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Self-organizing Networks for 5G: Directional Cell Search in mmW Networks

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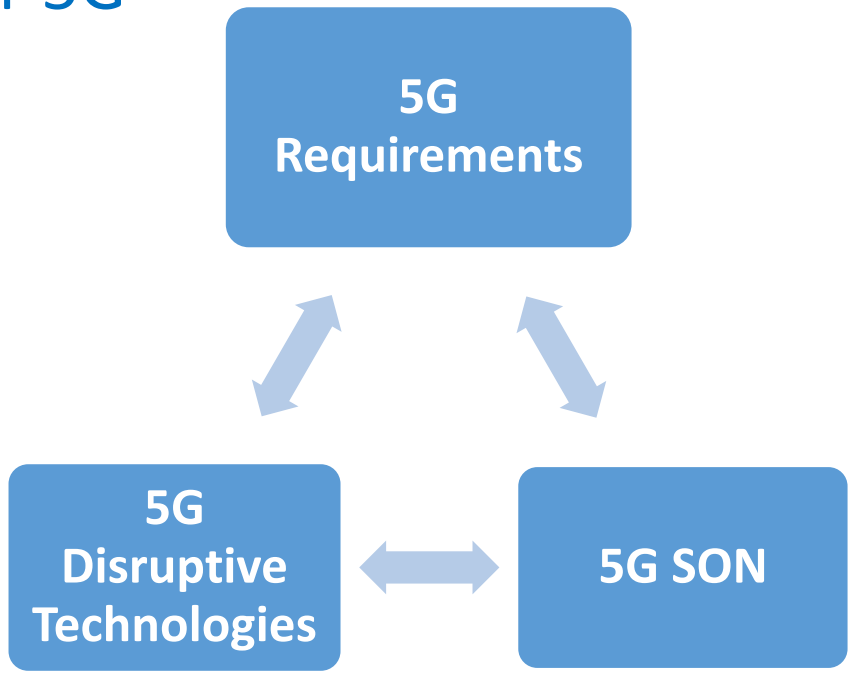
Overview

- Road to 5G SON
  - Possible use-cases for 5G SON
  - SON based on graph models
- Directional Cell Search(DCS) for mmW Networks
  - System model considered for DCS
  - Proposed framework for self-organized DCS
  - Beam assignment algorithm for DCS
  - Simulation results
- Conclusion and Future Work

SON for 5G

- Paradigms of 5G
  - Massive broadband
  - Massive M2M communication
  - Ultra-reliable communication
- Disruptive Technologies for 5G
  - Massive MIMO
  - millimeter wave (mmW)
  - Multi-RAT
  - SDN & C-RAN
- SON for 5G
  - Potentials & Challenges
  - User-centric
  - SDN-enabled



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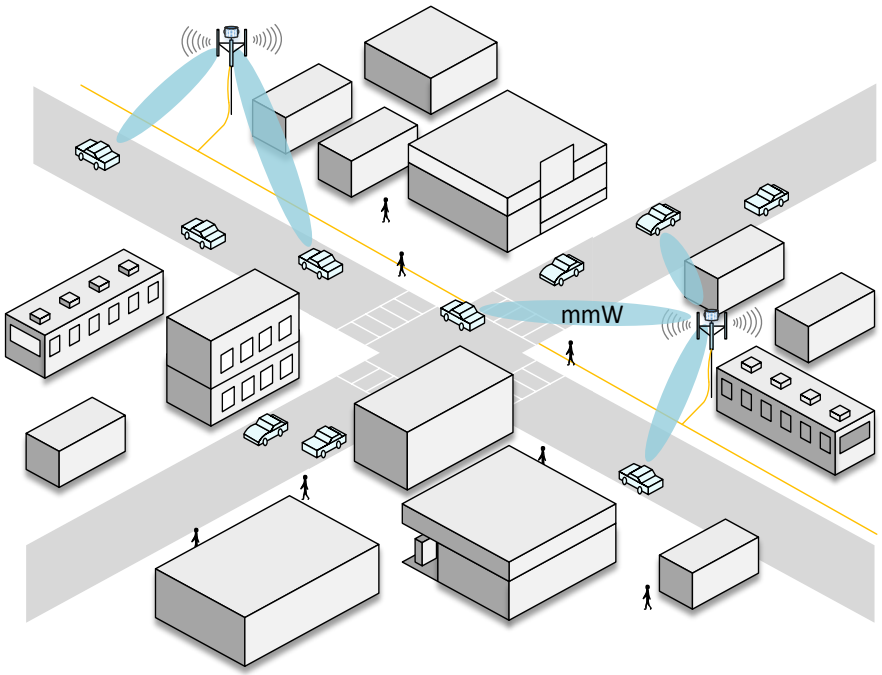
Road to 5G SON: Use Cases

- Spectrum Management and Sharing
  - Inter-operator spectrum sharing
- Optimization of User Association
  - User association for mmW network
- Multi-RAT Optimization
  - RAT-selection
  - Traffic steering
  - Inter-RAT handover
- **Directional Cell Search**
  - mmW beamforming for both data and control channel
  - Configuration of beams for efficient discovery



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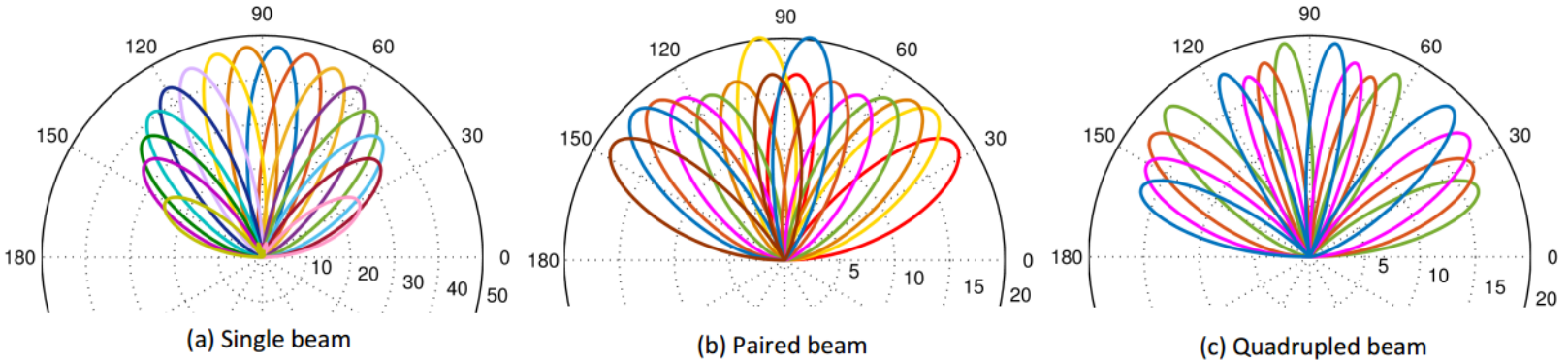
Road to 5G SON : Graph Models

- The actual complicated network state can be abstracted and modeled as a network graph.
- Nodes can be various physical and logical entities: such as TX/RXs, links, cells, sectors, beams etc.
- Edges can be channel coefficients, interferences, various couplings.
- Graph based models simplify the modeling and abstraction of networks, paving the way for efficient network-wide resource allocation and management.

Directional Cell Search : System Model

- Network consisting of I base stations
- Each cell has B analog beams for cell discovery
- Time division multiplexing for beam broadcast
- Handover margin (HOM) specifies handover users



Analog beamforming for 8×8 planar array

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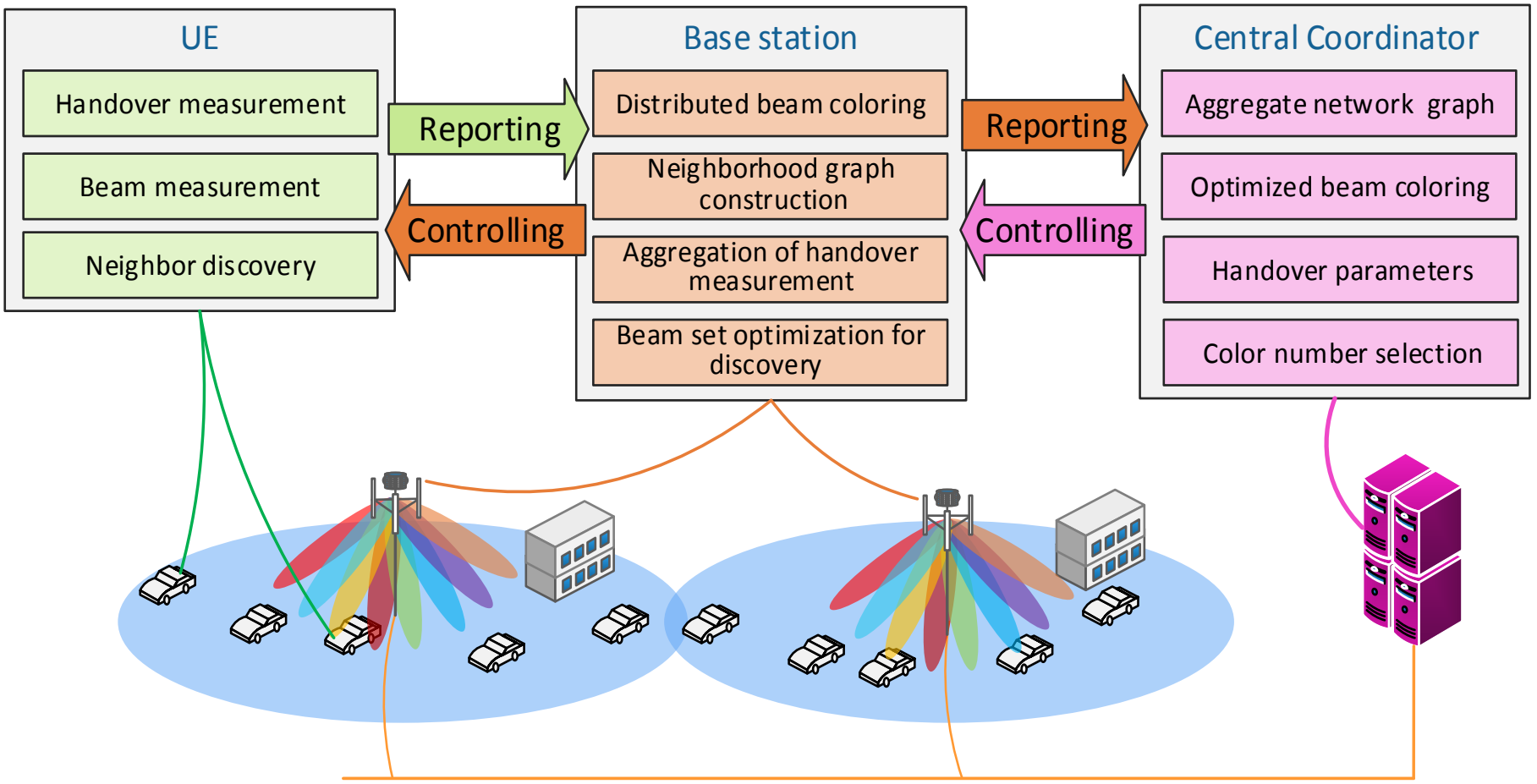
Directional Cell Search : Aggregation of Measurements & Control



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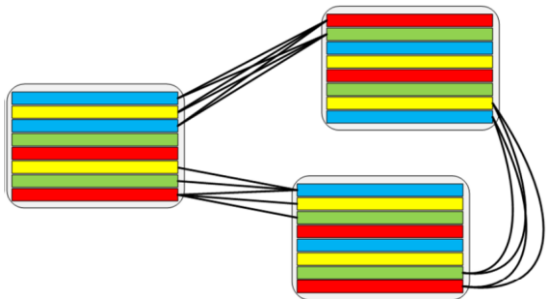
Directional Cell Search : Graph Multicoloring Formulation

- Consider Handover Relationships between Cells for History Users.
- Let $G(\mathcal{I}, \mathcal{E}, w)$ denote a multigraph representation of the network, A function w related to interference is defined on the edge set $\mathcal{E}$.
- *Weighted Directed Multigraph*: The graph is constructed on the basis of user measurements by considering interference-to-carrier (I/C) ratios between the strongest beam of potential handover candidate cell, and the beams in own-cell.

Directional Cell Search : Graph Multicoloring Formulation

- A user receives multiple beams with varying powers from each base station.
- There are potential handover candidate beams from neighbor cells
- For each history handover user, there exists a single potential handover beam.
- An I/C vector is calculated based on the interference a user receives from its own-cell beams and the received power from potential handover beam.



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Directional Cell Search : Beam Assignment Algorithm

Algorithm 1 Beam Assignment Algorithm

1: Cell i using a valid beam schedule c, selects a new schedule $c' = \mathrm{RandPerm}\{c\}$ for cell i. Keep the beam schedules for other cells fixed.
2: Find the set of UEs $\mathcal{U}_i$ which are associated with cell i. For $\mathcal{U}_i$, calculate the I/C vector V_c and $V_{c'}$ for beam schedules c and c'. Compute $\Delta = \max(V_{c'}) - \max(V_c)$,
3: **if** $\Delta < 0$ **then**
4: $\quad c \leftarrow c'$
5: **else**
6: $\quad c \leftarrow c$
7: **end if**

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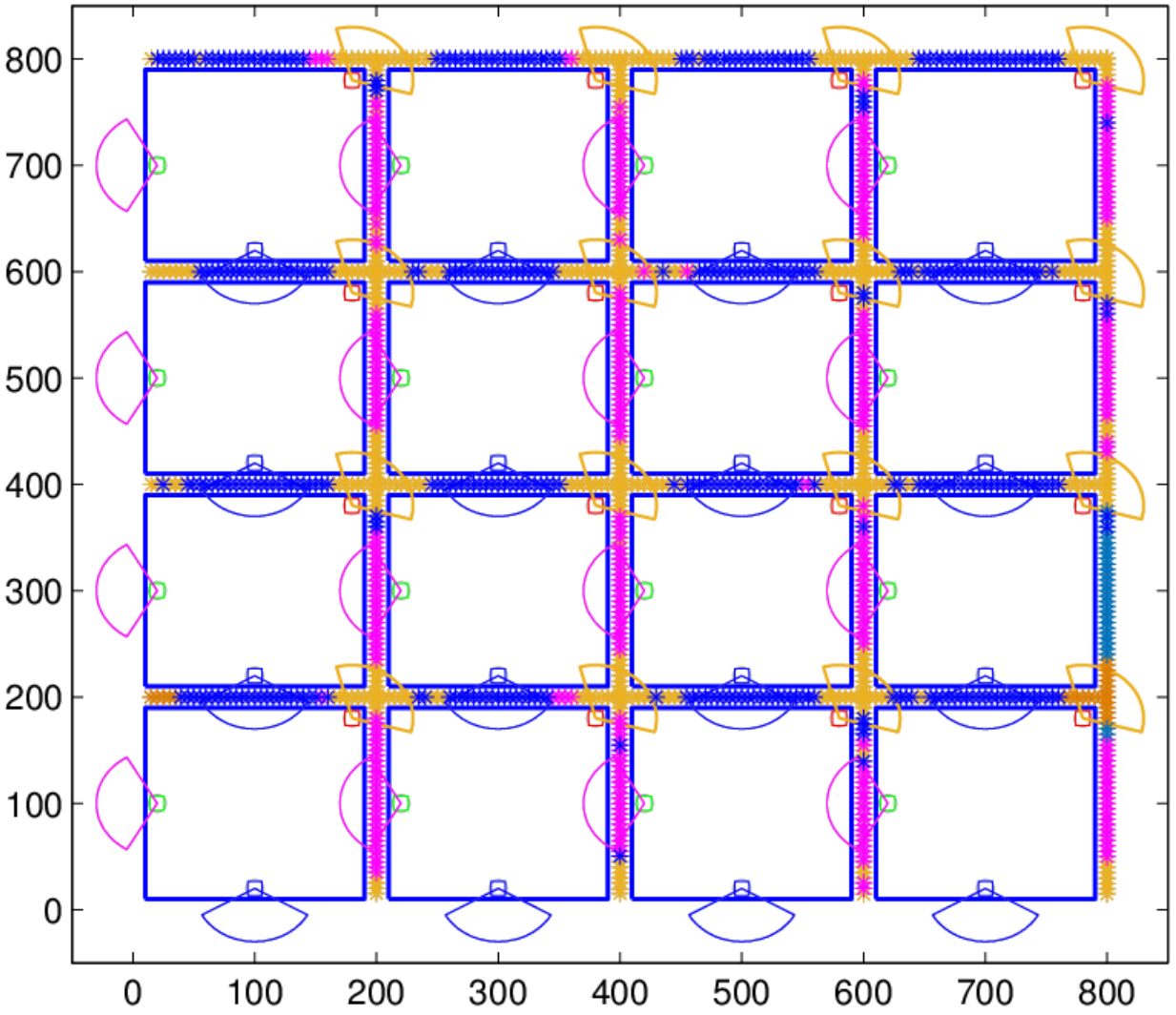
Directional Cell Search : Simulation Setting

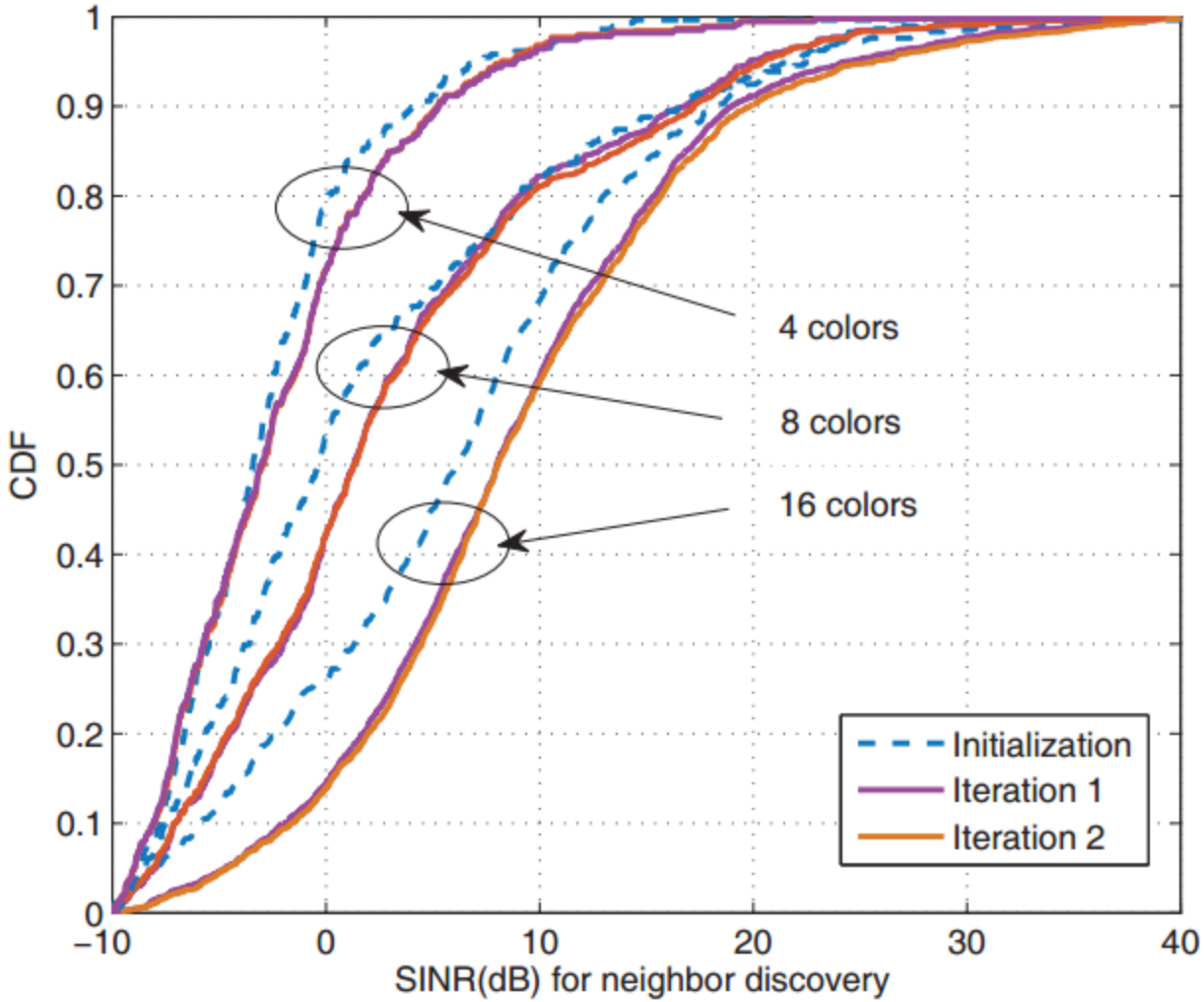
TABLE I
SIMULATION PARAMETERS

Simulation Configuration	
Scenario	Manhattan grid, 800 × 800m
Boundary conditions	Wrap-around in all directions
Average Inter-site Distance	100m
Number of BSs	48
Number of UE positions	2560
mmW carrier frequency	28 GHz
LOS PL model for mmW	$61.4 + 20\log_{10}(d)$
NLOS PL model for mmW	$72.0 + 30\log_{10}(d)$
LOS probability model	$\left(\min\left(\frac{d_1}{d}, 1\right)\left(1 - \exp\left(\frac{-d}{d_2}\right)\right) + \exp\left(\frac{-d}{d_2}\right)\right)^2$
LOS correlation distance	10 m
Maximum mmW TX power	24 dBm
mmW antenna for BS	8 × 8 planar array
Beamforming setting	Analog beamforming with simple precoding
Number of beams	16, 8 or 4
Number of colors	16, 8 or 4
Handover margin(HOM)	10dB

Directional Cell Search : Simulation Setting



Directional Cell Search : Simulation Results



Directional Cell Search : Simulation Results

- The setting of 16 colors with 16 directional single beams results in best handover discovery SINR performance.
- Using less colors results in less overhead in neighbor cell search, but SINR performance will degrade and leads to an increased number of Radio Link Failures (RLFs).
- One iteration is almost optimal by local update of color patterns for each cell.

Future Work

- Extending the proposed self-organization framework to model other relevant aspects of 5G SON, most notably energy efficiency.
- Joint self-optimization of multiple parameters such as beam direction and transmission power.