Blind Timing and Carrier Synchronization in Decode and Forward Cooperative Systems

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1 Motivation

- **Synchronization in Decode and Forward (DF) cooperative communication systems** is a complex and challenging task requiring estimation of many independent timing and carrier offsets at each relay in the broadcasting phase and multiple timing and carrier offsets at the destination in the relaying phase.
- It has been shown that if the synchronization errors are large, the performance is hugely degraded and the benefits of cooperation may even vanish
- Recently, there has been growing interest in **blind solutions** because the use of initial training sequences can reduce the date rate and may become unrealistic or impractical, especially in the context of emerging wireless ad hoc and cooperative networks which operate on opportunistic communication paradigm.

2 System Model

We focus on blind synchronization and channel estimation in DF cooperative communication systems with one source, M relays and one destination equipped with $N = M + 1$ multiple antennas.

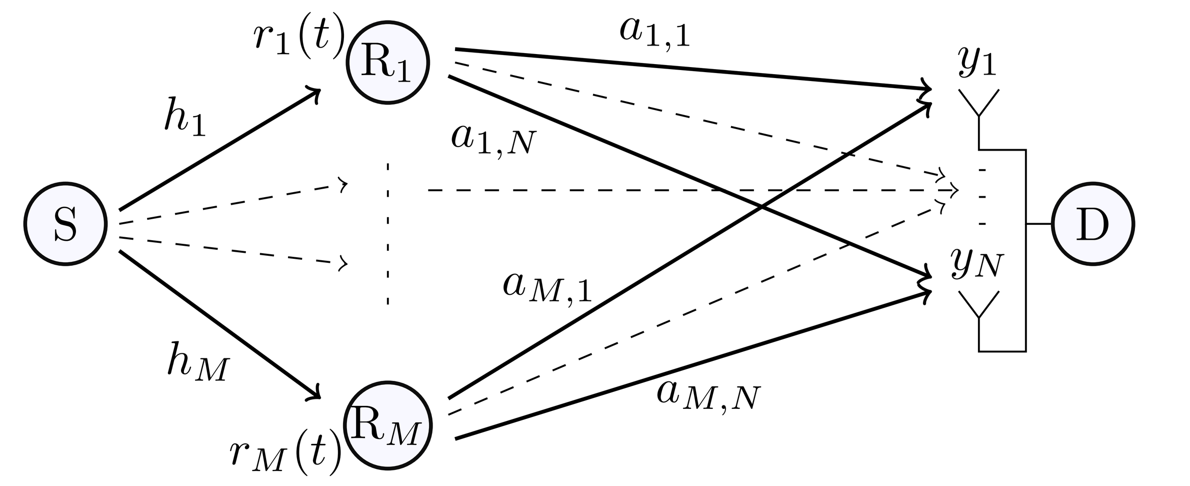

Figure 1: System model for blind cooperative communication.

3 Broadcasting phase

Synchronization problem is identical to the Single Input Single Output (SISO) systems and appropriate SISO techniques can be employed [1].

Source Transmitter:

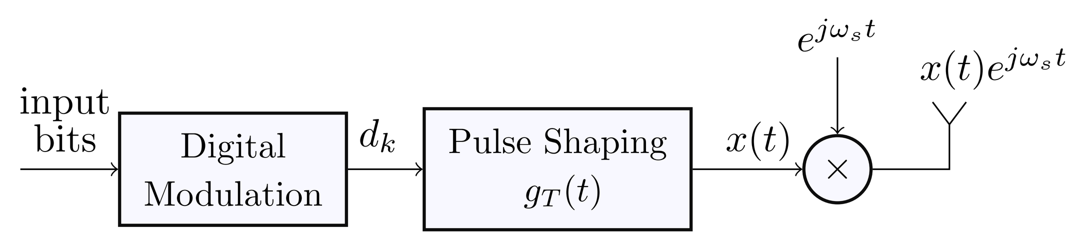

Figure 2: Source Transmitter.

$$x(t) = \sum_{k=0}^{D-1} d(k)\, g_T(t - kT), \qquad (1)$$

Proposed Relay Receiver:

$$\tilde{r}_{m,\tau_m}(bT_s) = h_m \sum_{k=0}^{D-1} d(k)\, g_T(bT_s - kT - \tau_{s,m}T) e^{j2\pi f_{s,m} b} + v_{r,m}(bT_s) \qquad (2)$$

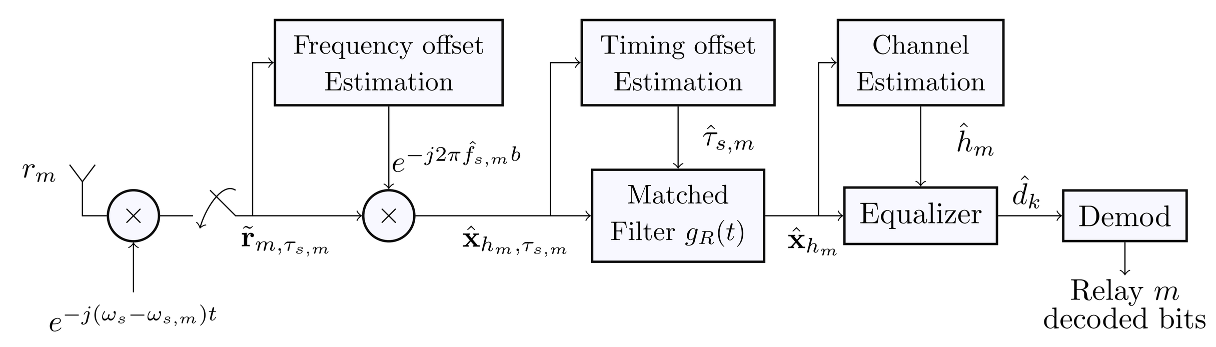

Figure 3: Relay m receiver.

$$\hat{\mathbf{x}}_{h_m,\tau_{s,m}}(bT_s) = h_m \sum_{k=0}^{D-1} d(k)\, g_T(bT_s - kT - \tau_{s,m}T) + \hat{v}_{r,m}(bT_s) \qquad (3)$$

$$\hat{\mathbf{x}}_{h_m}(bT_s) = h_m \sum_{k=0}^{D-1} d(k) g_T(bT_s - kT) + \hat{v}'_{r,m}(bT_s) \qquad (4)$$

4 Relaying phase

The synchronization problem in the relaying phase is more difficult and complicated than in the broadcasting phase. This is because of the need to estimate multiple timing and carrier offsets at the destination node.

Proposed Relay Transmitter:

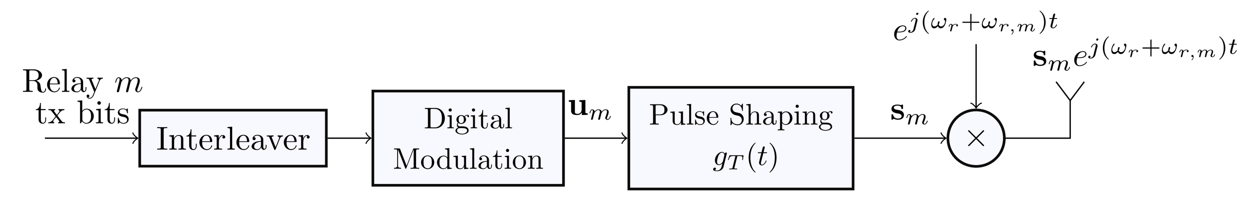

Figure 4: Relay m transmitter.

Block Interleaving:

Each relay m interleaves the decoded bits using a matrix interleaver with m rows and $(D \times K)/m$ columns, where K is the number of bits per symbol, m is the relay index and D is the frame length.

$$s_m(t) = \sum_{k=0}^{D-1} u_m(k)\, g_T(t - kT), \quad \text{for} \quad m = 1, \ldots, M \qquad (5)$$

Proposed Destination Receiver:

- We use Blind Source Separation (BSS) at the destination node to decouple the timing and carrier offsets from user to user.
- This converts the difficult problem of estimating multiple offsets into more tractable sub-problem of estimating many independent timing and carrier offsets.
- For BSS, we use the JADE (Joint Approximate Diagonalization of Eigen matrices) algorithm [2].

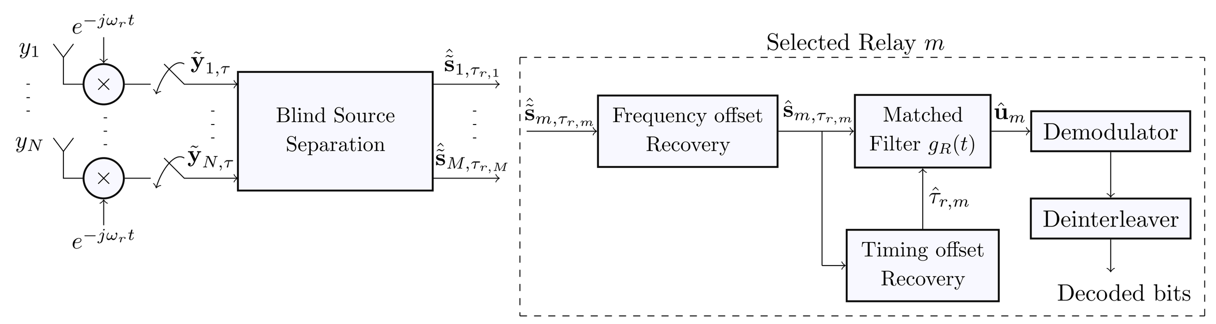

Figure 5: Destination Receiver.

$$\tilde{y}_{i,\tau}(bT_s) = \sum_{m=1}^{M} a_{m,i} \sum_{k=0}^{D-1} u_m(k)\, g_T(bT_s - kT - \tau_{r,m}T) \times e^{j2\pi f_{r,m} b} + v_{d,i}(bT_s) \qquad (6)$$

$$\hat{\tilde{s}}_{m,\tau_{r,m}}(bT_s) = \sum_{k=0}^{D-1} u_m(k)\, g_T(bT_s - kT - \tau_{r,m}T)\, e^{j2\pi f_{r,m} b} + \breve{v}_{d,m}(bT_s) \qquad (7)$$

Relay Selection:

$$R_{\text{sel}} = \arg\max_{m} \{\min\{h_m, \min_{j}\{a_{mj}\}\}\} \qquad (8)$$

The best relay is selected according to the Relay selection criteria (8) and finally its synchronization parameters are estimated [2].

5 Simulation Results

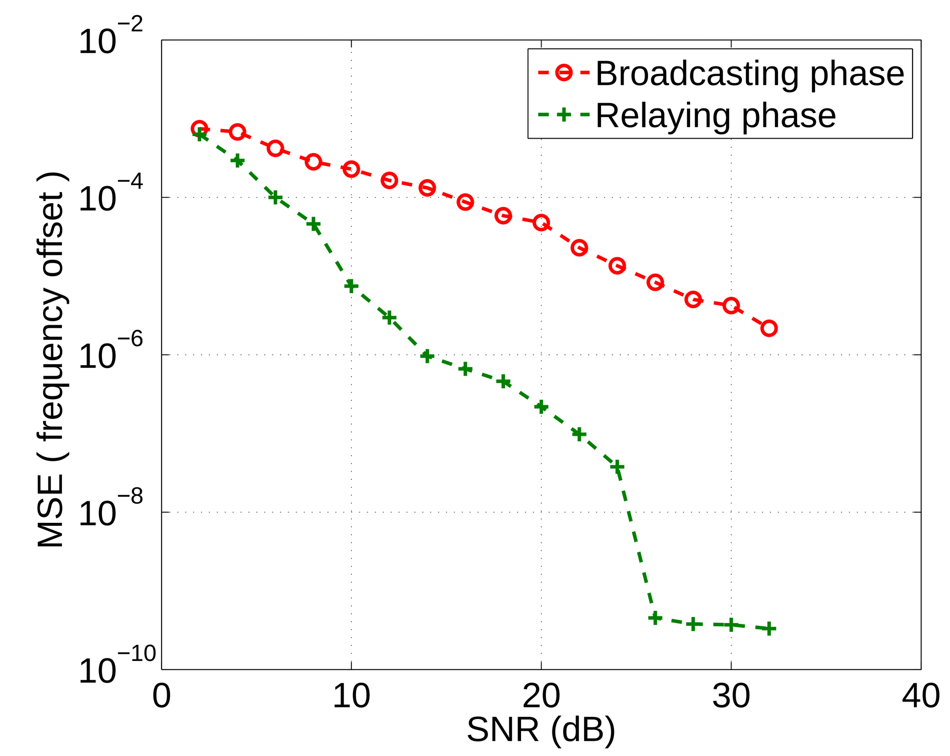

Figure 6: MSE of frequency offset estimation as a function of SNR (dB), with $M = 4$ Relays and $N = 5$ antennas at destination.

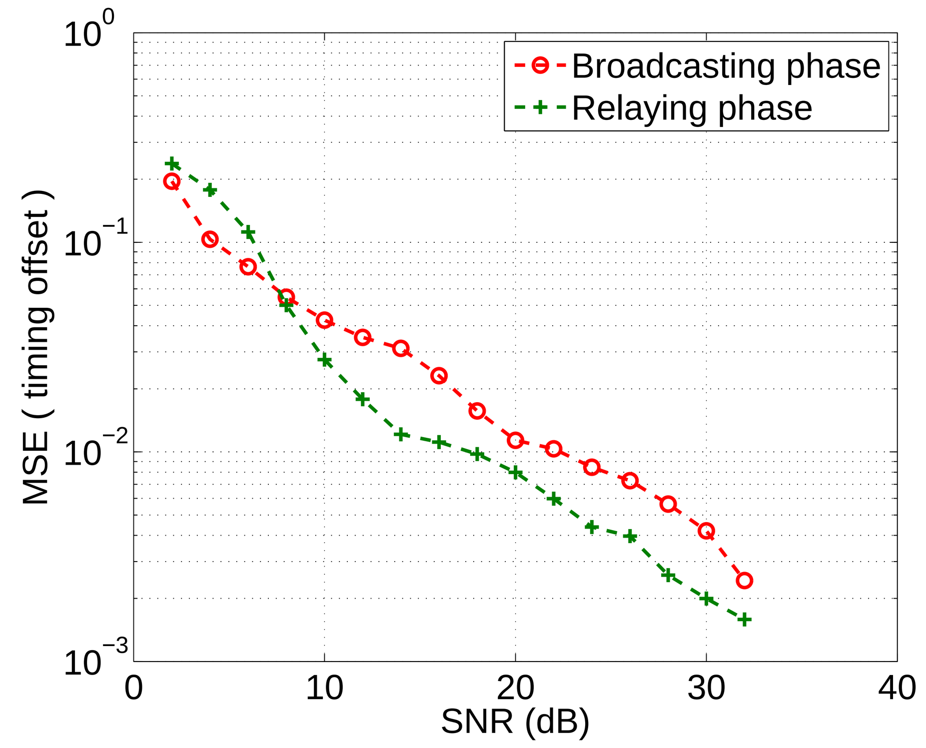

Figure 7: MSE of timing offset estimation as a function of SNR (dB), with $M = 4$ Relays and $N = 5$ antennas at destination.

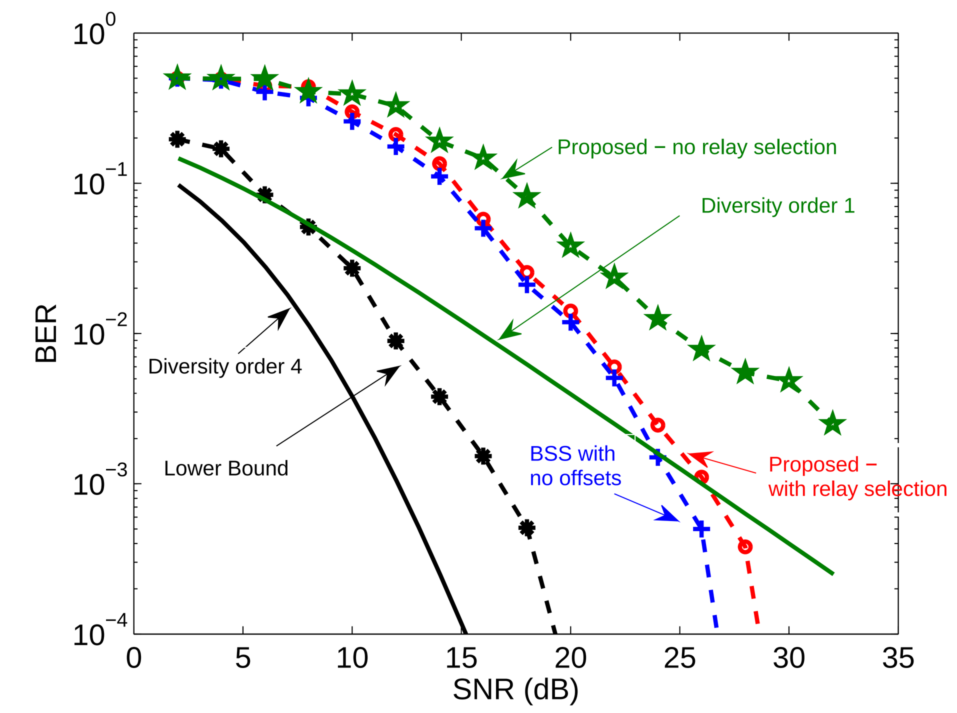

Figure 8: End-to-end BER of blind DF cooperative communication as a function of SNR (dB), with $M = 4$ Relays and $N = 5$ antennas at destination.

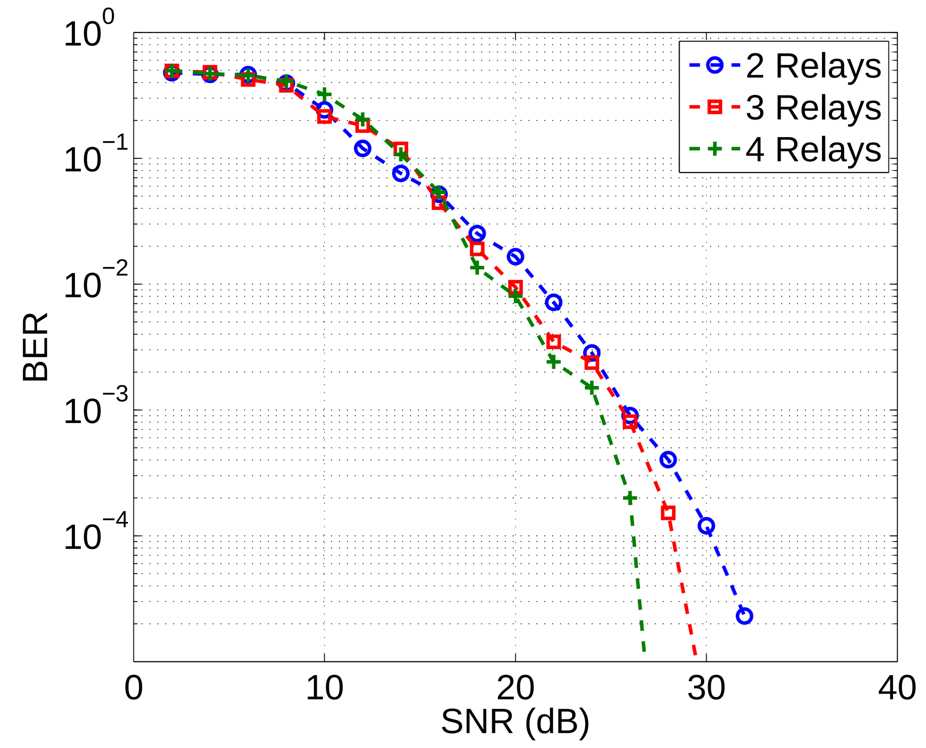

Figure 9: End-to-end BER of blind DF cooperative communication as a function of SNR (dB), with M Relays and $N + 1$ antennas at destination.

6 References

[1] A. A. Nasir, S. Durrani, and R. A. Kennedy, "Blind Timing and Carrier Synchronization in Decode and Forward Cooperative Systems, in **Proc. IEEE ICC**, 2011."

[2] A. A. Nasir, S. Durrani, and R. A. Kennedy, "Blind timing and carrier synchronization in distributed MIMO communication systems," accepted in **IET Transactions on Communications**, 2011 (in press).