Reduced Complexity Blind Compute-and-Forward

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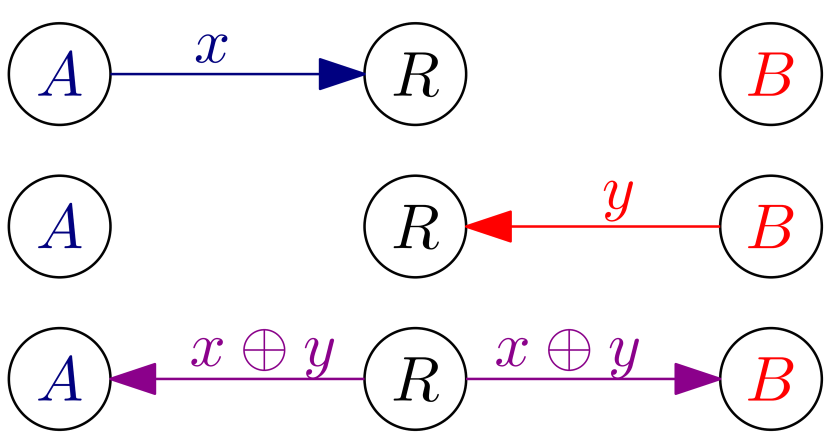
Abstract

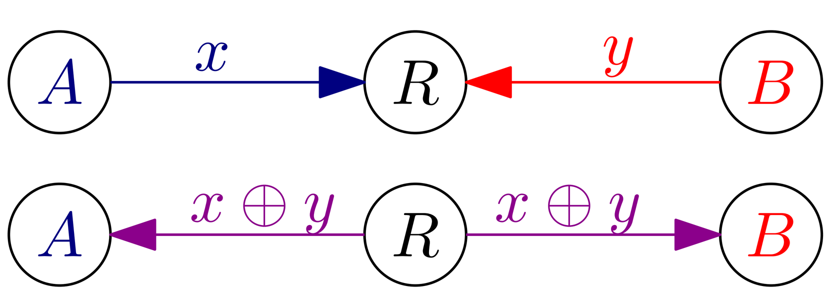
The objective of this work is to understand and improve a wireless non-coherent transmission scheme, that is, with no knowledge of the effect that the channel has on the signals. This is known as Blind Compute-and-Forward, and its coherent counterpart is denoted as Compute-and-Forward. **The contribution of this research will be to lower the complexity of decoding algorithms already implemented in [1].** Also, we aim to contribute with new theoretical information regarding the transmission scheme.

Network Coding



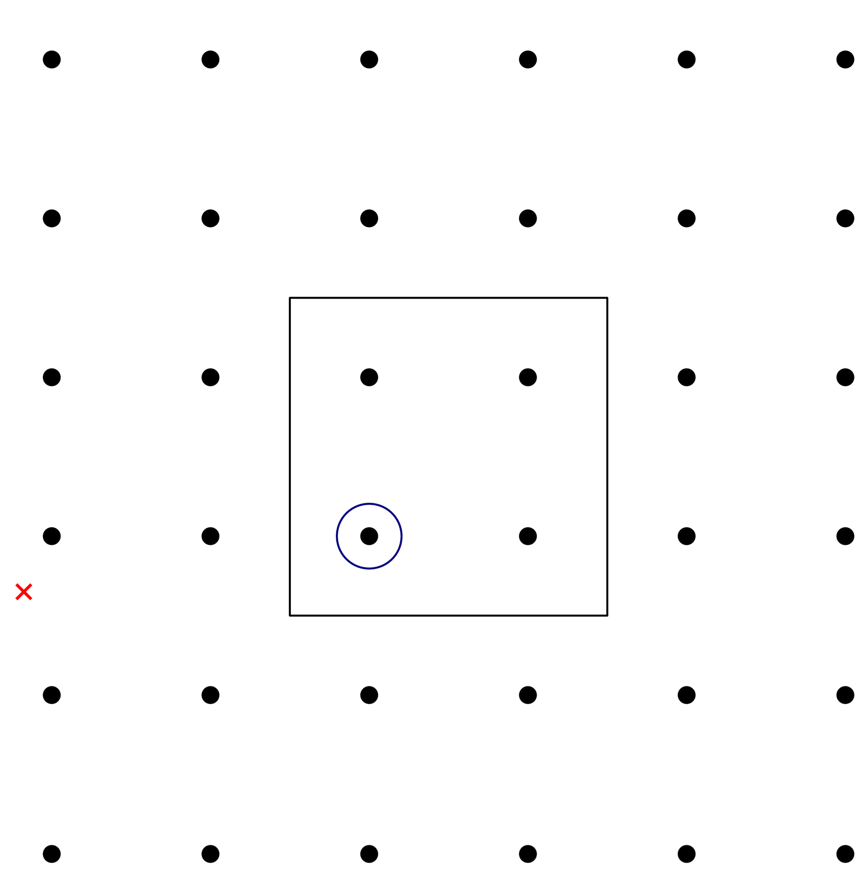
3 time slots

Phy. Layer Net. Coding

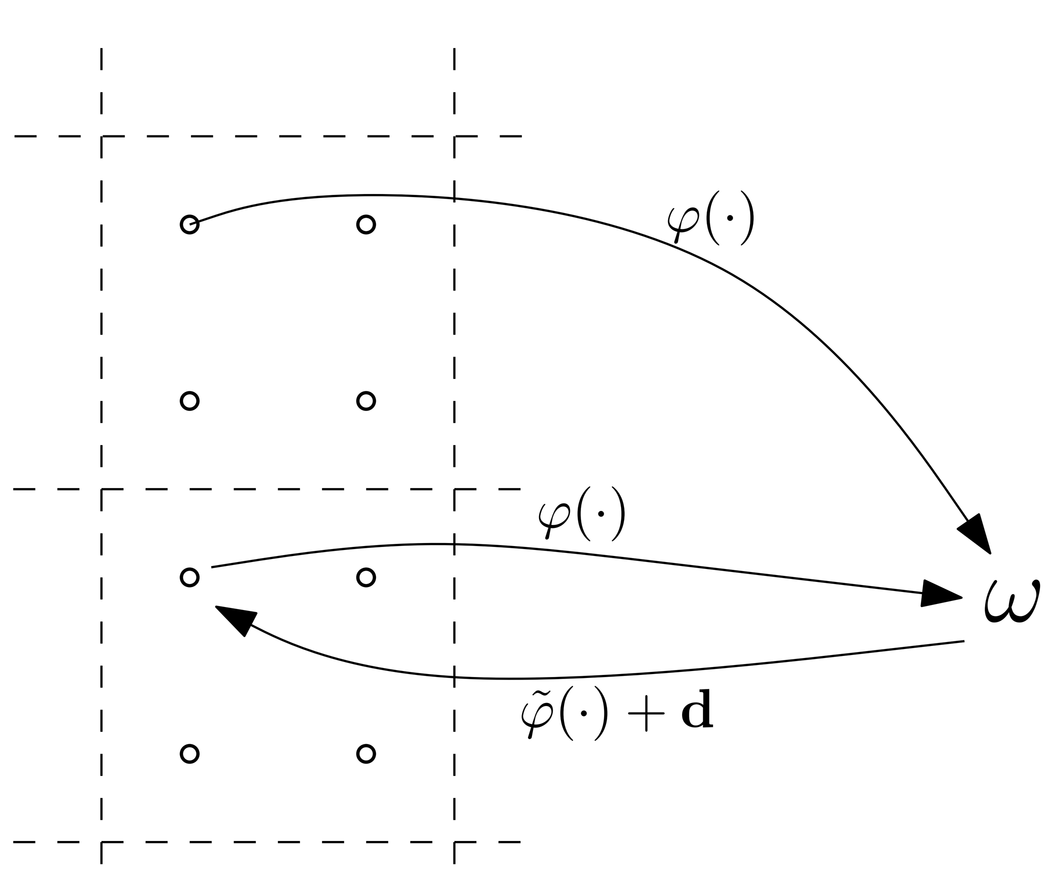


2 time slots

Lattice Decoding (4-QAM)

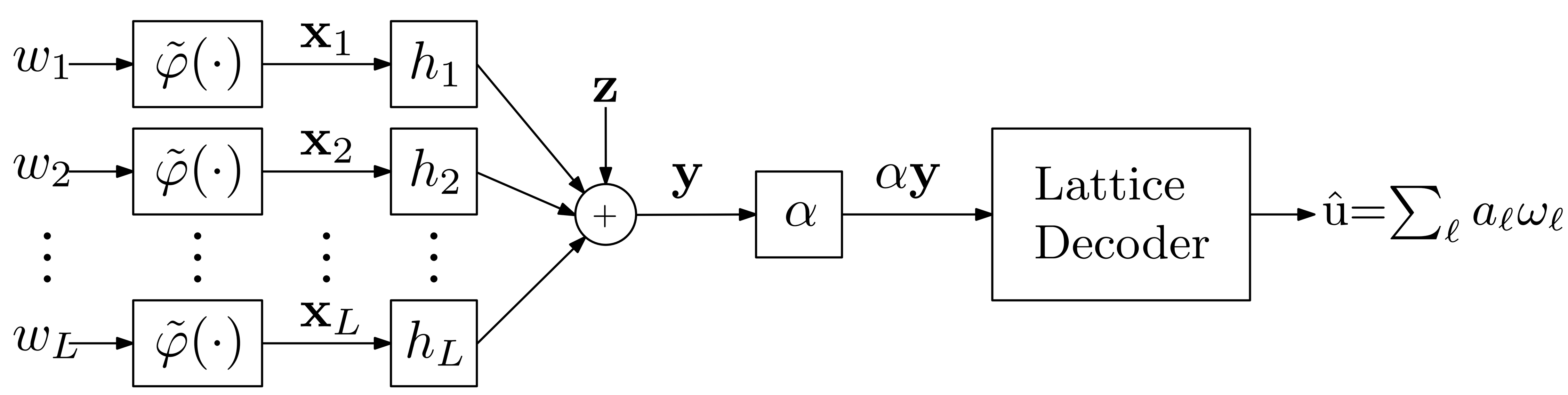


Labeling



Compute-and-Forward [2]

In its simplest form, with L users, C&F consists of a scheme where an intermediator receives a signal $\mathbf{y} = \sum_\ell h_\ell \mathbf{x}_\ell + \mathbf{z}$, where $\mathbf{h} = [h_1, ..., h_L]$ are the flat-fading channel coefficients, $\mathbf{x}_\ell$ are signals chosen from a nested lattice code and $\mathbf{z}$ is AWGN. For decoding, a scaling factor α is calculated using the information of $\mathbf{h}$ and $\mathbf{a} = [a_1, ..., a_L]$.



$$\alpha\mathbf{y} - \mathbf{d}\sum_\ell a_\ell = \sum_\ell a_\ell \tilde{\varphi}(\mathbf{w}_\ell) + \mathbf{n_{eff}} \qquad R_{comp} = -\log_2\left(\|\alpha\mathbf{h} - \mathbf{a}\|^2 + \frac{|\alpha|^2}{\text{SNR}}\right)$$

$$\alpha = \frac{\mathbf{a}\mathbf{h}^H}{\|\mathbf{h}\|^2 + 1/\text{SNR}}$$

Blind Compute-and-Forward [1]

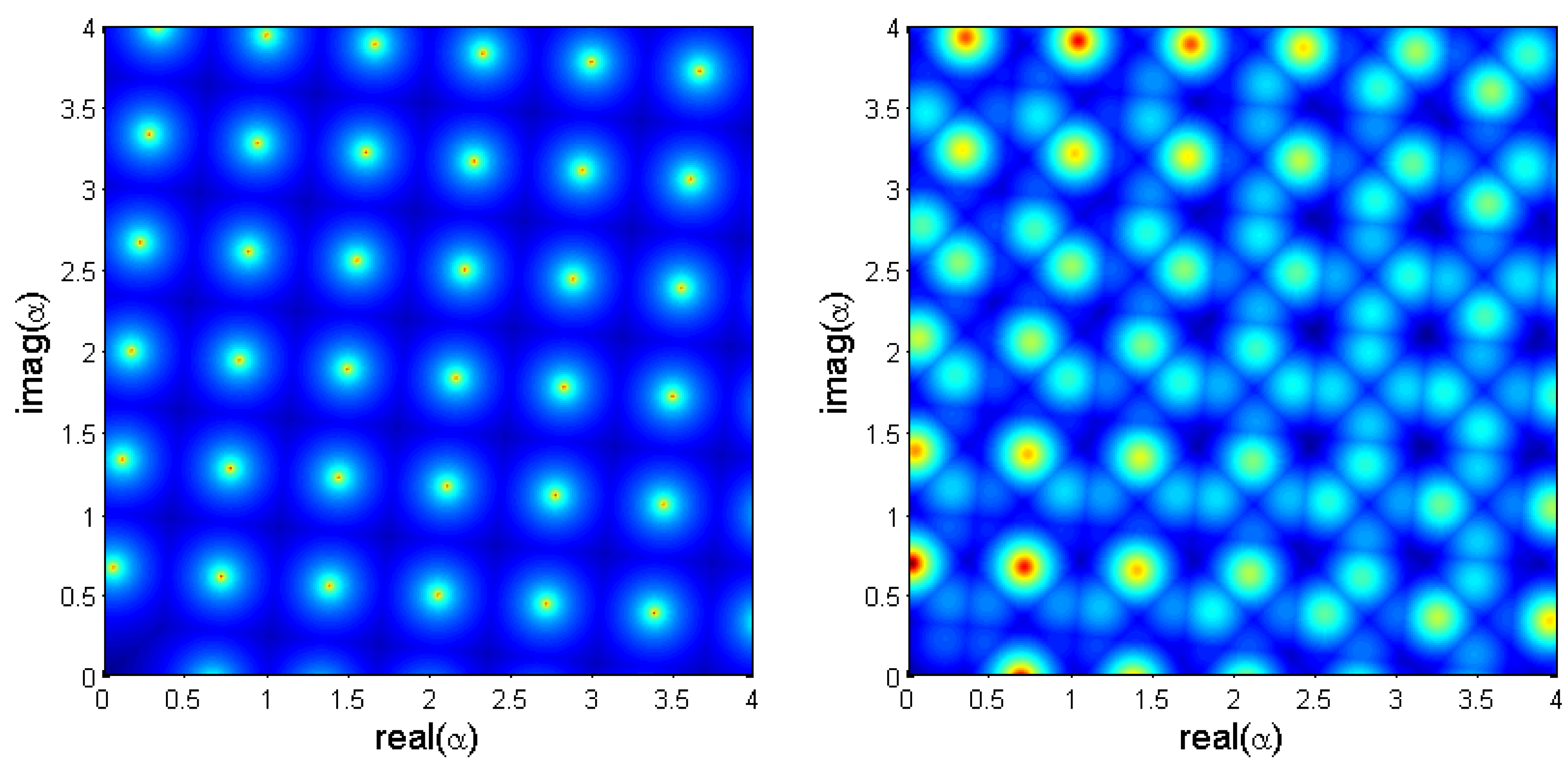
The central idea of *Blind C&F* is that we do not need the optimal value of α for each $\mathbf{a}$ and $\mathbf{h}$. A *good* scalar will suffice for decoding. For a specific class of nested lattice codes, [1] proposes a computationally efficient algorithm to determine if a given α is good or bad.

Smoothing Lemma: Let $\mathbf{n}$ be an i.i.d circularly-symmetric complex Gaussian random vector with mean μ and variance σ^2. Let f_Λ be the probability density function of $\mathbf{n}$ mod Λ. The Smoothing Lemma says that $\mathbf{n}$ mod Λ tends to be uniform over the Voronoi Region of Λ as σ grows.

Algorithm:

1. For a given α, calculate $\mathbf{y}\prime = \alpha\mathbf{y}$ mod Λ;
2. Calculate the sample variance of $\mathbf{y}\prime$;
3. Decide if α is good based on some predefined threshold δ.

The Optimization Problem



Algebraic Properties of f

1. All good scalars are bounded by $|\alpha|^2 < SNR/2^R$; [1]
2. The region of good scalars consists of a union of disks. These disks are pairwise disjoint if the message rate $R \geq 2$; [1]
3. The function f has an underlying lattice structure which can be seen clearly for $L = 1$ (1 user);
4. The best and second best α's are a basis for the lattice that contains all other optimal scalars ...

References

1. C. Feng, D. Silva, and F. R. Kschischang, "Blind compute-and-forward," in *Proc. of IEEE Int. Symp. on Inf. Theory*, Cambridge, MA, Jul. 1–6, 2012, pp. 408–412.
2. B. Nazer and M. Gastpar, "Compute-and-forward: Harnessing interference through structured codes," *IEEE Trans. Inf. Theory*, vol. 57, no. 10, pp. 6463–6486, Oct. 2011.