Master's Thesis
석사 학위논문

Frequency efficiency enhancement by using successive interference cancellation for UAV

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Department of
Information & Communication Engineering

DGIST

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A thesis submitted to the faculty of DGIST in partial fulfillment of the requirements for the degree of Master of Science in the Department of Energy Science & Engineering. The study was conducted in accordance with Code of Research Ethics[1]

01. 02 . 2017

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[1] Declaration of Ethical Conduct in Research: I, as a graduate student of DGIST, hereby declare that I have not committed any acts that may damage the credibility of my research. These include, but are not limited to: falsification, thesis written by someone else, distortion of research findings or plagiarism. I affirm that my thesis contains honest conclusions based on my own careful research under the guidance of my thesis advisor.

Frequency efficiency enhancement by using successive interference cancellation for UAV

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Accepted in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Since wireless mobile communication has been used, the number of wireless communication devices is increasing. In addition, mobile communication terminals are demanding a large amount of communication resources in response to an increasingly high communication speed requirement. In this situation, users are currently experiencing a serious lack of communication resources. In order to solve this problem, various researches have been carried out for efficient use of communication resources, especially frequency resources. One of them is successive interference cancellation (SIC), which is the core technology of non-orthogonal multiple access.

In this paper, we will apply the SIC technique to mobile base station, especially UAV which is used as base station. UAV is also often used as an alternative to communications in many extreme situations, such as disaster situations. In extreme situations, the supply of communication resources may not be smooth and it is difficult to guarantee QoS of communication due to various constraints. Therefore, to improve the efficiency of frequency bandwidth, which is one of communication resources, we apply SIC technology to UAV characteristics and propose scheduling algorithm. In order to simultaneously consider the channel capacity and fairness in the whole system, a proportional fairness algorithm is applied to the user pairing algorithm of SIC technology. The performance of this algorithm is compared with the previously proposed algorithms and simulation calculated.

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Keywords: Successive interference cancellation, UAV, scheduling, proportional fairness

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I. INTRODUCTION

1.1 Non-orthogonal Multiple Access

Since the beginning of cellular communication, radio access technologies for cellular mobile communication has been developed in a variety of ways and has been also used communication resources in a variety of ways, e.g., frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access(OFDMA) is used for 4th generation cellular communication. The above-mentioned radio access methods are orthogonal multiple access (OMA) which means one resource block can be used by only one user. Although OMA is an effective way to achieve a stable system and throughput with single user detection, this schemes serve a single user in each orthogonal resource block and this characteristic causes a shortage of resources. Because of the exponentially accelerates the demand for high speed communication and rapidly increase use of mobile internet, resources such as frequency bandwidth are experiencing a serious shortage. Accordingly, various methods for spectrum efficiency enhancement have been discussed. One of them is non-orthogonal multiple access (NOMA). NOMA is a promising candidate technology discussed in 5G with future radio access [1].

The basic concept of NOMA is to serve multiple users in the same resource block like frequency bandwidth, subcarrier, etc. OMA defines this situation as collision, but NOMA can decode it using several techniques. The difference between NOMA and OMA is briefly shown in the figure 1.

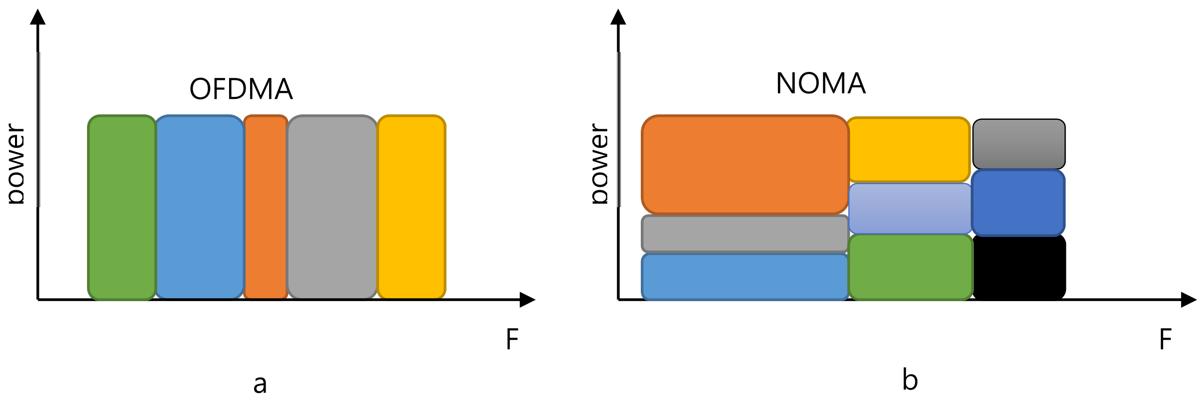


Figure 1 Simple comparision example of OMA(OFDMA) and NOMA

The figure on the left shows users orthogonal to each other, and the figure on the right shows NOMA and superposed users.

There are many kinds of NOMA technologies but they can be broadly divided into two categories: power domain NOMA and code domain NOMA. Power domain NOMA attains multiplexing in power domain. Similarly, code domain NOMA attains multiplexing in code domain. The code domain NOMA is common to CDMA in that it shares all the resources (time, frequency), but the difference is that the code domain NOMA uses spreading sequences for each user. There are several kind of code domain NOMA like low-density spreading CDMA, low-density spreading-based OFDM, etc. But this paper will focus primarily on power domain NOMA. [2].

As mentioned earlier, Power Domain NOMA is a technology that decodes superposed two or more signals by using the difference of power level. There are two techniques that play an important role in this Norma which are superposition coding(SC) and successive interference cancellation(SIC).

The SC is a well-known non-orthogonal technique that was first proposed in []. The SC allow the transmitter to send information of multiple users simultaneously. When two signals are superimposed, a simplified representation of the transmitted signal is shown below [2].

$$\mathrm{X(n)} = \sqrt{P\alpha}S_1 + \sqrt{P(1-\alpha)S_2} \qquad (1)$$

P denoted that total power and α represent s a power ratio.

The following figure is a simplified representation in order to show how SC is performed in two different QPSK signals with different power.

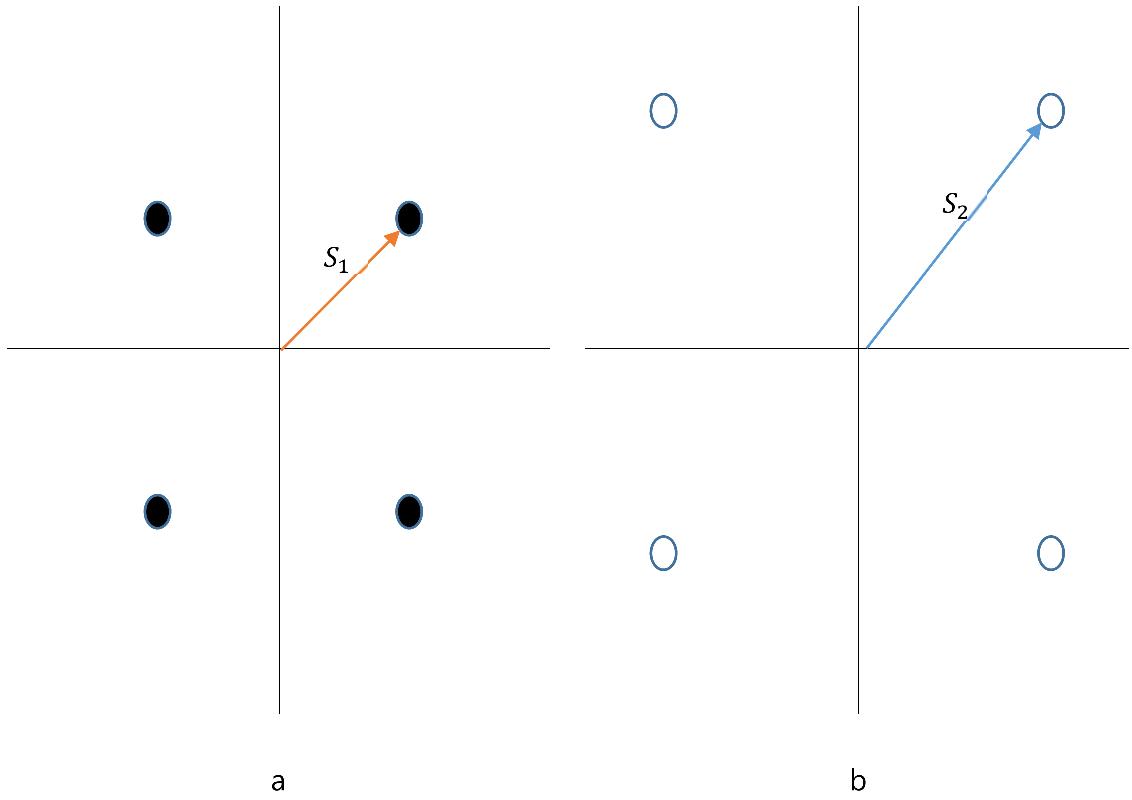


Figure 2 example of superposition coding

The constellation of user 1 with lower transmitting power is superposed with constellation of user2 with higher transmitting power. The result of superposing the two signals' constellation is shown in Figure 3.

The phase and magnitude of the transmitted signal is determined by the vector sum of the two signals. There are many studies in SC. Basic concept of SC is introduced in [13], and [14] proposed the scheme of using SC for greatly improving the performance of relaying communication. In [15], the author proposed the optimal rate allocation in channel by using SC because coding with single fixed rate could not achieve the optimal point of throughput. There are various studies and algorithms are proposed but I will not cover it in this paper.

1.1.2 Successive Interference Cancellation

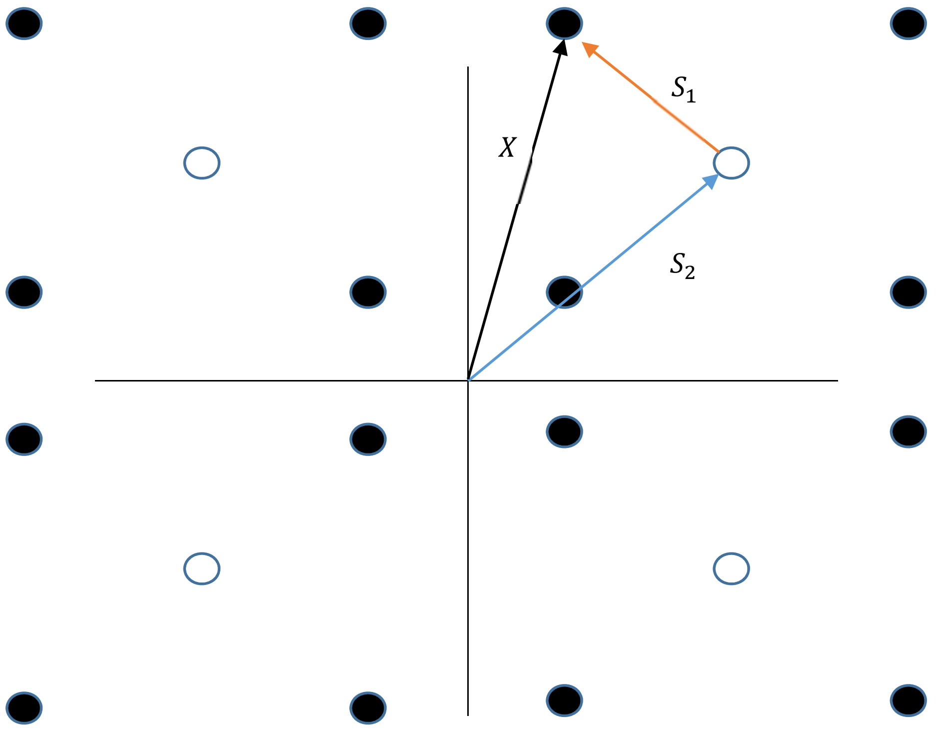


Figure 3 superposed constellation

Successive interference cancellation is an also well-known physical layer technique for decoding two or more superposed signals. The basic concept of SIC is to successively decode two or more signals with different powers level. When a superposed signal arrives, it decodes the signal with the highest power level, and subtracted from the original signal. After removing the decoded signal from the superposed signal, receiver decodes the user's signal with the next highest power level. The mathematical expression of this process is as follows. It is a formula of SIC with N users and i∈ $\{1,2, \dots, \mathrm{N}\}$ is user index. Each user's channel is sorted in ascending order as $|h_1| \leq |h_2| \leq \cdots \leq |h_N|$. The superposed transmission signal can be expressed as

$$\mathrm{X(n)} = \sum_{i=1}^{N} \sqrt{P\beta_i} S_i \qquad (2)$$

Where β_i is The power ratio of the user i. P denotes that total power and $\mathrm{S_i}$ is transmit signal. Therefore, the received signal over the channel is given by

$$\mathrm{Y(n)} = \sum_{i=1}^{N} \sqrt{P h_i \beta_i} S_i + w_i \qquad (3)$$

Where h_i is the channel gain of user i and w_i is AWGN of user i. Y(n) is a superimposed signal. The SIC receiver receives this signal and repeatedly decodes and removed it in order.

The channel capacity of superposed signal is as follows.

$$\mathrm{r_i} = W \log_2(1 + SINR) \qquad (4)$$

$$\mathrm{r_i} = W \log_2\left(1 + \frac{S_i}{\sum_{k=i+1}^{N} S_k + \sigma^2}\right) \qquad (5)$$

$$\mathrm{r_i} = W \log_2\left(1 + \frac{\beta_i P |h_i|^2}{P|h_i|^2 \sum_{k=i+1}^{N} \beta_k + \sigma^2}\right) \qquad (6)$$

W denotes that the bandwidth. All other signals except user i are interference, so all other signals are put into the denominator in the SNR equation. For a more intuitive and simple example, let's assume that there are two users, N = 2.

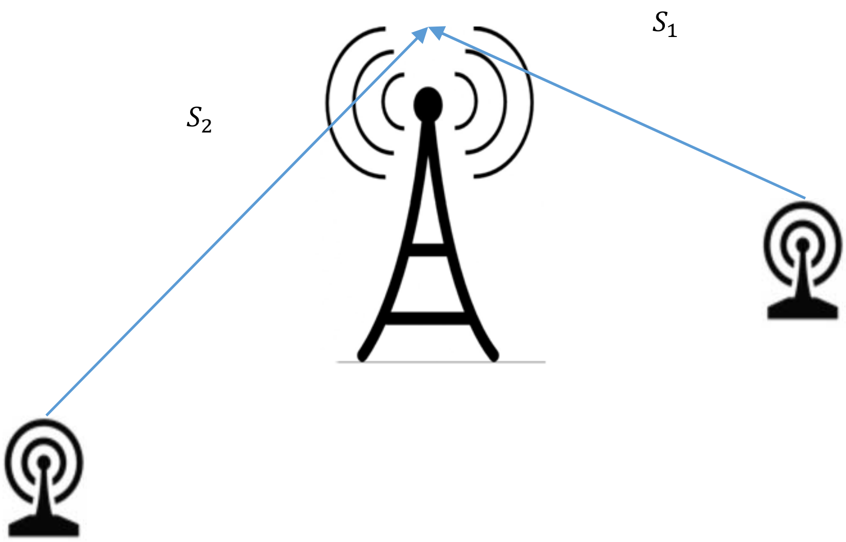


Figure 4 2 user SIC

We assume that the path loss is large because S_2 is far from the base station, and path loss is small because S_1 is close to the BS. The received signal Y is the sum of the two signals, as shown in the following equation.

$$\mathrm{Y(n)} = \sqrt{h_1 \beta P} S_1 + \sqrt{h_2 (1-\beta) P} S_2 \qquad (7)$$

Because of the difference in channel environment, the power of S_1 is larger than the other, so it is decoded first from S_1.

The channel capacity of signal S_1 is as follows

$$r_1 = W\log_2(1 + \frac{\beta P|h_1|^2}{(1-\beta)P|h_1|^2+\sigma^2}) \tag{8}$$

After the decoding of S_1 is finished, $S_1$is erased from the original signal. Then the channel capacity of S_2 is as follows.

$$r_2 = Wlog_2\left(1 + \frac{(1-\beta)P|h_2|^2}{\sigma^2}\right) \tag{9}$$

Interestingly, the signal with better channel gain can be seen to have a smaller channel capacity due to interference effects.

Now we want to see what is the difference between using and not using SIC. Let's take a look at the case of two users. For ease of presentation, the signal power of the first user is S_1 and the signal power of the second user is S_2. In this situation, the channel capacity can be expressed by the following equation.

$$C_{withoutSIC} = \max(\log_2\left(1 + \frac{S_1}{N}\right), \log_2(1 + \frac{S_1}{N})) \tag{10}$$

If the SIC is not used, the stronger one of the two signals is decoded, so the equation can be expressed as (10).

$$C_{withSIC} = \log_2\left(1 + \frac{S_1}{S_2+N}\right) + \log_2\left(1 + \frac{S_2}{N}\right) \tag{11}$$

$$= \log_2(1 + \frac{S_1+S_2}{N}) \tag{12}$$

Figure 5 shows the two user norms on the downlink. In the case of using SIC, it can be confirmed from the formula that performance is higher than when it is not used.

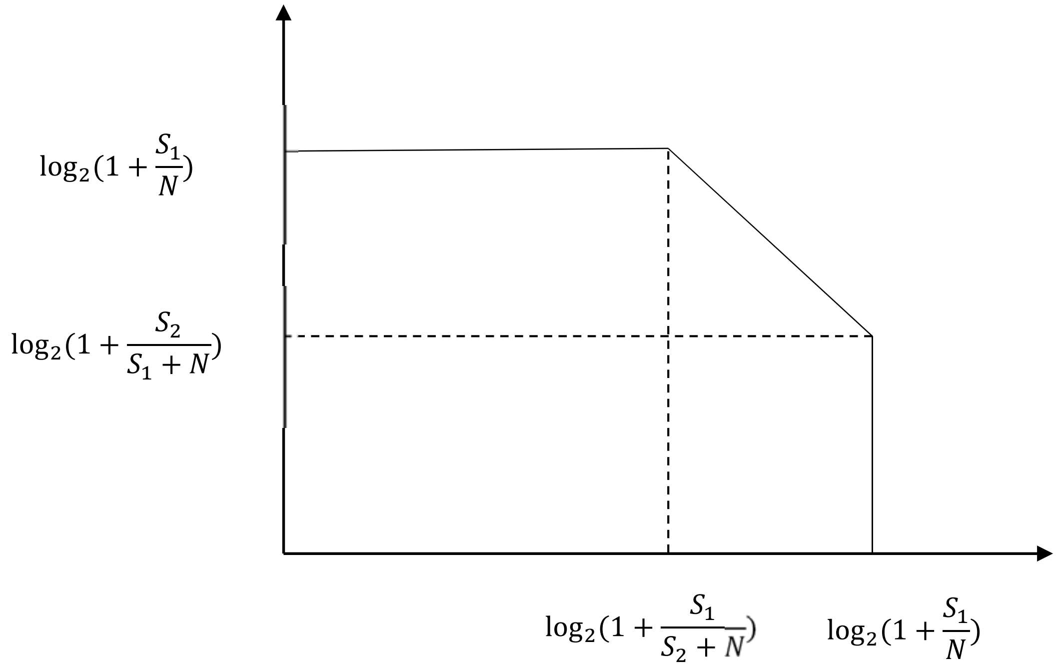


Figure 5 gain with SIC

Figure 5 (which is reproduce here from [4]) show the gain of SIC

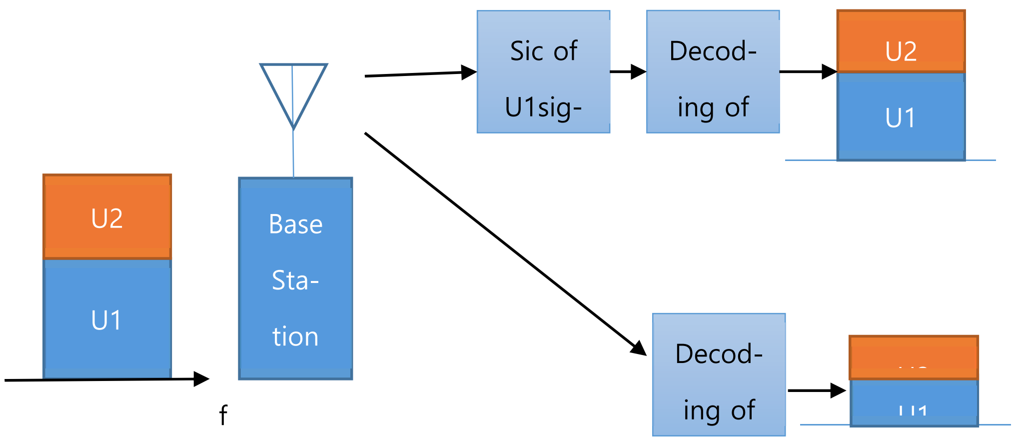


Figure 6 NOMA schemes for 2user case

Figure 6 (which is reproduce here from [2]) shows the two user NOMA scheme on the downlink. SIC is used to separate the signals successively. Figure 6 is a picture of the downlink, but it can be understood as a similar driving principle on the uplink.

1.2 Unmanned Aerial Vehicle

Unmanned Aerial Vehicle(UAV), commonly known as a drone, has enormous potential not only in the field of communications networks but also in many other fields, and has been studied in many fields as a rising field. The development of the military UAV has been around for a long time, and it has attracted a great deal of attention in the public sector, especially as a communication replacement device. Unmanned aerial vehicles can be used as communication alternatives base station when people are not easily accessible or when communication infrastructure is destroyed in mountainous areas or disaster areas such as earthquake and terror. Especially in disaster area, rescue activities are very important and it is easy to rescue and support when communication quality is guaranteed. However, in such a case, if the communication infrastructure is destroyed by the disaster situation, it is difficult to maintain the QoS guaranteed communication. Therefore, UAV can easily replace communication infrastructure because it has mobility, and if UAV is replaced with communication infrastructure as base station, it can be guaranteed to guarantee QoS for a relatively short period of rescue time. In addition to the disaster situation, methods of enhancing the communication efficiency or strengthening the communication channel by using the UAV as a relay are being studied. Furthermore, research is underway to build networks through the characteristics of UAV such as high mobility and longer communication distance.

UAVs vary in flight altitude, size, and purpose, but UAVs can be classified into two major types, fixed wing drones and rotary wing drones, depending on the wing shape and flying style.

Rotary drones are generally drones with propellers. The rotor drones have the advantage of being capable of hovering, but they are powered by a propeller, which consumes a lot of power so cannot fly for a long time. Beside, heavy equipment cannot be loaded or transported by Rotary drones.

On the other hand, fixed wing drones cannot hover but can fly for a long time. The advantage of long flight times is that it is appropriate to use a communication infrastructure such as a base station, but because of the mobility of the UAV, the channel environment and path loss are constantly changing, so it is necessary to improve performance through resource allocation and scheduling

	Fixed wing UAV	Rotary wing UAV
Hovering	impossible	possible
Flight Time	Long flight	short
Height	high	low
Speed	fast	relatively slow.
Airstrip	necessary	Unnecessary
carrying capacity	Heavy things also possible	Only light thing

Table 1 comparision of fixed wing and rotary wing

Table 1 compares the characteristics and strengths and weaknesses of the rotary wing UAV and the fixed wing UAV. As each of the advantages and disadvantages will vary, the use of fixed-wing drones with longer flight times will be more appropriate for use as a base station. In addition to the fixed-wing and the rotary UAV, there are various types drones such as balloons and tiltrotor UAV. Rotary wing Unmanned aerial vehicles are divided into several types. There are three main types according to the shape of the propeller. A tail rotor that keeps the equilibrium of the gas with the propeller on the tail, a coaxial that keeps the balance of the gas while turning the two propellers in opposite directions, and a quad-copter method that uses four wings. Also, to save power, there are UAVs using kites and UAVs using the balloons mentioned above but this paper does not cover them.

1.3 Fairness

1.3.1 Jain's index

Due to the exponential growth of devices with the advent of the IoT era, the issue of allocating and sharing communication resources, which are limited, among communication terminals has become an important issue. Since the amount of resources required for each communication terminal is different, resource allocation is very important for increasing the efficiency of the entire system. There are several criteria for allocating communication resources, one of which is fairness. Although fairness is important, the reason for not pursuing fairness is often a trade-off between the fairness of the system

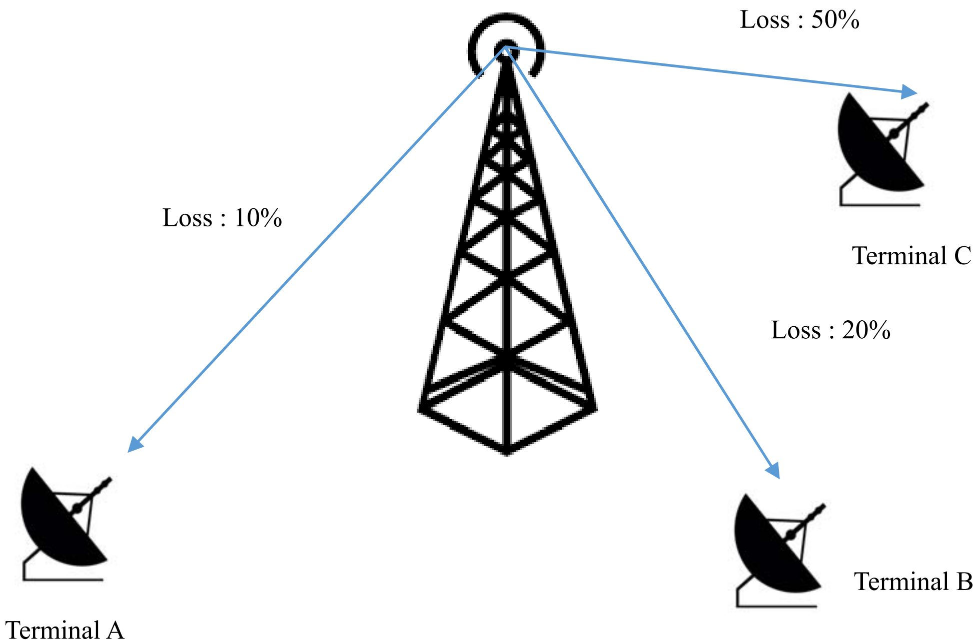


Figure 7 trade-off between throughput and fairness

and the throughput. A simple example is shown in Figure 7 to help for understand.

As shown in the figure, assume that the first path loss is 10%, the second is 20%, and the third one is 50%. Assuming a resource of 100, it would be the highest throughput to use 100 all at terminal 1. But it will not be fair. Allocating resources equally to all three terminals yields a throughput of 59. Though the amount is much different than the maximum throughput, all three terminals can receive the same amount of resources. There can be a trade-off between fairness and throughput, as in this example.

If equity is important, how can we measure fairness mathematically? There are several methods, but one of the first proposed methods is the Jain's index. Jane's index has four advantages.

- Independent of population size
- Independent of scale and metric
- Boundless
- Continuity

Jain's index is the most widely used face index because of these advantages. The Jain's index is defined as

$$J = \frac{(\sum x)^2}{n \sum x^2} \tag{13}$$

The following table shows the Jane's index and throughput using the example in Figure 7. As can be seen from the table fairer the users are, the closer index is to 1.

	Case1 : Max throughput	Case2 : Max fairness
A (10%loss)	100	25.478
B (20%loss)	0	28.662
C (50%loss)	0	45.860
Throughput	90	68.790
Jain's Index	0.33	0.99

Table 2 Throughput Fairness trade-off

1.3.2 Proportional Fairness

There are various type of scheduling algorithms having various performance. Some of them maximize throughput and others focus on fairness, delay or loss rate. As mentioned earlier, both fairness and throughput cannot be improved at the same time. The Proportional fairness (PF) algorithm is used when two conditions are trade-off relations. PF was first proposed by Frank Kelly in [3]. With PF, the logarithmic sum is maximized and thus both can be guaranteed in multi-resource allocation such as throughput and fairness. The algorithm main equation is as follows

$$i^* = \arg_i \max \frac{C_i(t)}{R_i(t)} \tag{14}$$

Where $C_i(t)$is a current state throughput of user i, and $R_i(t)$ is average of mount of data received by user i over time t. $C_i(t)$ represents throughput and dividing by average of throughput, $R_i(t)$,represent the fairness. If a single user has received a lot of resources so far, the denominator grows, leading to drop in priority. By that reason using the algorithm both fairness and throughput can be high. Therefore, the formula for calculating the average data rate is as

$$G_m(t+1) = \left(1 - \frac{1}{t_c}\right) G_m(t) + \frac{1}{t_c} \sum_{k=1}^{N} g_m(t) \tag{15}$$

where t_c is the averaging window size which limits the number of samples used in the average. Because the number of samples increases over time, old samples do not have a large impact on large systems, and they increase computation time, which slows algorithm computation. g_m is the throughput that the current user m can be obtained. In other words, the above expression reflects the current throughput while continuously updating the average throughput.

II. Successive Interference Cancellation for UAV

2.1 System modeling

As mentioned above, UAV has been widely used as a substitute for telecommunication, and it has been explained that it can replace communication infrastructure in particular. However, it can be a bad environment because the drones are used as a substitute for communication infrastructure, and the overall QoS of the system may be degraded due to lack of communication resources. Therefore, we applied SIC technology to UAV to increase resource efficiency. In addition, assuming that fixed-wing drones are used for continuous communication, fixed-wing drones will have a constant trajectory, so

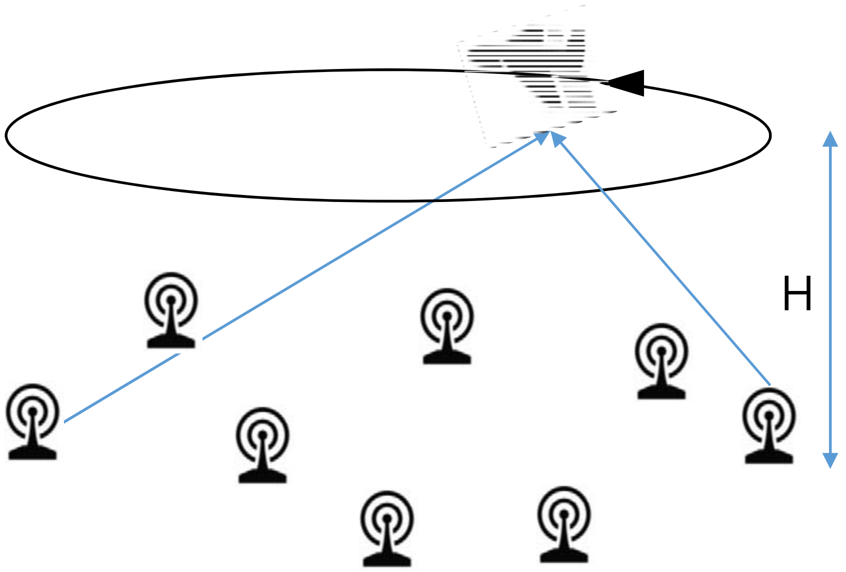


Figure 8 system model

the channel environment and the power gain between nodes and communication drones will have periodicity. In this situation, research on communication efficiency is essential. Therefore, in this paper, we proposed an algorithm for how to communicate effectively in this situation, simulated it, and studied communication method.

The system environment is shown in Figure 8. I considered a wireless communication system in which a UAV used as a base station communicates with N ground terminals. It is assumed that the UAV is flying in the cyclical trajectory at a constant altitude of H. And it is also assumed that the velocity of the UAV is constant in V and therefore moves with period T. There are N ground terminals(GT). I considered that the communication channel is a line of sight (LOS) environment, and it is assumed that the channel gain follows the distance attenuation, and the Doppler effect due to the movement of the UAV can be completely compensated. It is assumed that the terminals are superimposed on the two paired signals and that the signal can be completely decoded in the SIC receiver and then removed from the original signal.

2.2 User Pairing in SIC receiver for UAV

The problem of pairing and decoding some users in SIC technology is an important problem that can greatly affect the throughput of the entire system. Since the signal to be decoded later is treated as an interference of the signal to be decoded first, the channel capacity varies greatly depending on which user to select.

There are several ways to pair a user. The simplest pairing method is to randomly select users. A base station or a specific communication facility is a method of selecting two terminals at random. It is simple because it does not use the state or environment of the channel, but its performance is poor. But there is an advantage that the easiest, simplest, and lowest complexity. Another method which is proposed in [4] is sorting channels in order of channel gain and then pair the best channel with the worst channel. The algorithm is as follows.

- Calculate the channel gain h between the terminal and the base station.
- Sorting h in ascending order.
- Divide the N terminals sorted by channel gain into halves and divide them into groups in A and B
- Pair A(n) with B(n) where n = 1, 2,…, N/2

There is an advantage that the complexity is not high and is simple. However, depending on the situation, the throughput of the first decoded signal, which is largely affected by the second signal, may be significantly lowered, resulting in a lower fairness.

The last scheme is PF based user pairing scheme which is proposed in this paper. A terminal having the worst channel state is paired with a terminal having a channel having a higher priority through the PF algorithm.

The terminal having the highest priority in the PF algorithm is determined as the terminal to be decoded first. The specific algorithm process: First, the terminals are sorted in ascending order based on the channel gain of the terminals. The second decoded signal acts as an interferer, so the larger the signal, the worse the overall throughput is. Therefore, the terminal that will be used as the signal to be decoded secondly selects the channel with the worst channel condition. Now choose the terminal to be decoded first to ensure proper fairness and throughput. To take both throughput and fairness into account, we use the PF algorithm to obtain the priority. The terminal having the highest priority in the PF algorithm is determined as the terminal to be decoded first.

- Calculate the channel gain h between the terminal and the base station
- Sorting h in ascending order.
- Choose the worst channel: the second signal
- Use the PF algorithm to get the priority and choose the highest priority terminal: the first signal

This method allows both fairness and throughput to be considered at the same time and minimizes the effect of the second signal acting as an interference. Figure 9 shows a flow chart of the proposed user pairing when the UAV is flying over the circle.

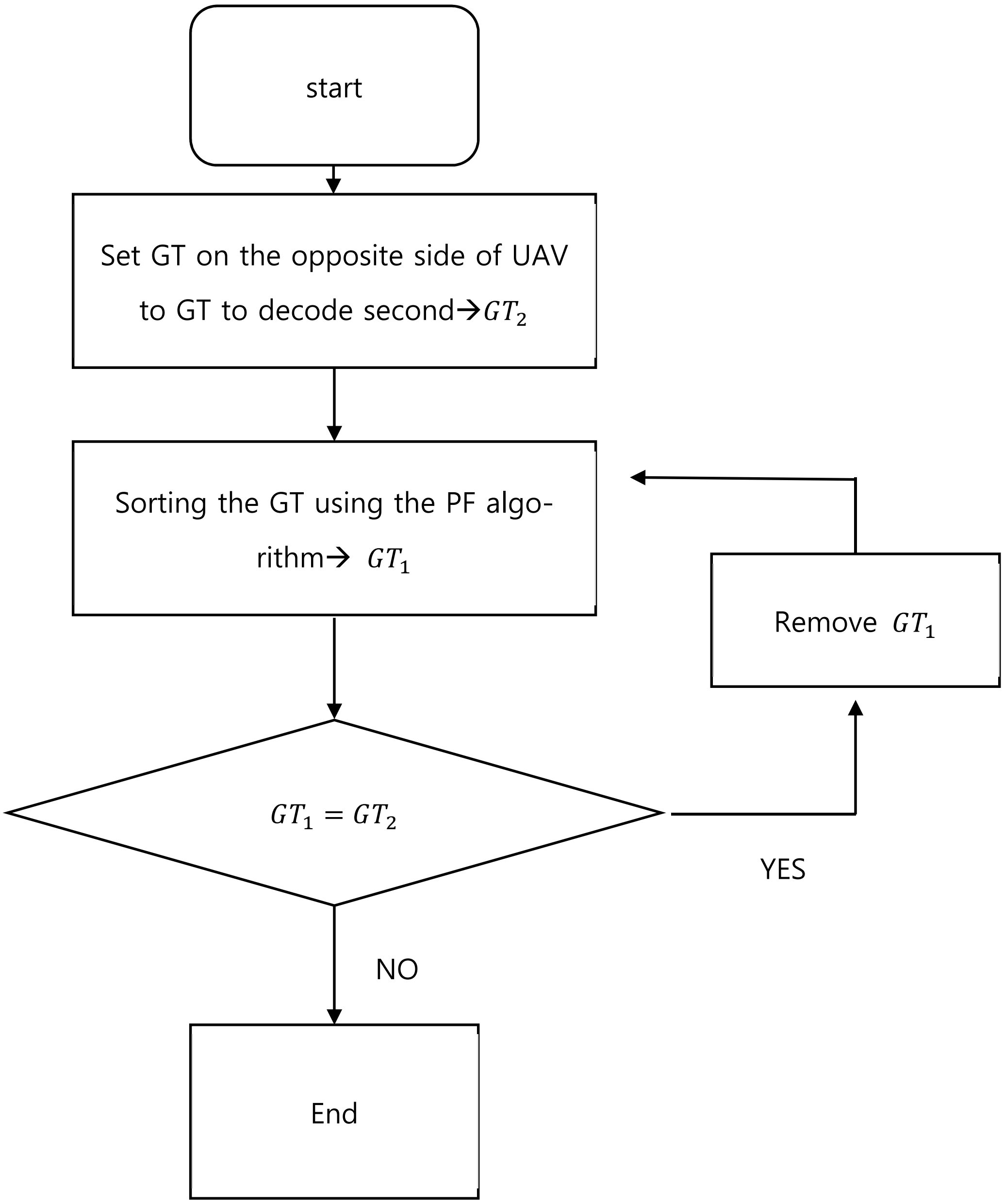


Figure 9 Process of proposed User Pairing

2.3 Scheduling in SIC receiver for UAV

As mentioned above, the UAV, which has a constant trajectory and height, also has a periodic gain. Also, as we assume, this scenario does not consider any fading other than path loss, so the distance between the UAV and the ground terminal has an absolute effect on the gain of the channel. The channel gain $h_k(t)$ between UAV and k-th terminal is as follows.

$$\mathrm{h_k(t)} = \frac{\beta}{(x(t)-n_k)^2 \ \ +H^2}, 0 \leq \mathrm{t} \leq \mathrm{T} \tag{16}$$

where the β denotes the channel gain and $x(t)$is the location of UAV. n_k denotes the k-th terminal's location. The x (t) is changing with a period of T as the UAV flies. The instantaneous channel capacity between ground terminal and UAV without SIC is as follows.

$$\mathrm{r_k} = \log_2(1 + SNR)$$

$$\mathrm{r_k} = \log_2(1 + \frac{Ph_k}{N_0}) \tag{17}$$

From Eq12 and Eq16,

$$\mathrm{r_k} = \log_2(1 + \frac{P(\frac{\beta}{(x(t)-n_k)^2 \ \ +H^2})}{N_0})$$

$$= \log_2(1 + \frac{P\beta}{N_0((x(t)-n_k)^2 \ \ +H^2)}) \tag{18}$$

Thus, while the UAV is flying for one cycle, the overall channel capacity is as follows

$$\int_{t=0}^{T} \log_2(1 + \frac{P\beta}{N_0((x(t)-n_k)^2 \ \ +H^2)})dt \tag{19}$$

Now let's calculate the case of applying SIC to UAV. From Eq 12 and Eq 17 the instantaneous channel capacity between ground terminal and UAV with SIC is as follows.

$$\mathrm{r_{k,l}} = \log_2(1 + \frac{P_1 h_k + P_2 h_l}{N})$$

Where the l, k are the terminal index and $\mathrm{P_1} + P_2 = P_t$, $\mathrm{P_t}$ denoted that total power. Therefore, the total channel capacity is obtained as

$$\int_{t=0}^{T} \log_2(1 + \frac{P_1 h_k + P_2 h_l}{N})dt$$

III. Simulation Results

2.3 System modeling

In this section, we will describe the results of the calculations for the three cases based on the previous formulas. In the first case, GT is arranged in a circle, and the intervals between GTs are the same. The communication method is as follows. Unmanned aerial vehicles fly at a certain altitude and

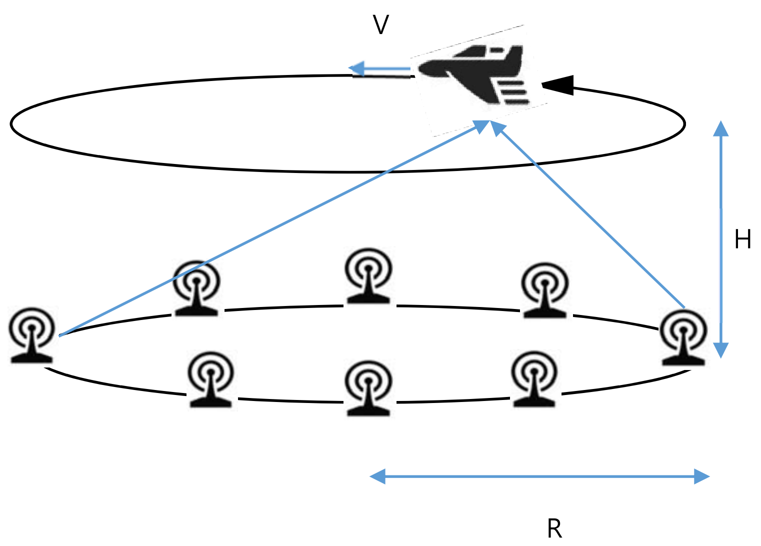


Figure 10 Placed on a circle at uniform distance

communicate with the nearest GT for obtaining a good communication channel. This method is called CMA and is proposed in [6]. It communicates with a good channel GT but has the disadvantage that the delay is too long. However, SIC receiver is used for UAV as mobile base station, multiple GTs can communicate in one-time slot, so it can reduce the delay by more than half. The use of SIC also improves throughput by increasing frequency bandwidth efficiency.

The number of GT is 12, the altitude(H) is 100m, the velocity(V) of the UAV is 30m / s, and the radius of the trajectory(R) is 40m. The SNR of the transmitter is set to 40dB.

3.2 Simulation Results

As can be seen in Figure 11, the throughput per terminal is lower using the SIC, but the overall throughput is 1.4 times higher. The scheduling method used in this case is to pair the nearest GT with the farthest GT when the UAV is in a constant trajectory. This graph computes instantaneous throughput rather than cumulative throughput. As the distance between the GT and the UAV is getting closer and closer, we can see that the throughput fluctuates.

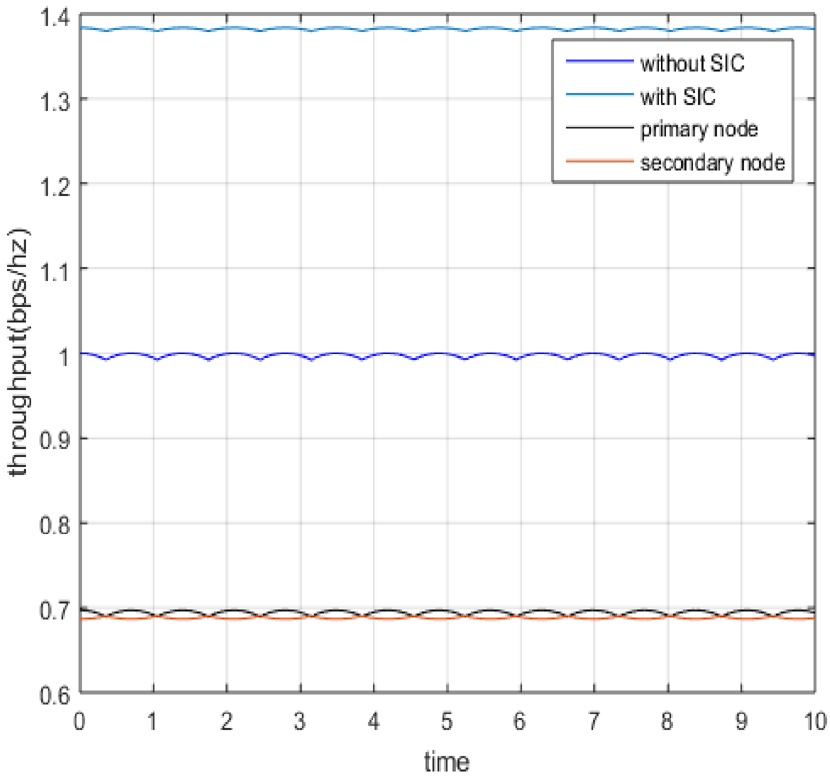


Figure 11 Comparison between SIC and non-SIC application

In the second case, the GTs are placed on the circle as in the first case, but the distances between the GTs are random. In the first case, there is no reason to use the PF algorithm because there was no randomness. On the other hand, scheduling is more important because the GT is random in the second case, and the benefit can be seen when applying the proposed algorithm.

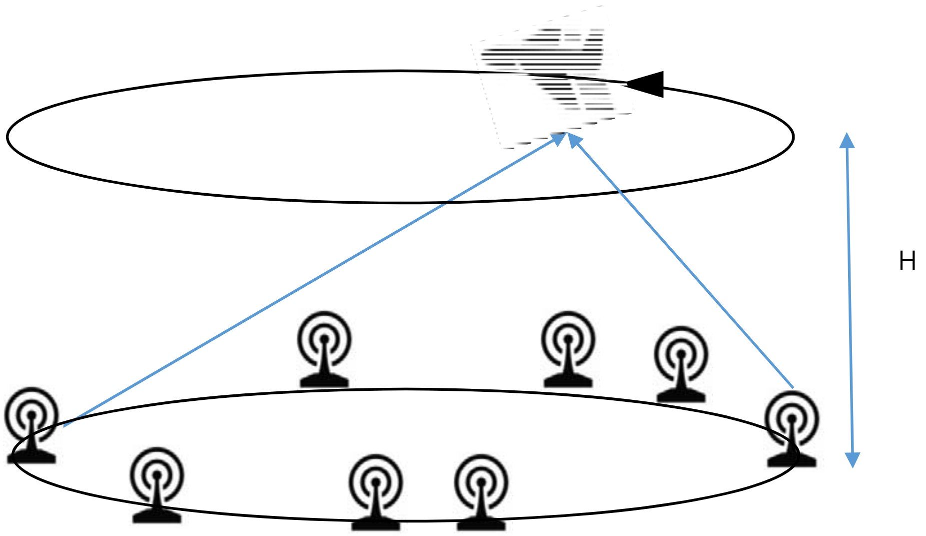
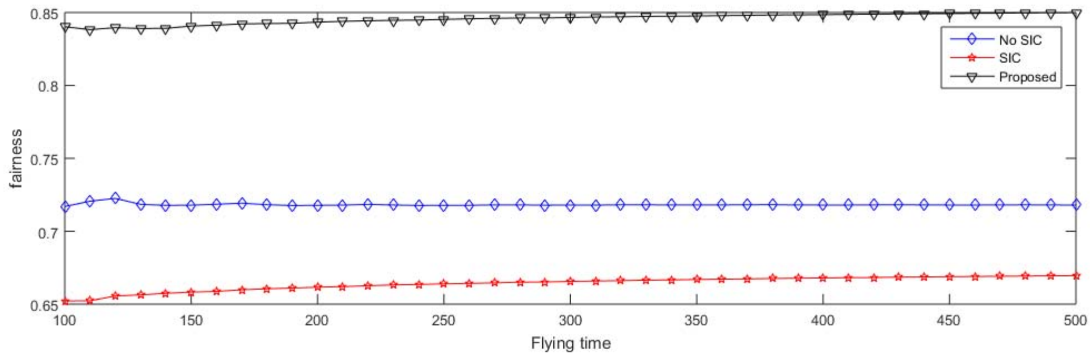


Figure 12 Placed on a circle at random distance

As mentioned above, the GTs are installed at random distances on the circle. Other than the deployment of the GT, this is the same situation as the first case earlier. It is closer to a realistic problem than the first. If it is possible to control the transmitting power at the GT, it can be mapped the GTs that are not in the circle as if they were on the circle.

In addition, randomness can result in unfairness between GTs. It is necessary that proper scheduling is required because the difference in throughput will increase as the GT repeats the cycle far from or near the UAV.



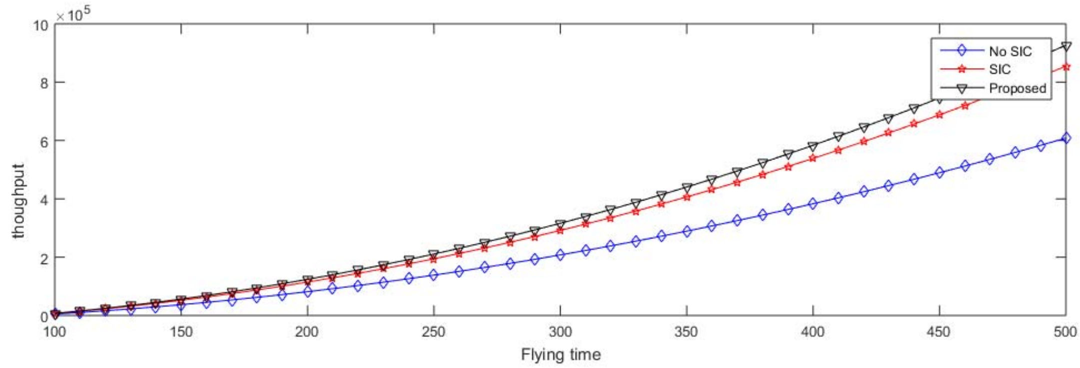


Figure 13 Fairness and Throughput of Case 2

Figure 13 shows the case of using PF base user pairing and the case of not using PF base user pairing mentioned above. In the case of a typical SIC, we used a method of pairing the bad channel with the good one, as I mentioned above. Pairing a GT with a good channel and a GT with a bad channel also has a fairly good performance compared to the usual random pairing. However, the proposed algorithm showed high perfor-

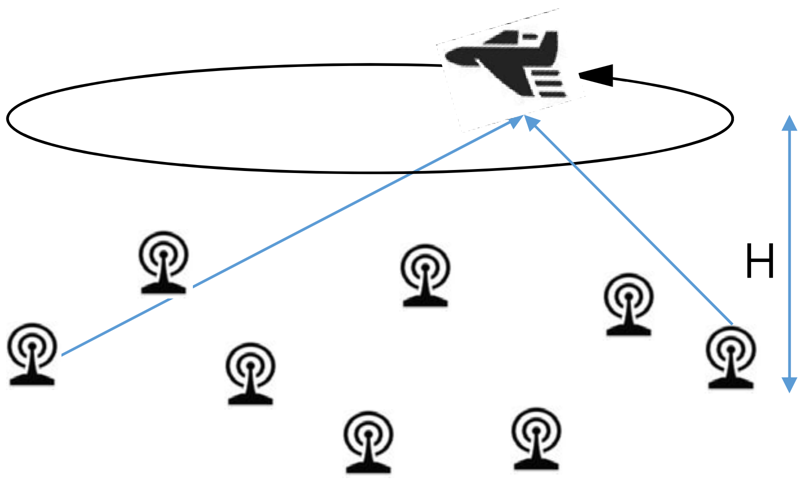


Figure 14 Randomly located GT

mance in both fairness and throughput. Especially, in case of fairness, SIC is not used, and performance is higher than when scheduling one by one to GT.

The last case is when the GTs are completely random as shown in Figure 14. The distribution of GT was assumed to follow the uniform distribution in polar coordinates. This is the most realistic case. Since GTs are no longer on the circle, you have to calculate them from the trajectory radius. The path of the UAV with circular path can be easily obtained by knowing only the position of GT. First, we will obtain the radius of the UAV trajectory through a simple calculation. Let D be the set of distances between the GT and the origin, let x be the radius of the trajectory of the UAV.

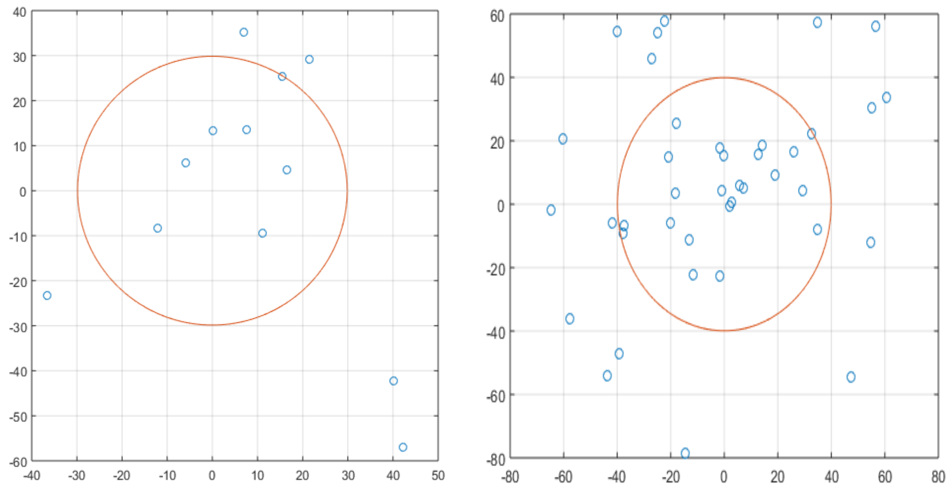
$$\min(\mathrm{D}-\mathrm{x})^2$$

$$\arg_{\mathrm{x}} \min(D-x)^2 = D$$

$$\therefore \mathrm{x} = \mathrm{avg}\ \mathrm{D}$$

Since the distance between the origin and the node is the uniform distribution, x can be expressed as the average of D.

As the randomness increases, the throughput becomes significantly smaller than when the randomness is small. Although there are some differences according to the distribution, it can be seen that the performance of the proposed algorithm shows good performance in both fairness and throughput. Because the GT to be decoded secondarily affects the first decoded GT as a stronger interferer if the distance to the UAV is closer. Also, if the first GT to be decoded is far away from the UAV, the received power is weakened. If there is no randomness, it is easy to pair between GTs. However, if the randomness increases, there is a problem about which GTs are to be paired. In the case where the GT allocation is random, the complexity of the calculation becomes large and the calculation time is also greatly increased in order to obtain the optimal value. Therefore, an efficient scheduling technique is essential in a case where the calculation amount does not increase. The result is divided into two according to the number of GTs. In the first case, the number of GTs is 12 (Figure 15 (a)). In the second case, the number of GTs is 40 (Figure 15 (b)). The red circles in Figure 15 show the path of the UAV and the blue small circles show the positions of the GTs.



a) N=12 b) N=40

Figure 15 Deployment of GT

We used the algorithm shown in Fig. 9 as the communication scheduling method between UAV and GT. The result is shown in Figure 15. As mentioned earlier, throughput has dropped due to random-

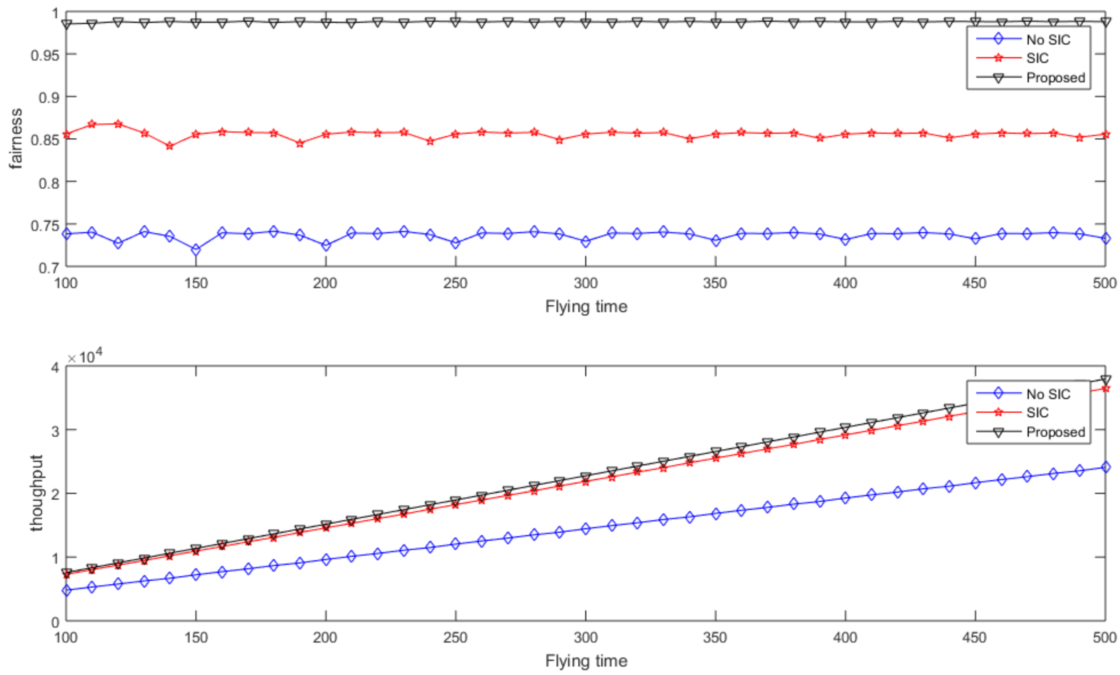


Figure 16 Fairness and Throughput of Case 3 (a)

ness, but Fairness has seen a much larger difference from other algorithms. Simulation results do not show a significant difference in throughput when the number of GTs is 12 or 40. In the case of fairness,

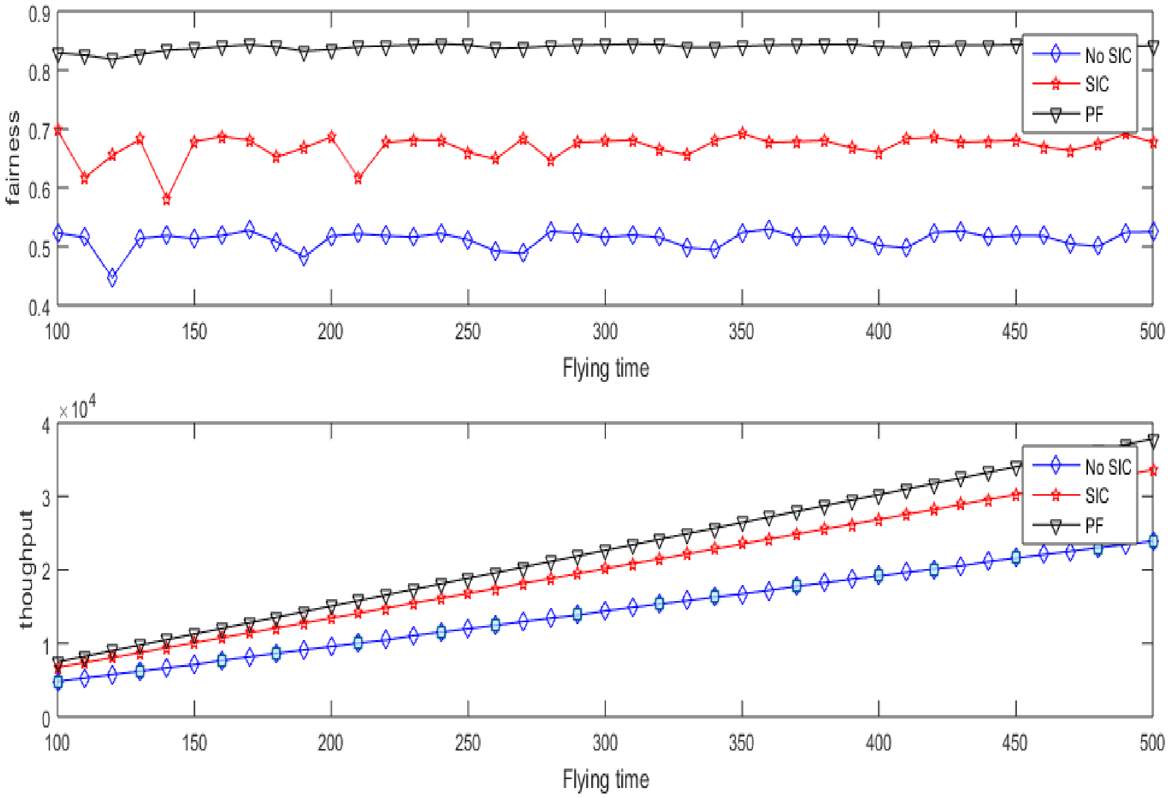


Figure 17 Fairness and Throughput of Case 3 (b)

the number of GTs is lower than that of 12 when the number of GTs is 40, but the proposed algorithm still shows the highest performance. The results show that the performance of the proposed algorithm is good in all three cases.

IV. Discussion and Conclusion

In this paper, we discuss NOMA, one of future radio access technologies, and successive interference cancellation, which is one of the core technologies of NOMA. In addition, considering the recent interest in using UAV as a base station, we have studied the application of SIC technology to UAVs used as mobile base stations. The case where UAV is used as a mobile base station is often a situation where communication QoS is likely to be lowered, for example, when natural disasters, terrorism, or the number of users become too many to allow good communication state. Therefore, in this paper, various algorithms are introduced to increase the communication efficiency and increase the resource efficiency such as frequency. Especially, in this paper, we propose an algorithm for user pairing problem which is still open problem among several problems to be solved in SIC technology by using proportional fairness algorithm. The performance of the proposed algorithm is also verified by comparing the proposed algorithm with the existing algorithm. The function of SIC varies greatly depending on which user is selected and communicates at the same time. As I mentioned, because the users act as interferers to each other. Therefore, in this paper, we propose an algorithm to communicate with users while minimizing interference. But the problem with pairing is still the open problem. As mentioned above, since throughput and fairness are trade-off relations, the scheduling method will be largely changed depending on which of throughput and fairness is more important.

In this paper, we also propose scheduling of user pairing in SIC, and there are many unspecified assumptions. This is why realization of SIC or NOMA is still difficult. First, there is a problem with synchronization. Also at the MAC layer, performance may be worse than expected due to packet hole, which is a problem that occurs when the packet size of the two signals is not matched. Decreasing the amount of information and distorting the data caused by decoding and decoding the original signal must be resolved. Despite the variety of problems, SIC technology at NOMA is a highly valued technology that is currently undergoing a lack of frequency and is still highly regarded for future radio access technology or future communication technology like cognitive radio. Furthermore, if SIC technology is applied to UAV, the synergy is expected to be large.

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요 약 문

무인기에서 연속간섭제거 기법을 이용한 주파수 자원 효율 증대 기법

무선 이동통신이 사용되어진 이후, 무선 통신 기기들의 증가하고 있다. 게다가 이동통신 단말들이 점점 빠른 통신 속도의 요구로 많은 통신 자원을 요구하고있다. 이러한 현실에서 현재 심각한 통신 자원 부족을 겪고 있다. 이런 문제를 해결하기 위해서 통신 자원 특히 주파수 자원을 아끼기 위한 여러가지 연구들이 진행되어왔다. 그 중에 하나가 Non orthogonal multiple access 의 핵심기술인 Successive interference cancellation 이다.
본 논문에서는 위에 기술을 이용해서 모바일 베이스 스테이션 특히 UAV 에 적용해보려고 한다. UAV 역시도 재난상황 등 여러 극단적인 상황에서 통신대체시설로 사용되는 경우가 많다. 극단적인 상황인 만큼 통신 자원의 공급이 원활하지 않을 수 있고 여러가지 제약조건들로 인해서 통신의 QoS 도 보장하기 어렵다. 따라서 본 논문에서는 통신 자원 중 하나인 주파수 대역폭의 효율을 향상시키기 위해 SIC 기술을 UAV 특성이 맞게 적용하고 또한 스케쥴링 알고리즘을 제안하였다. 전체 시스템에 채널 용량과 공평성을 동시에 고려하기 위해서 비례공정 알고리즘을 응용하여 연속간섭제어 기술 중 User Pairing 알고리즘에 변형 및 적용하였다. 또한 이 알고리즘의 성능 평가를 위해 기존에 제안되었던 알고리즘과 비교하고 수치적으로 계산하였다.

핵심어: 연속간섭제거, 무인기, 스케쥴링, 비례공정