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Modified Resource Allocation Algorithm based on Co-channel Interference Prediction in Local 5G Environments

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Abstract—**This study proposes an approach for local 5G base stations to independently perform interference mitigation. This approach integrates a dynamic resource allocation algorithm, the "Worst-Case Avoidance (WCA) method," which is based on predicted interference, with an Interference Threshold Adjustment Process (ITAP) for allocation schedules. By combining the WCA method with the ITAP, our system performs resource allocation that circumvents predicted high-interference timings. Subsequently, the system controls resource allocation to suppress exceeding the set interference power threshold.**

To evaluate the performance of this integrated WCA approach, we used greedy and round-robin algorithms as comparative benchmarks. Our simulations validated the effectiveness of our proposal. The results confirm that our proposed method not only suppresses interference but also achieves fair resource allocation. Furthermore, we evaluated the trade-off between interference suppression capability and fairness based on the Thresholds set by ITAP.

I. INTRODUCTION

As local 5G is densely deployed in specific areas, co-channel interference (CCI) between base stations becomes a serious issue [1]. To suppress this CCI, coordination between owners is required in Japan before operation [2], which has become a barrier to its widespread adoption. Although frequency sharing among autonomous local 5G systems is being considered [3][4], research on directly suppressing CCI has not sufficiently progressed. In this study, we focused on allocation algorithm to suppress CCI under beamforming communication.

In this paper, we propose a new resource allocation method called the "Worst-Case Avoidance (WCA)" method. A preliminary concept of the WCA was previously introduced in an oral presentation [5]. However, the interference suppression performance when this method is applied independently by multiple cells has remained unevaluated. Therefore, in this study, we evaluate the effectiveness of a configuration where two local 5G base stations autonomously operate the WCA method and an Interference Threshold Adjustment Process (ITAP) based on predicted interference power to keep it below a set threshold. Through computer simulations, we clarify that this configuration can reduce CCI and ensure fairness in resource utilization opportunities for each terminal compared to existing methods.

II. SYSTEM MODEL

A. Cellular Environment and UE Deployment

This paper assumes a two-cell local 5G environment, as depicted in Figure 1. For the evaluation environment, we define the left and right sides in Figure 1 as Cell A and Cell B, respectively. The base stations (BSs) are deployed as follows: BS-A for Cell A is located at coordinates (0, 5), and BS-B for Cell B is at (500, 5). Each cell serves 10 user equipments (UEs), and we assume that handovers between cells do not occur.

To focus on the interference suppression effect of vertical beamforming (tilt angle control), this study assumes a model in which UEs move at a constant velocity of 1 m/s along the straight line connecting the two BSs.

B. Propagation and Antenna Model

The vertical antenna gain of the BS and the propagation model are compliant with the 3GPP standard document [6]. The antenna gain is modeled using Equation (1), with a 3dB beamwidth of 10 degrees and a Side Lobe Attenuation (SLA) of 30 dB.

$$A_{\text{dB}}(\theta, \phi = 0^\circ) = -\min\left\{12\left(\frac{\theta - 90^\circ}{\theta_{3\text{dB}}}\right)^2, SLA_V\right\} \quad (1)$$

with $\theta_{3\text{dB}} = 10^\circ$, $SLA_V = 30$ dB and $\theta \in [0^\circ, 180^\circ]$

For the propagation model, Equation (2) is applied for Line-of-Sight (LoS) conditions between the BS and UE, while Equation (3) is used for Non-Line-of-Sight (NLoS) conditions.

$$PL_{\text{LOS}} = 32.4 + 21\log_{10}(d_{3\text{D}}) + 20\log_{10}(f_c) \quad (2)$$

$$\begin{aligned} PL_{\text{NLOS}} = {} & 35.3\log_{10}(d_{3\text{D}}) + 22.4 \\ & + 21.3\log_{10}(f_c) - 0.3(h_{\text{UE}} - 1.5) \end{aligned} \quad (3)$$

where $d_{3\text{D}}$ is the 3D distance between BS and UE [m], f_c is the carrier frequency [GHz], and h_{UE} is the UE height [m].

The determination of LoS/NLoS is based on the breakpoint distance calculated using Equation (4).

$$d_{\text{BP}} = \frac{4(h_{\text{BS}} - 1)(h_{\text{UE}} - 1)f_c \times 10^9}{3 \times 10^8} \quad (4)$$

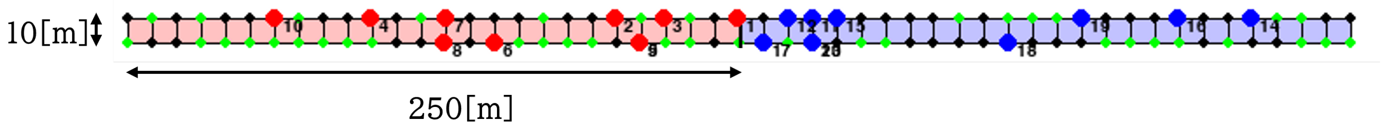


Fig. 1: Two-cell local 5G base station and UE communication environment

Furthermore, to account for path loss fluctuations from shadowing, this variation is represented as a random variable following a log-normal distribution. The standard deviation σ is set to 4 dB for LoS and 7.82 dB for NLoS environments, with a spatial correlation of 10 m. A spatial shadowing map is generated for the entire simulation area from the perspective of each BS and is applied accordingly.

C. Interference power prediction method

To suppress the interference its UEs cause to the adjacent cell, each BS predicts future interference power. This prediction is performed rapidly by applying the UE's predicted position to a pre-calculated interference prediction map.

This interference prediction map is created to evaluate worst-case interference. Specifically, it maps the interference power that a virtual interfered UE, placed at the cell boundary (coordinates (250, 5)), would receive from the BS sidelobes when an in-cell UE is communicating at an arbitrary position. The value of this interference power is calculated using the simulation parameters in Table I and Equation (5).

$$P_I = P_T + G_{T,\text{max}} + A(\theta, \phi) - PL + \sigma_{SF} \tag{5}$$

- P_T [dBm]: Transmit Power
- $G_{T,\text{max}}$ [dBi]: Maximum Transmitting Antenna Gain
- $A(\theta, \phi)$ [dBi]: Antenna Angle Gain (vertical)
- PL [dB]: Path Loss
- σ_{SF} [dB]: Shadowing Fading Variation (a log-normally distributed random variable with standard deviation σ)

As an example, Figure 2 shows the interference prediction map generated by Cell A. The horizontal axis represents the x-coordinate of the in-cell UE, while the vertical axis represents the interference power received by the virtual interfered UE. Note that in this calculation, the range in which the BS forms a beam is limited to within 50 m of the station.

D. Resource Scheduling

In this simulation, each BS performs resource scheduling independently. The allocation period is 30s, and the resource allocation interval is 1s. Consequently, there are a total of 30 scheduling opportunities within this period.

At each scheduling instance, the BS determines the resource allocation based on a scheduling algorithm and executes communication with the UEs according to that schedule.

III. ALLOCATION ALGORITHM

TABLE I: Experimental Parameters

Parameter	Value
Transmit Power	20 [dBm]
Carrier Frequency	4.9 [GHz]
Channel Bandwidth	100 [MHz]
Base Station Height	10 [m]
User Equipment Height	1.5 [m]
Max. Transmitting Antenna Gain	8 [dBi]
Receiving Antenna Gain	0 [dBi]
Thermal Noise Power	-93.97 [dBm]

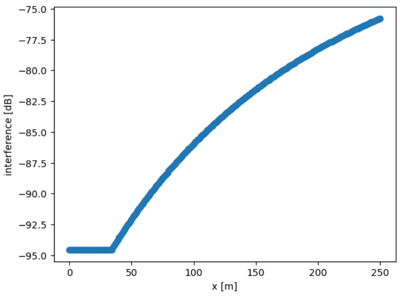


Fig. 2: Interference prediction map for cell A

The interference suppression algorithm proposed in this study predicts future interference fluctuations associated with UE movement and performs dynamic resource allocation based on this prediction. The proposed method consists of two stages: Stage 1 - peak interference suppression control using the Worst-Case Avoidance (WCA) method, and Stage 2 - average interference suppression control using the Interference Threshold Adjustment Process (ITAP).

A. Stage 1: Worst-Case Avoidance (WCA)

This algorithm aims to avoid the worst-case timing that causes severe interference. The basic flow of this process is illustrated in Figure 3.

In this flowchart, we define the following terms used in our algorithm:

- Group 1: UEs that are candidates for allocation in the current scheduling period
- Group 2: UEs that have already been allocated resources in the current period
- Group 3: UEs that are not candidates for allocation in the current period

The WCA method operates as follows: First, among the UEs eligible for scheduling, the algorithm identifies the one predicted to cause the highest predicted interference. Next, peak interference is suppressed by allocating this UE to the time slot with the lowest predicted interference. However, even if this target allocation slot has the minimum interference for the selected UE, if the predicted interference power at that time exceeds a set threshold T1 (target allocation interference

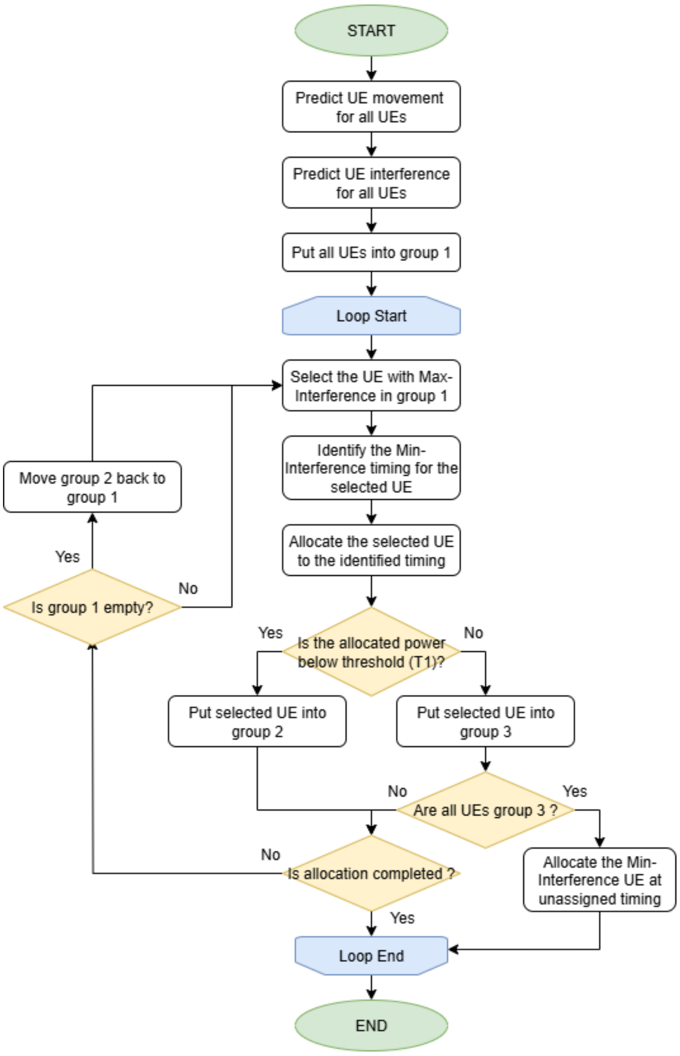


Fig. 3: WCA method flowchart

threshold, set to -82dBm in our baseline evaluation), no further allocations are made to that UE within the same period after this initial allocation.

B. Stage 2: Interference Threshold Adjustment Process (ITAP)

After the allocation using the WCA method (Stage 1), the predicted average interference power for the entire scheduling period is calculated. If this average interference power exceeds a separately defined threshold T2 (average interference power threshold), an adjustment process is executed. The overall flow of this process is shown in Figure 4.

In the adjustment process, the allocation of a UE with a high contribution to the average interference power is identified and its allocation is changed to a different, low-interference UE. This process continues iteratively until the period's overall average interference power falls below the threshold T2.

The value of T2 is a critical parameter that controls the trade-off between interference suppression and allocation fairness. In our evaluations, we tested various values (-85dBm, -88dBm, and -91dBm) to demonstrate this relationship, with lower values prioritizing interference suppression at the expense of fairness.

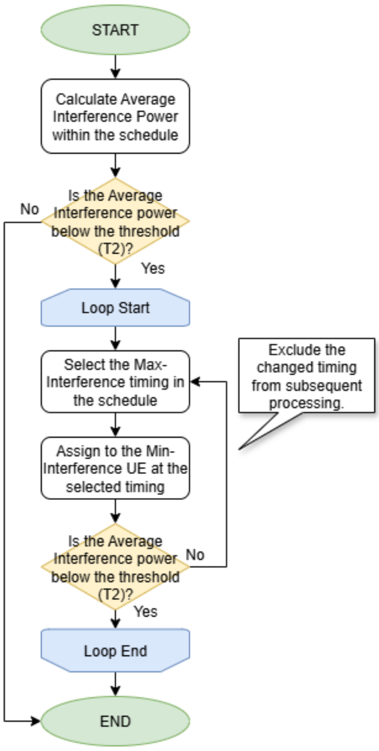


Fig. 4: ITAP flowchart

C. Comparison Algorithms

To evaluate the effectiveness of the proposed method, two basic scheduling algorithms are used for comparison: a Greedy method and a Round-Robin method. The Greedy method always selects and allocates resources to the UE with the lowest predicted interference power to the adjacent cell at each scheduling instance. This approach prioritizes interference suppression. The Round-Robin method periodically allocates resources to all UEs according to a predetermined sequence. As it does not consider channel or interference conditions, this approach prioritizes fairness.

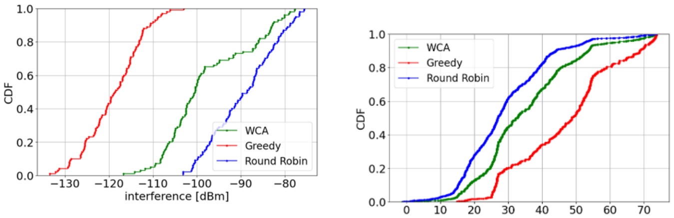
IV. SIMULATION RESULTS

The performance of each allocation algorithm was evaluated over a total simulation time of 3000s. Furthermore, ideal mobility prediction is assumed. It should be noted that this simulation focuses solely on physical communication evaluation and does not consider any overhead elements such as communication protocols or encryption.

A. Performance Metrics

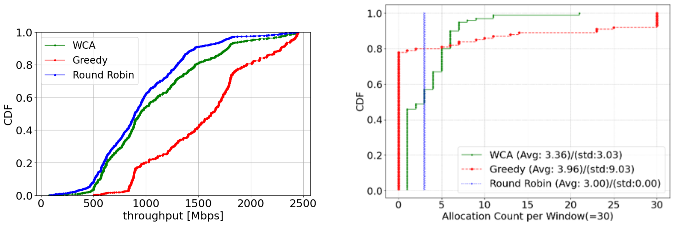
We evaluate the performance of the proposed and comparison methods using several metrics. The Signal-to-Interference-plus-Noise Ratio (SINR) is calculated as:

$$\mathrm{SINR} = \frac{P_S}{P_I + P_N} \tag{6}$$



(a) Average Interference Power within the section

(b) SINR



(c) Throughput

(d) Allocations per interval

Fig. 5: Comparison of Communication Quality by 3 Algorithms (CDF Evaluation)

where P_S is the received signal power, P_I is the interference power, and P_N is the Thermal Noise Power.

For throughput calculation, we use Shannon's channel capacity theorem, which provides the theoretical maximum data rate for a given bandwidth and SINR:

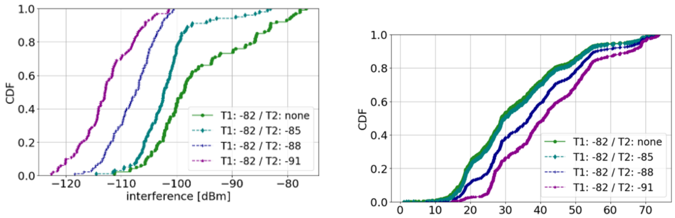
$$C = B\log_2(1 + \mathrm{SINR}_{\mathrm{linear}}) \tag{7}$$

where C is the channel capacity in bits per second (bps), B is the channel bandwidth.

B. Comparison of the Three Allocation Algorithms

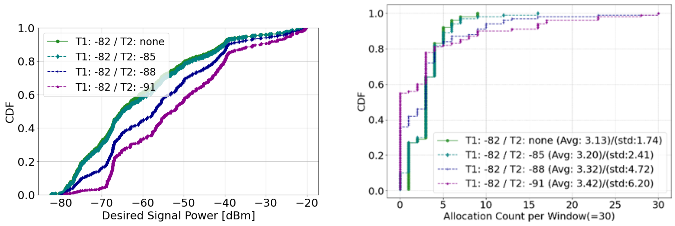
Figure 5 shows the communication quality for the basic Worst-Case Avoidance (WCA) method proposed in this paper (T1=-82dBm, T2=none) and the comparison methods, the Greedy and Round-Robin methods. From the Cumulative Distribution Function (CDF) of the average interference power shown in Figure 5a, it can be confirmed that the interference suppression performance is highest in the order of the Greedy method, the WCA method, and the Round-Robin method. This trend is also observed for SINR (Figure 5b) and throughput (Figure 5c).

On the other hand, the results evaluating allocation fairness are shown in Figure 5d. In this evaluation environment, the ideally fair number of allocations is 3 times per user. The mean and standard deviation of the number of allocations for each method were (3.0, 0.0) for the Round-Robin method, (3.13, 1.74) for the WCA method, and (3.96, 9.03) for the Greedy method. These results indicate that the WCA method is significantly fairer than the Greedy method and achieves allocation fairness close to that of the Round-Robin method.



(a) Average Interference Power within the section

(b) SINR



(c) Throughput

(d) Allocations per interval

Fig. 6: Comparison of Communication Quality for the WCA Method based on Parameter T2 of the ITAP (CDF Evaluation)

C. Effect of the Interference Threshold Adjustment Process (ITAP)

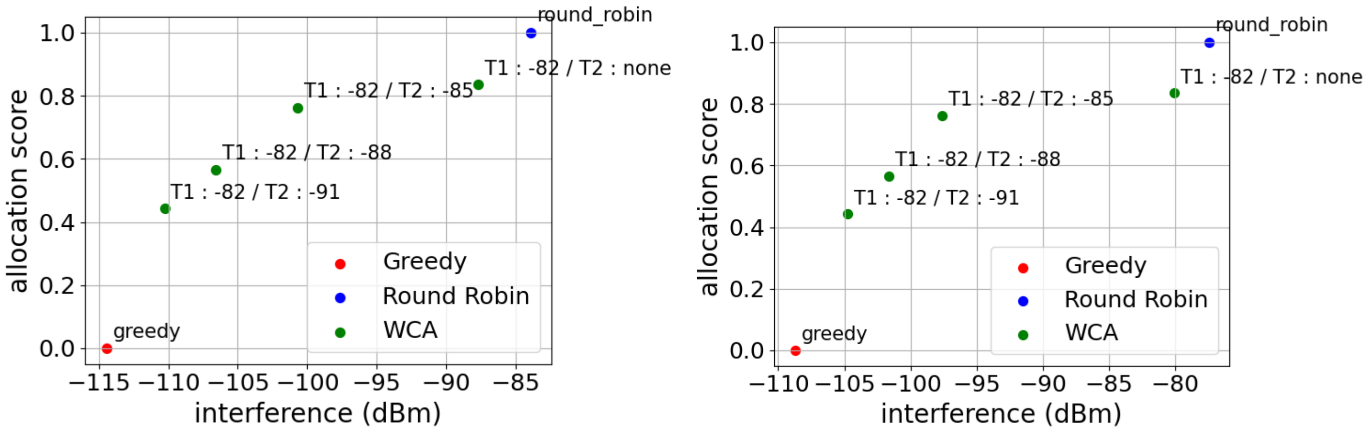
Next, to evaluate the effect of the Interference Threshold Adjustment Process (ITAP) within the WCA method, we analyze the impact of the parameter T2. Here, T1 is fixed at -82dBm, and we evaluated the interference suppression capability and fairness while varying the value of T2 among -85, -88, and -91 dBm. The results are shown in Figure 6.

From the interference power distribution in Figure 6a, it is evident that setting T2 to -85dBm and applying ITAP reduces interference compared to the case without the process. Furthermore, a trend can be seen where setting a lower T2 threshold results in stronger interference suppression, effectively reducing the average interference power. This interference reduction directly contributes to improvements in SINR (Figure 6b) and throughput (Figure 6c).

On the other hand, this improvement in communication quality comes at the cost of reduced allocation fairness. In the allocation count distribution in Figure 6d, it is shown that the lower the threshold T2, the greater the variance in the distribution. Particularly for T2 = -91 dBm, the mean and standard deviation of the allocation count are (3.41, 6.20), quantitatively confirming that fairness is significantly compromised.

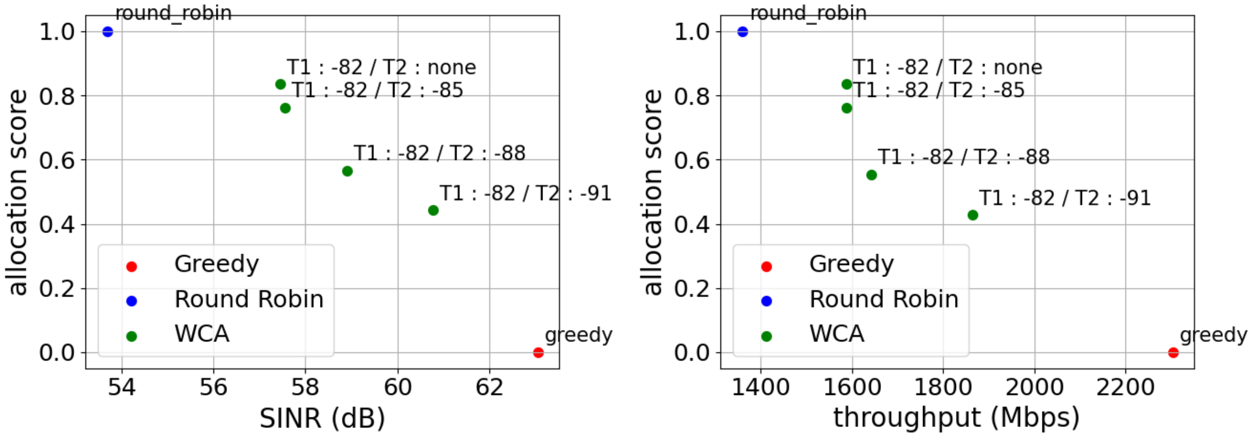
D. Evaluation of interference suppression capability and communication fairness

In this section, we conduct a comprehensive performance evaluation of each algorithm discussed so far, from the perspectives of interference suppression capability and communication fairness. Figure 7 shows the overall evaluation results for the Greedy method, the Round-Robin method, and the



(a) vs Mean Average Interference power within the section

(b) vs Average Interference power 95 percentile



(c) vs Mean SINR

(d) vs Mean Throughput

Fig. 7: Overall performance evaluation of allocation algorithms: Greedy, Round-Robin, and WCA with various T2 parameters.

Worst-Case Avoidance (WCA) method with its various T2 parameter settings.

In this evaluation, we introduced the Allocation Score to quantify allocation fairness. This score is a normalized index designed to approach 1 as the μ (mean) and σ (standard deviation) of the allocation count distribution get closer to their ideal values ($\mu_{target} = 3$ and $\sigma_{target} = 0$, respectively).

The Allocation Score (AS) is calculated through the following process:

$$P_\mu = |\mu - \mu_{target}| \tag{8}$$

$$P_\sigma = \sigma \tag{9}$$

$$\bar{P}_\mu = \frac{P_\mu - \min(P_\mu)}{\max(P_\mu) - \min(P_\mu)} \tag{10}$$

$$\bar{P}_\sigma = \frac{P_\sigma - \min(P_\sigma)}{\max(P_\sigma) - \min(P_\sigma)} \tag{11}$$

$$P_{total} = w_\mu \cdot \bar{P}_\mu + w_\sigma \cdot \bar{P}_\sigma \tag{12}$$

$$\bar{P}_{total} = \frac{P_{total} - \min(P_{total})}{\max(P_{total}) - \min(P_{total})} \tag{13}$$

$$AS = 1 - \bar{P}_{total} \tag{14}$$

where P_μ and P_σ are the raw penalties for deviations in mean and standard deviation, $\bar{P}_\mu$ and $\bar{P}_\sigma$ are the normalized penalties between 0 and 1, w_μ and w_σ are the weights for each penalty (both set to 1.0 in our evaluation), P_{total} is the weighted sum of normalized penalties, and $\bar{P}_{total}$ is the re-normalized total penalty to ensure the final score ranges from 0 to 1, with higher values indicating better fairness. This method allows us to objectively compare allocation fairness across different algorithms.

Figures 7a and 7b plot interference power (mean and 95th percentile values) on the horizontal axis against the aforementioned fairness score on the vertical axis. A position in the upper-left indicates superior overall performance. The results confirm that the Greedy and Round-Robin methods have performance skewed towards either interference suppression or fairness, placing them at the extremes of the graph. In contrast, the WCA method demonstrates intermediate characteristics by adjusting the value of T2. Notably, the WCA method with T2 set to -85 dBm achieves the most balanced performance, maintaining an Allocation Score of approximately 0.8 while effectively suppressing interference power.

Furthermore, Figures 7c and 7d show that the WCA method with T2=none and T2=-85dBm can achieve over 14% higher throughput than the Round-Robin method while maintaining high fairness.

V. CONCLUSION

In this study, we proposed and evaluated a dynamic resource allocation algorithm for local 5G based on interference prediction, the "Worst-Case Avoidance" (WCA) method. Through simulations, we confirmed that the WCA method can achieve fair resource allocation while effectively suppressing interference. We also investigated using the Interference Threshold Adjustment Process (ITAP) and confirmed that while decreasing the T2 parameter enhances interference suppression capability, it does so at the cost of reduced fairness.

Future work includes creating a more realistic simulation environment, evaluating the interference suppression performance of dynamic resource allocation algorithms like WCA when applied to groups of mobile terminals. Additionally, developing a resource allocation method that considers not only predicted interference but also throughput is a key challenge for future research.

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