

Final Thesis

Suitability of Modern Wi-Fi for Wireless Infield-Communication

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Agenda

- Motivation Final Thesis
- Physical Layer Technologies
- Field Measurements
- Simulation Experiments

Motivation Final Thesis

FIRST REPORT AND ORDER, FURTHER NOTICE OF PROPOSED RULEMAKING, AND ORDER OF PROPOSED MODIFICATION

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By the Commission: Chairman Pai and Commissioners O’Rielly and Carr issuing separate statements;
Commissioners Rosenworcel and Starks concurring.

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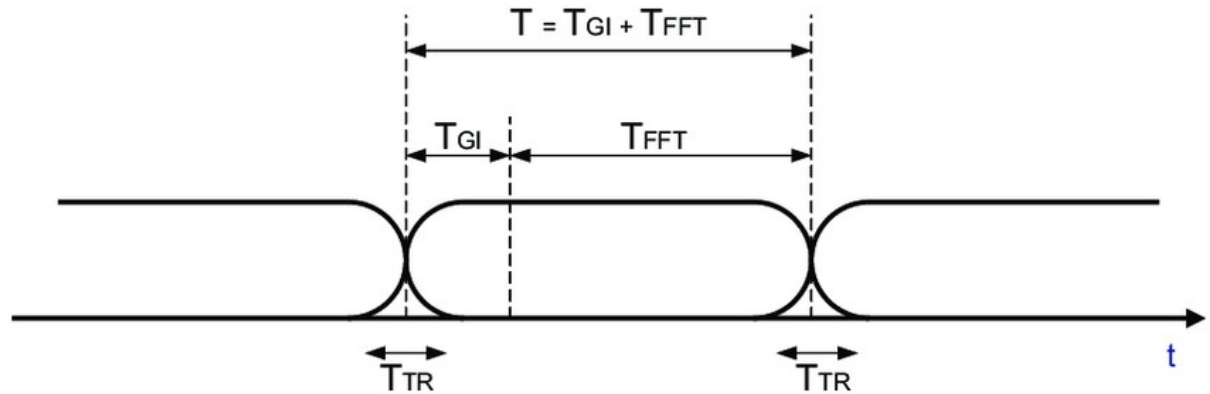
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Modern Wi-Fi

	IEEE 802.11ac (Wi-Fi 5)	IEEE 802.11ax (Wi-Fi 6)
Spectrum	5 GHz	2.4 GHz, 5 GHz
Bandwidth	Up to 160 MHz	Up to 40 Mhz (2.4 GHz), 160 Mhz at 5 GHz
OFDM Guard Interval	0.4 or 0.8 μ s	0.8, 1.6 or 3.2 μ s
Maximal Data Rate	6.9 Gbit/s	9.6 Gbit/s
Max Modulation Coding Scheme	256-QAM	1024-QAM
Multi-User Technology	MU-MIMO	MU-MIMO, OFDMA
Multi-User Transmission Direction	Downlink	Downlink und Uplink

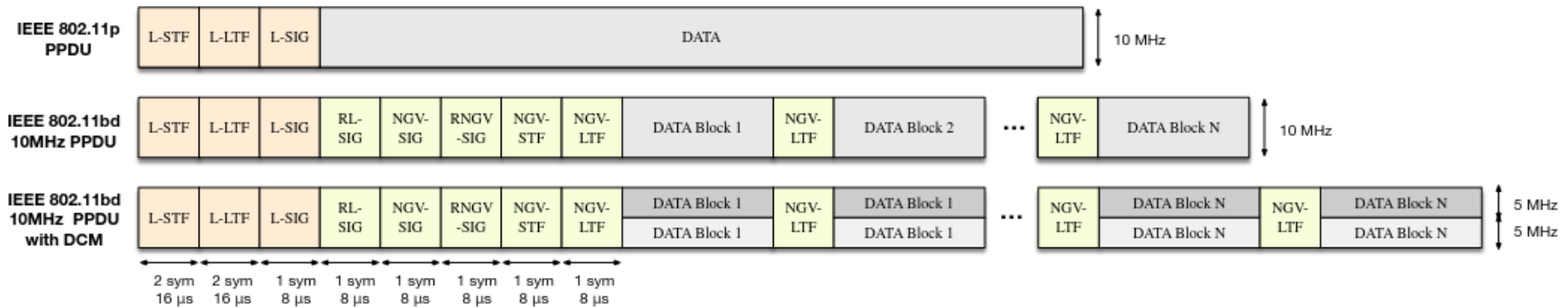
Physical Layer Technologies

OFDM Guard Interval

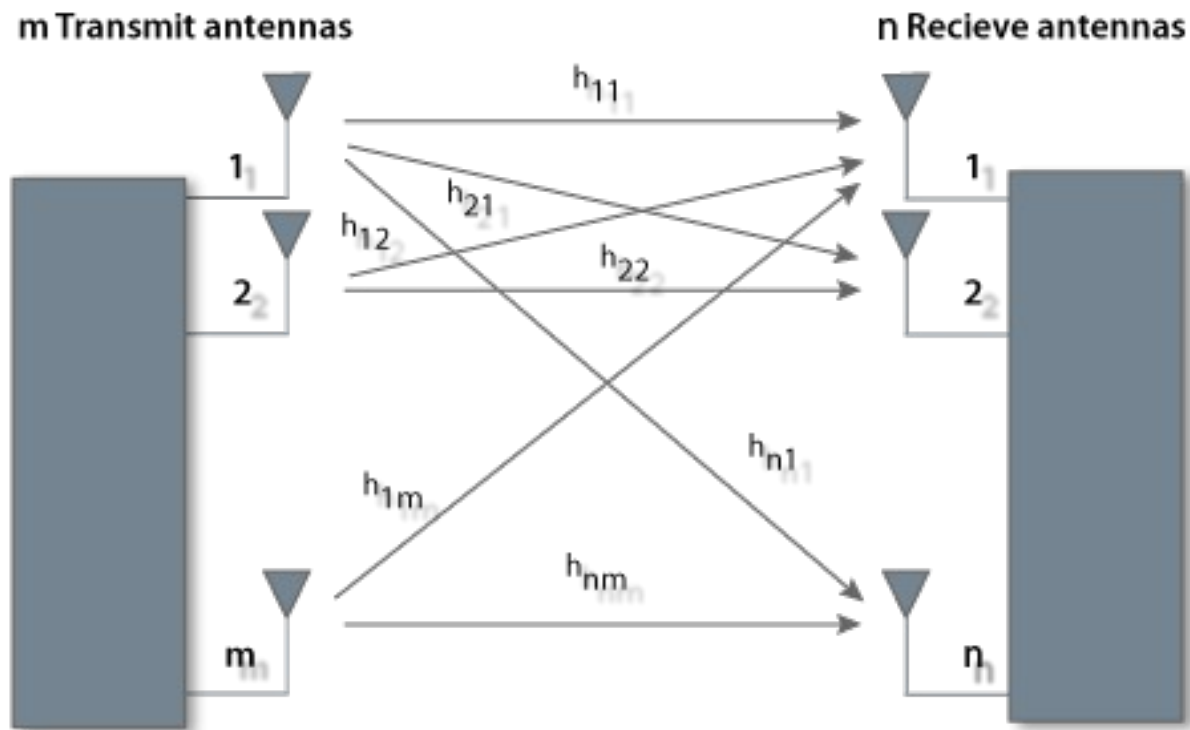


Wi-Fi Standard	OFDM Guard Interval	Bandwidth attenuation = $100 * T_{FFT} / T$ [%]
Wi-Fi 4 & 5	400 ns	89 %
Wi-Fi 4 & 5	800 ns	80 %
Wi-Fi 6	800 ns	94 %
Wi-Fi 6	1600 ns	89 %
Wi-Fi 6	3200 ns	80 %

Dual Carrier Modulation (DCM)

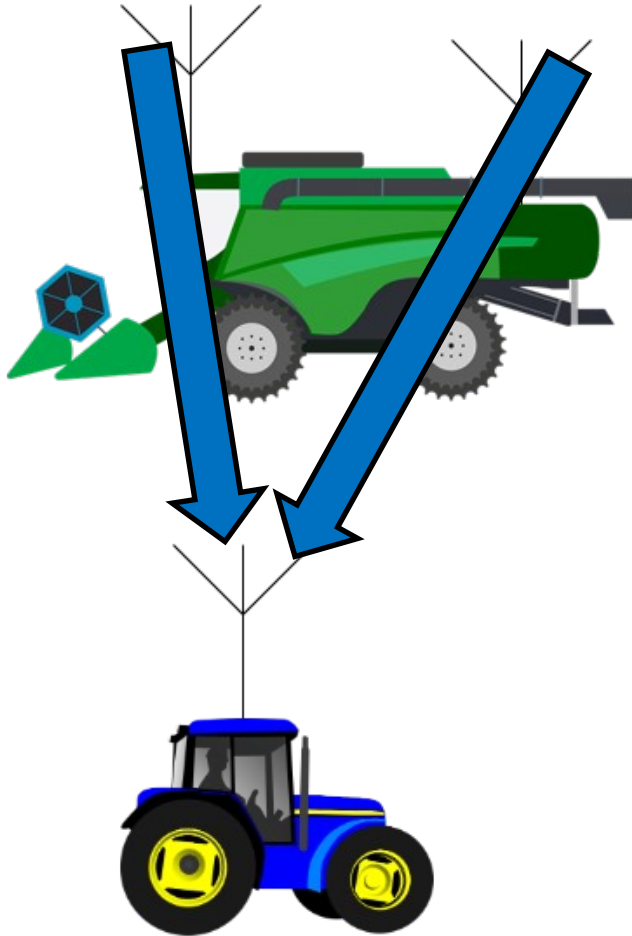


Multiple Input Multiple Output (MIMO)



Space-Time-Block-Codes

- Increases robustness
- Decreases data rate



Extended Range Mode

- Available for 802.11ax, 802.11bd
- Preamble power-boosting up to 3 db



HE SU PPDU Format



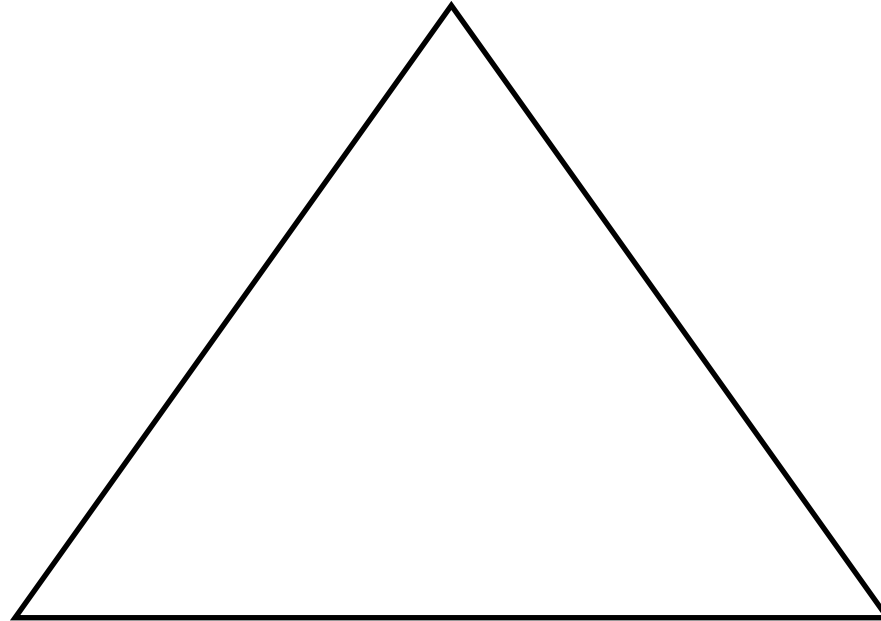
HE Extended Range SU PPDU Format

Bandwidth in 5 GHz Frequency Range

Wi-Fi Standard	Bandwidth	Transmission Power Extend for transmission power CSX
802.11 p, 802.11bd	10 MHz	33 dbm 802.11p, 802.11bd
802.11 bd, 802.11ax, 802.11ac	20 MHz	33 dbm 802.11bd 30 dBm 802.11ax, ac 50 mW / MHz
802.11ax, 802.11ac	40 MHz	25 mW / MHz
802.11ax, 802.11ac	80 MHz	12.5 mW / MHz
802.11ax	80 + 80 MHz	6.25 mW / MHz
802.11ax	160 MHz	6.25 mW / MHz



Range



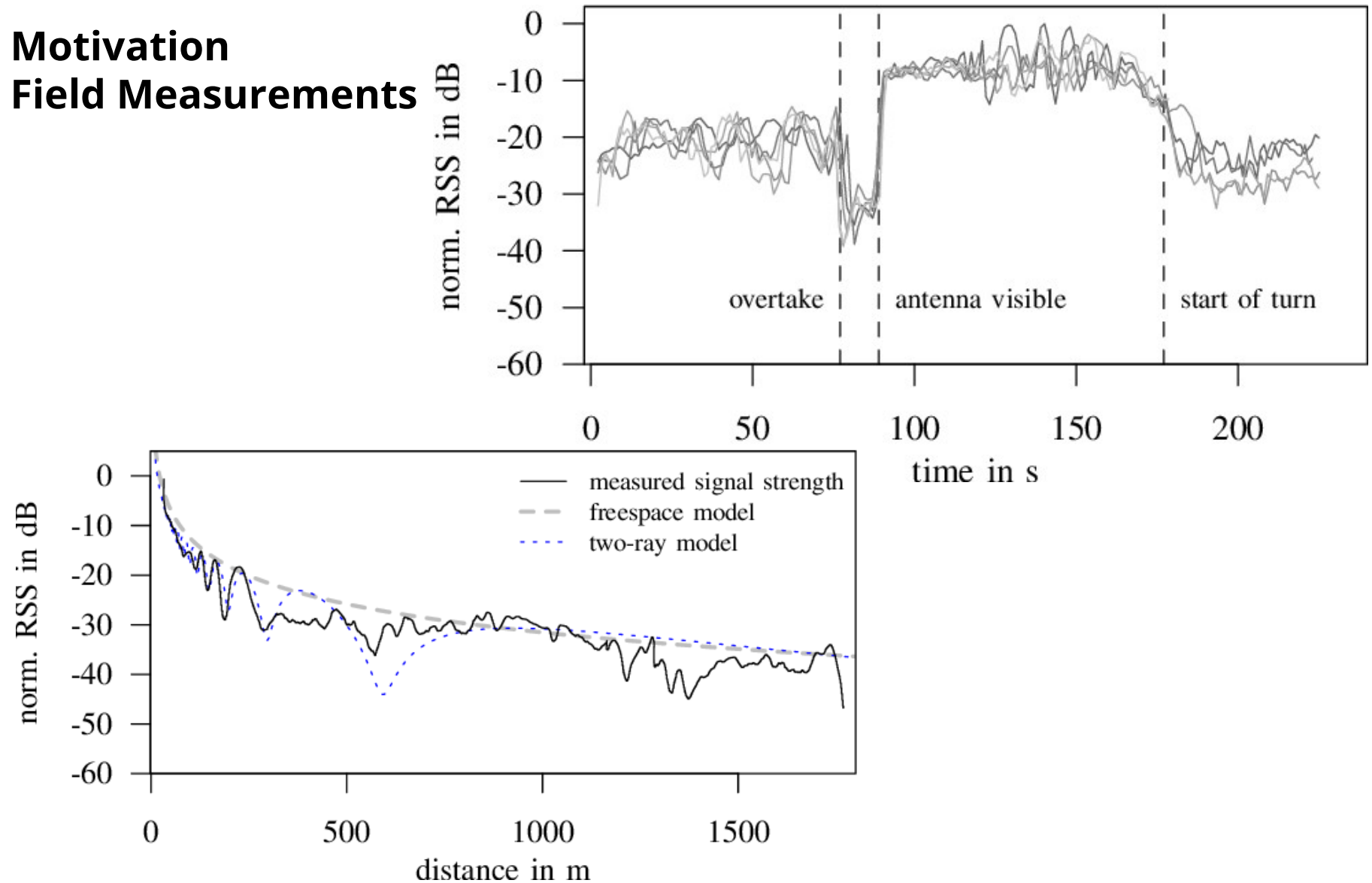
Throughput

Robustness

Field Measurements

Motivation

Field Measurements



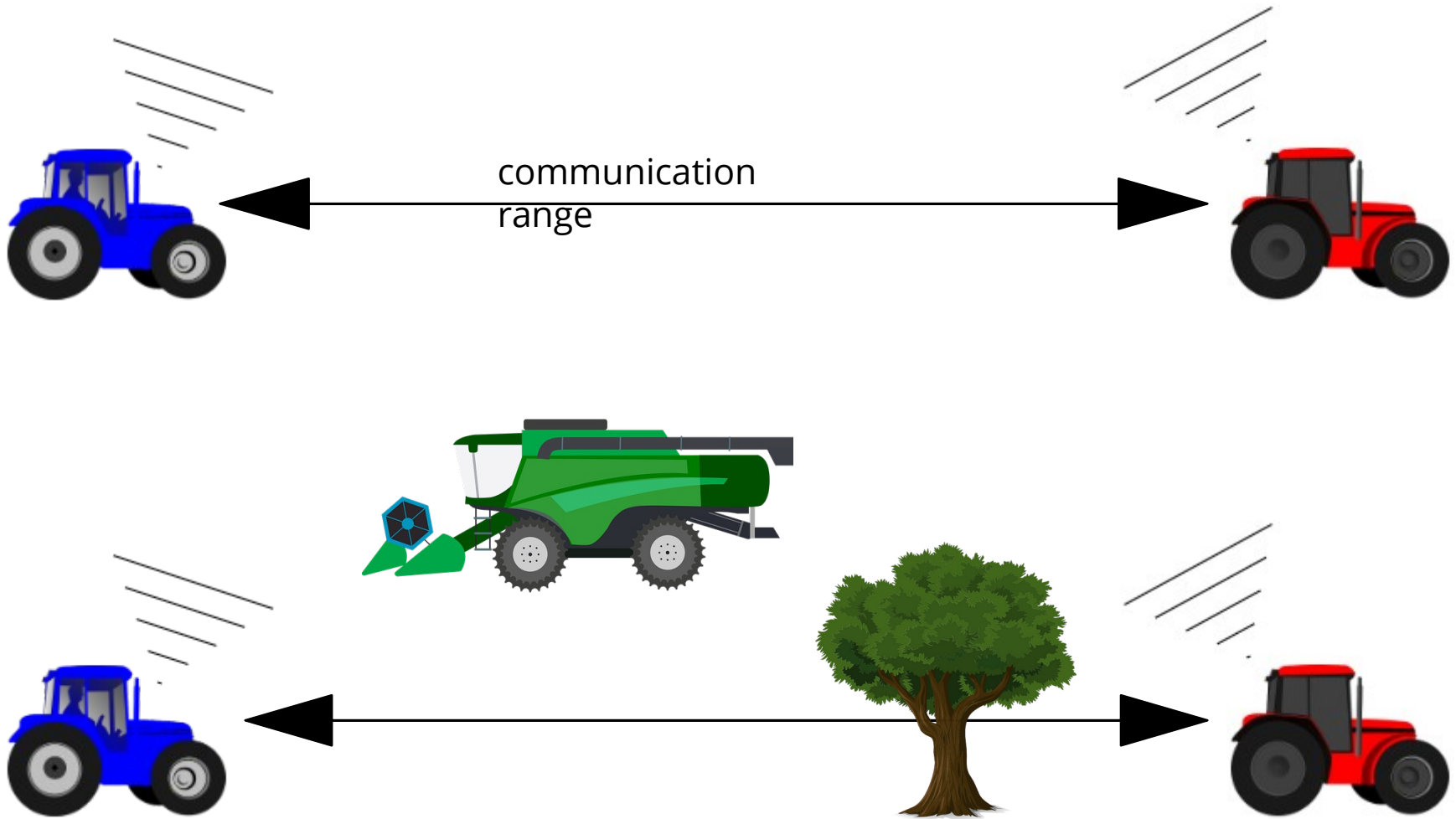
From F. Klingler, J. Blobel, and F. Dressler, "Agriculture meets IEEE 802.11p: A Feasibility Study," DOI: 10.1109/ISWCS.2018.8491239.

Field Measurements Equipment

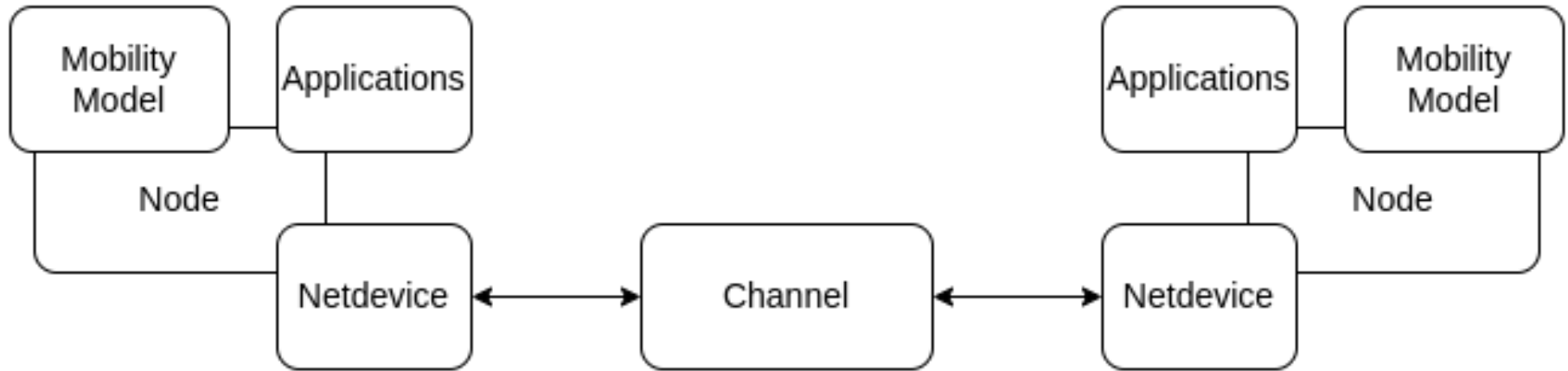


- Wi-Fi 6E Chips Intel AX210
- Universal Software Radio Peripheral B 200
- Industrial Router Milesight UR75

Field Experiments



Network Simulation



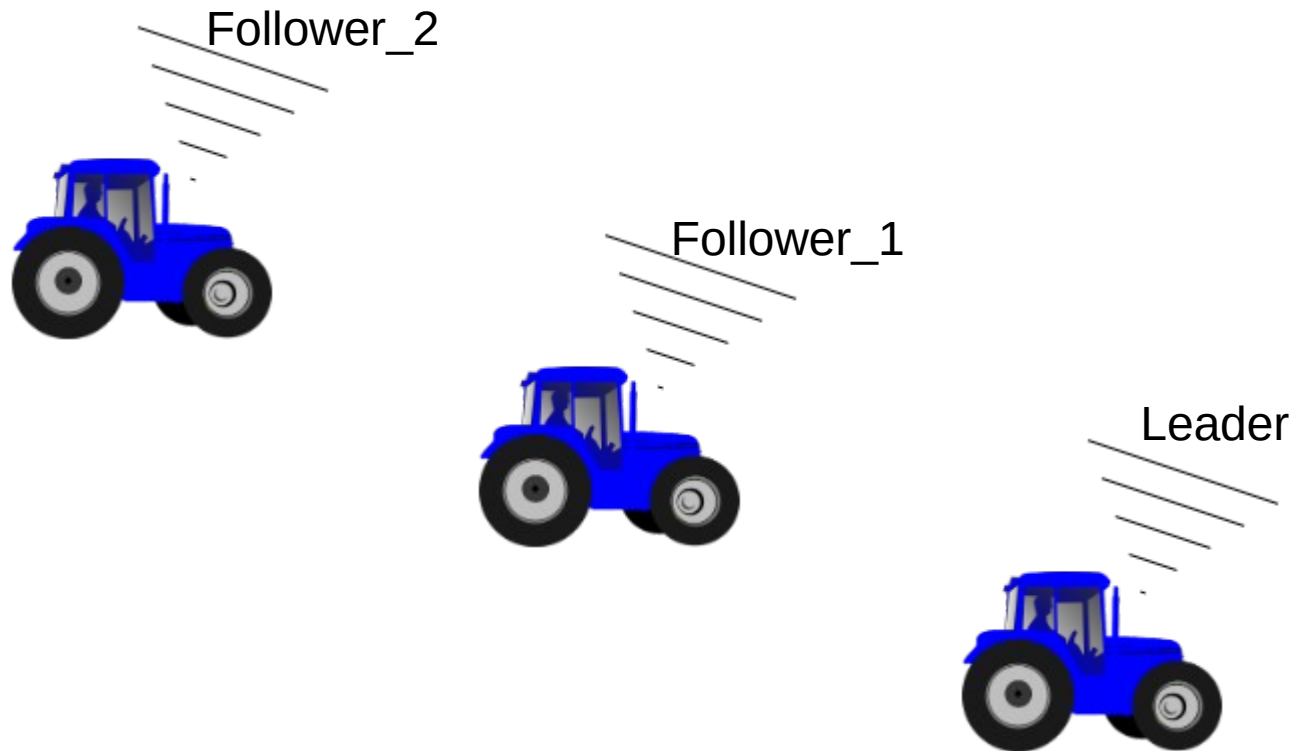
Simulation

Harvest Platooning Service



Simulation

Agricultural Platooning Service in Leader-Follower-Scenario



Summary

- Analyzing Telemetry data of Use Cases
 - required latency
 - required data Rate
 - required communication distance
- Field measurements
 - communication range
 - received signal strength in agricultural scenarios
 - Latency
- Simulation
 - Leader-Follower-Scenario
 - Harvest-Platoon-Scenario



Thanks!
