Fingerprint-based Positioning with Joint Antenna and Area Selection in Cell-Free Systems

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***Abstract*—–TBD...**

***Index Terms*—Fingerprint-based positioning, Antenna Selection, Cell-Free systems, Distributed MIMO, Adaptive Search Area, K-Means Clustering**

I. Introduction

II. System Model

A Cell Free System(CFS) consisting of L geographically dispersed BS/AP in the coverage area is considered for the positioning scenario. Each of the L AP is equipped with a Uniform Linear Array of N antennas. The ensemble of L APs jointly serve K single antenna UEs. It is assumed that all the L APs co-serve the K UEs by joint coherent transmission and reception. The APs are connected to edge-cloud processors called Central Processing Unit (CPU) through fronthaul links. The CPU(s) coordinate the operation of APs within the CFS. The system model is shown in Fig 1

The uplink (UL) channel from UE k to AP l, denoted by $\mathbf{h}_{kl} \in \mathbb{C}^N$ is modeled using a Coherence Block Fading model, wherein the channel coefficients are assumed remain constant for a duration corresponding to τ_c complex samples. The received combined UL signal $\mathbf{Y}_l \in \mathbb{C}^{N\times K}$ at AP l from all K UEs is given by

$$\mathbf{Y}_l = \sum_{k=1}^{K} \sqrt{\rho_k}\mathbf{h}_{kl}\boldsymbol{\phi}_k^T + \mathbf{N}_l \tag{1}$$

where ρ_k is the transmit power of UE k, $\mathbf{N}_l \in \mathbb{C}^{N\times K}$ is the combined noise at AP l with i.i.d elements distributed as $\mathcal{N}_{\mathcal{C}}(0,\sigma_n^2)$. $\boldsymbol{\phi}_k \in \mathbb{C}^{\tau_p}$, $k=\{1,2,...,K\}$ are the mutually orthogonal pilot vectors assigned to UEs when they gain access to the network i.e.

$$\boldsymbol{\phi}_i^H\boldsymbol{\phi}_j = \begin{cases} 1 & i=j \\ 0 & i\neq j \end{cases} \tag{2}$$

It is assumed that $(K \leq \tau_p < \tau_c)$ so that there is no interference between UEs due to pilot contamination, for the purpose of positioning. The signal $\mathbf{y}_{kl} \in \mathbb{C}^N$ corresponding to UE k at AP l obtained post correlating the received signal $\mathbf{Y}_l$ with the conjugate of the pilot $\boldsymbol{\phi}_k$ is given by [3]

$$\mathbf{y}_{kl} = \mathbf{Y}_l\boldsymbol{\phi}_k^H = \sqrt{\rho_k}\mathbf{h}_{kl} + \mathbf{n}_{kl} \tag{3}$$

where $\mathbf{n}_{kl} \sim \mathcal{N}_{\mathcal{C}}(\mathbf{0}_N, \sigma_n^2\mathbf{I}_N)$ and $\mathbf{h}_{kl}$ is characterized using an uncorrelated Rayleigh fading model in each coherence block i.e.

$$\mathbf{h}_{kl} \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_N, \mathbf{R}_{kl}) \tag{4}$$

Here $\mathbf{R}_{kl} = \beta_{kl}\mathbf{I}_N \in \mathbb{R}^N$ denotes the diagonal spatial correlation matrix. For β_{kl}, the large-scale fading coefficient 3GPP 38.901 Urban Micro street canyon NLOS Path Loss model [4] is adopted i.e.

$$\begin{aligned}\beta_{kl}[dB] =& 22.4 + 35.3\log_{10}(d_{kl}) + 21.3\log_{10}(f_c) \\ &- 0.3(h_{UE}-1.5) + \nu\end{aligned} \tag{5}$$

Where d_{kl} is the three dimensional distance between UE k and AP l, f_c is the carrier center frequency in GHz, h_{UE} is the vertical distance of the UE from the ground plane and $\nu \sim \mathcal{N}_{\mathcal{C}}(0,\sigma_{SF}^2)$ is the shadowing noise. While the shadowing noise can be mitigated through spatial averaging during the online phase, it persists during the offline phase due to the

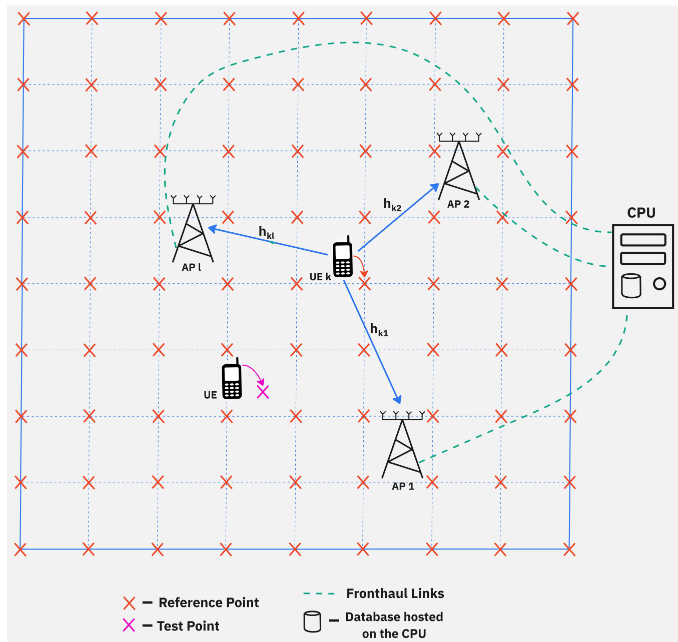

Fig. 1. System Model

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unavailability of UE position information, rendering spatial averaging infeasible [5], [6].

To mitigate the variations in RSS due to small scale fading in the UL channel $\mathbf{h}_{kl}$, modeled by the complex normal distribution in 4, channel hardening is implicitly assumed in the system [1]–[3]. RSS calculation and position estimation is performed within the duration of this hardened channel by averaging the small scale variations across multiple coherence blocks.

The estimated RSS $\boldsymbol{\theta}_{kl} \in \mathbb{R}$ for UE k at AP l, considering channel hardening is given by [2]

$$\begin{aligned}\boldsymbol{\theta}_{kl} &= \mathbb{E}\{\|\mathbf{y}_{kl}\|^2\}\\ &= \mathbb{E}\{\|\sqrt{\rho_k}\mathbf{h}_{kl} + \mathbf{n}_{kl}\|^2\}\\ &= \rho_k\mathbb{E}\{\|\mathbf{h}_{kl}\|^2\} + N\sigma_n^2\\ &= \rho_k\|\beta_{kl}\mathbf{I}_N\|^2 + N\sigma_n^2\\ &= \rho_k N\beta_{kl} + N\sigma_n^2\end{aligned} \tag{6}$$

where the expectation is with respect to the channel realizations.

Equations 5 and 6 reveal that the RSS in decibels from a UE to an AP is directly proportional to the distance between the two entities. This relationship serves as a basis for estimating the unknown location of a UE during the online positioning phase.

III. FINGERPRINT-BASED POSITIONING

1) The Offline Phase:

2) The Online Phase:

3) Joint Antenna and Area Selection (JAAS) Algorithm:

4) JAAS Complexity:

IV. SIMULATION RESULTS

V. CONCLUSION

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