Propagation channel models and system performance for device-to-device communications for public safety application

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Introduction

- Device-to-Device (D2D) communication is critical in improving the reliability of communication in emergency situation

- Before assessing systems' performance in scenarios of interests, we have to know the channel model

- Channels for D2D communications are "Unknown"
  - 3GPP channel models for cellular are not concerned with reliability
  - No measurements for channels below 1 GHz

Outcomes and Purposes

- Outcome
  - Channel models for different scenarios, specific for Public Safety Applications
    - V2V communication (communications between emergency vehicles)
    - I2O communication (communications between an outdoor unit – possibly a firetruck – with an indoor unit – possibly a firefighter -)
- Purposes
  - Improvements that can be done on D2D communications without changing standards
  - Input to other projects/system designers that need propagation channel characteristics knowledge to accurately assess performance.

Methodology (1)

- Channel Sounder Design: Our channel sounder should <u>simultaneously</u> feature the following:
  - Multiple Antennas capabilities at both Transmitter (Tx) and Receiver (Rx) nodes.
  - Dynamic measurements and continuous monitoring of the channel

- Extensive measurement campaigns
  - V2V measurements
  - I2O measurements

Methodology (2)

- Channel measurements evaluation using High-Resolution Parameter-Extraction (HRPE) and Extended Kalman Filter (EKF)
  - Use SAGE for parameter extractions and evaluations
  - Extend EKF algorithm to handle fast time-varying channels
  - Path tracking and clustering procedure

- Channel modeling
  - Use evaluation results to build channel models to be used for future system development

Methodology (3)

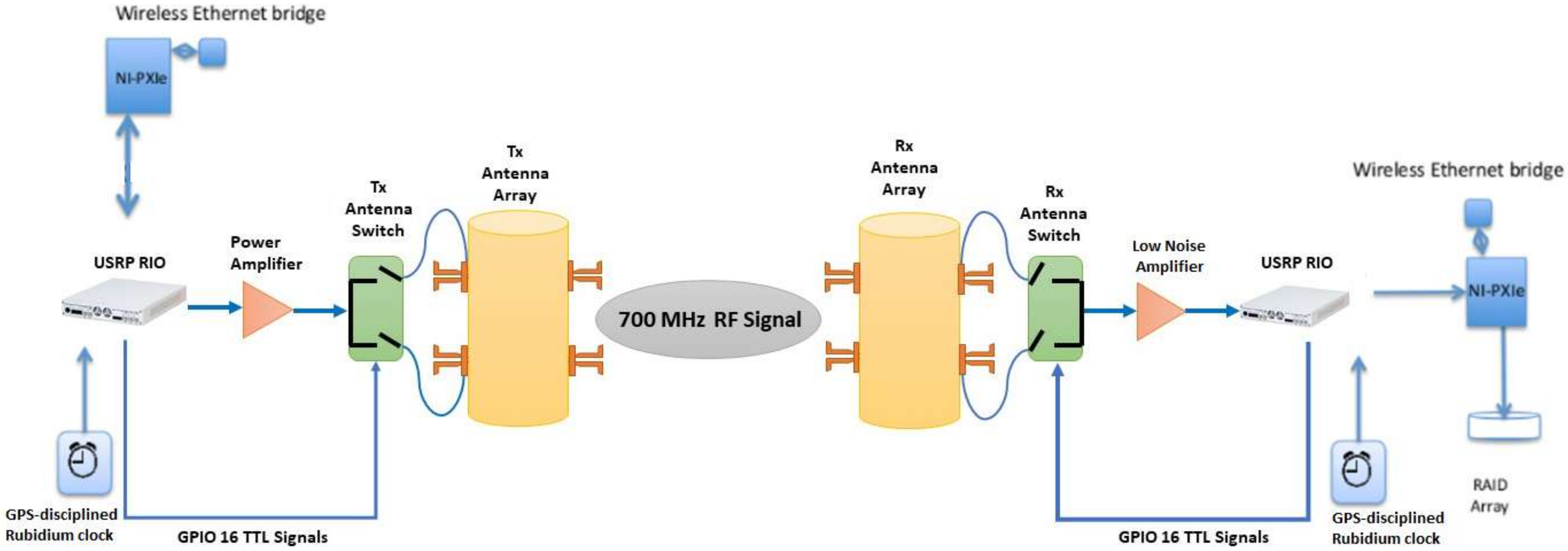
- Assess performance of LTE-Direct system
  - Use MATLAB LTE-Sidelink package to simulate a D2D transceiver
  - Simulate with directly measured channels and develop GSCM model
  - Determine performance limitation (max. distance between devices)

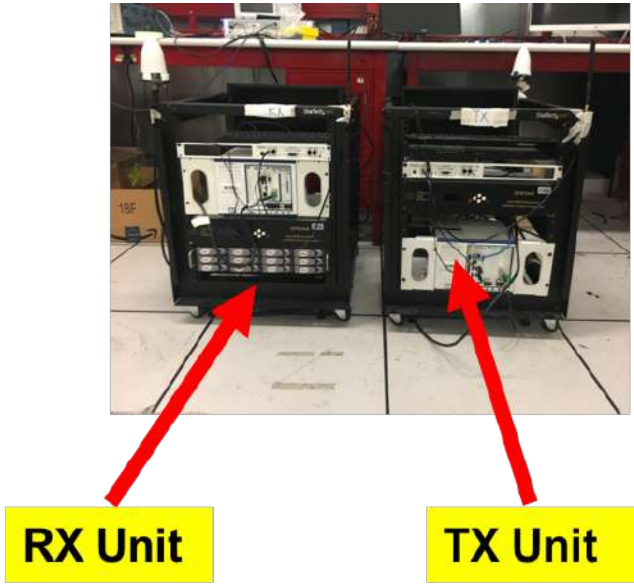
- Investigate improvements on LTE-Direct
  - Check performance gains of using antenna arrays
  - Enhance reliability of LTE-Direct without changing standards

Project Status

Measurement Setup (1)

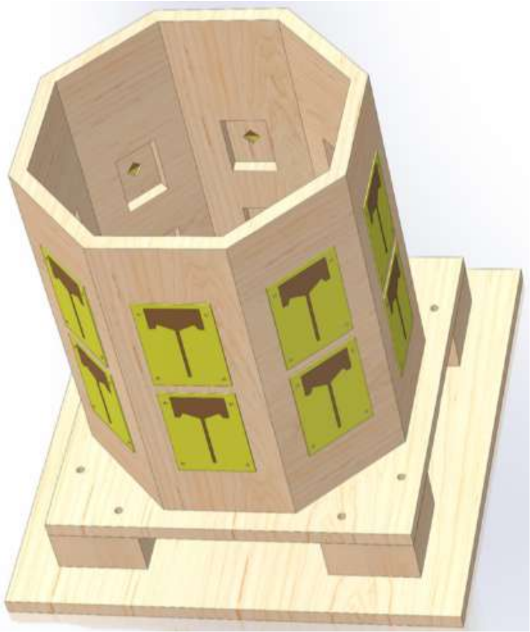
- Design and build a MIMO channel sounder that can
  - Do 3D measurements (Azimuth and Elevation) at both Tx and Rx ends
  - Continuously monitor the channel and stream data for later processing





Measurement Setup (2)

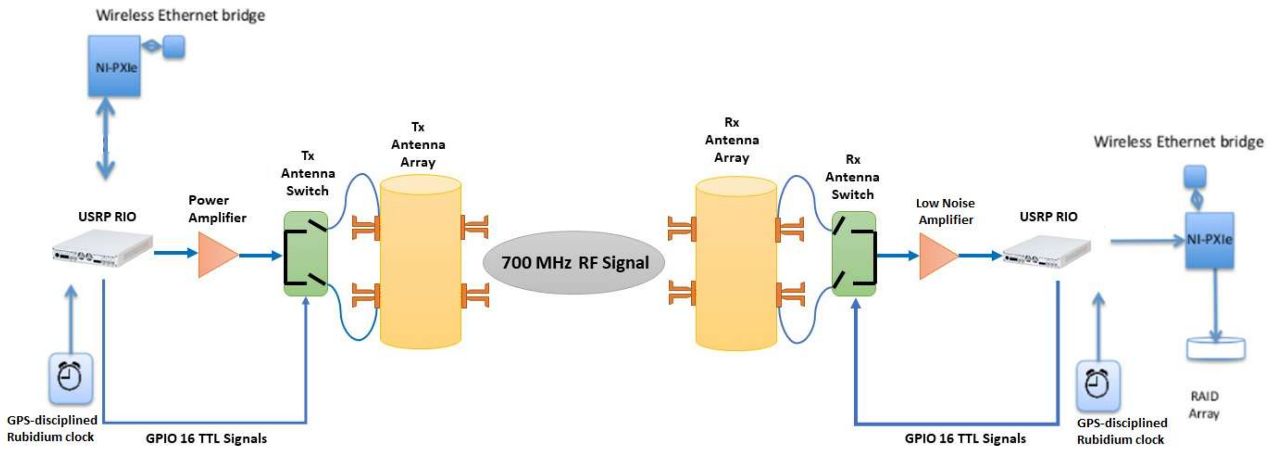
- Design and build 2 antenna arrays
  - Spherical uniform circular patch antenna array (SUCPA)
  - 2-rings, 8 elements per ring
  - Operates in the Public safety band (700 MHz – 1 GHz)



Measurement Setup (3)

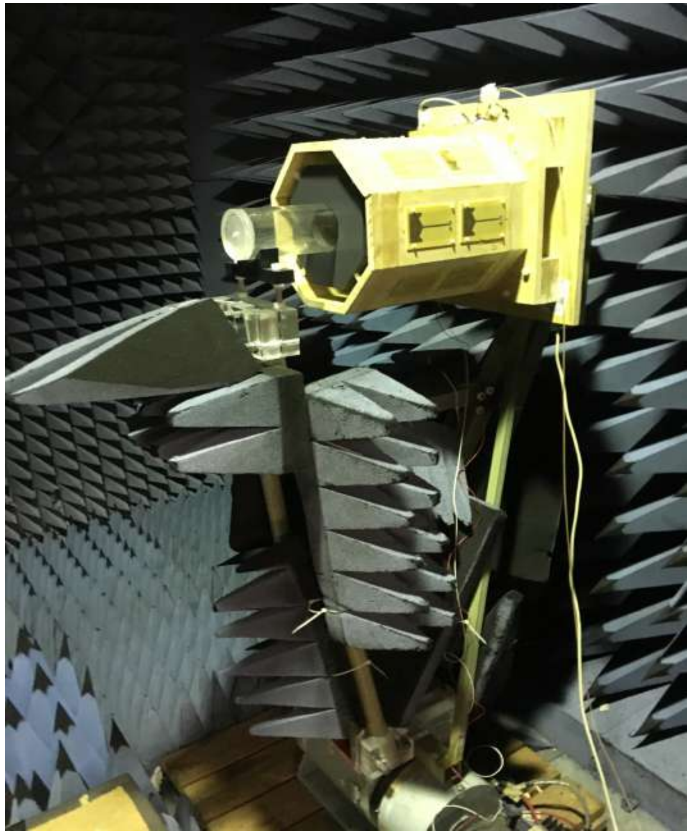
- Sounding Waveform
  - Multitone OFDM-like waveform
  - 461 frequency points over 23 MHz bandwidth

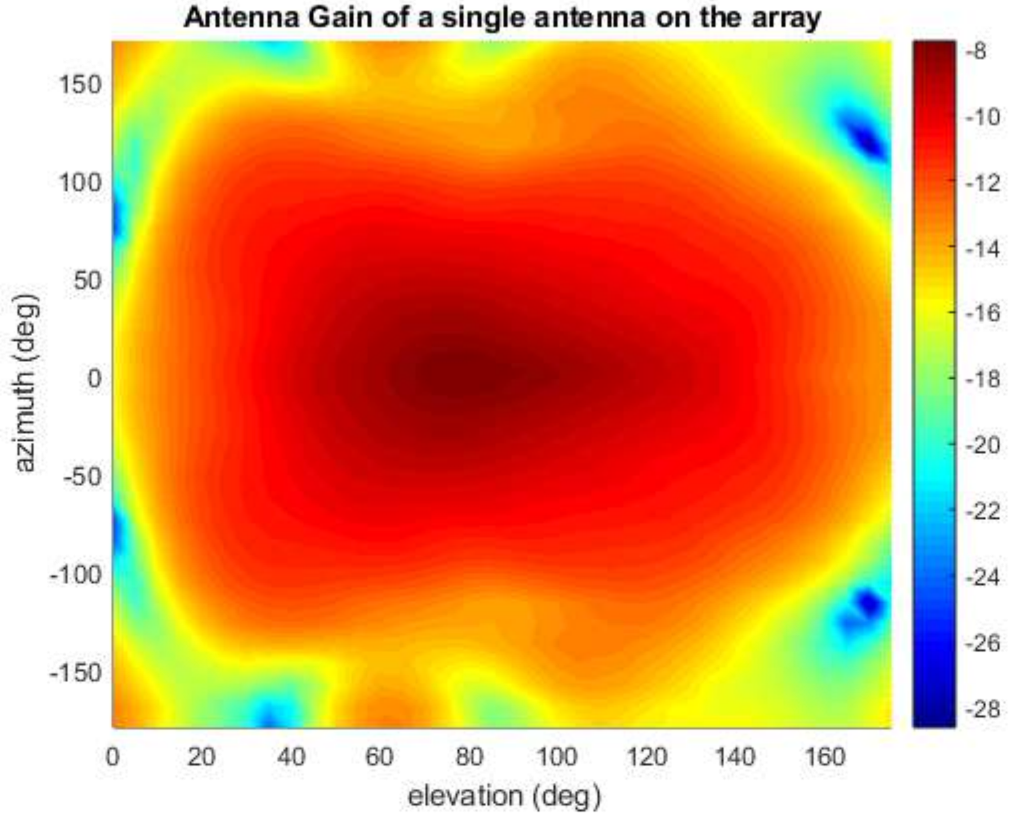
- Transmission mode
  - Switched-Array mode
  - 100 snapshots, 256 repetition of waveform per snapshot
  - Controlled by USRP 2954



Array Calibration

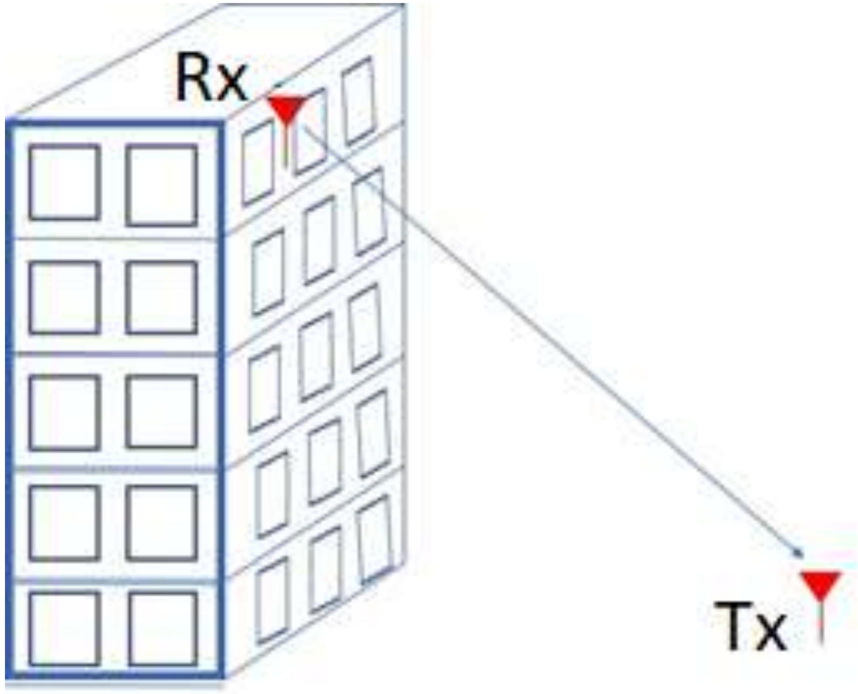
- Calibration was performed in anechoic chamber at USC





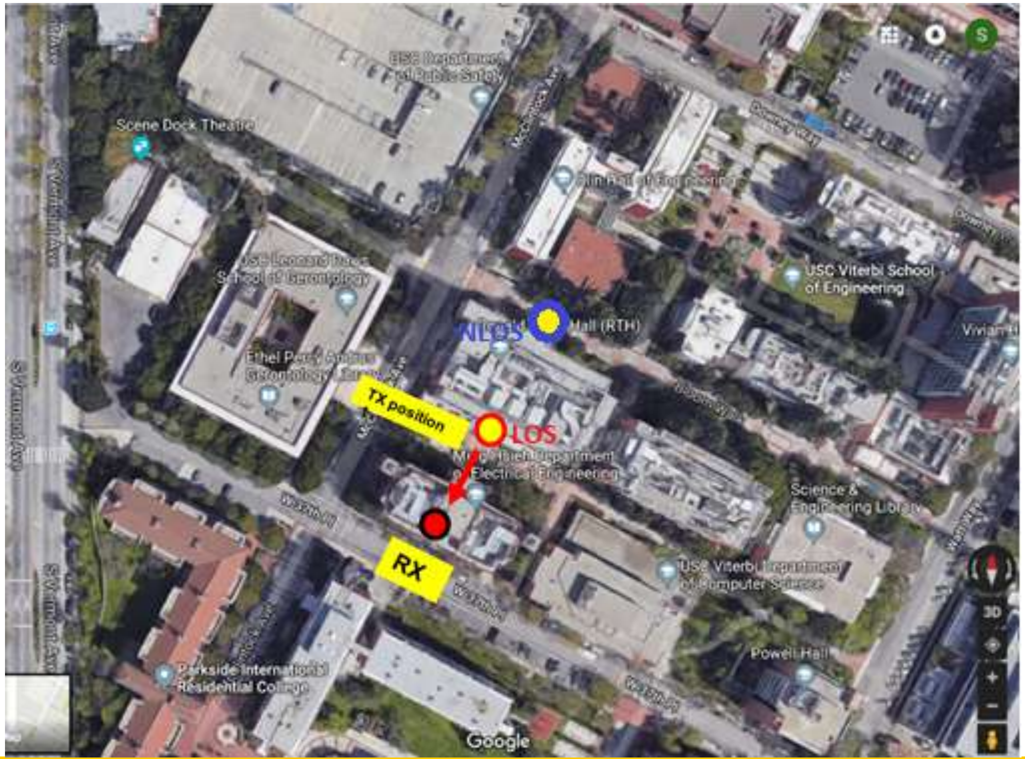
I2O Propagation Channel Measurement (1)

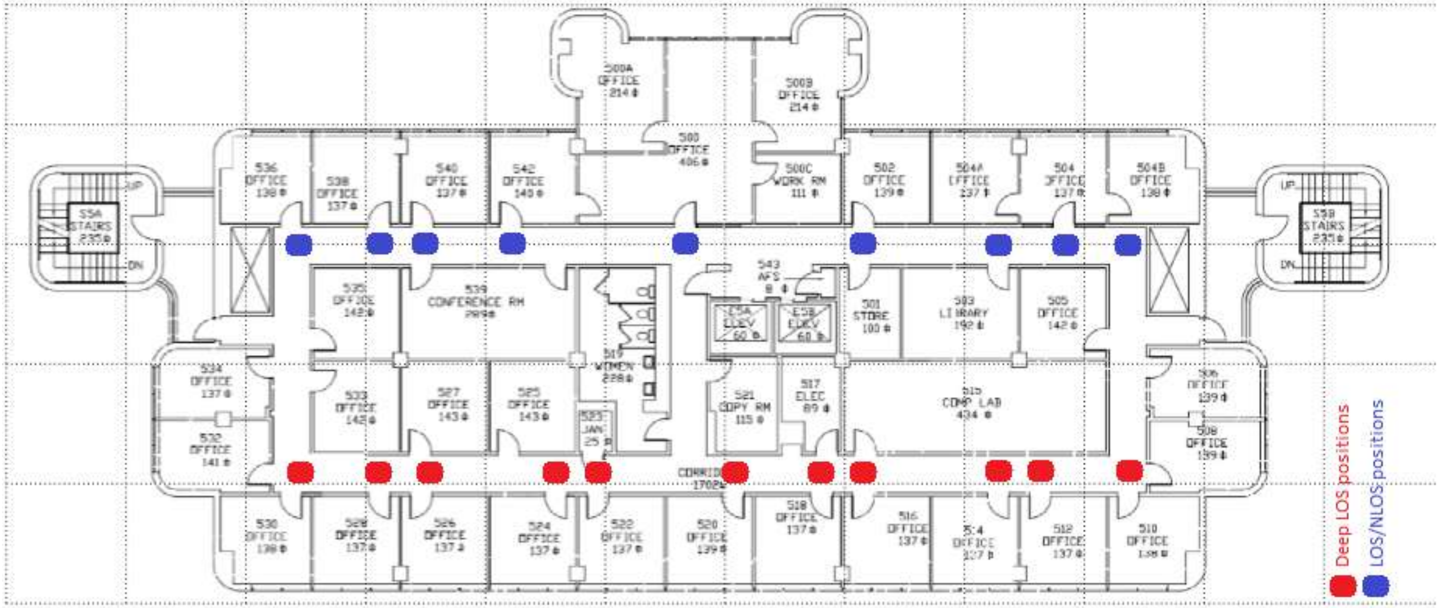
- I2O measurements performed on USC's campus – Electrical Engineering Building.
- Measurements were done over 138 positions, over 3 different scenarios



I2O Propagation Channel Measurement (2)

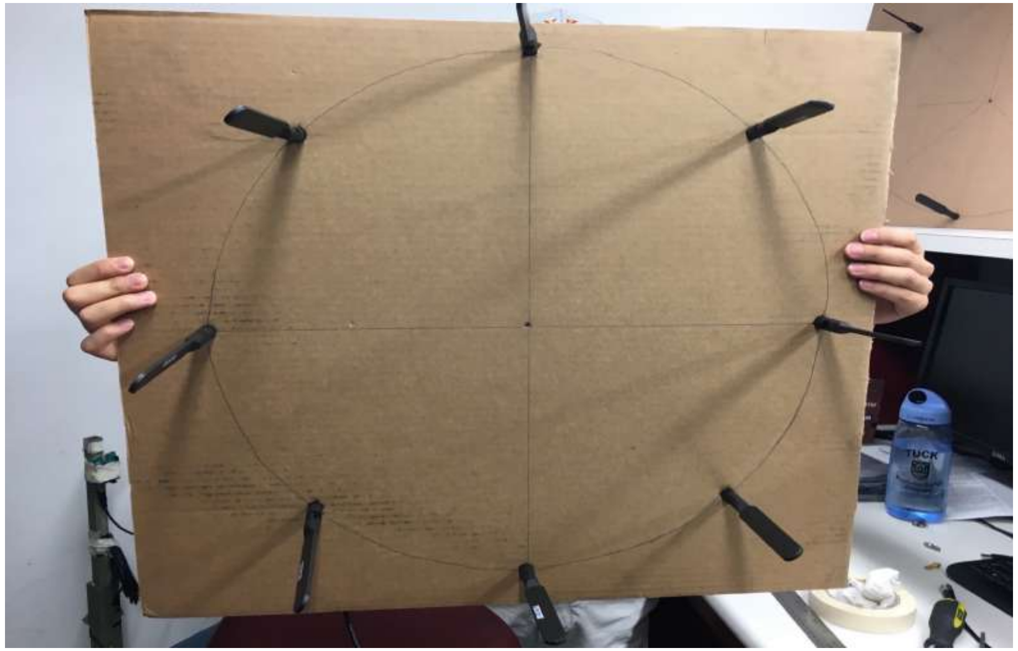
- I2O measurement scenarios (LOS, DeepLOS, NLOS)

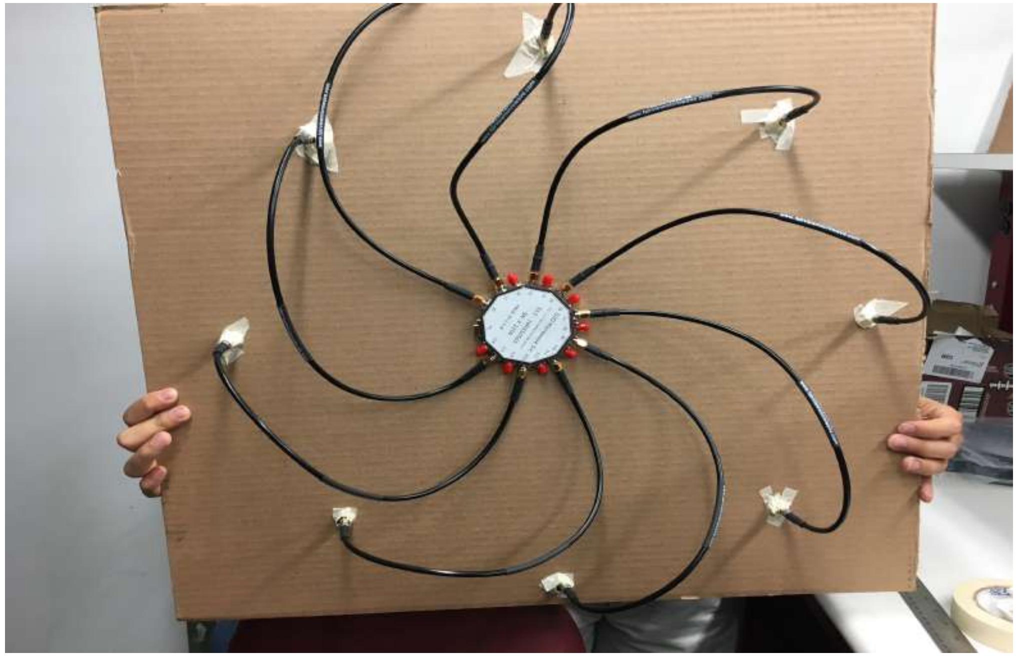




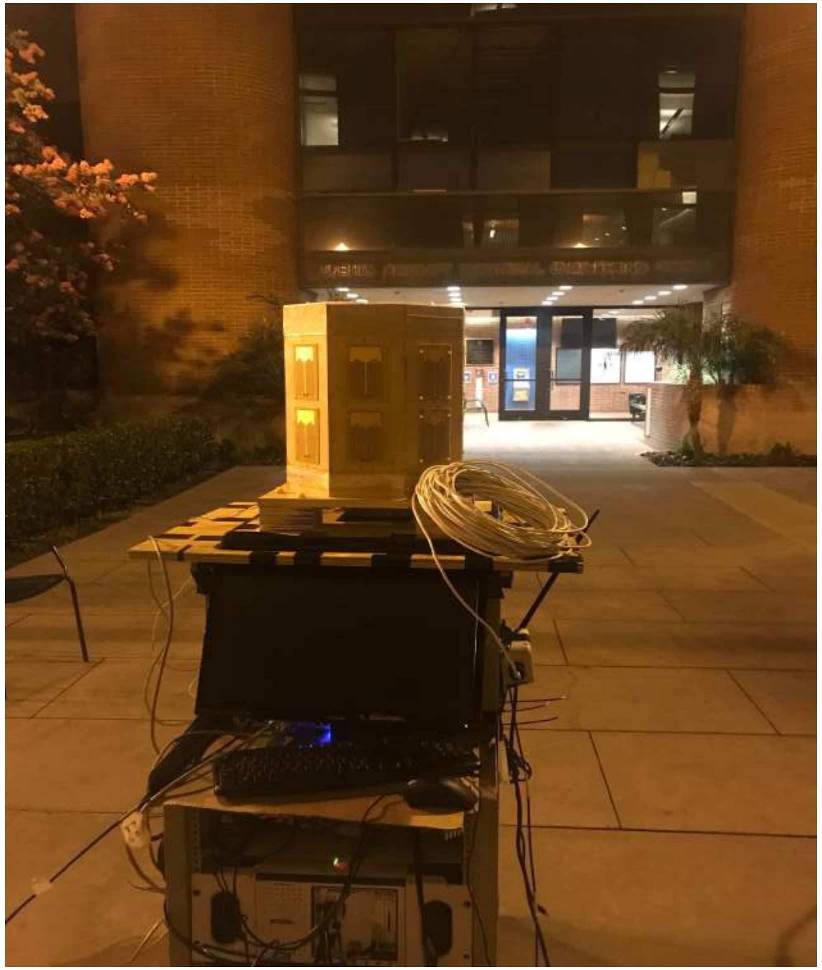
I2O Propagation Channel Measurement (3)

- Performed measurements over 2 stages
  - First stage using an 8-element circular array
  - Second stage using the 16-elements array described before





I2O Propagation Channel Measurement (4)



I2O Propagation Channel Measurement (5)

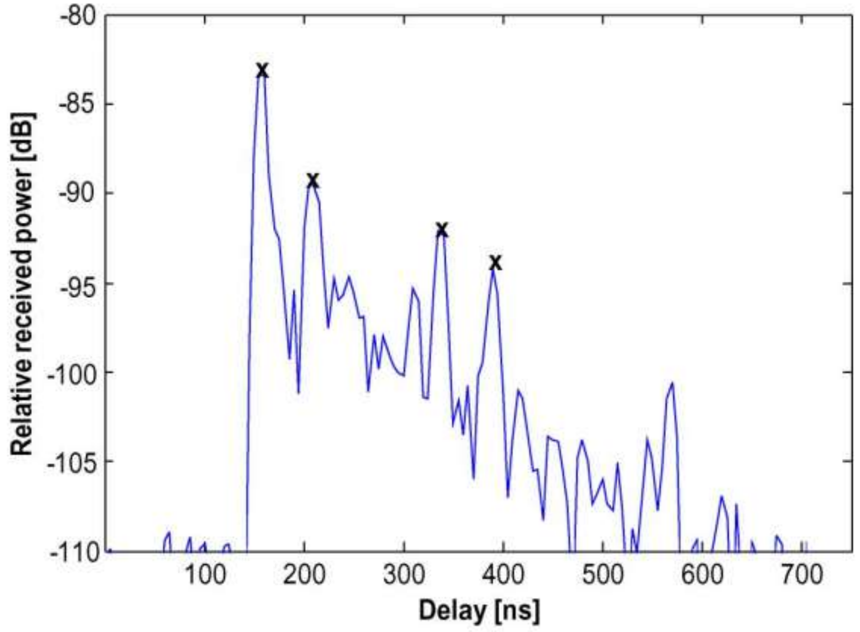
- Problems and difficulties
  - GSM interference
  - Wireless bridges interference
  - Repeated Array calibration

I2O Measurements Evaluations

- Three HRPE algorithms in investigation
  - CLEAN
  - SAGE
  - RiMAX

CLEAN/SAGE	RiMAX
Less complexity	More Dynamic range
More suitable for Indoor	More accuracy

- Operation (CLEAN/SAGE)
  1. Choose MPC with maximum power
  2. Find corresponding delay and angles parameters
  3. Use those parameters to estimate the MPC contribution on the total channel transfer function
  4. Deduct estimated contribution from measured transfer function
  5. Repeat step 1-4 until you extract desired MPCs number

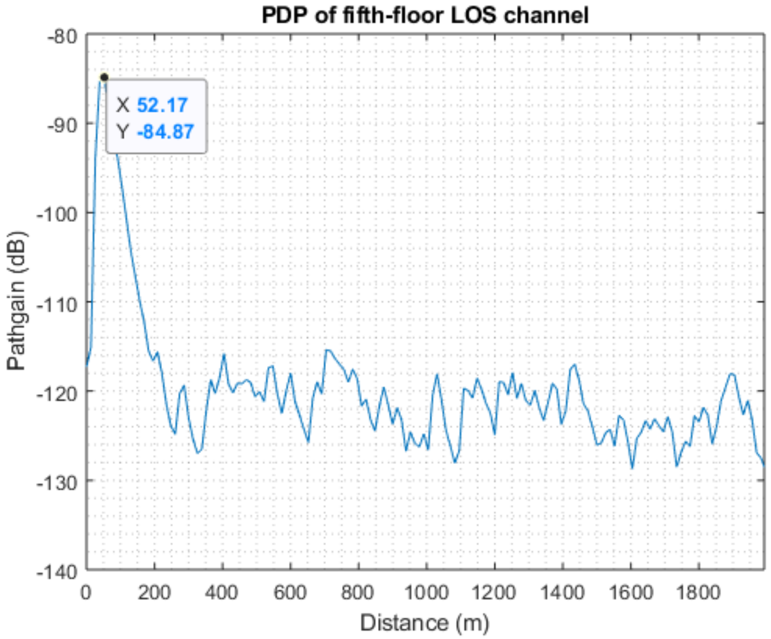


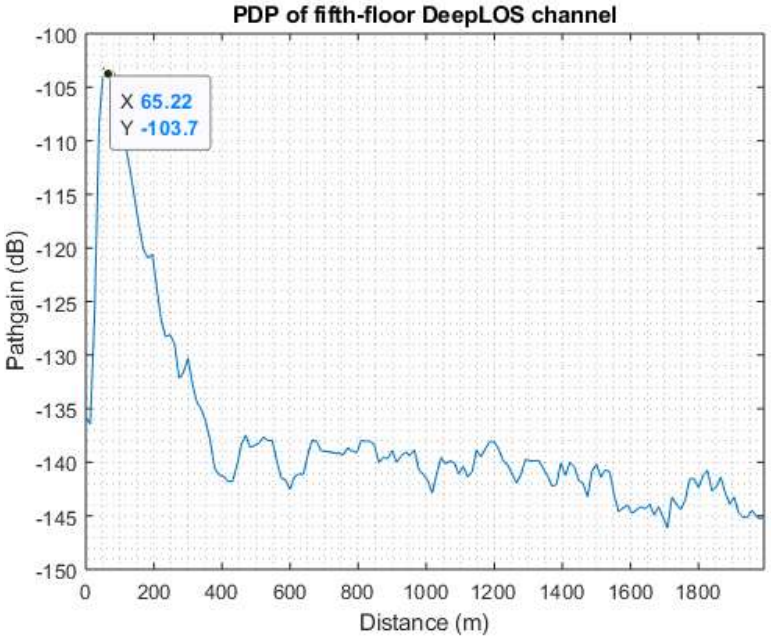
I2O Measurements Results (1)

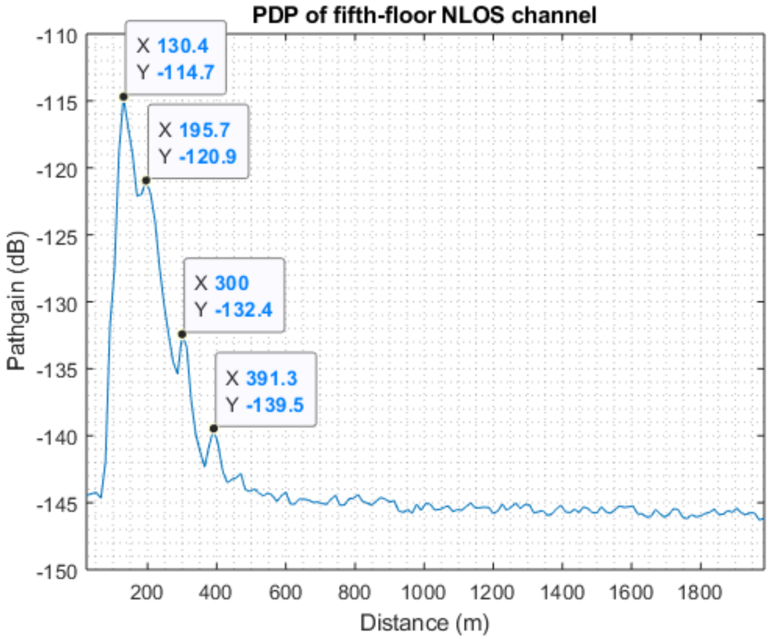
- We study the trend of the following parameters over different floors, in different measurement scenarios
  - Mean and Std deviation of path gain
  - Mean rms and Std deviation of rms delay spread
  - Mean angles of departure
  - Mean angles of arrival

I2O Measurements Results (2)

- Sample Power-Delay Profile (PDP) results (5th floor)







I2O Measurements Results (3)

Floor	Mean path gain (dB)	Std. dev of path gain (dB)	Mean rms delay spread (dBs)	Std. dev of rms delay spread (dBs)
5	-80.06	2.04	-74.00	1.86
4	-82.77	1.43	-73.12	0.35
3	-77.44	2.09	-72.90	0.93
2	-75.60	3.26	-73.61	0.73
1	-65.91	4.13	-74.50	0.69

LOS

Floor	Mean path gain (dB)	Std. dev of path gain (dB)	Mean rms delay spread (dBs)	Std. dev of rms delay spread (dBs)
5	-97.36	3.74	-73.18	1.74
4	-94.72	2.25	-70.70	0.53
3	-92.82	2.47	-72.20	0.82
2	-89.40	2.50	-73.61	0.96
1	N/A	N/A	N/A	N/A

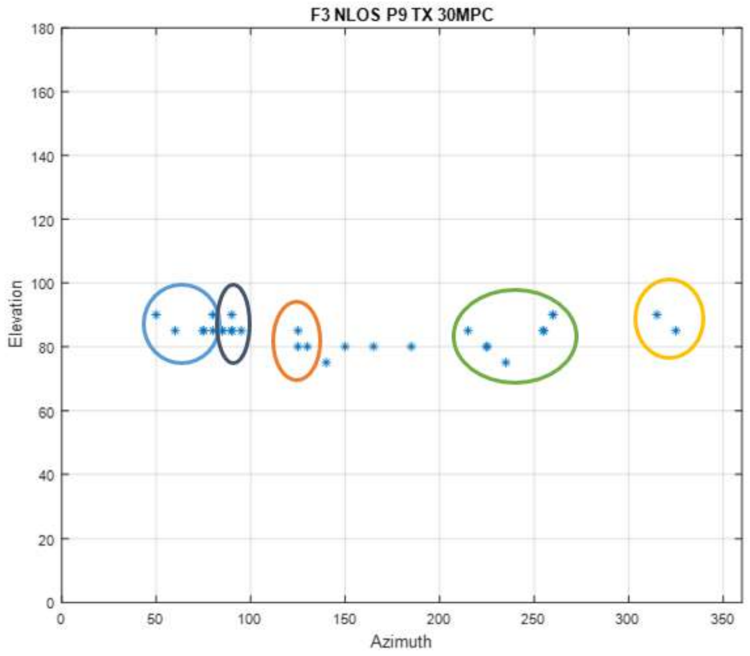
DeepLOS

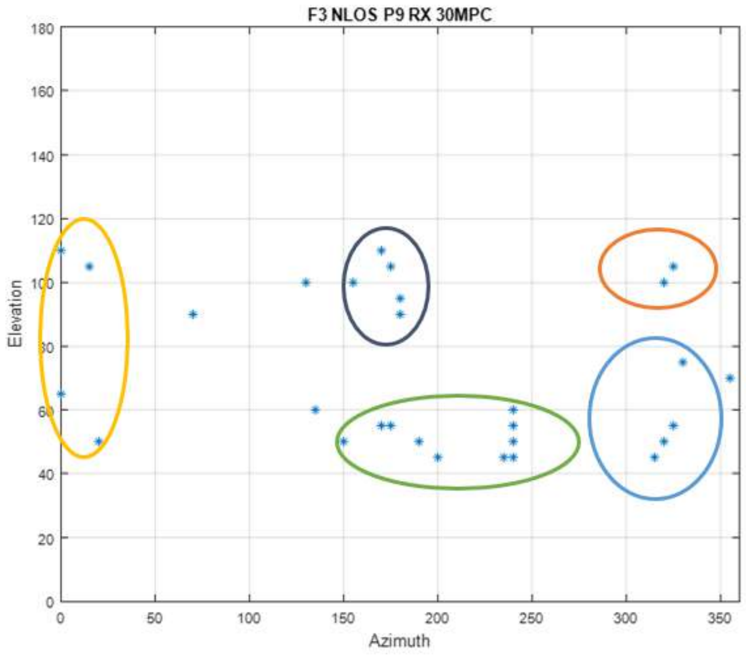
Floor	Mean path gain (dB)	Std. dev of path gain (dB)	Mean rms delay spread (dBs)	Std. dev of rms delay spread (dBs)
5	-109.64	4.11	-73.34	2.23
4	-107.08	7.06	-74.20	3.03
3	-100.36	7.11	-71.40	1.24
2	-105.32	6.95	-70.80	0.90
1	N/A	N/A	N/A	N/A

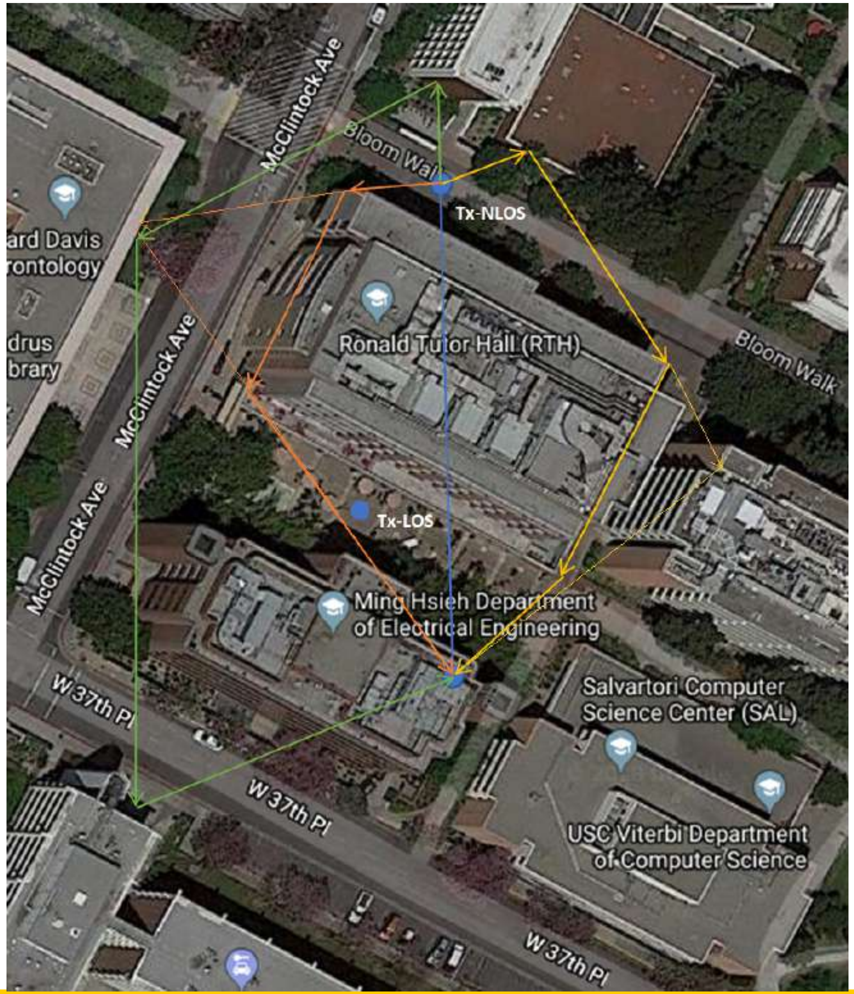
NLOS

I2O Measurements Results (4)

- Sample Angular analysis







I2O Measurements Results (5)

- Path gains and delays make sense and conform with the geometry

- Angular analysis problematic: Elevation angle of Departure (EoD) observed is almost horizontal even when we measure on higher floor.
    - This issue is still under investigation
    - Full Angular analysis results and estimated parameters were not included until we make sure all results do make sense.

I2O Measurements Results (6)

- Debugging steps
  - Channel Sounder (Checked)
    - Moved system into Anechoic chamber and used VNA instead of our sounders
    - Observed same results
  - HRPE algorithm (Checked)
    - Algorithms were extensively tested on synthetic measurements
    - Compared results of SAGE vs CLEAN
    - Algorithms working properly

I2O Measurements Results (7)

- Debugging steps
  - Measurement campaign (Checked)
    - ➢ Repeated measurement in other locations on campus
    - ➢ Indoor: Inside Anechoic chamber, inside lab
    - ➢ Outdoor: Parking structure, Open soccer field
    - ➢ Same results were observed
  - Calibration (Under investigation)
    - ➢ Repeated Calibration
    - ➢ Analysis underway

Future Work

V2V Propagation Channel Measurement

- Study different scenarios
  - LOS: Optical line-of-sight between Tx and Rx
  - NLOS: Obstruction between Tx and Rx (e.g. a truck)

- Study different environments
  - USC campus
  - Suburban environment
  - Urban environment
  - Freeway

Modelling and Beyond

- Use evaluated measurements for both I2O and V2V scenarios to build channel models
- Assess performance of LTE-Direct and explore limitations
- Investigate Enhancements on LTE-Direct by exploring MIMO capabilities

Expected Impact

- Provide realistic frameworks for testing D2D communications for PSOs
- Provide suggestions for system improvements to meet reliability constraints
- Develop channel models for future system development
- Provide channel measurements data that can be used by related projects