IWN Final Project – 5G HO simulator

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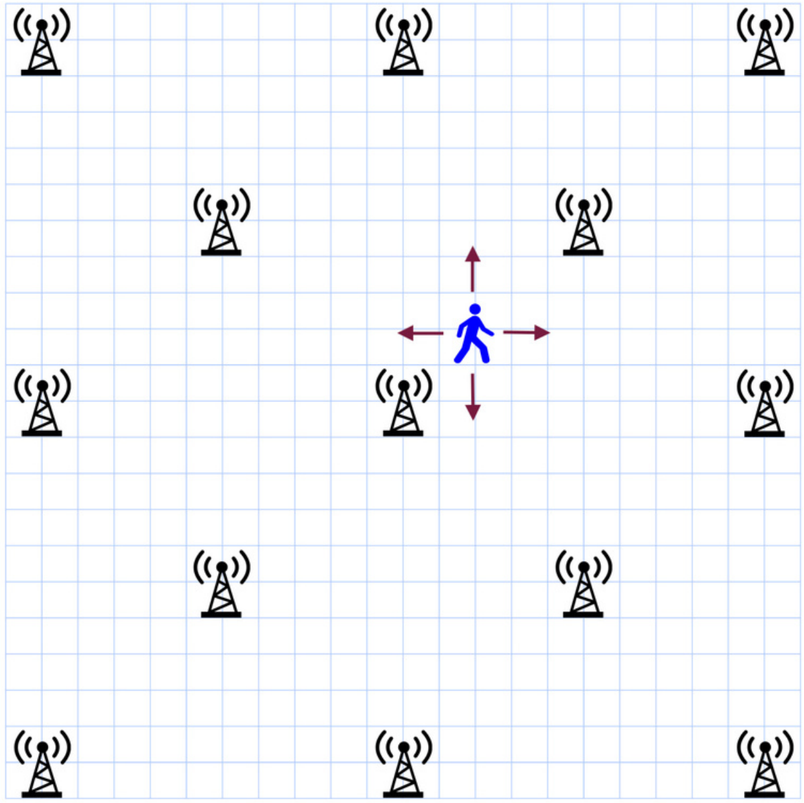
OUTLINE

- Introduction
- Functions
- Experiments
  - **Distance** Based HO
  - **SINR** Based HO
- Comparison & Conclusions
- Reference

INTRODUCTION

5G HO Simulator

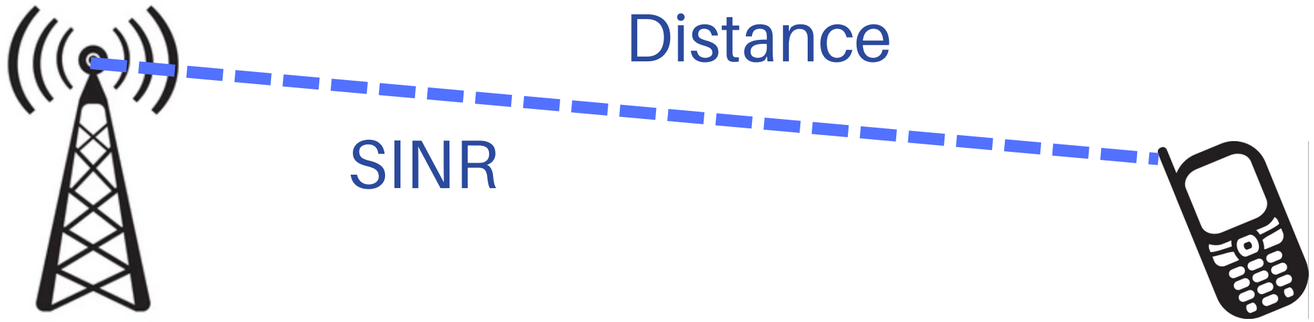
- A simple 5G Handoff simulator written in Python.
- This mobile simulator emulates the devices handoff within a **5G network**
- The simulator operates in a **45x45** grid environment shown below:



System Design – Base Station

- Base Station **Indicators**:
  - **Equivalent favoritism** towards all base stations, able to constantly **monitor the 3 closest/best SINR** base stations

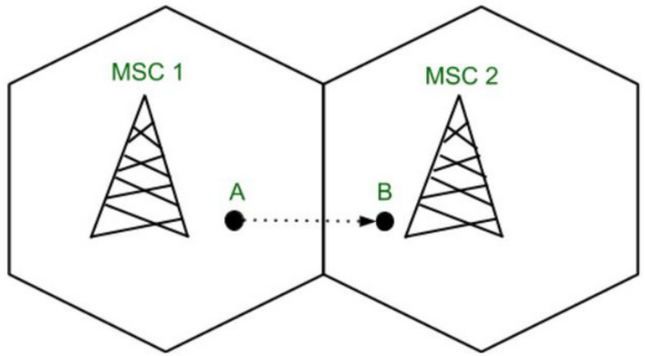
- Base Station **Allocation**:
  - Allocation represents the **combined/average performance** measured by the users
  - We chose 9, 7, and 5 to show a more **significant difference** in allocations (for comparison)



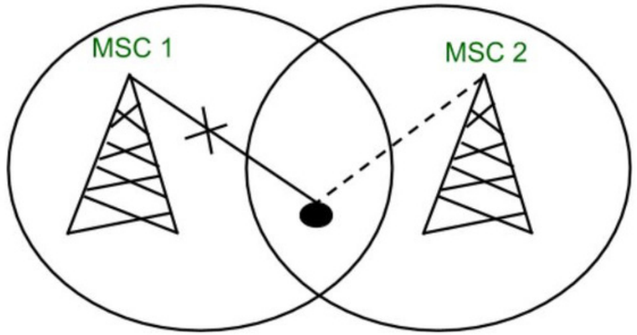
Soft vs Hard Handoff

Defining Handoff

- Check the 3 best SINR/Distance
  - After each step, check it
- **Hard** Handoff
  - break in the connectivity **immediately** after not in region
- **Soft** Handoff
  - keep connection **for a while**, then break once device continues to leave the region and connect to the other base station.



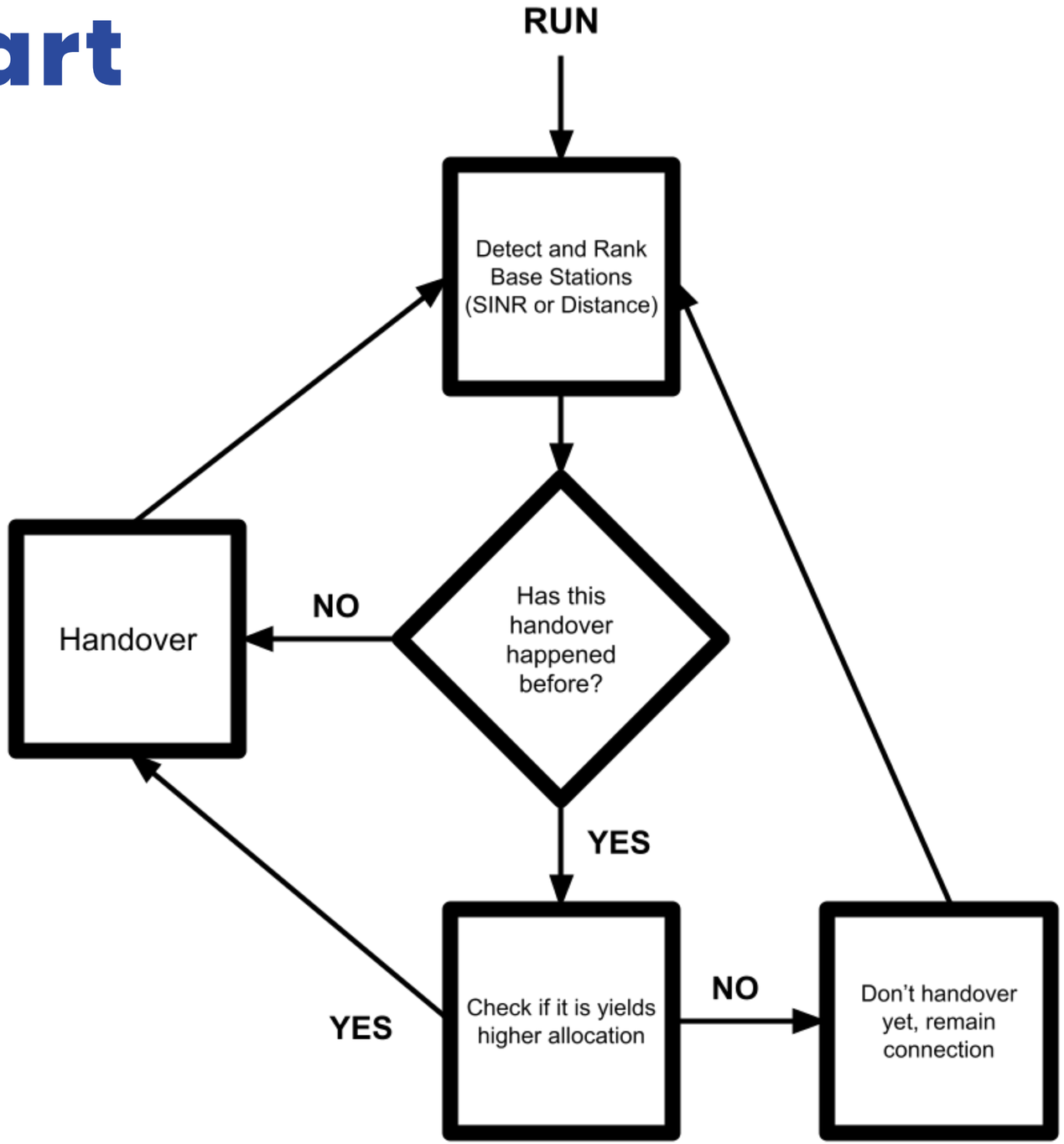
Hard Handoff



Soft Handoff

Photo Reference:https://www.geeksforgeeks.org/handoff-in-cellular-telecommunications/

Flow Chart


RUN
Detect and Rank Base Stations (SINR or Distance)
Has this handover happened before?
NO
Handover
YES
Check if it is yields higher allocation
YES
NO
Don't handover yet, remain connection

5G HO Simulator

- The simulation starts with a device placed at grid **position [23,23]** since we have a **BS at [22,22]** and we have to make sure that the **distance won't be zero**

- From here the device does a **random walk** at the speed you want (entered by the user and each step represents a block). This walk is completed continuously 15000 times for a single round of simulation by default.

- The function that user can **enter** the speed, BW, BS and MS power.

```
speed, BW, ptx, pm = map(int, map(str.strip, input("Enter speed, BW, BS power(dB), MS power(dB) separated by comma: ").split(',')))
```

FUNCTIONS

Functions for Calculation

- **get_distance**: output would be a list contains 13 distances

```
def get_distance(coords):
  total_distance = []
  for bs in BS_coords:
    delta_x = bs[0]-coords[0]
    delta_y = bs[1]-coords[1]
    distance = math.sqrt(delta_x**2 + delta_y**2)
    total_distance.append(distance)
  return total_distance
```

- **get_bs**: output would be a list contains 3 **closest** base stations

```
def get_bs(coords, debug=False):
    if debug: print("Mobile Position: " + str(coords))
    closest_bs = []
    distances = []
    distances = get_distance(coords)
    closest_bs = np.argsort(distances)[:3]
    closest_bs = [x+1 for x in closest_bs]
    if debug: print("Closest Base Stations are :", closest_bs)
    return closest_bs
```

Functions for Calculation

- **get_receivepower**: output is a list contains 13 receive power

```
def get_receivepower(gd):
  PR = []
  for x in gd:
    pr = x*ptx_W*g_bs_W*g_m_W
    PR.append(pr)
  return PR
```

- Here we consider the **path loss** only radio propagation (without shadowing and fading). And we use **Two-ray-ground** model as the propagation model for our simulation.
- **gd** is the list of the 13 path loss

- **get_interference**: output is a list contains 13 interferences

```
def get_interference(PR):
  interference = []
  pr_all = sum(PR)
  for pr in PR:
    temp = pr_all - pr
    interference.append(temp)
  return interference
```

- We do **DL** in our simulation
- Interference is caused by all the **other BS**

Functions for Calculation

- **get_SINR**: output is a list contains 13 SINR

```
def get_SINR(PR, interference):
  SINR = []
  for i in range(len(PR)):
    temp = PR[i]/(interference[i]+noise)
    SINR.append(temp)
  return SINR
```

- **get_bs_sinr**: output is a list contains 3 base stations with **largest SINR**

```
def get_bs_sinr(coords, debug=False):
  if debug: print("Mobile Position: " + str(coords))

  chosen_bs = []
  distance = get_distance(coords)
  pathloss = get_pathloss(distance)
  receive_power = get_receivepower(pathloss)
  interference = get_interference(receive_power)
  SINR = get_SINR(receive_power, interference)
  chosen_bs = np.argsort(SINR)[::-1][:3]
  chosen_bs = [x+1 for x in chosen_bs]
  if debug: print("Closest base stations are :", chosen_bs, "SINR be like: ", SINR)
  return chosen_bs
```

Functions for Experiment

- **mobile_move**: simulate the device's movement

```
def mobile_move(location, n):
    current_x = location[0]
    current_y = location[1]
    for i in range(n):
      valid_step = False
      while not valid_step:
        step = random.choice(['N', 'W', 'E', 'S'])
        new_x = current_x
        new_y = current_y
        if step == 'N' and current_y < 44:
          new_y = current_y + 1
        elif step == 'S' and current_y > 0:
          new_y = current_y - 1
        elif step == 'E' and current_x < 44:
          new_x = current_x + 1
        elif step == 'W' and current_x > 0:
          new_x = current_x - 1
        if (new_x, new_y) not in BS_coords:
          valid_step = True
          current_x = new_x
          current_y = new_y
    return (current_x, current_y)
```

```
def get_allocation(low_service_area, BS, coords):
    allocation = BS_allocations[BS-1]
    if low_service_area:
        if coords in low_service_areas:
            allocation = low_service_area_allocation
    return allocation
```

- **get_allocation:** set the allocation to the grid it passed

Functions for Experiment

- **main_function:**

```
def main_function(soft_handoff=False, low_service_area = False, num_trials=10, num_walks=1000, num_steps=5, exp_type = "distance", debug=False):
```

  - **soft_handoff**: determine the type of HO
  - **low_service_area**: determine the allocation 1 area exists or not
  - **num_trials**: how many round we'll walk in a single experiment
  - **num_walks**: how many walk per round
  - **num_steps**: how many steps per walk (1 step = 1 grid)
  - **exp_type**: enter "distance" or "sinr"
  - **debug**: enter True if we need to debug

Functions for Experiment

- **main_function:**
  - **HO decision:**

```
if current_rank[0] != new_rank[0]:
    handoff_events += 1
    handoff = current_rank + new_rank
    handoff = tuple(handoff)
```

```
if handoff not in handoff_record:
    if debug: print("New handoff")
    new_allocation = get_allocation(low_service_area, new_rank[0], mobile_coords)
    difference = new_allocation - current_allocation

    allocation_dict[handoff] = difference

    handoff_record[handoff] = True

    current_rank = new_rank
    current_allocation = new_allocation
    handoff_counter += 1
```

  - **HO type:**

```
else:
    if allocation_dict[handoff] >= handoff_threshold: # If expected allocation is higher, make the handoff
        if debug: print("Better Handoff, handoffing to new base station.")
        new_allocation = get_allocation(low_service_area, new_rank[0], mobile_coords)
        current_allocation = new_allocation
        handoff_counter += 1
    else: # If expected allocation is lower:
        if not soft_handoff: # If soft_handoff is not activated make the handoff(false)(hard handoff)
            new_allocation = get_allocation(low_service_area, new_rank[0], mobile_coords)
            current_allocation = new_allocation
            handoff_counter += 1
        else:
            if debug: print("Worst Handoff, not handoffing to new base station.")
            if new_rank[0] == 5 and mobile_coords in low_service_areas:
                current_allocation = 7
            else:
                neglected_counter += 1
            pass # If soft_handoff is activated(true) do not make the handoff(soft handoff)
```

EXPERIMENTS
-DISTANCE BASED

Distance Based HO Introduction

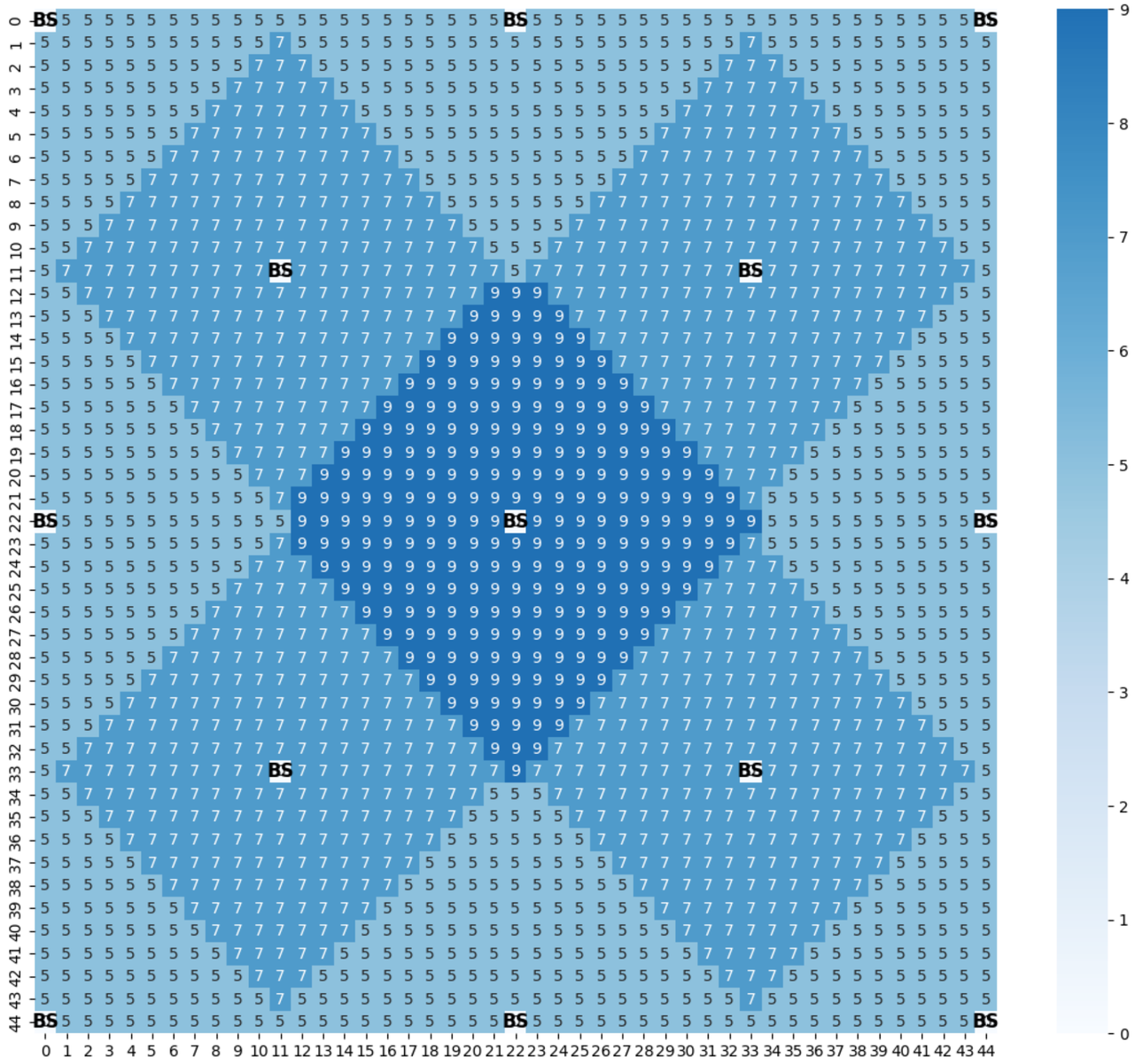
- The simulation environment runs two different simulations:

1. The default behavior of connecting to the **closest** base station is used

2. An **override** is performed in certain conditions to enhance performance

- We also do the experiment that having **low service** area in both type of HO
- Number of Trials = 300, Number of Walks = 15000, Number of Steps = 10

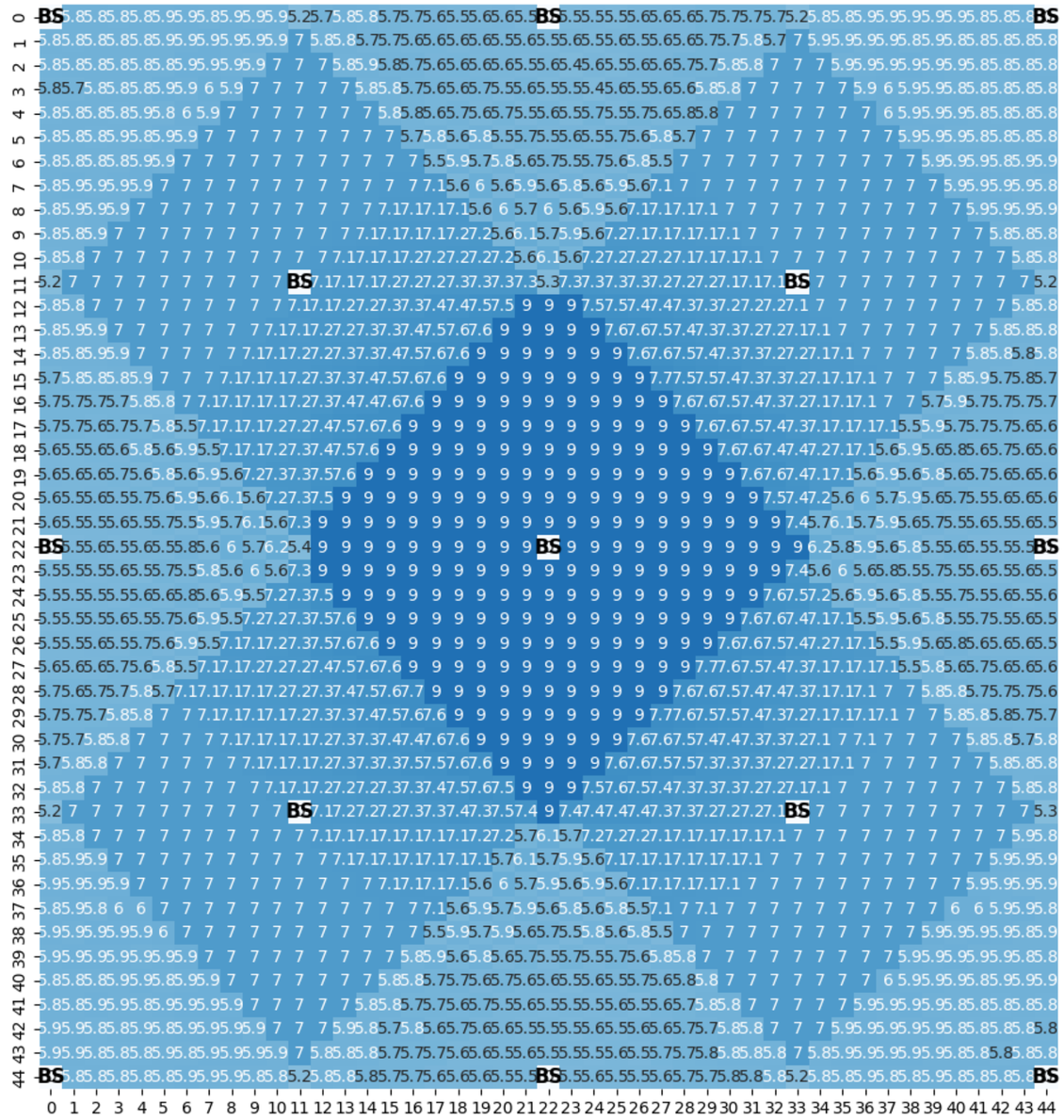
Distance Based HO Observation



- **Hard** HO Allocation Map
- Having pretty clear distribution
- As long as passing the board, handover occurs **immediately**

```
if not soft_handoff:
    new_allocation = get_allocation(low_service_area, new_rank[0], mobile_coords)
    current_allocation = new_allocation
    handoff_counter += 1
```

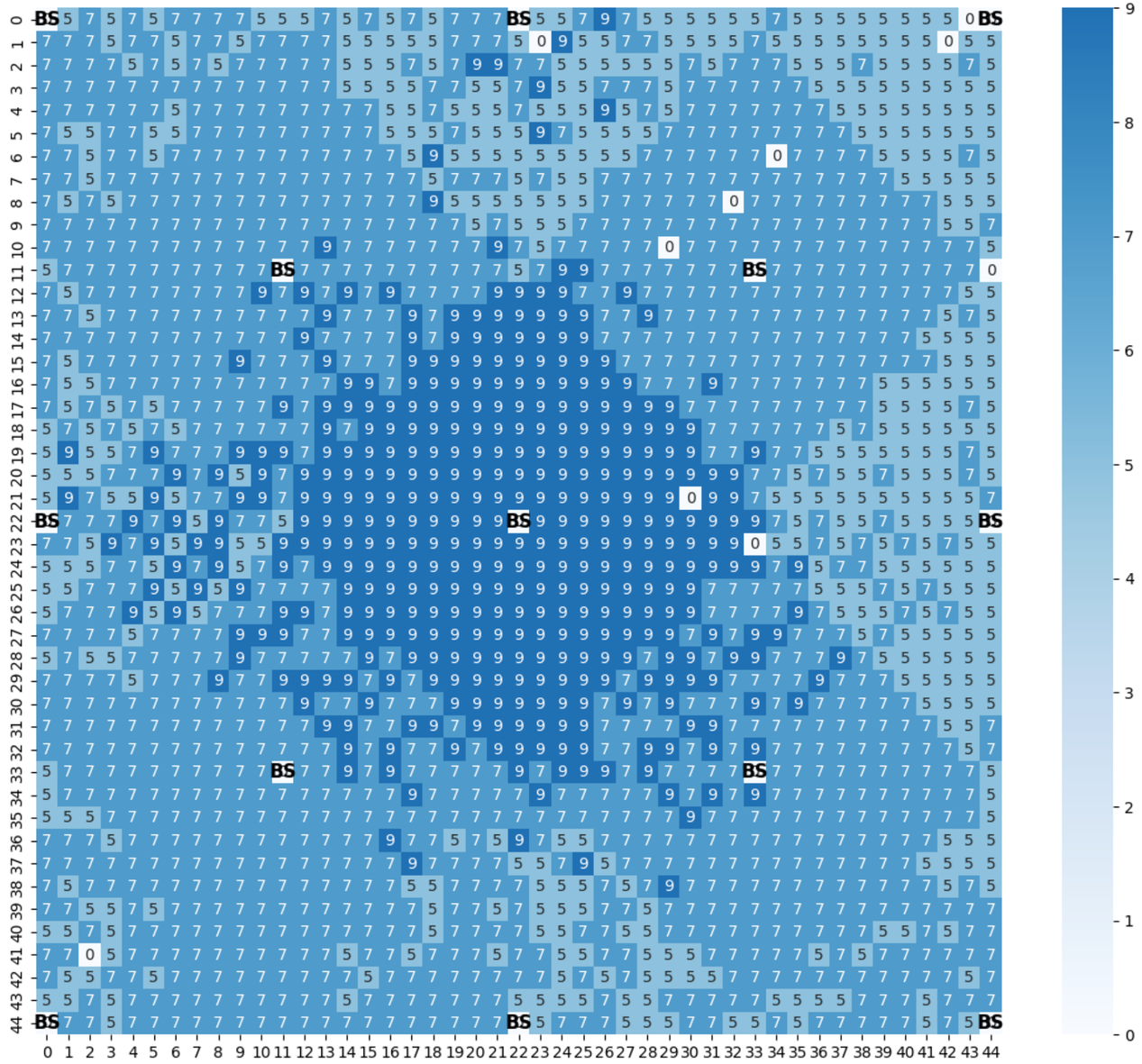
Distance Based HO Observation



- **Soft** HO Allocation Map
- For the **pass**: If soft handoff is activated (true), do not make the handoff (soft handoff)
- The HO occur when the device **continues leaving** the BS
- The **closer** to the center, the **better** the performance is

```
else:
    if debug: print("Worst Handoff, not handoffing to new base station.")
    if new_rank[0] == 5 and mobile_coords in low_service_areas:
        current_allocation = 7
    else:
        neglected_counter += 1
    pass
```

Distance Based HO Observation



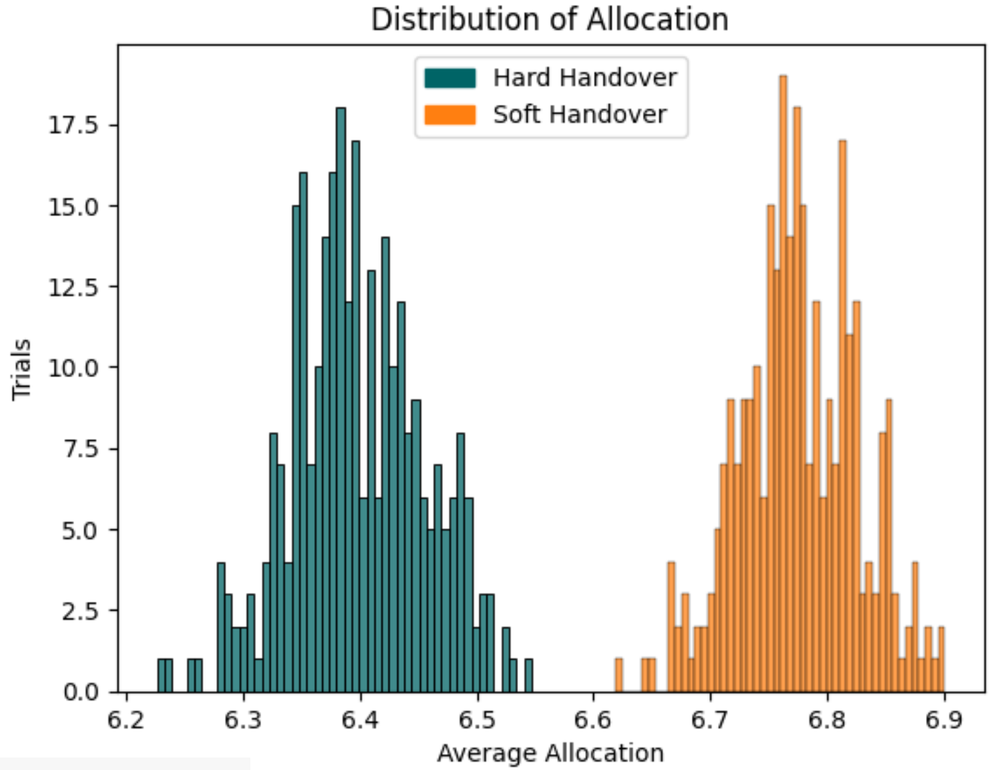
- **Single** round of **soft** HO Allocation Map
- Some of the grid is **0** for **not passing** the grid yet
- The **Closer** to the center, the **better** the performance

Distance Based HO Observation

- **Final Simulation Result**

```
Normal Environment / Distance_Based / Hard Handoff Mobile:
All Handoff Events:  1922045
Neglected(soft) handoffs:  0
Actual handoffs:  1922045
Neglect Percentage:  0.0
Average Allocation: 6.397113777777778
Min Allocation: 6.226266666666667
Max Allocation: 6.5468

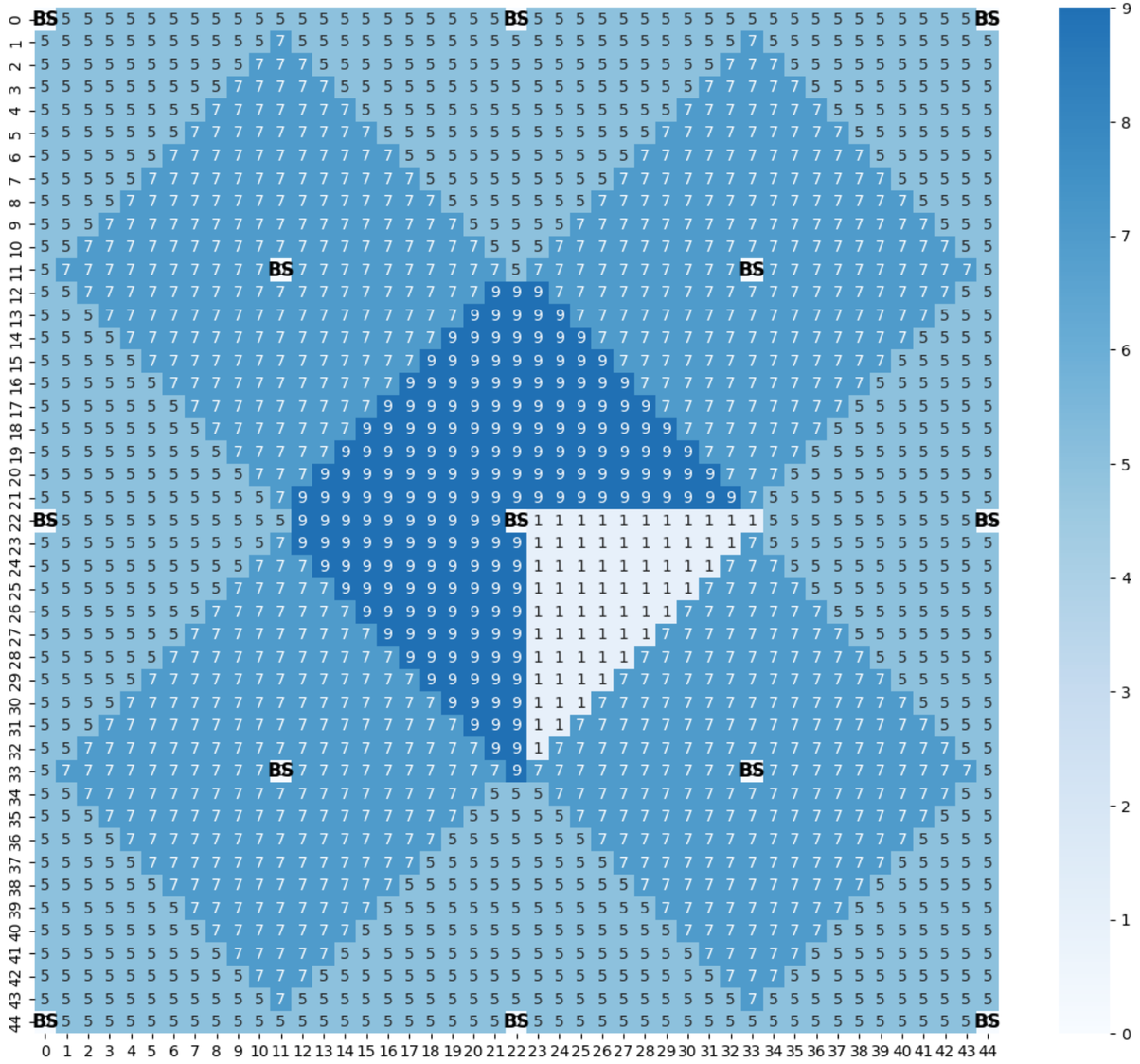
Normal Environment / Distance_Based / Soft Handoff Mobile:
All Handoff Events:  1928715
Neglected(soft) handoffs:  855000
Actual handoffs:  1073715
Neglect Percentage:  0.4433
Average Allocation: 6.776071555555556
Min Allocation: 6.619066666666667
Max Allocation: 6.9008
```




```
else: # If expected allocation is lower:
    if not soft_handoff: # If soft_handoff is not activated make the handoff(false)(hard handoff)
        new_allocation = get_allocation(low_service_area, new_rank[0], mobile_coords)
        current_allocation = new_allocation
        handoff_counter += 1
    else:
        if debug: print("Worst Handoff, not handoffing to new base station.")
        if new_rank[0] == 5 and mobile_coords in low_service_areas:
            current_allocation = 7
        else:
            neglected_counter += 1
        pass # If soft_handoff is activated(true) do not make the handoff(soft handoff)
```

- This is how we determine **neglect** the HO or not

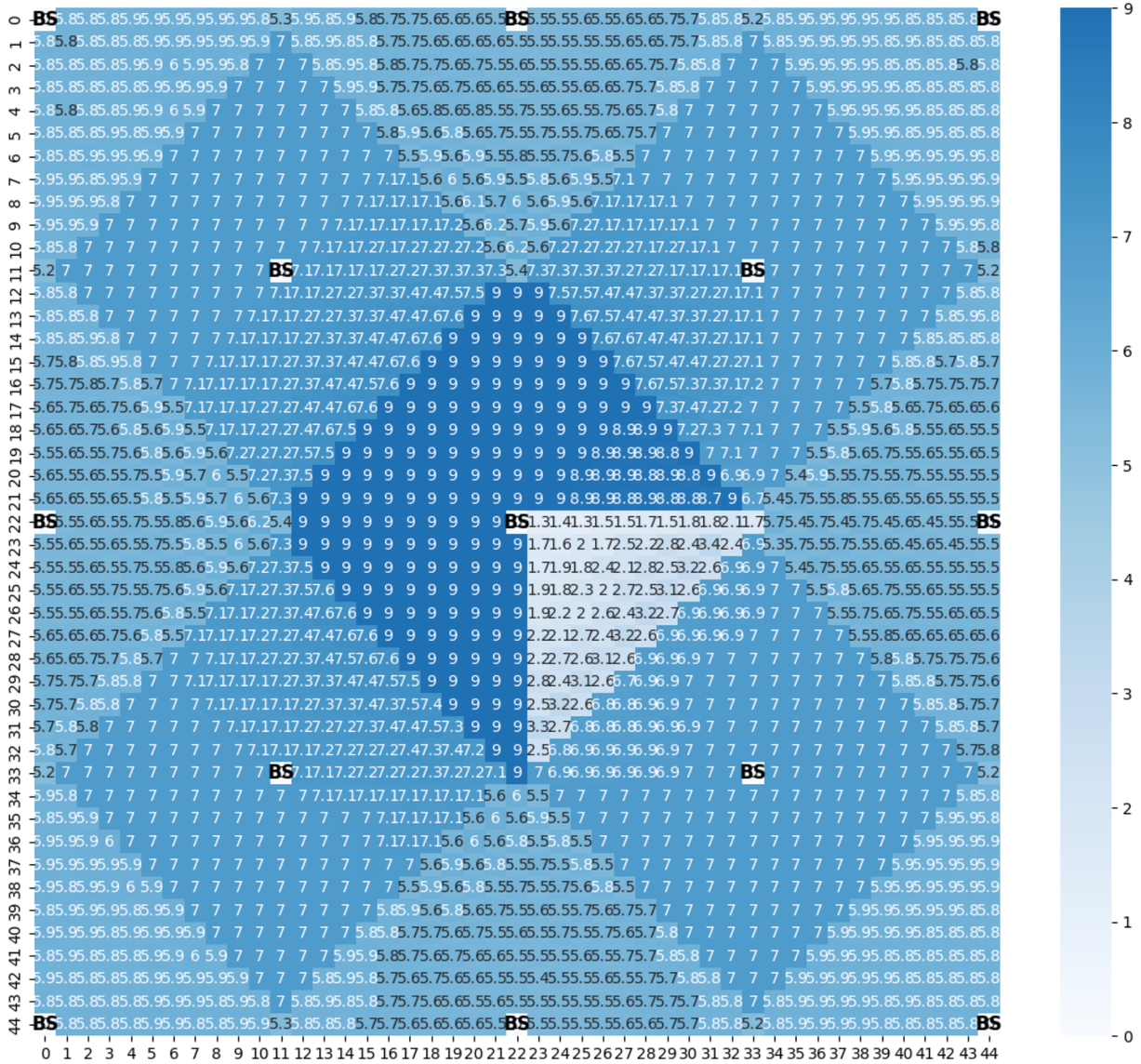
Distance Based HO Observation



- **Hard** HO Allocation Map
- As long as passing the board, handover occurs **immediately**
- Considering **low service area**
- If MS is in **low service area**, the allocation is **1**

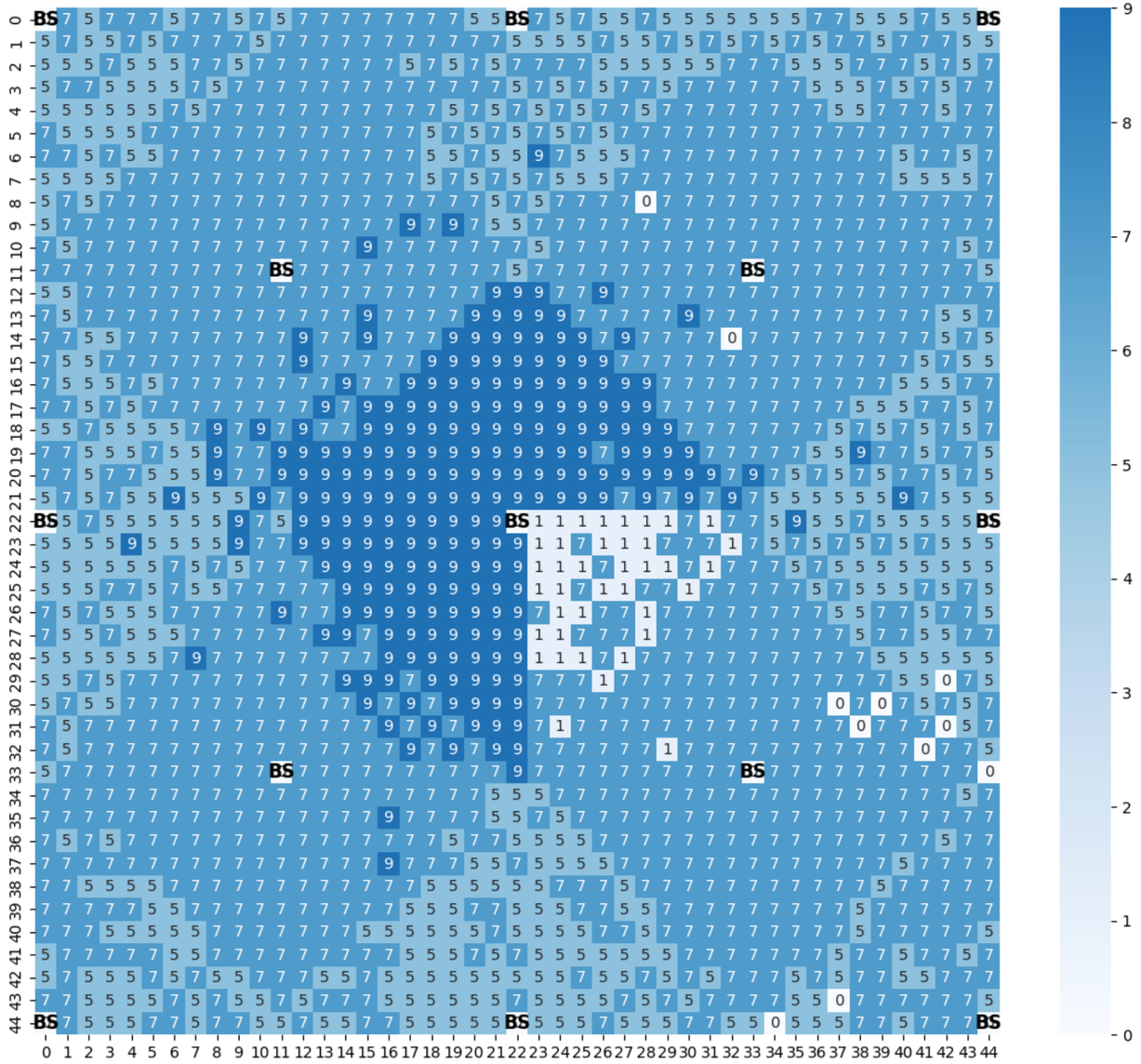
```
def get_allocation(low_service_area, BS, coords):
    allocation = BS_allocations[BS-1]
    if low_service_area:
        if coords in low_service_areas:
            allocation = low_service_area_allocation
    return allocation
```

Distance Based HO Observation



- **Soft** HO Allocation Map
- Considering **low service area**
- If MS moves from **9 to 1** area: set to **1**
- If MS moves from **5 or 7 to 1** area: set to **7**
  - since it's closer to BS10 (allocation=7)
- The **closer** to the center, the **better** the performance is

Distance Based HO Observation

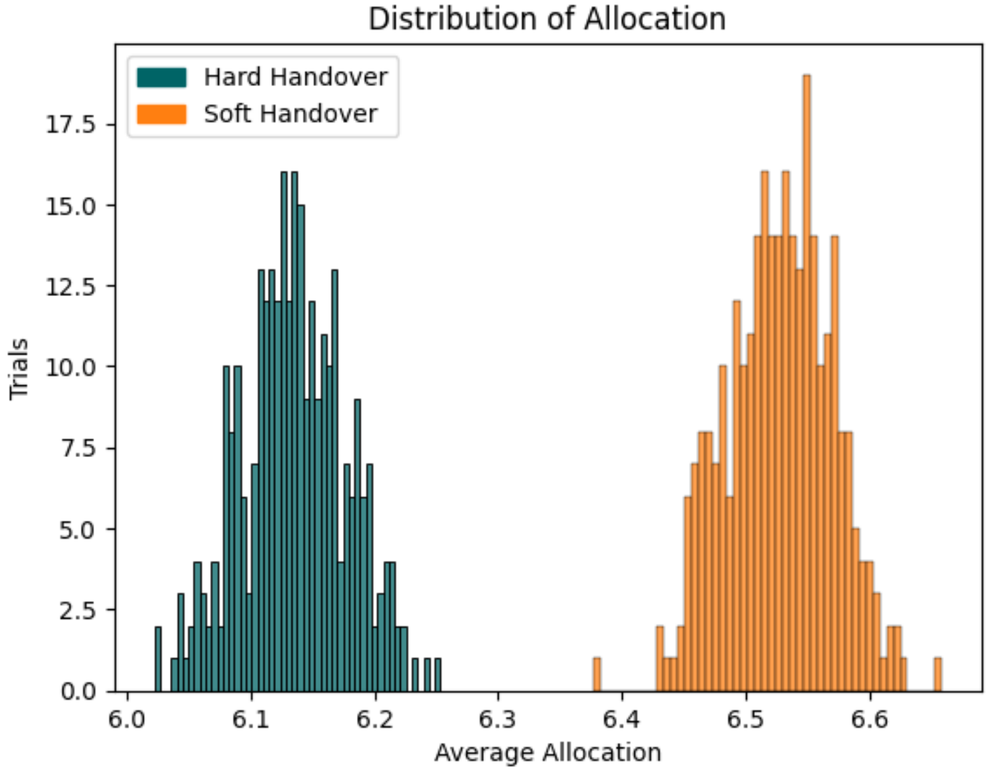


- **Single** round of **soft** HO Allocation Map
- Some of the grid is **0** for **not passing** the grid yet
- The **Closer** to the center, the **better** the performance
- The **low service** area's allocation = **1** initially

Distance Based HO Observation

```
Lower Service Environment / Distance_Based / Hard Handoff Mobile:
All Handoff Events:  1922647
Neglected(soft) handoffs:  0
Actual handoffs:  1922647
Neglect Percentage:  0.0
Average Allocation: 6.134792444444444
Min Allocation: 6.022266666666667
Max Allocation: 6.253333333333333

Lower Service Environment / Distance_Based / Soft Handoff Mobile:
All Handoff Events:  1920722
Neglected(soft) handoffs:  816743
Actual handoffs:  1072024
Neglect Percentage:  0.4252
Average Allocation: 6.527056444444445
Min Allocation: 6.376533333333334
Max Allocation: 6.658533333333334
```



EXPERIMENTS
-SINR BASED

SINR Based HO Introduction

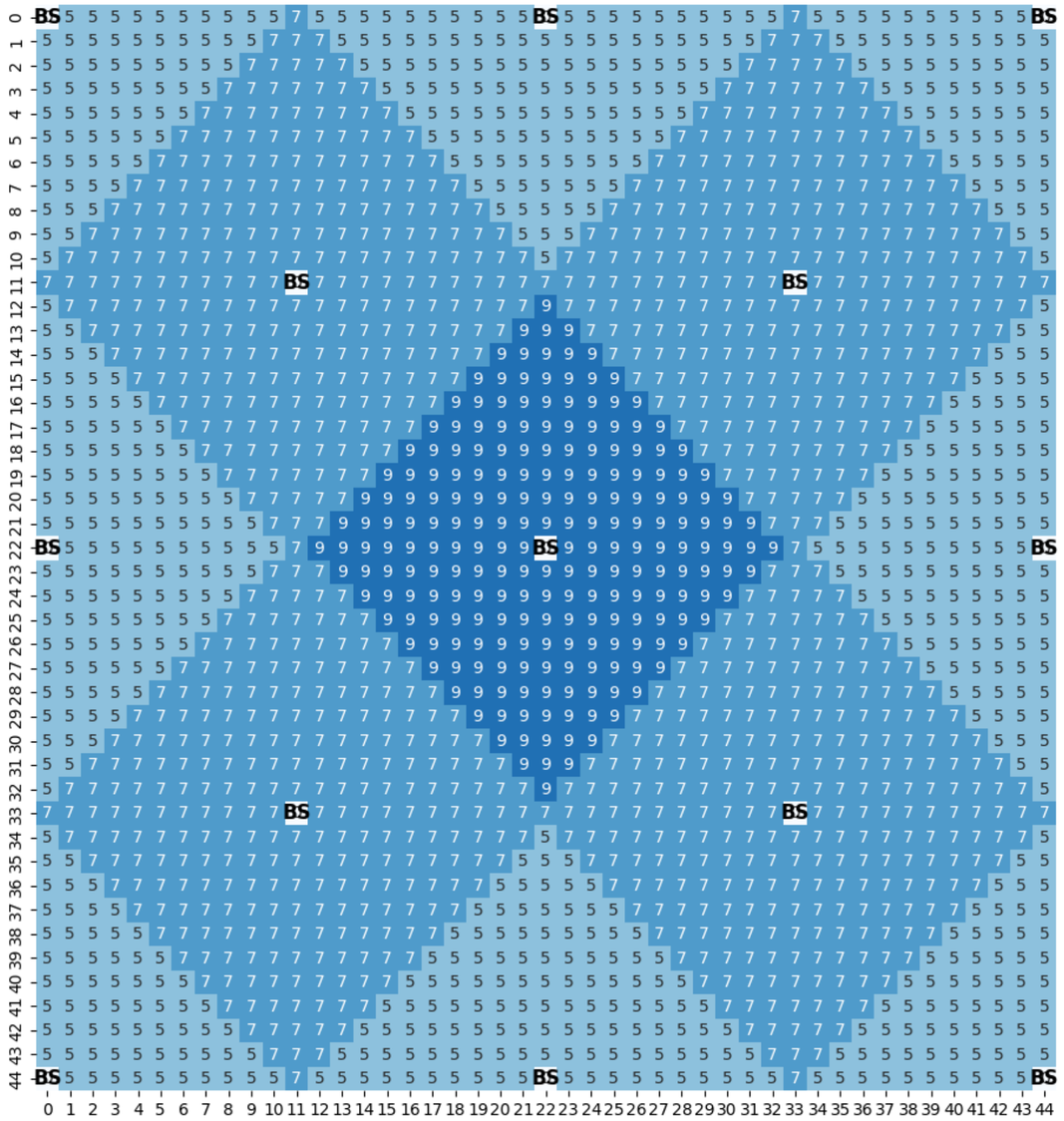
- The simulation environment runs two different simulations:

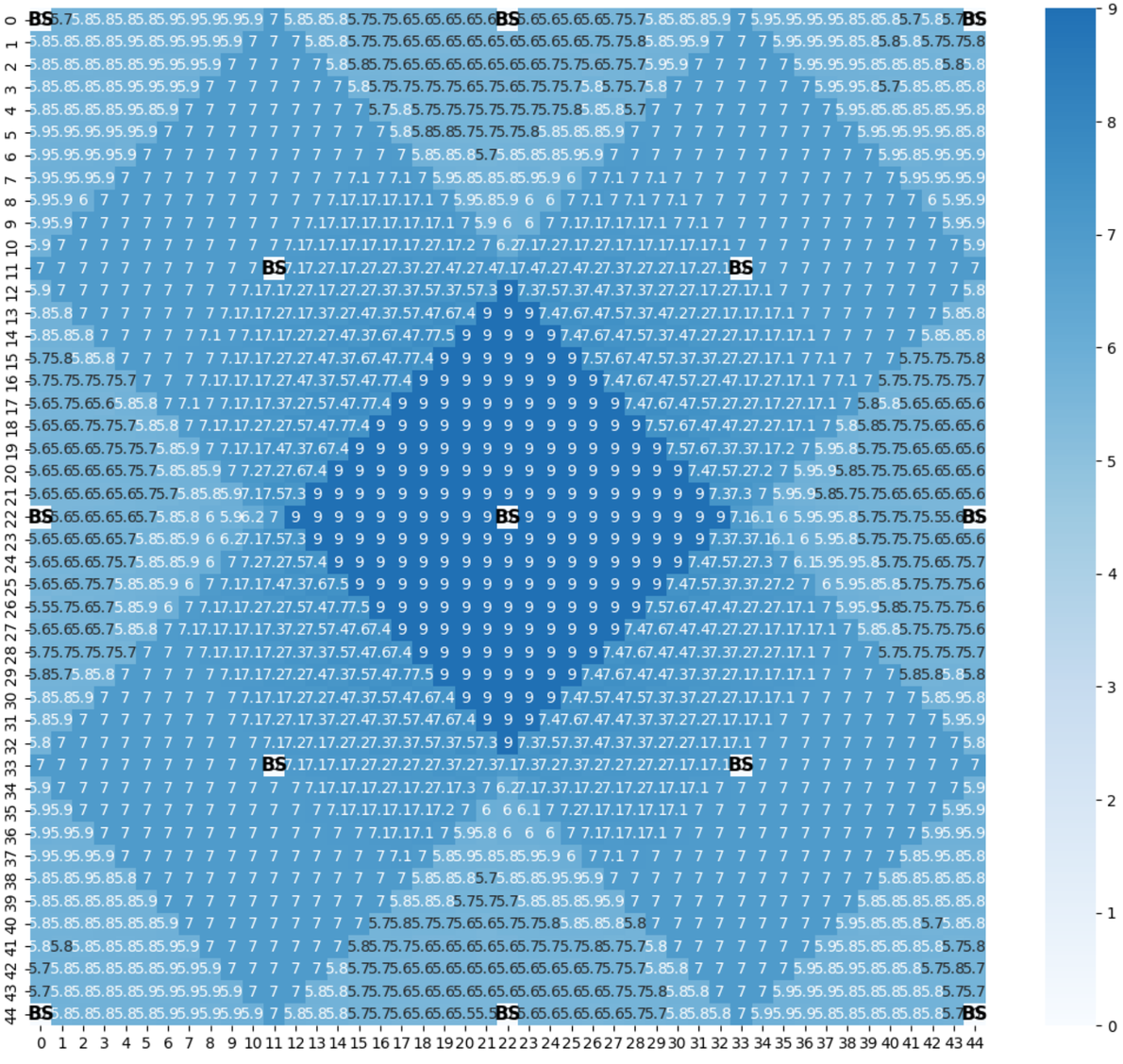
1. The default behavior of connecting to the base station having **largest SINR**

2. An **override** is performed in certain conditions to enhance performance

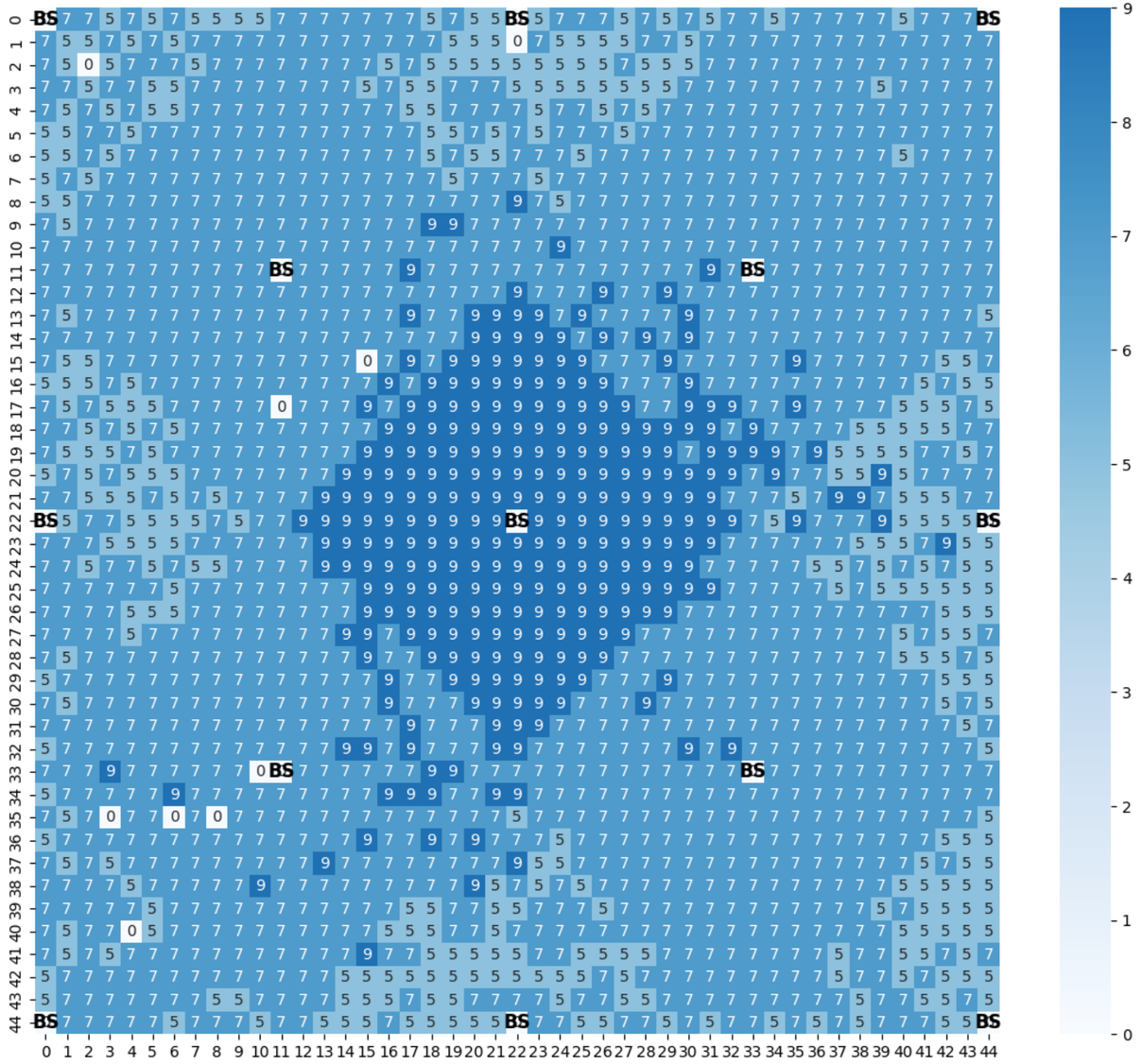
- We also do the experiment that having **low service** area in both type of HO
- Number of Trials = 300, Number of Walks = 15000, Number of Steps = 10

SINR Based HO Observation



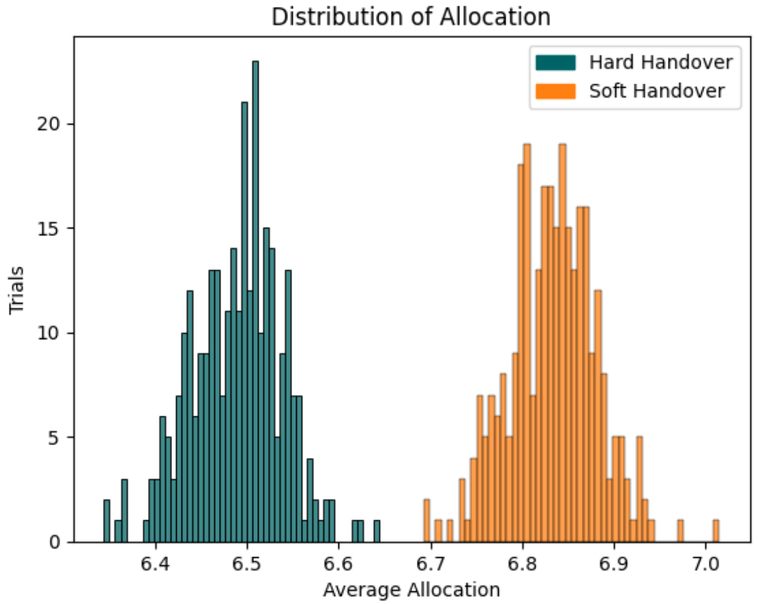


SINR Based HO Observation

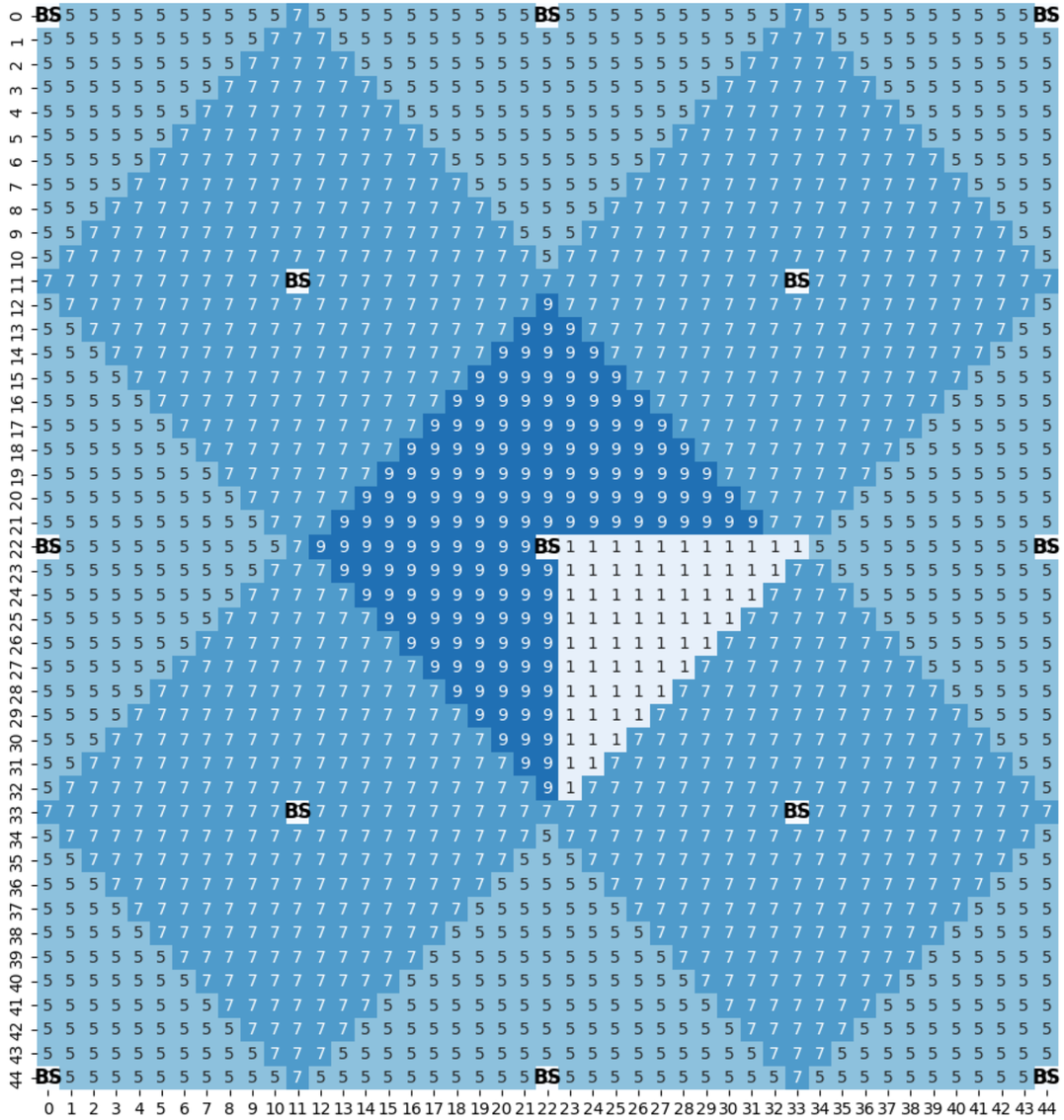


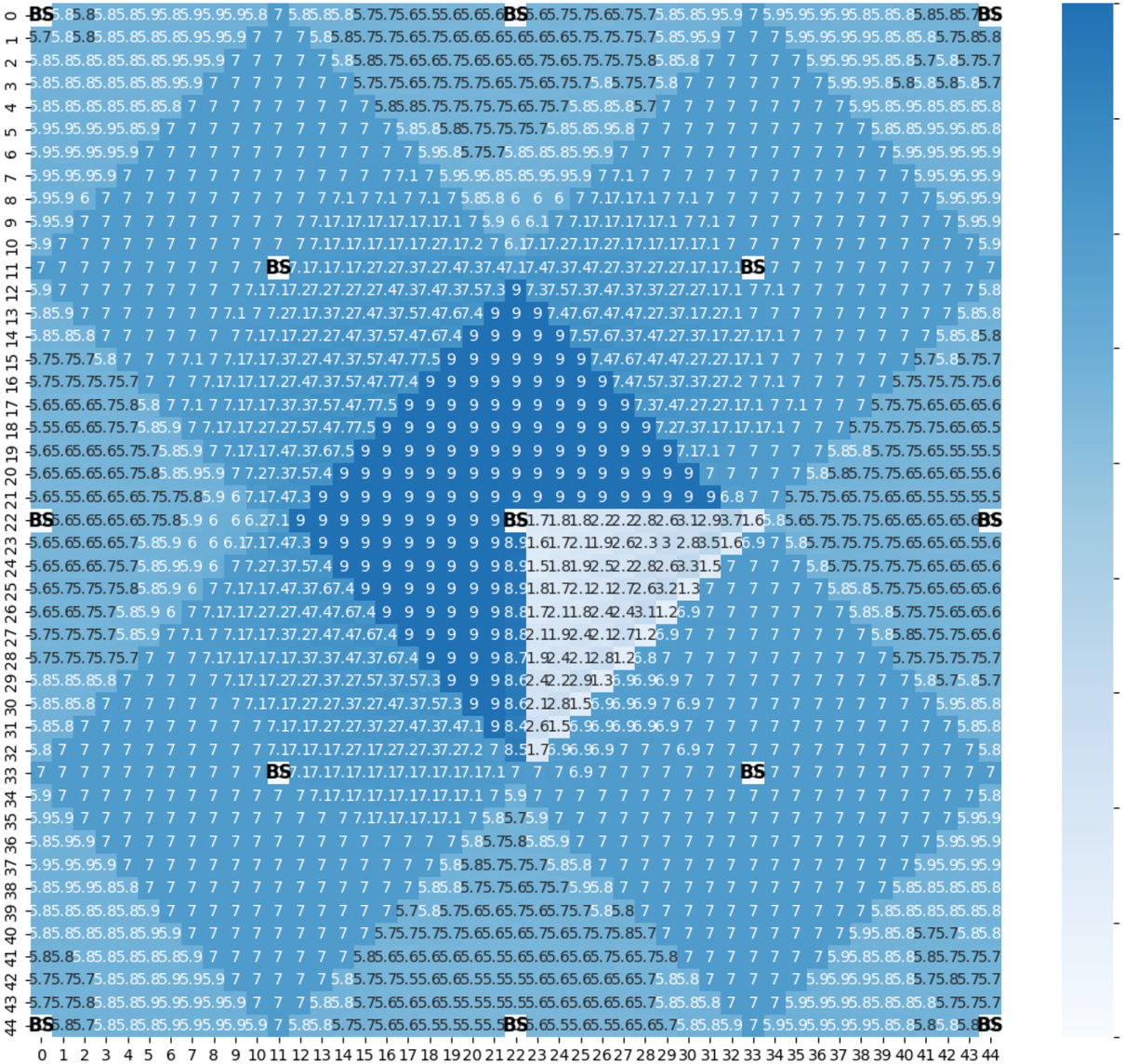
```
Normal Environment / SINR_Based / Hard Handoff Mobile:
All Handoff Events:  1922494
Neglected(soft) handoffs:  0
Actual handoffs:  1922494
Neglect Percentage:  0.0
Average Allocation: 6.4884493333333335
Min Allocation: 6.3444
Max Allocation: 6.6436

Normal Environment / SINR_Based / Soft Handoff Mobile:
All Handoff Events:  1926465
Neglected(soft) handoffs:  769808
Actual handoffs:  1156657
Neglect Percentage:  0.3996
Average Allocation: 6.833177777777778
Min Allocation: 6.692933333333333
Max Allocation: 7.0149333333333335
```

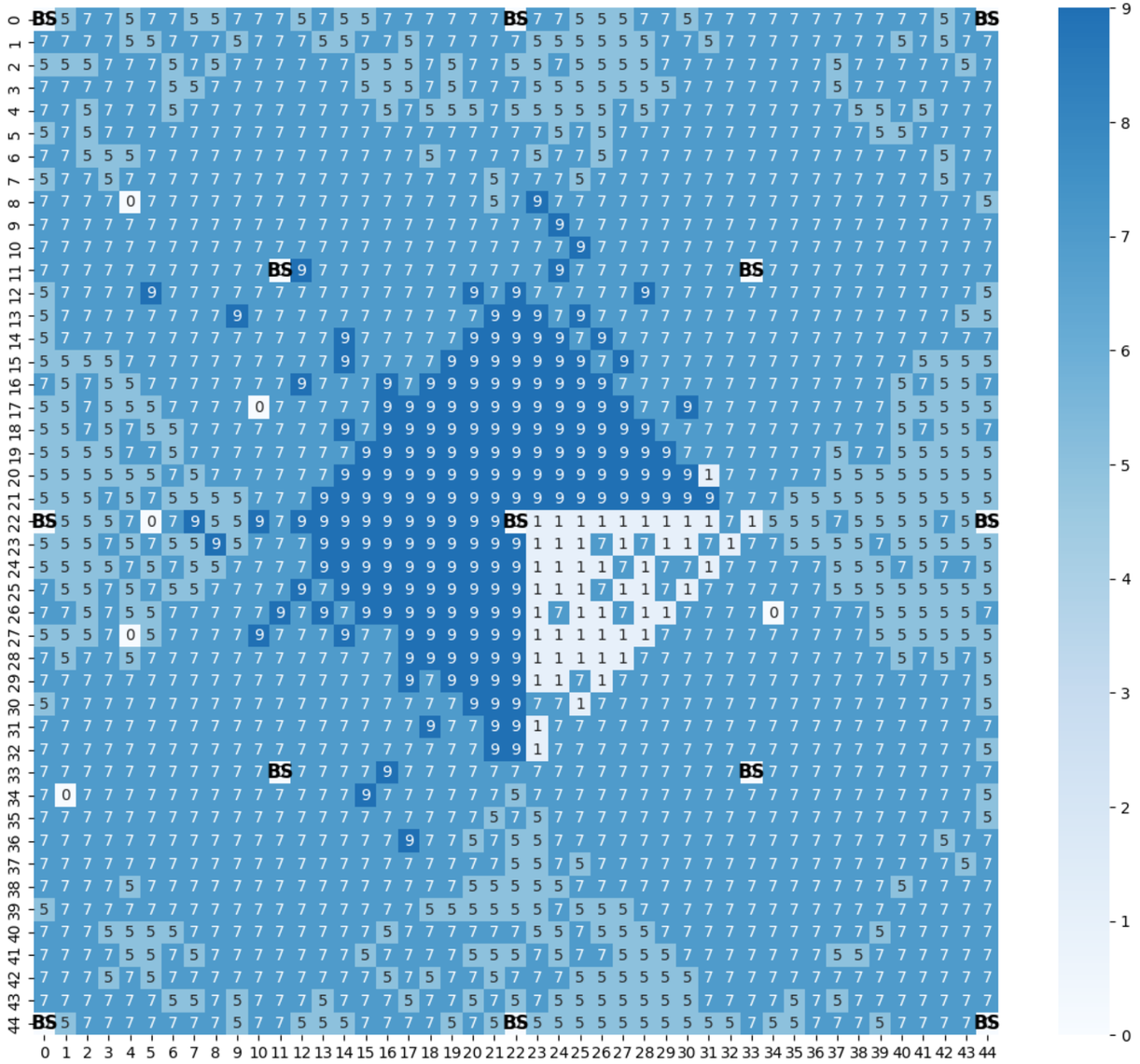


SINR Based HO Observation



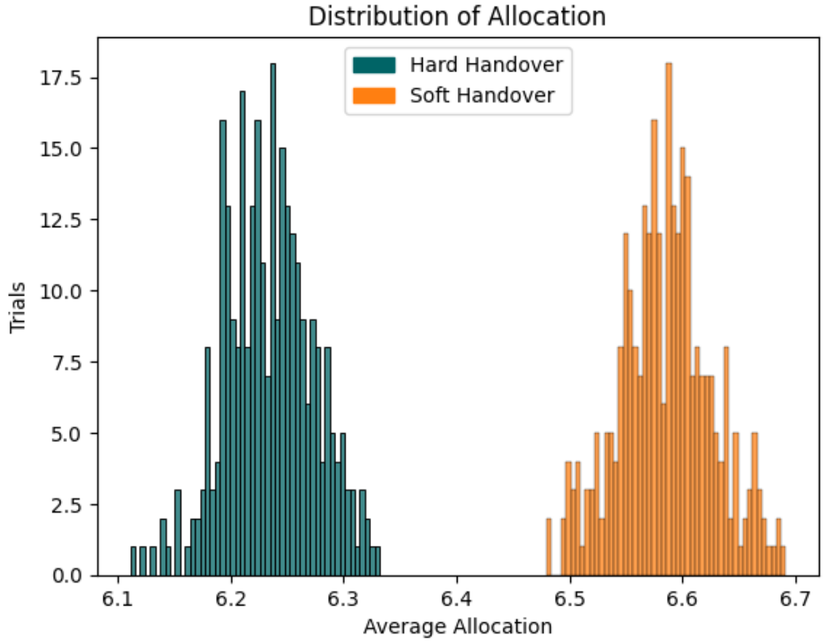


SINR Based HO Observation



```
Lower Service Environment / SINR_Based / Hard Handoff Mobile:
All Handoff Events:  1924272
Neglected(soft) handoffs:  0
Actual handoffs:  1924272
Neglect Percentage:  0.0
Average Allocation: 6.233843555555555
Min Allocation: 6.1108
Max Allocation: 6.331733333333333

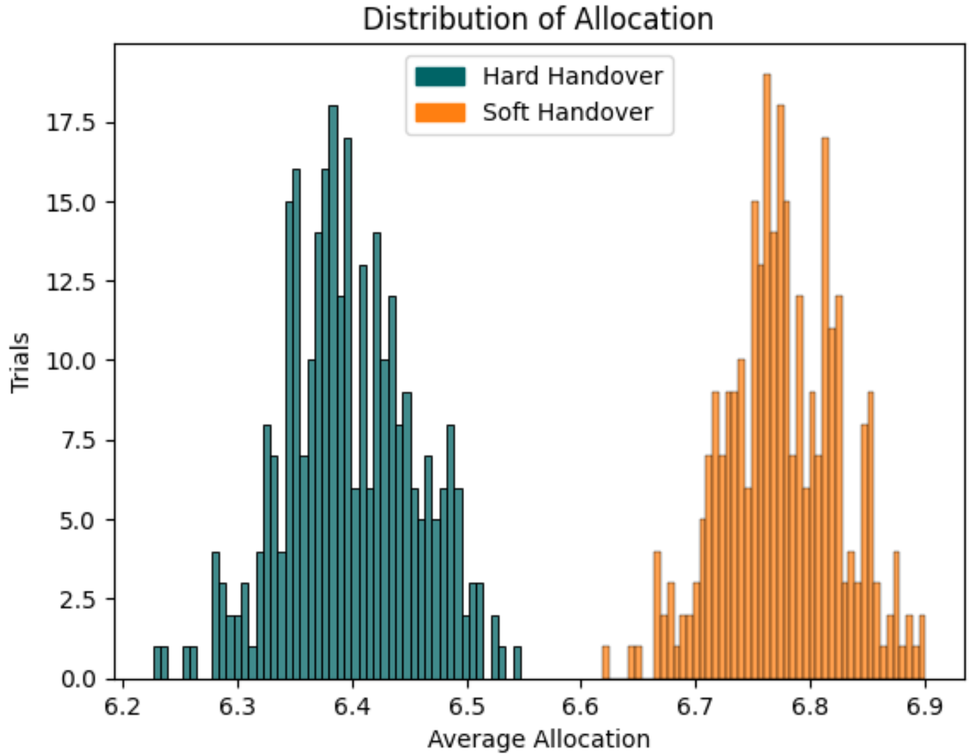
Lower Service Environment / SINR_Based / Soft Handoff Mobile:
All Handoff Events:  1926554
Neglected(soft) handoffs:  740702
Actual handoffs:  1156642
Neglect Percentage:  0.3845
Average Allocation: 6.585241777777779
Min Allocation: 6.479866666666667
Max Allocation: 6.6916
```



COMPARISON & CONCLUSION

Soft Handoff vs Hard Handoff

- 44.33% of the the total handover is **override**
  - Higher average allocation in areas bordering the higher allocation zone
- **Soft** Handoff's average allocation is **5.92% higher** than Hard Handoff

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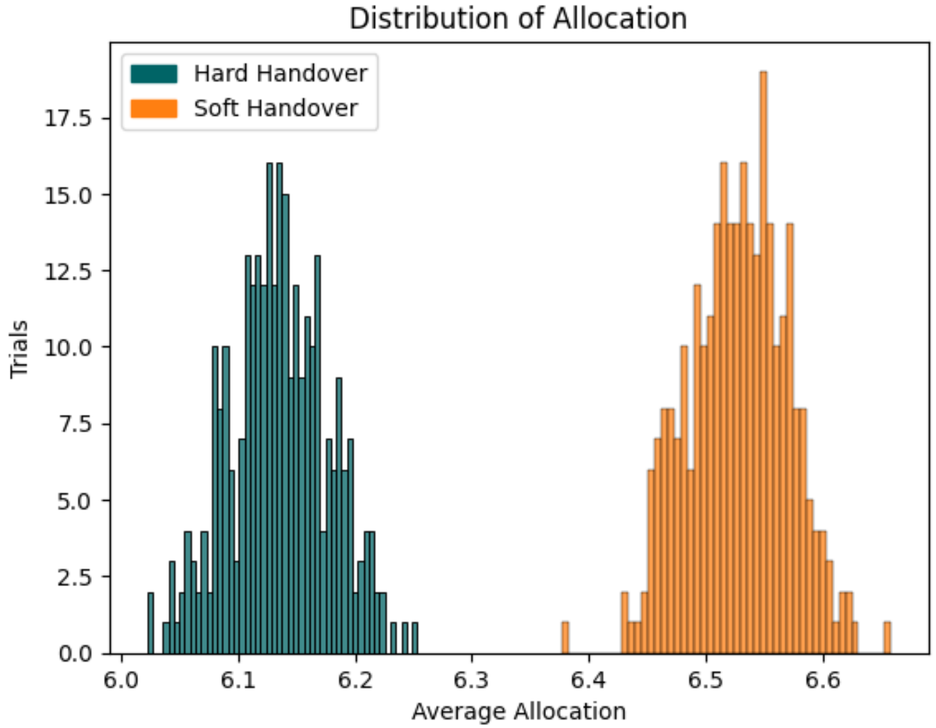
Average Allocation: 6.776071555555556
Min Allocation: 6.619066666666667
Max Allocation: 6.9008
```

Soft Handoff vs Hard Handoff
Low Service Environment

- 42.52% of the the total handover is **override**
  - Higher average allocation in areas bordering the higher allocation zone
- **Soft** Handoff's average allocation is **6.21% higher** than Hard Handoff




```
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Neglect Percentage:  0.0
Average Allocation: 6.134792444444444
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Actual handoffs:  1072024
Neglect Percentage:  0.4252
Average Allocation: 6.527056444444445
Min Allocation: 6.376533333333334
Max Allocation: 6.658533333333334
```

	Soft Handoff	Hard Handoff
Default Environment	Soft Handoff Override Rate: 44.33% Average Allocation: 6.776 Total Handover: 1073715	Soft Handoff Override Rate: 0% Average Allocation: 6.397 Total Handover: 1922045
Low Service Area	Soft Handoff Override Rate: 41.52% Average Allocation: 6.527 Total Handover: 1072024	Soft Handoff Override Rate: 0% Average Allocation: 6.134 Total Handover: 1922647

Difference of SINR and Distance

```
Normal Environment / Distance_Based / Hard Handoff Mobile:
All Handoff Events:  1922045
Neglected(soft) handoffs:  0
Actual handoffs:  1922045
Neglect Percentage:  0.0
Average Allocation: 6.397113777777778
Min Allocation: 6.226266666666667
Max Allocation: 6.5468

Normal Environment / Distance_Based / Soft Handoff Mobile:
All Handoff Events:  1928715
Neglected(soft) handoffs:  855000
Actual handoffs:  1073715
Neglect Percentage:  0.4433
Average Allocation: 6.776071555555556
Min Allocation: 6.619066666666667
Max Allocation: 6.9008
```

```
Normal Environment / SINR_Based / Hard Handoff Mobile:
All Handoff Events:  1922494
Neglected(soft) handoffs:  0
Actual handoffs:  1922494
Neglect Percentage:  0.0
Average Allocation: 6.4884493333333335
Min Allocation: 6.3444
Max Allocation: 6.6436

Normal Environment / SINR_Based / Soft Handoff Mobile:
All Handoff Events:  1926465
Neglected(soft) handoffs:  769808
Actual handoffs:  1156657
Neglect Percentage:  0.3996
Average Allocation: 6.833177777777778
Min Allocation: 6.692933333333333
Max Allocation: 7.0149333333333335
```

```
Lower Service Environment / Distance_Based / Hard Handoff Mobile:
All Handoff Events:  1922647
Neglected(soft) handoffs:  0
Actual handoffs:  1922647
Neglect Percentage:  0.0
Average Allocation: 6.134792444444444
Min Allocation: 6.022266666666667
Max Allocation: 6.253333333333333

Lower Service Environment / Distance_Based / Soft Handoff Mobile:
All Handoff Events:  1920722
Neglected(soft) handoffs:  816743
Actual handoffs:  1072024
Neglect Percentage:  0.4252
Average Allocation: 6.527056444444445
Min Allocation: 6.376533333333334
Max Allocation: 6.658533333333334
```

```
Lower Service Environment / SINR_Based / Hard Handoff Mobile:
All Handoff Events:  1924272
Neglected(soft) handoffs:  0
Actual handoffs:  1924272
Neglect Percentage:  0.0
Average Allocation: 6.233843555555555
Min Allocation: 6.1108
Max Allocation: 6.331733333333333

Lower Service Environment / SINR_Based / Soft Handoff Mobile:
All Handoff Events:  1926554
Neglected(soft) handoffs:  740702
Actual handoffs:  1156642
Neglect Percentage:  0.3845
Average Allocation: 6.585241777777779
Min Allocation: 6.479866666666667
Max Allocation: 6.6916
```

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THANKS