Optimal Location Strategy for UAV BSs in Massive MIMO

- ML-based low-complexity algorithm to optimize the locations of UAV BSs by minimizing the collective wireless received signal strength experienced by the GNs being served.

- The proposed algorithm reduces the propagation loss in the system and provides a lower bit error rate than the widely-used Euclidean benchmark.

- Massive MIMO wireless communication setting;
- Low-complexity unsupervised ML algorithm for optimal UAV positioning according to the collective wireless channel conditions experienced by the GNs being served.
- Evaluation of bit error rate, number of UAVs in the fleet, and convergence performance.

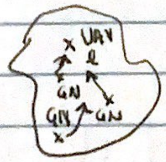
System Model

(a) L UAVs, each equipped with M antennas, each UAV capable of serving K GNs (single-antenna) simultaneously.

(b) Channel gain between k^{th} GN and m^{th} UAV antenna $\triangleq g_k^m$. (UAV l)

For UAV $l \in \{1,2,3,\ldots L\}$ (map it to clustering) : $g_k^m = \sqrt{\beta_k}\, h_k^m$, $k = 1, 2, 3, \ldots, K$; $m = 1, 2, 3, \ldots, M$.

β_k → large-scale fading coefficient (prob. LoS-NLoS distance-based) ... h_k^m → small-scale fading coefficient (Rayleigh fading with a K-factor) Rician



Channel gain between all UEs and the M UAV antennas:

$$G = \begin{bmatrix} g_1^1 & g_2^1 & g_3^1 & \cdots & g_K^1 \\ \vdots & \vdots & \vdots & & \\ g_1^M & g_2^M & g_3^M & \cdots & g_K^M \end{bmatrix}_{M \times K}$$

(c) The received signal at the UAV's m^{th} antenna is:

$$y_m = \sqrt{\rho_{UL}} \sum_{k=1}^{K} g_k^m x_k + \underbrace{w_m}_{\text{AWGN } \{\mathcal{CN}(0, \sigma^2_{noise})\}}, \quad \forall m.$$

ρ_{UL}: Uplink (UL) SNR

$$\mathbb{E}\left[|x_k|^2\right] \leq 1, \quad \mathbb{E}\left[x_k\right] = 0, \forall k.$$

$$\therefore \underline{y} = \left[y_1, y_2, y_3, \ldots, y_M\right]^T = \sqrt{\rho_{UL}} \sum_{k=1}^{K} g_k x_k + \underline{w}$$

$$= \sqrt{\rho_{UL}}\, G \underline{x} + \underline{w}, \text{ where}$$

$$\underline{x} = \left[x_1, x_2, x_3, \ldots, x_K\right]^T, \quad g_k = \left[g_k^1\ g_k^2\ g_k^3 \cdots g_k^M\right]^T, \text{ and}$$

$$\underline{w} = \left[w_1, w_2, w_3, \ldots, w_K\right]^T.$$

→ Until this point, this deployment model, communication model, and the channel model looks very similar to Hermes / ACCUSTOM.

U UAVs $\quad G$ GNs $\quad A_u$ antennas, for $u \in \{1, 2, 3, \ldots, U\}$

A_g antennas, for $g \in \{1, 2, 3, \ldots, G\}$

<u>Offline Centralized Formulation</u>

GNs with requests in $\{1, 2, 3, \ldots, G\}$ are clustered into $C = U$ clusters; $\underbrace{\text{one UAV per cluster deployed from the depot node.}}_{\text{Design this positioning \& trajectory.}}$

ADAPTED ITERATIVE VORONOI DECOMPOSITION [Morocho-Cayamcela et al.]

INITIALIZATION: Random deployment of GNs : $f_g^i = f_g, \forall g \in \mathcal{G}, \forall i;$ (fixed throughout)

$E_u^0, \forall u \in \mathcal{U}$ Initial random deployment of UAVs from depot : $f_u^0, \forall u \in \mathcal{U};$

initiate the energy cost here as well (crow-flies)

$i = 0;\ f_g^0 = \infty, \forall g \in \mathcal{G};\ \varepsilon$ given; $\mathcal{R}_u^0 = \{\}, \forall u \in \mathcal{U}.$

ITERATION: while ~~i>0 and~~ $\left| f_g^i - f_g^{i-1} \right| > \varepsilon, \forall g \in \mathcal{G}, i > 0:$

$i \leftarrow i+1;$

for $u \in \mathcal{U}$:

$$\mathcal{R}_u^i \leftarrow \left\{ f_g, \forall g \in \mathcal{G} : f_g^i\left(f_u^{i-1}\right) \leq f_g^i\left(f_{u'}^{i-1}\right), \forall u' \in \mathcal{U}, u \neq u' \right\},$$

where $$f_g^i \leftarrow \sum_{n=1}^{A_u} \left| \sqrt{P_{Tx}} \cdot \left[h_{n1}\ h_{n2}\ h_{n3} \cdots h_{nA_g}\right] \underline{x}_g + w_n \right|,$$

if $f_g \in \mathcal{R}_u^i$, and we are using an RSSI cost function ; or

$$\underline{x}_g = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_{A_g} \end{bmatrix}$$

where $f_g^i \leftarrow \left\| f_u^i - f_g \right\|_2$, if $f_g \in \mathcal{R}_u^i$ and we are using a distance cost function

3D Euclidean distance

$$\sqrt{\left(x_u^i - x_g\right)^2 + \left(y_u^i - y_g\right)^2 + \left(z_u^i - z_g\right)^2}$$

$$f_u^i \leftarrow \frac{1}{\left|\mathcal{R}_u^i\right|} \sum_{f_g \in \mathcal{R}_u^i} f_g, \quad E_u^i \leftarrow E_u^0 + \text{'Energy to fly as-the-crow-flies'};$$

with a constant hz & vert. velocity (use our energy model)

return $f_u^{*}, E_u^{*}, \forall u \in \mathcal{U}$, where i^* is the iteration index at convergence.