Performance of DS-CDMA Using Relay-Assisted Diversity

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Motivation and Outline

- Why using relay-assisted diversity in cellular DS-CDMA system?
- Channel modelling;
- Detection algorithms;
- Single-user scenario;
- Multiple-user scenario:
  - Cooperation Strategy I;
  - Cooperation Strategy II;
- Performance results.
Why Using Relay-Assisted Diversity in Cellular DS-CDMA System?

- Relay-assisted diversity can be employed for
  - offering spectral efficiency,
  - achieving a high capacity,
  - mitigating the limitation of mobile units;

- DS-CDMA has been a typical multiple-access scheme in the second and third generations of wireless communications systems;

- Without any doubt, it will be an important candidate in the future generations of wireless communications systems.
Channel Modelling

The channel is modelled as generalized Nakagami-\( m \) fading channel with and without considering propagation pathloss.

- **Fast fading**
  - ★ Channel fading gain \( h = |h|e^{j\theta_h} \);
  - ★ Channel amplitude \(|h|\) is assumed to obey the Nakagami-\( m \) distribution

\[
f_{|h|}(y) = \frac{2m^m y^{2m-1}}{\Gamma(m)\Omega} e^{-(my^2/\Omega)}, \; i = 1, 2
\]  \hspace{1cm} (1)

where

\[
m = E^2[|h|^2]/\text{Var}[|h|^2],
\]  \hspace{1cm} (2)

and

\[
\Omega = E[|h|^2]
\]  \hspace{1cm} (3)
Channel Modelling

- Propagation pathloss
  - nth power law;
  - The pathloss as a function of transmitter-receiver (T-R) separation distance $d$ can be expressed as

$$L_p(d)(dB) = L_s(d_0)(dB) + 10n \log\left(\frac{d}{d_0}\right)$$

(4)

where
- $L_s(d_0)$: the pathloss measured at the reference distance $d_0$;
- $n$: the pathloss exponent, which usually takes a typical value of 2 in free-space and 4 in cellular mobile systems.
Detection Algorithms

- Information transmitted by the $k$th user is detected using three types of detection schemes:
  - Maximal ratio combining (MRC) assisted single-user combining (SUC);
  - Minimum-mean-square-error (MMSE) assisted multiuser combining (MUC).
  - Maximal signal-to-interference-plus-noise ratio (MSINR) assisted multiuser combining (MUC).
Figure 1: Channels in a relay-assisted DS-CDMA, where one transmitter is assisted by $L$ relays.
Single-User Scenario

DS-CDMA using binary phase shift keying (BPSK) baseband modulation.

The transmitted signal by the $k$th user is given by

$$s_k(t) = \sqrt{2P_k} b_k(t) c_k(t) \cos (2\pi f_c t + \phi_k)$$

(5)

where

- $P_k$: Transmitted power, $f_c$: Carrier frequency, $\phi_k$: Initial phase angle;
- $b_k(t)$: Binary data waveform;
- $c_k(t)$: Spreading waveform of the $k$th user.
Single-User Scenario

The transmitted signal by the \( l \)th relay is given by

\[
s_{l}(k)(t) = \sqrt{2P_{kl}\hat{b}_{k}[n]}c_{l}^{(k)}(t) \cos \left( 2\pi f_{c} t + \phi^{(k)}_{l} \right)
\]  

(6)

where

- \( P_{kl} \): Transmitted power, \( f_{c} \): Carrier frequency, \( \phi_{k} \): Initial phase angle;
- \( \hat{b}_{k}[n] \): Estimate of the transmitted bit \( b_{k}[n] \);
- \( c_{l}^{(k)}(t) \): Spreading waveform of the \( l \)th relay.
Figure 2: Schematic block diagram for the Cooperation Strategy I used in the relay-assisted DS-CDMA system supporting multiple users.
Multiple-User Scenario

Figure 3: Schematic block diagram for the Cooperation Strategy II used in the relay-assisted DS-CDMA system supporting multiple users.
Figure 4: Single-user scenario under equal power allocation. MRC-assisted SUC and random sequences. $L$ represents the number of relays, $m$ denotes the Nakagami fading parameter.
Figure 5: Single-user scenario under equal power allocation. MSINR-assisted MUC, \textit{m}-sequences and random sequences. \textit{L} represents the number of relays, \textit{m} denotes the Nakagami fading parameter.
Performance Results

Figure 6: BER versus \((\alpha, \delta)\) performance for using \(m\)-sequences and the MSINR-assisted MUC. \(\alpha\) is the ratio of the transmitted power in the first time-slot and the total transmitted power for transmitting one bit. \(\delta\) is the normalized distance between the relay and the BS. Simulation parameters: \(m_0 = m_{l_1} = 1, m_{l_2} = 2, L = 3, E_b/N_0 = 4dB, n = 4\).
Performance Results

Figure 7: Single-user scenario with pathloss. MSINR-assisted MUC, random sequences. $L$ represents the number of relays. Simulation parameters: $m_0 = m_{l1} = 1$, $m_{l2} = 2$, $L = 1, 2, 3$, $\alpha = 0.9$, $\delta = 0.3$, $n = 4$. 
Figure 8: Multiple-user scenario for Cooperative Strategy I. MSINR-assisted MUC, \(m\)-sequences. Simulation parameters: \(m_0 = m_{l1} = 1, m_{l2} = 2, K=2, L = 1, 2, 3, 4\)
Figure 9: Multiple-user scenario for Cooperative Strategy II. MSINR-assisted MUC, $m$-sequences. Simulation parameters: $m_0 = m_{l_1} = 1$, $m_{l_2} = 2$, $K=2$, $L = 1, 2, 3, 4$
Performance Results

$m_0=1 \ m_{l1}=1 \ m_{l2}=2 \ K=2$

Figure 10: Multiple-user scenario for Cooperative Strategy I. MSINR-assisted MUC at the BS, $m$-sequences. Simulation parameters: $m_0 = m_{l1} = 1$, $m_{l2} = 2$, $K=2$, $L = 1, 2, 3, 4$, $\alpha = 0.9$, $\delta = 0.3$, $n = 4$
Performance Results

Figure 11: Multiple-user scenario for Cooperative Strategy II. MSINR-assisted MUC, $m$-sequences. Simulation parameters: $m_0 = m_{l1} = 1$, $m_{l2} = 2$, $K=2$, $L = 1, 2, 3, 4$, $\alpha = 0.9$, $\delta = 0.3$, $n = 4$
Future Work

- Investigate the downlink performance of relay-assisted DS-CDMA using relay- and destination-based interference mitigation methods.
- Investigate the downlink performance of relay-assisted DS-CDMA using transmit preprocessing method (interference-free at the relays).
- Consider possible cross-layer design of cooperative diversity.
Thank you!