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Wireless Intelligence Lab

Synergy and Coexistence of Millimeter Wave Wireless Communications, Imaging, and Localization

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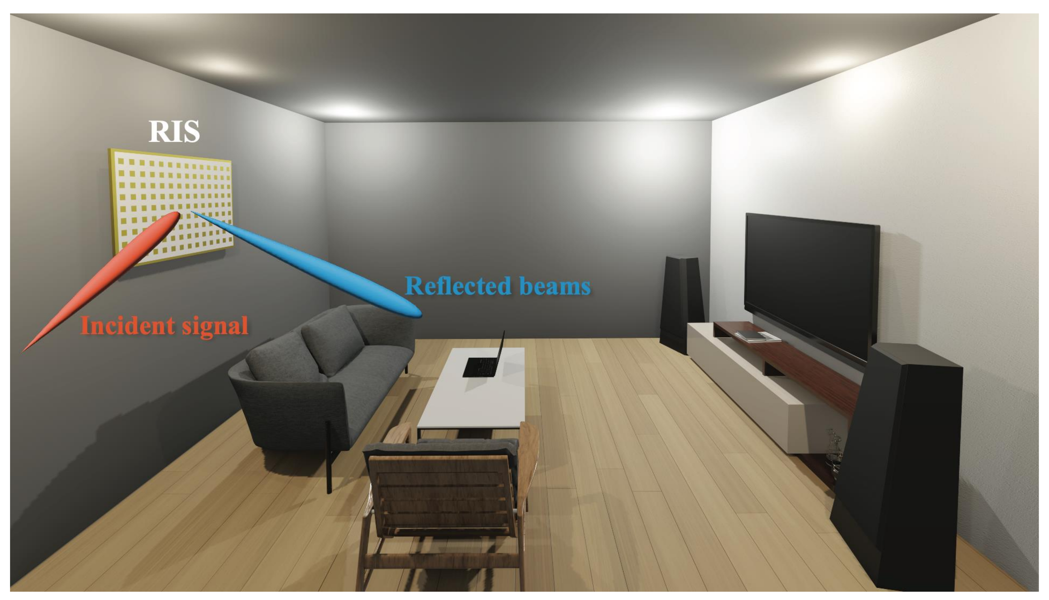
RIS Beam Training is a Key Challenge

Large numbers of antennas | Narrow beams

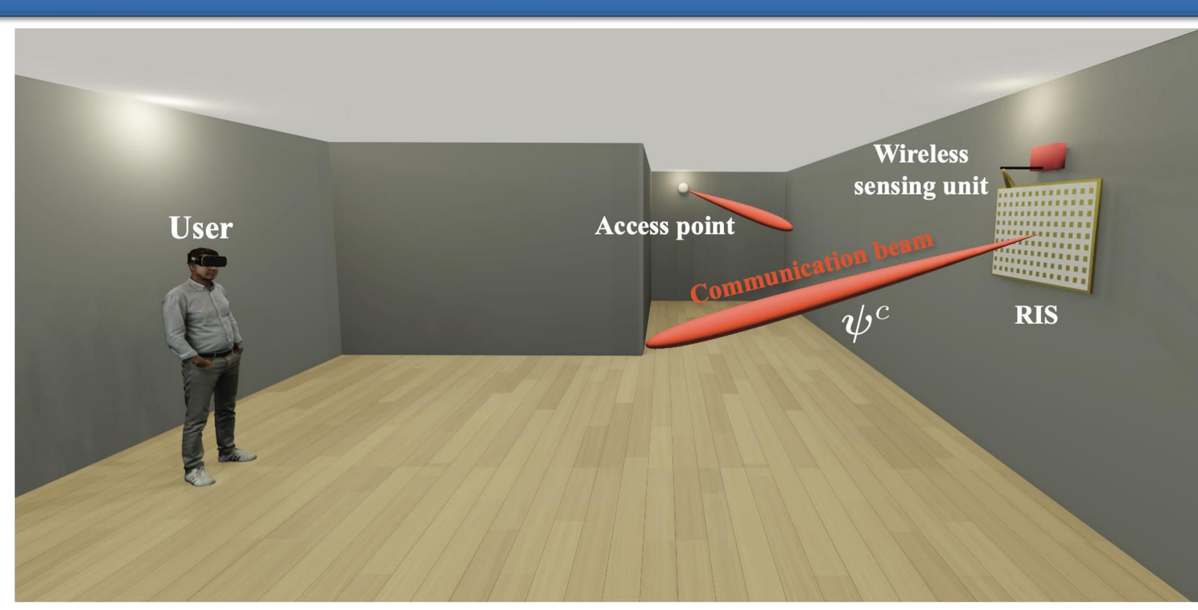


➢ RIS offers an opportunity for high spatial-resolution imaging

Can imaging assist RIS beam training for communication?

System Model

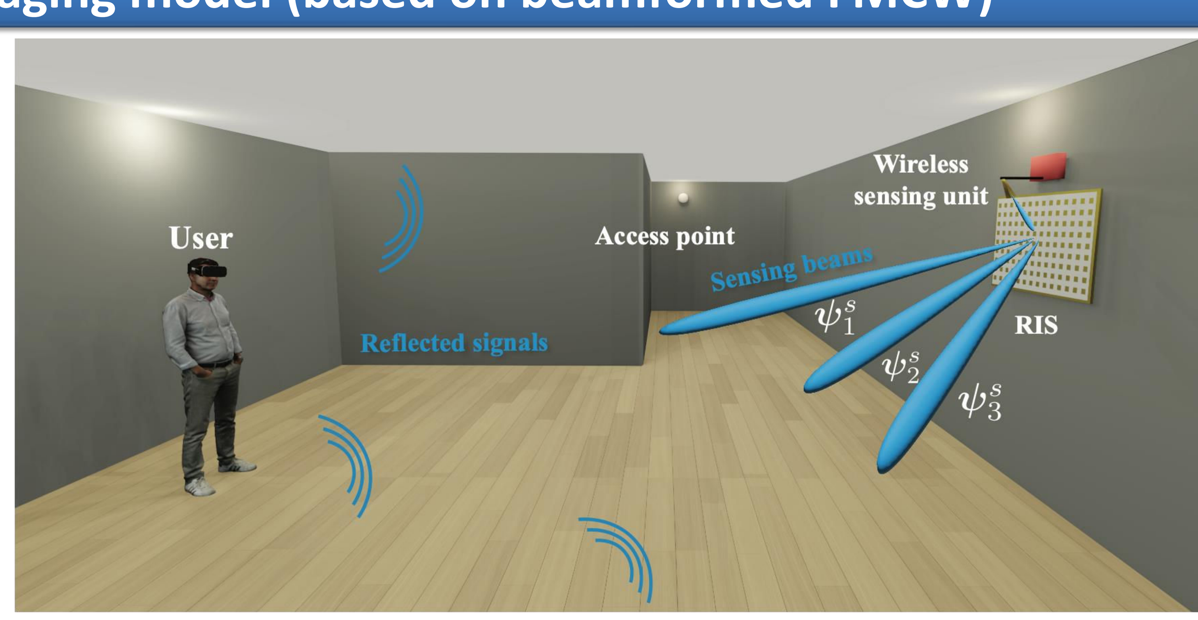
➢ Communication model



Received signal $y_c = (\mathbf{h}_R \odot \mathbf{h}_T)^T \boldsymbol{\psi}^c x_c + w_c$

RIS-UE channel ($\mathbf{h}_R$); AP-RIS channel ($\mathbf{h}_T$); RIS interaction vector for communication ($\boldsymbol{\psi}^c$)

➢ Imaging model (based on beamformed FMCW)



Received baseband digital signal

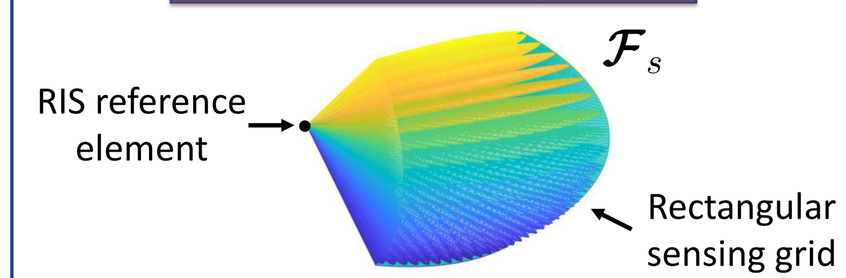
$$z[u,v] = \sum_{k=1}^{K} \sum_{\ell=1}^{L_k} \sqrt{\rho_{k,\ell}}\, e^{-j\vartheta_{k,\ell}}\, e^{+j\Xi_{k,\ell}} + w_s[u,v] e^{j\chi[u]}$$

u^{th} ADC sample; Path gain and phase; v^{th} sensing beam (chirp); Contain range information

Problem Formulation

➢ RIS-aided depth estimation

Sensing codebook



Depth estimation function

$$\mathbf{D}_{map} = \mathbf{p}_d(\mathbf{Z}; \mathcal{F}_s)$$

Received signal matrix after sensing beam sweeping ($\mathbf{Z}$)

[Taha'23] A. Taha, H. Luo, and A. Alkhateeb, "Reconfigurable Intelligent Surface Aided Wireless Sensing for Scene Depth Estimation," in IEEE ICC, 2023.

➢ RIS beam selection problem with a predefined codebook

User detection function

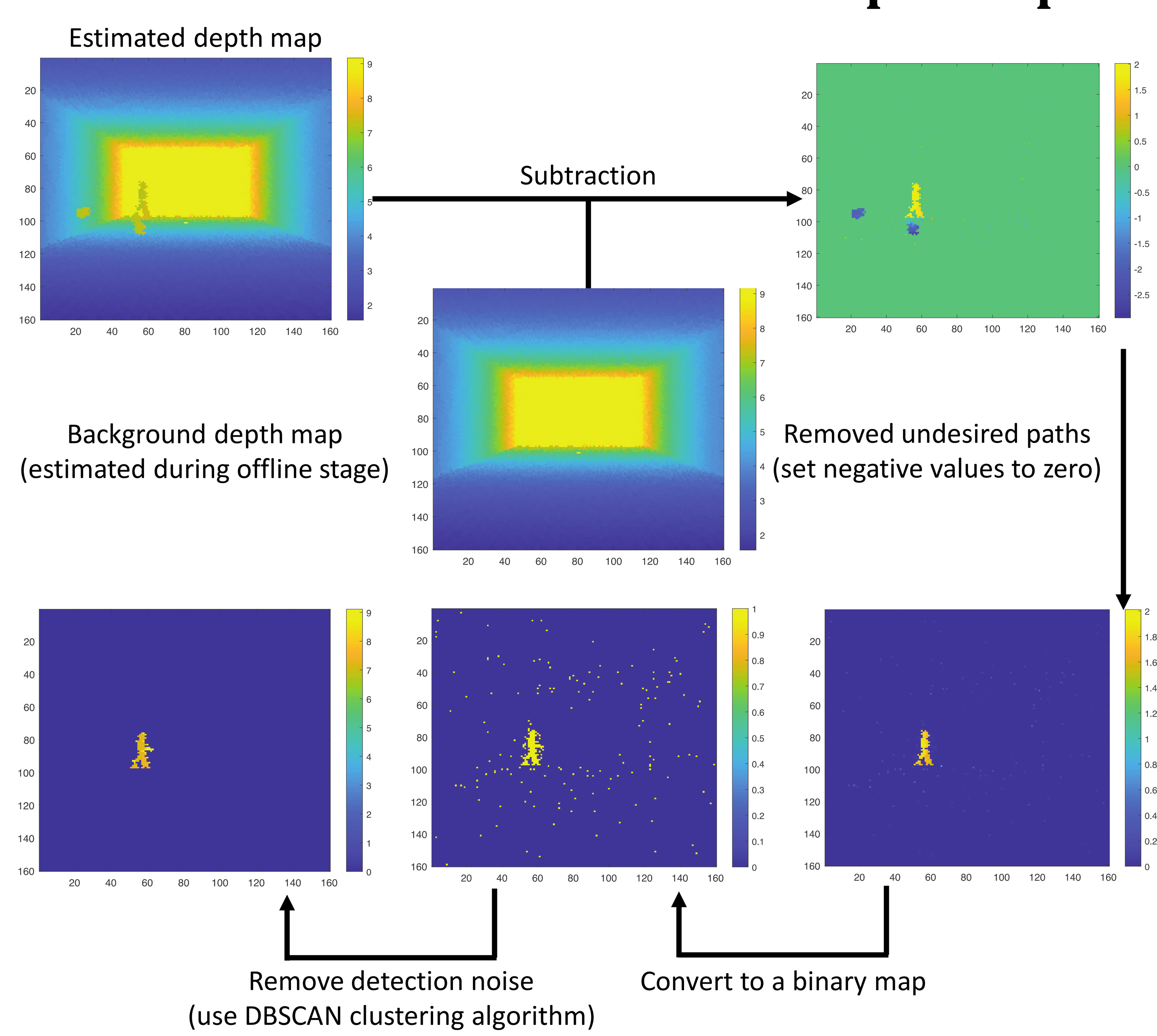
$$(\tilde{\theta}^{az}_{UE}, \tilde{\theta}^{ze}_{UE}) = \mathbf{p}_u(\mathbf{D}_{map})$$

Optimal beam index

$$m^\star = \underset{\psi^c_m \in \mathcal{F}_c}{\arg\max} \left|(\mathbf{h}_R \odot \mathbf{h}_T)^T \boldsymbol{\psi}^c_m\right|$$

➢ Objective: Find the optimal beam based on user detection

User Detection in RIS-based Depth Map

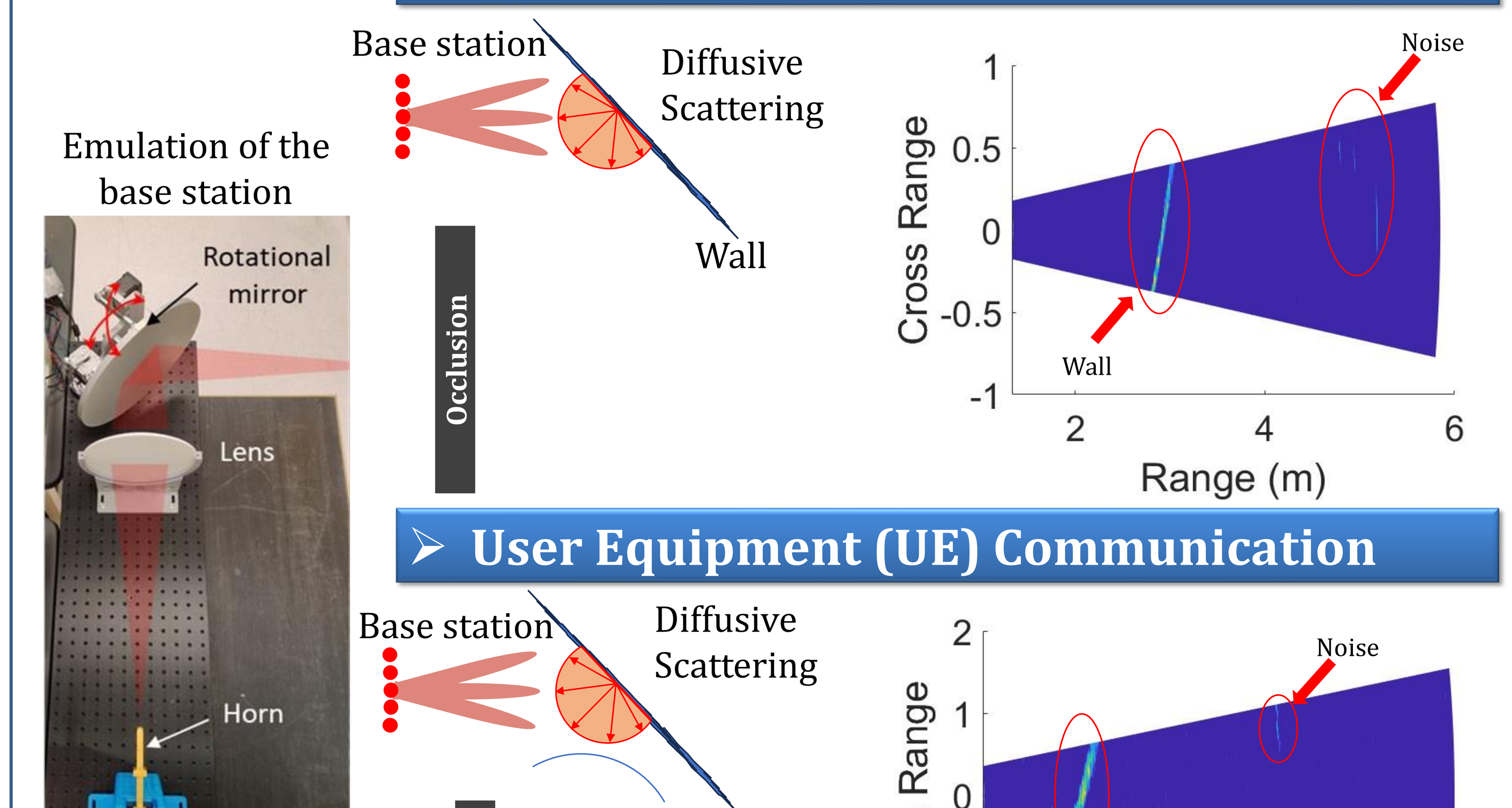


➢ **To determine the azimuth and zenith angles towards the user**

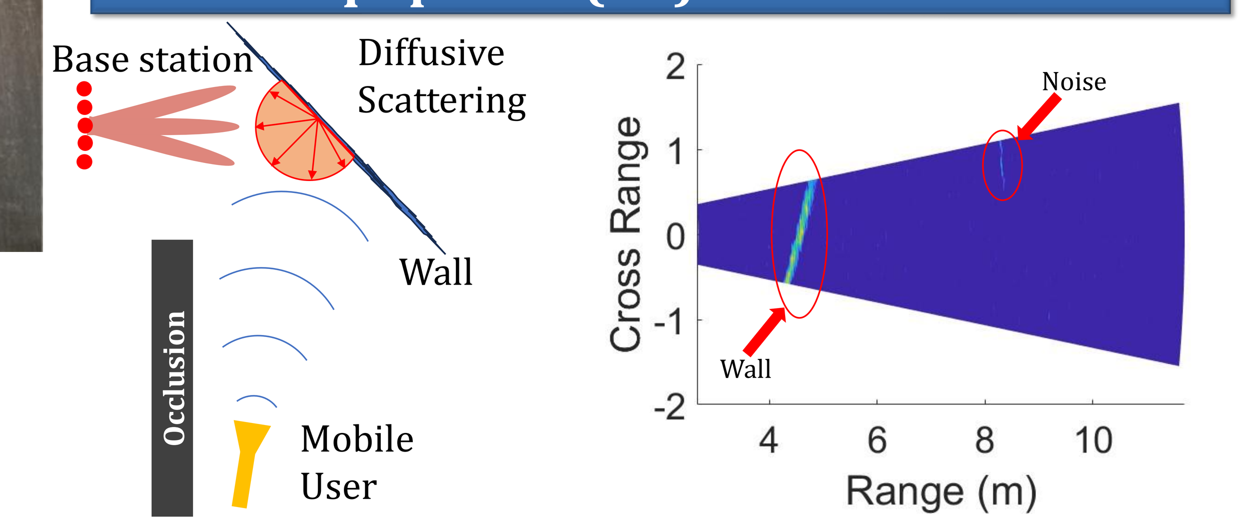
- **Find the mean of the user's pixel coordinates**
- **Each pixel is estimated by a sensing beam of a predefined reflected direction**

NLoS Localization (280 GHz)

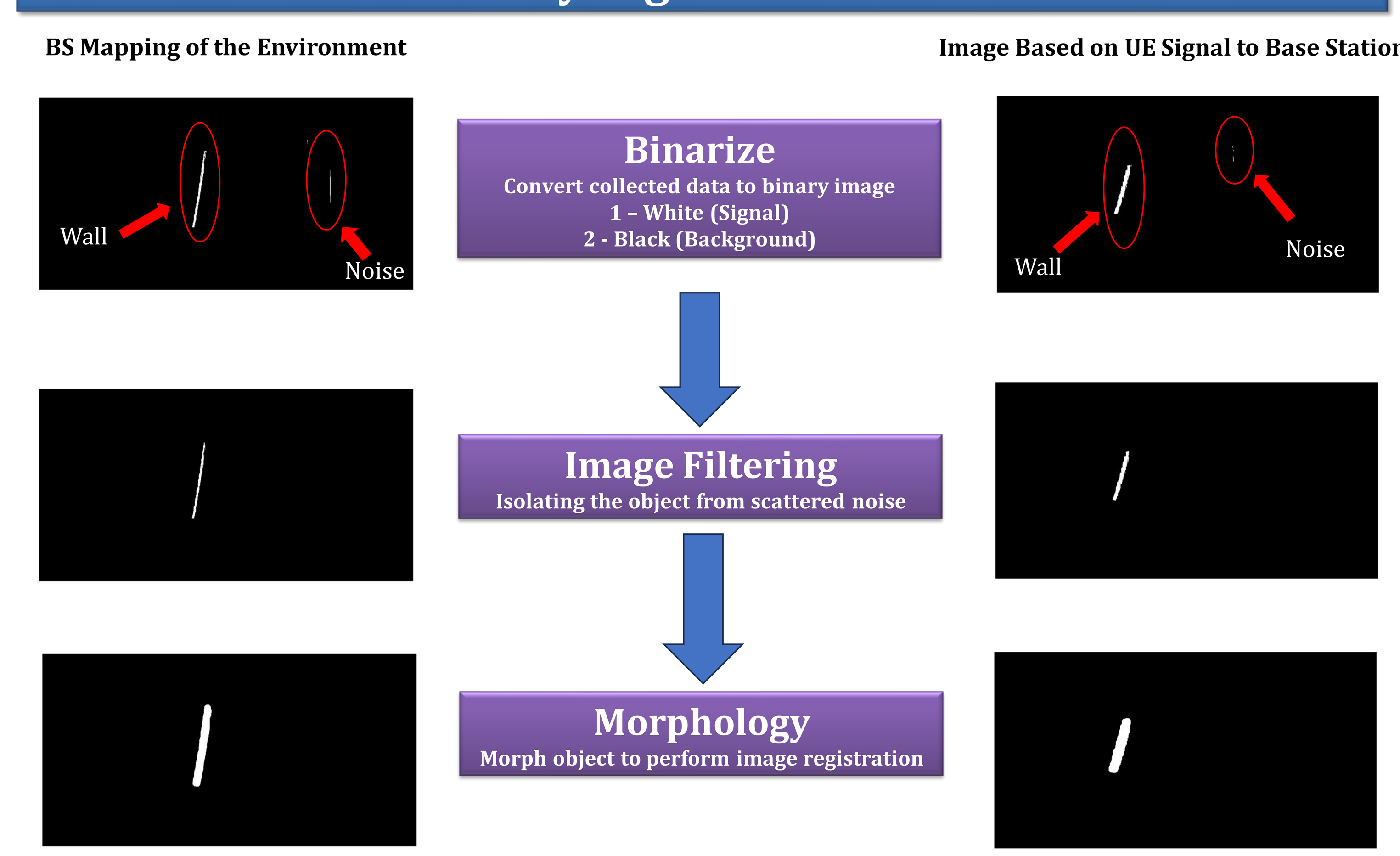
➢ Base Station (BS) Environmental Mapping



➢ User Equipment (UE) Communication



➢ UE Location Recovery Algorithm



➢ User localization

Rotation Matrix

$$R(\theta) = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}$$

Rotation of the UE image with respect to the BS mapping

Translation Matrix

$$T = \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

Translation of the UE image with respect to the BS mapping

$$x' = x\cos(\theta) - y\sin(\theta) + t_x$$
$$y' = x\sin(\theta) + y\cos(\theta) + t_y$$

(x', y') – Position coordinate of the UE