

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

By: **Lara Deek**

Xia Zhou

Kevin Almeroth

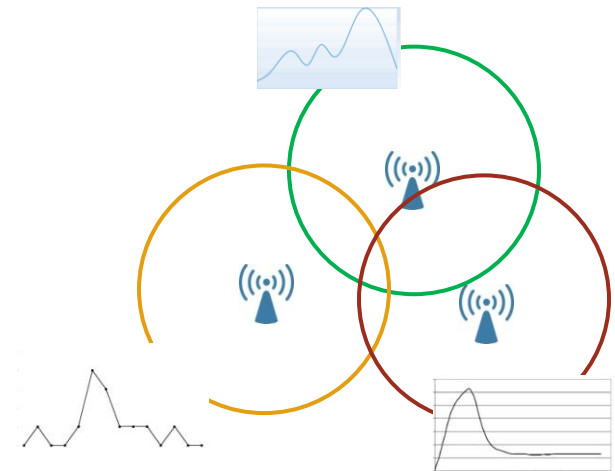
Haitao Zheng



Department of Computer Science  
University of California Santa Barbara

# Dynamic Spectrum Auctions

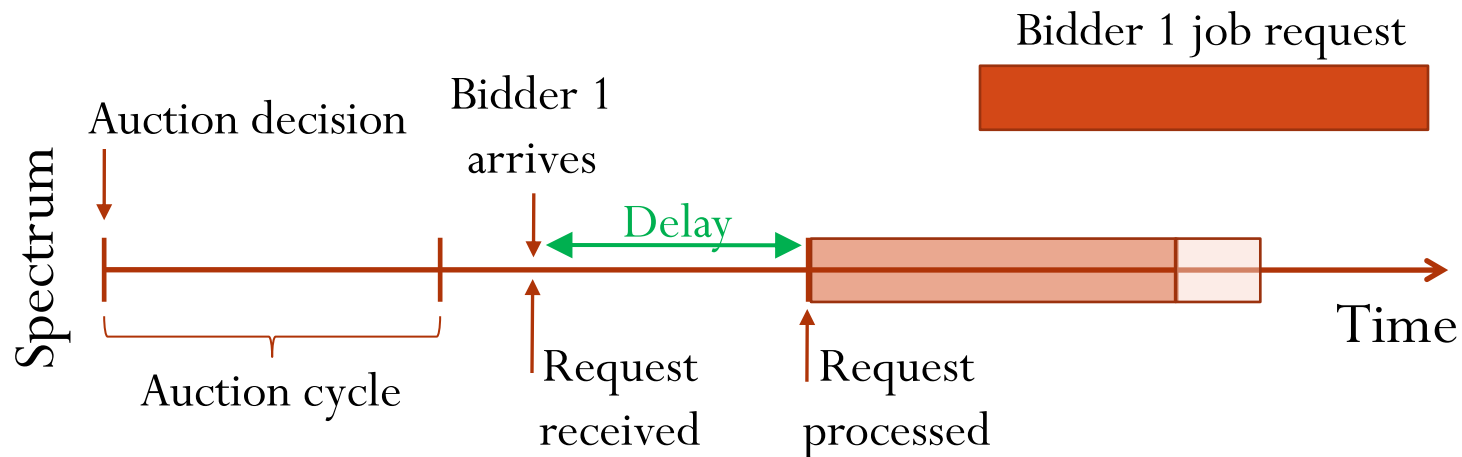
- Large number of co-existing wireless networks that need spectrum
- Time-changing demand for spectrum



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

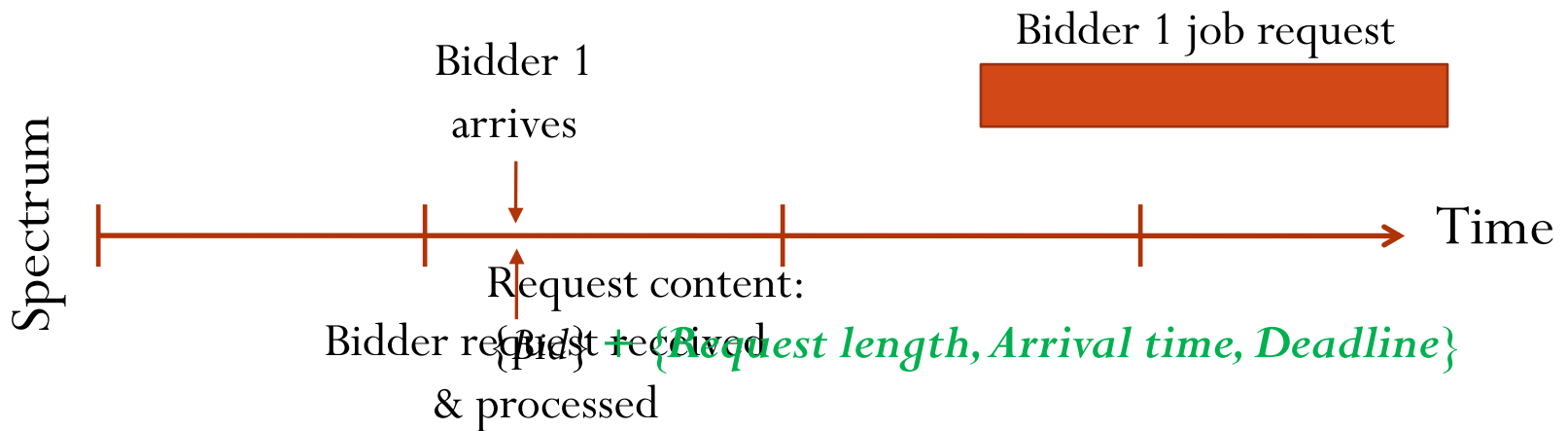
# Problems of Periodic Auctions

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

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



# 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



## Bidder request

### format:

Bid  
Arrival time  
Deadline  
Request length

- 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**

- Falsely reporting arrival time and deadline
- Not addressed for spectrum auctions

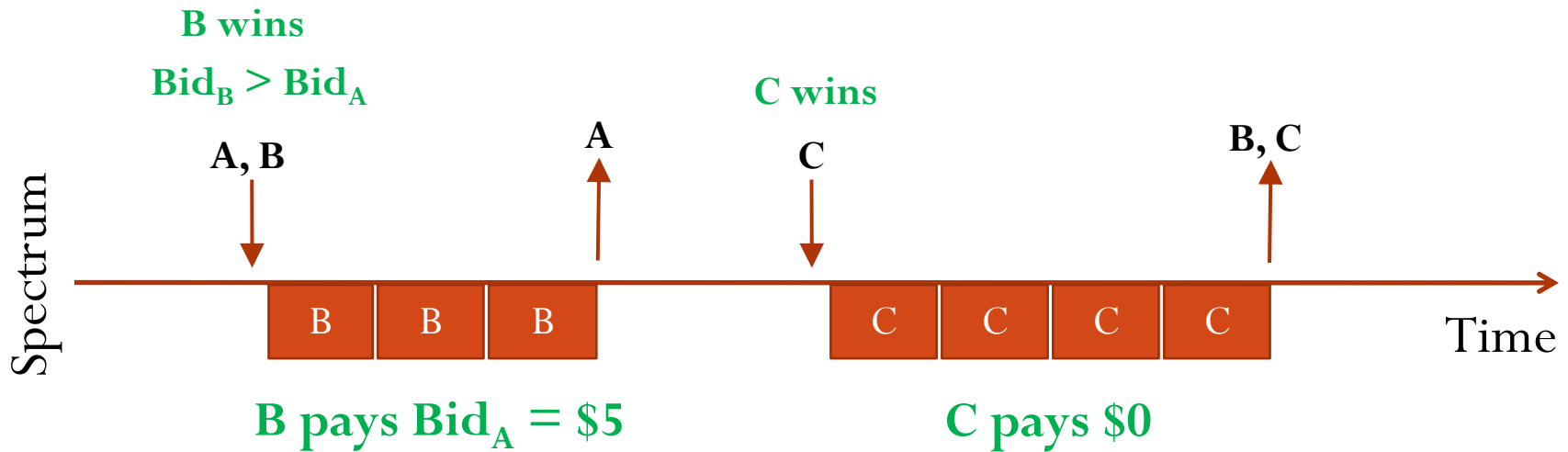
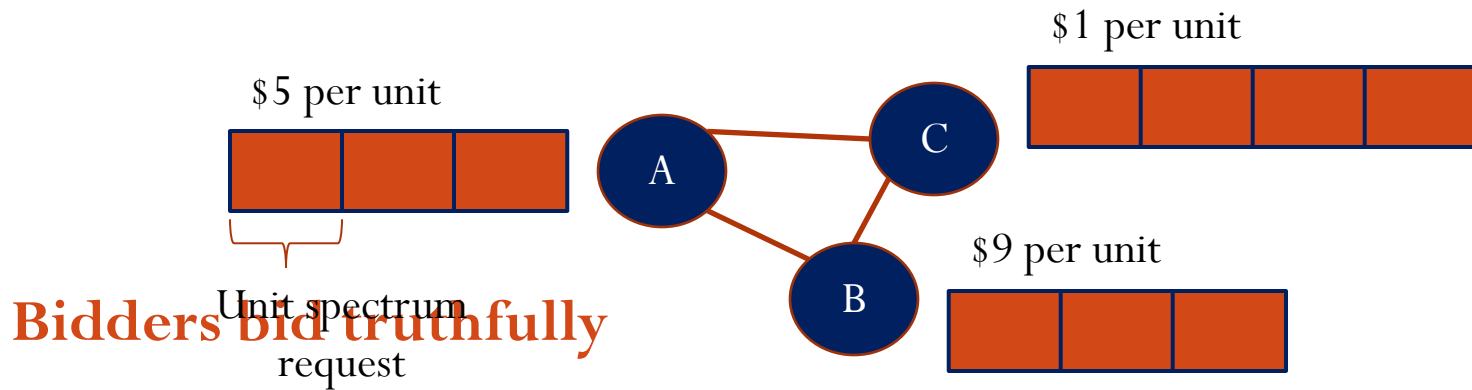
## Bidder request

### format:

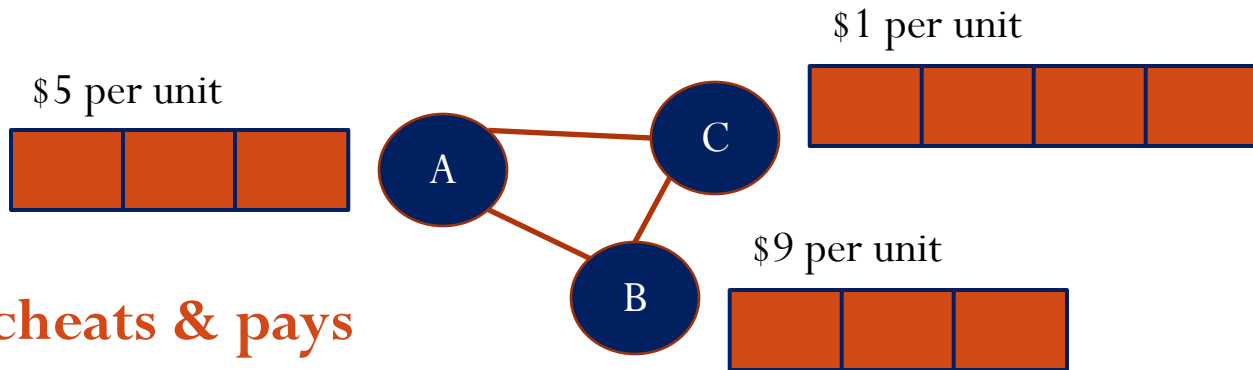
Bid  
Arrival time  
Deadline  
Request length

- 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*

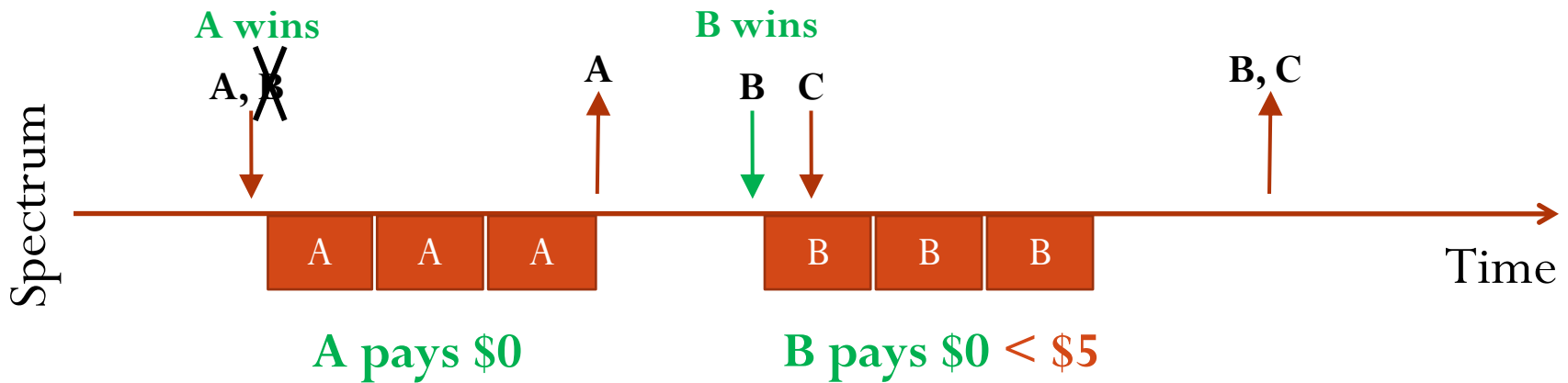
# Time-based Cheating



# Time-based Cheating



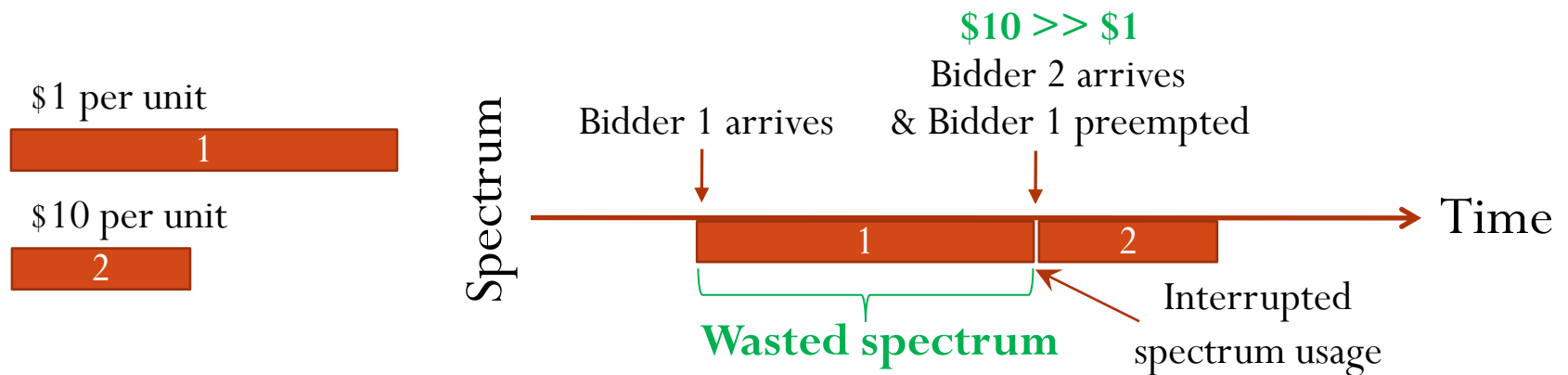
**Bidder B cheats & pays less!**



**Untruthful Auction**

# Challenge 2: Decision Uncertainty

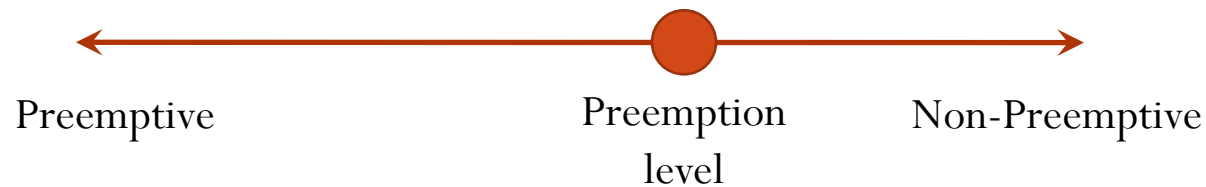
- On-the-fly decisions with uncertainty of future arrivals can sacrifice *auction revenue* and *spectrum utilization*
  - Auctioneer has the option to **preempt** allocated bidders



- 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

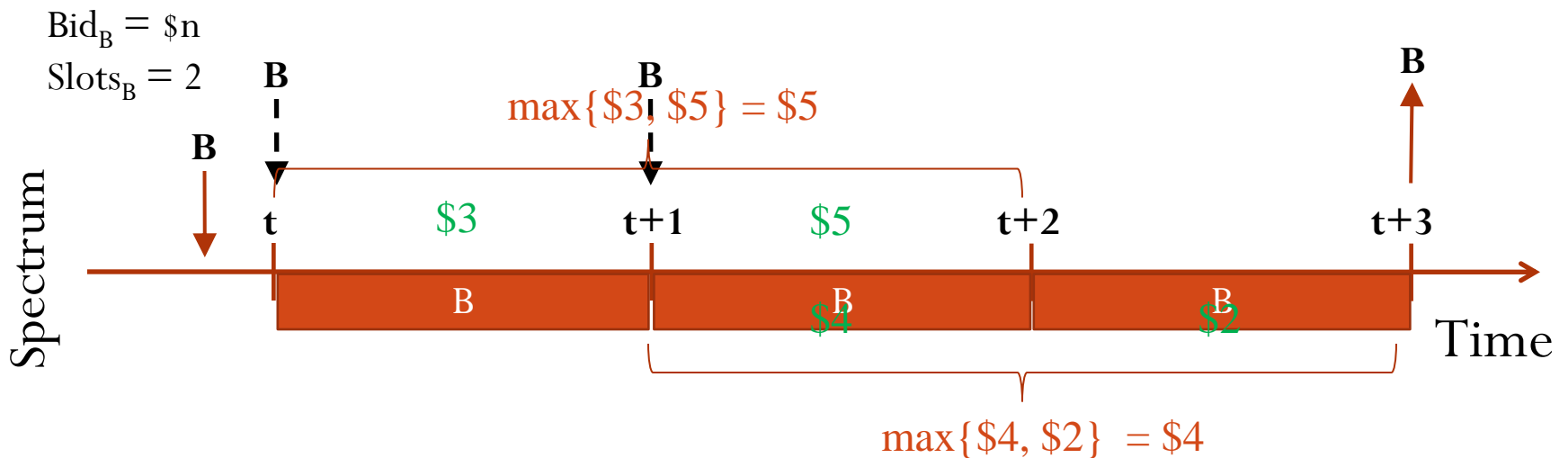
1. Sort bidders' per-unit bids in non-increasing order
2. 3D bin-packing sequentially following their orders



# 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



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

# Topaz with Preemption

## Allocation

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



## Pricing

- Price charged no higher than bid
- Reduce bid by raised factor " $f^{\varphi_i}$ "

# 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*



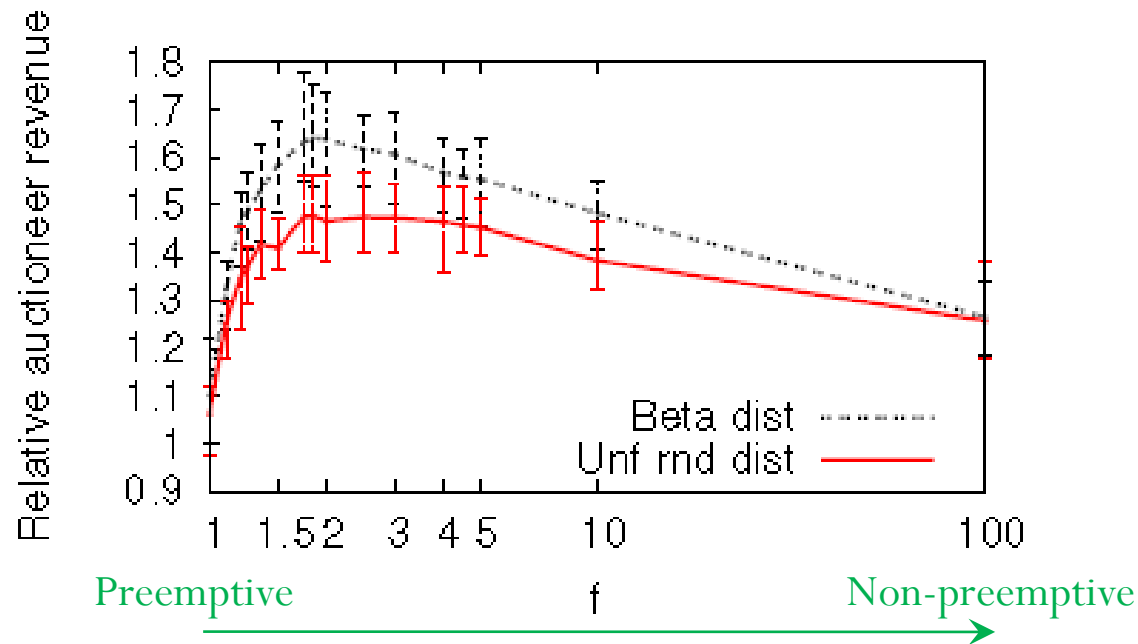
- Evaluation goals: **Investigate the Impact of Preemption**
  - **Auction Revenue**
  - **Spectrum Utilization**



- Evaluation configurations:
  - **Bid distribution:** uniform and non-uniform bid distribution
  - **Arrival and Departure model:** Poisson and uniform random
  - **Bidder request length:** Uniform

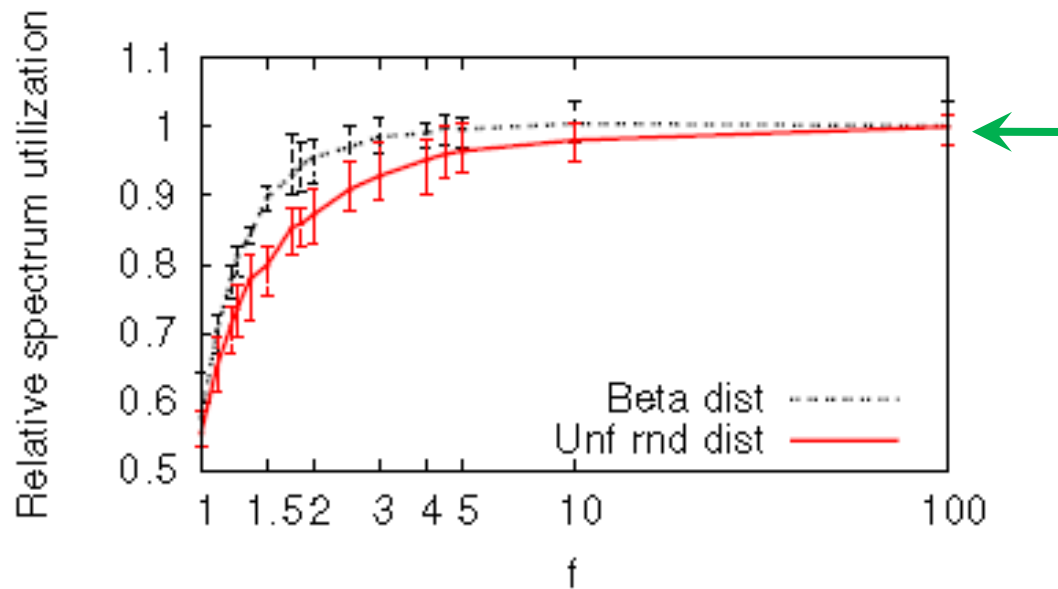
# Impact of Preemption: “ $f$ ”

- 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?