A Spectrum Sharing Criterion Based on Capacity Conservation Ratio of Primary User

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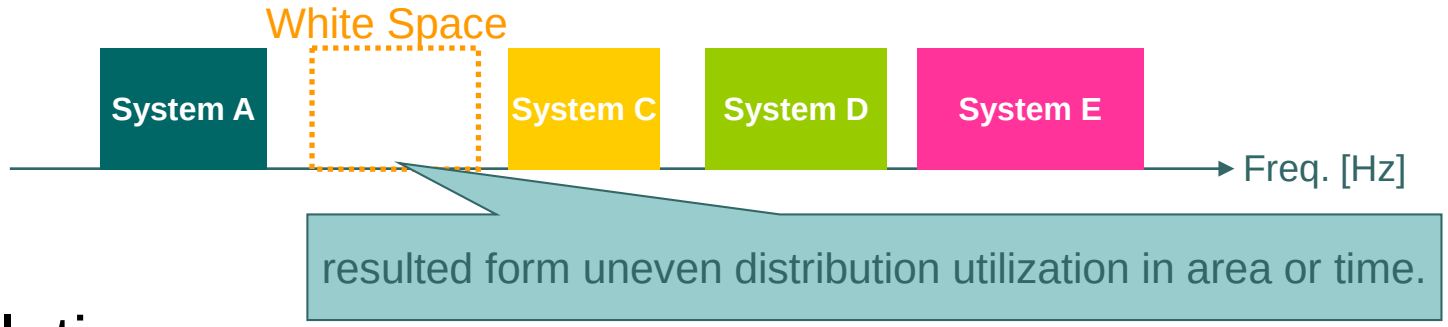
1. Introduction

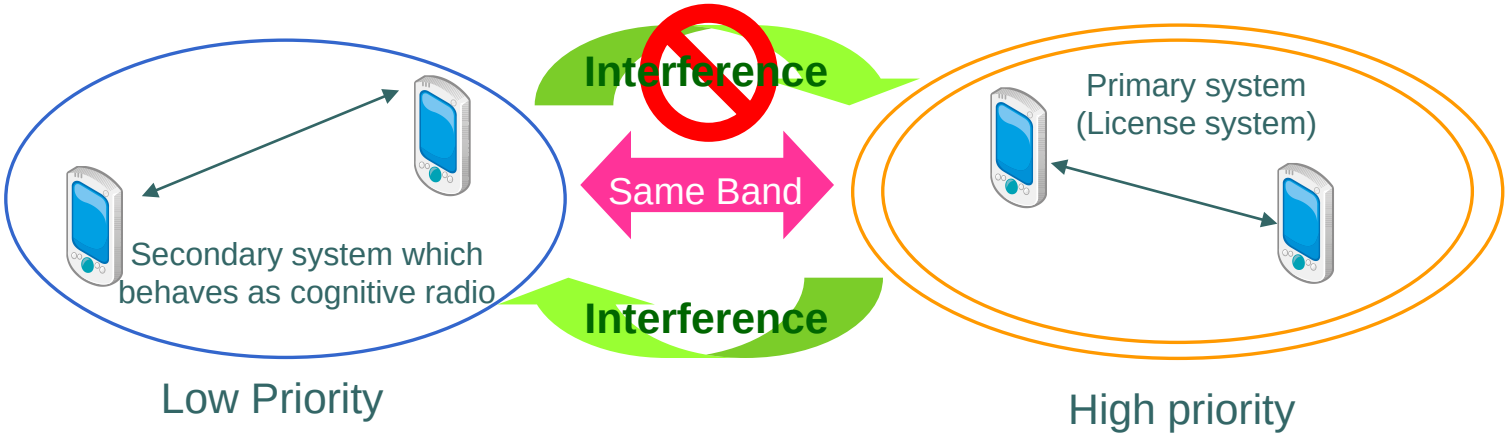
- Shortage of Frequency Resource
  - In the current radio regulation, assignment policy exclusively allocates frequency resources.
  - It is reported that the long-term utilization efficiency of frequency is not high.



- Solution
  - Spectrum sharing using cognitive radio technology can improve efficiency of frequency utilization.

Spectrum sharing

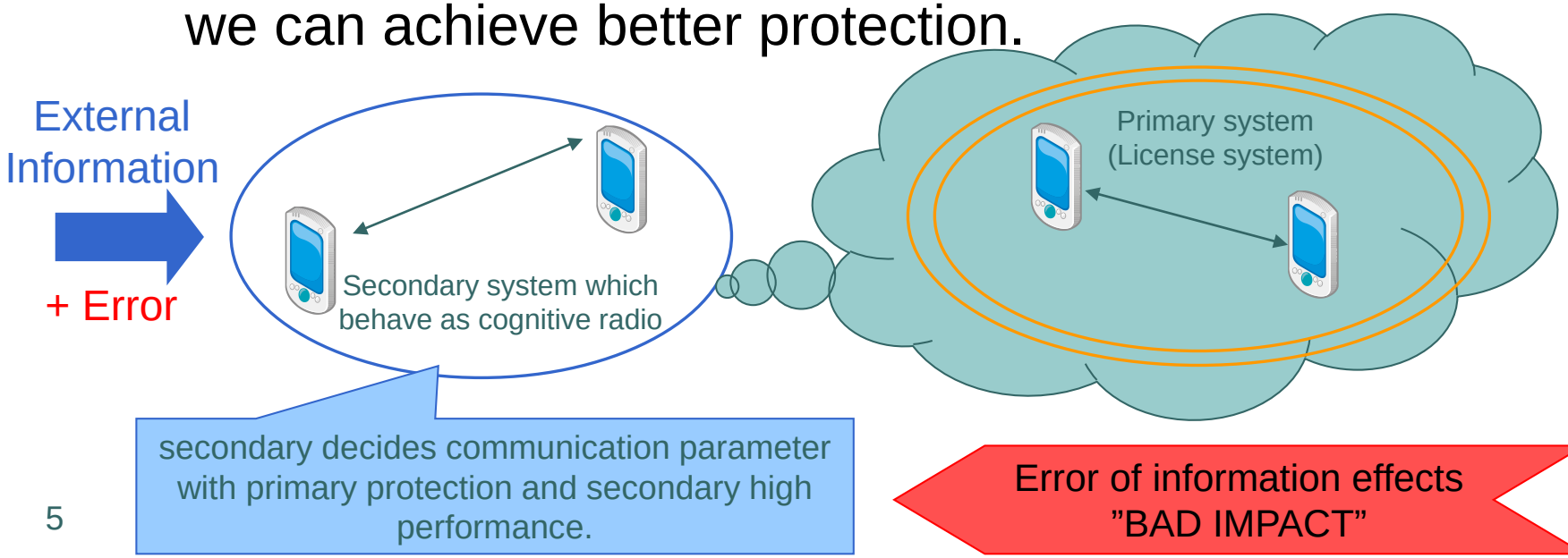
- Concept of spectrum sharing in Cognitive radio
  - Secondary system has to avoid interference toward primary system for protecting the primary system.
  - Interference avoidance leads to a degradation on secondary performance.



  - How to achieve protection of primary with keeping high performance of secondary?

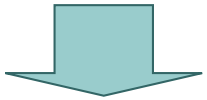
Spectrum sharing using external Information

- Interference control based on External Information
  - Secondary system obtains some information as: path loss information, primary transmit power, etc.
  - By utilizing these information in spectrum sharing, we can achieve better protection.



Decides allowable interference

- Spectrum sharing requires criterion which decides allowable interference at primary receiver.
- Evaluation parameters of traditional criteria
  - Maximum Received interference power
  - Minimum Signal-to-interference ratio (SIR) of primary
  - Minimum Outage Probability



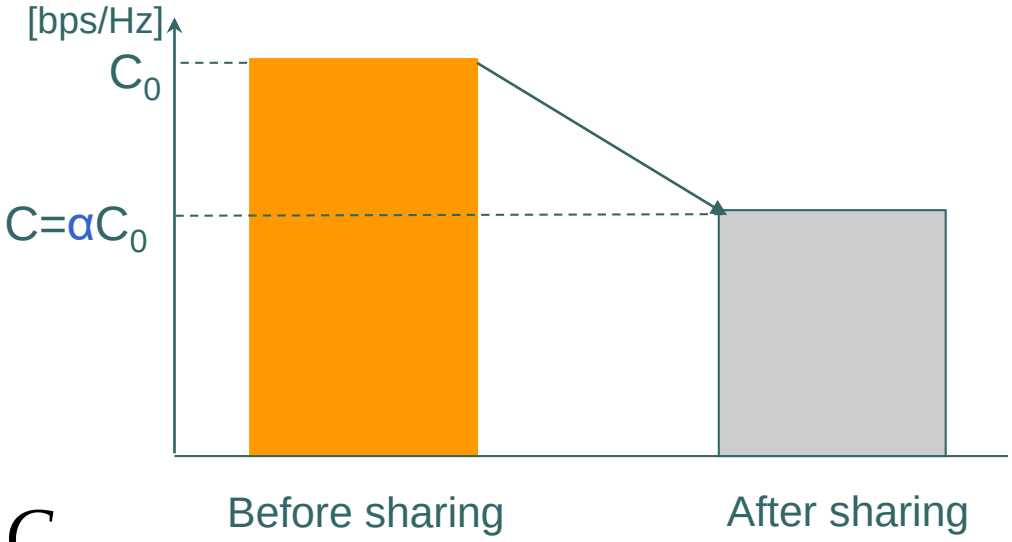
- There is a possibility that degradation of primary performance is led in changing SNR environment.

Motivation of this study

- Technical issues
  - It is difficult to protect primary terminal which has Low or High capacity in the traditional criterion for spectrum sharing.
  - Spectrum sharing using external information is effected badly by the error on the obtained information.
- Solution
  - We propose a new criterion parameter which is capacity conservation ratio, and power control method based on CCR.
  - We propose power control method considering error.

2. Spectrum Sharing Criterion

- Capacity Conservation Ratio (CCR)
  - CCR is a ratio of the primary capacity with secondary interference and that without secondary interference.



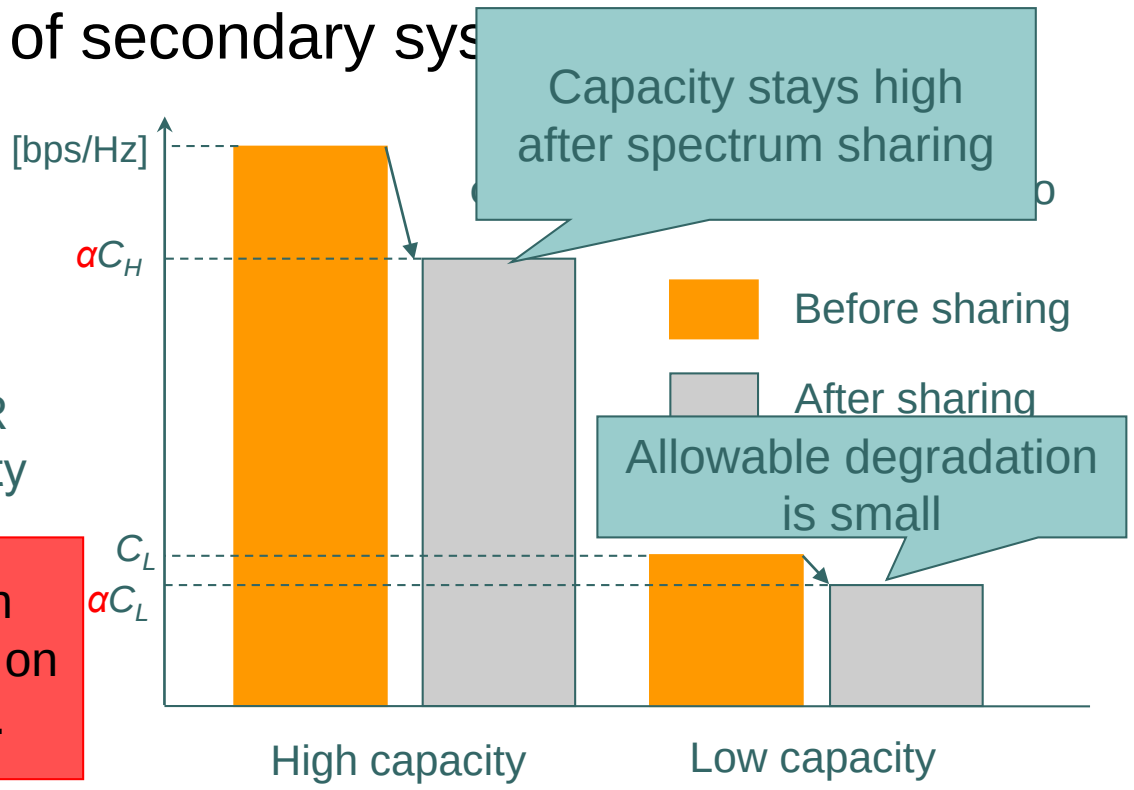
$\frac{C}{C_0}$: Capacity Conservation Ratio

2. Spectrum Sharing Criterion

- Criterion based on CCR
  - Criterion based on CCR requires keeping CCR at primary terminal of secondary sys

$$\Pr\left[\frac{C}{C_0} \le \alpha\right] \le \beta$$

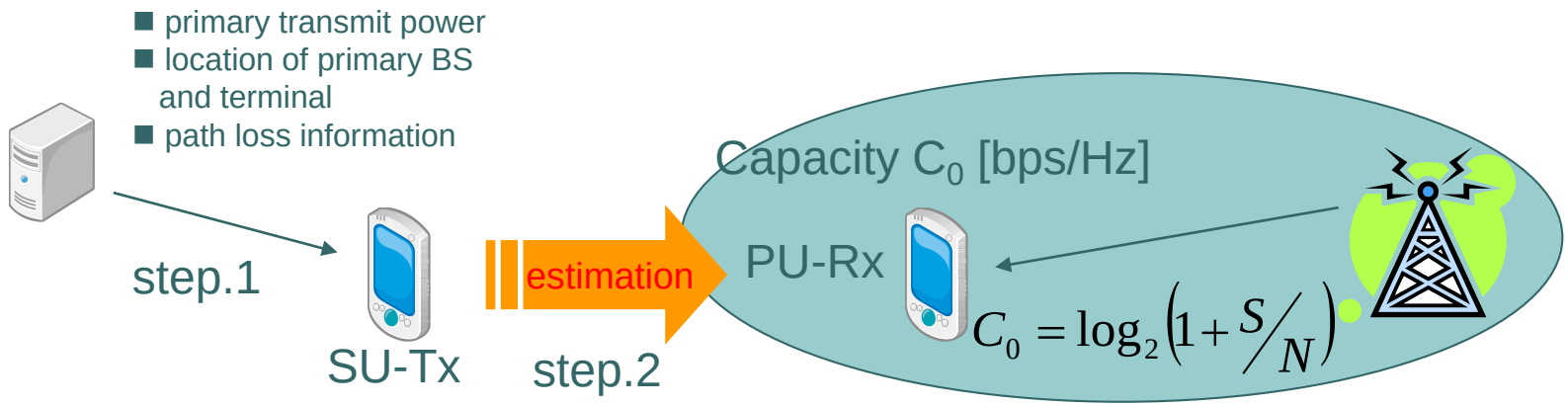
α: allowable minimum CCR
β: allowable outage probality



Criterion based on CCR can keep performance depending on capacity of primary terminal.

3. Power Control Method Based on Capacity Conservation Ratio

- Secondary system decides allowable transmit power based on CCR using external information.
  - Secondary terminal obtains information from server for spectrum sharing; primary transmit power, location, path loss information.
  - Secondary terminal estimates the capacity of primary terminal using obtained information.

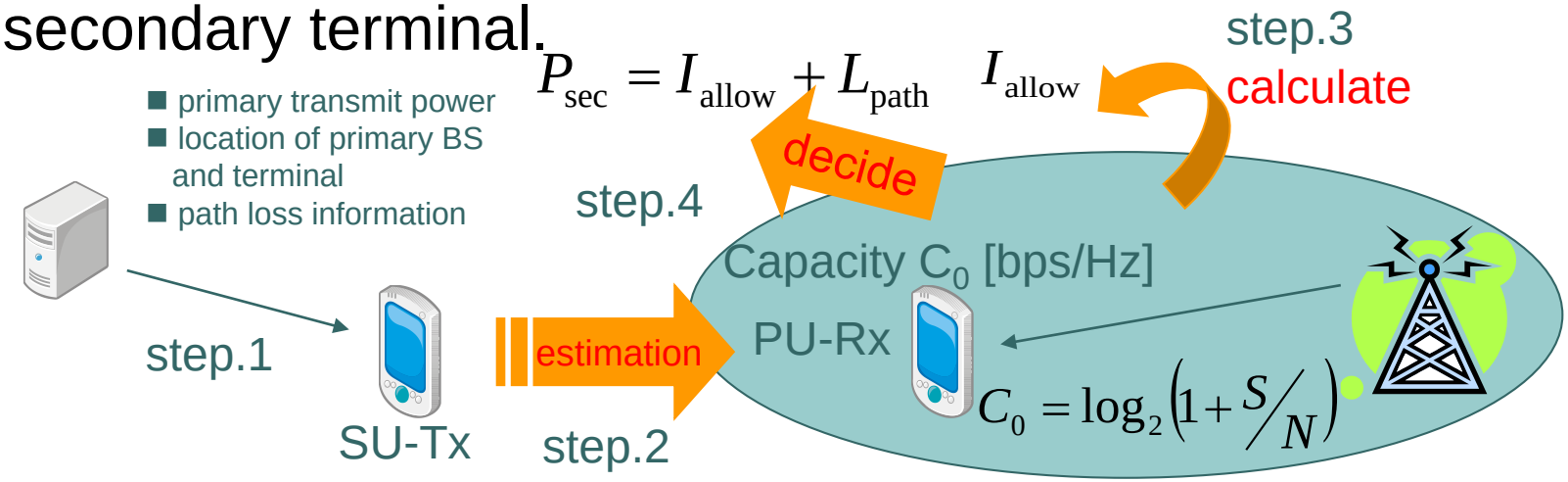


3. Power Control Method Based on Capacity Conservation Ratio

- Allowable maximum Interference is calculated based on primary capacity. Calculation formula is as follow:

$$I_{\text{allow,max}} = \frac{S}{\left(1+\frac{S}{N}\right)^{\alpha}-1} - N$$

- Secondary terminal decides transmit power considering propagation loss between primary and secondary terminal.



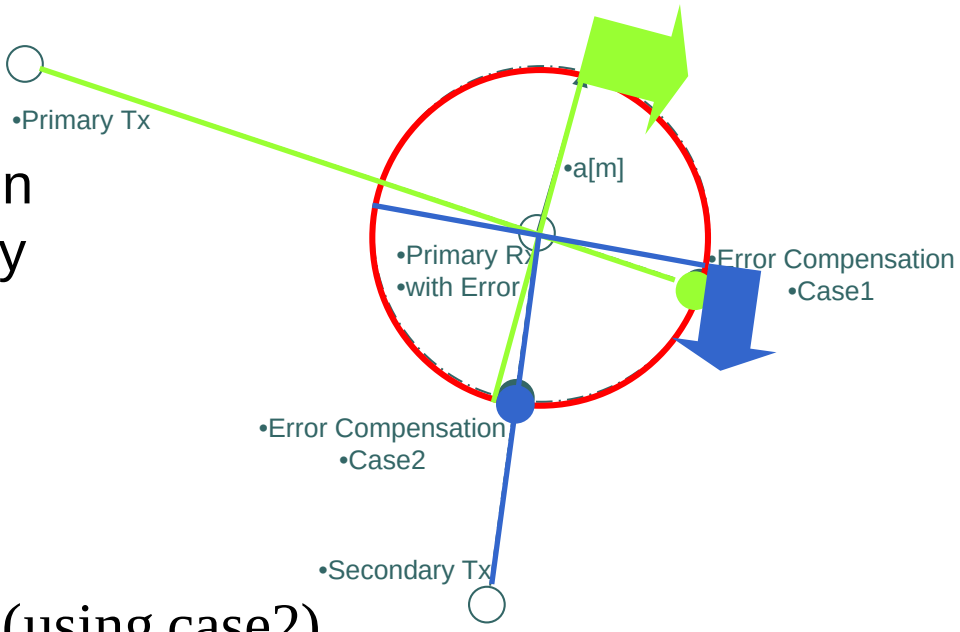
4. Power Control Method Considering Location Error

- Assume
  - Consider location information is 2D Gaussian.
  - Other external information are perfect.
- Failure case of protected primary
  - Estimated primary capacity is larger than the actual one.
  - Estimated propagation loss is smaller than the actual one.
- The above situation leads to interference.

4. Power Control Method Considering Location Error

- Considering the effect of location error.
  - Location error effects allowable interference and path loss.
  - We consider two elements separately.

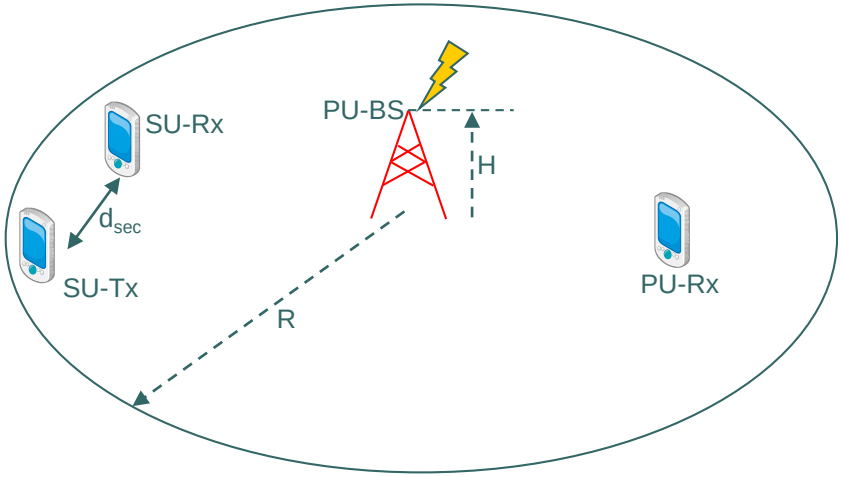
- Limited distribution of error to circle of probability 1 – ξ.
- Recalculate I_{allow} using location of Case1 that distance primary Tx and Rx is largest in the circle.
- Similarly, recalculate L_{path} using location of Case2.



$$P_{\sec} = I_{\text{allow}}(\text{using case1}) + L_{\text{path}}(\text{using case2})$$

5. Computer Simulation

- Simulation conditions



we consider down link in cellular system as a primary system

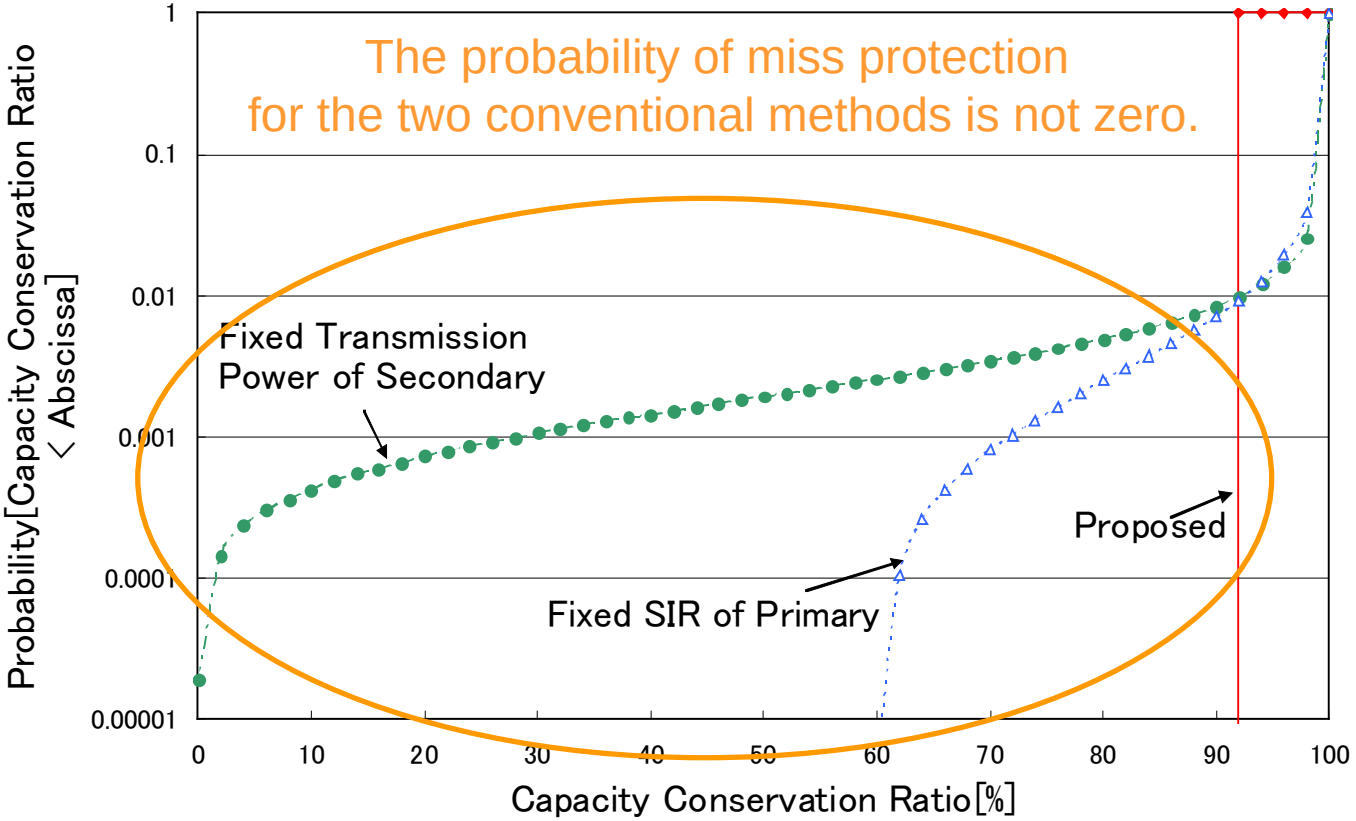
Propagation loss	n	3(cubic law)
Carrier frequency	f	2.5[GHz]
Noise floor	NF	-95.38[dBm]
Radius of primary cell	R	1400[m]
Transmit power of primary	P_{pri}	30[dBm]
Allowable minimum CCR	α	0.92
Allowable outage probability	β	0.01
Communication distance of secondary	d_{sec}	50[m]
Distribution of location error		2 dimensional Gaussian

Evaluation

- Power control method based on CCR
  - Compared methods
    - Based on SNR at primary receiver (used external info)
    - Using constant low transmit power (unused external info)
- Evaluation
  - Complementary Cumulative Distribution Function of Secondary Capacity
  - Cumulative Distribution Function of CCR

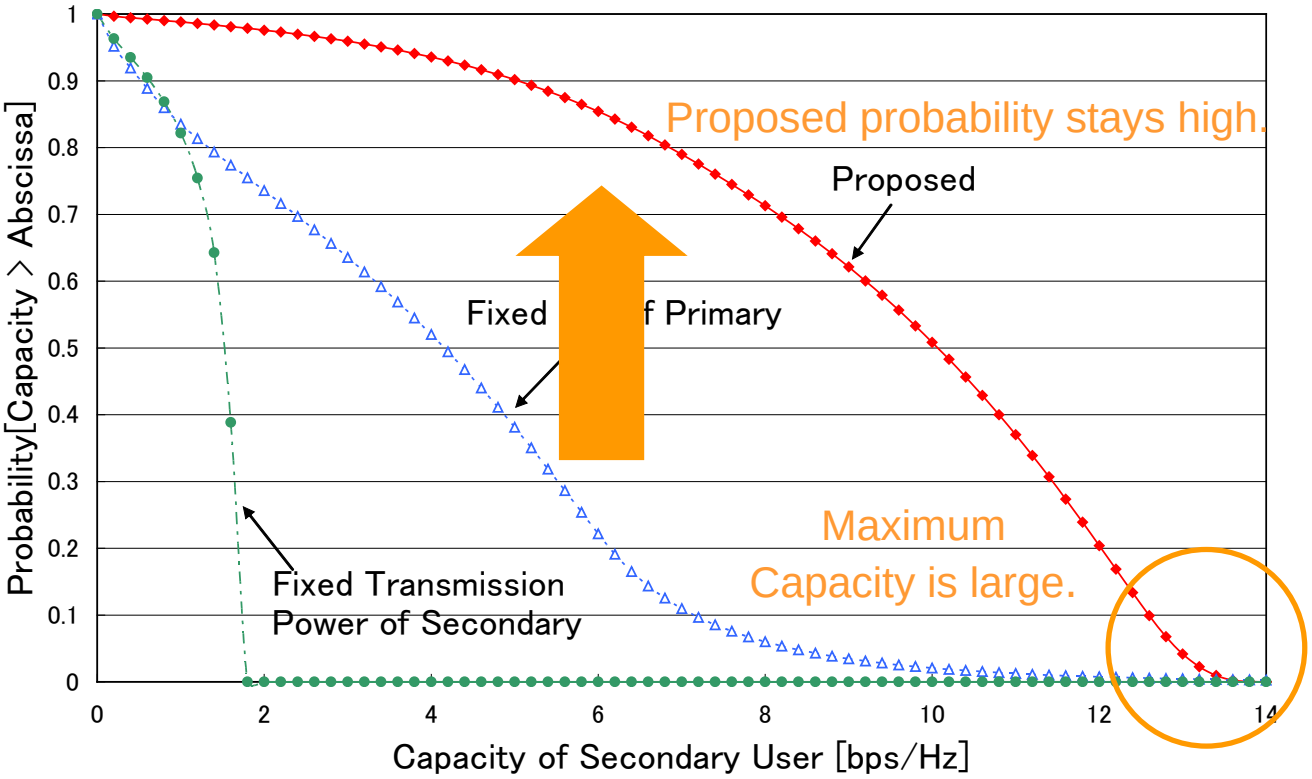
Simulation Results

- Cumulative Distribution Function of CCR
  - Criterion parameter :α=0.92, β=0.01



Simulation Results

- CCDF of secondary capacity
  - Criterion parameter :α=0.92, β=0.01

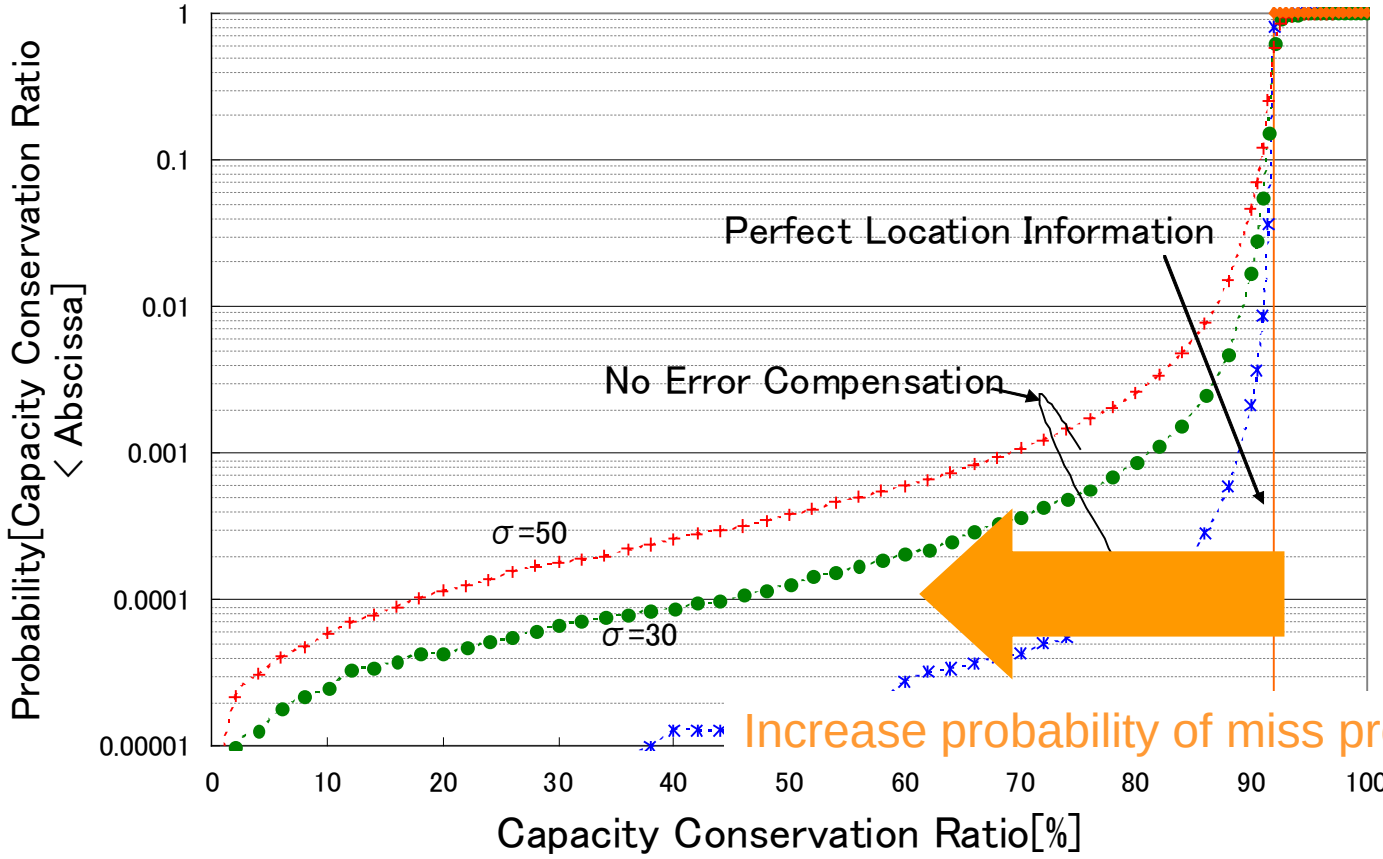


Evaluation

- Power control method considering location error
  - Error is a two dimensional Gaussian distribution
  - deviation σ:10, 30, 50[m]
- Evaluation
  - Probability of miss protection without compensation.
  - Probability of miss protection with compensation.

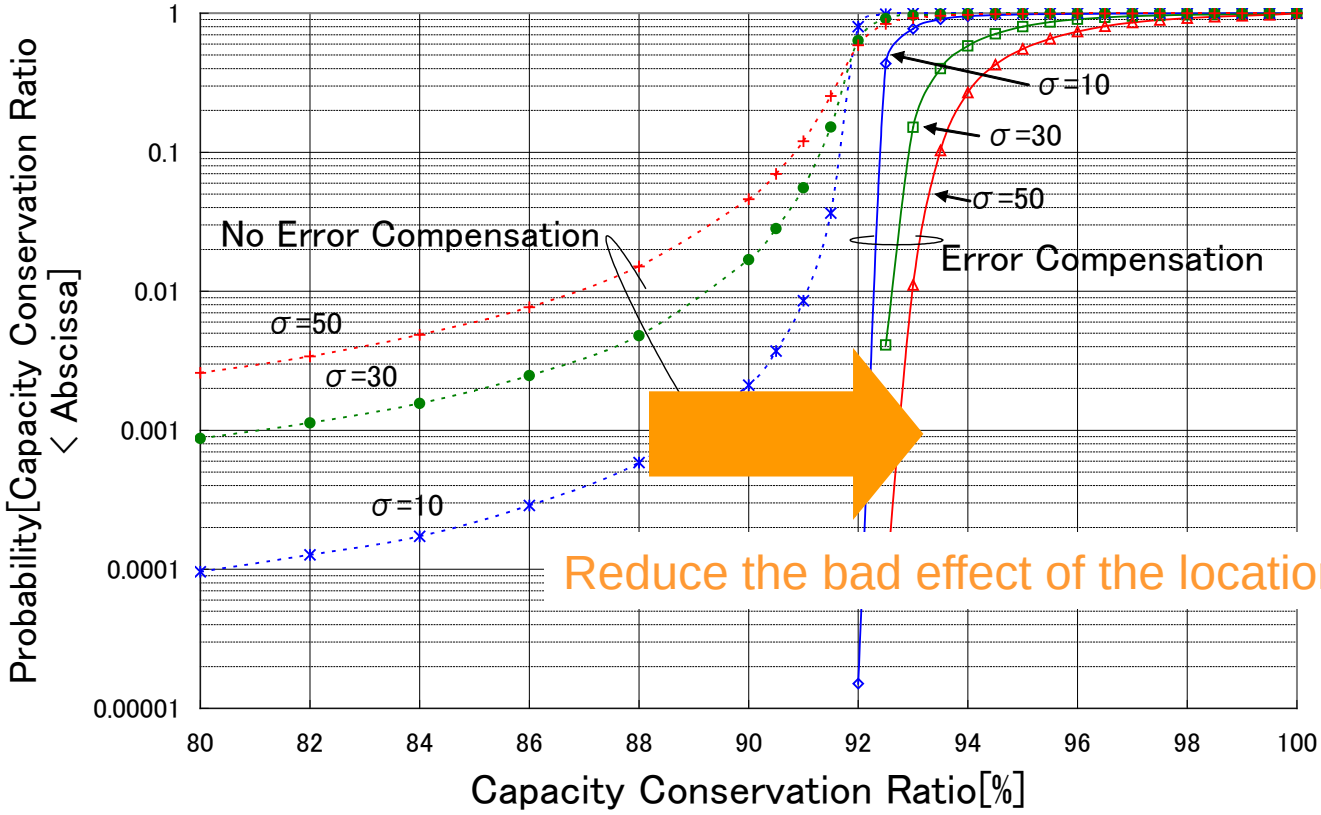
Simulation Results

- Degradation CDF of CCR with Location Error
  - Criterion parameter :α=0.92, β=0.01



Simulation Results

- Improvement CDF of CCR with Location Error
  - Criterion parameter :α=0.92, β=0.01



6. Conclusion

- A novel spectrum sharing method has been proposed for variable primary SNR environment.
- Additionally, we have proposed power control method considering location error.

- Proposed method can protect primary system with keeping secondary performance.
- Proposed power control method can reduce probability of miss protection with location error.

Changing capacity of criterion parameter α