Distributed Double-Differential Orthogonal Space-Time Coding for Cooperative Networks

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What will be Presented

"**Distributed Double - Differential Orthogonal Space - Time Code for Cooperative Networks**" In Proc. for IEEE Global Telecommunications Conference, GLOBECOM 2008, (New Orleans, LA, USA), IEEE, November - December 2008.

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Review of Previous Work (Among Others)

- Double-differential (DD) coding for SISO channels [Simon and Divsalar, 1992].
- DD coding for MIMO channels [Liu et. al, 2001].
- SER expressions for DD modulation over SISO channels [Bhatnagar and Hjørungnes, 2007].
- DD coding for two user cooperative network with AF [Bhatnagar et al., 2008].
- Distributed DD coding for arbitrary number of *perfect regenerative* relays (DF) [Cano et. al, 2007].

Contributions

- Distributed DD coding for one S-D pair and two relays under AF.
- Linear decoder.
- PEP upper bound.
- Optimized power distribution.

Single Differential Modulation:

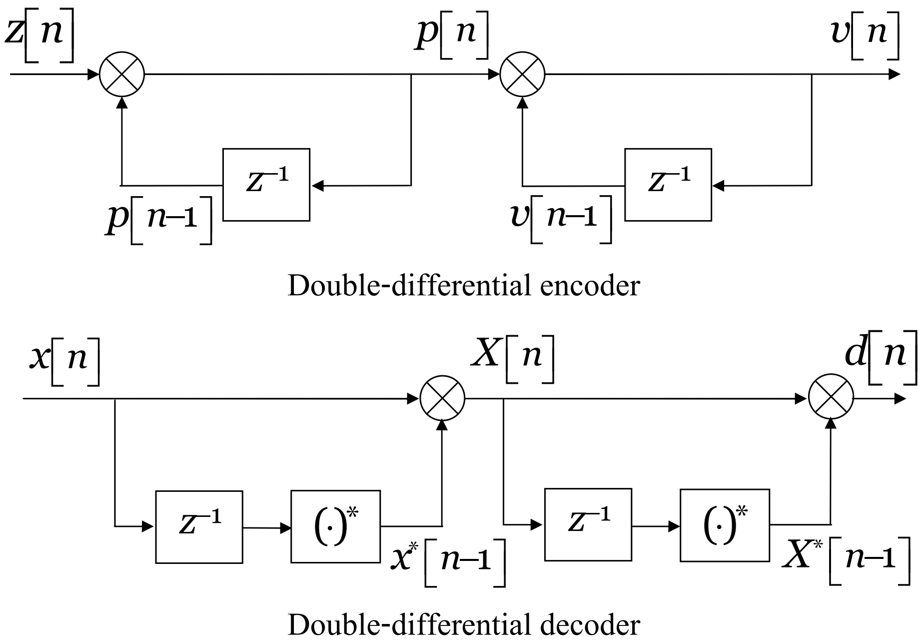
- Avoids the transmission of training data for channel estimation.
- Low complexity decoder can be obtained?

Single Differential Cooperative System:

- Useful for practical implementation.
- Improved data rate.

Limitations:

- Channel related.
- Carrier offsets.



Double-differential (a) encoder and (b) decoder.

Need of Distributed DD Coding

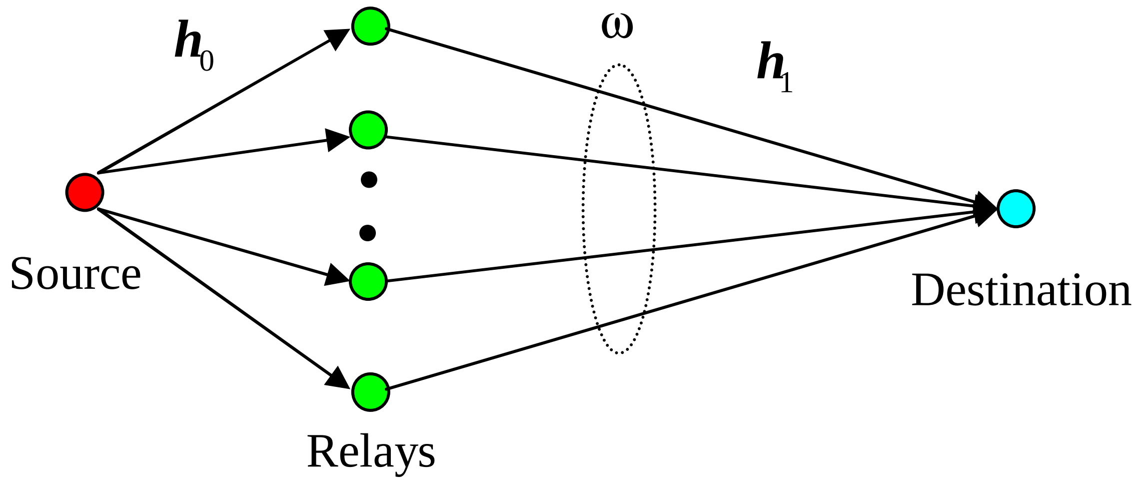
DD Modulation:

- Avoids pilot transmissions.
- Improves data rate.
- Low complexity decoders are possible?

Distributed Coding:

- Suitable for large number of relays.
- Optimal utilization of virtual spatial dimensions.
- Improved data rates.

System Model



Cooperative system with relay.

Source:

$$\boldsymbol{C}_k = \boldsymbol{C}_{k-1}\boldsymbol{S}_k,$$

$$\boldsymbol{d}_k \triangleq \boldsymbol{d}_{k-1}\boldsymbol{C}_k = \boldsymbol{d}_{k-1}\boldsymbol{C}_{k-1}\boldsymbol{S}_k = \boldsymbol{d}_{k-2}\boldsymbol{C}_{k-1}^2\boldsymbol{S}_k,$$

$\boldsymbol{S}_k$ is Alamouti STBC.

Relays:

$$\tilde{\boldsymbol{d}}_{i,k} = \boldsymbol{y}_{0,i,k}\boldsymbol{U}_i + \boldsymbol{y}_{0,i,k}^*\boldsymbol{V}_i,$$

where $\boldsymbol{U}_i$ and $\boldsymbol{V}_i$ are real unitary matrices.

Decoding of the Distributed DD Code

- P.d.f. of data received in *three* consecutive blocks can be written assuming perfect knowledge of all unknowns.
- For ML estimation the p.d.f. must be maximized w.r.t. all unknowns.
- Maximization of p.d.f. results into minimization of ML metric.
- Minimization is very complex and ML estimate of data may depend upon carrier offset!

Linear Decoder of Distributed DD Code

- The ML metric can devided into two parts.
- Each part can be minimized separately.
- It results into a suboptimal decoder.
- It can be shown that this is a linear decoder.

Theorem:

The probability of detecting $\boldsymbol{S}_k$ in place of $\boldsymbol{S}_k^0$ can be upper bounded as

$$\mathbb{E}_{\boldsymbol{h}_{0,i}}\left[\Pr\left\{\boldsymbol{S}_k^0 \rightarrow \boldsymbol{S}_k|\boldsymbol{h}_1\right\}\right] \leq \left|\boldsymbol{I}_2 + \frac{P_1 P_2 \lambda_{\min}^2\left(\boldsymbol{\mathcal{X}}_k'\right)\sigma_0^2}{6(1+P_1\sigma_0^2+P_2\|\boldsymbol{h}_1\|^2)} \times \left(\boldsymbol{S}_k^0-\boldsymbol{S}_k\right)\boldsymbol{H}_1\left(\boldsymbol{S}_k^0-\boldsymbol{S}_k\right)^{\mathcal{H}}\right|^{-1}.$$

Optimized Power Allocation

Optimization Problem:

$$\max_{P_1,P_2 \geq 0} \quad \tau = \frac{P_1 P_2 \lambda_{\min}^2\left(\boldsymbol{\mathcal{X}}_k'\right)\sigma_0^2\sigma_1^2}{6(1+P_1\sigma_0^2+2P_2\sigma_1^2)}$$

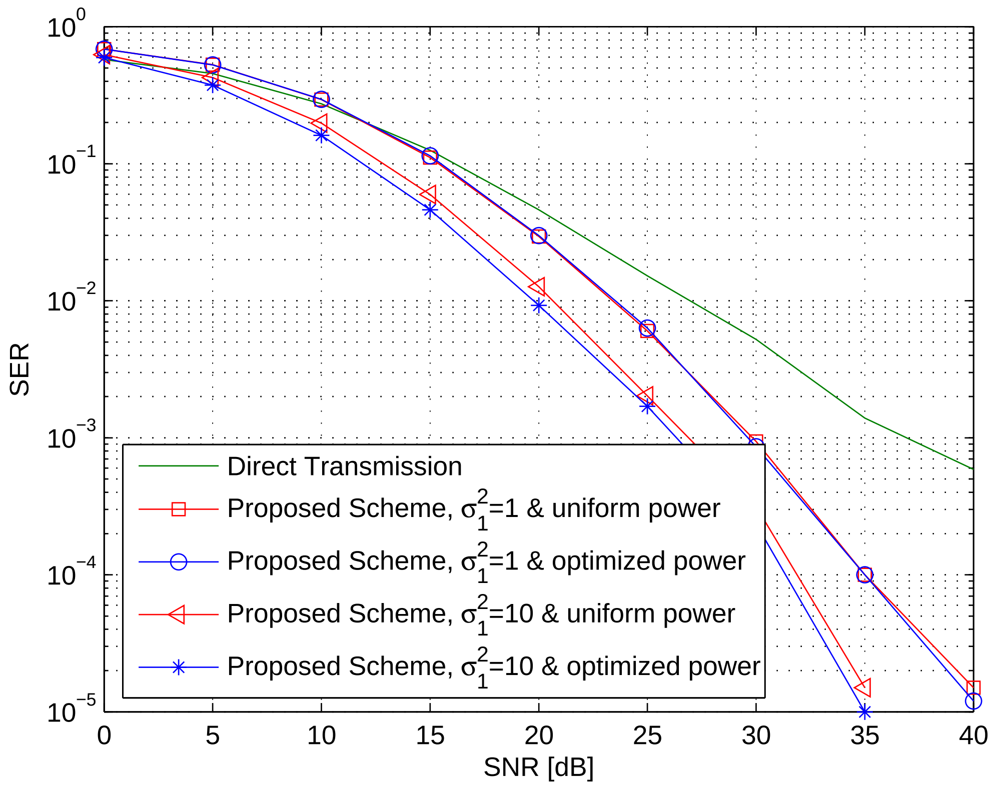
$$\text{subject to} \quad P = P_1 + P_2,$$

Solution:

$$P_1 = \frac{\left(2\sigma_1^2 P + 1\right) - \sqrt{\left(2\sigma_1^2 P + 1\right)\left(P\sigma_0^2 + 1\right)}}{2\sigma_1^2 - \sigma_0^2},$$

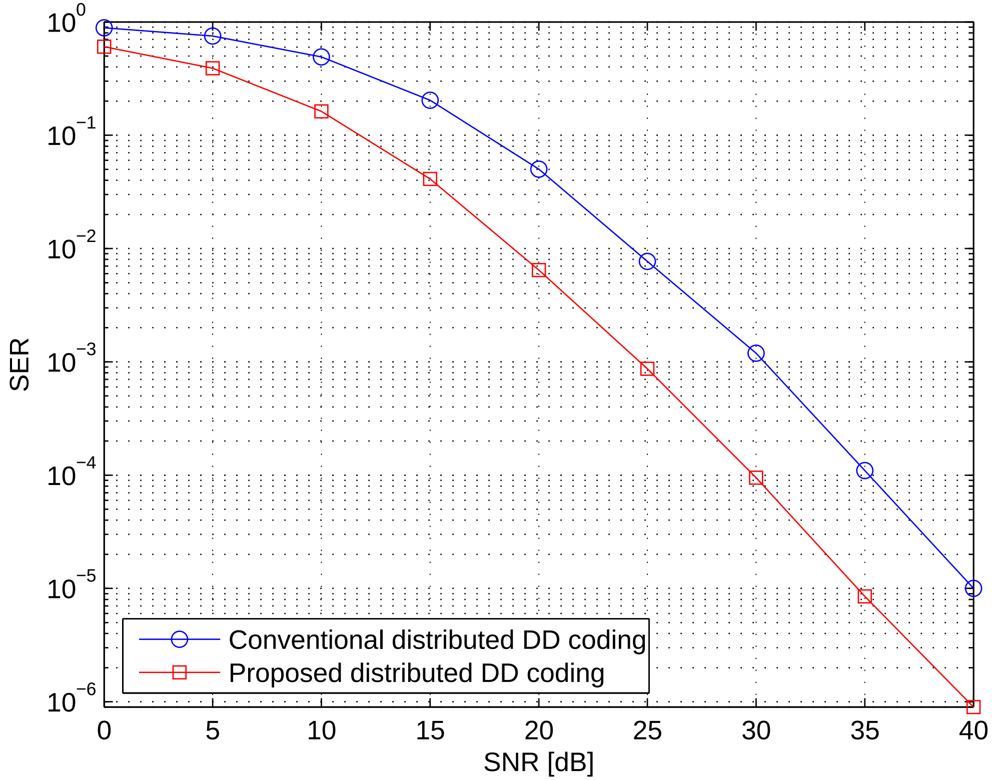
$$P_2 = \frac{\sqrt{\left(2\sigma_1^2 P + 1\right)\left(P\sigma_0^2 + 1\right)} - \left(P\sigma_0^2 + 1\right)}{2\sigma_1^2 - \sigma_0^2}.$$

Performance Results and comparisons (1/2)



Performance of the proposed distributed DD coding with uniform and optimized power allocation as compared to the direct transmission DD scheme with $\sigma_0^2 = 1$.

Performance Results and comparisons (2/2)



Comparison of the proposed distributed DD code with the conventional distributed DD code of [Cano et. al, 2007].

[Cano et. al, 2007] A. Cano, E. Morgado, A. Caamano, and J. Ramos, "Distributed double differential modulation for cooperative communications under CFO," In Proc. IEEE GLOBECOM, pp. 3447-3441, Nov. 2007, Washington, DC, USA.

Conclusions

- Proposed distributed DD coding.
- OSTBC are involved.
- Better data rates.
- Better than conventional DD scheme.

References

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Thank You!