

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

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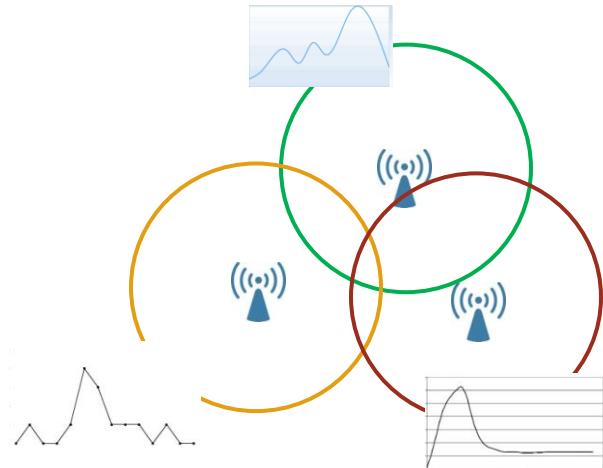
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Dynamic Spectrum Auctions

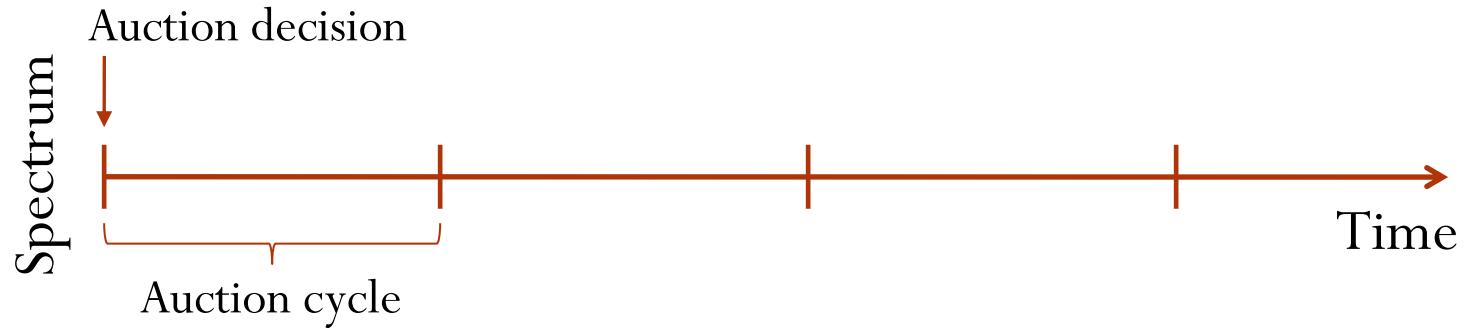
- Large number of co-existing wireless networks that need spectrum
- Time-changing demand for spectrum



➡ Dynamic spectrum auctions using short-term periodic auctions
[Jia09, Zhou09, Zhou08, Ghandi07]

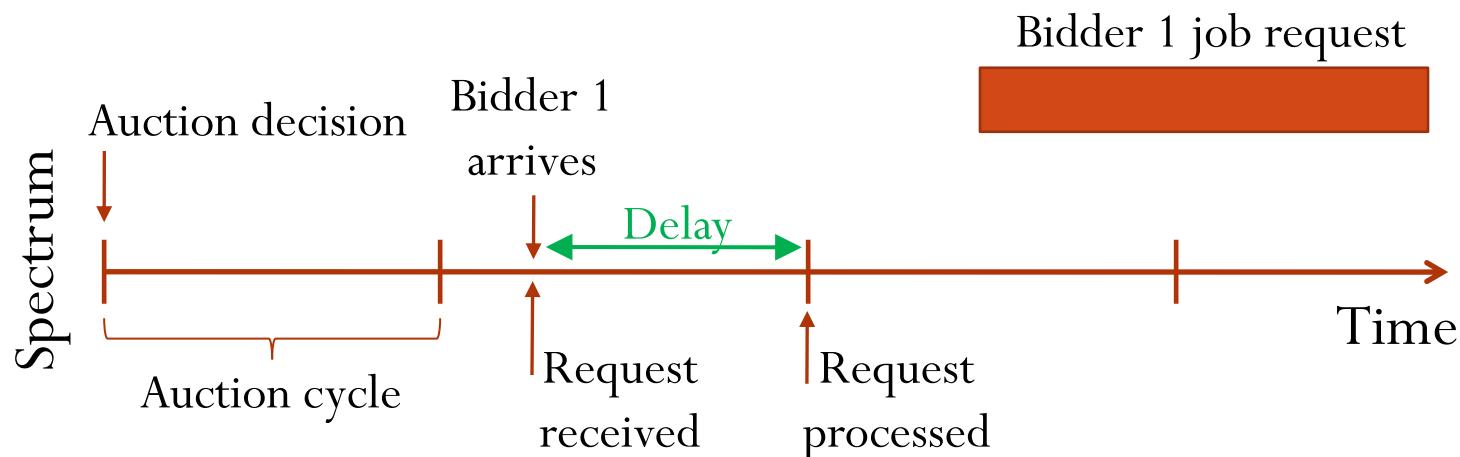
Problems of Periodic Auctions

- Periodic auction cycles
- Auction decisions made at the start of each cycle



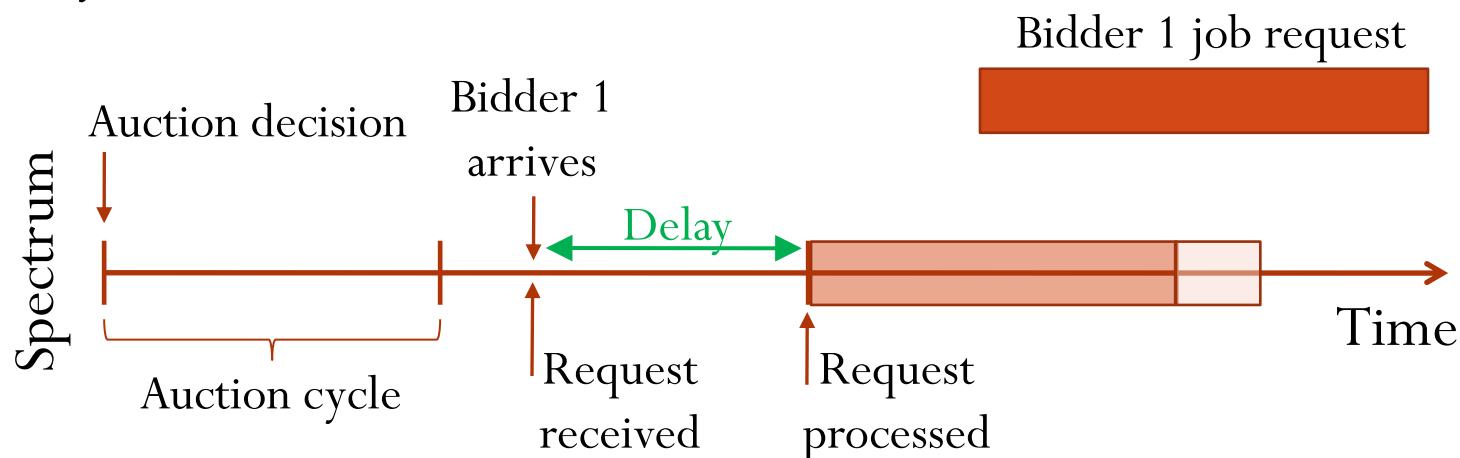
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- Introduce inconvenience to the bidder
 - Delay to participate in next auction cycle



Problems of Periodic Auctions

- 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



Online Spectrum Auctions

- Auctioneer processes requests instantaneously
- Bidders request spectrum “on-demand”



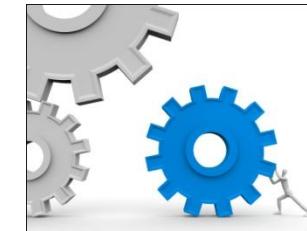
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Outline

- 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



Bidder request format:

Bid
Arrival time

Deadline

Request length

- 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*

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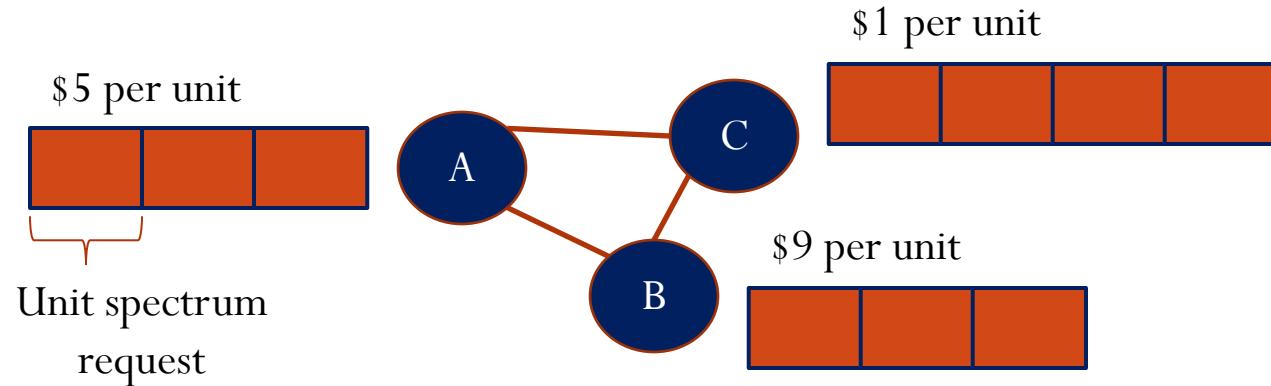


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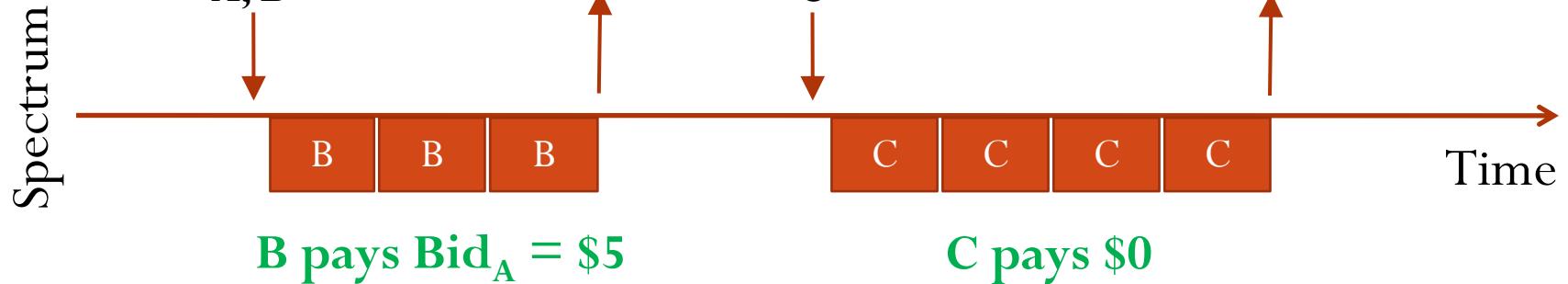
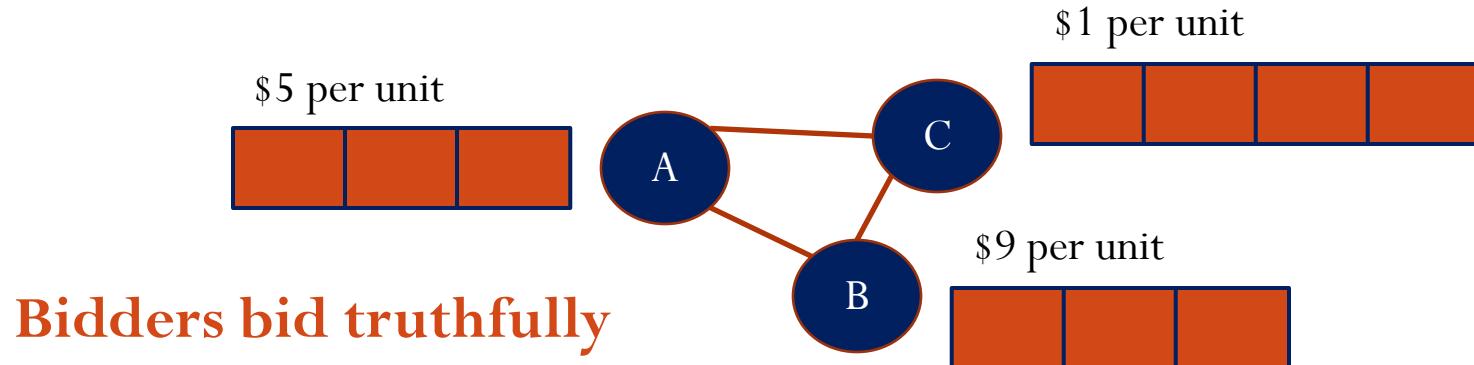
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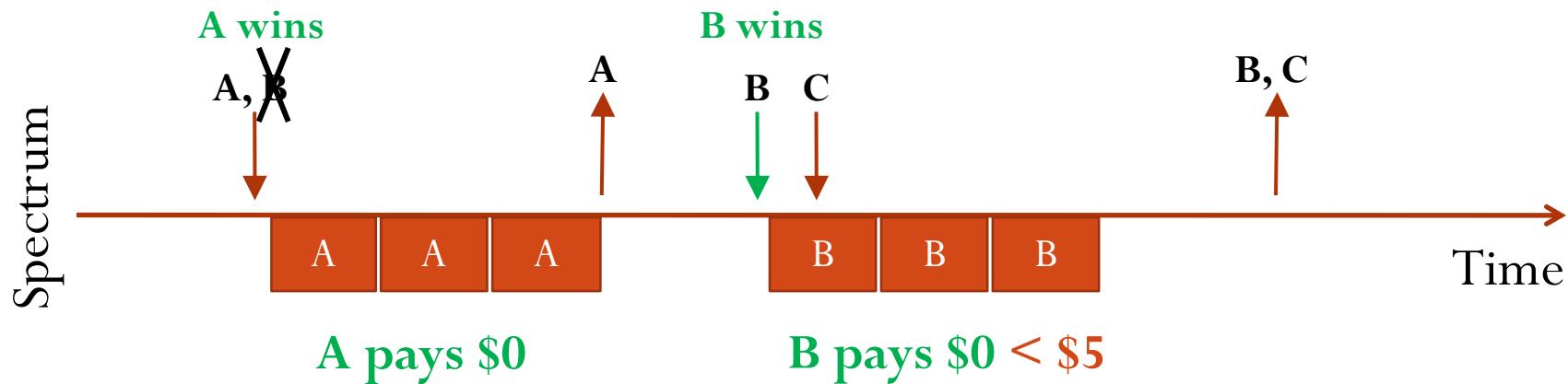
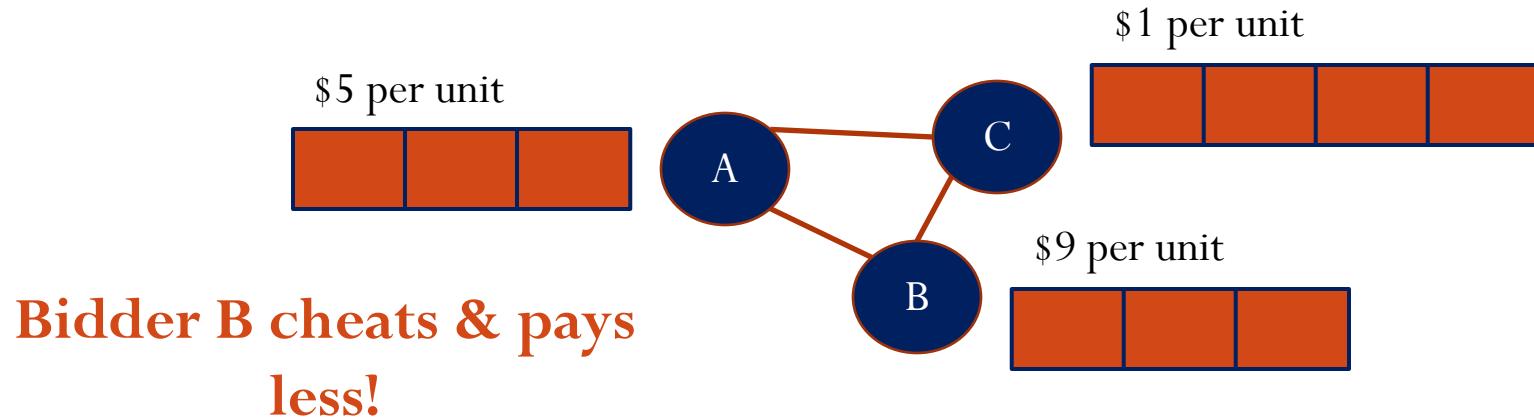
Time-based Cheating



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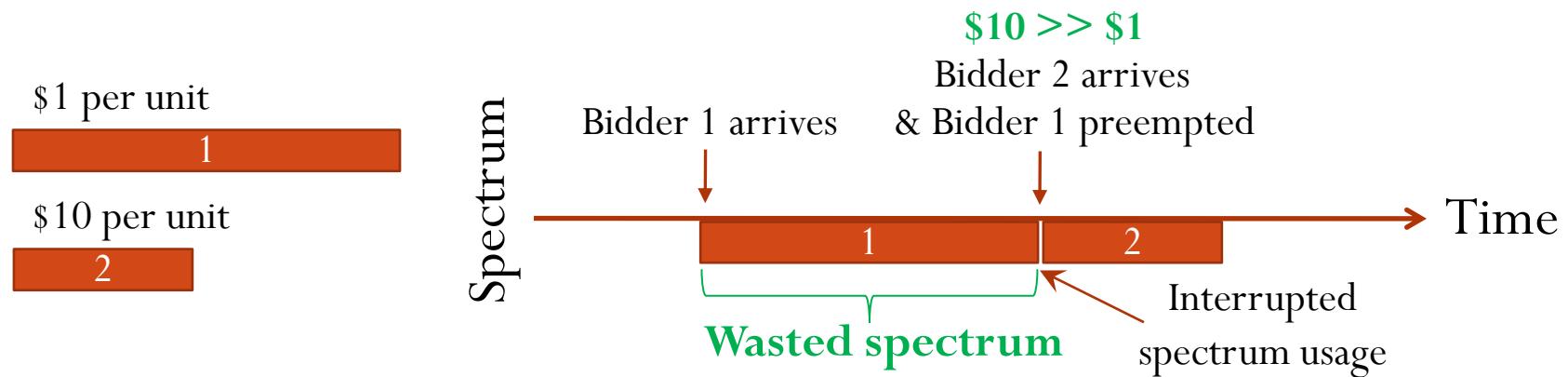
Time-based Cheating



Untruthful Auction

Challenge 2: Decision Uncertainty

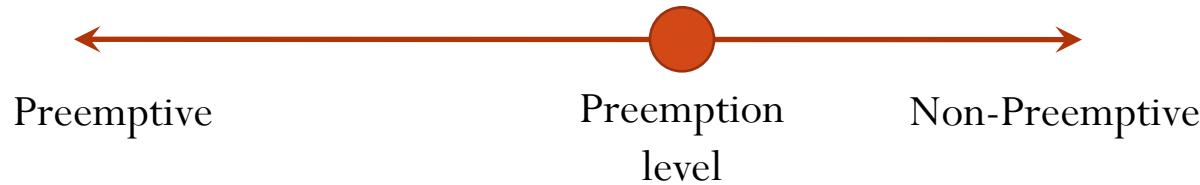
- On-the-fly decisions with uncertainty of future arrivals can sacrifice *auction revenue* and *spectrum utilization*
 - Auctioneer has the option to **preempt** allocated bidders



- Tradeoff between *auction revenue* and *spectrum utilization*
- Time-cheating is 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

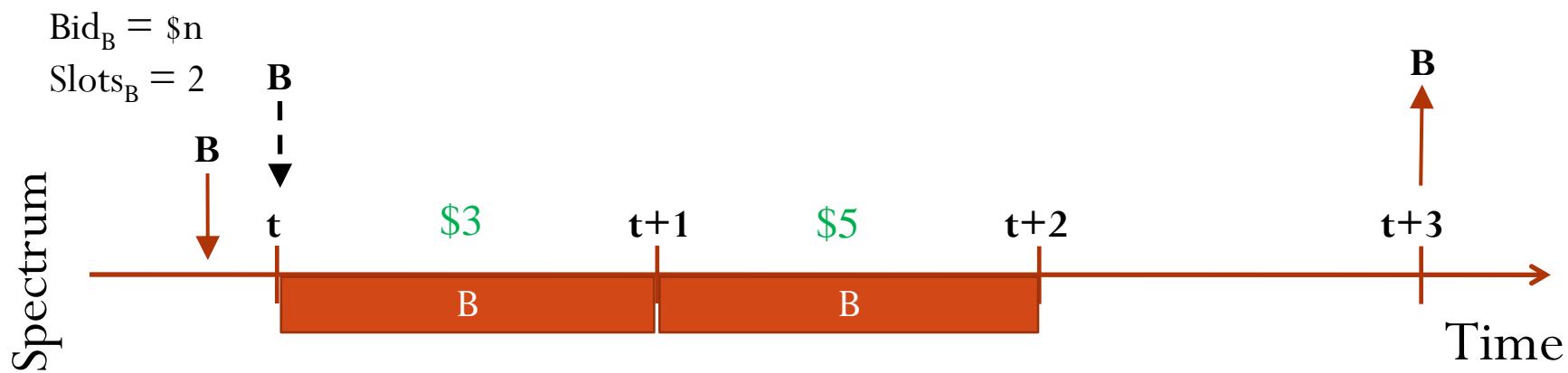
1. Sort bidders' per unit bids in non-increasing order
2. 3D bin-packing sequentially following their orders



Running Topaz

Pricing

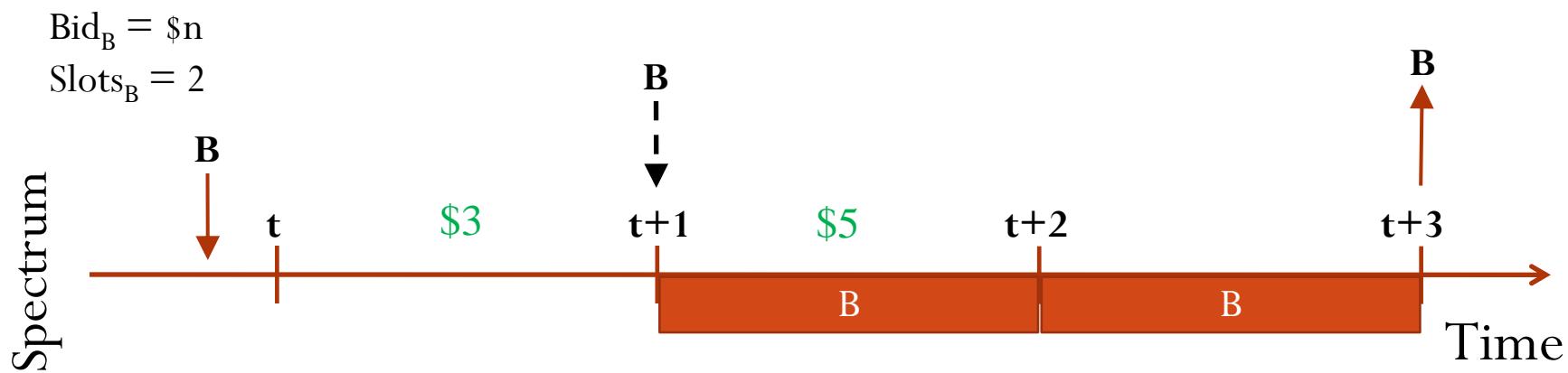
1. Calculate minimum bid required for B to win each slot
2. Calculate price to win contiguous request slots as the maximum of slot prices among the consecutive slots
3. Charge minimum price of candidate groups of consecutive slots



Running Topaz

Pricing

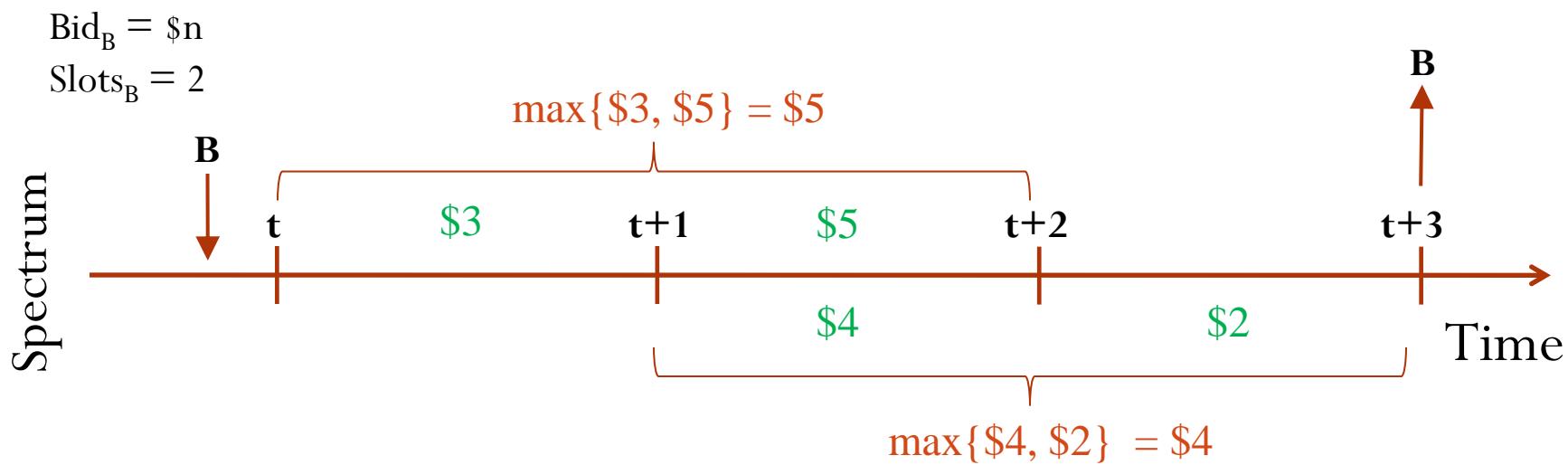
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Running Topaz

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$$\text{Price}_B = \min\{\$5, \$4\} = \$4$$

Topaz with Preemption

Allocation

- Provides higher priority to allocated bidders
- Raise allocate bidder's bid by factor " f^{φ_i} "
 - $f \geq 1$
 - $\varphi_i = (\text{contiguously-allocated slots}) / (\text{requested slots})$



Pricing

- Price charged no higher than bid
- Reduce bid by raised factor " f^{φ_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

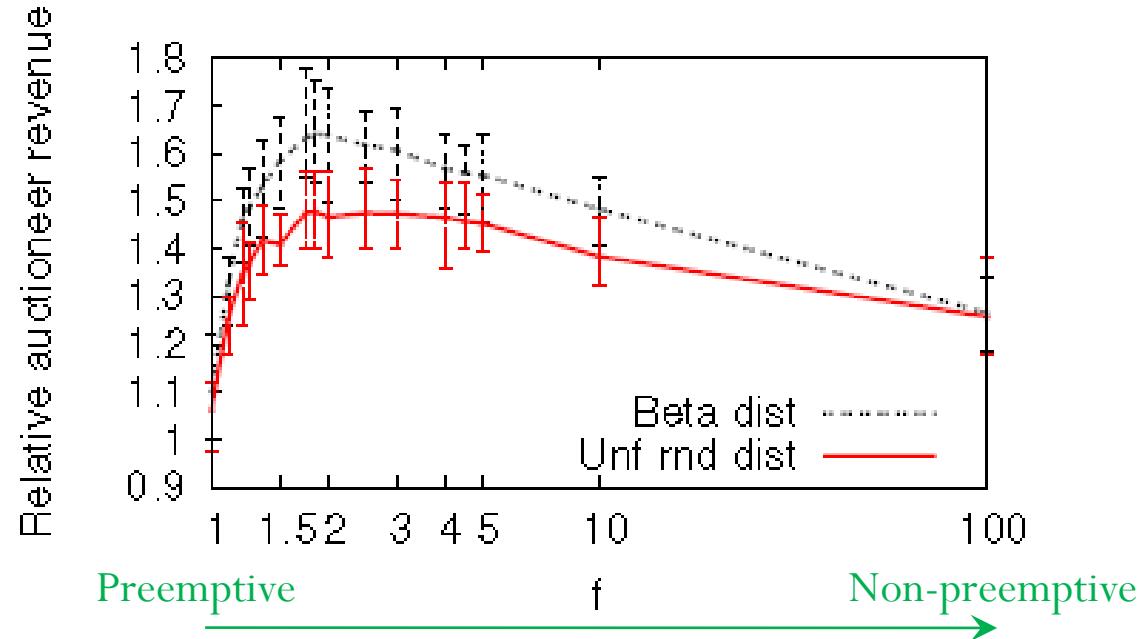


- Evaluation goals: **Investigate the Impact of Preemption**
 - **Auction Revenue**
 - **Spectrum Utilization**
- Evaluation configurations:
 - **Bid distribution:** uniform and non-uniform bid distribution
 - **Arrival and Departure model:** Poisson and uniform random
 - **Bidder request length:** Uniform



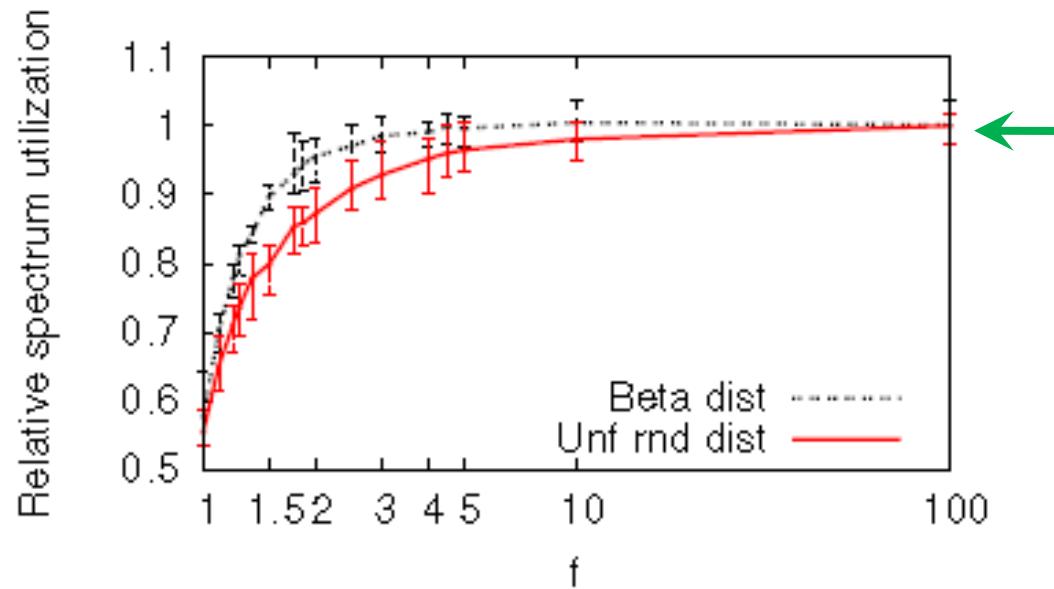
Impact of Preemption: “ f ”

- 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?