Efficient Mechanism Design for Competitive Uplink Carrier Selection and Rate Allocation

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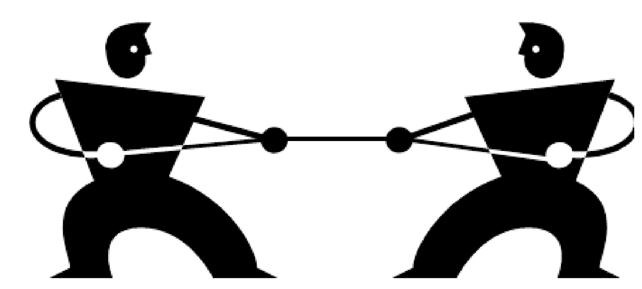


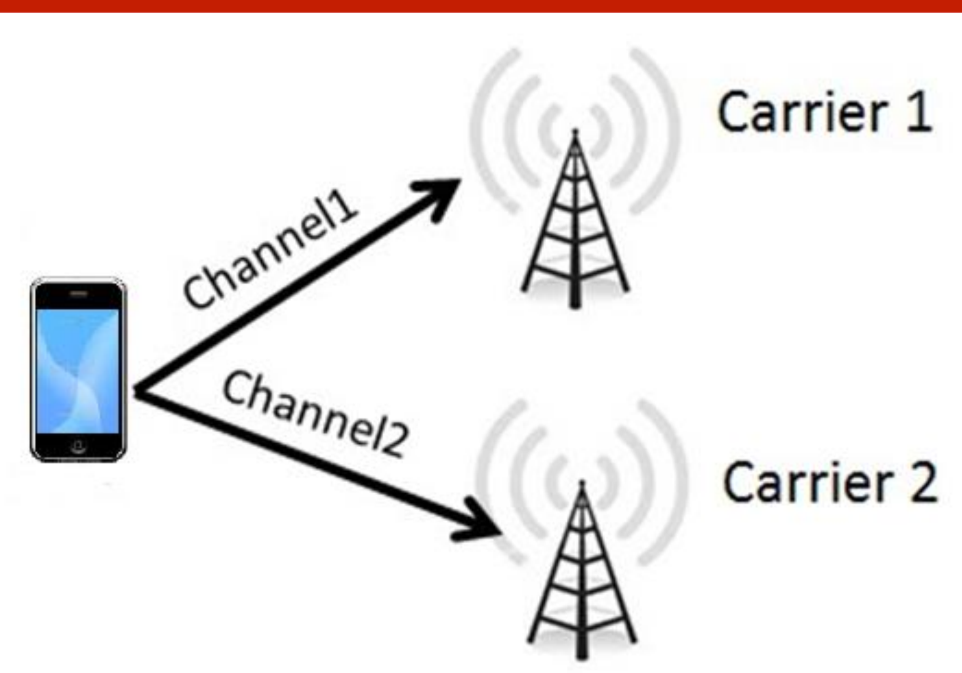
Introduction

- We introduce a competitive rate allocation game in which two carriers compete to carry data from a transmitter in exchange for some payment.
- At each time slot the channel from the transmitter to each carrier is an independent random variable with two states, high or low, affecting the amount of data that can be transmitted.
- Carriers make "bids" on the state of their channel and the transmitter allocates power and data rate accordingly.
- Carriers are rewarded for successful transmissions and penalized for unsuccessful transmissions.

Goal

The goal of the transmitter is to set the game parameters such as rewards and penalties in such a way that even if the carriers are selfish, the total data rate is close to the optimal data rate.

Model



- Channels are independent of each other and the channel states come from an i.i.d. distribution.
- p_i: the probability that channel i is in state high at any time.

Single Bit Bid

Carrier's payoff table:

Carrier 2 / Carrier 1	L	H
L	(1,1)	$(1, \frac{p_2 R_1}{R_0})$
H	$(\frac{p_1 R_1}{R_0}, 1)$	$(\frac{p_1 R_1}{R_0}, \frac{p_2 R_1}{R_0})$

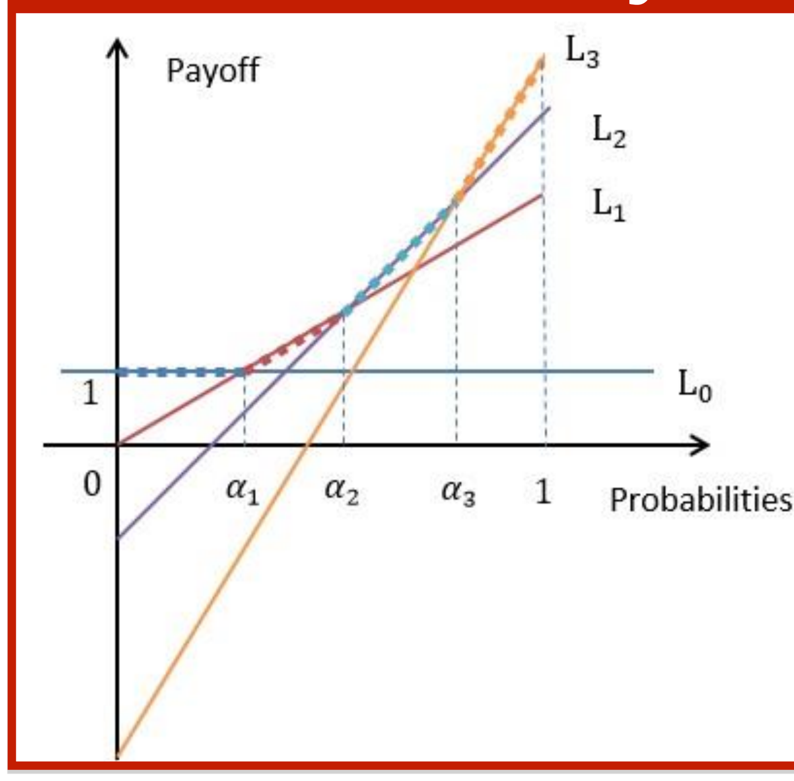
$$R_0 < R_1 < R_2 < 2R_1$$

❖ ***Theorem:*** *In this game, there exists a threshold based strictly dominant strategy for both carriers, and the total data rate for the transmitter is at least half of the maximum achievable rate, in other words, PoA from the transmitter's point of view is bounded by 2.*

Multiple-Bit Bid

- The transmitter divides the whole probability range into *n* parts: [0, 1], [1, 2]...[*n*−1, *n*], and broadcasts this information to the carriers.
- At the beginning of a time slot, each carrier sends a m bits bid to the transmitter, $m \geq \log_2(n)$, claiming a range that their channel parameter is in.
- The transmitter allocates power and data based on the bids, rewards the carriers for successful transmission and penalize them for failure.

Payoff Design



- Suppose $p_i \in [\alpha_m, \alpha_{m+1}]$
- Allocate power

$$R = \begin{cases} k_m + l_m & \text{if succeeds} \\ l_m & \text{if fails} \end{cases}$$

- Do not allocate power

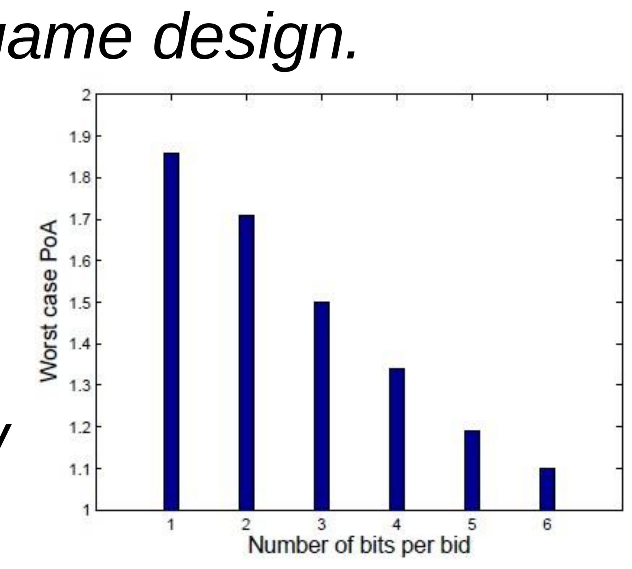
$$R = k_m \alpha_m + l_m$$

Unharmful Imperfect Truthfulness

- If the transmitter allocates power to this channel, the corresponding carrier will bid truthfully.
- If the transmitter does not allocate power to this channel, the corresponding carrier may overbid. However, it will not overbid too much to make the transmitter allocate power.

❖ ***Theorem:*** *The carriers will bid unharmful imperfect truthfully with this game design.*

❖ ***Theorem:*** *For fixed rates setting, when the granularity of the probability range approaches 0, the PoA from the transmitter's point of view approaches 1.*



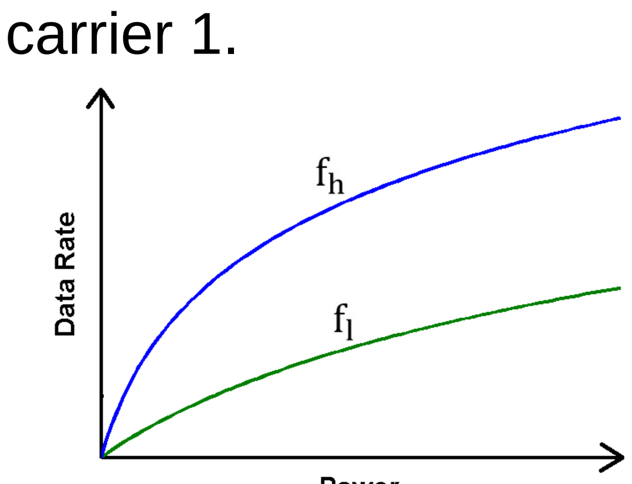
Extension

- The payoff design can be easily extended to solve the following problems:
  - ✓ Flexible Power and Data Allocation

    Assume the total power is 1, let *P* denote the portion of power allocated to carrier 1.

$$V_{opt}(P) = \max\{f_l(P) + f_l(1-P), \; f_l(P) + \hat{p}_2 f_h(1-P), \; \hat{p}_1 f_h(P) + f_l(1-P), \; \hat{p}_1 f_h(P) + f_h(1-P)\}$$

$$V_{opt} = \max\{V_{opt}(P) \;\; P \in [0,1]\}$$



  - ✓ Multiple Carriers

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