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Radio Interference Analysis of Industrial Wireless Networks: From Legacy Systems to New Standards

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Outline

- Introduction
- Motivation and objectives
- Methodology
- System specification
- Simulation scenarios
- Results and conclusion

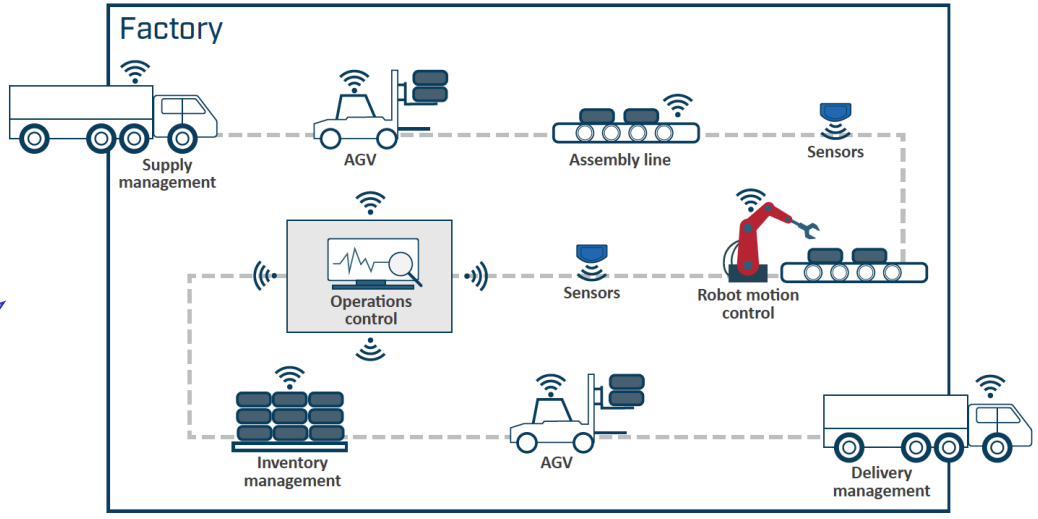
Introduction

- In the last 30 years, the industry has automated everything that can be automated in the factory shop-floor, using wired technology.
- Logistics, material handling and factory automation can only be fully automated using wireless technologies.
  - HMI
  - AGVs
  - Inventory
  - Supply & delivery
  - Assembly lines
  - …

Technologies:

WiFi, Bluetooth,

wirelessHART



Source: 5G for Connected Industries and Automation, 2nd Ed, 5G-ACAI, February 2019

Motivation and objectives

Motivation

Common wireless technologies in use (WiFi, Bluetooth, wirelessHART):

- Interference from different radio technologies and standards
- The same frequency band (ISM band)
- No radio resource management between communication systems

5G NR systems:

- Planned Frequencies avoid ISM bands. Low interfence probability.

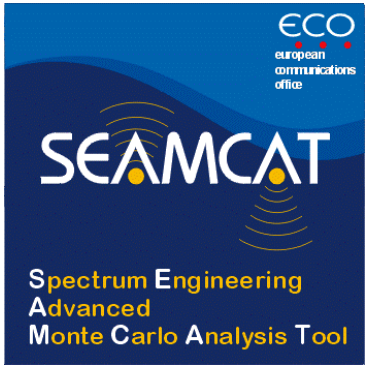
Objectives

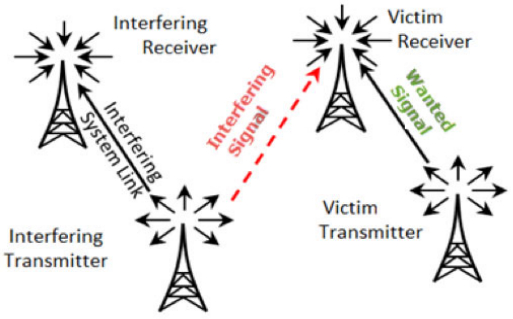
- Coexistence study between existing wireless technology (WiFi, Bluetooth and WirelessHART) using 2.4 GHz ISM band

Methodology

SEAMCAT simulation tool (ECO)

- Radio specifications
  - power, carrier frequency, bandwidth
  - antenna pattern and height
  - transmitter emission mask
  - receiver blocking mask
- System specifications
  - propagation model, distance
  - transmission probability
  - area (80 m x 80 m shop-floor
  - frequency hopping pattern
- Interfererence criterium
  - I/N < -6 dB

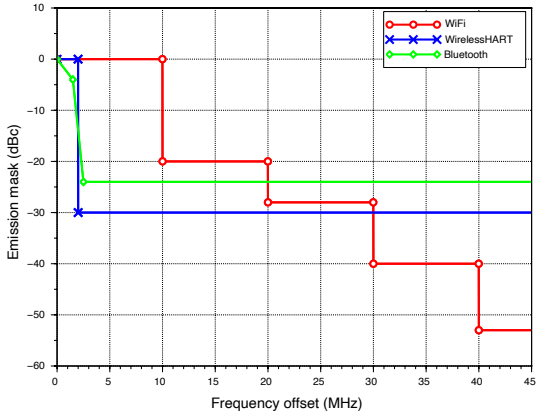




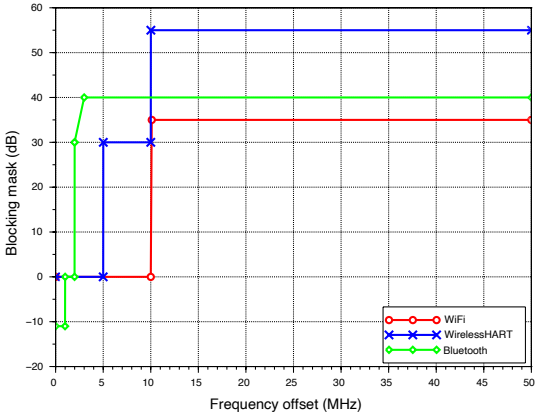
- Results of simulation (20000 events for each simulation):
  - Probability of interference < 1 % (stipulated value)

Legacy systems specifications

Transmitter emission mask



Receiver blocking mask



Legacy systems (ISM band)

Property \ System	WirelessHART	WiFi	Bluetooth
Frequency band	2400-2483.5 MHz		
Channel bandwidth	1 MHz	22 MHz	1 MHz
Channel spacing	5 MHz	25 MHz	1 MHz
Number of channels	16	3 (1,6,11)	79
In-Block EIRP	10 dBm	20 dBm	0 dBm
Antenna height	Tx: 2.5 m Rx: 1.0 m	Tx: 3.0 m Rx: 1.5 m	Tx: 1.5 m Rx: 1.5 m
Antenna type	omnidirectional		
Antenna gain	Tx: 2 dBi Rx: 0 dBi	Tx: 6 dBi Rx: 0 dBi	Tx: 0 dBi Rx: 0 dBi
Receiver sensitivity	-90 dBm	-95 dBm	-95 dBm
Environment	50 % indoor 50 % outdoor	100 % indoor below roof	
Propagation model	ITU-R P.1546-6		Extended Hata SRD
Coverage radius	200 m	50 m	20 m
Prob. Transmission	10 %	90 %	50 %

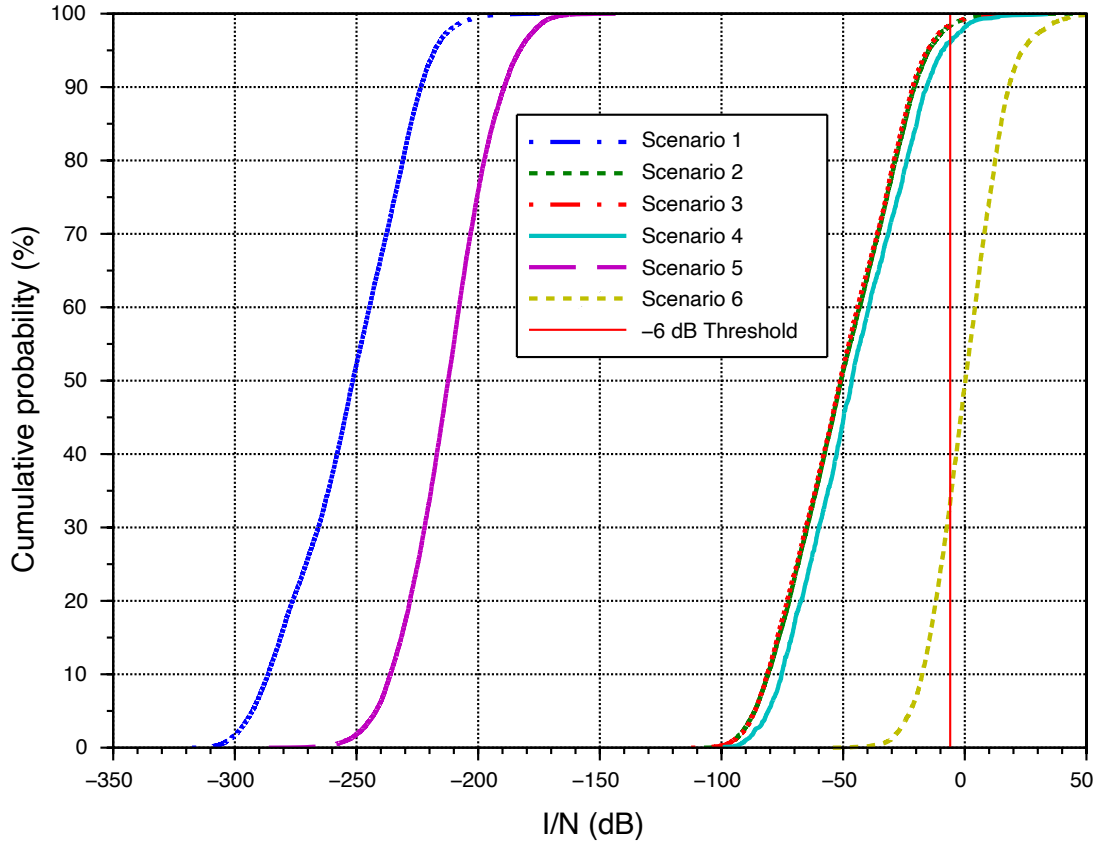
Coexistence scenarios

1. victim: WiFi - interferer: WirelessHART;
2. victim: WirelessHART - interferer: Bluetooth;
3. victim: WirelessHART - interferer: WiFi;
4. victim: Bluetooth - interferer: WiFi;
5. victim: WiFi - interferer: Bluetooth;
6. victim: Bluetooth - interferer: WirelessHART.

- All simulations scenarios are composed of one victim receiver and one or more interferers.
- The relative position between the victim and interferer systems follows a uniform spatial distribution (mobility)
- Each system is configured to implement frequency hopping among their available channels.

Results

- Cumulative Density Function for I/N (dB)
- Values higher than -6 dB threshold correspond to excessive interference to the victim system.



Results

- Probability of interfence (limit stipulated as < 1 %)
- WiFi is the only system that can withstand interference below the stipulated limit.
- Bluetooth systems have the worst performance, with a probability of interference reaching 5 %, when WirelessHART is the interferer.

Victim / Interferer	WiFi	WirelessHART	Bluetooth
WiFi	-	1.6 %	3.3 %
WirelessHART	0.1 %	-	5 %
Bluetooth	0.2 %	2.9 %	-

Conclusions

- SEAMCAT is an effective agnostic tool to simulate interference scenarios between different wireless systems (WiFi, wirelessHART and Bluetooth)
- Legacy systems are prone to suffer interference from other legacy systems, working in cochannel arrangements (e.g. 2.4 GHz ISM band)
- Interference levels affect the receiver performance of wireless systems differently.

Future work

- Measurement campaigns on the factory shop-floor to support and confirm the simulation results.
- Include 5G NR networks (IIoT) to evaluate interference levels with legacy wireless systems.

Thank you for your attention!

Questions?

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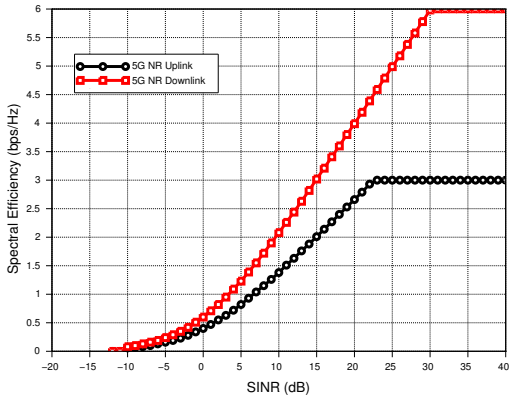
5G NR specifications

Macrocell

System / Property	Base station	User Equipment
Frequency band	2483.5 - 2495 MHz (n53, TDD)	
System bandwidth	10 MHz	
Bandwidth of a RB	180 kHz	
Maximum RB per BS	52	
Number of RB per UE	13	
In-Block EIRP	46 dBm	24 dBm
Antenna height	30 m	1.5 m
Antenna type	tri-sector 3GPP	peak gain antenna
Antenna gain	15 dBi	0 dBi
Min. Coupling Loss	70 dB	
Receiver Noise Figure	4 dB	8 dB
Propagation Model	ITU-R P.1546-6, mobile	
Handover margin	3.1 dB	
Environment	100 % outdoor	10 % outdoor, 90 % indoor: wall loss = 10 dB std. dev. = 5

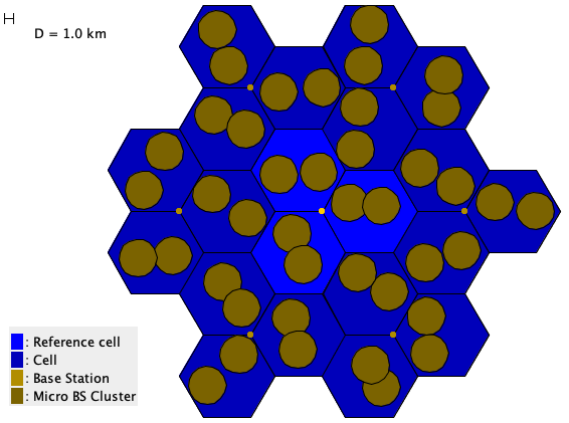
Spectral efficiency profile



Microcell

System / Property	Base Station	User Equipment
Frequency band	2483.5 - 2495 MHz (n53, TDD)	
System bandwidth	10 MHz	
Bandwidth of a RB	180 kHz	
Maximum RB per BS	52	
Number of RB per UE	13	
In-Block EIRP	46 dBm	24 dBm
Antenna height	6 m	1.5 m
Antenna type	peak gain antenna	
Antenna gain	6 dBi	0 dBi
Min. Coupling Loss	53 dB	
Receiver Noise Figure	4 dB	8 dB
Propagation Model	ITU-R P.1546-6, mobile	
Handover margin	3.1 dB	
Environment	100 % outdoor	10 % outdoor, 90 % indoor: wall loss = 10 dB std. dev. = 5

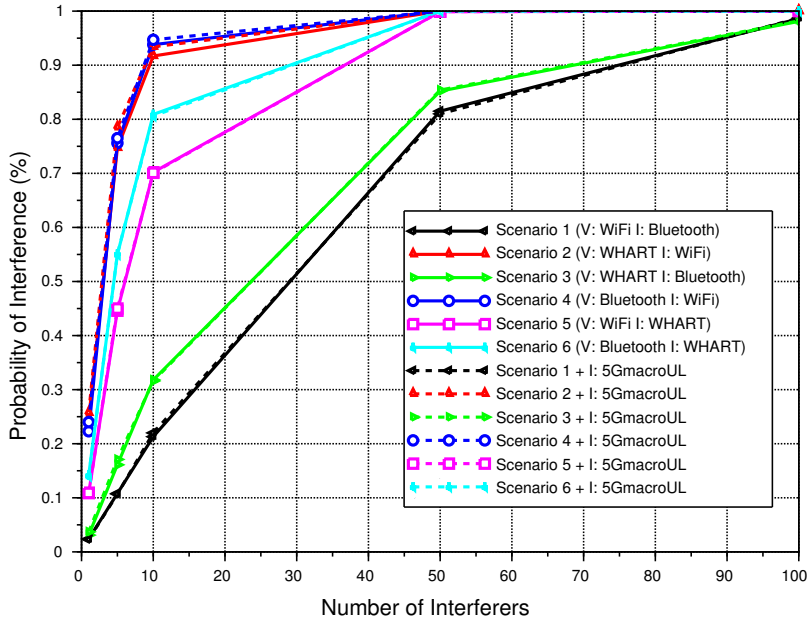
Network (2-tier micro /



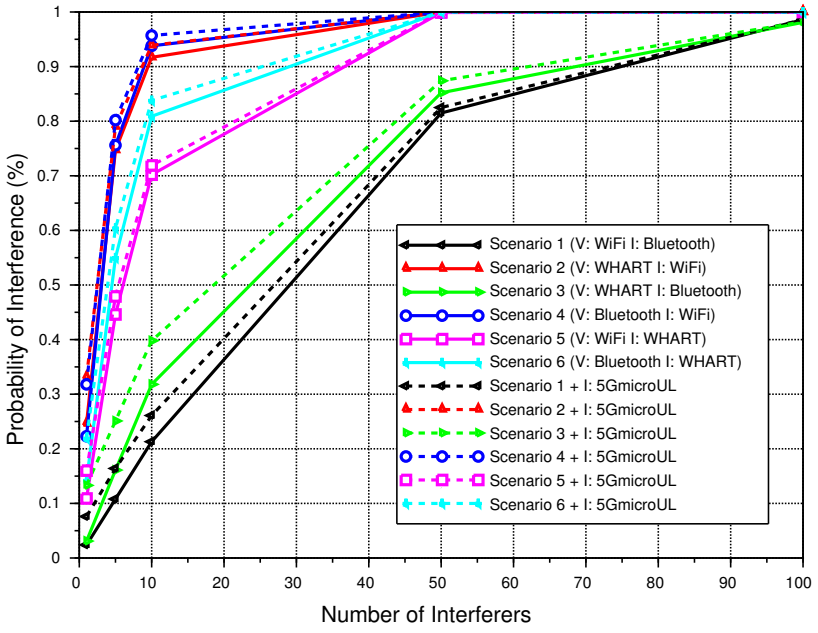
Results

Scenario 2 - Interference over legacy systems, from legacy systems and 5G UL

- Overall deterioration of interference levels, more pronounced with in the micro cell scenario.



5G UL - macro cell

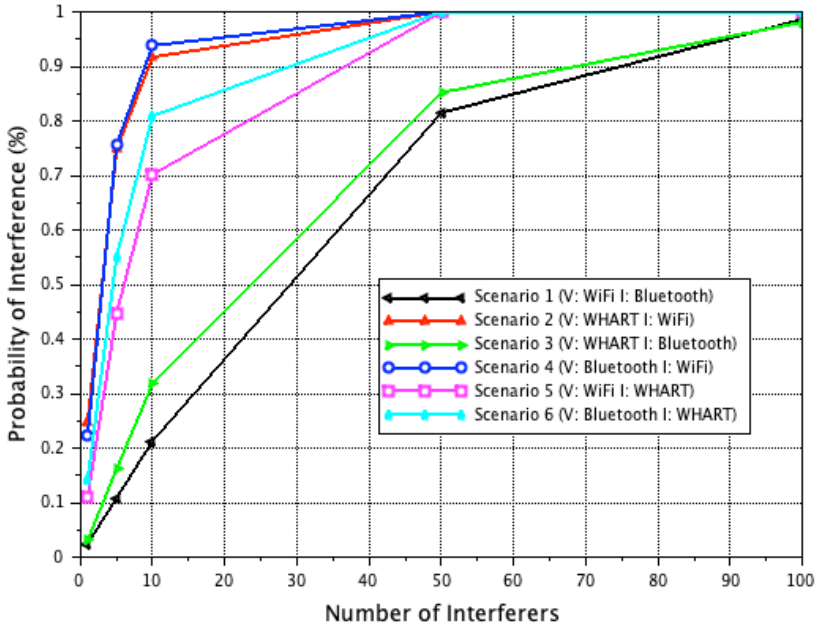


5G UL - micro cell

Results

Scenario 1 - Interference over legacy systems, from legacy systems

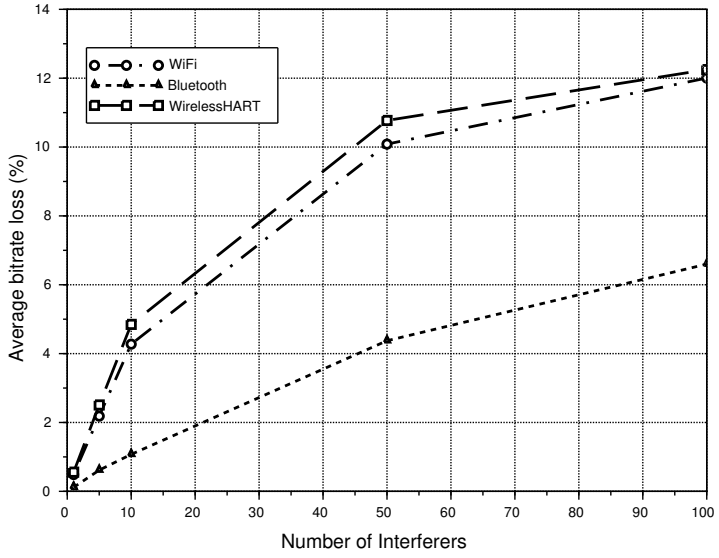
- Increase of interference levels with the number of interferers
- Worst case interference : WiFi over Bluetooth



Results

Scenario 3 - Interference over 5G UL from legacy systems

- The average bitrate loss increases proportionally with the number of interferers
- Similar bitrate degradation effect from WiFi and wirelessHART interferers over a 5G uplink



Results

Scenario 3 - Interference over 5G DL, from legacy systems

- The average bitrate loss increases proportionally with the number of interferers
- WiFi causes higher bitrate losses over a 5G DL