Comparing Application- and Physical-Layer Approaches to Diversity on Wireless Channels

Presented by Emin Martinian[1]

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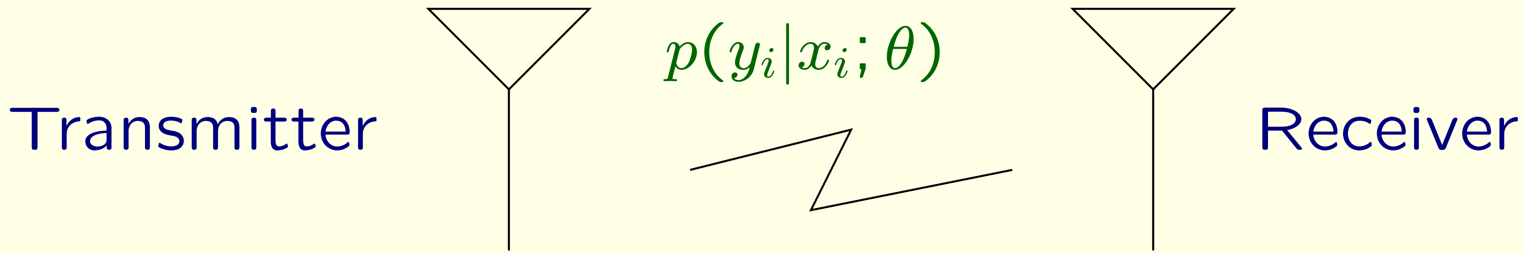
1 MIT, 2 HP Labs, 3 University of Notre Dame

Problem:

- Transmit over channel with unknown state, e.g. path loss/interference/slow fading/congestion/etc.



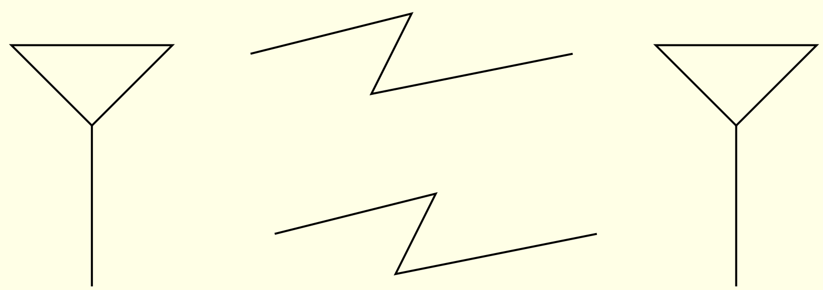
Goal:

- Minimize average distortion: $E_\theta[D]$.

Diversity: Transmit source over a parallel channel (multiple frequencies, time slots, etc.)

Channel 1: $p(y_i|x_i;\theta_1)$

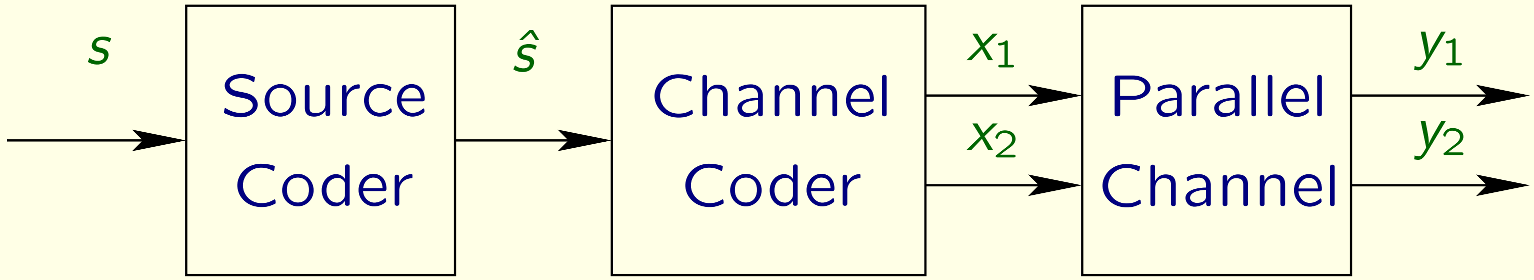
Transmitter



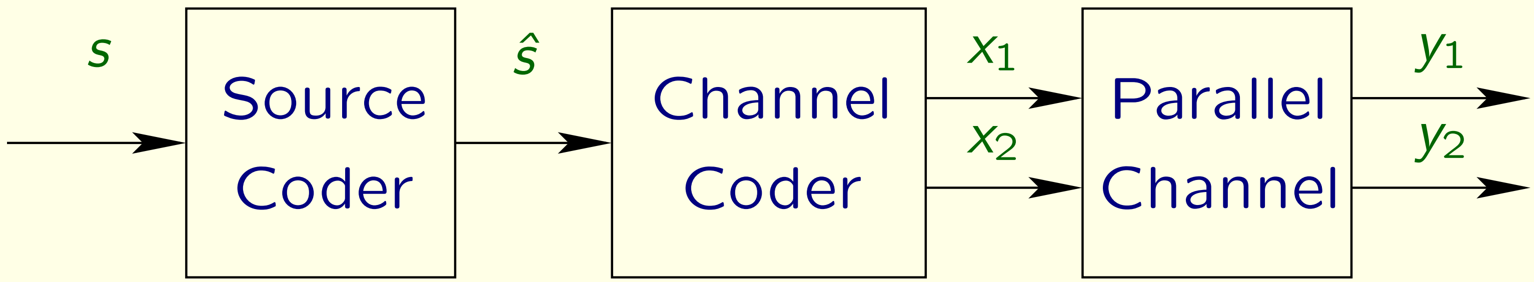
Receiver

Channel 2: $p(y_i|x_i;\theta_2)$

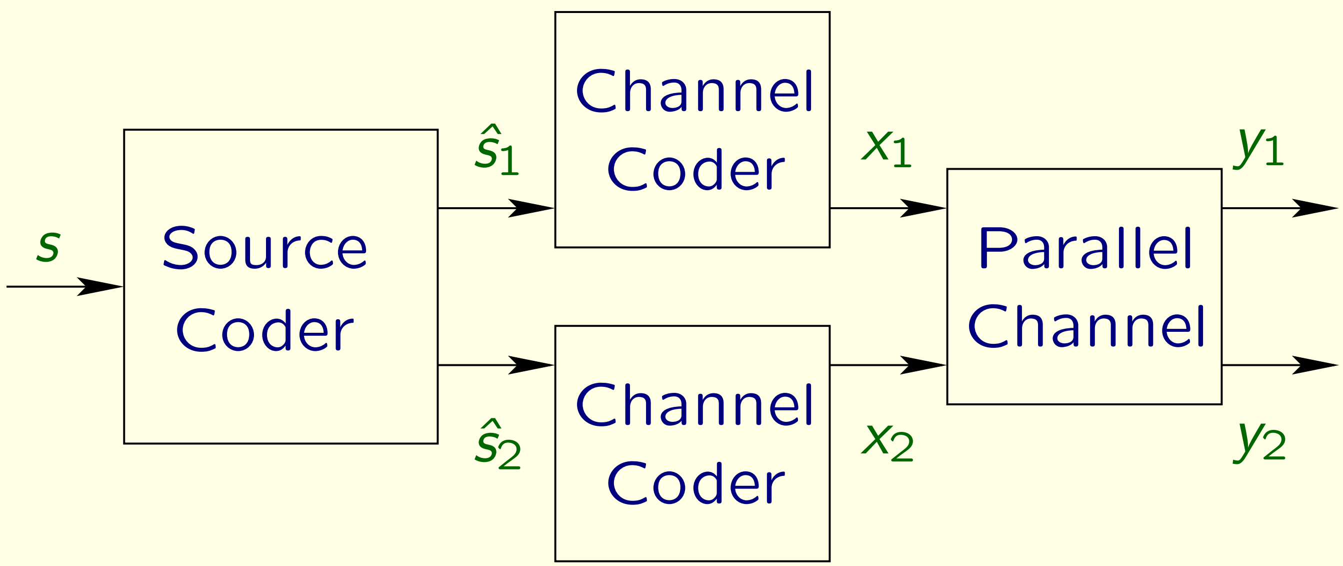
The Physical Layer Approach:



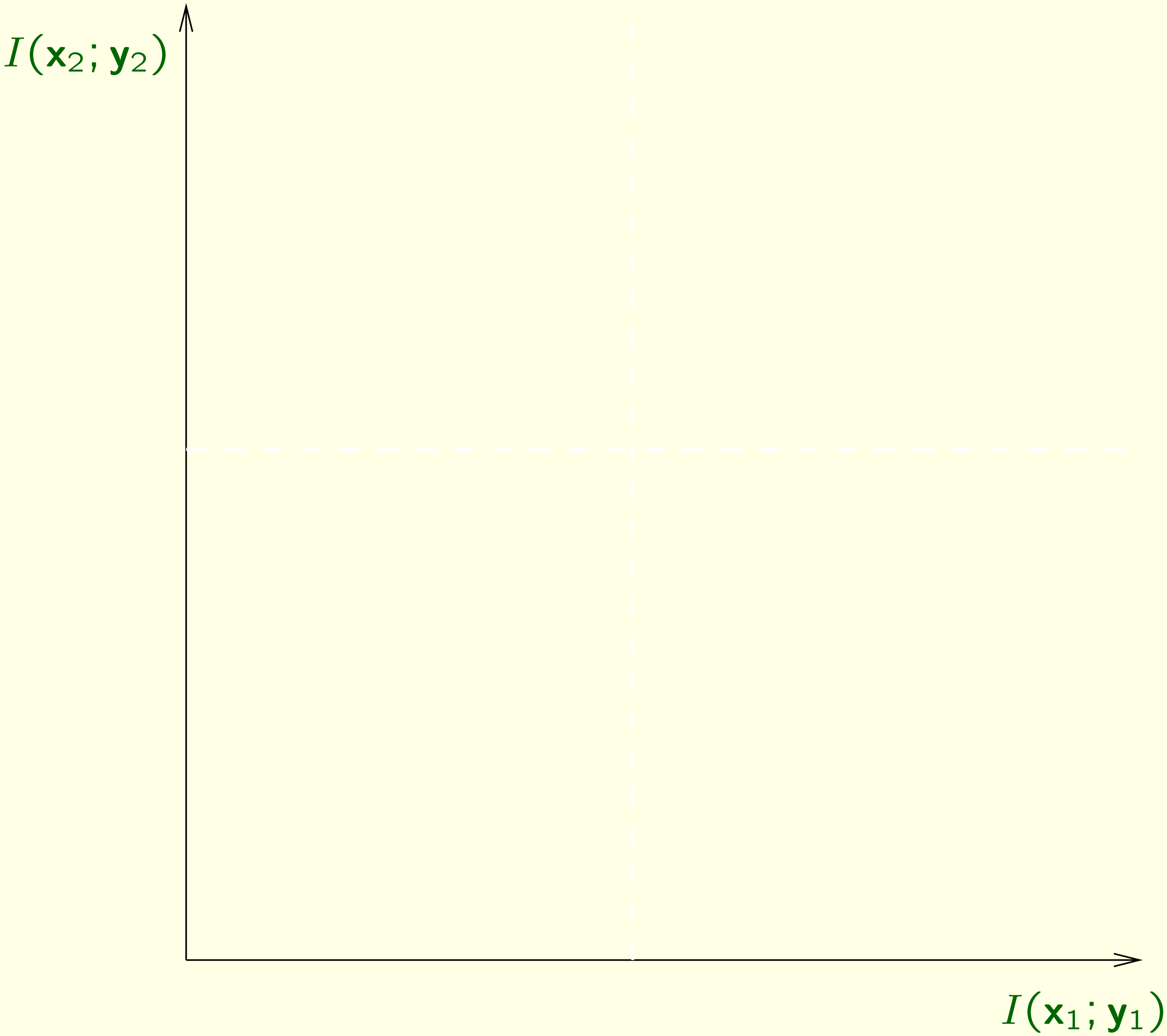
The Physical Layer Approach:



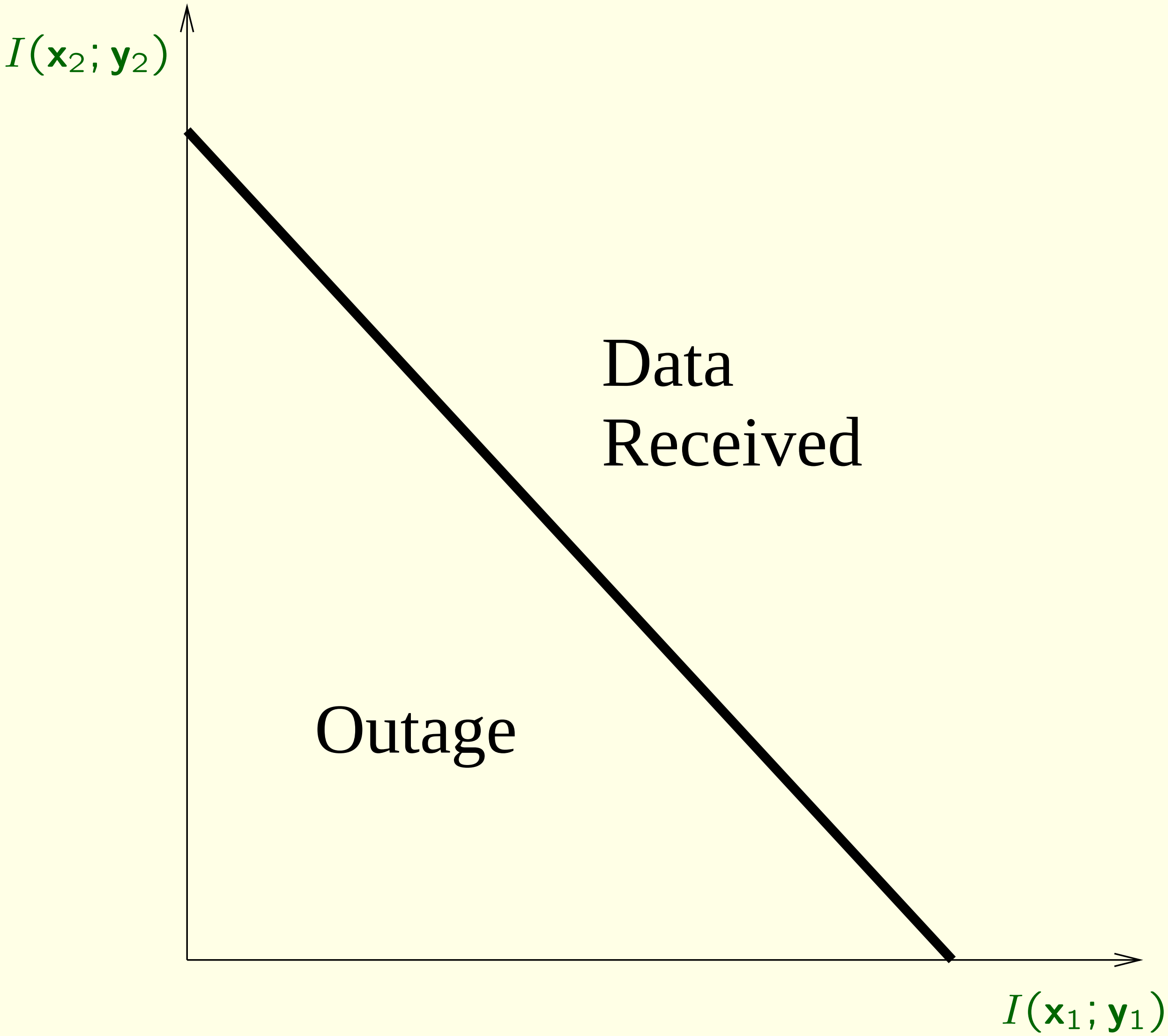
The Application Layer Approach:



Physical Layer Approach:

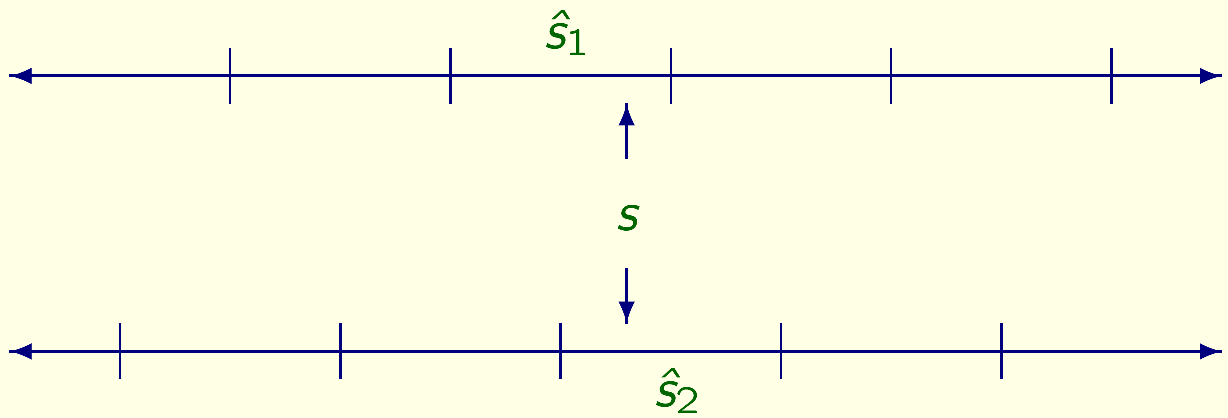


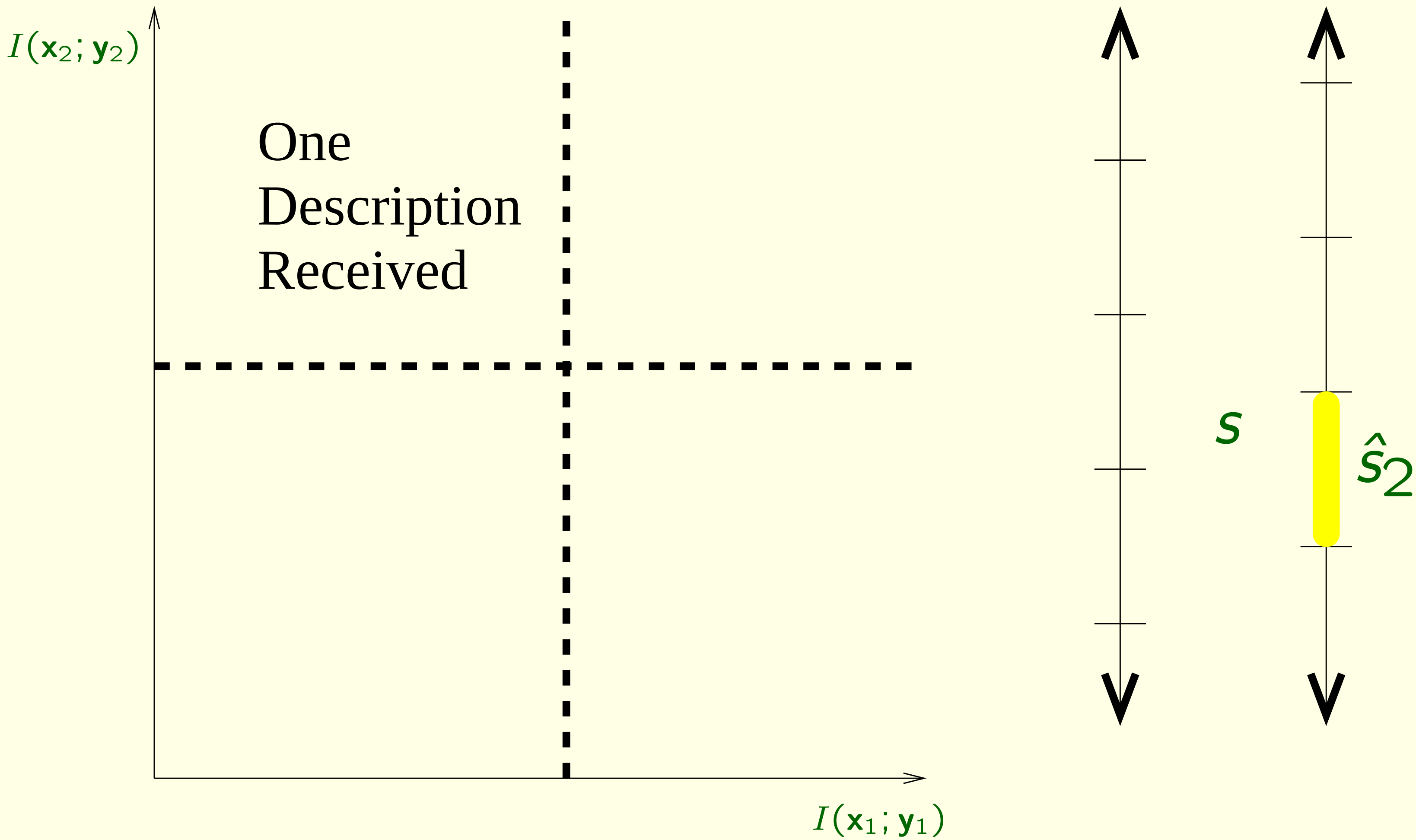
Physical Layer Approach:



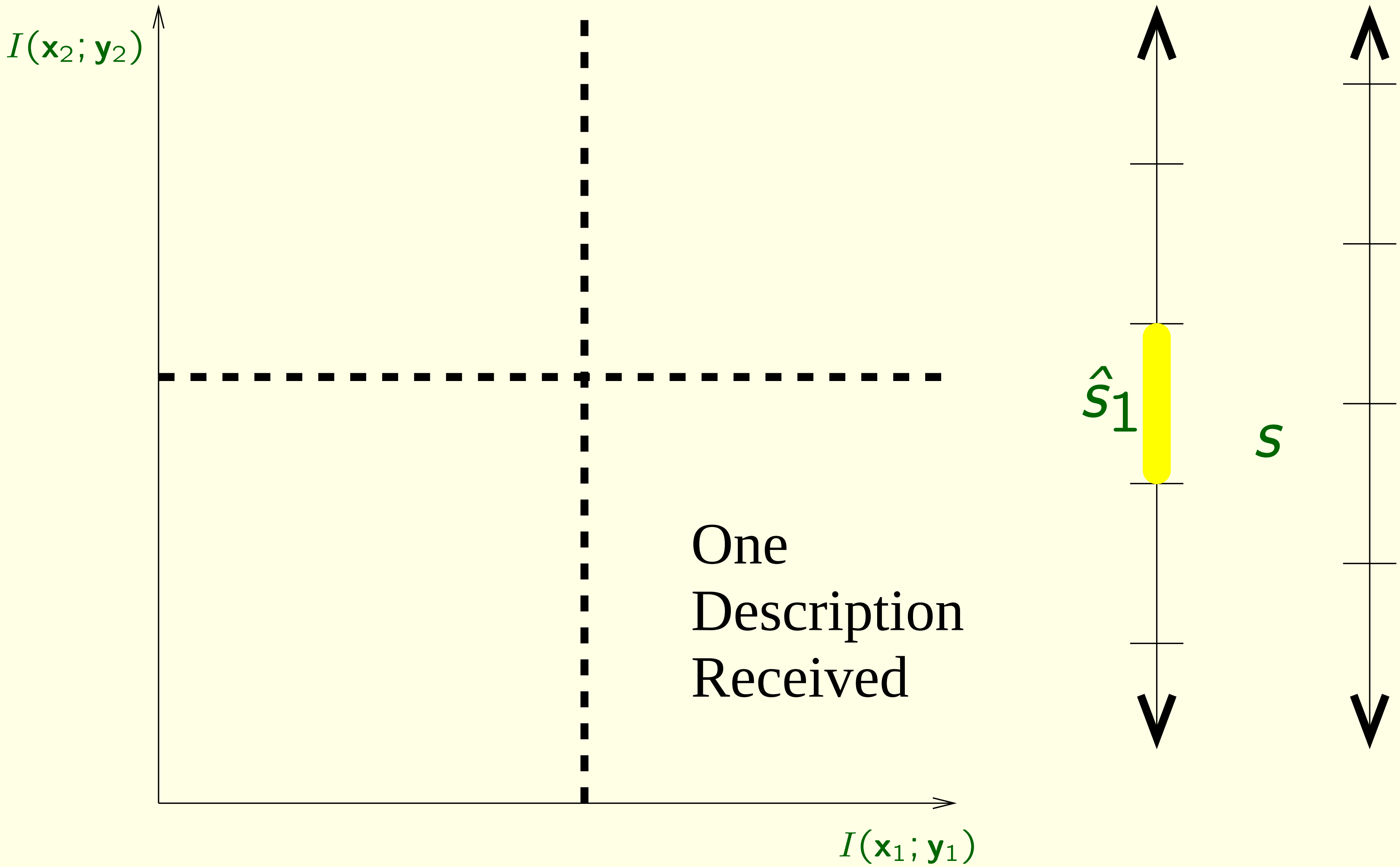
Diversity Via MD Coding:

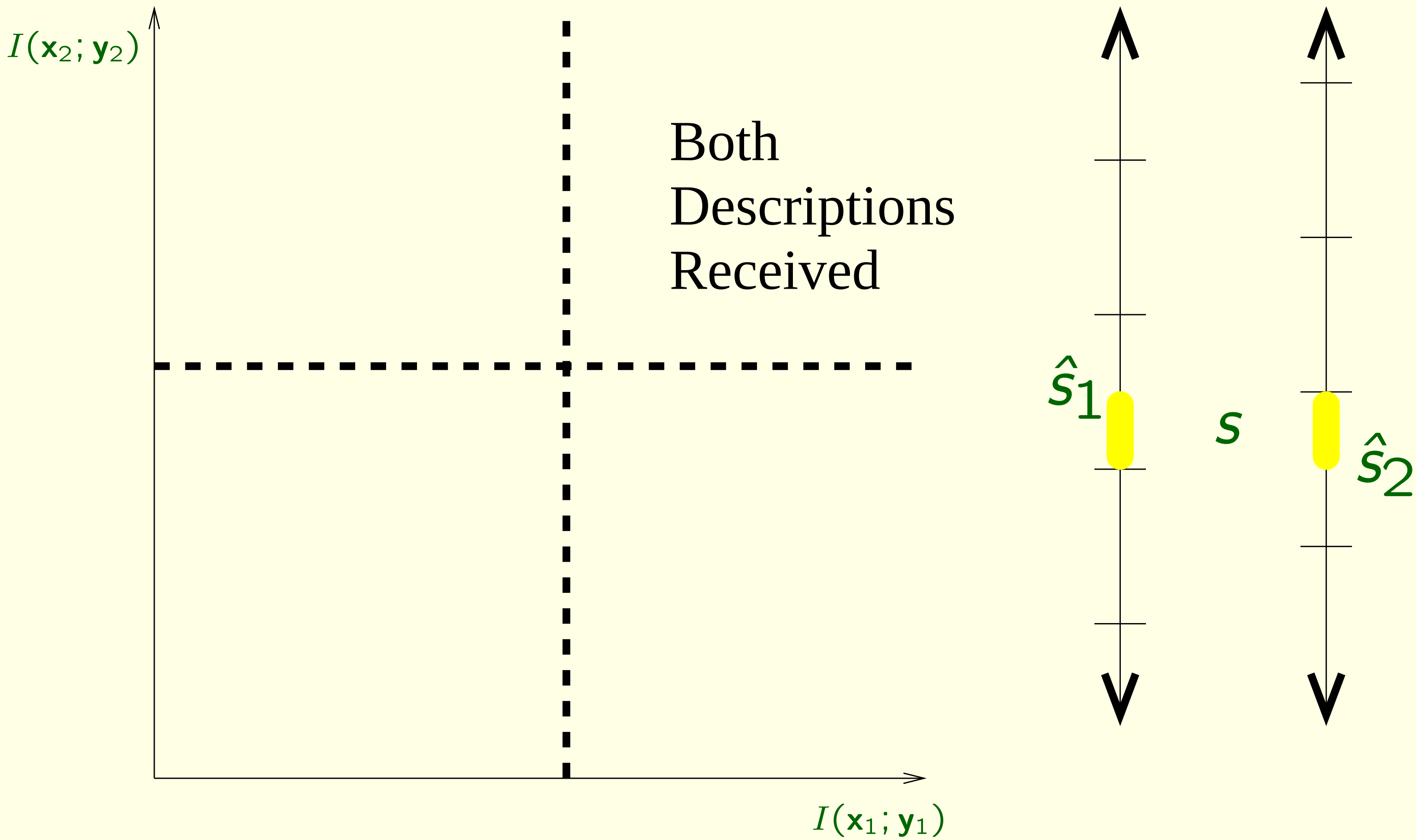
- Quantize source, s, to two descriptions, $\hat{s}_1$, $\hat{s}_2$.





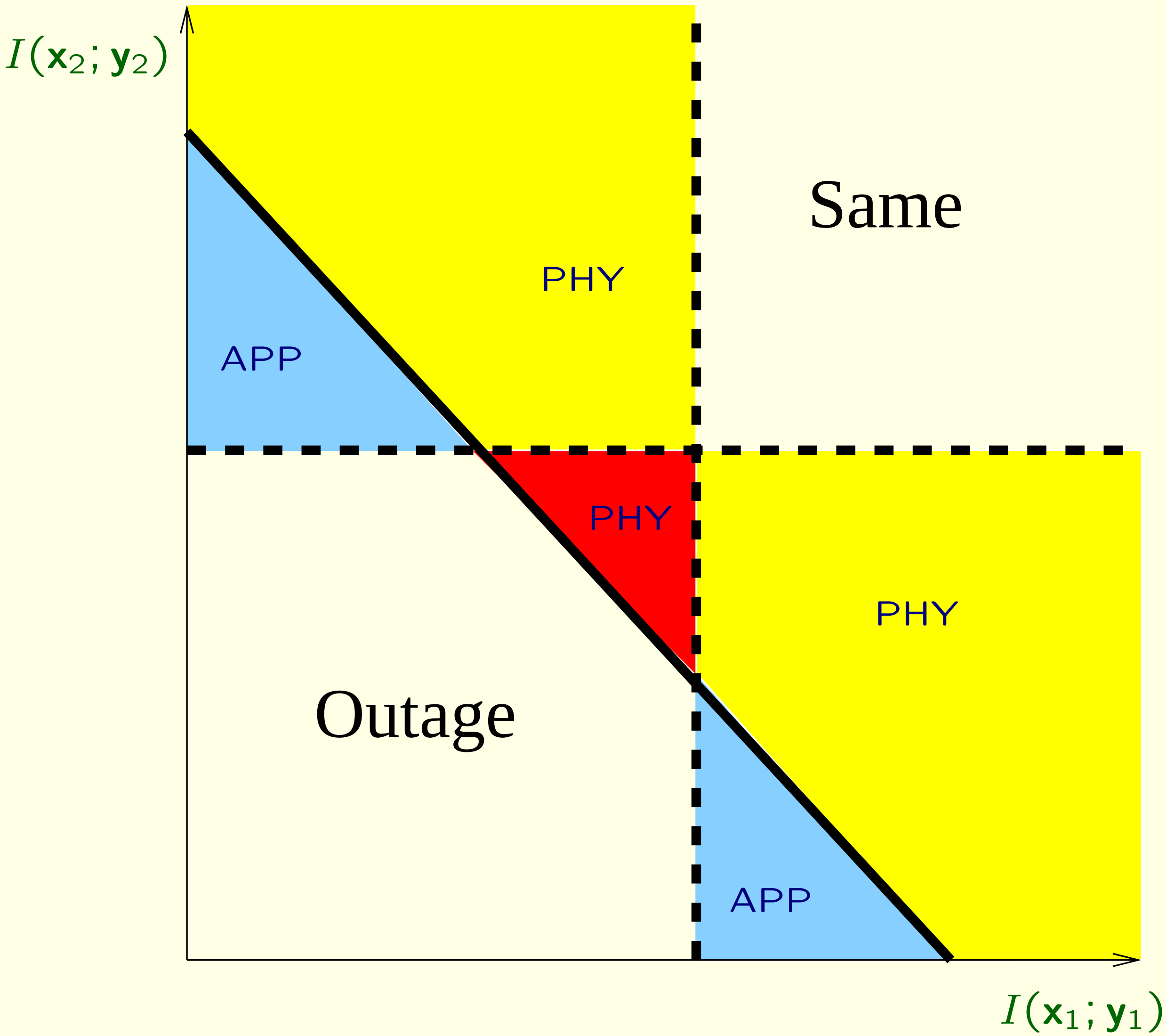
$I(\mathbf{x}_2;\mathbf{y}_2)$
One
Description
Received
$I(\mathbf{x}_1;\mathbf{y}_1)$
s
$\hat{s}_2$


$I(\mathbf{x}_2;\mathbf{y}_2)$
$I(\mathbf{x}_1;\mathbf{y}_1)$
One
Description
Received
$\hat{s}_1$
s



$I(\mathbf{x}_2;\mathbf{y}_2)$
Both
Descriptions
Received
$\hat{s}_1$
s
$\hat{s}_2$
$I(\mathbf{x}_1;\mathbf{y}_1)$

MD vs. SD Performance:



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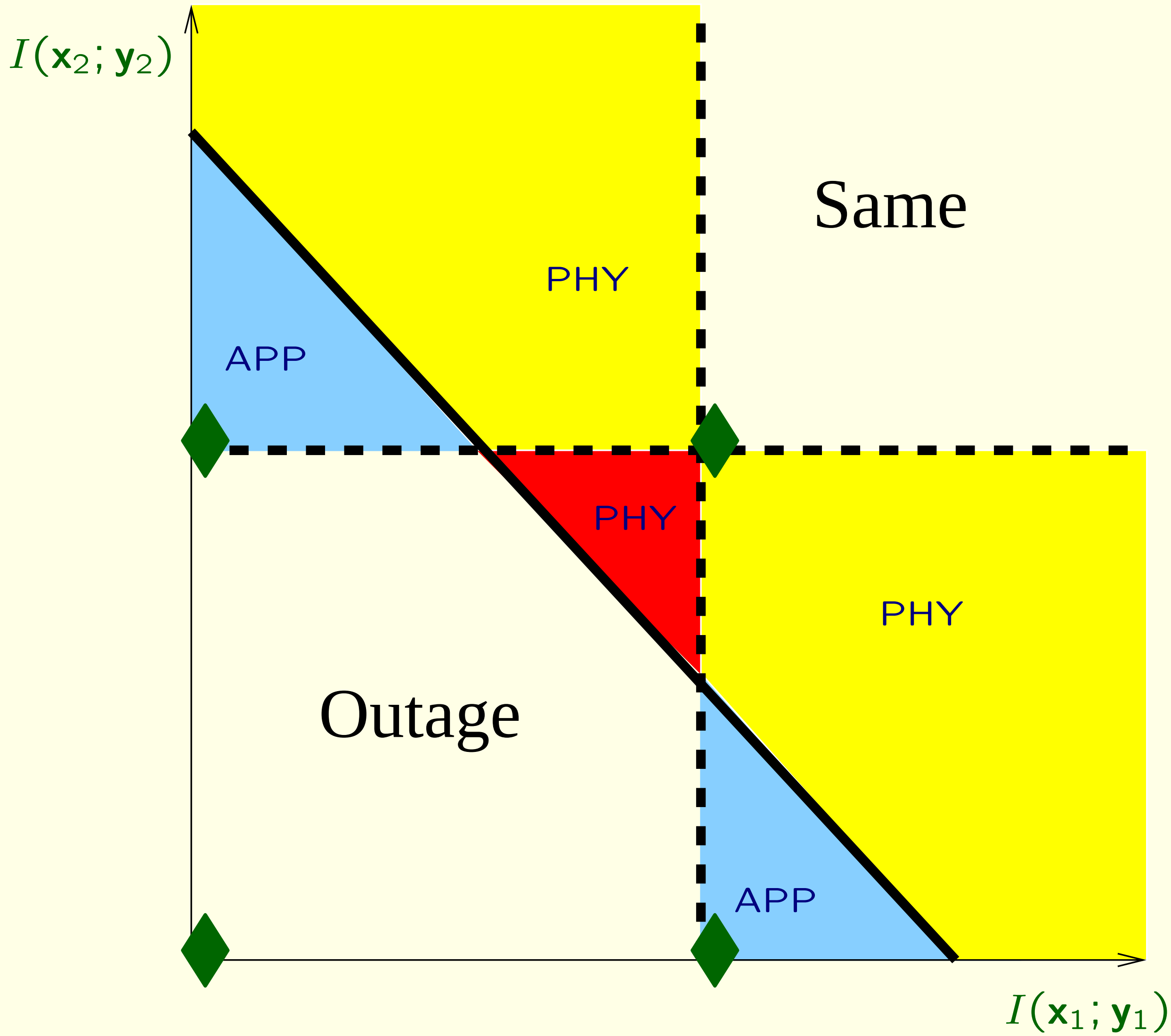

Performance For Gaussian Model:

- Unit variance Gaussian source, MSE distortion
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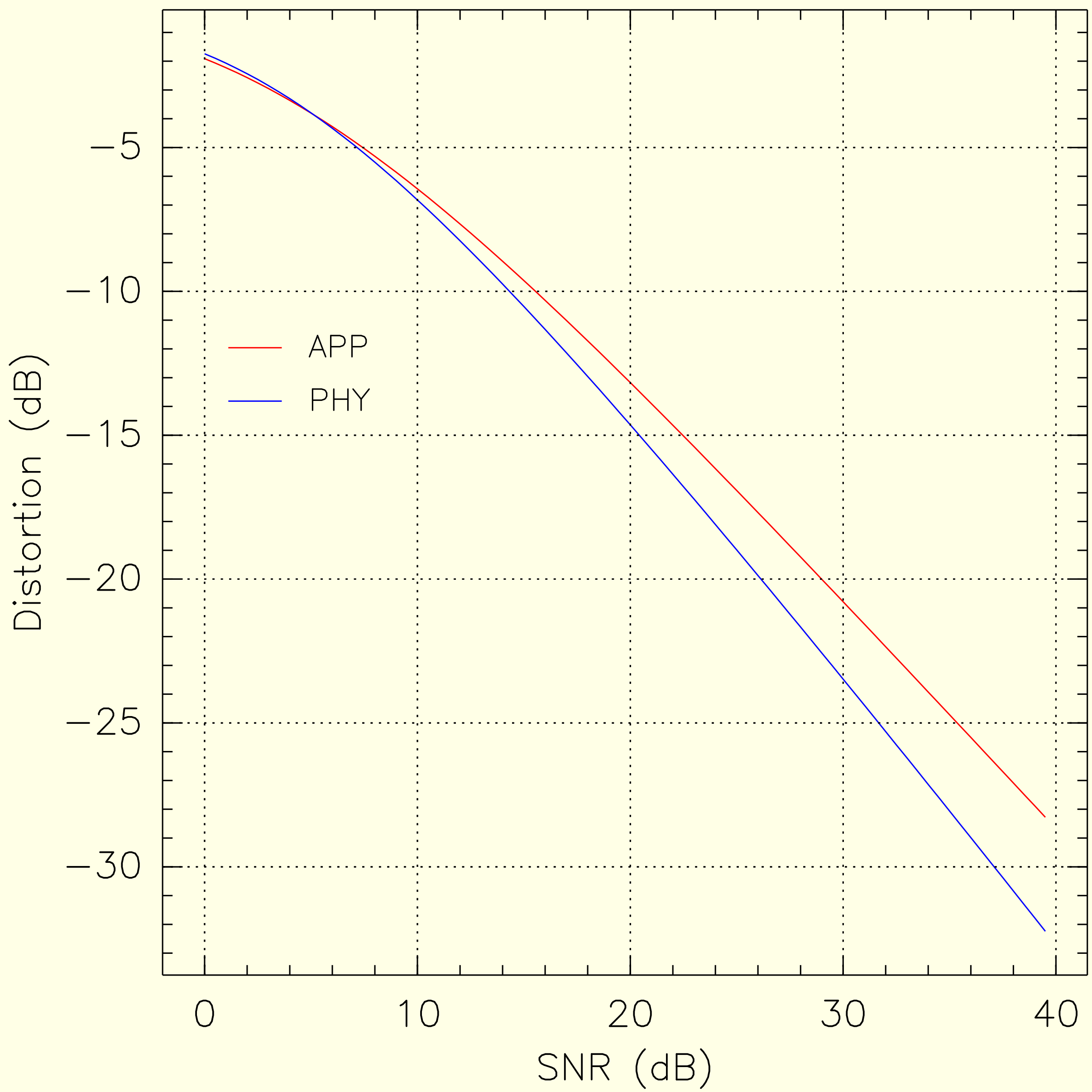
Optimal application layer diversity performance:

$$E[D] \approx \min_{\mathsf{R}} p_{\mathsf{ic}}^{\mathsf{out}}(\mathsf{R}/L)^2 + 2 \cdot D_{\mathsf{single}} \cdot p_{\mathsf{ic}}^{\mathsf{out}}(\mathsf{R}/L) + D_{\mathsf{both}}$$


−5
−10
−15
−20
−25
−30
Distortion (dB)
0
10
20
30
40
SNR (dB)
APP
PHY

Average Distortion (No Diversity)

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$$\begin{aligned} E[D] &\approx \min_{\mathsf{R}} p_{\mathsf{pc}}^{\mathsf{out}}(\mathsf{R}/L) + D(\mathsf{R}) \\ &= \min_{\mathsf{D}} \Pr\left[I(x;y) < \frac{1}{L} \log \frac{1}{\mathsf{D}} \right] + \mathsf{D} \end{aligned}$$

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$$
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\frac{\delta}{\delta \mathsf{D}}\left[\frac{\mathsf{D}^{-1/L}}{\mathsf{SNR}} + \mathsf{D}\right] &= \frac{-1}{L} \cdot \frac{\mathsf{D}^{-(L+1)/L}}{\mathsf{SNR}} + 1
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\mathsf{D}^* &= L^{-L/(L+1)} \cdot \mathsf{SNR}^{-L/(L+1)}
\end{aligned}
$$

Distortion Exponents For $L = 1$:

For high SNR, $E[D] \approx \mathsf{SNR}^{-\Delta}$:

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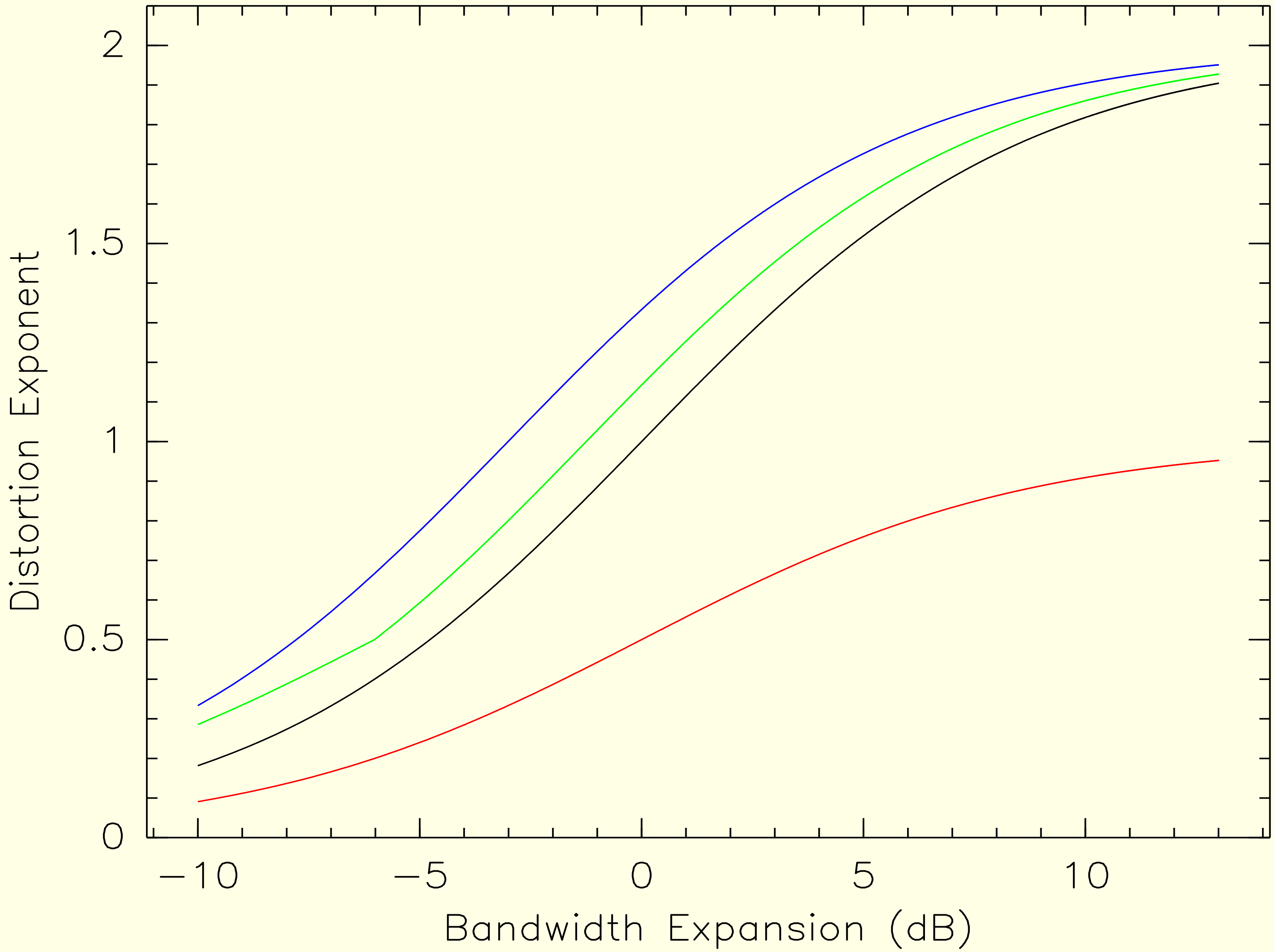
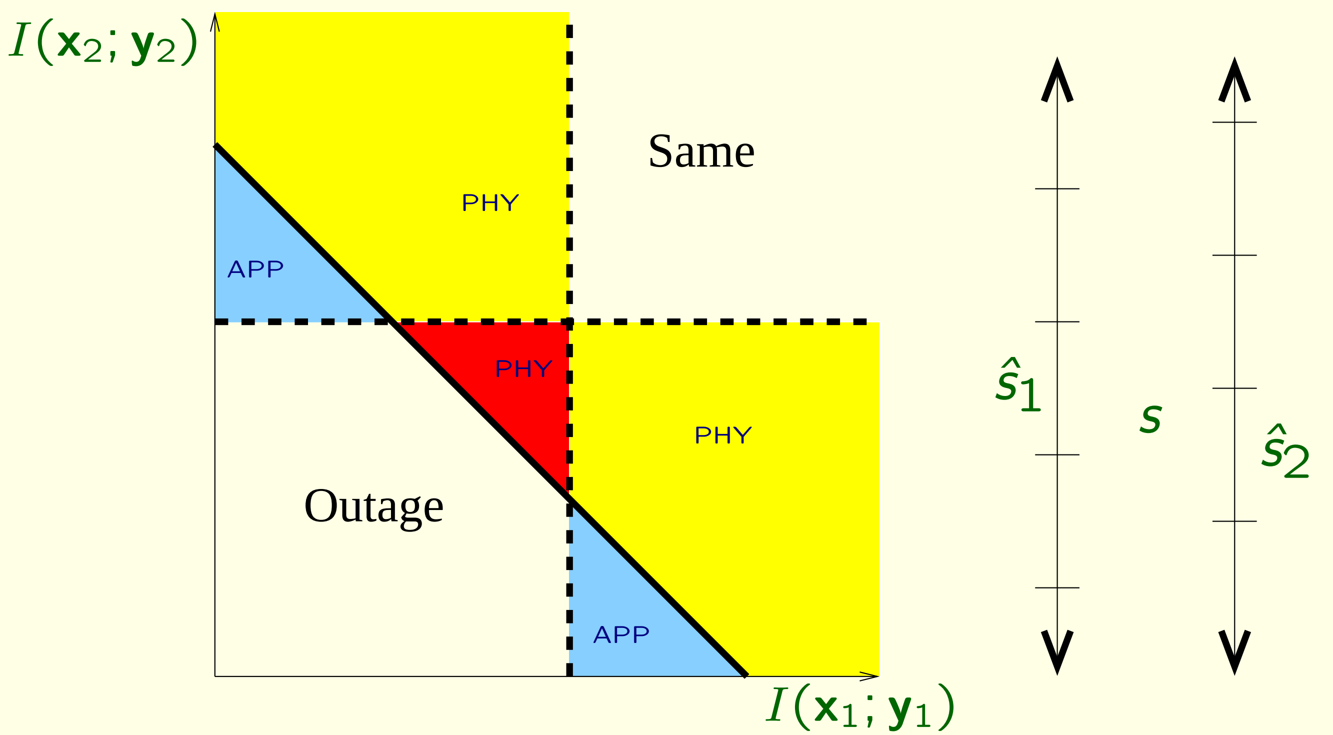
Parallel Rayleigh	SD	RC	$\frac{2L}{L+2} = \frac{2}{3}$



Distortion Exponent
Bandwidth Expansion (dB)
0
0.5
1
1.5
2
−10
−5
0
5
10

Joint Source-Channel Decoding



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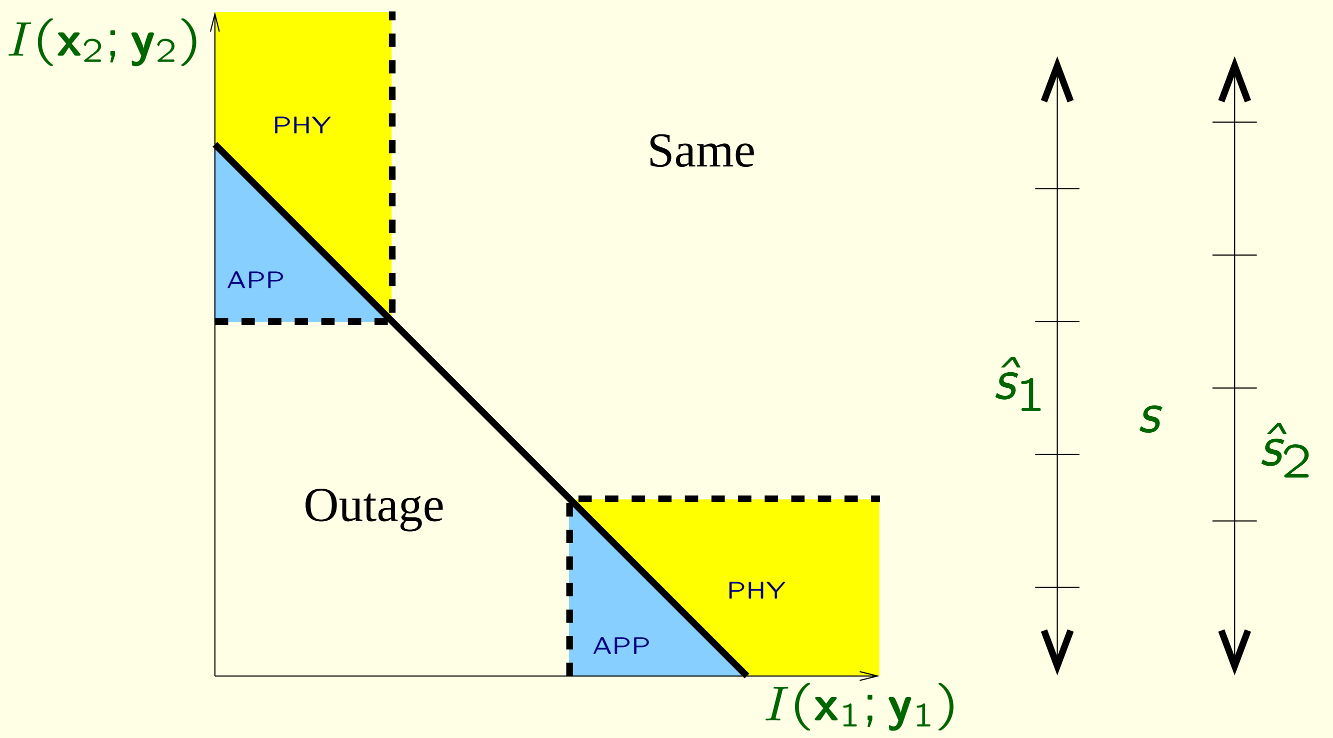

Conclusions:

- Inteference limited channels favor app. layer diversity.
- For noise limited channels, $E[D] \sim \mathsf{SNR}^{-\Delta}$.
- Physical layer systems have slightly better Δ.
- Joint decoding combines best features of both.

(Similar results for other source/channel models)