Modified Channel Model For Outdoor Open Area Hotspot Access Scenario

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Abstract

- **This contribution proposes a modified channel model for Open Area Outdoor Hotspot Access scenario considering dominant reflected paths from surrounding walls**

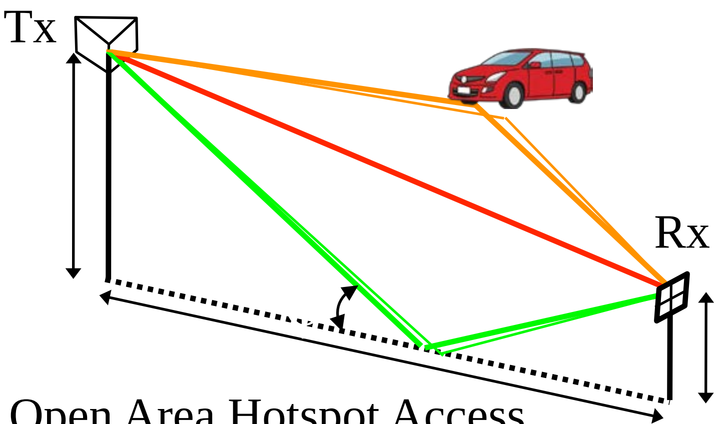
Introduction

- **Our previous contribution (IEEE802.11-16/0342r0 [1])**
  - Measurement campaign in an outdoor Open Area Hotspot Access scenario
  - Investigation of dominant propagation mechanisms
  - Channel model parameter extraction (Q-D model)
- **This contribution**
  - Propose simple and more realistic model considering dominant reflected paths from sur-rounding walls
  - Channel model parameters revised
  - SU-MIMO (Conf #1) performance evaluation

Channel Modeling

IEEE802.11ay Q-D Channel Model

- **Quasi-deterministic model based on MiWEBA [2]**
- **Deterministic components (D-Ray)**
  - LoS, Ground reflection, Near-wall reflection
  - Determined by the location of Tx and Rx in the surrounding environment
- **Random components (R-Ray)**
  - Reflection from far-away static objects and random objects
  - Statistically modeled

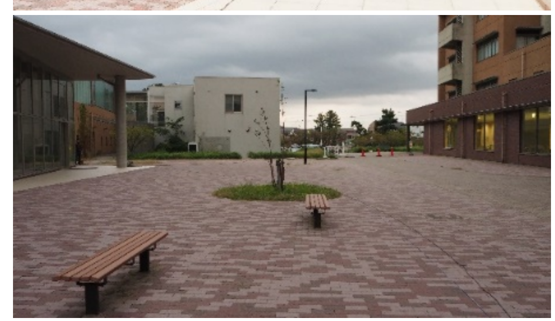


Open Area Hotspot Access Scenario [2]

Problem of Existing Open Area Hotspot Channel Model

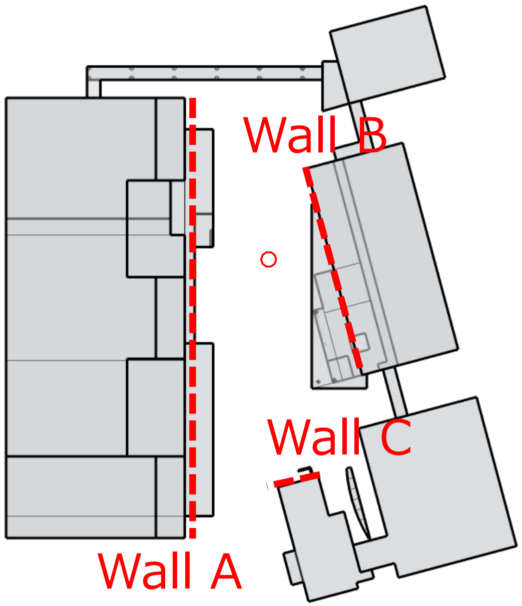
- **In most cases, the environment are surrounded by a few buildings**
- **Dominant wall reflection should be counted as a D-Ray**

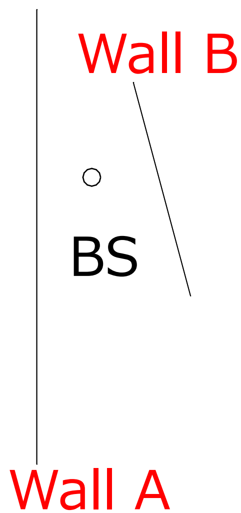

Map data @Google,ZENRIN

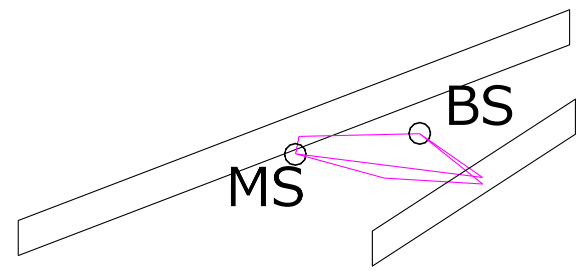


Modified Channel Model: D-Ray

- **New D-ray components are calculated by the first order reflection from the surrounding walls of the specific environment as**

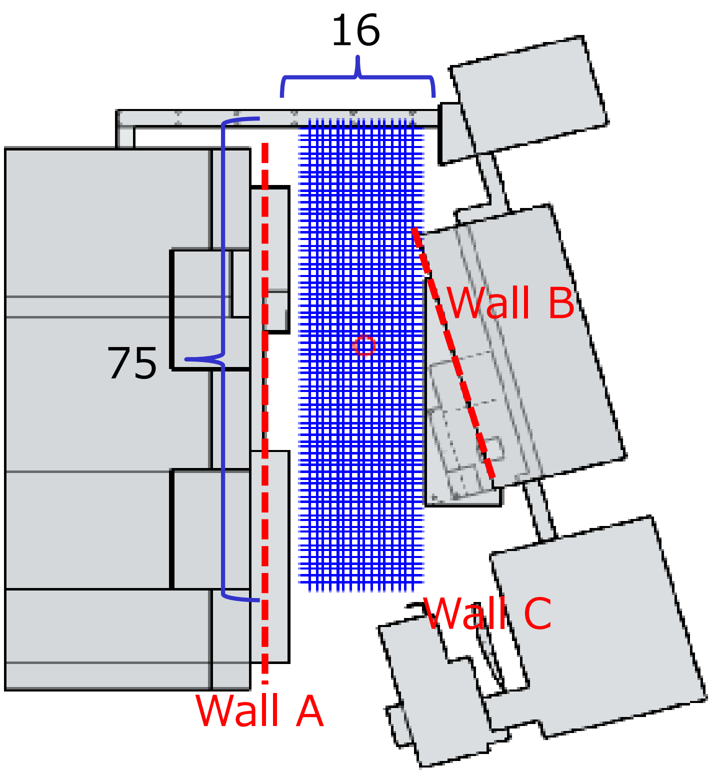




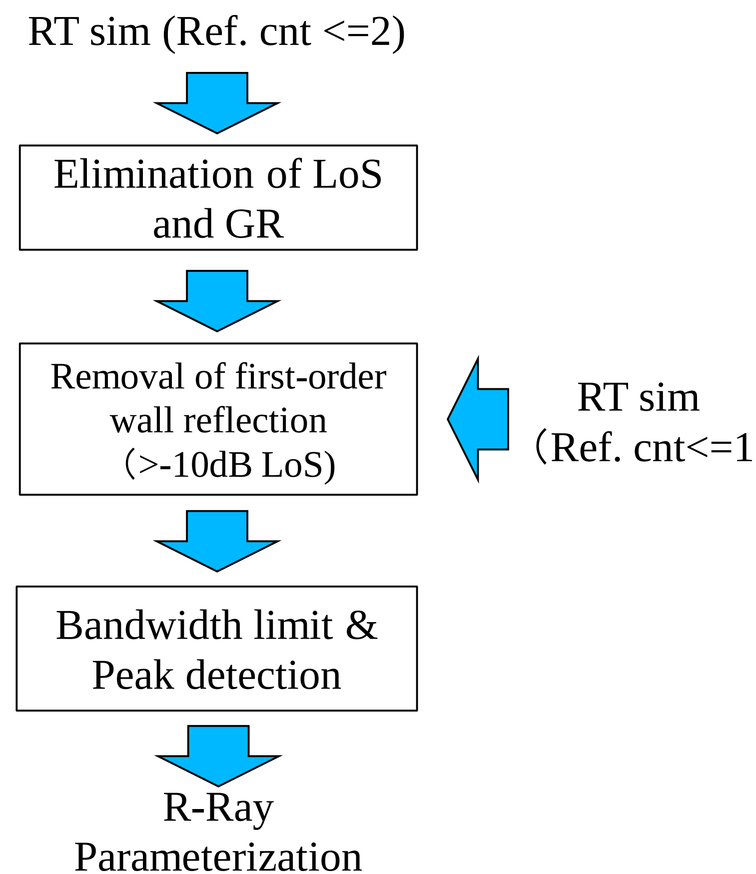


Modified Channel Model: R-Ray

Statistical parameters of R-Ray were extracted from ray tracing simulations



1200 (16 × 75) points (1 m spacing)



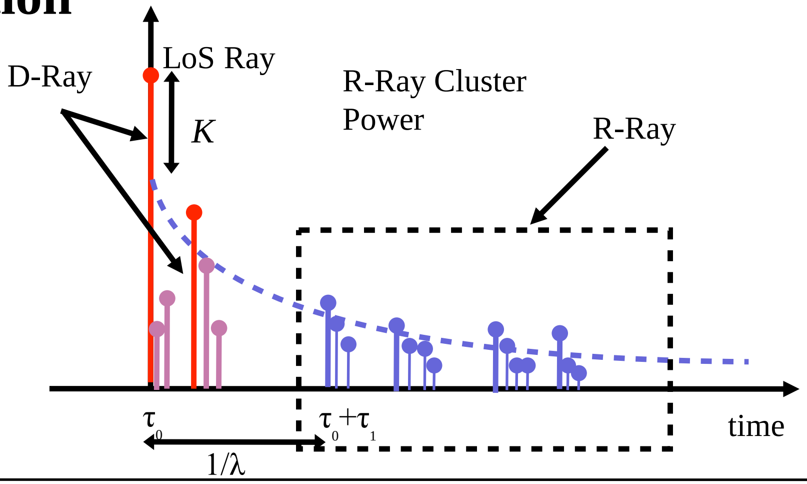
Channel Parameters

Deterministic components

- **Loss is calculated by Friis equation and Fresnel reflection equation**
- **AoA (Angle-of-arrival), AoD (Angle-of-departure) and delay are determined by the location of Tx and Rx**

Random components

- **No Clusters, N_c**
- **Cluster arrival rate, λ**
- **Cluster power-decay constant, γ**
- **Ray K factor**
- **AoA and AoD**



R-Ray Parameters

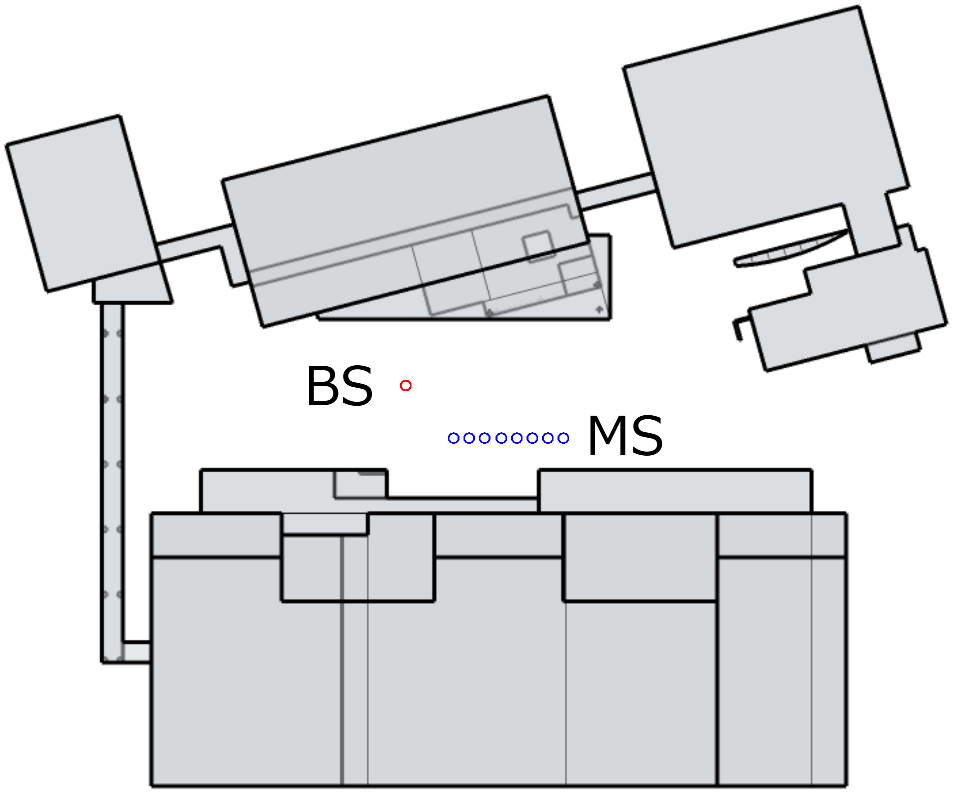
			This model	IEEE802.11ay [3]
Delay	No. Clusters, N_c		N(1.7,0.8)	3
	Cluster arrival time offset, τ_0		40 ns	-
	Cluster arrival rate, λ		0.0084 ns^{-1}	0.05 ns^{-1}
	power-decay constant, γ		27.4 ns	15 ns
	K factor		7 dB	6 dB
Angle	AoA	Elevation	$A_{\mathrm{AoA}} = 0.85$ $B_{\mathrm{AoA}} = 1.9$ $\sigma^2_{\mathrm{AoA}} = 3.5$ ※1	U[-20 : 20°]
		Azimuth	U[−180 : 180 °]	U[−180 : 180 °]
	AoD	Elevation	$A_{\mathrm{AoD}} = 1.4$ $B_{\mathrm{AoD}} = 2.2$ $\sigma^2_{\mathrm{AoD}} = 2.7$ ※2	U[-20 : 20°]
		Azimuth	U[−180 : 180 °]	U[−180 : 180 °]

※1: $10^{-A_{\mathrm{AoA}} \times D - B_{\mathrm{AoA}}} + N(0, \sigma^2_{\mathrm{AoA}})$ ※2 : $-10^{-A_{\mathrm{AoD}} \times D - B_{\mathrm{AoD}}} + N(0, \sigma^2_{\mathrm{AoD}})$

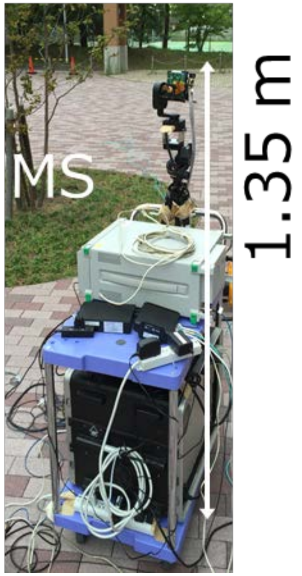
Evaluation

Measurement Campaign

8 Points (2 m spacing)



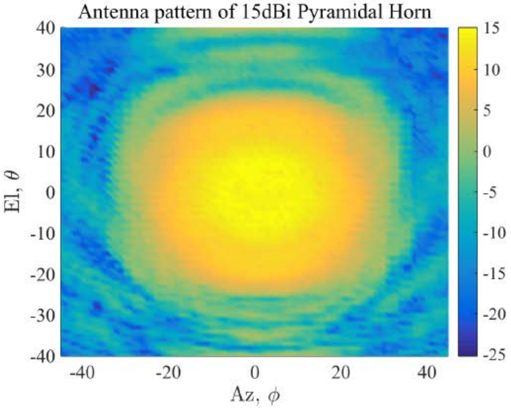
Frequency	58.5 GHz
Bandwidth	400 MHz
Signal	Multitone
No. tones	256
Delay res.	2.5 ns

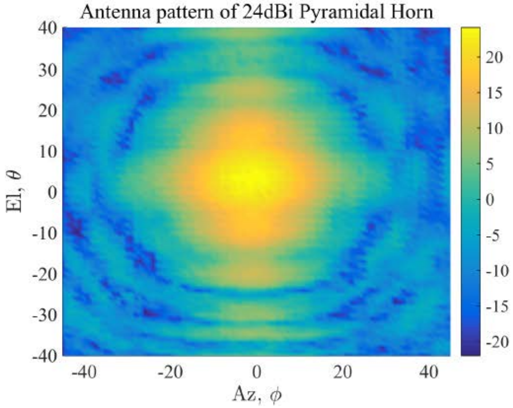


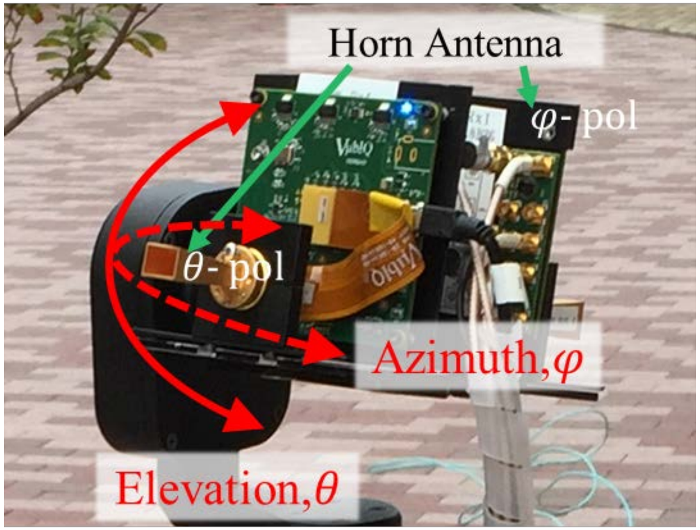
Measurement Campaign (cont'd)

Full polarimetric double-directional measurement [4]

Tx Antenna	15dBi Pyramidal Horn
Rx Antenna	15dBi Pyramidal Horn
Tx Antenna Rotation	Az:-180~+180, El:-30~+30 Step:30 deg.
Rx Antenna Rotation	Az:-180~+180, El:-30~+30 Step:30 deg.







Data Processing

- **Double directional channel impulse response**

AoA AoD Polarization

$$h_{\mathrm{qp}}(\tau,\vartheta_i,\varphi_j,\vartheta'_m,\varphi'_n) = \mathcal{F}^{-1}\{H_{\mathrm{qp}}(f,\underbrace{\vartheta_i,\varphi_j}_{\text{AoA}},\underbrace{\vartheta'_m,\varphi'_n}_{\text{AoD}})\}$$

$\mathrm{p} \in \{\vartheta,\varphi\}$
$\mathrm{q} \in \{\vartheta,\varphi\}$

- **Double directional angle delay power spectrum (DDADPS)**

$$P_{\mathrm{qp}}(\tau,\vartheta_i,\varphi_j,\vartheta'_m,\varphi'_n) = \left|h_{\mathrm{qp}}(\tau,\vartheta_i,\varphi_j,\vartheta'_m,\varphi'_n)\right|^2$$

Data Processing (cont'd)

- **Synthetic spectrum (omni-directional)**

Angular power spectrum

$$\mathrm{APS_{qp}}(\vartheta_i, \varphi_j) = \frac{1}{\zeta_{\mathrm{Tx}}} \sum_{\tau,m,n} P_{\mathrm{qp}}(\tau, \vartheta_i, \varphi_j, \vartheta'_m, \varphi'_n)$$

Power delay profile

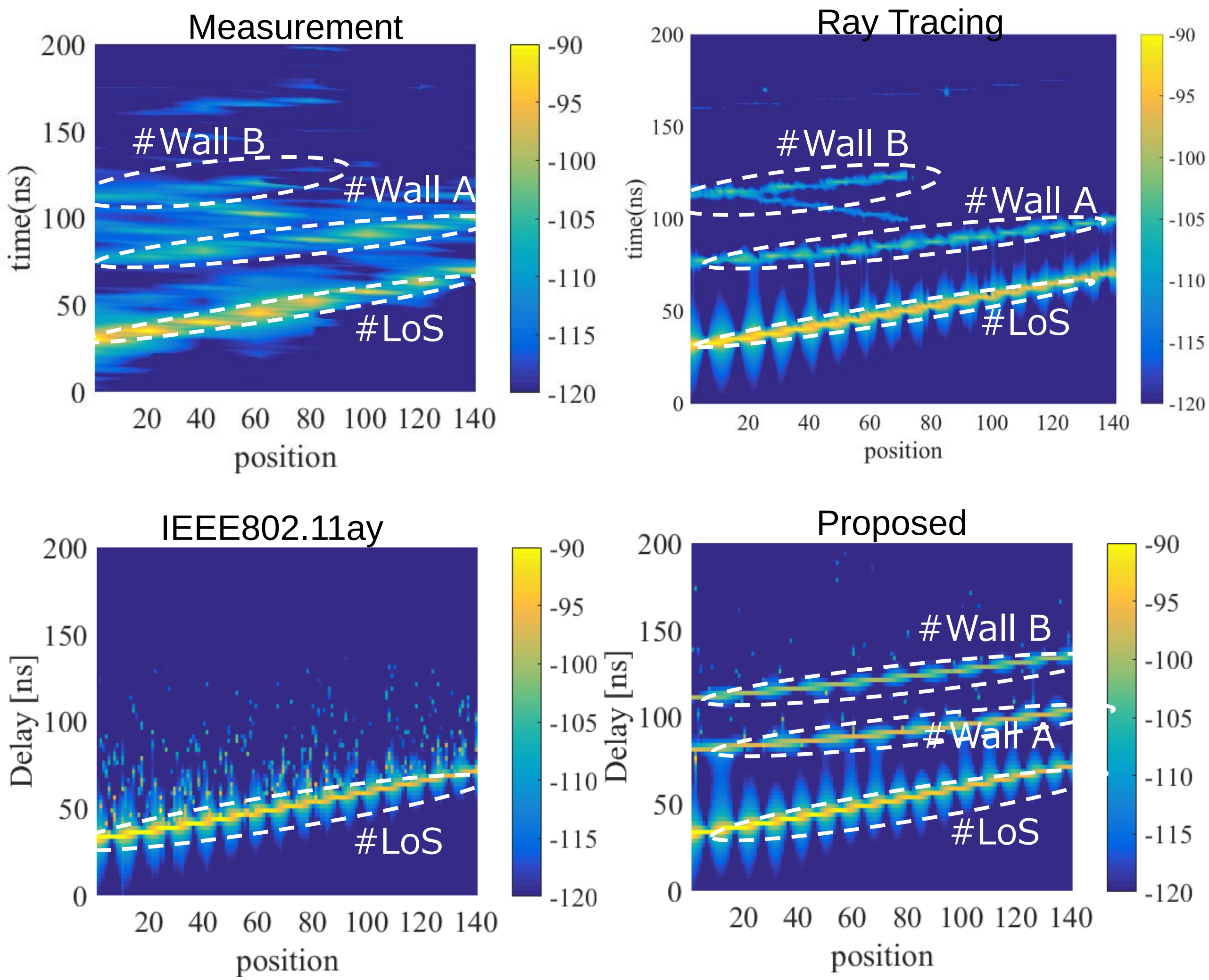
$$\mathrm{PDP_{qp}}(\tau) = \frac{1}{\underbrace{\zeta_{\mathrm{Tx}}\zeta_{\mathrm{Rx}}}_{\text{Gain correction}}} \sum_{i,j,m,n} P_{\mathrm{qp}}(\tau, \vartheta_i, \varphi_j, \vartheta'_m, \varphi'_n)$$

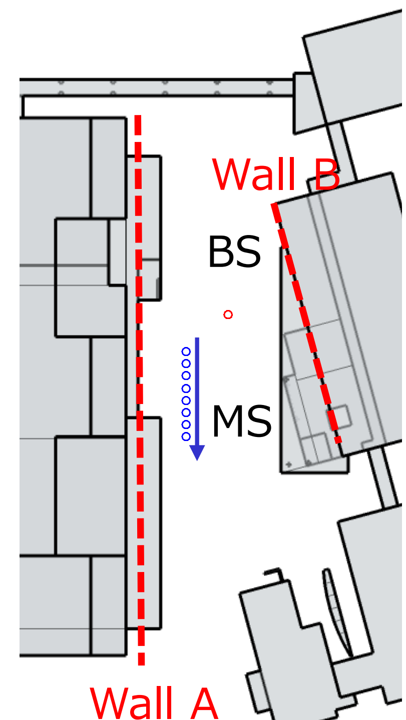
- **Polarization combination**

$$\mathrm{APS_{\Sigma}}(\vartheta_i, \varphi_i) = \frac{1}{2} \sum_{\mathrm{p}\in\{\vartheta,\varphi\}} \sum_{\mathrm{q}\in\{\vartheta,\varphi\}} \mathrm{APS_{qp}}(\vartheta_i, \varphi_j)$$

$$\mathrm{PDP_{\Sigma}}(\tau) = \frac{1}{2} \sum_{\mathrm{p}\in\{\vartheta,\varphi\}} \sum_{\mathrm{q}\in\{\vartheta,\varphi\}} \mathrm{PDP_{qp}}(\tau)$$

Channel Reconstruction





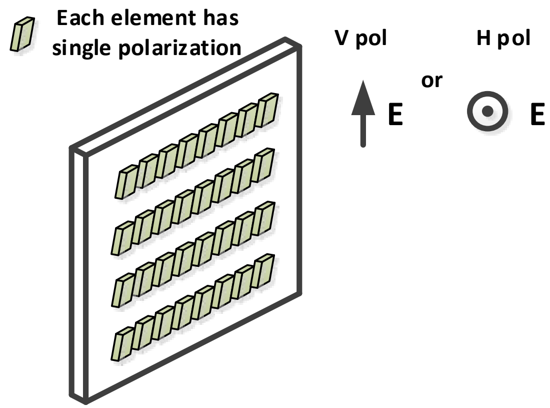
MIMO Beamforming (MIMO BF)

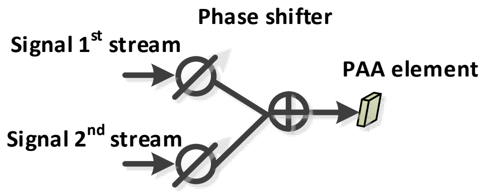
- **IEEE802.11ay SU-MIMO [3]**

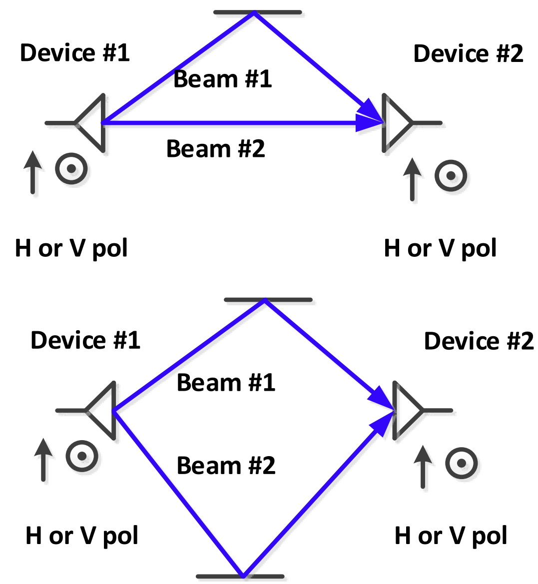
  Single polar (V-pol) 2 × 2 MIMO transmission → 2 Streams

Configuration #1

Phased Antenna Array







MIMO Channel Selection Metric

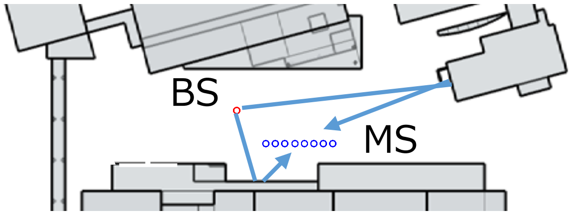
- **Based on IEEE802.11-16/1209r0 [5]**
  - $\boldsymbol{H}$ is generated by Ray-based search
  - Per-subcarrier capacity metric

$$\boldsymbol{H} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}$$

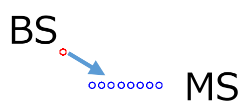
$$C = \det\left(\boldsymbol{I} + \frac{P_t}{P_\mathrm{n}} \boldsymbol{H}\boldsymbol{H}^\mathrm{H}\right) \text{ [bits/s/Hz]}$$

- **TX and RX antenna arrays**
  - “Gaussian” antenna pattern (equivalent to 8x8 antenna array).
  - Gain 24 dBi, Beamwidth 12°
  - Vertical polarization
  - Ideal beam steering: antenna broadside is rotated in the desired direction

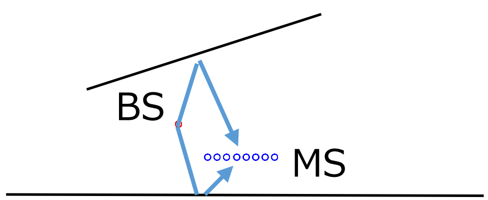
Average Channel Capacity



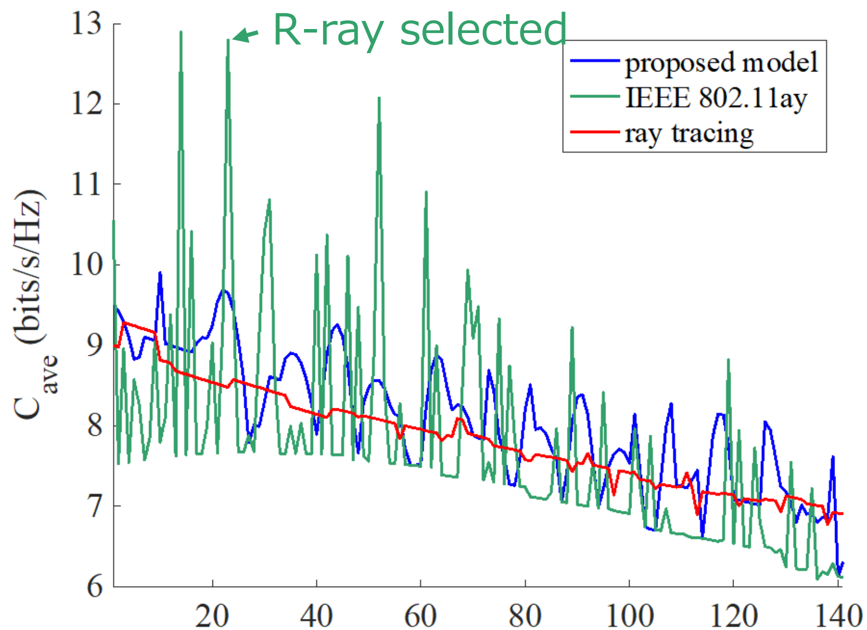
Raytracing



IEEE 802.11ay



This model



IEEE 802.11ay

- LoS and GR paths are used for parallel channels
- Some times strong R-ray is employ for the 2nd path

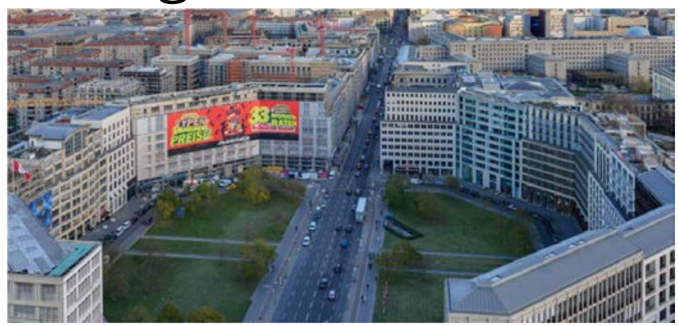
Proposed model

- Wall-A or Wall-B are realistically selected for the 2nd path
- Channel capacity is well matched to those of RT results

Summary

- **Existing open area hotspot channel model doesn't consider surrounding walls**

Our environment



Open square in Berlin (MiWEBA)

Open square in Helsinki (METIS, ,mmMAGIC)

- **This contribution proposed a modified model including dominant first-order wall reflection as D-Ray**
- **SU-MIMO Capacity Evaluation**
  - Proposed model is well matched to that by detail Ray tracing
  - Simply adding the wall reflected paths in site-specific manner provide better representation

References

[1] “Channel Model for Outdoor Open Area Access Scenarios,” *IEEE Document 802.11-16/0342r0*, Mar. 2016.

[2] MiWEBA, FP7 ICT-2013-EU-Japan, http://www.miweba.eu

[3] “Channel Models for IEEE 802.11ay,” *IEEE Document 802.11-15/1150r2*, Sept. 2015.

[4] Karma Wangchuck, Minseok Kim, Kento Umeki, Kento Umeki, Kentaro Saito, and Jun-ichi Takada, ``Polarimetric Millimeter Wave Propagation Channel Measurement and Cluster Properties in Outdoor Urban Pico-cell Environment," The 27th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC2016), Sept. 2016.

[5] “Hotel lobby SU-MIMO channel modeling: 2x2 golden set generation,” *IEEE Document 802.11-16/1209r0*, Sept 2016.