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# Spectrum Sharing among Multiple Secondary Users Using Channel Assignment Method of High Spatial Efficiency Based on Mutual Interference

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# Outline

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## ◆ Introduction

- Cognitive Radio
- Related Work

## ◆ Proposed Method

- Channel Assignment Method of High Spatial Efficiency

## ◆ Simulation

- Simulation parameters
- Comparative methods
- Simulation results

## ◆ Conclusion

# Introduction

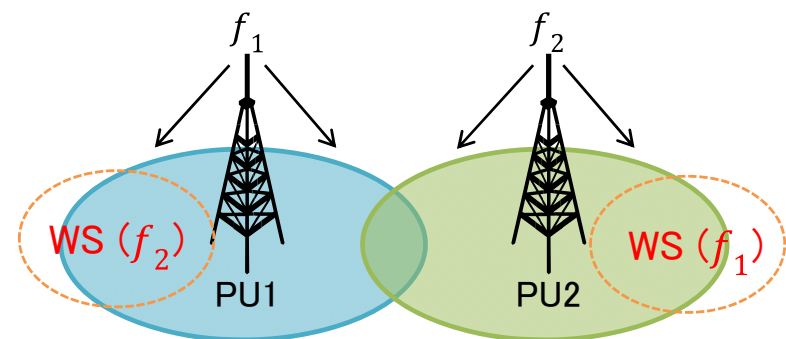
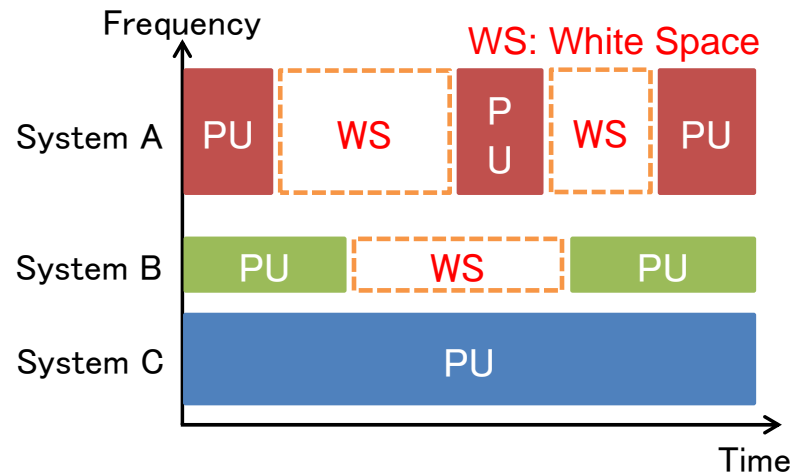
- ◆ Spectrum resource is scarce due to increased demand for wireless communication systems.



Cognitive Radio

- ◆ Cognitive Radio

- Cognitive radio is able to change communication parameters according to the surrounding wireless environment.
- Secondary user (SU) can access licensed band which is not used by primary user (PU).

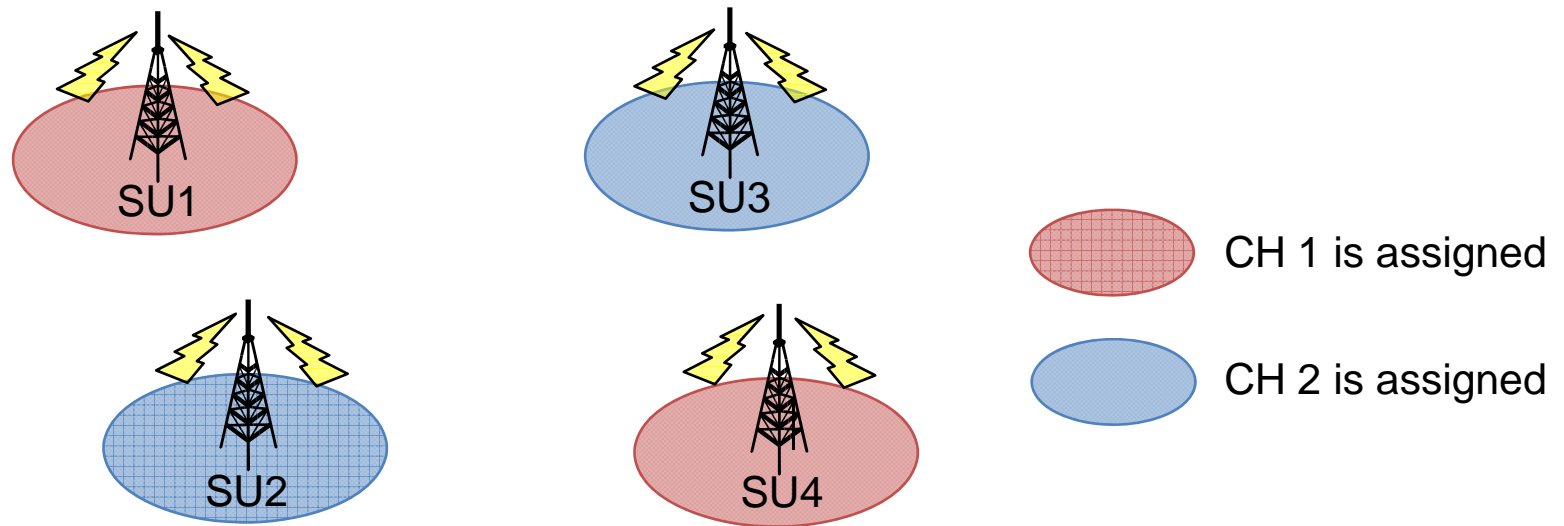


- The interference toward the PU has to be avoided.

# Related Work

- ◆ Channel assignment method for maximizing SU throughput
  - In the case of sharing multiple channels by multiple SUs

The relative distance between SUs have the same channel is maximized.



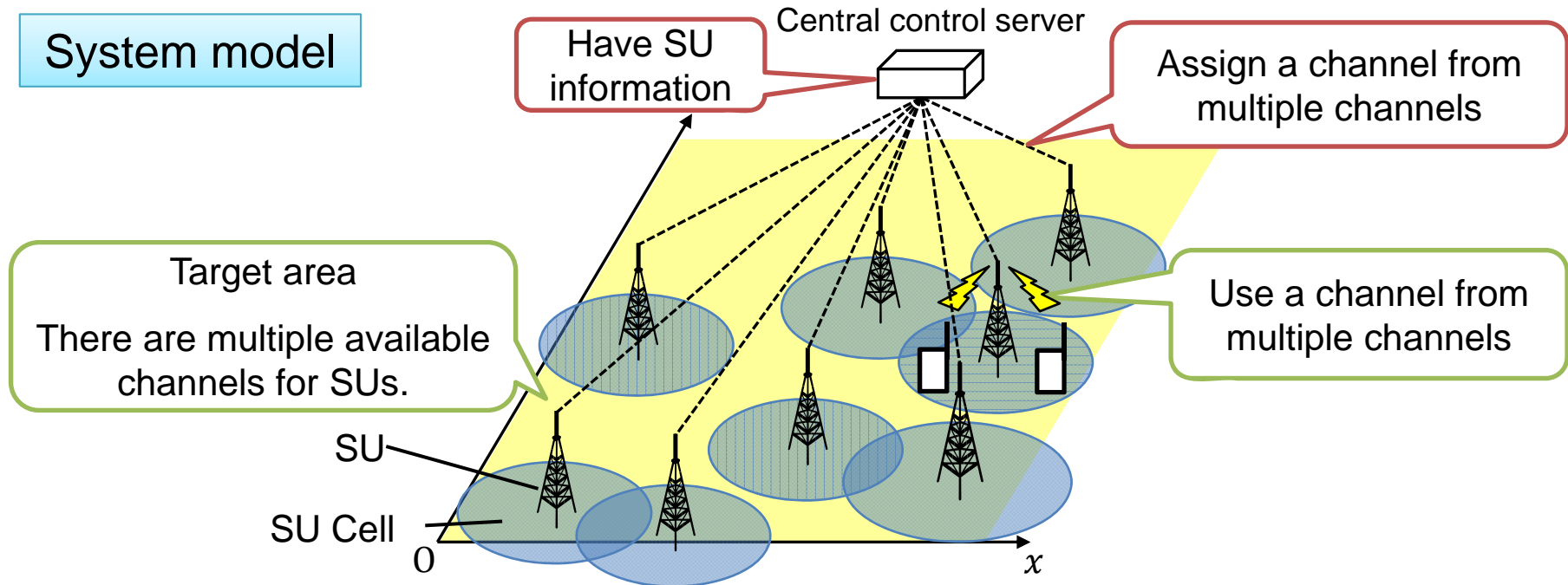
Disadvantage: Cause a spatially sparse utilization of frequency resources

Frequency usage efficiency decreases

# Proposed Method

## ◆ Proposed channel assignment method

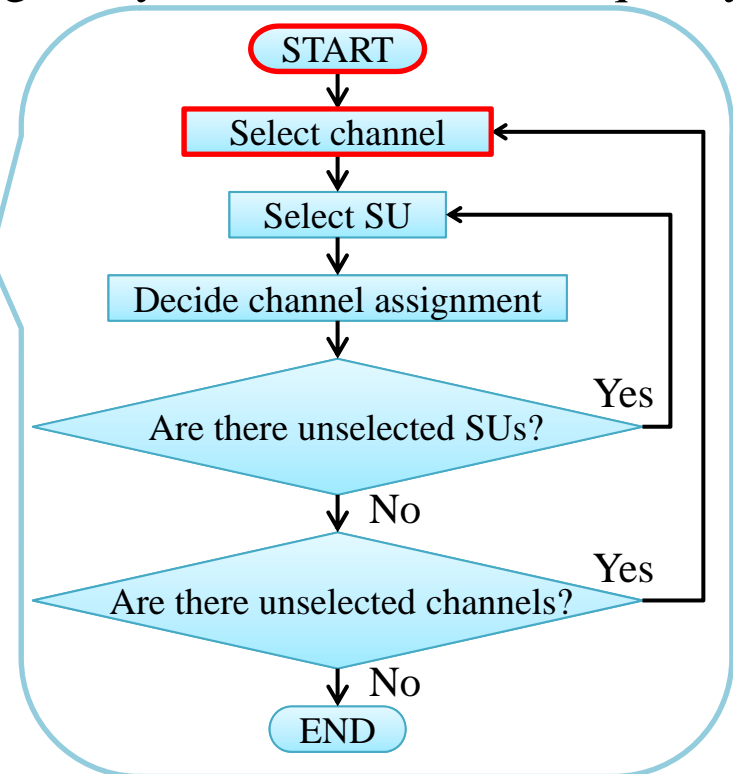
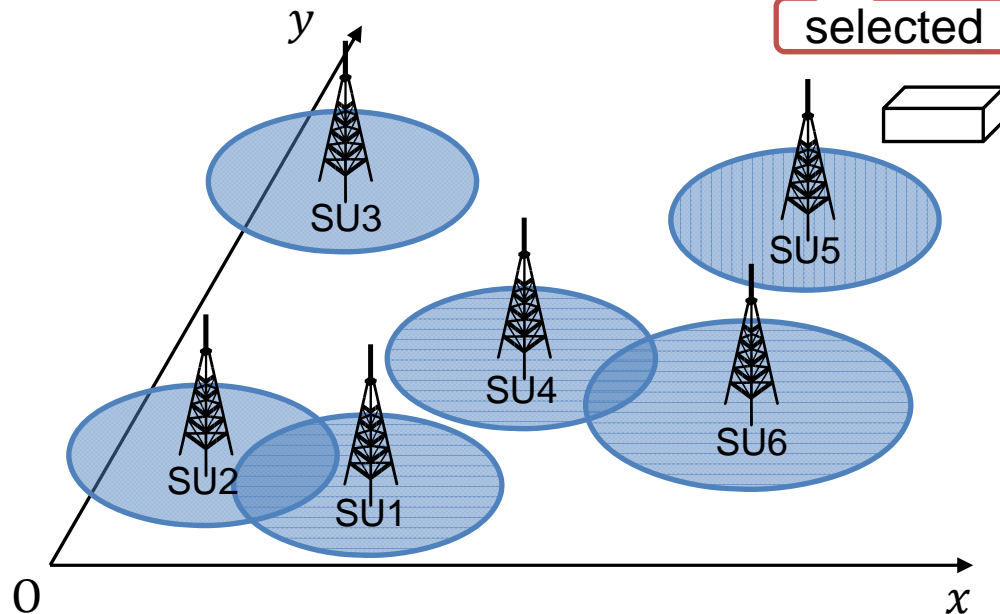
- Spectrum can be shared densely while keeping every SU communication quality.
- The central control server assigns the channels under considering mutual interference among SUs.



# Channel Assignment Procedure

- ◆ The channel is densely assigned while keeping every SU communication quality.

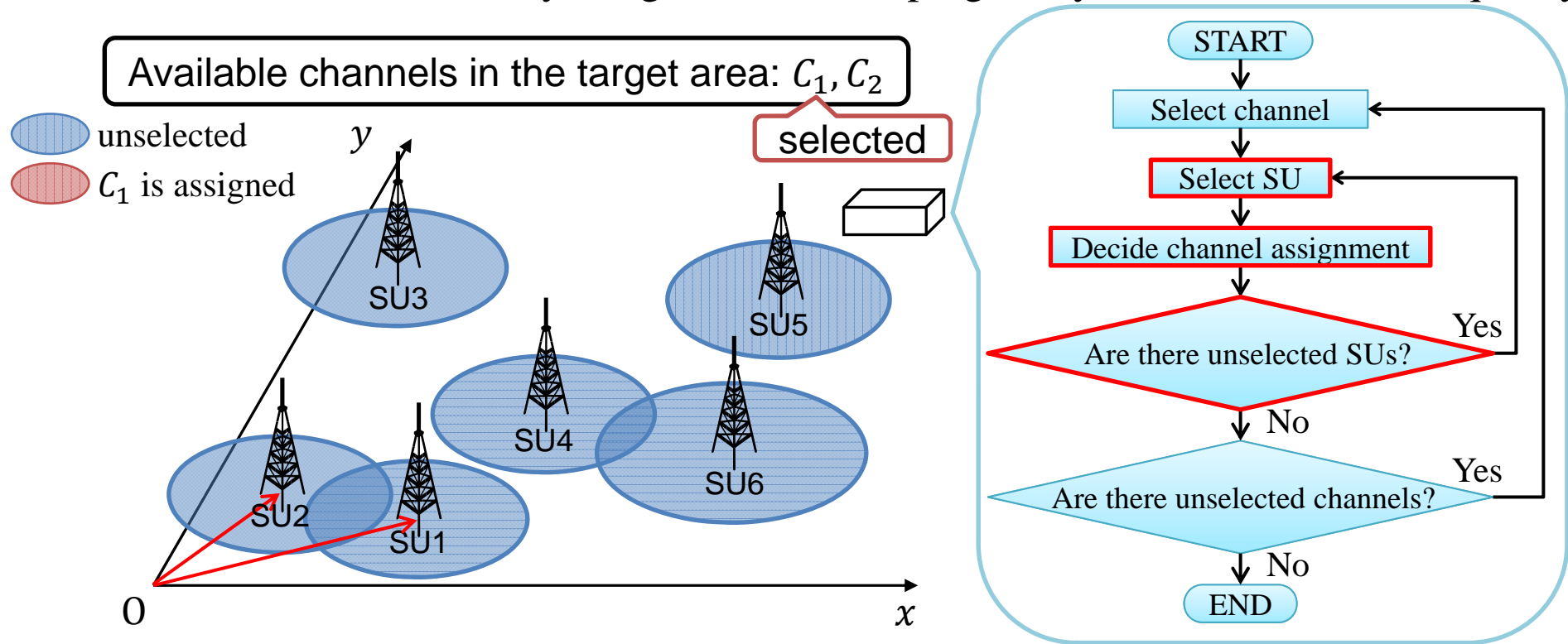
Available channels in the target area:  $C_1, C_2$



- The central control server selects the candidate channels from the order of a lower frequency channel.  
(Suppose frequency of  $C_1$  is lower than  $C_2$ .)
  - The central control server selects  $C_1$ .

# Channel Assignment Procedure

- ◆ The channel is densely assigned while keeping every SU communication quality.

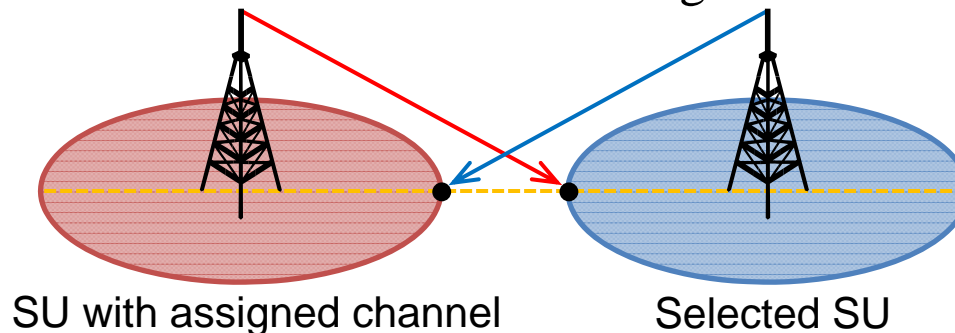


- The number of SUs with the assigned channel is 0. The central control server unconditionally assigns the channel  $C_1$  to the selected SU.

# Channel Assignment Decision

## ◆ (Number of SU with assigned channel) = 1

- The central control server calculates the coordinate of two maximum interference points by using SU information.
- The central control server assigns the channel if the interference is lower than allowable interference with the margin at the two points.



Allowable interference

$$P_i = \frac{S_{\text{BDry},i}}{\gamma_i} - N$$

$P_i$ : Allowable interference of  $i$ -th SU

$S_{\text{BDry},i}$ : Signal power of  $i$ -th SU at cell boundary

$\gamma_i$ : Minimum required SINR of  $i$ -th SU

$N$ : Average noise power

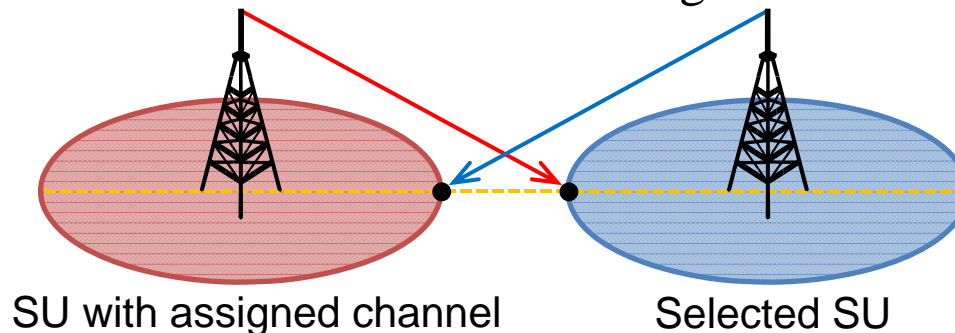
SINR(Signal to Interference and Noise power Ratio)



# Channel Assignment Decision

## ◆ (Number of SU with assigned channel) = 1

- The central control server calculates the coordinate of two maximum interference points by using SU information.
- The central control server assigns the channel if the interference is lower than allowable interference with the margin at the two points.



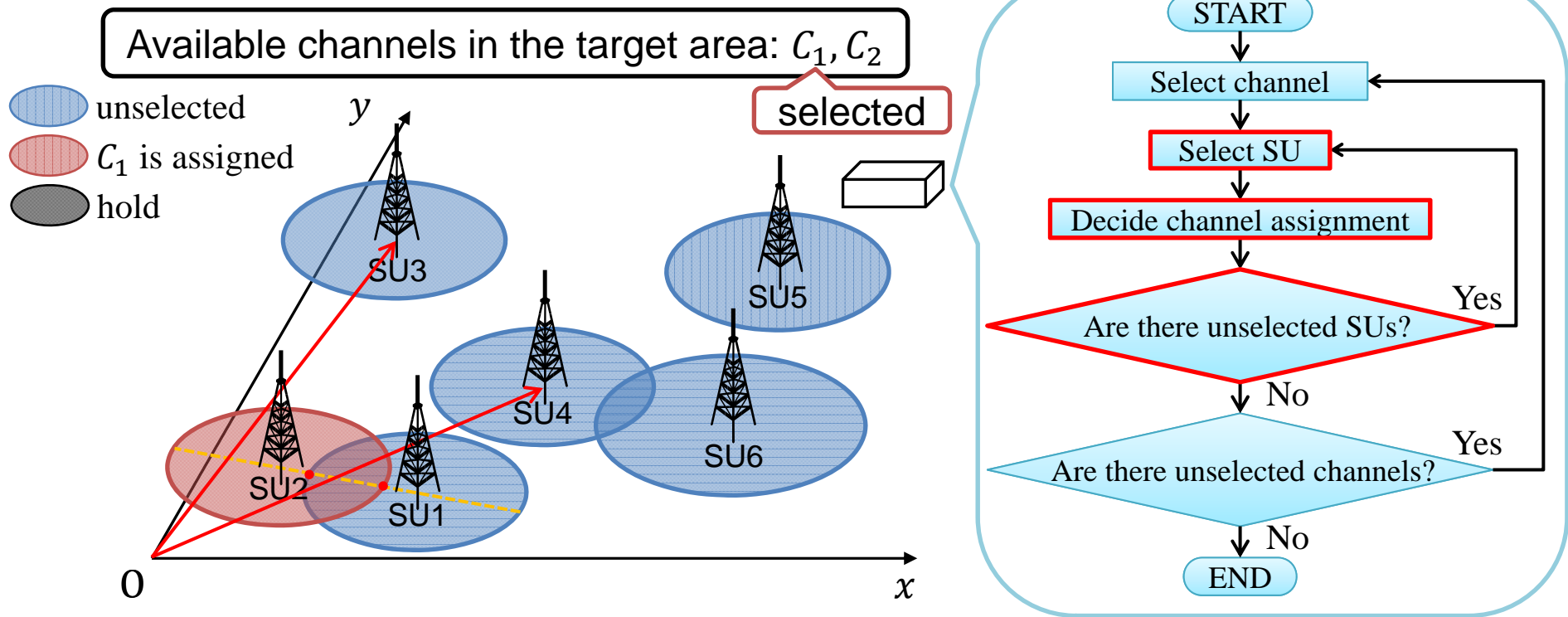
Allowable interference with the margin

$$P_i \times (1 - M) \quad M: \text{Margin of allowable interference } (0 \leq M < 1)$$

The minimum required SINR is satisfied in the cell  
if the number of SUs that have the same channel increases.

# Channel Assignment Procedure

- ◆ The channel is densely assigned while keeping every SU communication quality.

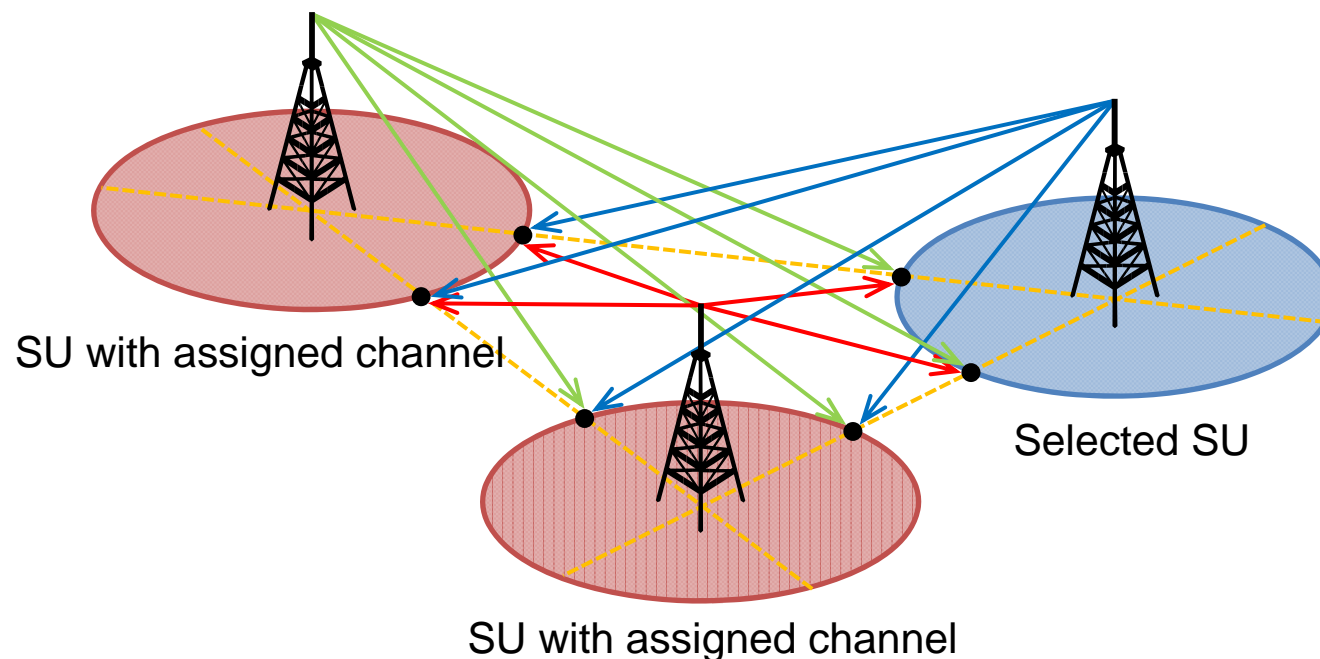


- The central control server is located at the origin 0.

# Channel Assignment Decision

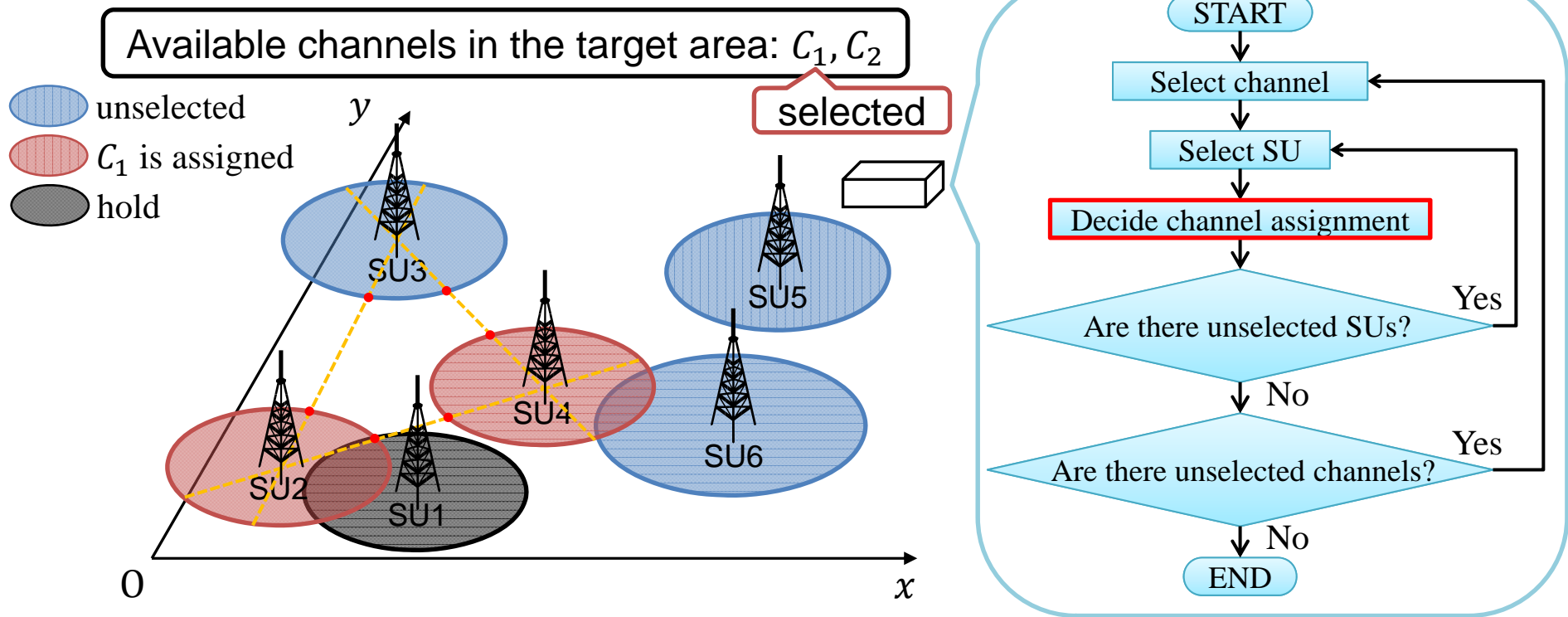
## ◆ (Number of SU with assigned channel) $\geq 2$

- The central control server calculates the coordinate of six large interference points by using SU information.
- The central control server assigns the channel if the interference is lower than allowable interference with the margin at the six points.



# Channel Assignment Procedure

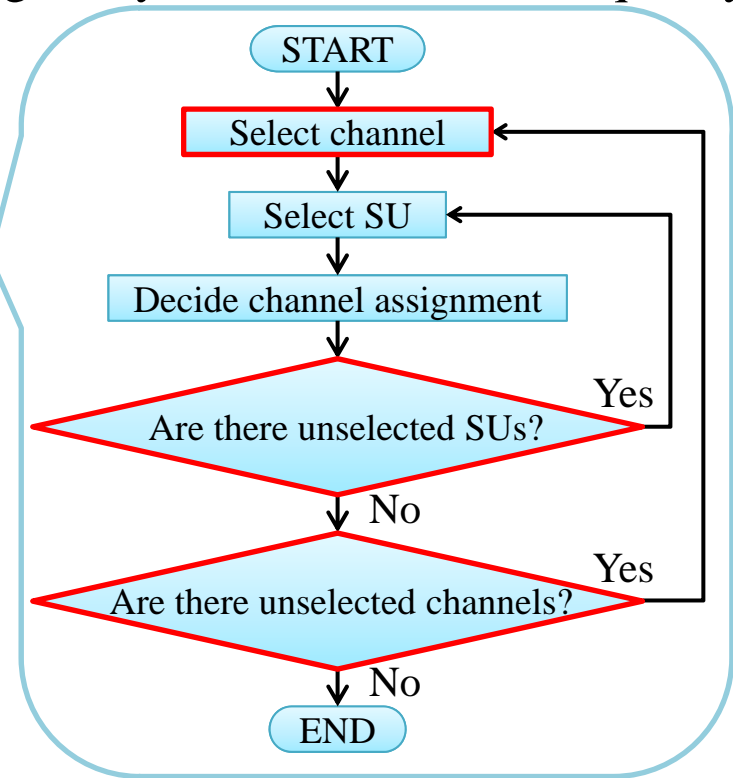
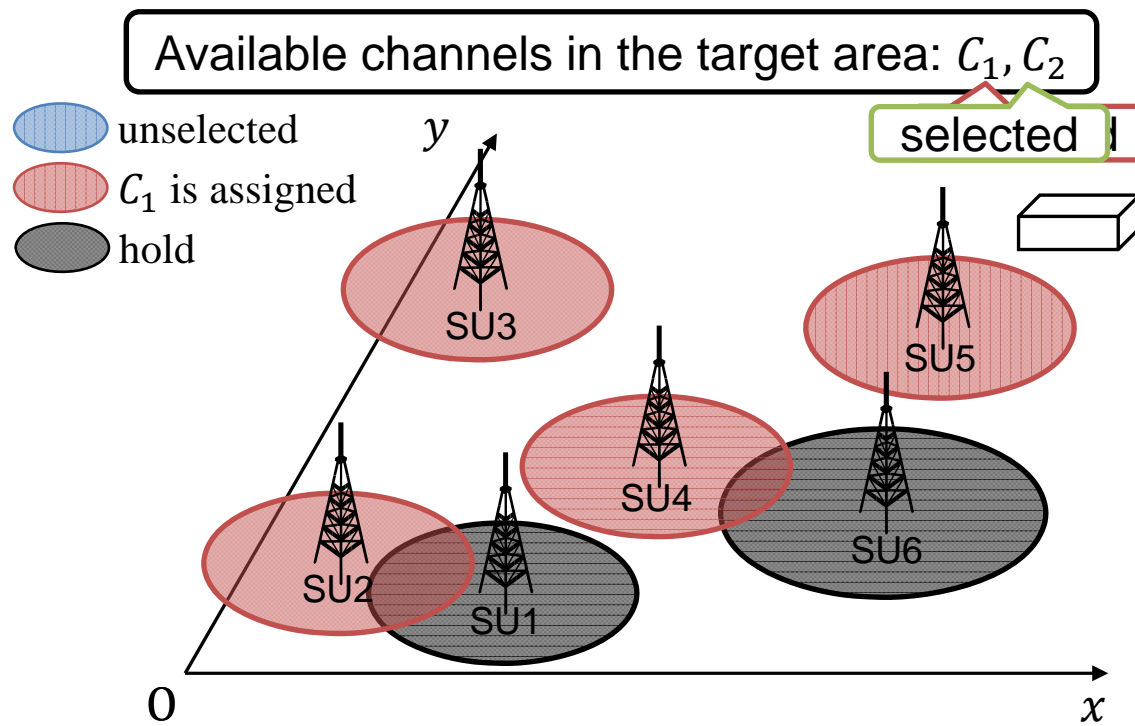
- ◆ The channel is densely assigned while keeping every SU communication quality.



- The central control server assigns  $C_1$  because the condition is met.

# Channel Assignment Procedure

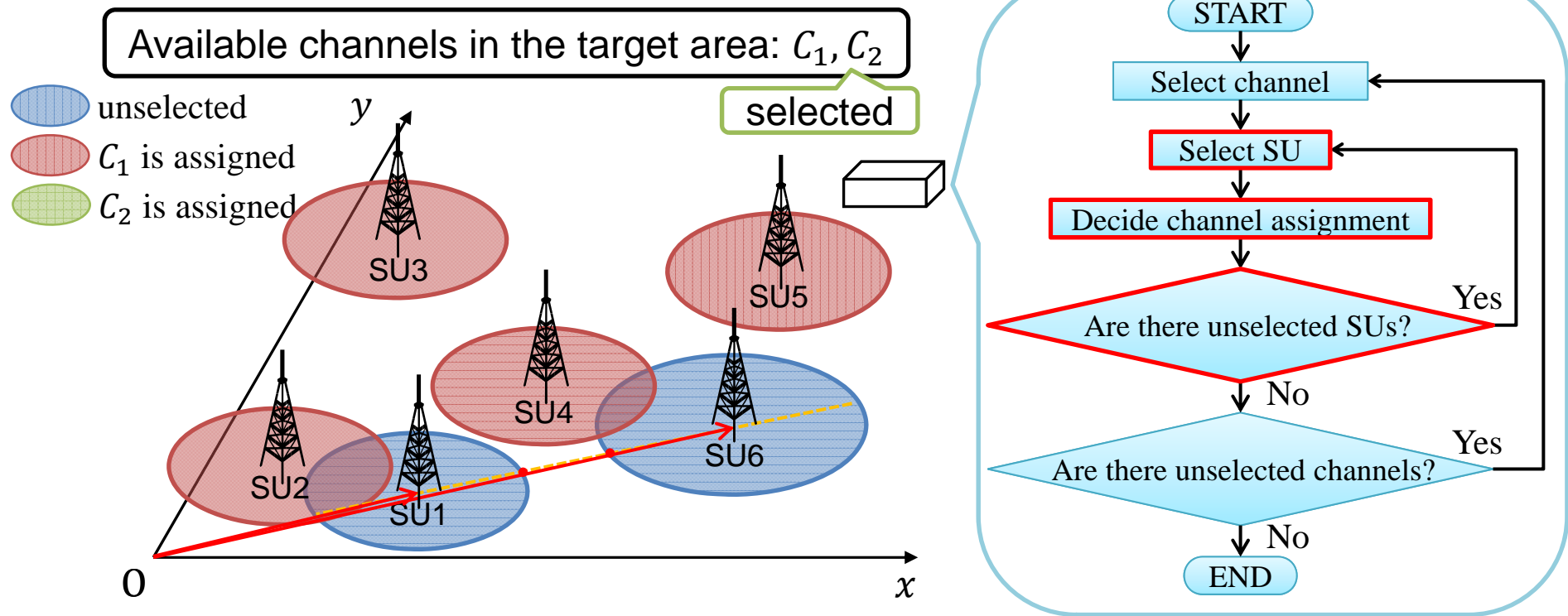
- ◆ The channel is densely assigned while keeping every SU communication quality.



□ The “Are there unselected SUs?” decision is made at channel selected SUs.

# Channel Assignment Procedure

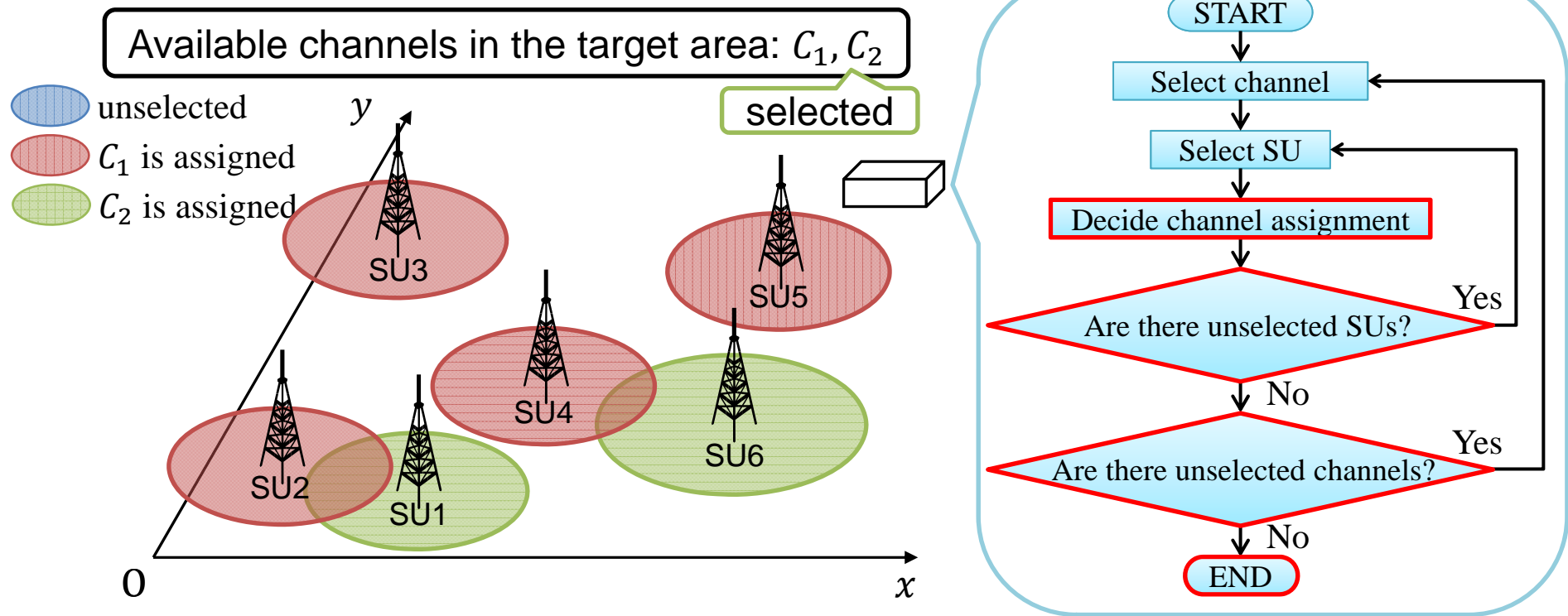
- ◆ The channel is densely assigned while keeping every SU communication quality.



- The number of SUs with the assigned channel is 0. Unselected SU from the origin 0. The central control server unconditionally assigns the channel  $C_2$  to the selected SU.

# Channel Assignment Procedure

- ◆ The channel is densely assigned while keeping every SU communication quality.



- The channel assignment is finished because the condition is met.  
SUs and channels.

# Simulation

- ◆ Number of SUs with an assigned channel
- ◆ SU with successful channel assignment ratio
- ◆ Change of Number of SUs with an assigned channel according to the margin  $M$
- ◆ Change of outage probability according to the margin  $M$

Outage probability: Probability of SINR at cell boundary is less than minimum required SINR.



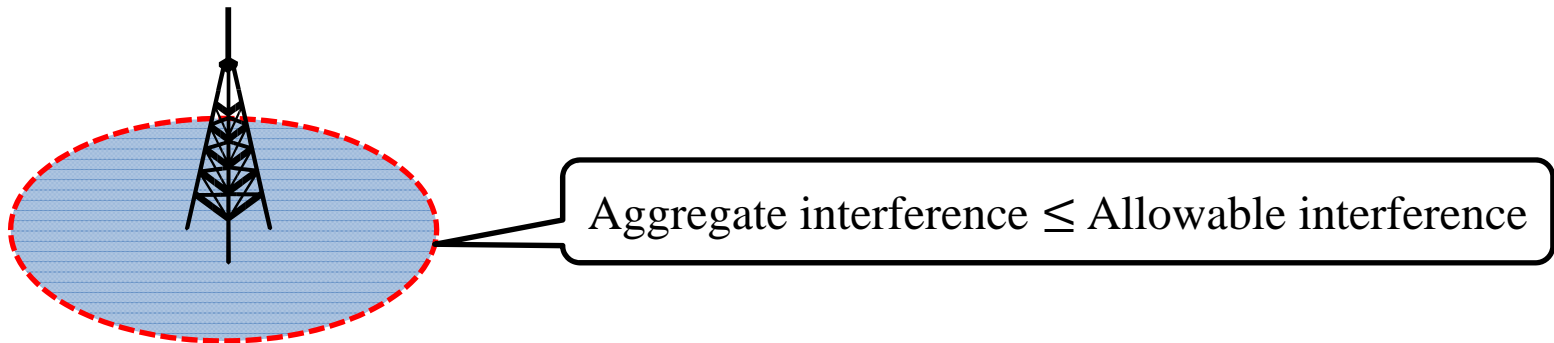
# Simulation Parameters

Parameter	Value
Size of target area	$5 \times 5$ [km <sup>2</sup> ]
Distribution of SU	uniform distribution
Number of available channels (Center frequency of each channel)	5 (500, 550, 600, 650, 700 MHz)
Transmit power of SU	20 [dBm]
Average noise power	−100 [dBm]
Cell radius of SU	100~150 [m]
Minimum required SINR	10 [dB]
Propagation factor	3.5
Reference distance	10 [m]
Antenna height	10 [m]
Number of trials	1000

# Comparative Method

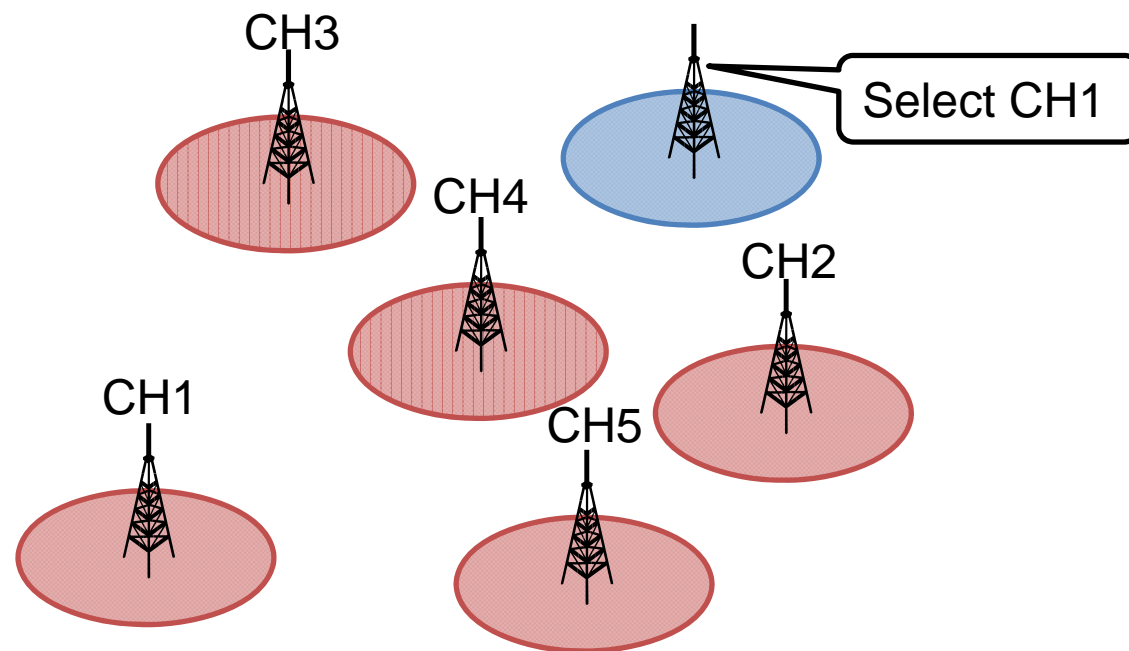
## ◆ Random assignment method

- The SU selects a channel at random.
- The central control server does not exist.
- SU accesses the channel if the aggregate interference is lower than allowable interference at cell boundary in all direction.



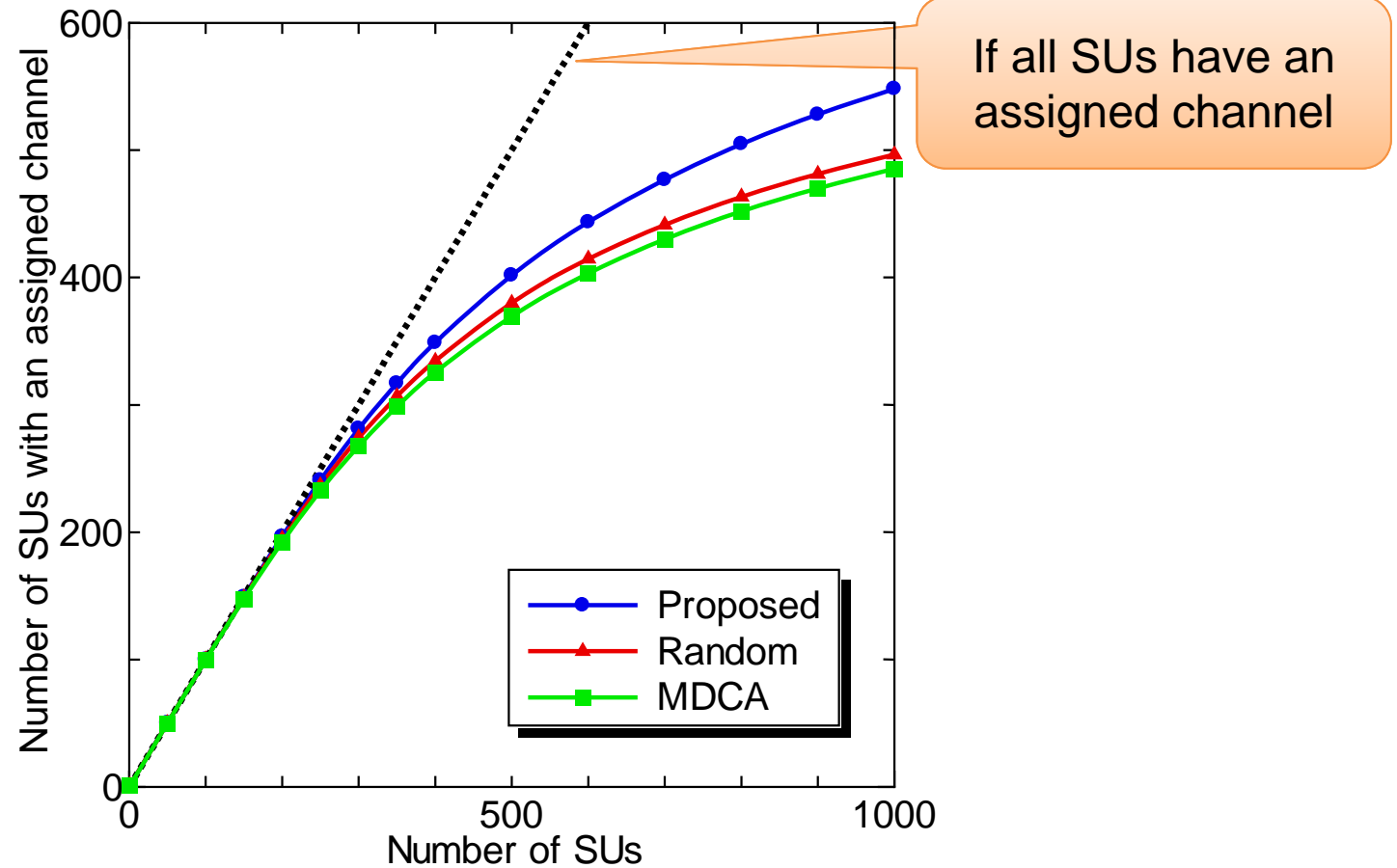
# Comparative Method

- ◆ Maximum distance channel assignment method (MDCA)
  - The distance among SUs which have same channel is maximized.
  - The channel that is used in the distance is selected.
  - SU accesses the channel if the aggregate interference is lower than allowable interference at cell boundary in all direction.



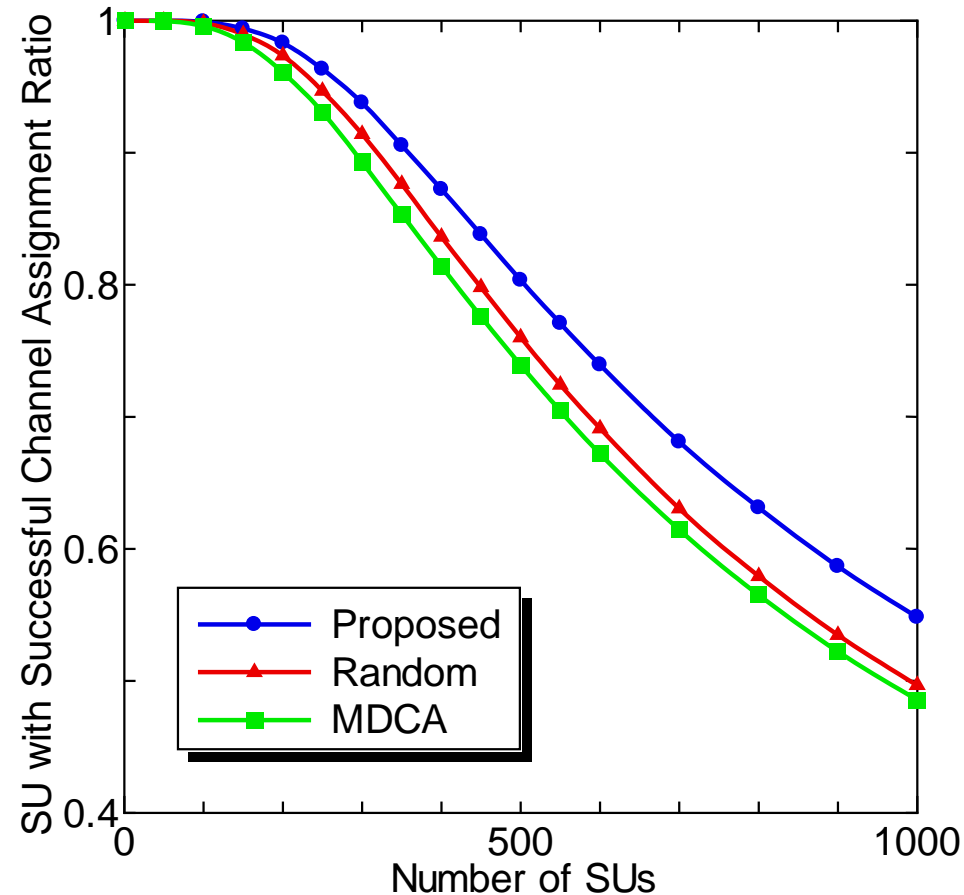
# Simulation Result

- ◆ Number of SUs with an assigned channel ( $M = 0.05$ )



# Simulation Result

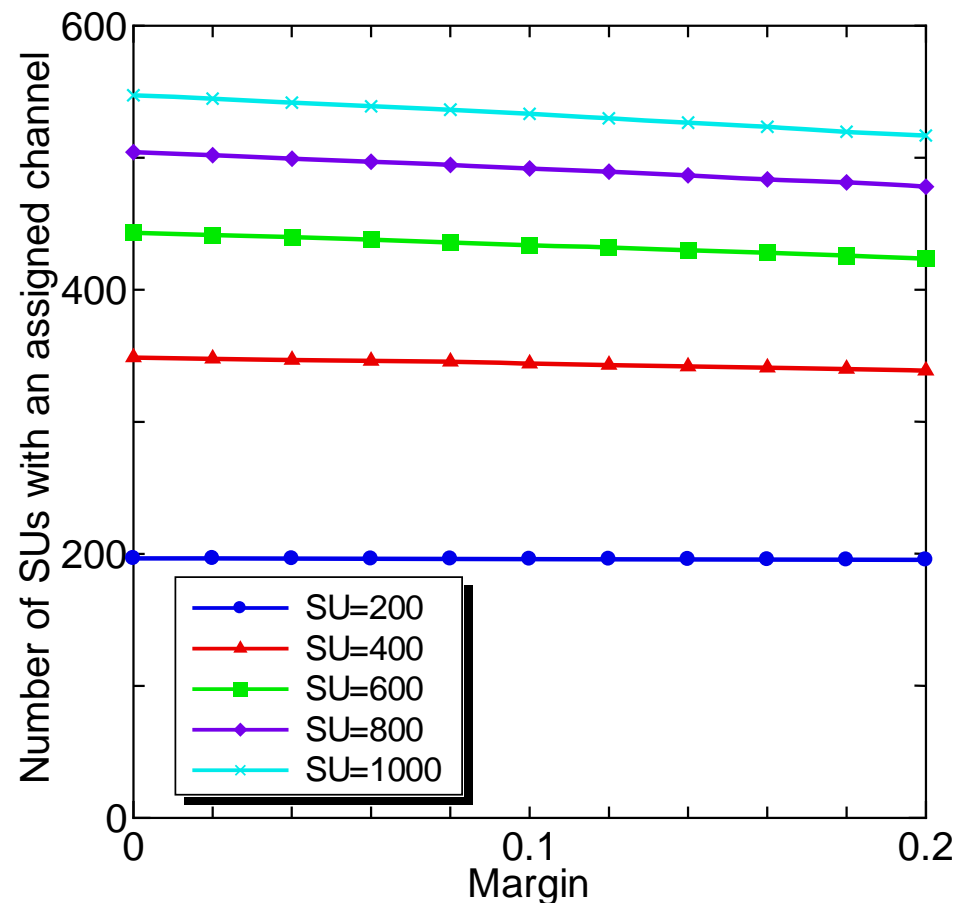
- ◆ SU with successful channel assignment ratio ( $M = 0.05$ )



The proposed method can efficiently assign the channels to SUs.

# Simulation Result

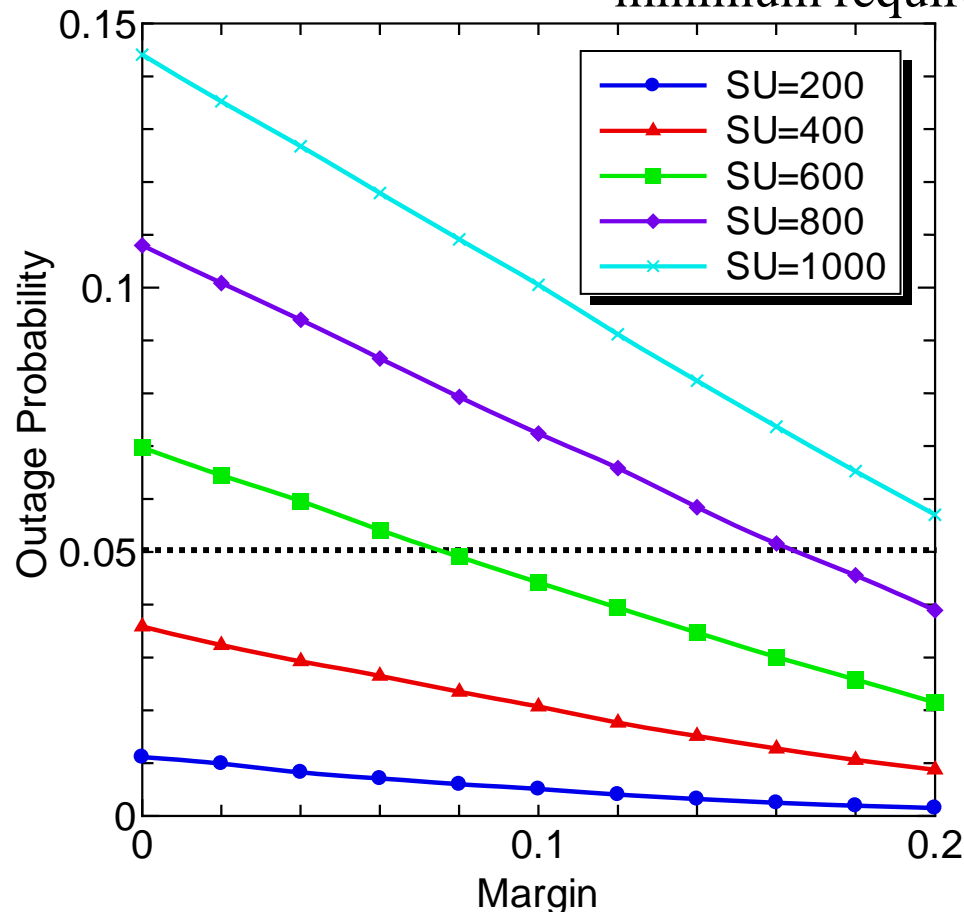
- ◆ Change of Number of SUs with an assigned channel according to  $M$



# Simulation Result

## ◆ Change of outage probability according to $M$

Outage probability: Probability of SINR at cell boundary is less than minimum required SINR.



The margin of the allowable power increases



The outage probability decreases

# Conclusion

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- ◆ The channel assignment method for maximizing SU throughput when multiple channels are shared by multiple SUs
  - Frequency usage efficiency decreases
  
- ◆ Proposed channel assignment method
  - The central control server assigns the channels under considering mutual interference among SUs.
  - The central control server assigns a channel to the SU if the interference is lower than allowable interference at cell boundary in all direction.
  - Spectrum can be densely shared while keeping every SU communication quality.



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Thank you for your attention