Locating Primary Users in Cognitive Radio Networks by Generalized Method of Moments

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PU Localization in Cognitive Networks

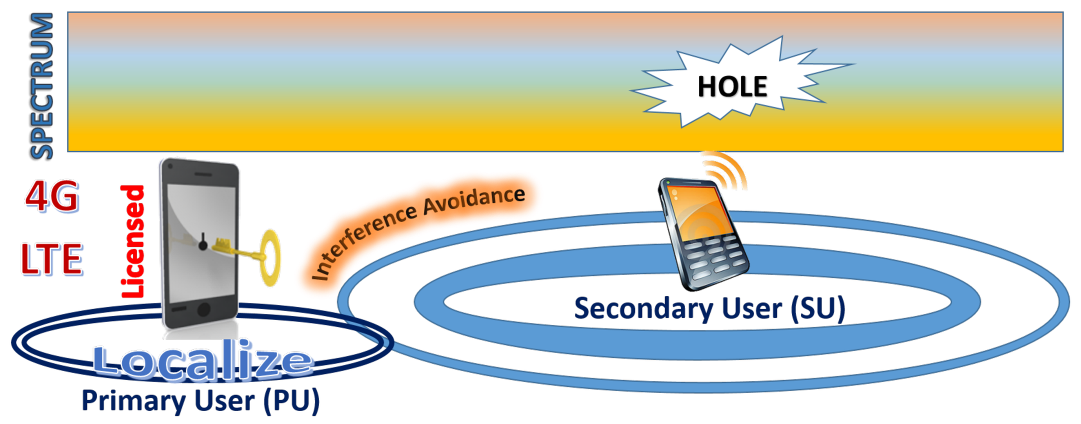

Figure 1: Spectrum Utilization by Cognitive Radio Users

Proposed Method

- **Single SU** localizes using *received signal strength*
- **GMM** estimation in **linear time**
- Localization with the **required accuracy**

Estimation with Single SU: High Accuracy Localization in Cellular Networks

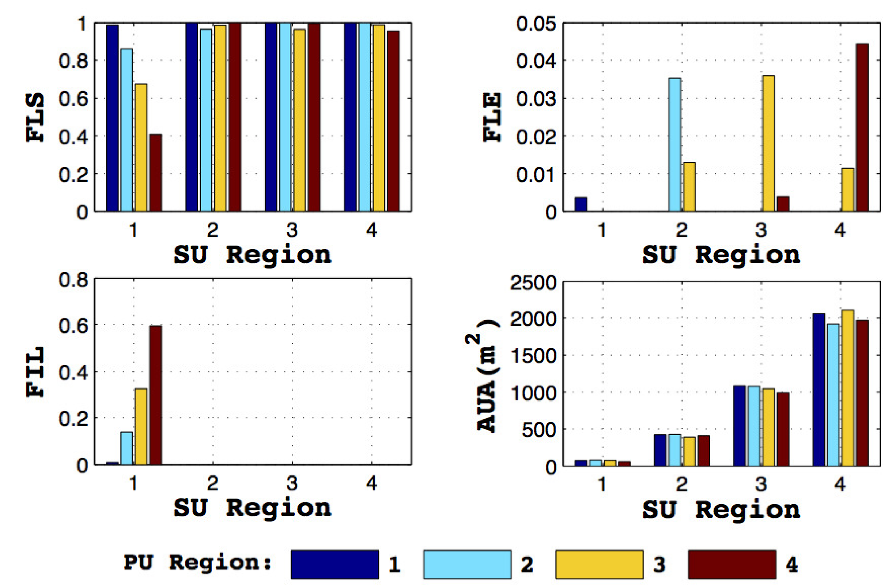

Figure 2: Downlink Results

Localization Performance Measures

- *GMM estimation*: Three possible outcomes:
1. *Fractional indecision in localization (**FIL**)* J-test fails.
2. *Fractional localization success (**FLS**)*
3. *Fractional localization error (**FLE**)*

Downlink Results

- Localization with high *FLS*
- *AUA* increases with SU's distance from the BS
- PU and SU in the same zone increases *FLE*
- High received power near the BS increases *FIL*

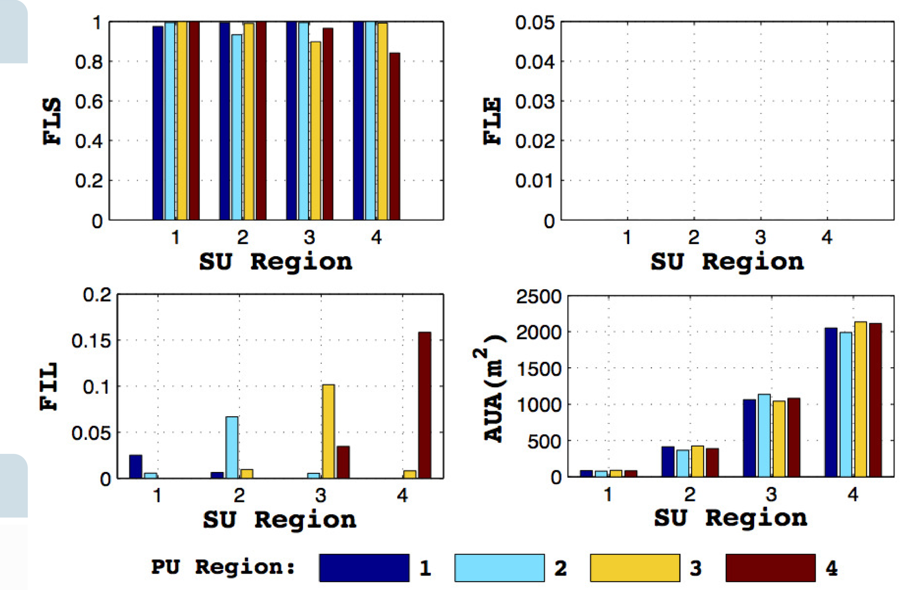

Figure 3: Uplink Results

SU Performance Measure

- *Average utilized area (**AUA**)* A notion of the coverage area of the SU

Uplink Results

- High *FLS*, specially near the BS
- *FLS* lower for PUs near to the edge
- *AUA* follows the same trend
- Successful hypothesis testing
- Negligible *FLE* in uplink
- *FIL* higher for smaller PU and SU dist

Cognitive Radio Network: System Model

Traffic Model

- Random traffic from an active PU
- Distributed uniformly over $[c_0, c_1]$

Power Control

- Base station (BS) schedules traffic
- Tx power relies on the PU location

Channel Model

- Exponential pathloss with distance
- Rayleigh fading channel

A1: An SU knows the *channel* model. **A3**: It knows the PU *traffic* model.
A2: It knows its *distance* from the BS. **A4**: *Scheduling* rule is known to an SU.

Note: The distribution of $\mathbf{P_R}$ at the SU is a function of the **k-parameter**.

k-parameter

$$k = \begin{cases} E_b\,(d_S)^{-\alpha}\,(d_P)^{\alpha}, \text{downlink} \\ E_b\,(d_{S,P_i})^{-\alpha}\,(d_P)^{\alpha}, \text{uplink} \end{cases}$$

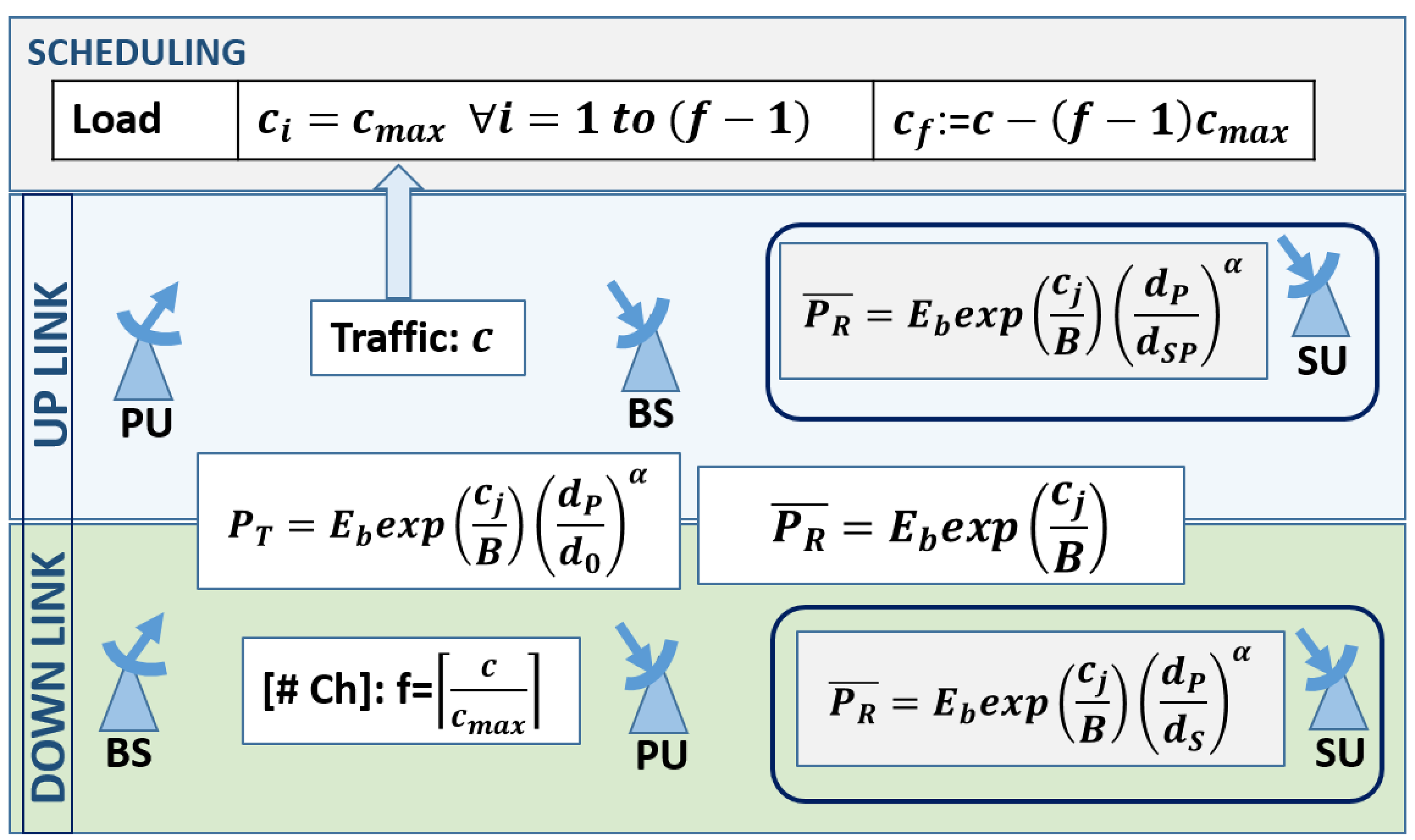

Figure 4: Signal Propagation

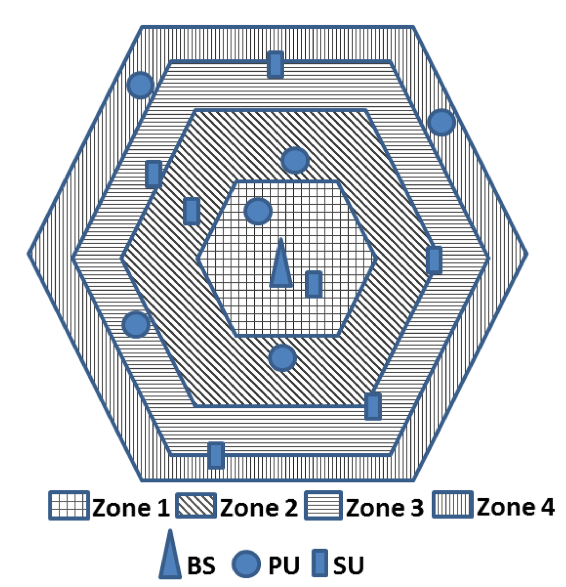

Figure 5: Cellular Network

Notations

- α, $\mathbf{d_0}$: Pathloss parameters
- $\mathbf{E_b}$:Power const $\mathbf{B}$:Channel b/w
- $\mathbf{c_j}$:Load in j-th channel
- $\mathbf{P_T}$:Tx power $\mathbf{P_R}$:Rx power
- $\mathbf{d_P}$:distance btw PU and the BS
- $\mathbf{d_S}$:distance btw SU and the BS
- $\mathbf{d_{SP}}$:distance btw PU and SU

GMM Estimation

- **GMM** [1] used to estimate **k-parameter**
- PU localization with estimated **k-parameter**

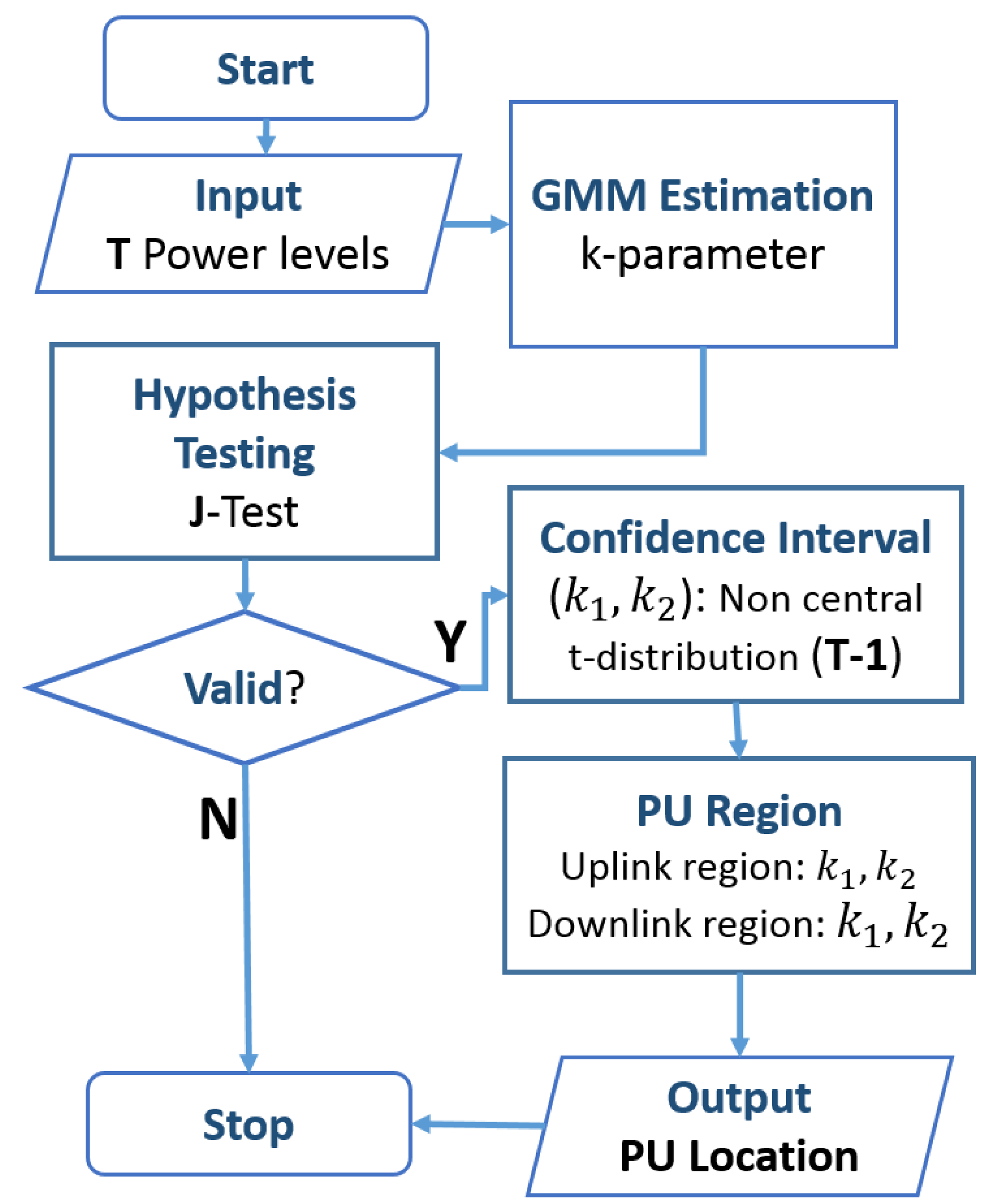

Figure 6: GMM Estimation Flowchart

Geometric Localization of the PU

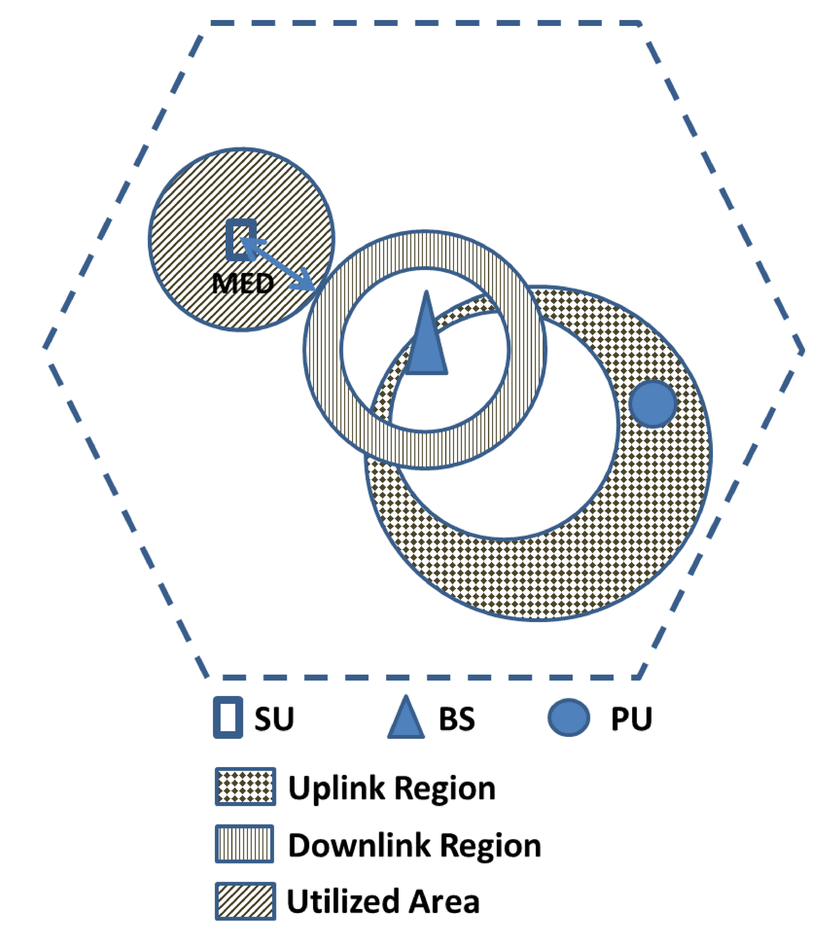

Figure 7: PU Localization

PU Location

- **Downlink region**: PU downlink transmission
- **Uplink region**: PU uplink transmission
- **PU region**: Union of *downlink* and *uplink* regions
- **Minimum estimated distance (MED)**: The distance of the SU from the *PU region*
- **Utilized area (UA)**: Area of the circle centered at SU with radius *MED*.

Future Work

- Adopting traffic arrival models, e.g. **Poisson**
- Adopting channel allocation, e.g. **water-filling**
- **SU collaboration** to increase the utilization
- Developing **power allocation** algoritms for SUs

Acknowledgement

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References

[1] A R Hall. *Generalized Method of Moments*. OUP, 2005.