Advancing Localization and Sensing Technologies for 5G & Beyond

Harish Viswanathan
Nokia Bell Labs

NOKIA

© 2024 Nokia

Precise indoor positioning

5G-based indoor positioning is crucial for verticals for private indoor / campus networks:

- GPS is not available (indoor)
- Independence from GPS (campus)
- One single radio system for communication and positioning
- Performance target **50cm accuracy @ 99%**

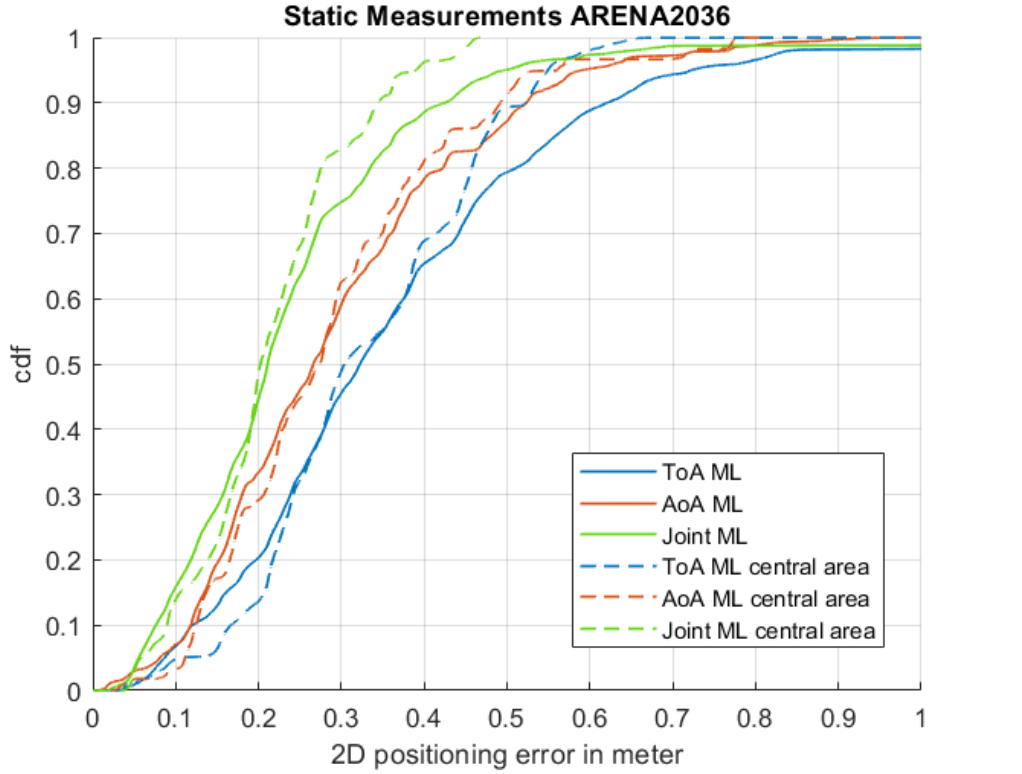
© 2023 Nokia

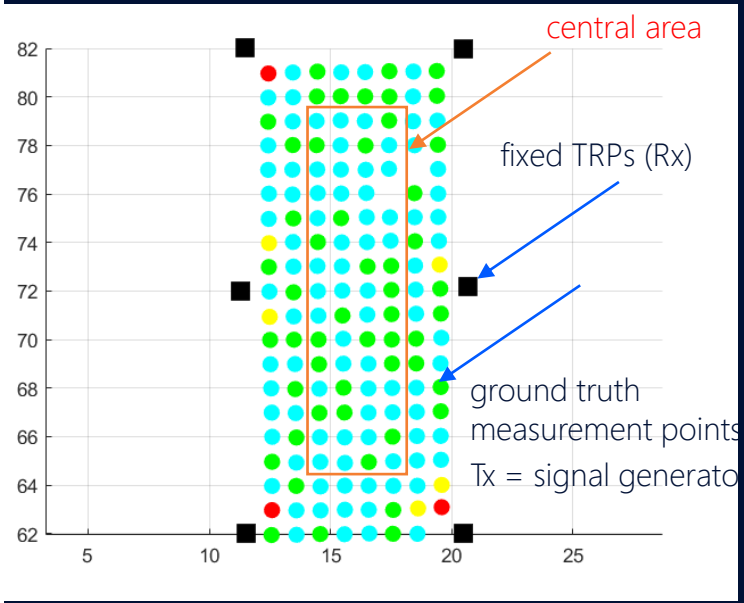
Experimental deployment in ARENA 2036

PoC Architecture

© 2023 Nokia

Joint Angle of Arrival and Time of Arrival shows superior results



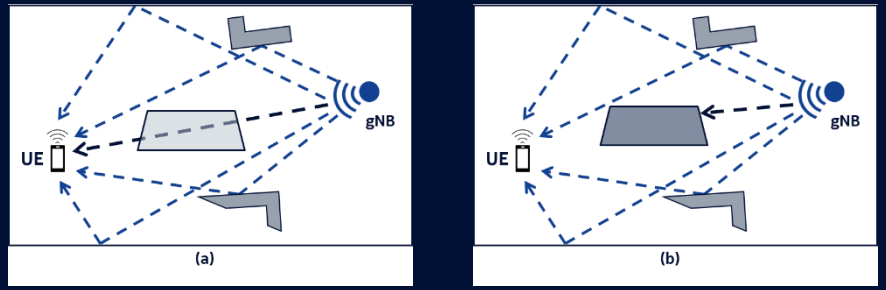


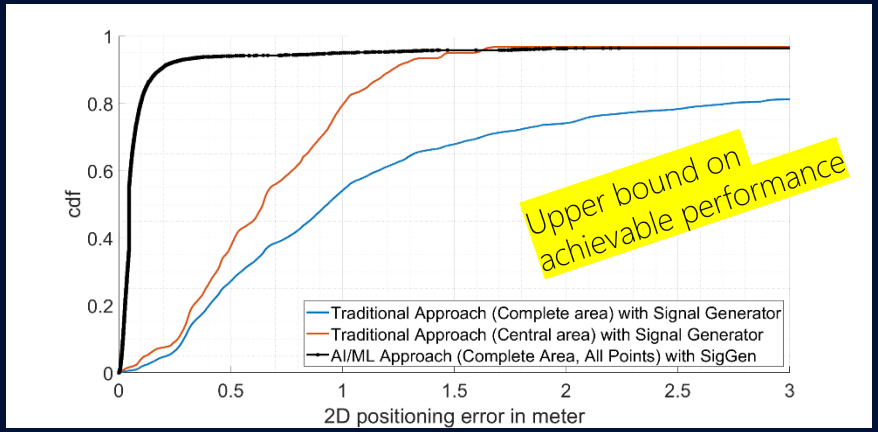
- 2D RMS error < 25 cm
- 25cm < 2D RMS error <= 50cm
- 50cm < 2D RMS error <= 1m
- 2D RMS error > 1m

© 2023 Nokia

AI/ML-based positioning

Positioning accuracy enhancements for different scenarios including, e.g., those with heavy NLOS conditions





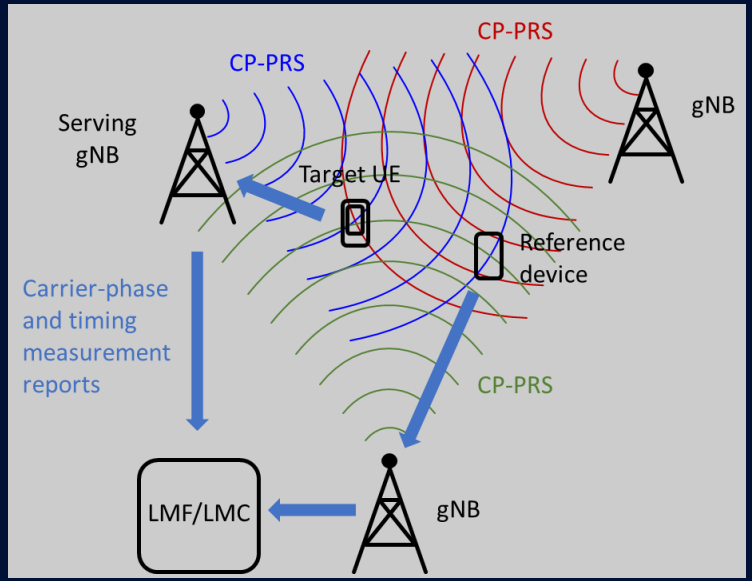
Proposed solution Direct AI/ML positioning: input is CSI and output is 2D position estimate

Challenge: how to avoid extensive training in new environments

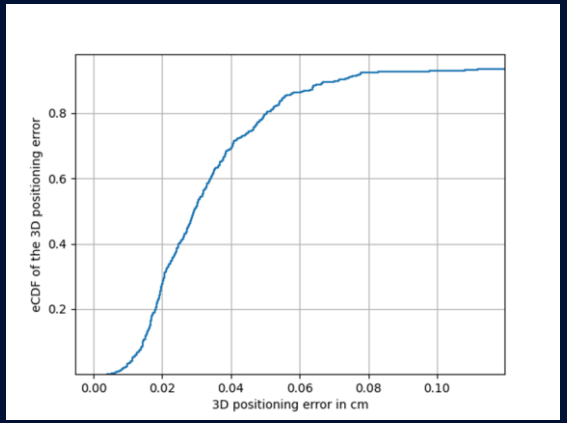
© 2023 Nokia

Carrier-Phase Positioning

- Carrier phase positioning is a method for significantly improving positioning accuracy by performing phase-of-arrival measurements on top of time-of-arrival measurements
- Target is to improve accuracy by about one order of magnitude to cm level



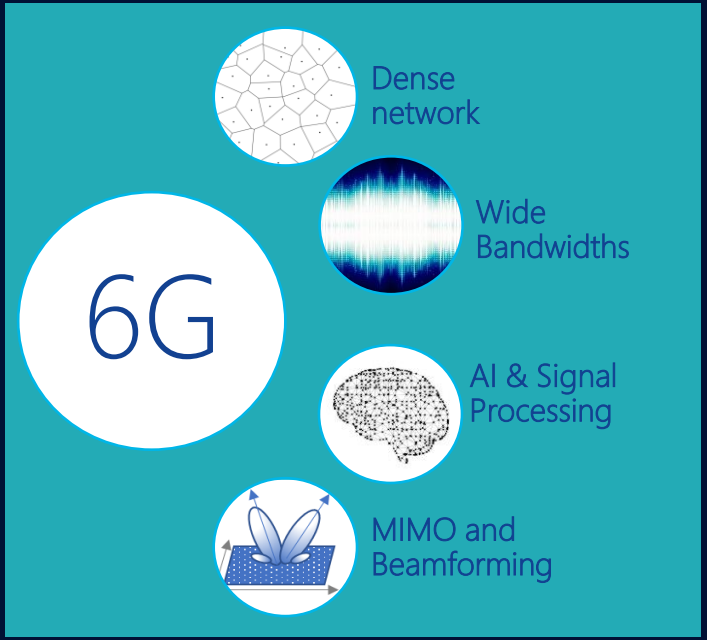
- Double differential measurements using the reference device and pairs of TRPs for mitigating unknown time/phase variations

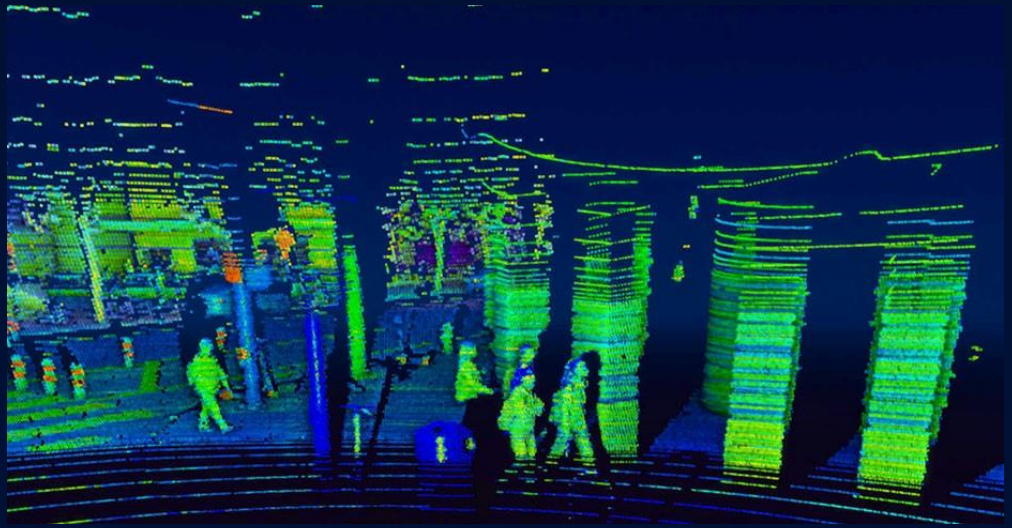


Preliminary results
with some experimental inconsistencies removed by data clean up

© 2023 Nokia

Network as a sensor: Access creating a “sixth sense”



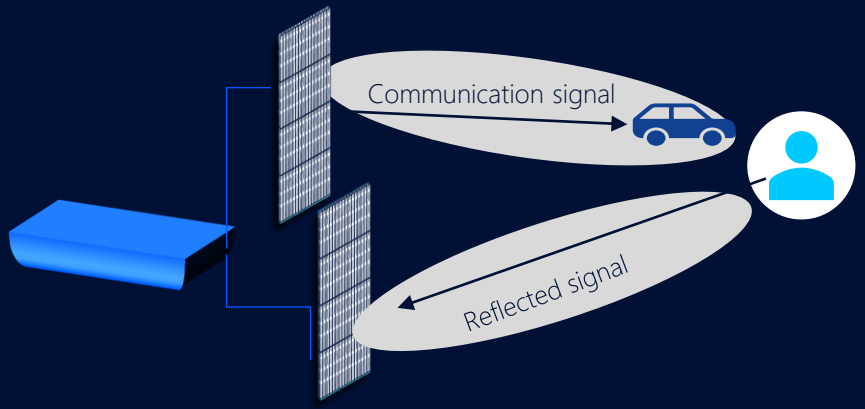


Create a revolution by enabling widespread sensing leveraging cellular infrastructure

© 2023 Nokia
BELL LABS

Efficient design

Joint communication and sensing

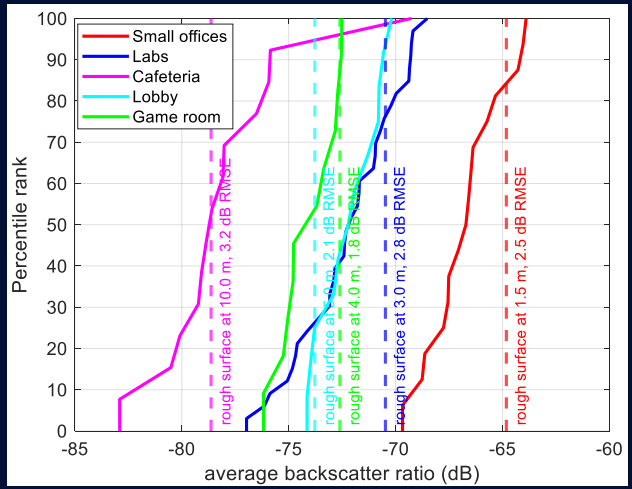


- Hardware reuse
- Opportunistic joint resource allocation
- Beam Sweeping Design
- Processing algorithms
- Improving Communications
- Object identification with AI/ML

© 2023 Nokia

Extensive measurements for ISAC channel modeling

Data Set	# of links	Room dimensions
8 offices metal furniture	16	3m × 3m
7 Labs metal furniture	33	20m × 6m
Cafeteria, metalized windows, counters	13	30m×20m
Lobby metalized windows	12	30m×20m
Game room metalized windows	11	25m×15m
Conference Room	26	7m×5m
Gym	17	30m×17m
Lab 1	15	15m × 5m
Lab 2	10	15m × 5m
Office 1	22	3.5m×2.7m
Office 2	17	4m × 3m
Study hall	22	15m × 9m
Café	15	14m×10m
Carleton Hall	22	25m×12m
Overall	251	

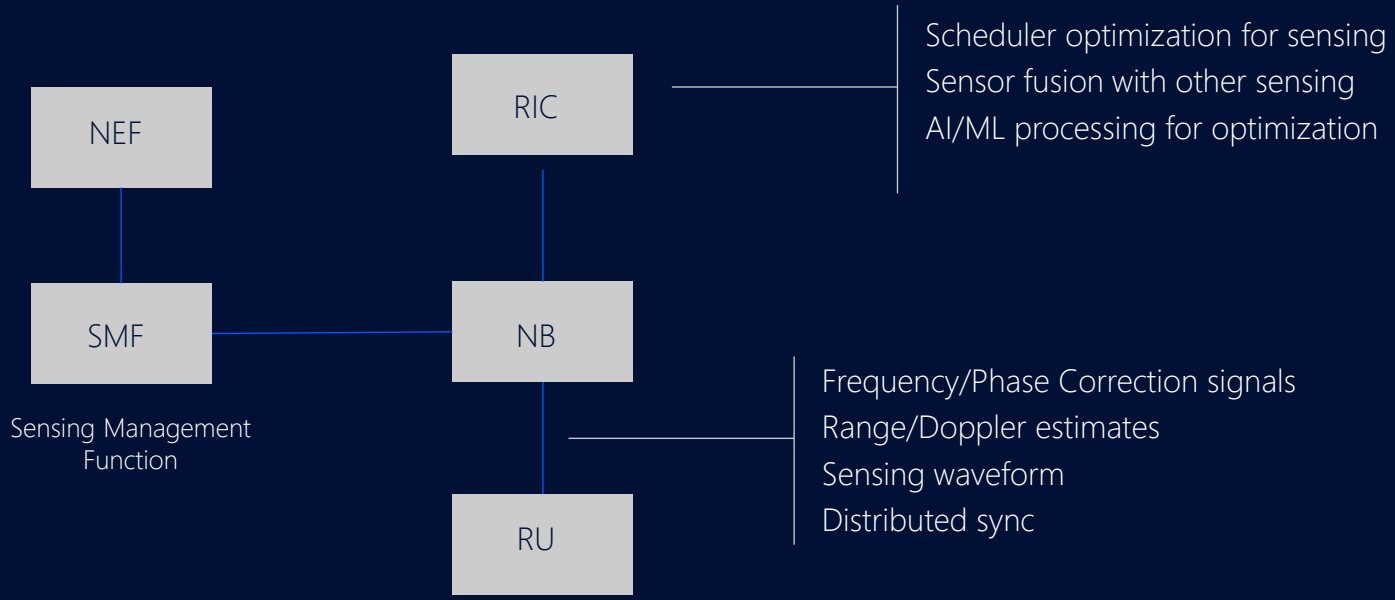


4 dB RMSE for th
model

$$\langle P_{\text{back}} \rangle = \frac{\langle P_{\text{clut}} \rangle_{\phi}}{P_{\text{T}}} = |\Gamma_{\text{wall}}|^2 \left(\frac{\lambda}{4\pi d_{\text{s}}} \right)^2$$

© 2023 Nokia

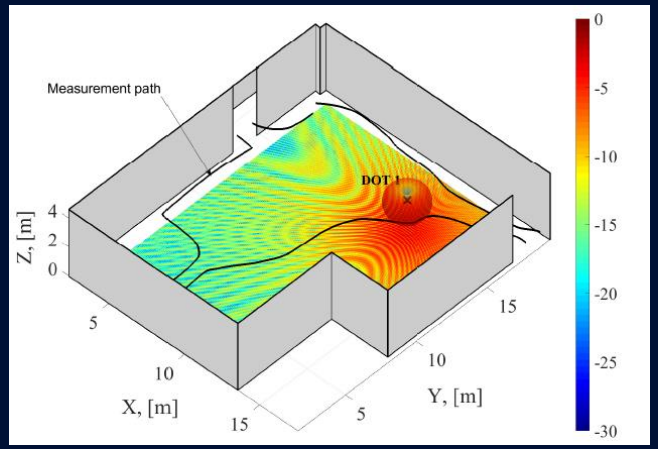
New Interfaces



© 2023 Nokia

Radio aware digital twin

Communications Enhancement



- Accurate and dynamic radio environment map
  - enhanced measurements and advanced propagation prediction engine
- Pro-active, anticipatory, intent-based resource allocation, beam management, handover
  - Overhead reduction
  - Blocking prevention
  - Enhanced reliability

© 2023 Nokia

NOKIA

Summary

Positioning technologies in 5G can achieve very high accuracy

- AoA/ToA in 5G and AI/ML & Carrier phase in 5G Adv

Network as a Sensor expands cellular network capabilities by sensing objects not connected to the network

- Potential for many new use cases across consumer and verticals
- New challenges for efficient system design

© 2023 Nokia

NOKIA
BELL
LABS