

The Impact of Difference Between Propagation Channel and Quantized CSI in ISAC for Device-Free Human Positioning

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Wi-Fi channel state information (CSI) is ideally equivalent to the propagation channel information between the transmitting and receiving antennas and can be used to sense the status or location of the human target, even if the target does not have any wireless devices. These types of sensing techniques are categorized as integrated sensing and communication (ISAC). However, Wi-Fi devices, which are communication systems, do not necessarily have the performance required for sensing, and it is difficult to use them as radar as they are. One problem is the asynchronous clocks between the separate transmitter and receiver in the communication system, whereas synchronization is not a problem in the radar system because the same clock is shared by the transmitter and receiver. The second problem is quantization noise, because the number of quantization bits in the communication system tends to be lower than in the radar.

By looking at these issues, this work investigates the effect of the quantization noise as well as the phase ambiguity in the Wi-Fi CSI-based positioning. Figure 1 shows the model considered in this study. There are M_T transmit and M_R receive antennas, and the frequencies of all stations are asynchronous. The signal is assumed to be Orthogonal Frequency Division Multiplexing (OFDM) with N_S subcarriers. The complex channel affected by the human body is defined as,

$$\mathbf{H}(t) = \mathbf{H}_0 + \mathbf{H}_v(t) \in \mathbb{C}^{M_R \times M_T \times N_S}, \quad (1)$$

where $\mathbf{H}_0$ is the direct wave component, $\mathbf{H}_v(t)$ is the matrix representing the component via the human body, where the human body's displacement is approximated to the sinusoidal waveform.

Figure 2 is the simulated results showing the spectrums when the Tx-Rx distance D_0 is changed, where the target with -10 dBsm radar-cross-section exists at $(x, y) = (3, 2)$, and the number of quantization bits is 8 for CSI-based positioning. The propagation channel-based positioning can estimate the position of the target well regardless of the Tx-Rx distance. On the other hand, the CSI-based positioning fails when $D_0 = 1$ m, while it succeeds when $D_0 = 4$ m. This is due to the quantization noise, which is enhanced by the strong direct path. In other words, CSI-based positioning works well by attenuating the direct path signal to a level comparable to the signal via the target.

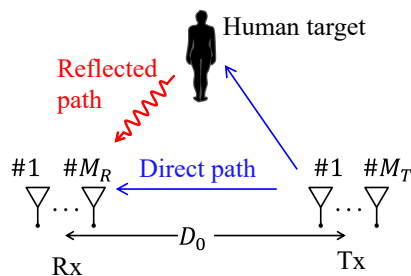


Figure 1. Model

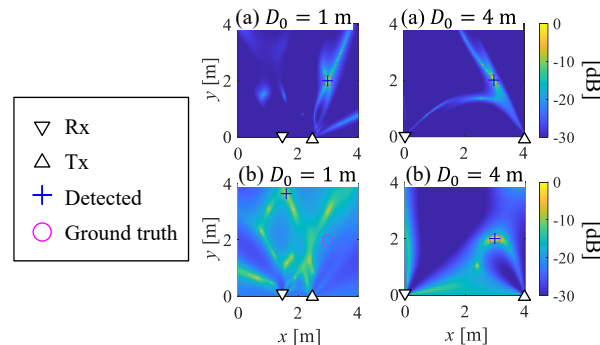


Figure 2. Capon spectrum: (a) Propagation-channel-based (b) CSI-based (w/o phase)