To Preempt or Not: Tackling Bid and Time-based Cheating in Online Spectrum Auctions

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Dynamic Spectrum Auctions

- Large number of co-existing wireless networks that need spectrum

- Time-changing demand for spectrum

Dynamic spectrum auctions using short-term periodic auctions

[Jia09, Zhou09, Zhou08, Ghandi07]
Problems of Periodic Auctions

- Periodic auction cycles
- Auction decisions made at the start of each cycle
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- Introduce inconvenience to the bidder
  - Delay to participate in next auction cycle
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- Periodic auction cycles
- Auction decisions made at the start of each cycle

- Introduce inconvenience to the bidder
  - Delay to participate in next auction cycle
  - Participate in multiple auction cycles

- Simplify auction design but difficult to support real-time dynamic traffic
Online Spectrum Auctions

Bidder 1 job request
Online Spectrum Auctions

- Auctioneer processes requests instantaneously

- Bidders request spectrum “on-demand”
Online Spectrum Auctions

- Auctioneer processes requests instantaneously
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Bidder 1 arrives

Request content: 
\{Bid\} + \{Request length, Arrival time, Deadline\}
Outline

• Motivation for Online Auctions

• Challenges of Online Auctions

• *Topaz*: Solution Methodology and Analysis

• Evaluation

• Conclusion
Challenge 1: Bidders Cheat

• Bidders falsely report their requests to gain unfair advantage

  • Rigging the bid value
    [Zhou09][Xu09][Zhou08][Hajiaghayi05]

  • Cheating in time
    • Falsely reporting arrival time and deadline
    • Not addressed for spectrum auctions

• Definition of *auction truthfulness* in online spectrum auctions
  • *No bidder can improve its utility by cheating either bid or time or any combination of them*
Challenge 1: Bidders Cheat

- Bidders falsely report their requests to gain unfair advantage
  - Rigging the bid value
    - [Zhou09][Xu09][Zhou08][Hajiaghayi05]
  - Cheating in time
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Bid request format:
- Bid
- Arrival time
- Deadline
- Request length
Time-based Cheating

$5 per unit

Unit spectrum request

$1 per unit

$9 per unit
Time-based Cheating

Bidders bid truthfully

B wins
Bid_B > Bid_A

A, B
A
B
B

C wins

A
C
C
C
C
C

B, C

B pays Bid_A = $5
C pays $0

$5 per unit

$9 per unit

$1 per unit

Spectrum

Time
Bidder B cheats & pays less!

A wins
A, X
A, A, A
A pays $0

B wins
B, B, B
B, C
B pays $0 < $5

Untruthful Auction
On-the-fly decisions with uncertainty of future arrivals can sacrifice *auction revenue* and *spectrum utilization*. Auctioneer has the option to preempt allocated bidders.

The tradeoff between auction revenue and spectrum utilization is evident in the figure. Time-cheating becomes even more harmful with preemption.
Topaz

- **Goal:**
  - Achieve truthfulness for *bid* and *time cheating* for both preemptive and *non-preemptive* case
  - Allow customized preemption degree for auctioneer

- **Methodology:**
  - *3D bin-packing based allocation*
  - *Time-smoothed critical value based pricing*
Running Topaz

**Allocation**

1. Sort bidders’ per unit bids in non-increasing order
2. 3D bin-packing sequentially following their orders
Running Topaz

1. Calculate minimum bid required for $B$ to win each slot
2. Calculate price to win contiguous request slots as the maximum of slot prices among the consecutive slots
3. Charge minimum price of candidate groups of consecutive slots

Bid$_B = \$n$
Slots$_B = 2$

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$B$
$t$
$\$3$
$t+1$
$\$5$
$t+2$
$t+3$
1. Calculate minimum bid required for B to win each slot
2. Calculate price to win contiguous request slots as the maximum of slot prices among the consecutive slots
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Running Topaz

Pricing

1. Calculate minimum bid required for B to win each slot
2. Calculate price to win contiguous request slots as the maximum of slot prices among the consecutive slots
3. Charge minimum price of candidate groups of consecutive slots

Bid_B = $n
Slots_B = 2

max{$3, $5} = $5
max{$4, $2} = $4
Price_B = min{$5, $4} = $4
Topaz with Preemption

**Allocation**

- Provides higher priority to allocated bidders
- Raise allocate bidder’s bid by factor “$f \phi_i$”
  - $f \geq 1$
  - $\phi_i = \frac{(contiguously-allocated \ slots)}{(requested \ slots)}$

**Pricing**

- Price charged no higher than bid
- Reduce bid by raised factor “$f \phi_i$”
Proof of Truthfulness

• 3D bin-packing algorithm and pricing based on critical value across time achieve truthfulness
  • No bidder can improve its utility by cheating its true bid, manipulating its arrival time or deadline, or any combination of them.
  • Analytical proof within the paper

• Topaz complexity of $\theta(n \cdot \log(n))$
Evaluating *Topaz*

- Evaluation goals: **Investigate the Impact of Preemption**
  - Auction Revenue
  - Spectrum Utilization

- Evaluation configurations:
  - **Bid distribution:** uniform and non-uniform bid distribution
  - **Arrival and Departure model:** Poisson and uniform random
  - **Bidder request length:** Uniform
Impact of Preemption: “f”

- Normalized to those of the non-preemptive auction

- Small $f$ preempts frequently
- Large $f$ is trapped by low bids
Impact of Preemption: “f”

- Small $f$ wastes spectrum
- Maximum utilization for non-preemptive
Conclusion

- *Topaz* is the first *online* spectrum auction design that addresses both *bid* and *time-cheating* while achieving *spectrum reuse*.
- *Topaz* provides flexibility for the auctioneer to adjust the *preemption level* based on its preferences.
- Evaluate the *impact of preemption* on online spectrum auctions systematically under diverse settings.
Thank you

Any questions?