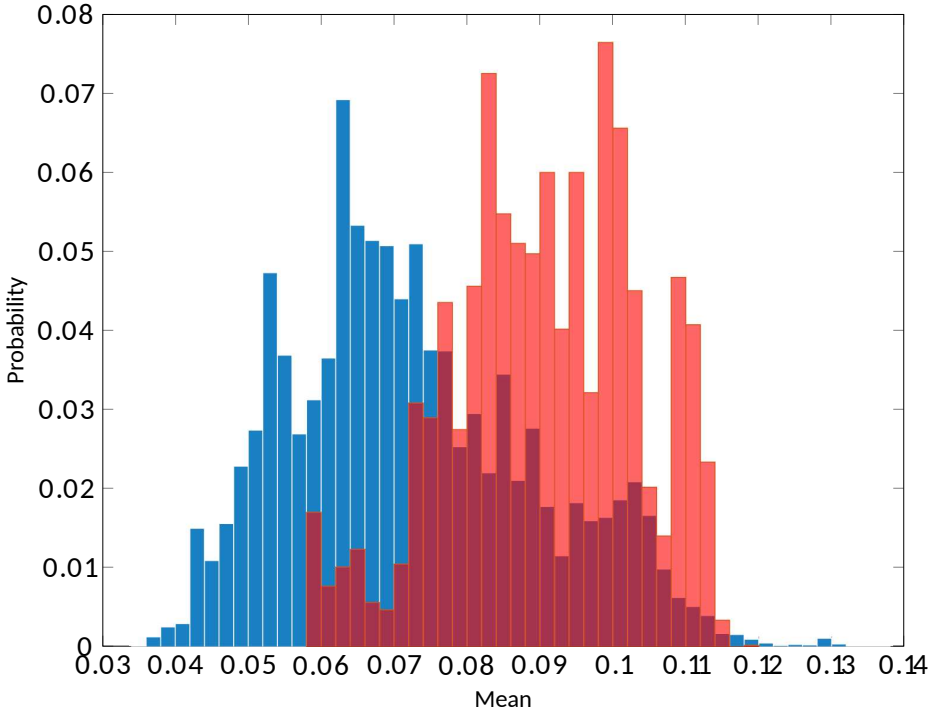


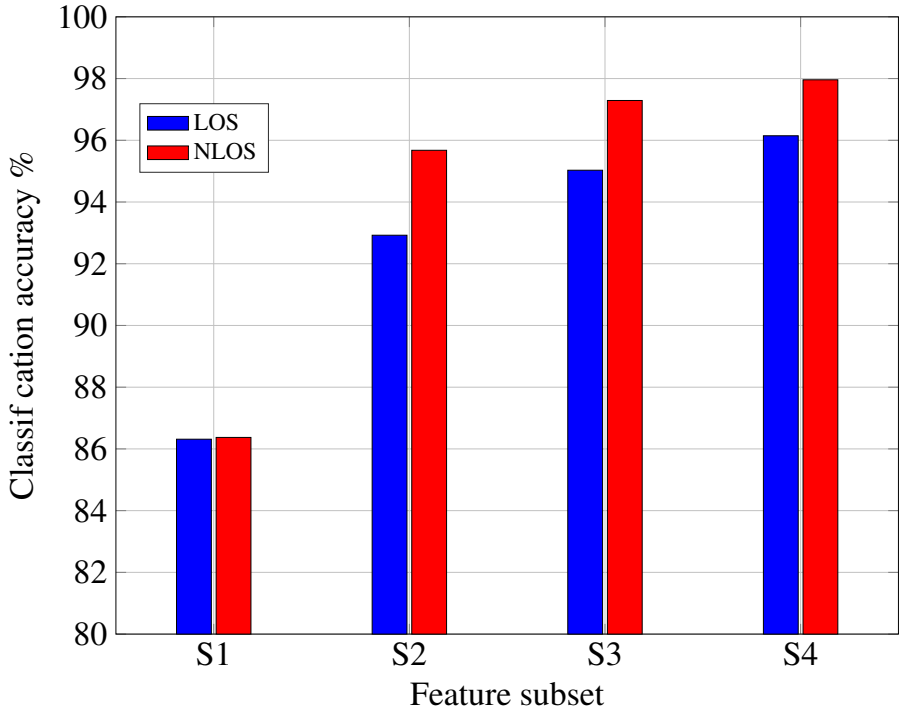


Localisation: NLOS Detection

- NLOS: degradation of performance
- CIR amplitude distribution
- Classification by machine learning

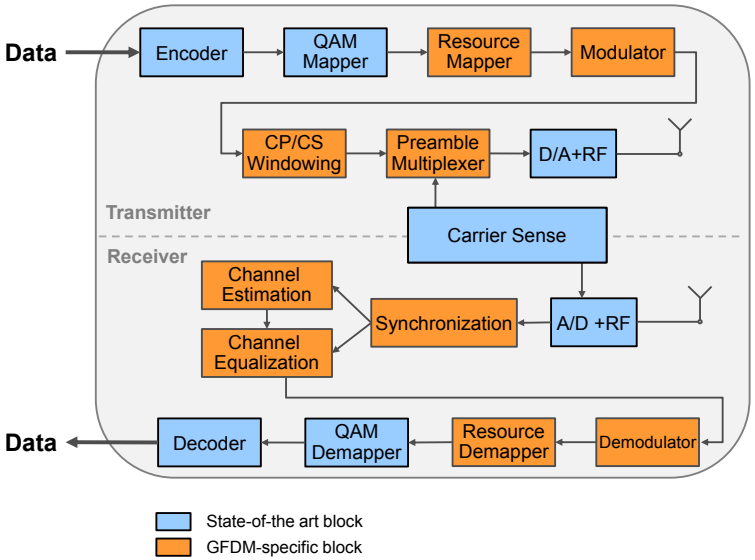
Subset	Feature			
	μ	σ	s	κ
S1		✓		
S2			✓	✓
S3		✓	✓	✓
S4	✓	✓	✓	✓

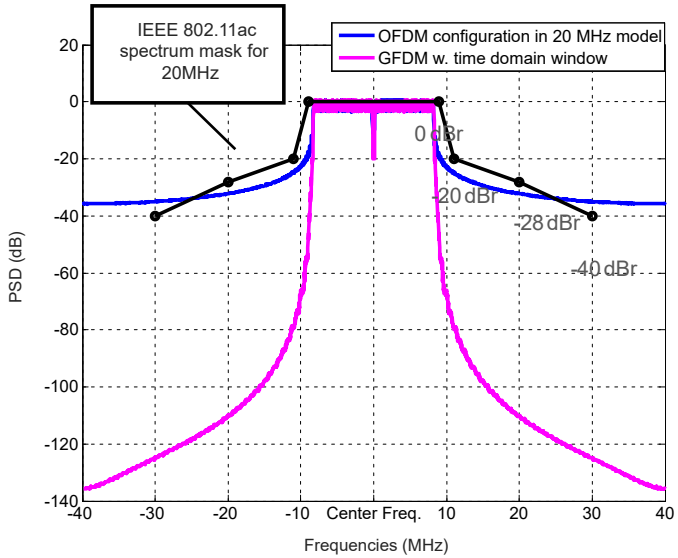




New Waveform

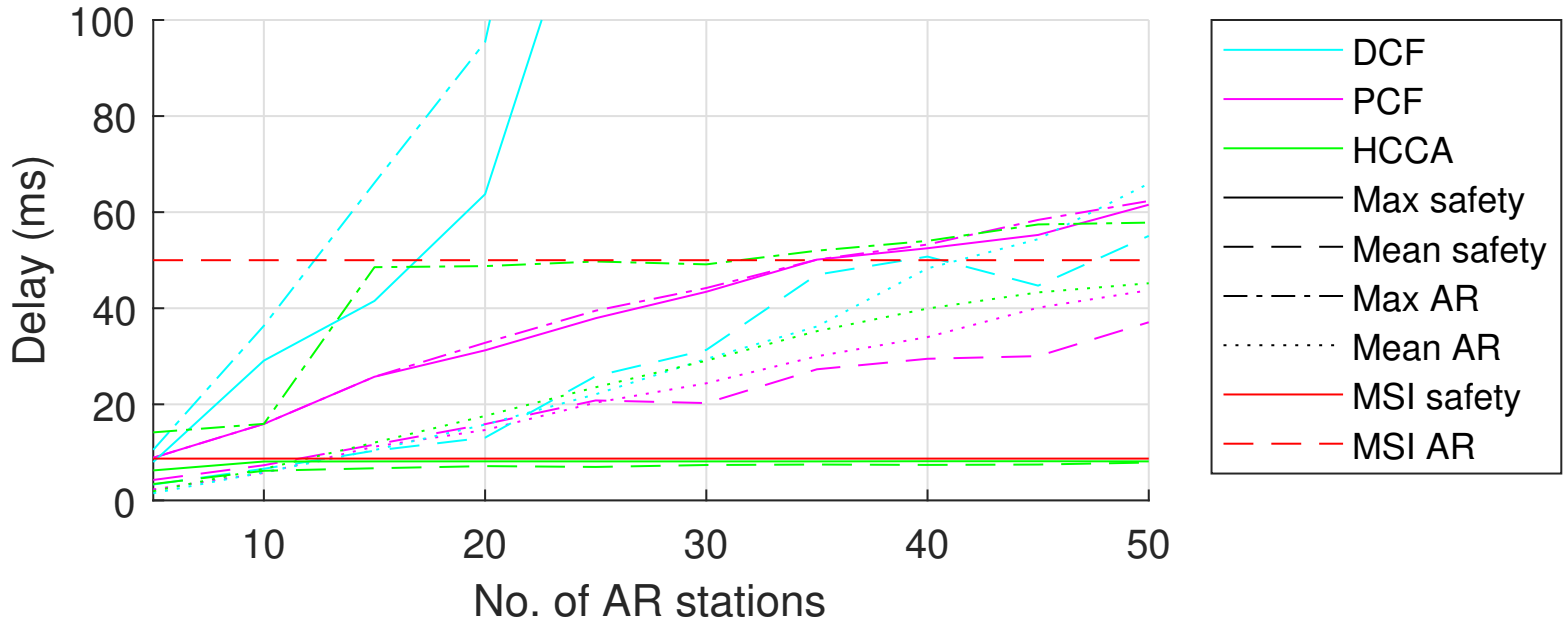
- Generalised Frequency Division Multiplexing
- Flexible waveform
- Low out-of-bounds emission
- Low cyclic prefix overhead





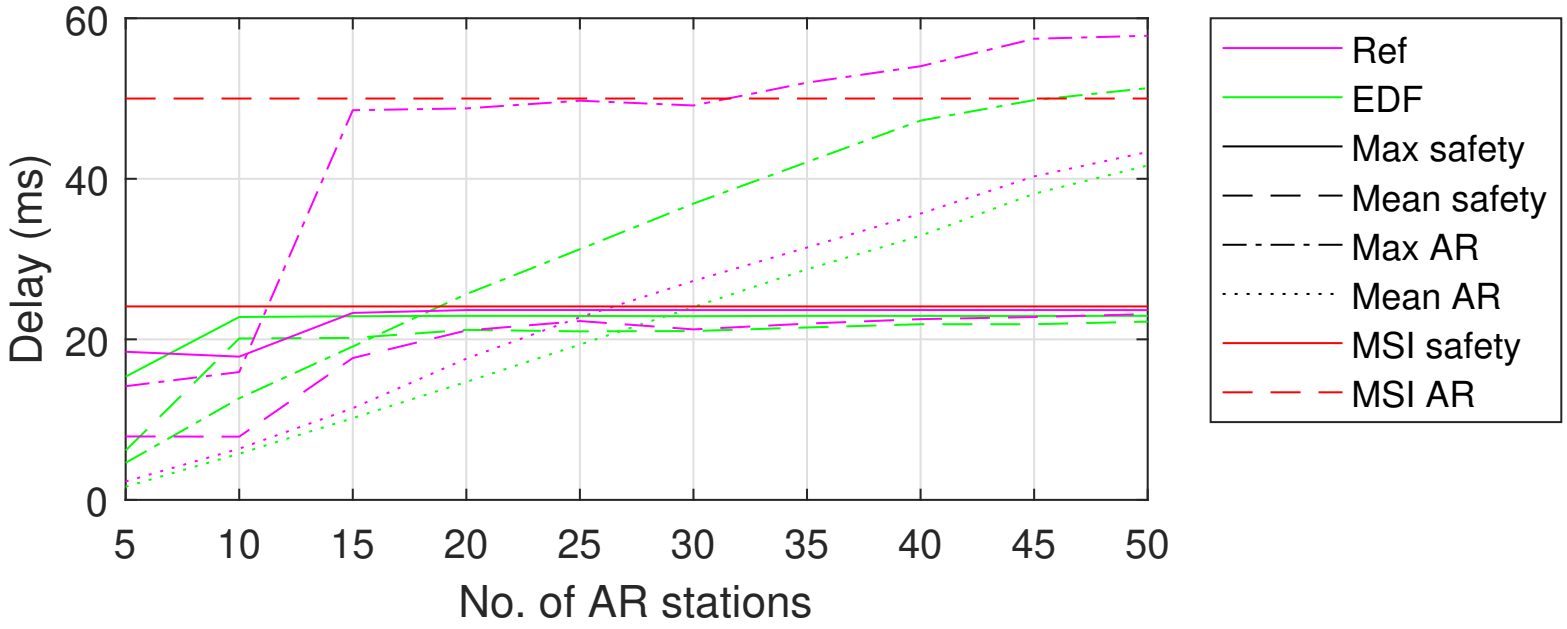
Channel Access

- Comparison of channel access techniques
  - DCF/EDCA: non-deterministic
  - PCF: inefficient for heterogeneous traffic
  - HCCA: best performance



Channel Access: Scheduling

- Reference vs. EDF scheduler



Conclusion

- Heterogeneous industrial HMI requirements
- New radio interface required
  - 60 GHz communication
  - Flexible waveform
  - Channel access
  - Localisation
- Future works
  - Mobility support
  - Security

Thank you!