AWCC

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Effect of Base-Station Cooperation in MIMO Cellular Systems

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   in a MIMO Cellular System
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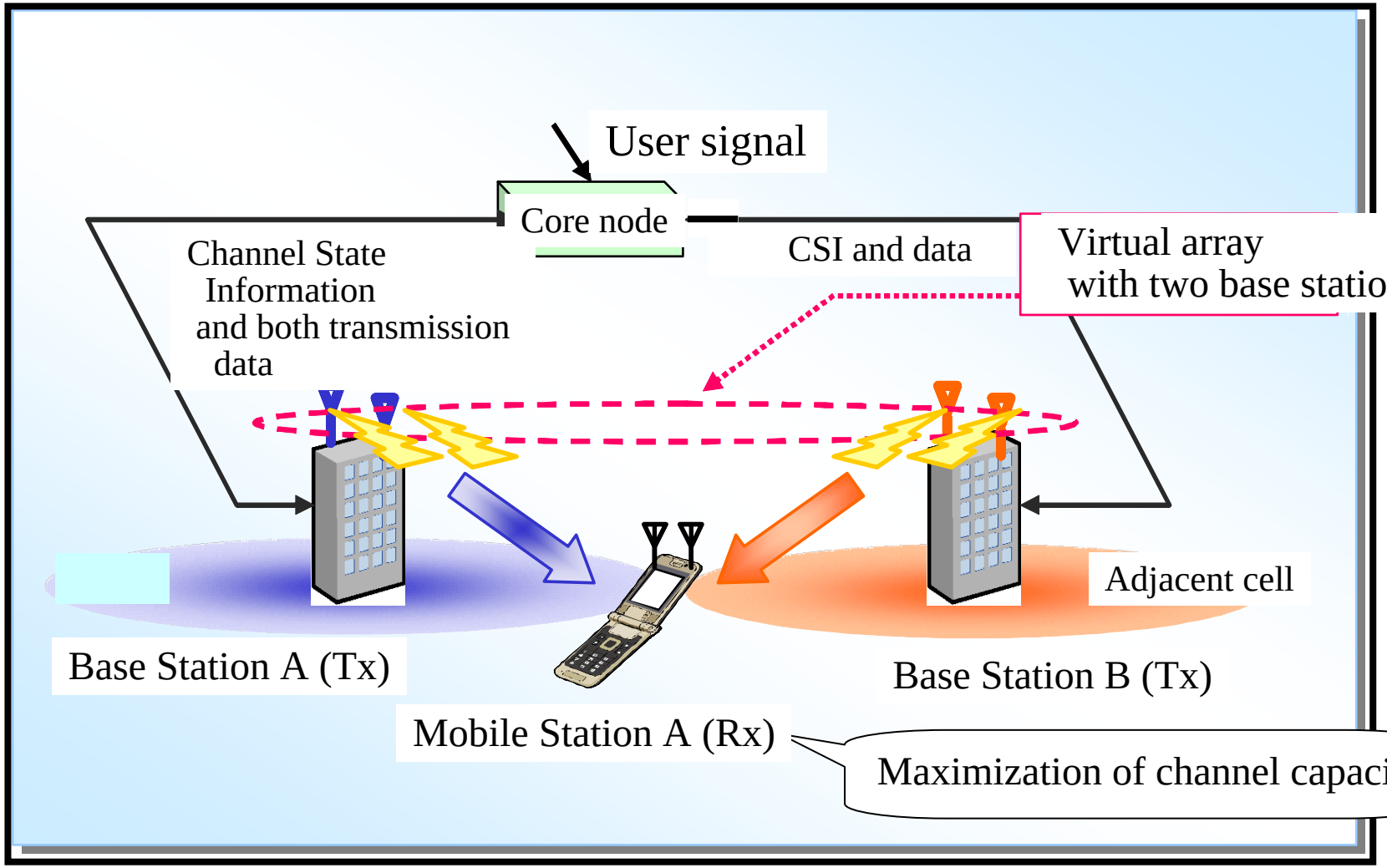
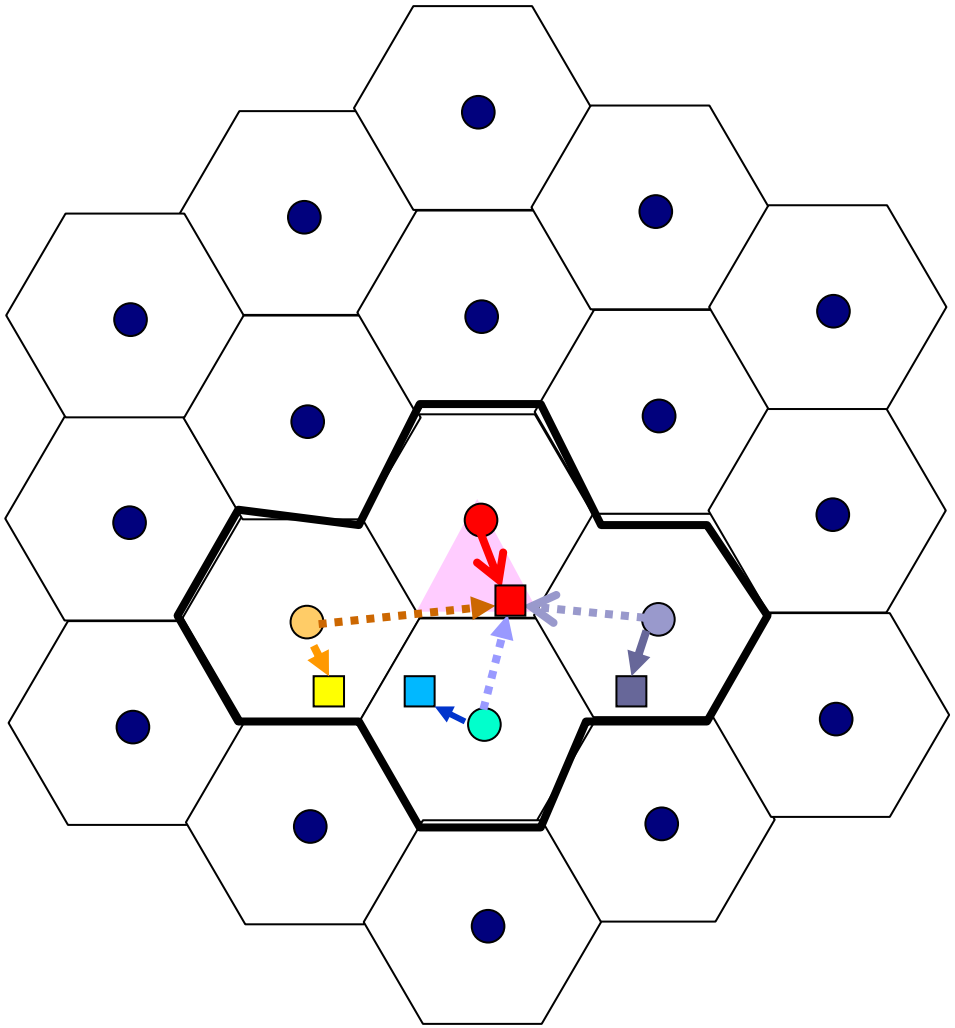
Image of Base Station Cooperation (CoMP) in the Era of IMT-Advanced

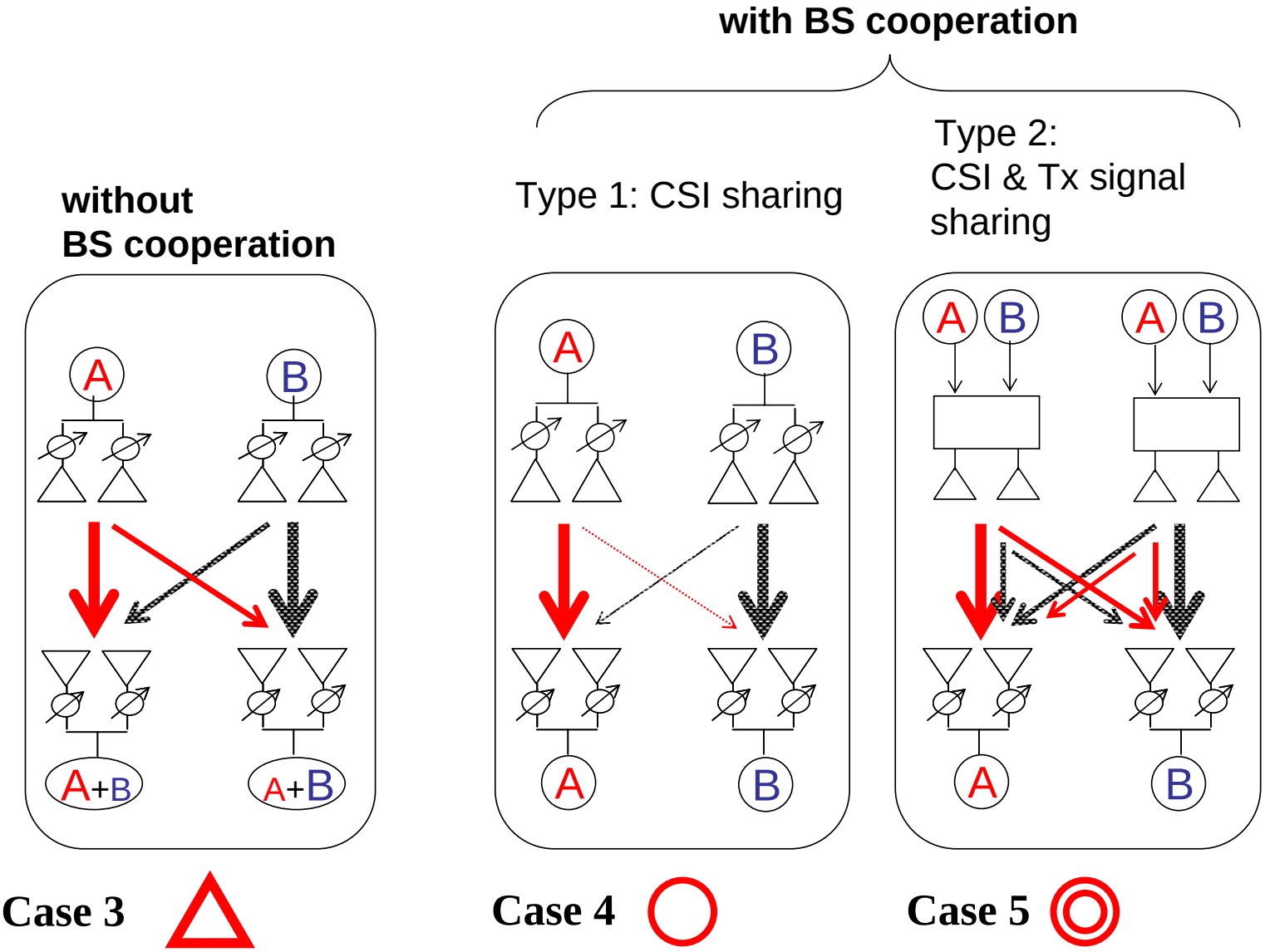


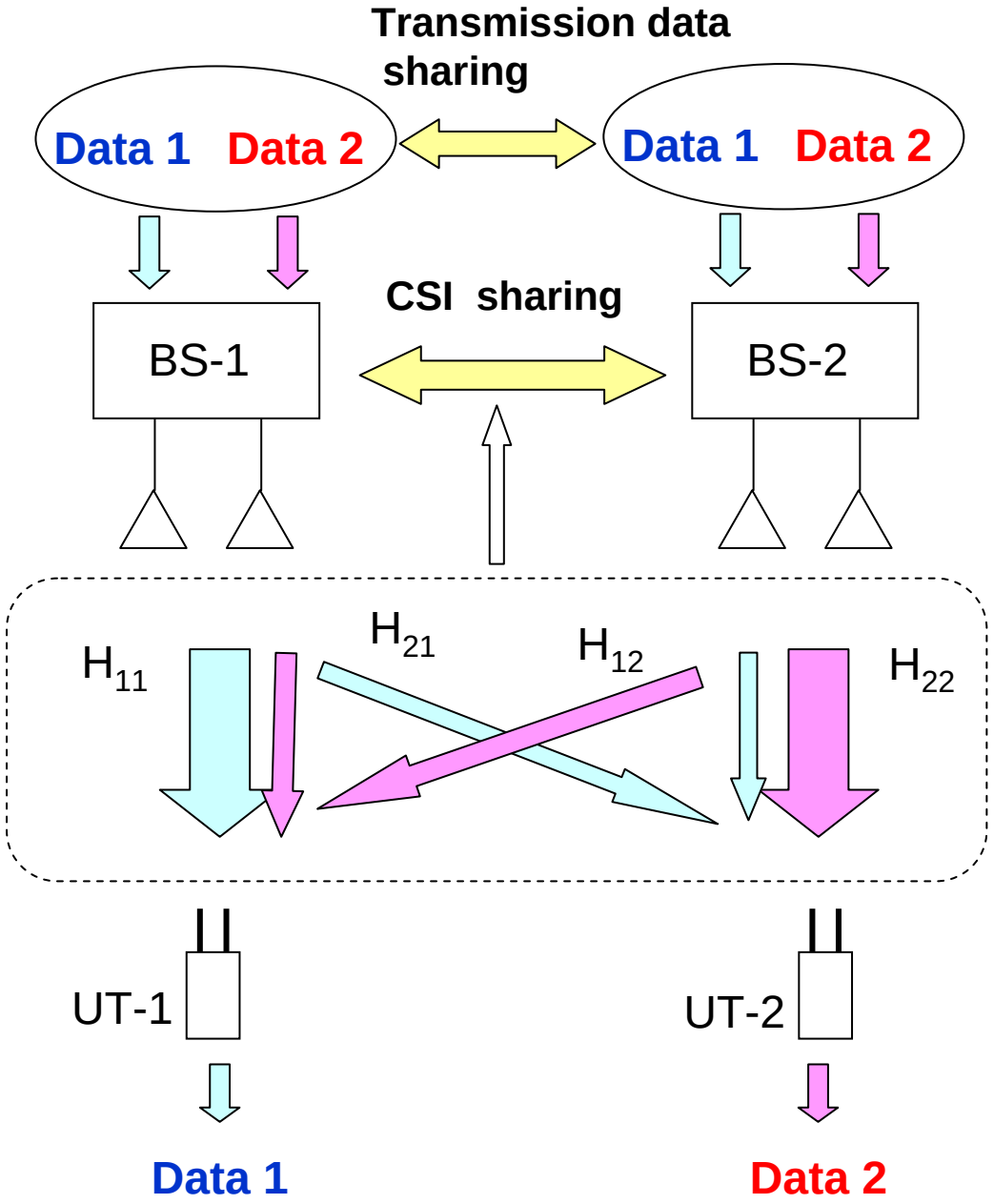
CoMP: Coordinated Multi-Point transmission/reception

Image of Base Station Cooperation (2)



Classifications of base station cooperation (types 1 and 2)





Type 2 (= Case 5)

We deal with the ideal case such that
- Obtained CSI is perfect.
- Antenna beamforming is done instantaneously.

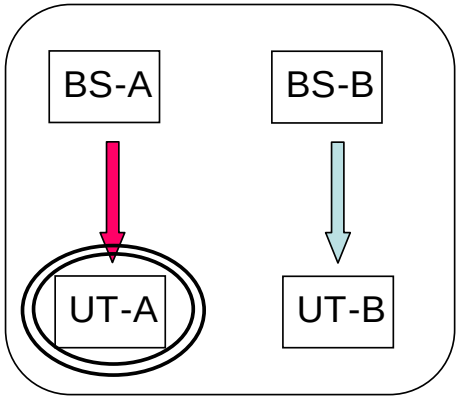
CSI

$$\boldsymbol{H} = \begin{bmatrix} \boldsymbol{H}_{11} & \boldsymbol{H}_{12} \\ \boldsymbol{H}_{21} & \boldsymbol{H}_{22} \end{bmatrix}$$

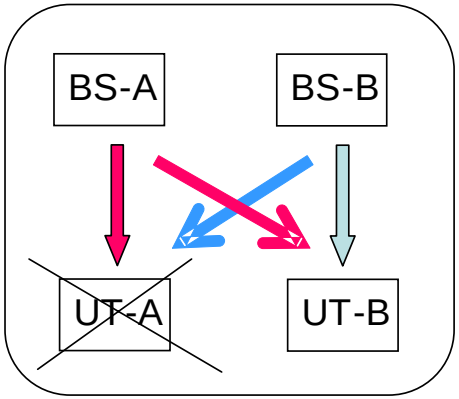
- distance dependence: $d^{-3.5}$
- Shadowing: log-normal (6dB)
- Short term: Rayleigh

Classification of cases for assessing cooperation effectiveness

[**Case 1**: No interference]
(MRC transmission)

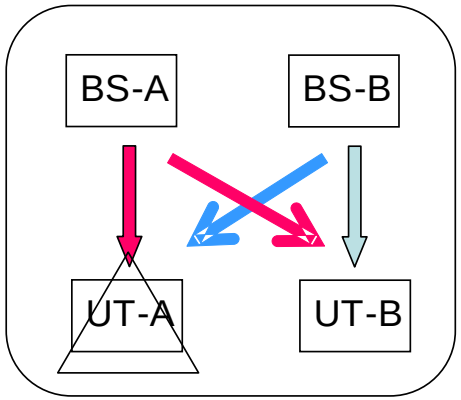


[**Case 2:** with interference & without countermeasure]
(Antenna weights are the same as Case 1)

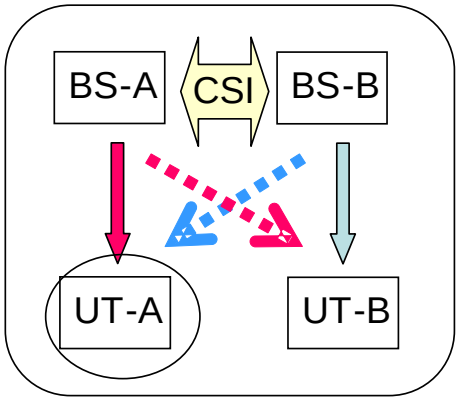


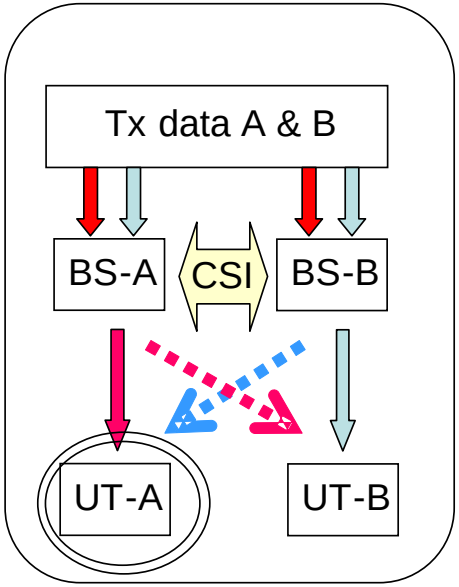
[Case 5:
BS cooperation with
CSI and Tx data
(Type 2)

[**Case 3:**
with interference]
(controlled at UT)

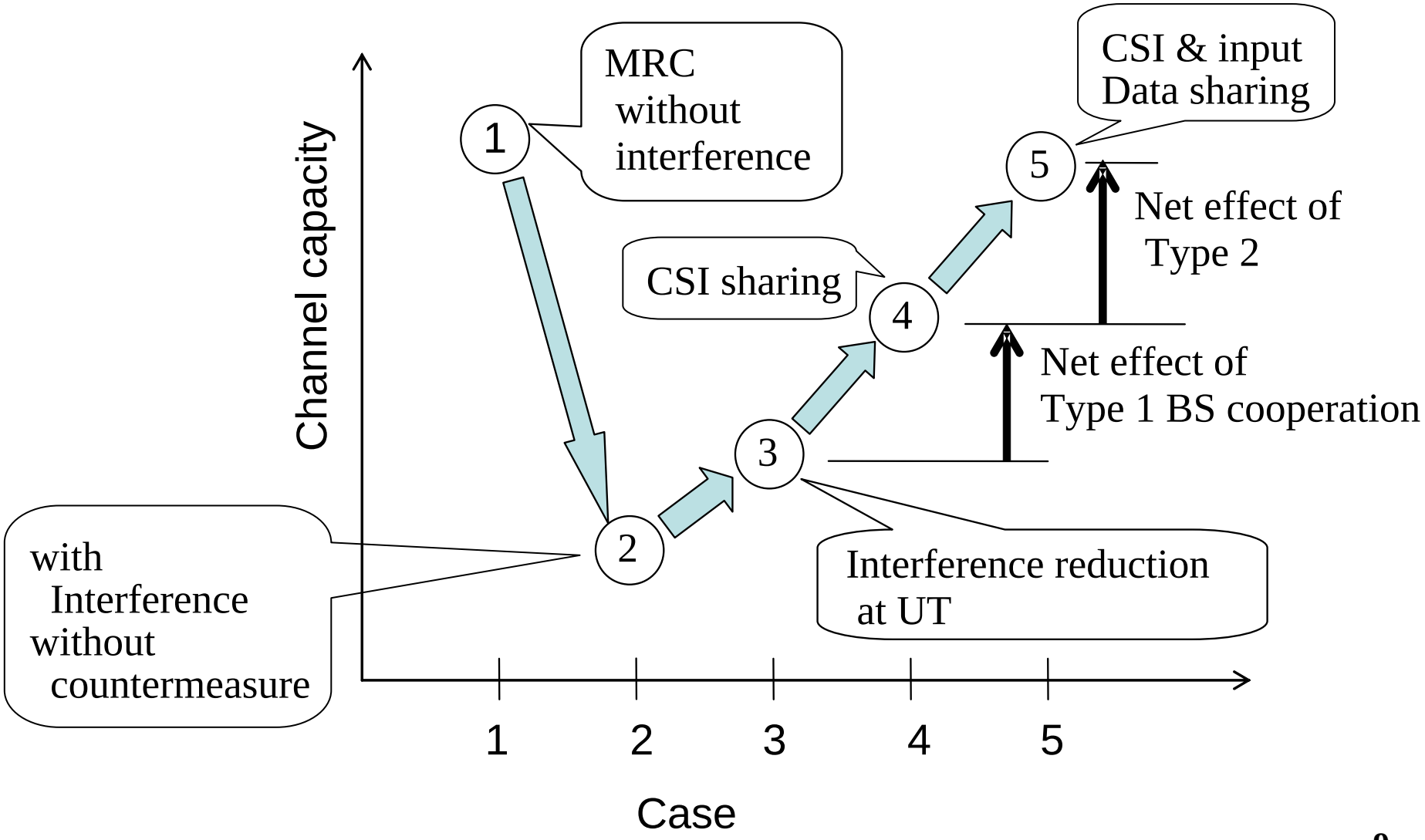


[**Case 4:**
BS cooperation
with CSI (Type 1)]

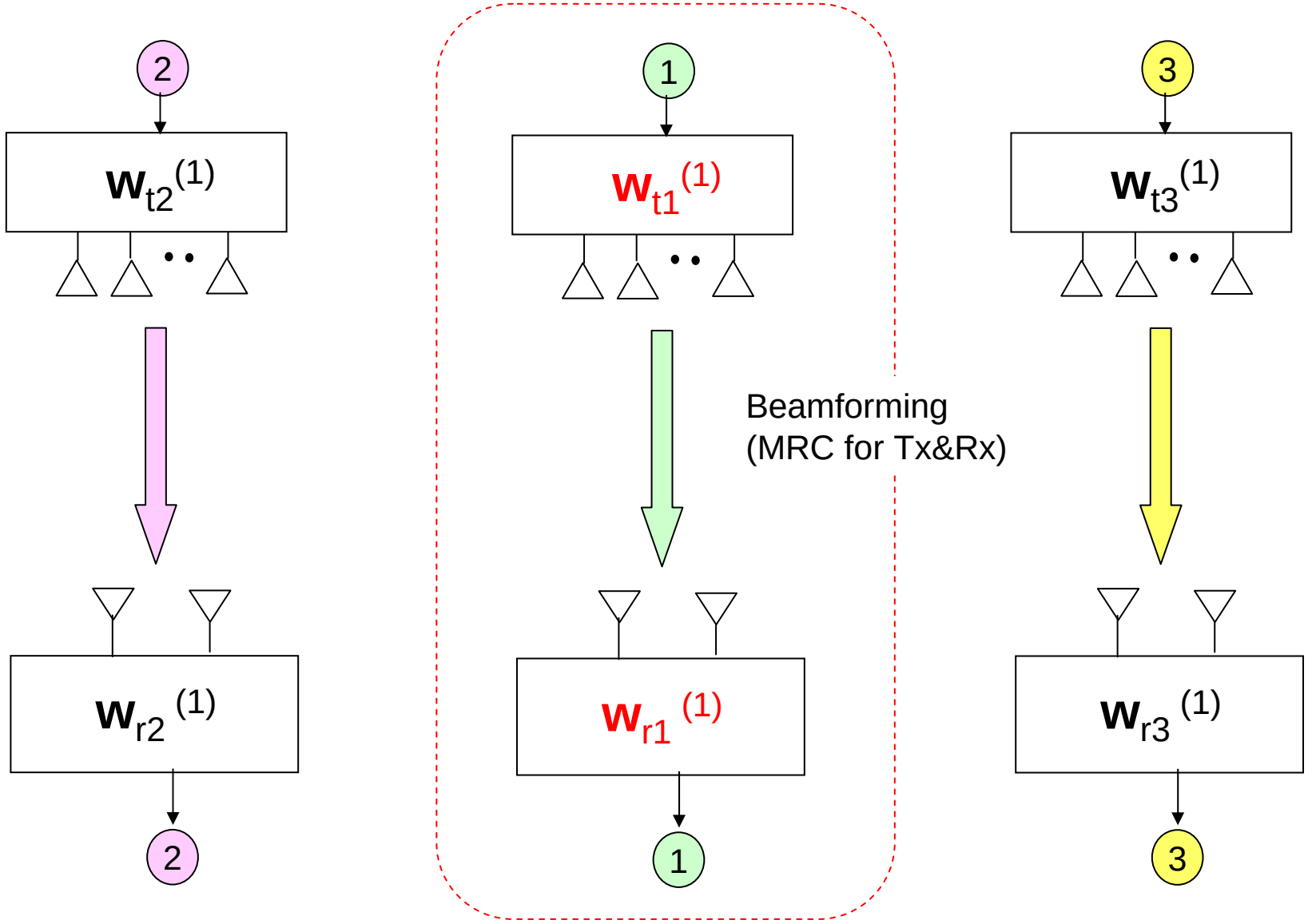




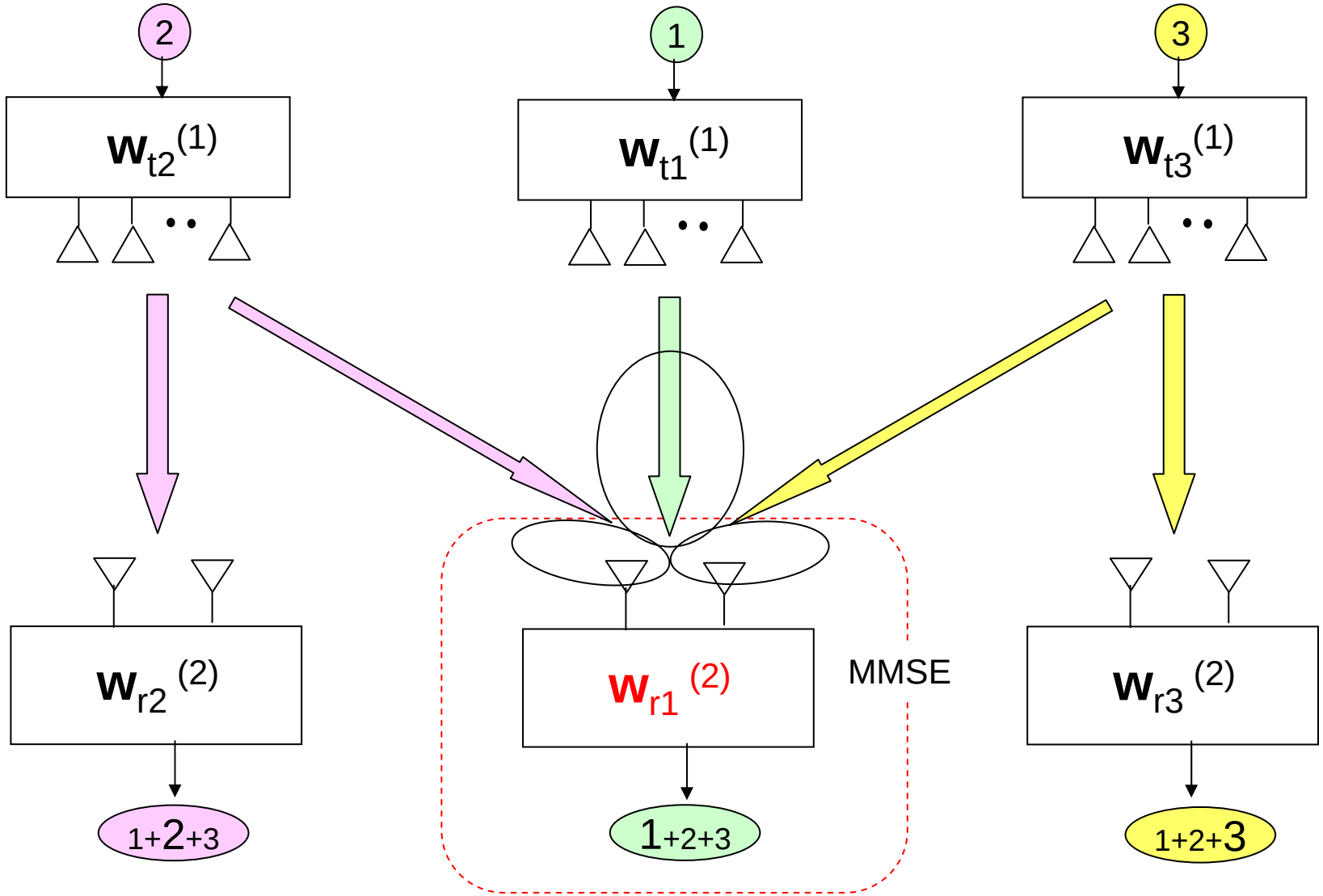
Expected trend in channel capacity for the different cases



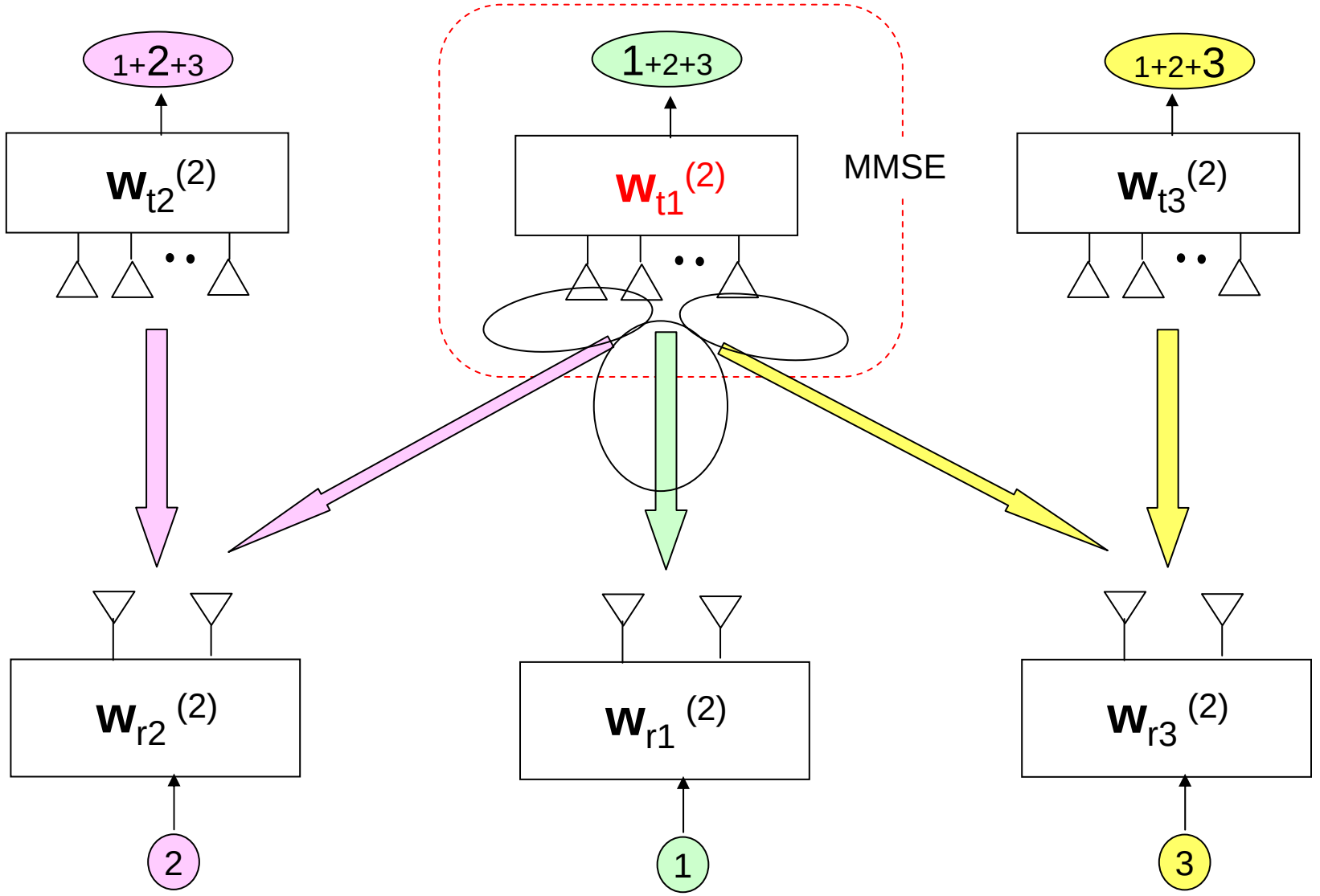
Case 1: Beamforming without considering Interference



Case 3: Interference Reduction based on MMSE at each UT



Case 4: Interference Reduction based on MMSE at each BS



In Case 4, the weight determination algorithm is as follows:

$$C_m = \log_2\left(1+\frac{P_s^{(m)}}{P_I^{(m)}+P_N^{(m)}}\right)$$

$$P_s^{(m)} = \left|\{\boldsymbol{w}_r^{(m)}\}^{\mathrm{H}}\boldsymbol{H}_{mm}\,\boldsymbol{w}_t^{(m)}\right|^2 P_0^{(m)}$$

$$P_I^{(m)} = \sum_{\substack{m'=1\\ m'\neq m}}^{M}\left|\{\boldsymbol{w}_r^{(m)}\}^{\mathrm{H}}\boldsymbol{H}_{mm'}\,\boldsymbol{w}_t^{(m')}\right|^2 P_0^{(m')}$$

$$\boldsymbol{w}_t^{(m)} = \frac{\boldsymbol{w}_{t0}^{(m)}}{\left\|\boldsymbol{w}_{t0}^{(m)}\right\|}$$

$$\boldsymbol{w}_{t0}^{(m)} = \left\{\boldsymbol{R}_{xx}^{(m)}\right\}^{-1}\boldsymbol{r}_{xd}^{(m)}$$

$$\boldsymbol{r}_{xd}^{(m)} = \left\langle \boldsymbol{x}_m(t)s_m^*(t)\right\rangle = \boldsymbol{H}_{mm}^{\mathrm{T}}\boldsymbol{w}_r^{(m)*}P_0^{(m)}$$

$$\boldsymbol{R}_{xx}^{(m)} = \left\langle \boldsymbol{x}\boldsymbol{x}^H\right\rangle = \sum_{m'=1}^{M}\boldsymbol{H}_{m'm}^{\mathrm{T}}\boldsymbol{w}_r^{(m')*}\boldsymbol{w}_r^{(m')\mathrm{T}}\boldsymbol{H}_{m'm}^{*}P_0^{(m')} + P_{N0}\boldsymbol{I}$$

[Propagation Channel]

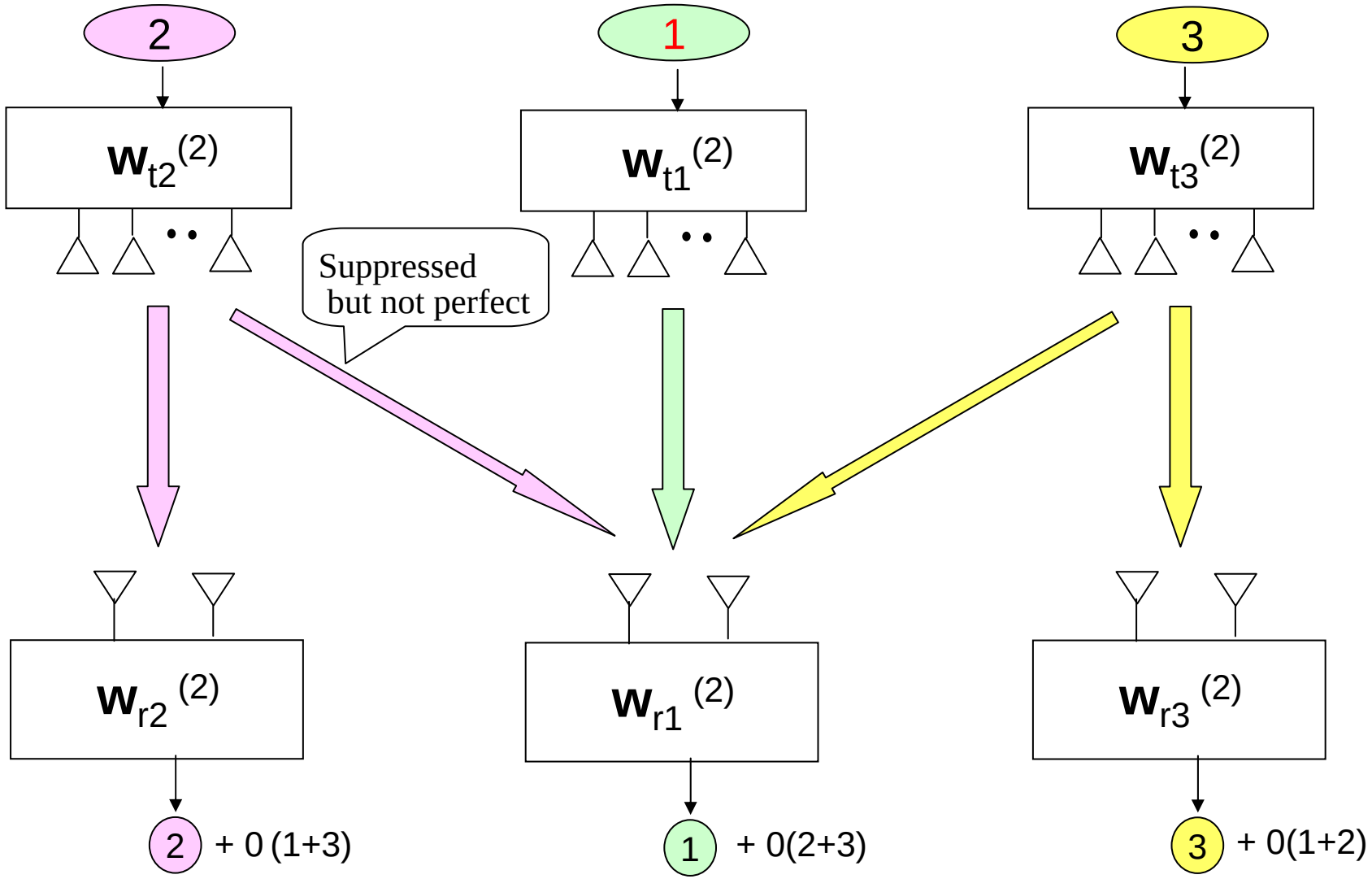
$$\boldsymbol{H} = \begin{bmatrix} \boldsymbol{H}_{11} & \boldsymbol{H}_{12} & \cdots & \boldsymbol{H}_{1M} \\ \boldsymbol{H}_{21} & \boldsymbol{H}_{22} & \cdots & \boldsymbol{H}_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{H}_{M1} & \boldsymbol{H}_{M2} & \cdots & \boldsymbol{H}_{MM} \end{bmatrix}$$

$$\boldsymbol{H}_{m'm} = \begin{bmatrix} h_{11}^{(m'm)} & h_{12}^{(m'm)} & \cdots & h_{1N_t}^{(m'm)} \\ h_{21}^{(m'm)} & h_{22}^{(m'm)} & \cdots & h_{2N_t}^{(m'm)} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_r1}^{(m'm)} & h_{N_r2}^{(m'm)} & \cdots & h_{N_rN_t}^{(m'm)} \end{bmatrix}$$

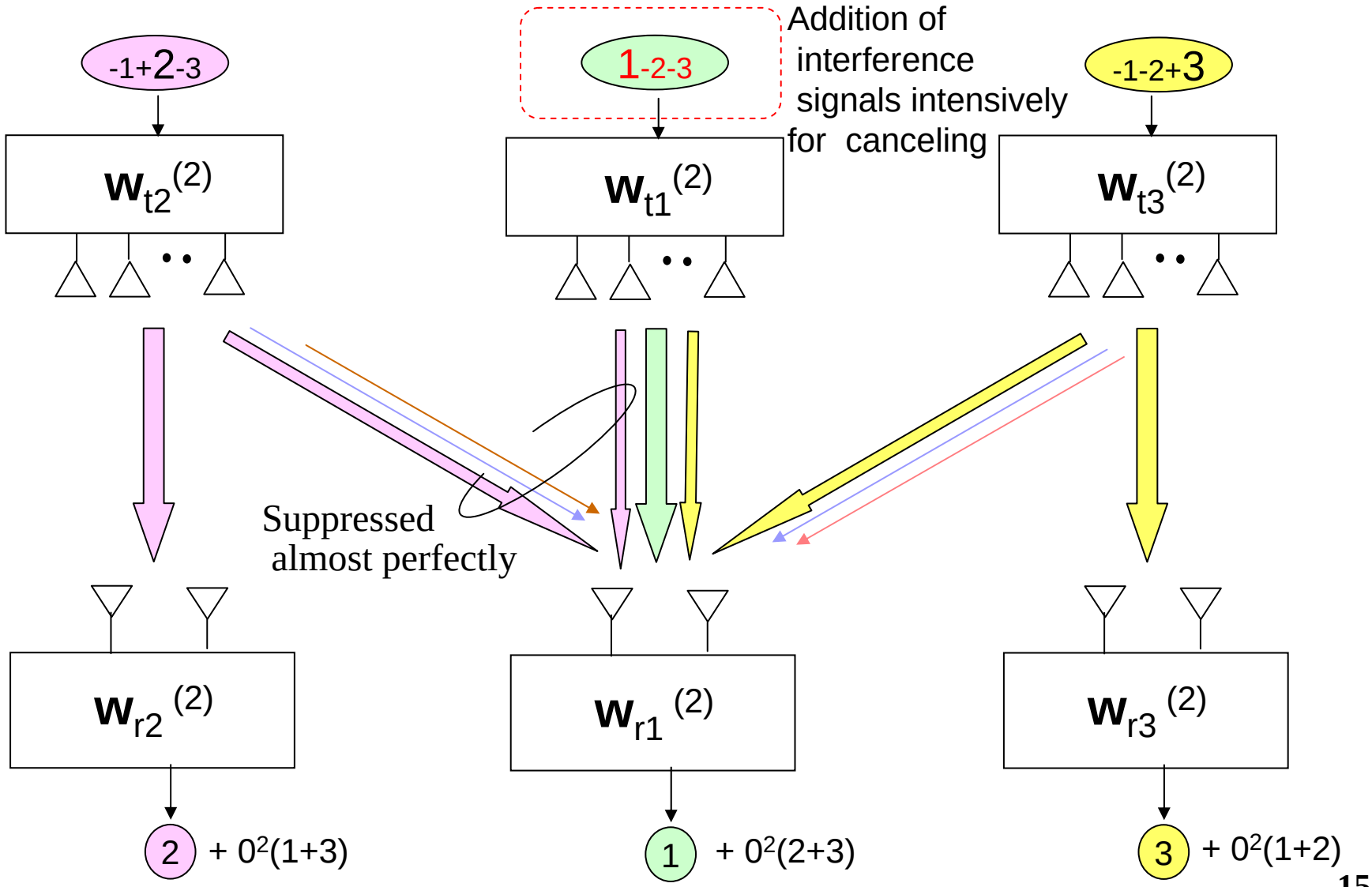
$$h_{uv}^{(m'm)} = b_{dist}\cdot b_{shadow}\cdot b_{Rayleigh}$$

$$b_{dist} = \sqrt{P_0^{(m)}\left(d^{(m'm)}/d_0\right)^{-n}}$$

Case 4 → Case 5: Further Interference Reduction
by adding Interference signals into Transmitting signals



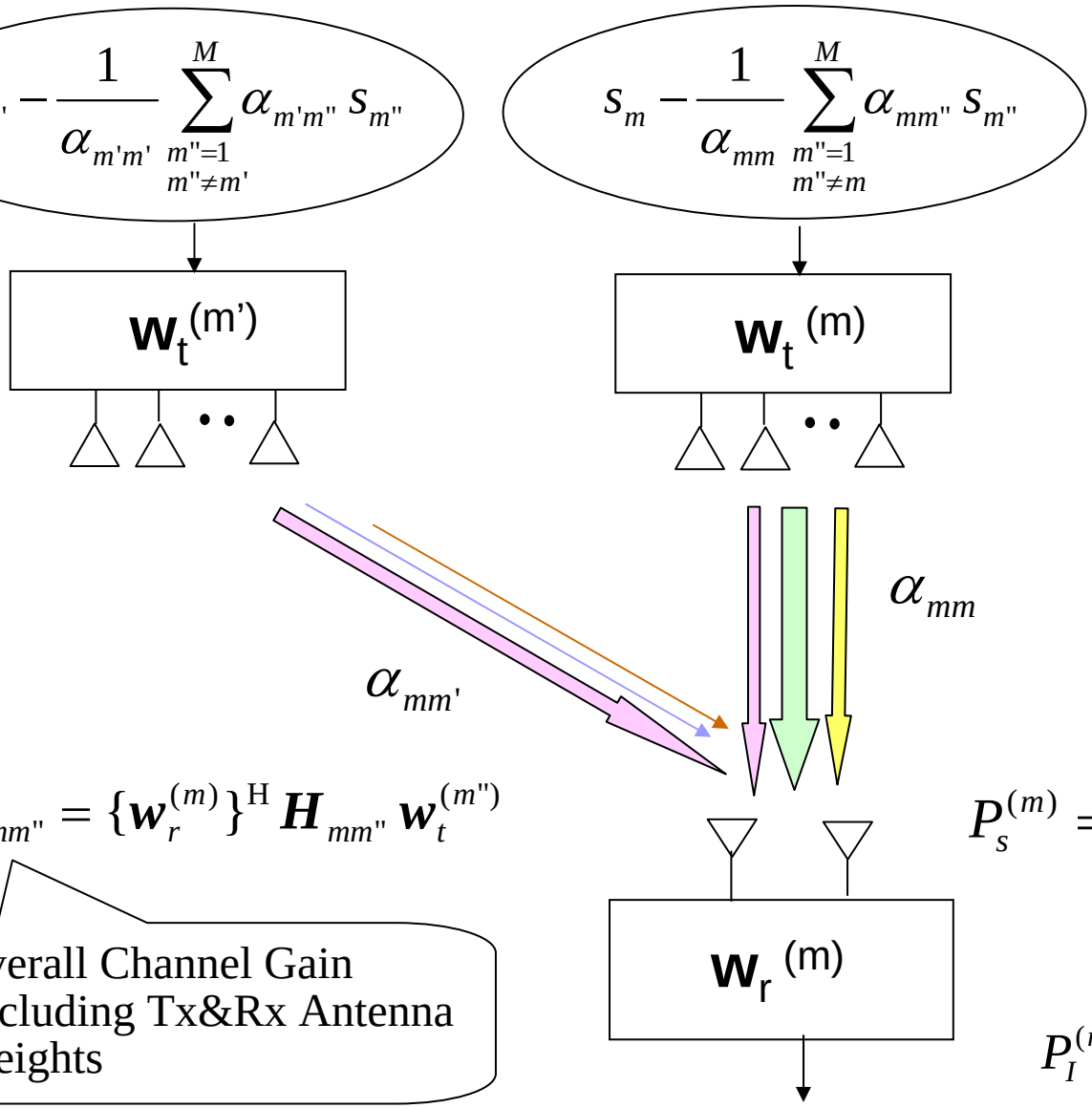
Case 5: Further Interference Reduction by adding Interference signals into Transmitting signals



Scheme realizing Case 5

$$s_{m'} - \frac{1}{\alpha_{m'm'}} \sum_{\substack{m''=1 \\ m''\neq m'}}^{M} \alpha_{m'm''}\, s_{m''}$$

$$s_{m} - \frac{1}{\alpha_{mm}} \sum_{\substack{m''=1 \\ m''\neq m}}^{M} \alpha_{mm''}\, s_{m''}$$



$\mathbf{w}_{tm}^{(2)}$	$\rightarrow \mathbf{w}_t^{(m)}$
$\mathbf{w}_{rm}^{(2)}$	$\rightarrow \mathbf{w}_r^{(m)}$

$$\alpha_{mm''} = \{\boldsymbol{w}_r^{(m)}\}^{\mathrm{H}}\, \boldsymbol{H}_{mm''}\, \boldsymbol{w}_t^{(m'')}$$

Overall Channel Gain including Tx&Rx Antenna Weights

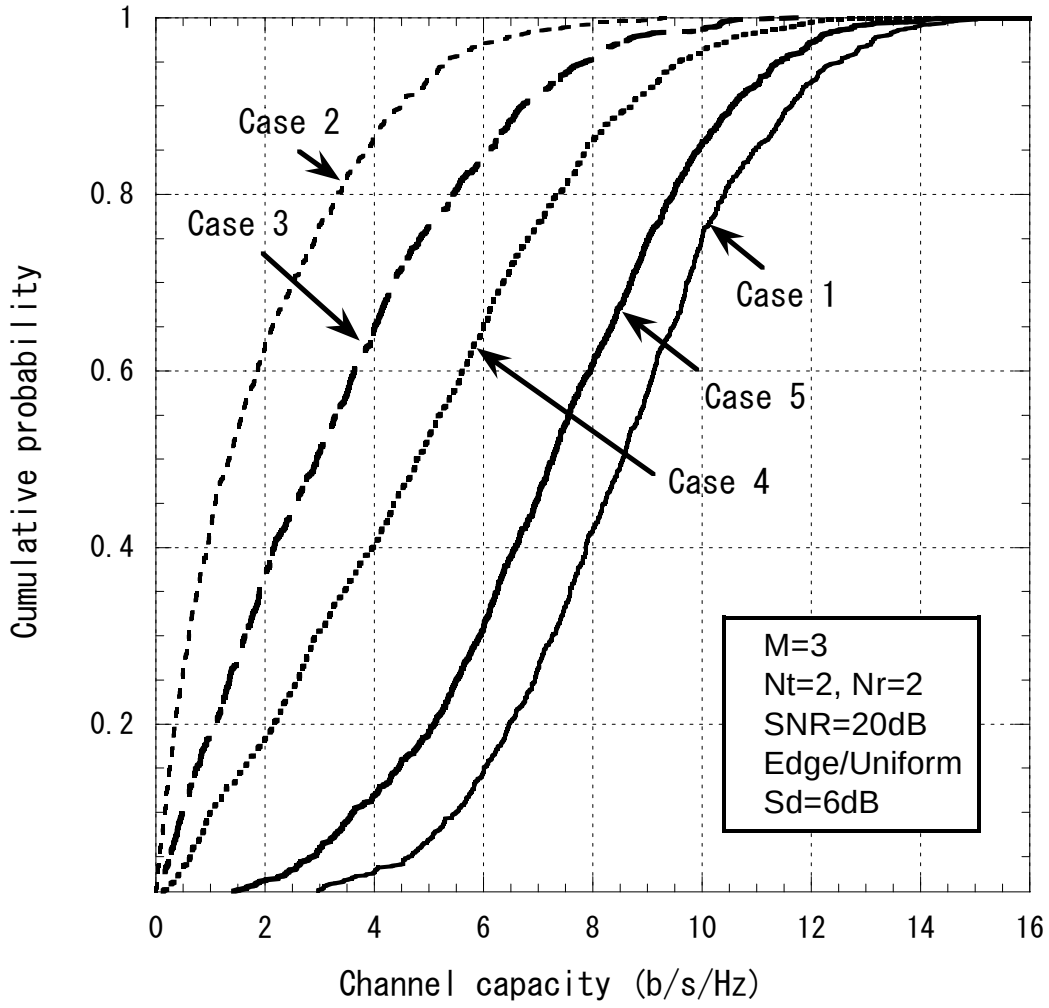
$$P_s^{(m)} = \left| \alpha_{mm} - \sum_{\substack{m'=1 \\ m'\neq m}}^{M} \frac{\alpha_{m'm}\alpha_{mm'}}{\alpha_{m'm'}} \right|^2 P_0^{(m)}$$

$$P_I^{(m)} = \sum_{\substack{m'=1 \\ m'\neq m}}^{M} \left| \sum_{\substack{m''=1 \\ m''\neq m \\ m''\neq m'}}^{M} \frac{\alpha_{m''m'}\,\alpha_{mm''}}{\alpha_{m''m''}} \right|^2 P_0^{(m')}$$

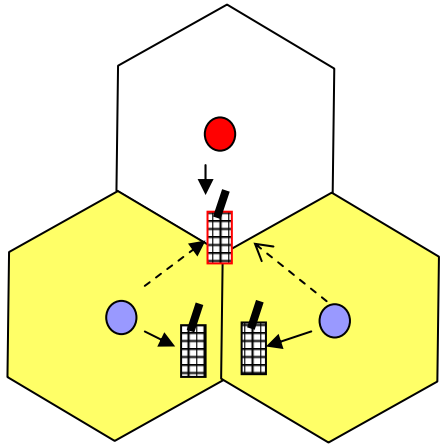
Assumed Conditions for Assessing a Base-Station Cooperation System

Parameters	Setting
Cell shape	Honeycomb structure
Transmission stream	Single stream
Tx antennas N_t	2, 4
Rx antennas N_r	2
Propagation model	Path loss: $d^{-3.5}$ Shadowing: Log-normal with SD of 6dB Short-term fading: Rayleigh (iid)
SNR at cell edge	10dB, 20dB, 30dB

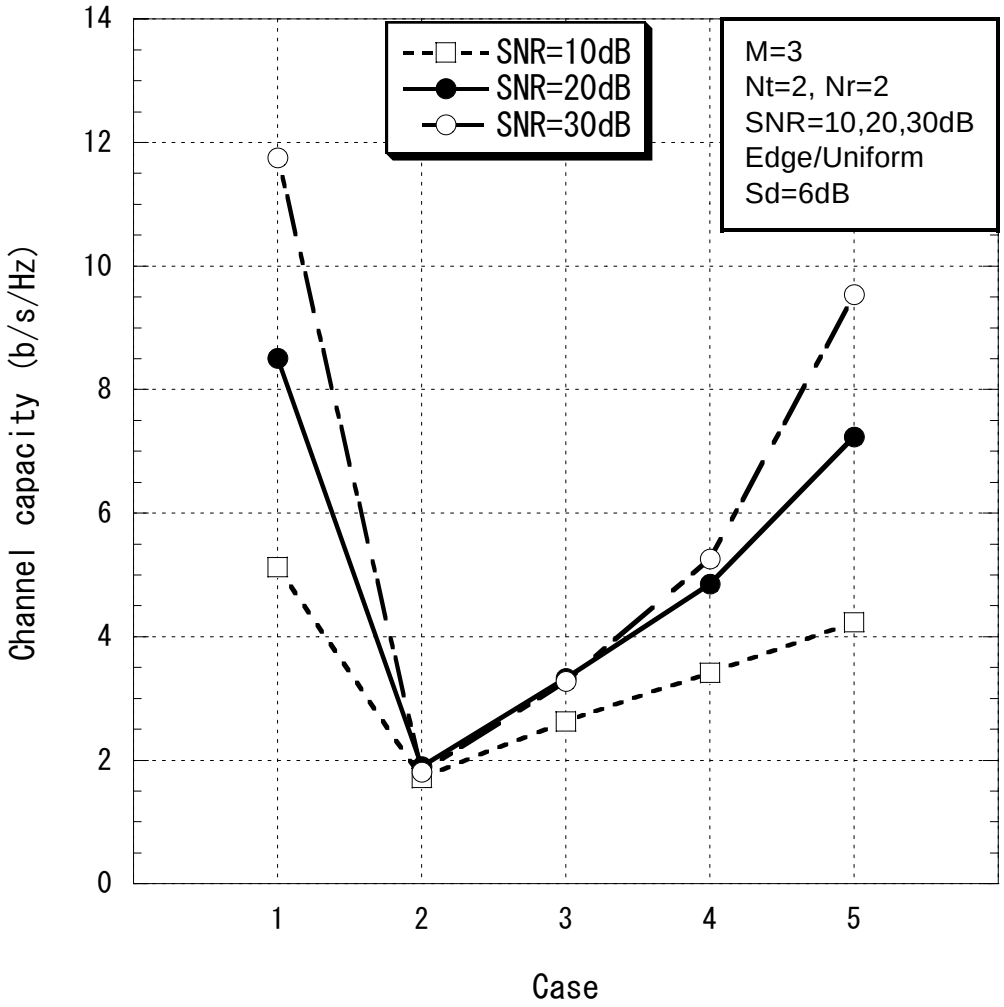
Effect of Three-Cell Cooperation (CDF of Channel Capacity)

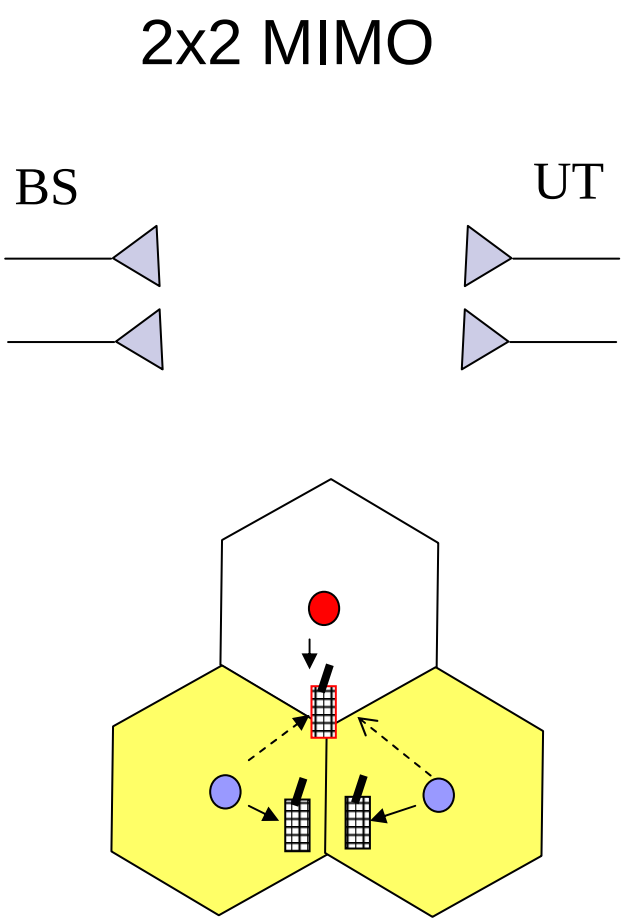


2x2 MIMO

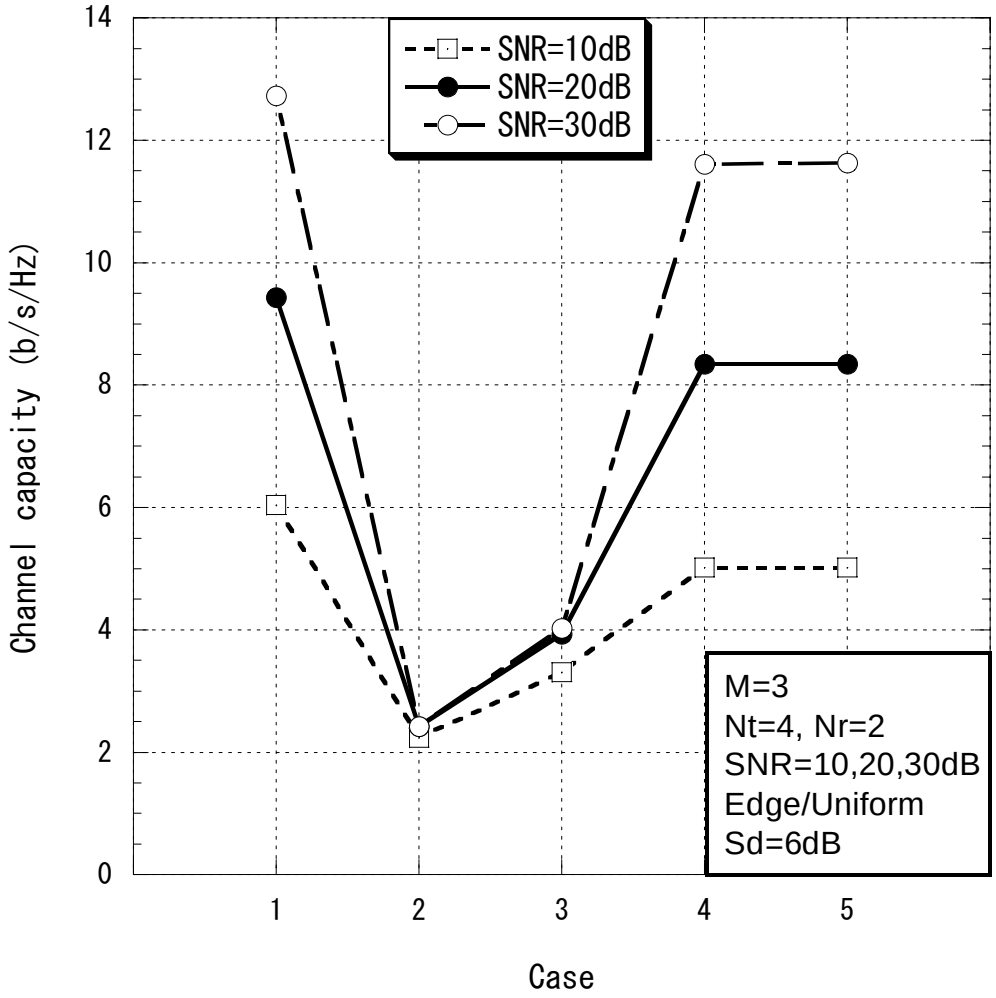


Effect of Three-Cell Cooperation (Average Channel Capacity)

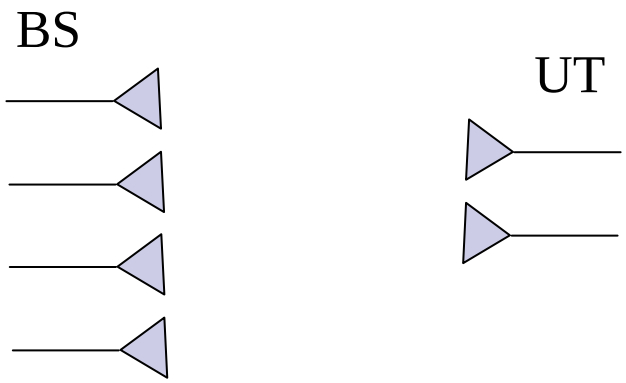


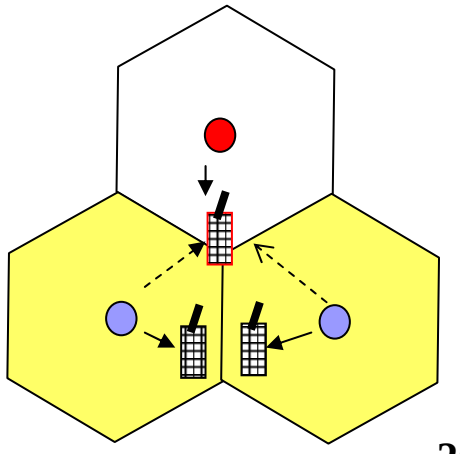


Effect of Three-Cell Cooperation (Average Channel Capacity)

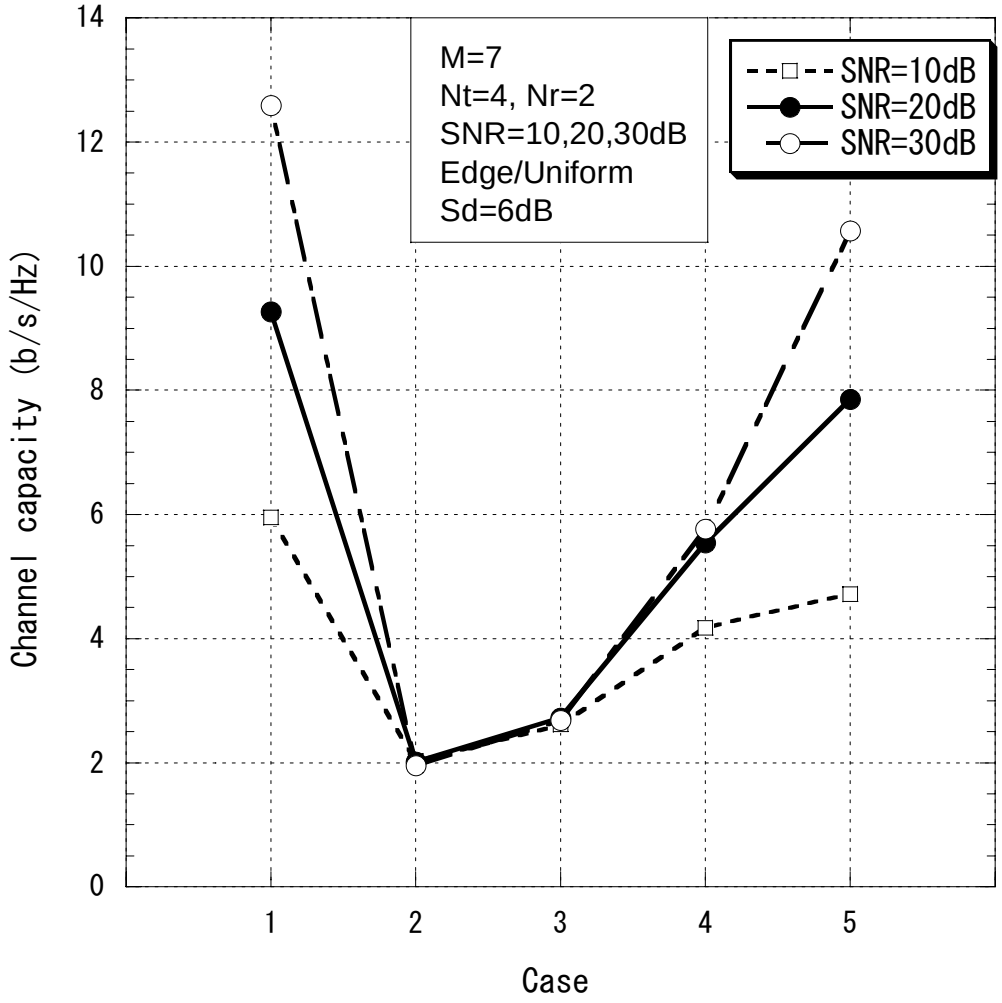


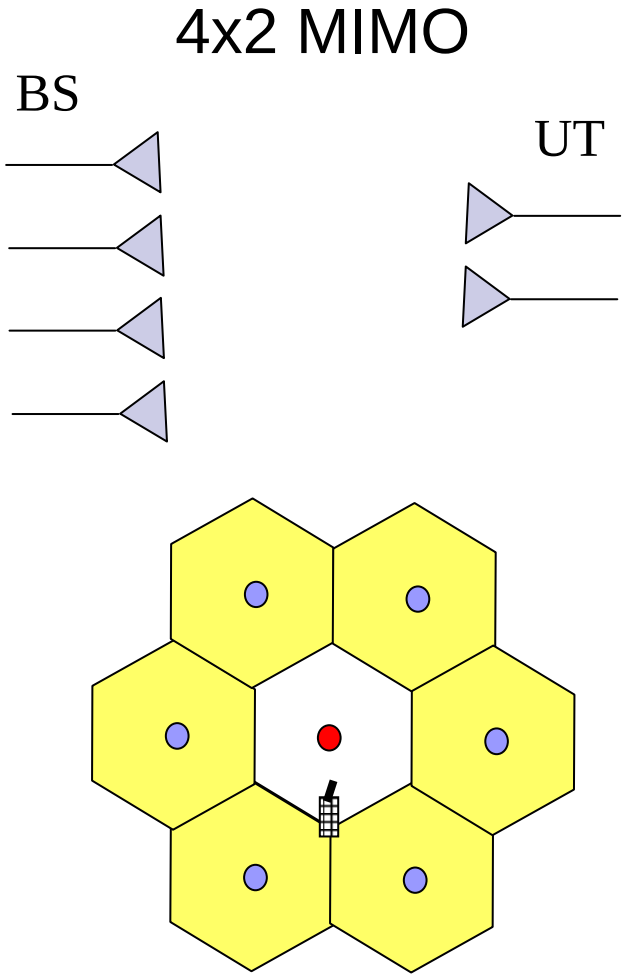
4x2 MIMO



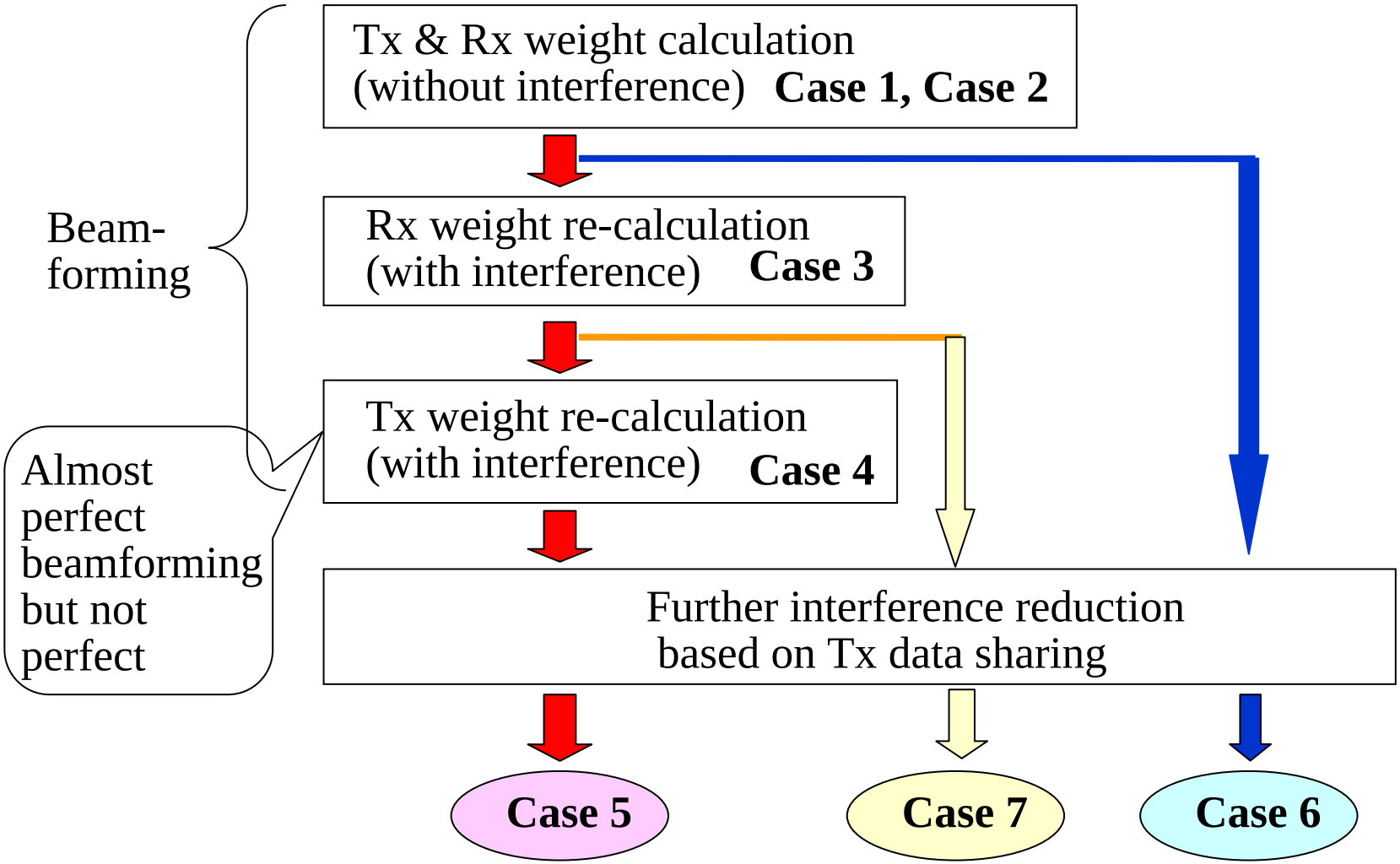


Effect of Seven-Cell Cooperation (Average Channel Capacity)

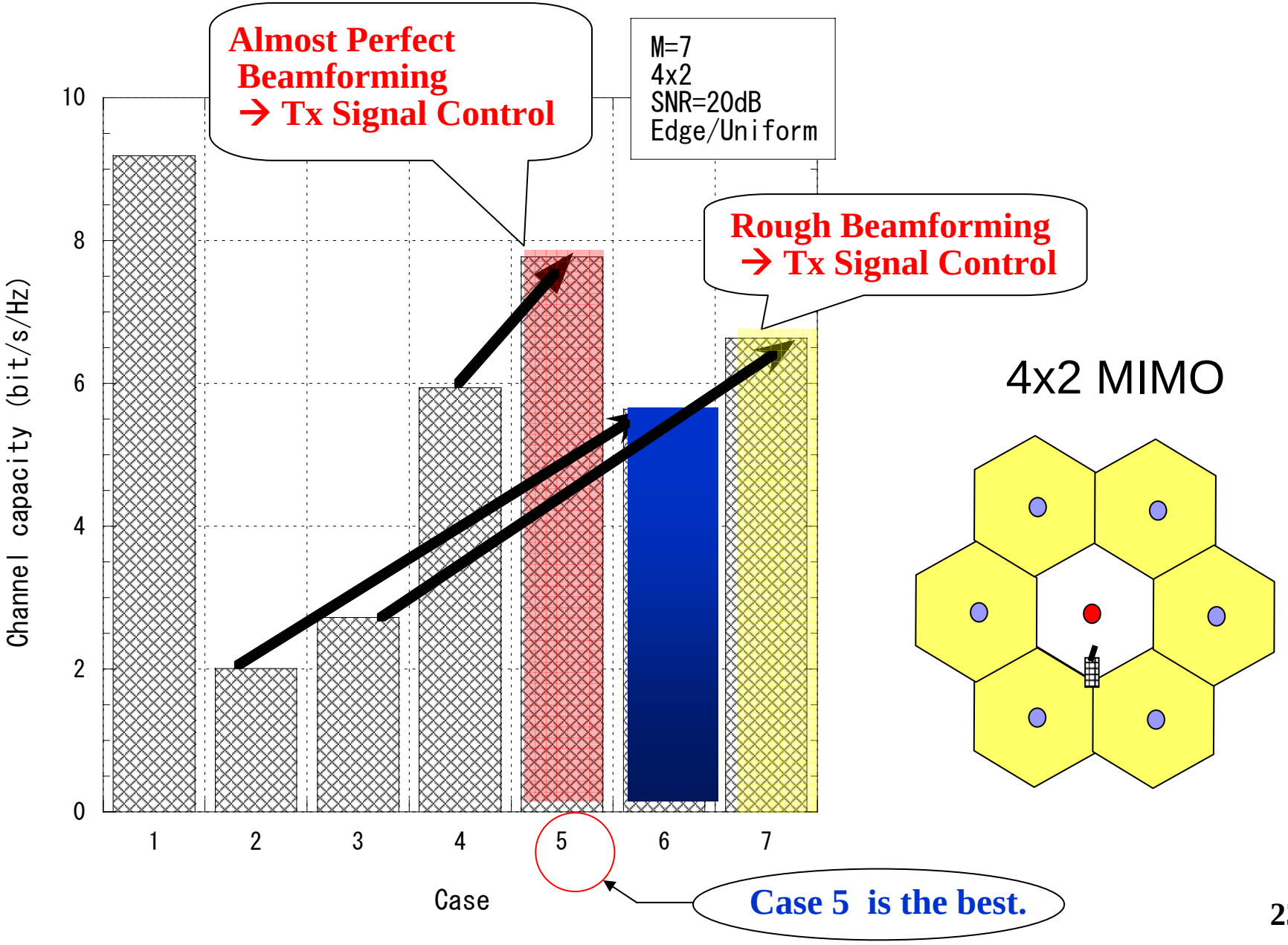




Tradeoff of Beamforming and Tx signal Control

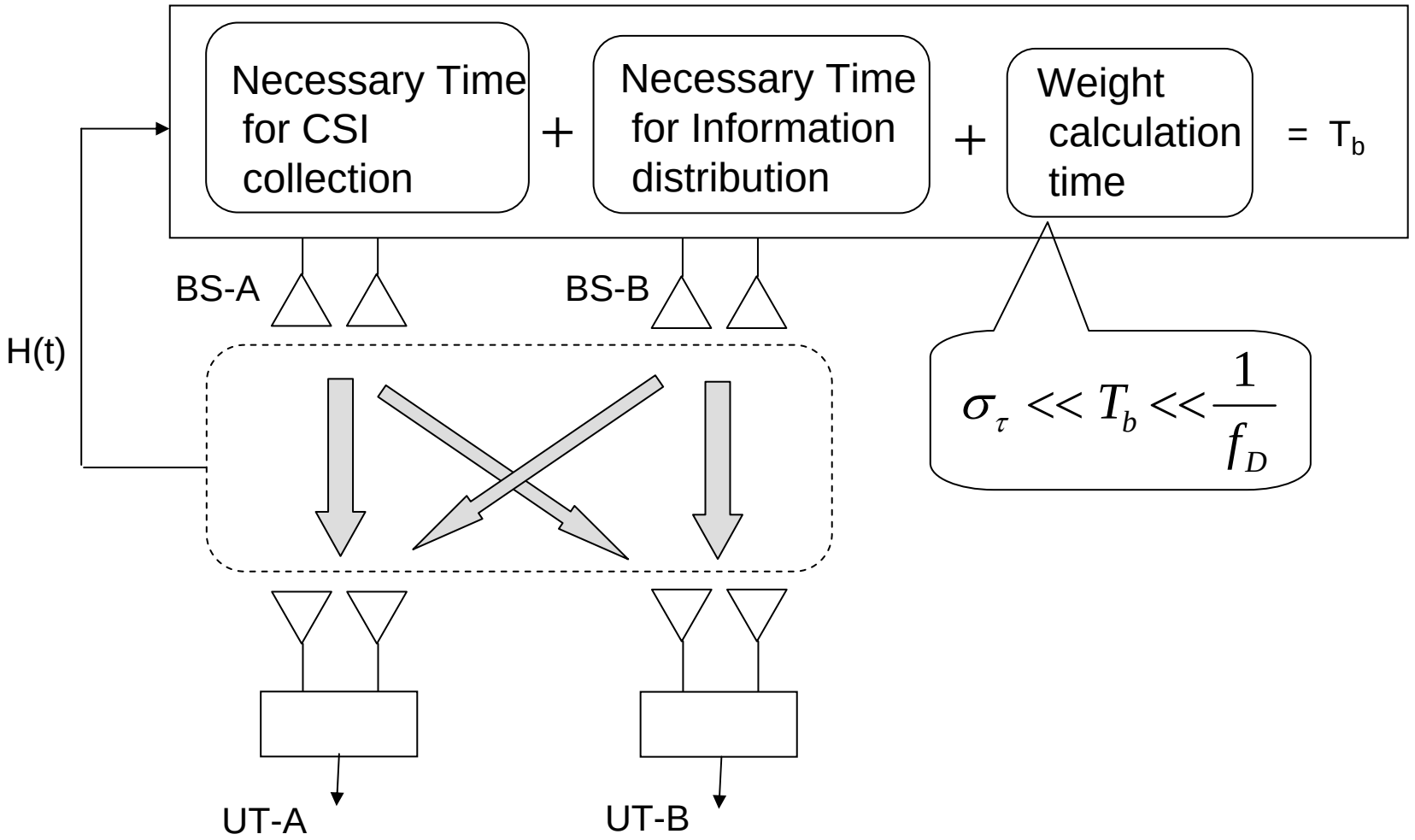


Tradeoff of Beamforming and Tx signal Control



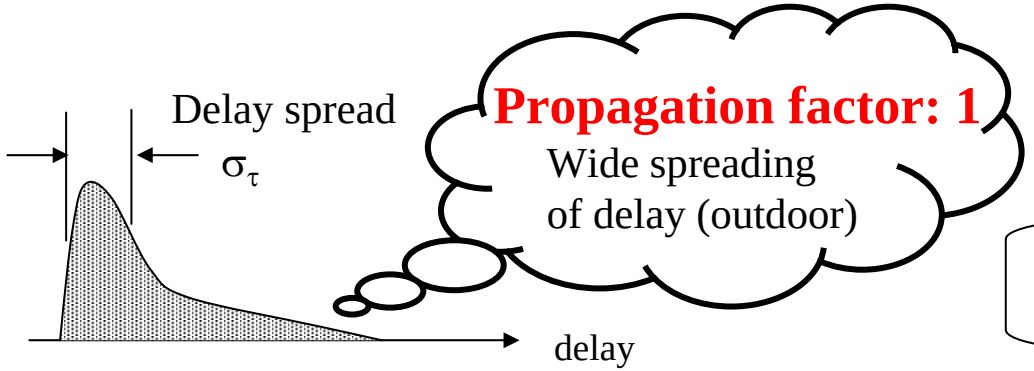
The gap between ideal and realistic operations

We dealt with the ideal case such that
- Obtained CSI is perfect.
- Antenna beamforming is done instantaneously.



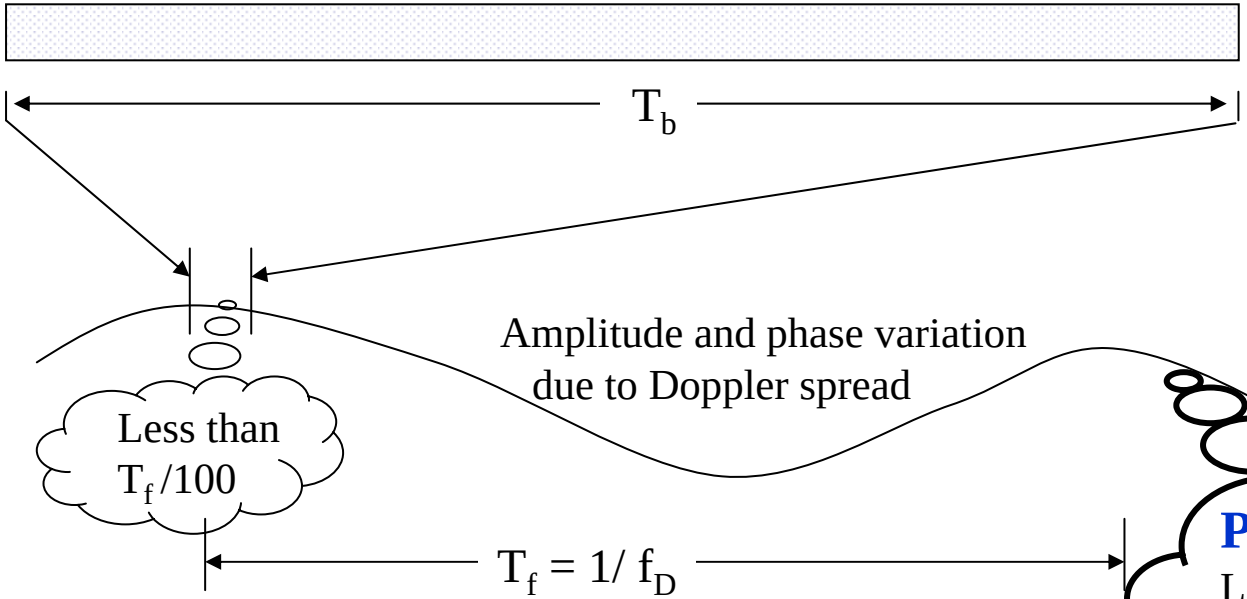
Two Propagation Factors in Block Signal Transmission

$$\sigma_\tau << T_b << \frac{1}{f_D}$$



Propagation factor: 1
Wide spreading of delay (outdoor)

Overall control has to be completed during a quasi-static period



T_b : Period of block length

Fading period（f_D: Maximum Doppler frequency）

Propagation factor: 2
Large Doppler spreading (higher freq. high speed)

Conclusions

BS cooperation scheme is a promising to realize high channel capacity.

The cooperation scheme is divided into two categories.
One is antenna beamforming based on exchanging all propagation information among cooperating Base Stations (Type 1).
The other is interference cancellation by adding interference signals intentionally after the beamforming (Type 2).

The results given above are for ideal cases, but it is also important to consider realistic cases. It seems difficult to achieve high reliability using this control scheme in practical systems. These investigations will be performed in a future study.

Thank you very much
for your kind attention.