Adaptive Mode Selection and Power Allocation for D2D Underlay Cellular Networks with Dynamic Fading Channel

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Outline

• Introduction
• System Model
• Problem Formulation and Analysis
• Procedure of Adaptive Power Allocation Scheduling
• Numerical Results and Discussions
1. Introduction

- **D2D Communications** [1][2]

- **Conventional communication** & **D2D communication**

- **Overlay inband, underlay inband, and outband D2D** for cellular scenarios.
2. System Model

- Two conventional modes for underlay D2D communications: D2D underlay mode and regular cellular mode
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- Hybrid mode:
  - DT multicasts its messages to DR via two links. The allocated transmitted power for these two links is set to be $\zeta P_D$ and $(1 - \zeta) P_D$, respectively.
  - The D2D direct link shares the same time-frequency resources with the cellular users.
  - The relay link participates in the cellular uplink session with the CUE, spectrum access rate is set to be $\beta$. 
2. System Model

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- Hybrid mode
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  - The D2D direct link shares the same time-frequency resources with the cellular users.
  - The relay link participates in the cellular uplink session with the CUE.

- Challenges/opportunity: How to allocate the transmitted power via direct & relay links, considering
  - Dynamic channel state
  - Different spectrum access rate
Dynamic channel state

- D2D applications: mobile devices or some specific environments with relative movements (e.g., indoor offices)
- Distribution of the channel amplitude: Rician fading
- Evolution: first-order finite-state Markov chain (FSMC)
3. Problem Formulation and Analysis

- The optimization objective: Maximize the achievable average throughput
- Adjustable system parameter: Mode selection and power allocation
- Limitation: Guaranteeing the minimum QoS of the CUE

\[
\max_{0 \leq \xi \leq 1} U(\xi, \beta, h_D),
\]

\[
\text{s.t. } SINR_C \geq \lambda_C.
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\]
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\]

- With the consideration of time-variant channel

\[
U(\xi, \beta, h_D) = \frac{1}{N} \sum_{n=0}^{N-1} u(\xi(n), \beta, h_D(n)),
\]
\[
\text{SINR}_C(n) = 10 \log_{10} \left( \frac{P_C |h_C|^2}{\xi(n) P_D |g_{DC}|^2 + \sigma^2} \right).
\]
Analysis

**First order partial derivative**

\[
F(\xi(n), \beta, h_D(n)) = \frac{\partial u(\xi(n), \beta, h_D(n))}{\partial \xi(n)}
= W \log_2 \left( 1 + \frac{\xi(n)P_D|h_D(n)|^2}{P_C|g_{CD}|^2 + \sigma^2} \right)
+ \beta W \log_2 \left( 1 + \frac{(1 - \xi(n))P_D|h_{DBD}|^2}{\sigma^2} \right).
\]

**Second order partial derivative**

\[
\frac{\partial^2 u(\xi(n), \beta, h_D(n))}{\partial \xi(n)^2} = \frac{\partial F(\xi(n), \beta, h_D(n))}{\partial \xi(n)},
= -\frac{WP_D}{\ln 2} \left\{ \frac{|h_D(n)|^4}{P_C|g_{CD}|^2 + \sigma^2 + [\xi(n)P_D|h_D(n)|^2]^2} \right. \\
+ \left. \frac{\beta|h_{DBD}|^4}{[\sigma^2 + (1 - \xi(n))P_D|h_{DBD}|^2]^2} \right\} < 0.
\]
Partial derivative of the underlay throughput under different conditions:

(a) $\beta P_D \|h_{DBD}\|^2 > \sigma^2$ (b) $\beta P_D \|h_{DBD}\|^2 < \sigma^2$
4. Procedure of Adaptive Power Allocation Scheduling

- The channel estimation: maximum \textit{a posteriori} probability (MAP) criterion
- Feed back to DT via feedback link
- Predictive channel gain: Markov characteristic
- Choose the optimal mode and power allocation under different Conditions\{\cdot, \cdot\}
5. Simulation Results

- Compared method: static D2D underlay mode and regular cellular mode.
- In high SNR region, the increasing performance of traditional underlay D2D mode saturates.
- When $\beta$ increases, the performance gaps between the adaptive scheduling and D2D direct scheduling expand.
Any questions?

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