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

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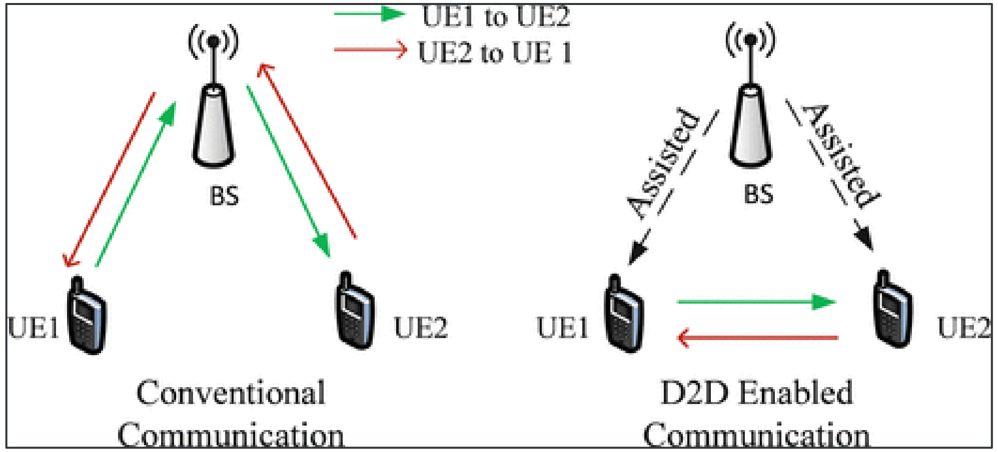
LEADERS IN IDEAS AND SOLUTIONS

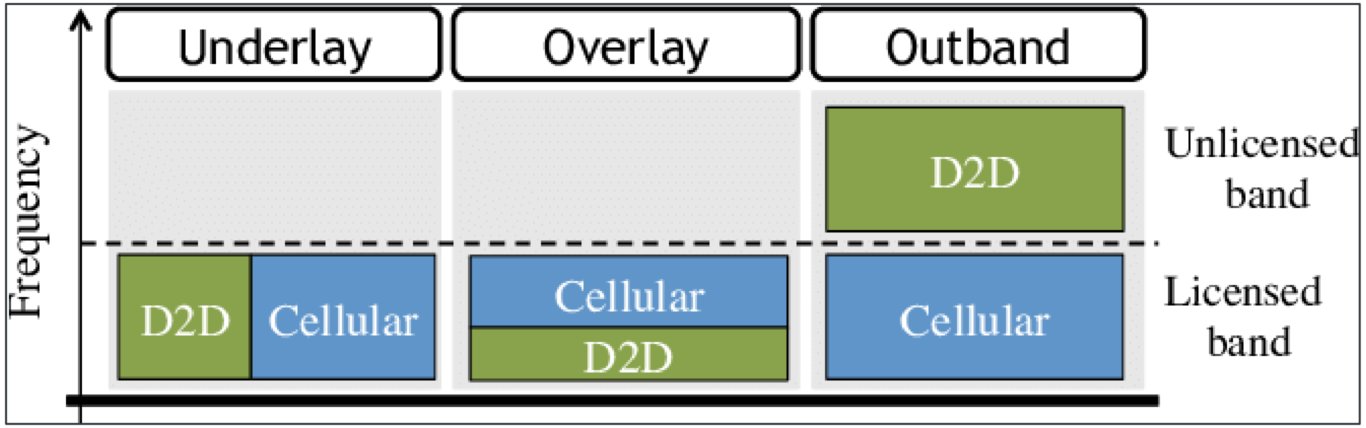
Outline

- 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

- ❑ Two conventional modes for underlay D2D communications: D2D underlay mode and regular cellular mode

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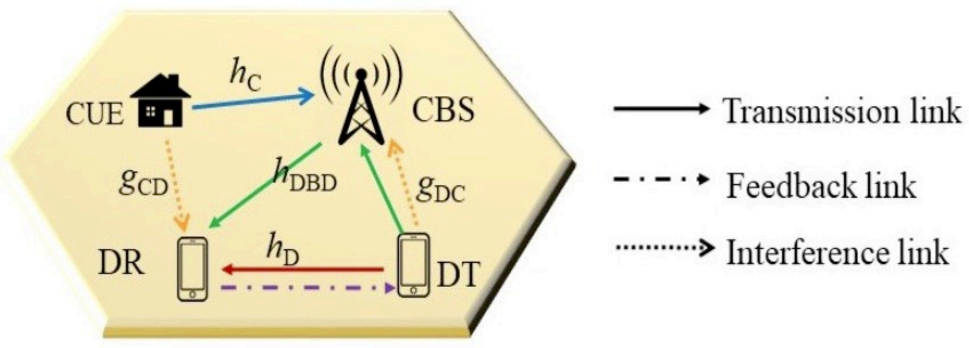
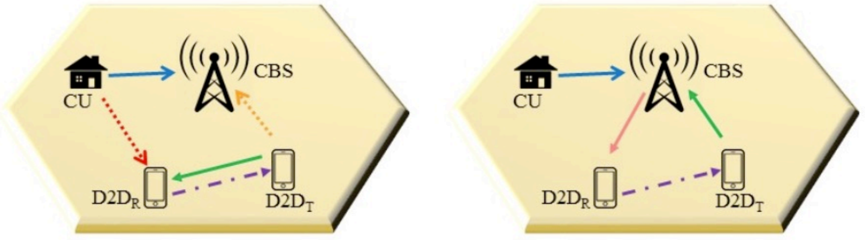


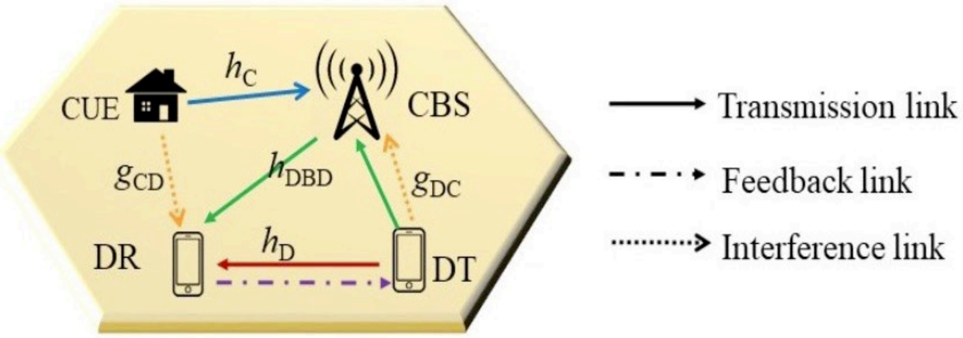
Hybrid mode

- ❑ Hybrid mode
- DT multicasts its messages to DR via two links. The allocated transmitted power for these two links is set to be ξP_D and $(1-\xi)P_D$, 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 β.

2. System Model



Two conventional modes



Hybrid mode

❑ Two conventional modes for underlay D2D communications: regular cellular mode and D2D underlay mode

❑ Hybrid mode

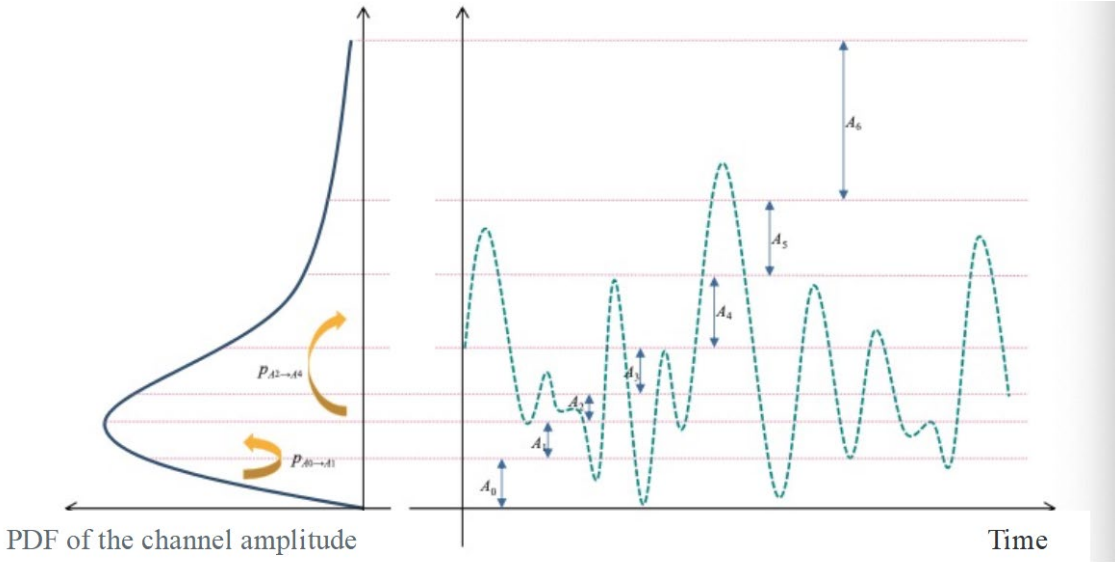
- DT multicasts its messages to DR via two links
- The D2D direct link shares the same time-frequency resources with the cellular users.
- The relay link participates in the cellular uplink session with the CUE.

❑ Challenges/oppotunity: 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

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

$$\text{s.t.} \quad SINR_C \geq \lambda_C.$$

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- The optimization objective: Maximize the achievable average throughput
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$$\max_{0 \le \xi \le 1} U(\xi, \beta, h_D),$$

$$\text{s.t.} \quad SINR_C \ge \lambda_C.$$

- With the consideration of time-variant channel

$$U(\xi, \beta, h_D) = \frac{1}{N} \sum_{n=0}^{N-1} u(\xi(n), \beta, h_D(n)),$$

$$SNIR_C(n) = 10 \log_{10} \left(\frac{P_C |h_C|^2}{\xi(n) P_D |g_{DC}|^2 + \sigma^2} \right).$$

Analysis

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

- First order partial derivative

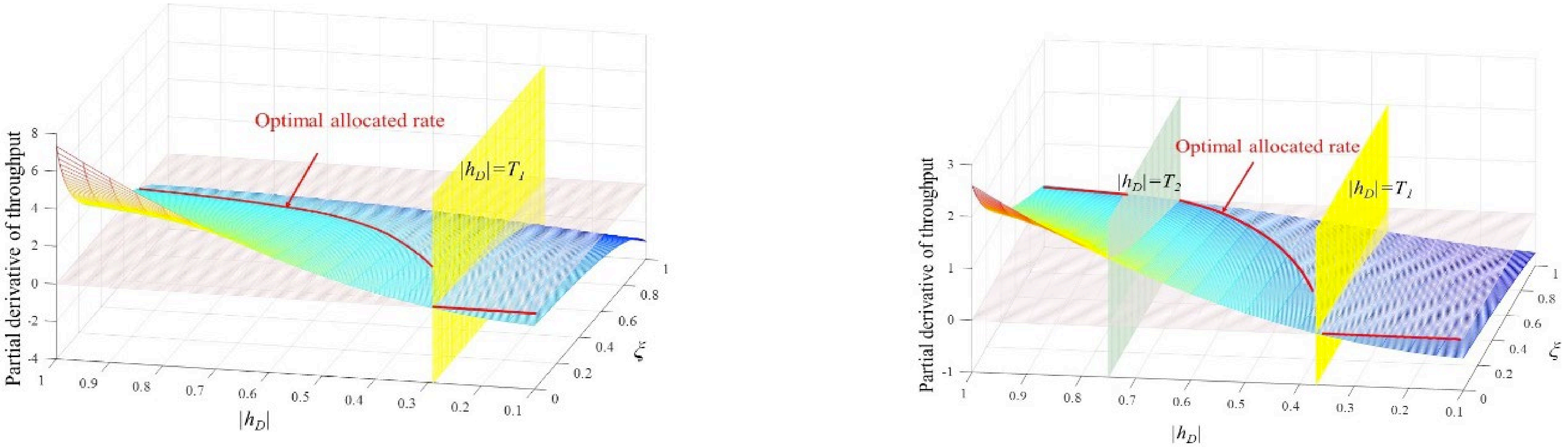
$$F(\xi(n),\beta,h_D(n)) = \frac{\partial u(\xi(n),\beta,h_D(n))}{\partial \xi(n)}$$
$$= W\frac{1}{\ln 2\left(1+\frac{\xi(n)P_D|h_D(n)|^2}{P_C|g_{CD}|^2+\sigma^2}\right)}\frac{P_D|h_D(n)|^2}{P_C|g_{CD}|^2+\sigma^2}$$
$$-\beta W\frac{1}{\ln 2\left(1+\frac{(1-\xi(n))P_D|h_{DBD}|^2}{\sigma^2}\right)}\frac{P_D|h_{DBD}|^2}{\sigma^2}$$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

- Second order partial derivative

$$\frac{\partial^2 u(\xi(n),\beta,h_D(n))}{\partial \xi(n)^2} = \frac{\partial F(\xi(n),\beta,h_D(n))}{\partial \xi(n)},$$
$$= -\frac{WP_D^2}{\ln 2}\left\{\frac{|h_D(n)|^4}{P_C|g_{CD}|^2+\sigma^2+[\xi(n)P_D|h_D(n)|^2]^2} + \frac{\beta|h_{DBD}|^4}{[\sigma^2+(1-\xi(n))P_D|h_{DBD}|^2]^2}\right\} < 0.$$

TABLE I: The first partial derivative of $u(\xi, \beta, h_D)$

Condition I	Condition II	Results
$\beta P_D \lvert h_{DBD} \rvert^2 > \sigma^2$	$\lvert h_D \rvert^2 > \frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 + P_D \lvert h_{DBD} \rvert^2}$, i.e., Condition $\{1, 1\}$	$F(\xi = 0) > 0, F(\xi = 1) < 0$
	$\lvert h_D \rvert^2 < \frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 + P_D \lvert h_{DBD} \rvert^2}$, i.e., Condition $\{1, 2\}$	$F(\xi = 0) < 0, F(\xi = 1) < 0$
$\beta P_D \lvert h_{DBD} \rvert^2 < \sigma^2$	$\frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 + P_D \lvert h_{DBD} \rvert^2} < \lvert h_D \rvert^2 < \frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 - \beta P_D \lvert h_{DBD} \rvert^2}$, i.e., Condition $\{2, 1\}$	$F(\xi = 0) > 0, F(\xi = 1) < 0$
	$\lvert h_D \rvert^2 > \frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 - \beta P_D \lvert h_{DBD} \rvert^2}$, i.e., Condition $\{2, 2\}$	$F(\xi = 0) > 0, F(\xi = 1) > 0$
	$\lvert h_D \rvert^2 < \frac{\beta(P_C \lvert g_{CD} \rvert^2 + \sigma^2) \lvert h_{DBD} \rvert^2}{\sigma^2 + P_D \lvert h_{DBD} \rvert^2}$, i.e., Condition $\{2, 3\}$	$F(\xi = 0) < 0, F(\xi = 1) < 0$

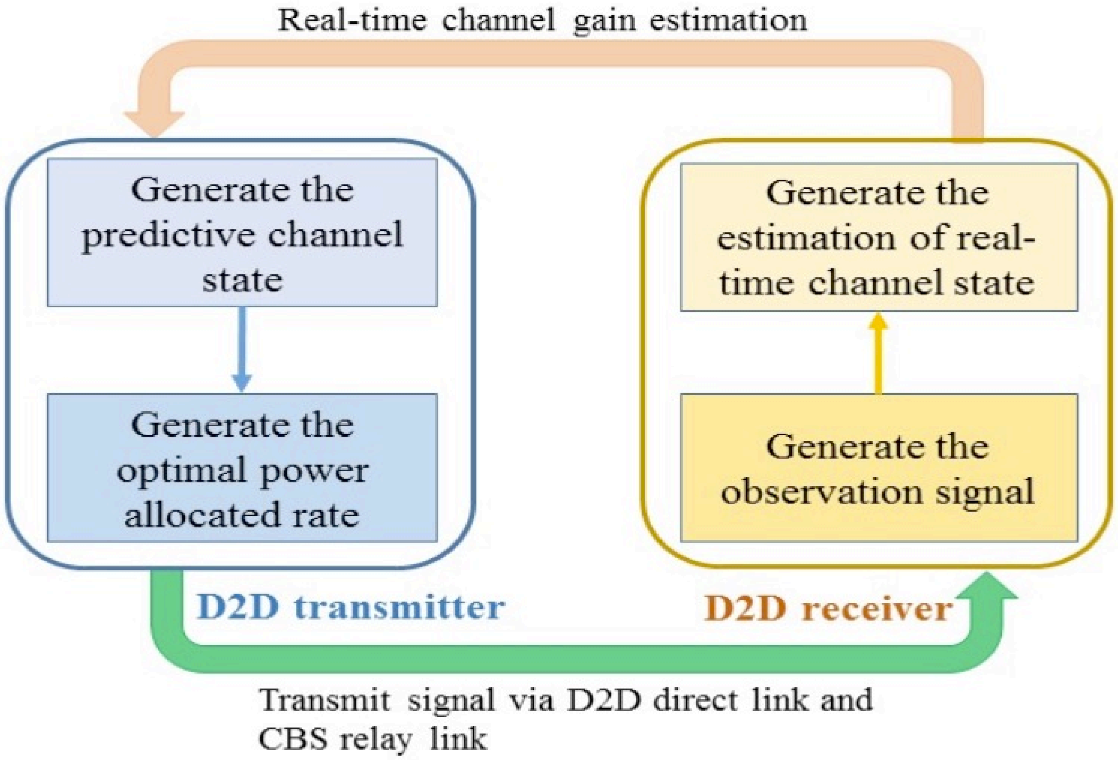


(a)

(b)

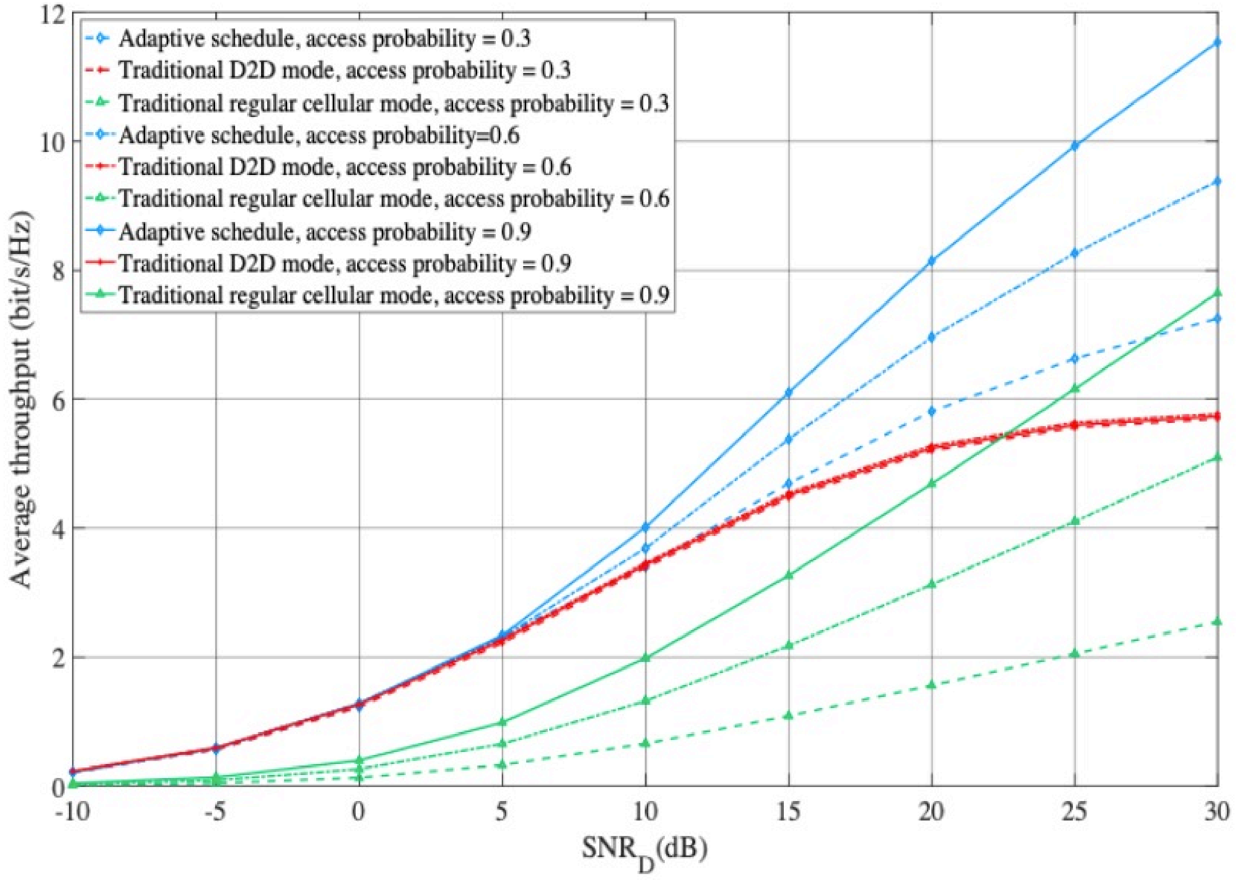
Partial derivative of the underlay throughput under different conditions:
(a) $\beta P_D \| h_{DBD} \|^2 > \sigma^2$ (b) $\beta P_D \| h_{DBD} \|^2 < \sigma^2$

4. Procedure of Adaptive Power Allocation Scheduling



- The channel estimation: maximum *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 β increases, the performance gaps between the adaptive scheduling and D2D direct scheduling expand.

Any questions?

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