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Validation of a CommSense Based ISAC System Using In-Situ mmWave Propagation Model

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CONASENSE Workshop, WPMC, 2023

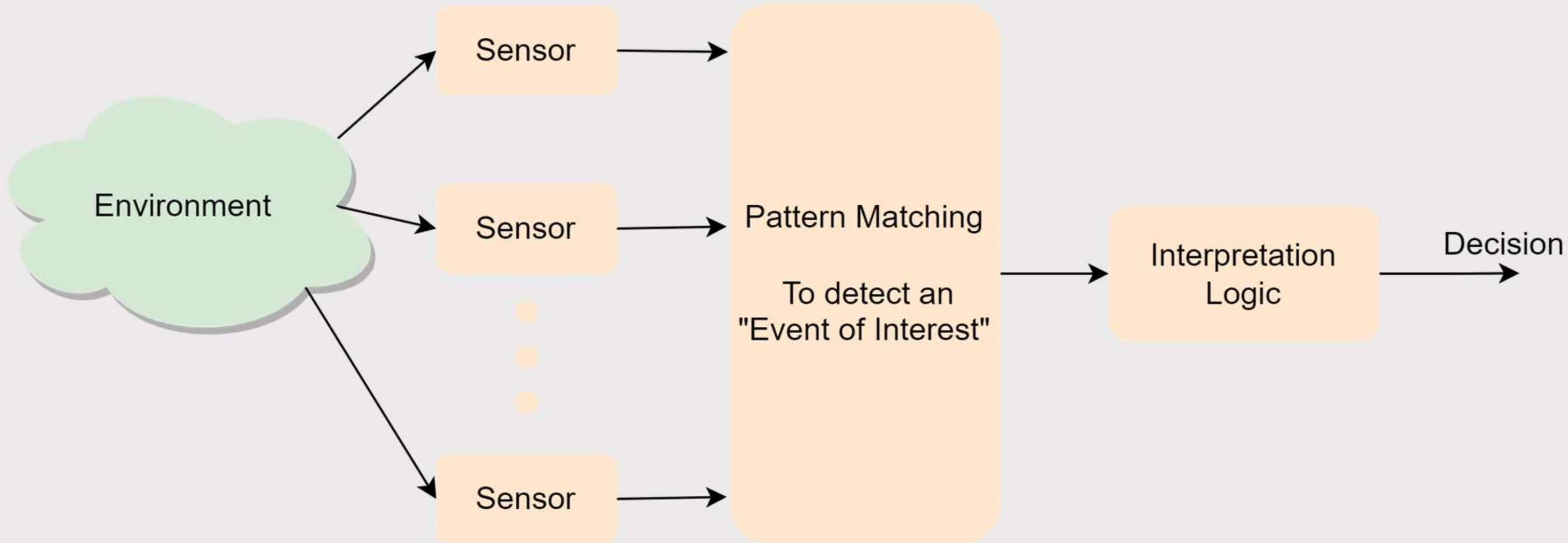
Overview

Motivation

- As we anticipate the arrival of 6G wireless networks, it's clear that traditional communication systems may not meet the demands of future technologies like IoT, autonomous vehicles, and smart cities.

- Context awareness in 6G then becomes crucial for dynamically allocating network resources, such as bandwidth and power, based on real-time environmental conditions, user behaviors, and application requirements, ensuring efficient and adaptive resource usage.

Application Specific INsrtumentation (ASIN)

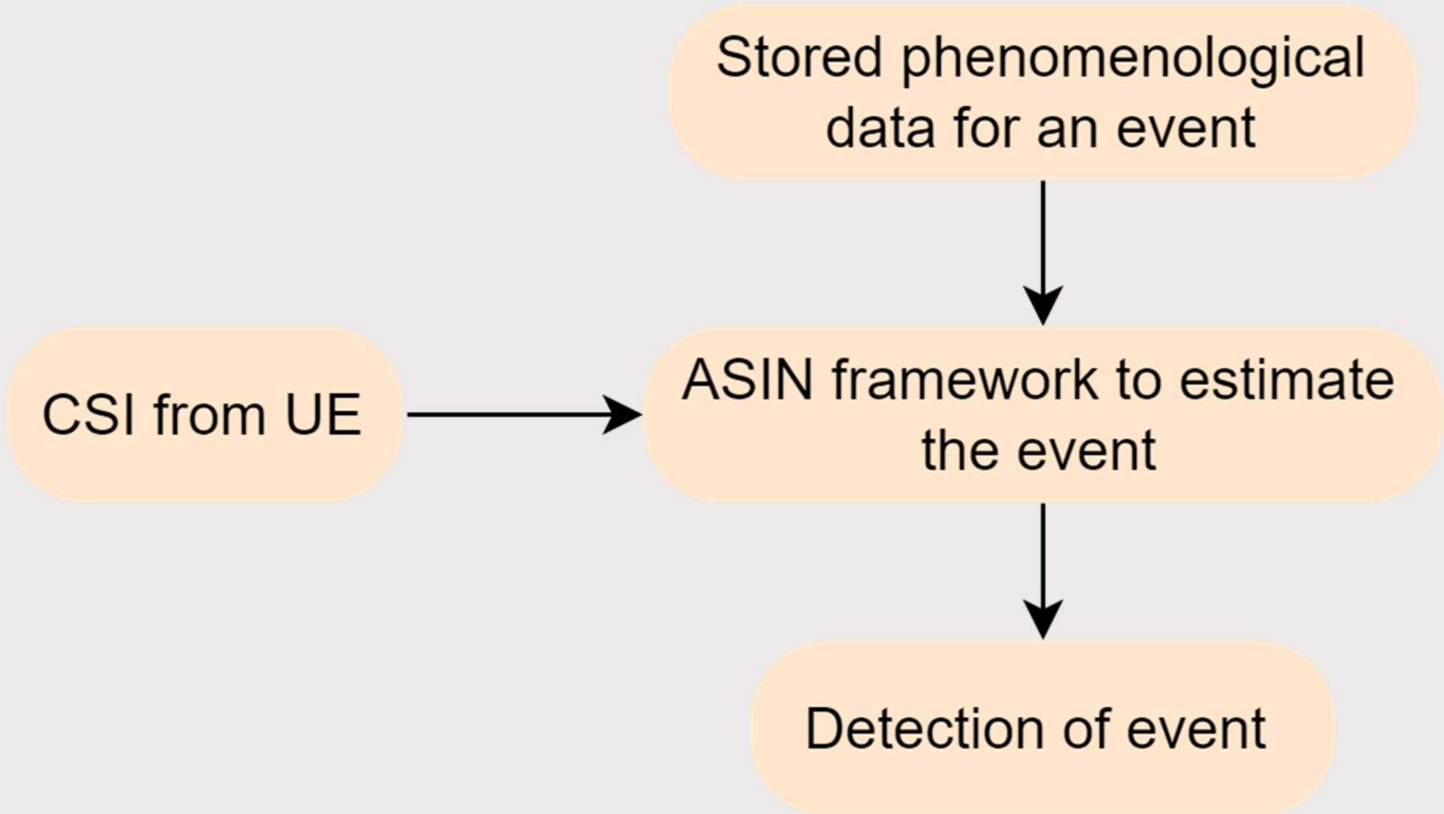


- Basic components of ASIN framework

Communication based Sensing (CommSense)

- Flow diagram of CommSense system

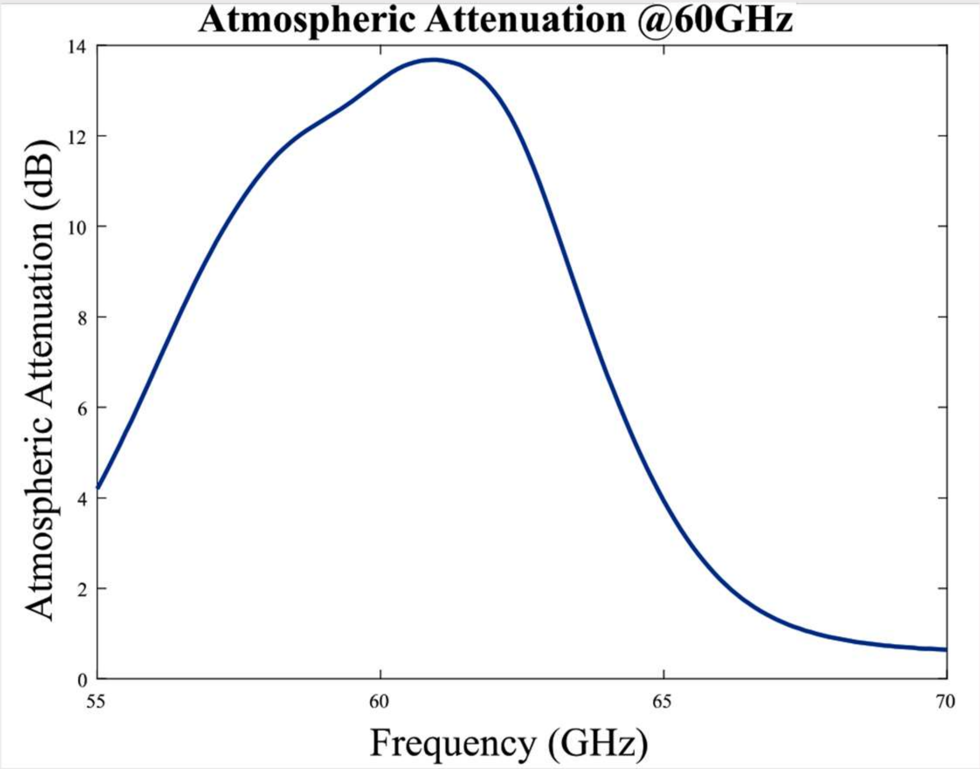
- Phenomenological data is being used to detect an event after it passes through the ASIN framework.



Propgation in mmWave Channels (60GHz band)

- **Free Space Path Loss (FSPL)**
- $FSPL = \left(\frac{4\pi d}{\lambda}\right)^2$
- $Where,$ d = Distance between transmitter and receiver, and λ = $Wavelength\ of\ propagating\ signal$
- e.g. For distance of 200m, The FSPL will be approximately 110dB

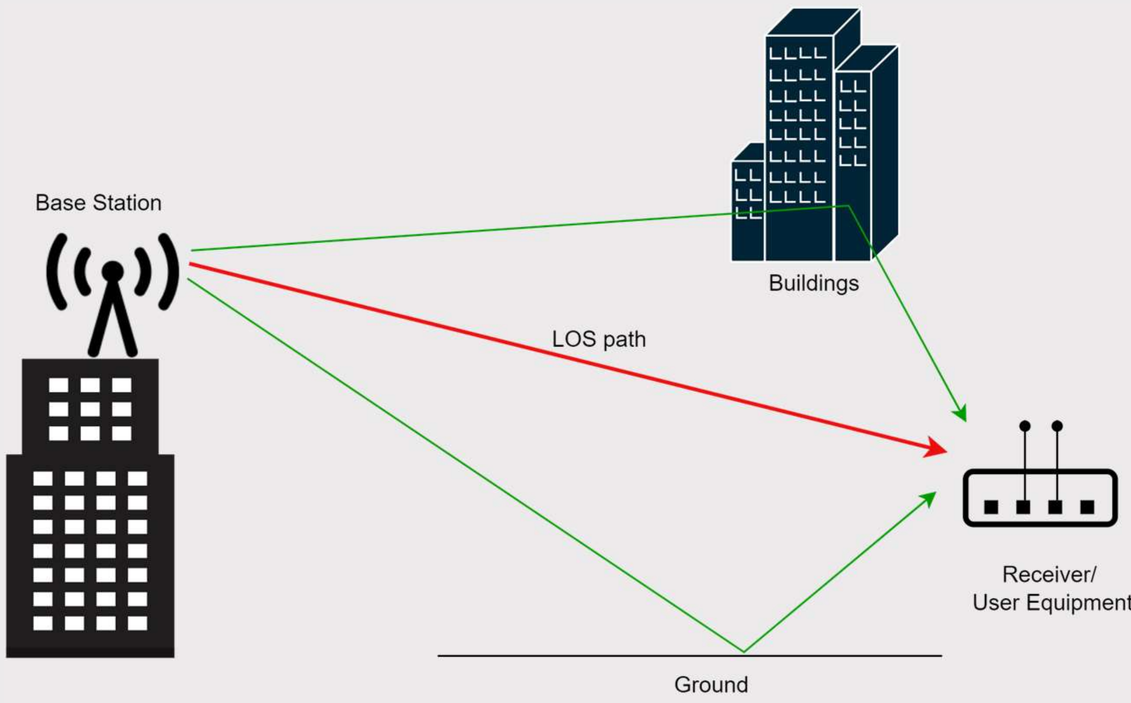
- **Atmospheric attenuation due to oxygen and water vapor**



Channel model using Ray Tracing

- Ray tracing serves as a valuable tool for designing and optimizing communication systems by offering insights into signal coverage, interference patterns, and the impact of the surrounding environment.

- This helps fine-tuning parameters, such as antenna placement and network configuration, to improve the overall performance of wireless networks.



Experimental set-up

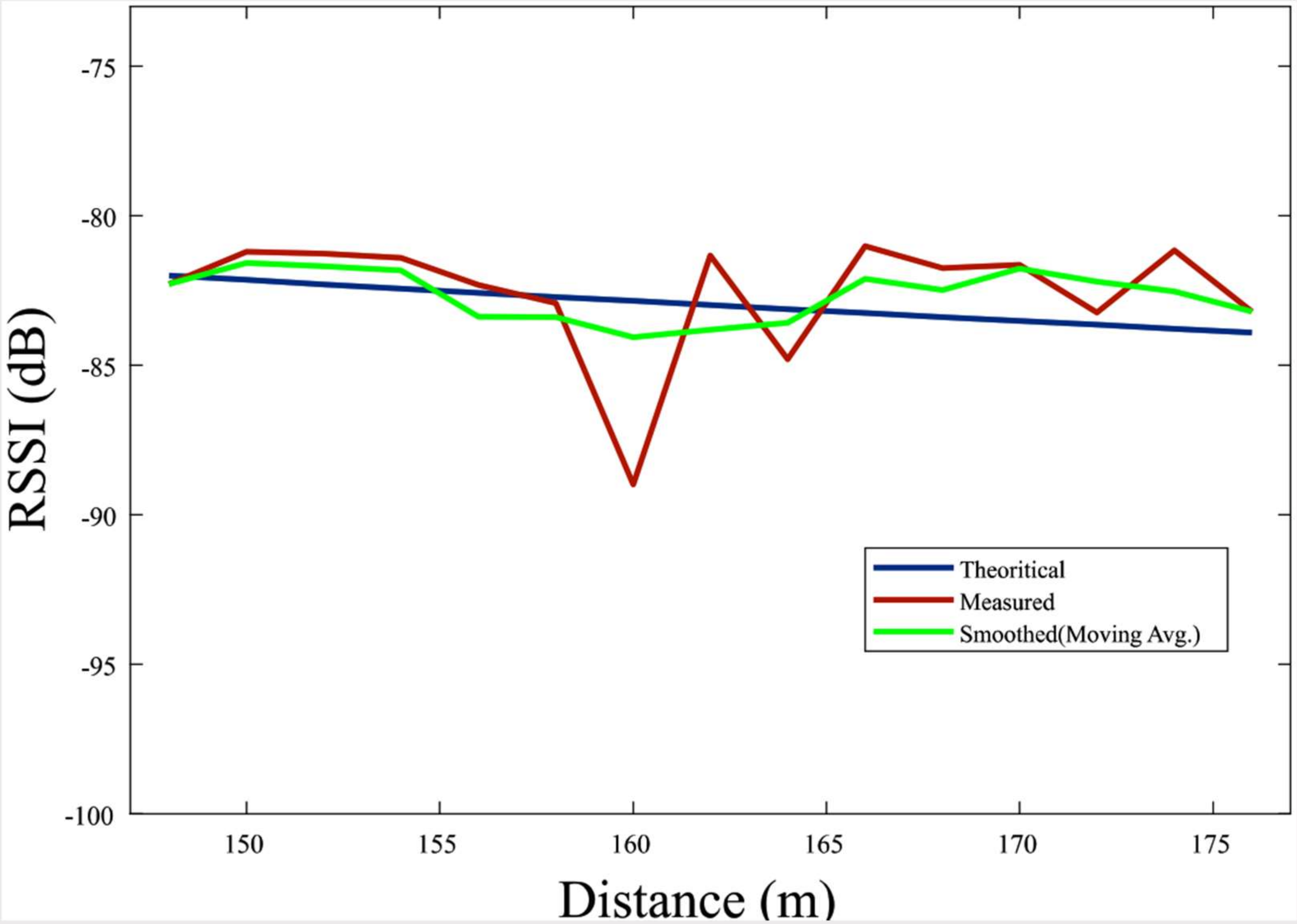
- **Centre Frequency:** 64.8GHz
- **Bandwidth:** 2.16GHz
- **Receiver Gain:** 22.5dBi

- Receiver was moved incrementally from Location 1 to 15, with a 2-meter step size between each location

Validation of measured RSSI

- Measured RSSI values were juxtaposed with those projected by a standard ITU model, as illustrated.

- We incur Root Mean Square Error (RMSE) of 2.082 dB and 1.046 dB when we compare the theoretical prediction with the actual measured data and smoothed data respectively.



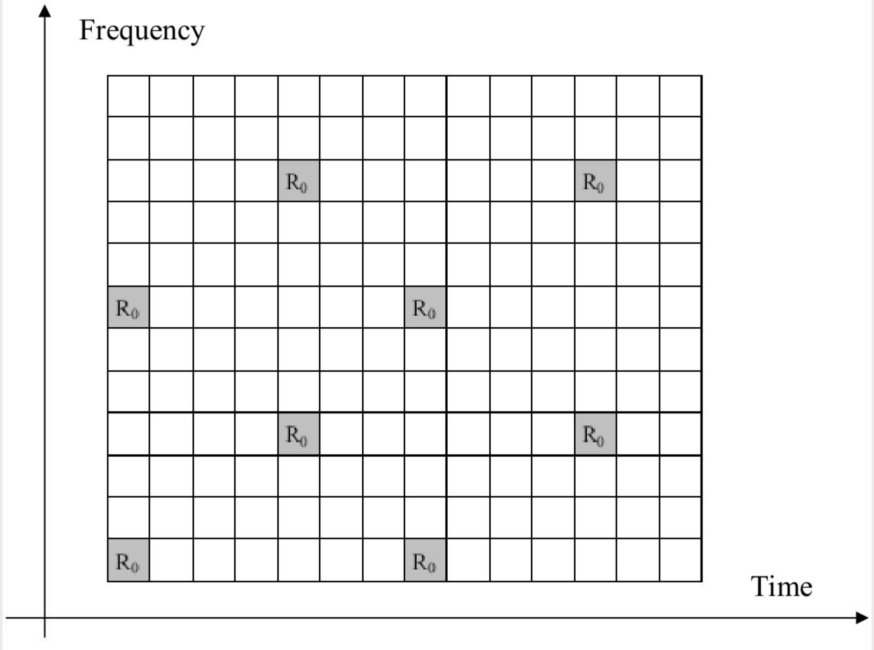
Derived In-situ Channels

- Derived channels based on the line of sight path and the path from the 1^{st} order reflection(s) (i.e. non-line of sight path received from a single bounce).

Location #	Path Delays (ns)	Path Gains(dB)	Angle of Departure (degrees)	Angle of Arrival (degrees)
1	[0 1.64]	[-111.51 -115.66]	[45.80 46.00]	[-134.19 -137.12]
2	[0 1.63]	[-111.62 -115.69]	[45.66 45.45]	[-134.33 -130.92]
3	[0 1.57 113.85]	[-111.73 -115.80 -121.56]	[45.52 45.45 52.58]	[-134.47 -133.55 107.87]
4	[0 1.59 111.95]	[-111.79 -115.78 -121.58]	[45.10 44.92 52.03]	[-134.89 -131.82 107.64]
5	[0 1.53 103.98]	[-111.89 -115.88 -121.56]	[44.97 44.92 51.62]	[-135.02 -134.35 109.42]
6	[0 1.56 102.09]	[-111.96 -115.83 -121.59]	[44.55 44.49 51.07]	[-135.44 -133.95 109.12]
7	[0 1.58 1.62 106.16]	[-111.98 -115.96 -115.85 -121.66]	[43.86 44.08 43.64 51.07]	[-136.13 -138.88 -131.57 112.03]
8	[0 1.55 109.93]	[-112.01 -115.99 -121.74]	[43.11 43.23 50.52]	[-136.88 -138.35 111.22]
9	[0 1.62 96.20]	[-112.15 -115.91 -121.68]	[43.27 43.21 50.11]	[-136.72 -134.98 114.47]
10	[0 1.485]	[-112.22 -116.09]	[42.83 42.80]	[-137.16 -136.73]
11	[0 1.58 1.52]	[-112.25 -116.00 -116.11]	[42.16 42.37 41.95]	[-137.83 -142.51 -135.21]
12	[0 1.49]	[-112.33 -116.08]	[41.66 41.52]	[-138.33 -135.80]
13	[0 1.43]	[-112.44 -116.19]	[41.53 41.52]	[-138.46 -138.37]
14	[0 1.51]	[-112.50 -116.13]	[41.16 41.09]	[-138.83 -136.93]
15	[0 1.53]	[-112.49 -116.12]	[40.20 40.24]	[-139.79 -140.91]

Methodology

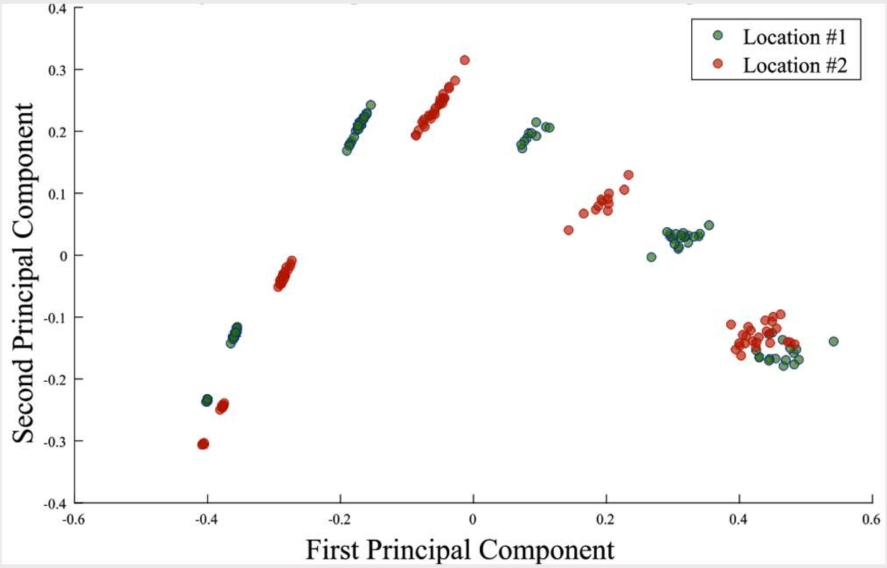
- The input reference signal is passed through the derived channels.
- Then channel is equalized after channel estimation. This estimated channel is of high dimensions.
- We use PCA on this estimated channel to reduce the dimensions and make it easier to take decision while distinguishing the channels using SVM.

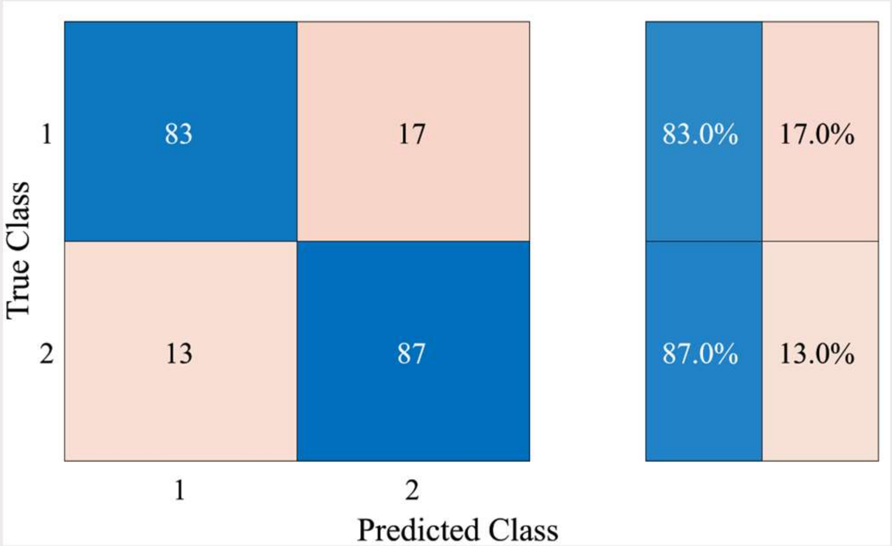


LTE Down-link Cell specific reference signal arrangement in time-frequency grid for 1 antenna port

Sensing accuracy between Location #1 & #2:

- By using Principal Component Analysis, the high-dimensional channel state information was projected into lower dimensions, while retaining crucial features.
- To evaluate sensing accuracy, SVM was applied to discriminate channels at different locations.
- Here we present one instance where we successfully discriminated between channels at Location #1 and Location #2 with 85% accuracy.

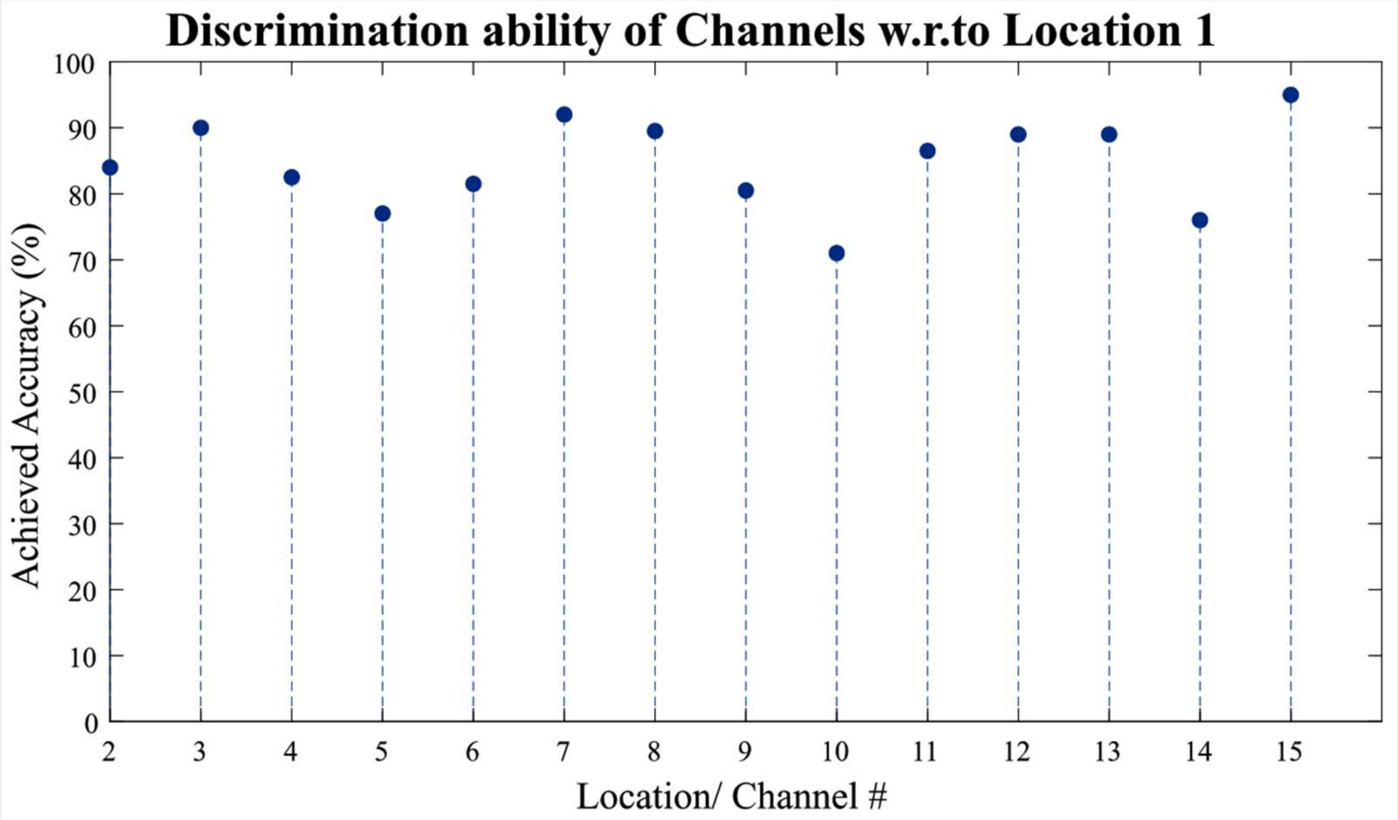




Overall sensing accuracy

- The result is showcasing the CommSense's effectiveness, achieving an average accuracy of over 84%.

- This makes it a robust and reliable approach for accurately detecting and interpreting environmental conditions in dynamic wireless environments.



Potential Applications

- **Smart Cities:** Sensors can collect real-time data to optimize city services (e.g. traffic management, environmental monitoring, crowd management) and enhance overall urban efficiency

- **Autonomous Vehicles:** Sensors can provide real-time data on the vehicle's surroundings, and communication capabilities allow vehicles to exchange information, improving safety and coordination on the road.

- **Home Automation:** In smart homes, integrated sensing and communication can automate various tasks, such as adjusting lighting and temperature based on occupancy, monitoring security, and managing energy consumption more efficiently.

Conclusions

- By validating the measured RSSI against a standard model for the 60GHz band, we have established the reliability of the experimental setup and data collection methodology.
- Building upon the validated measurements, this study derived in-situ channels through simulation.
- CommSense is effectively utilized and achieved a good level of accuracy in the sensing performance.

Thank You