Breaking Bidder Collusion in Large-Scale Spectrum Auctions

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The Need for Dynamic Spectrum Distribution

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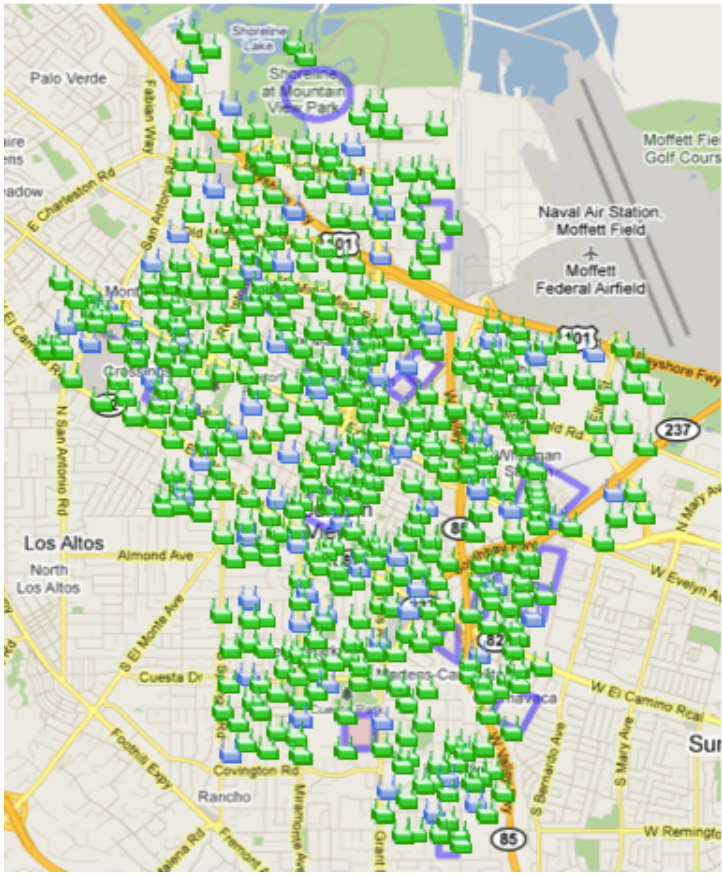
  - Dynamical demands, local wireless service



GoogleWiFi Network

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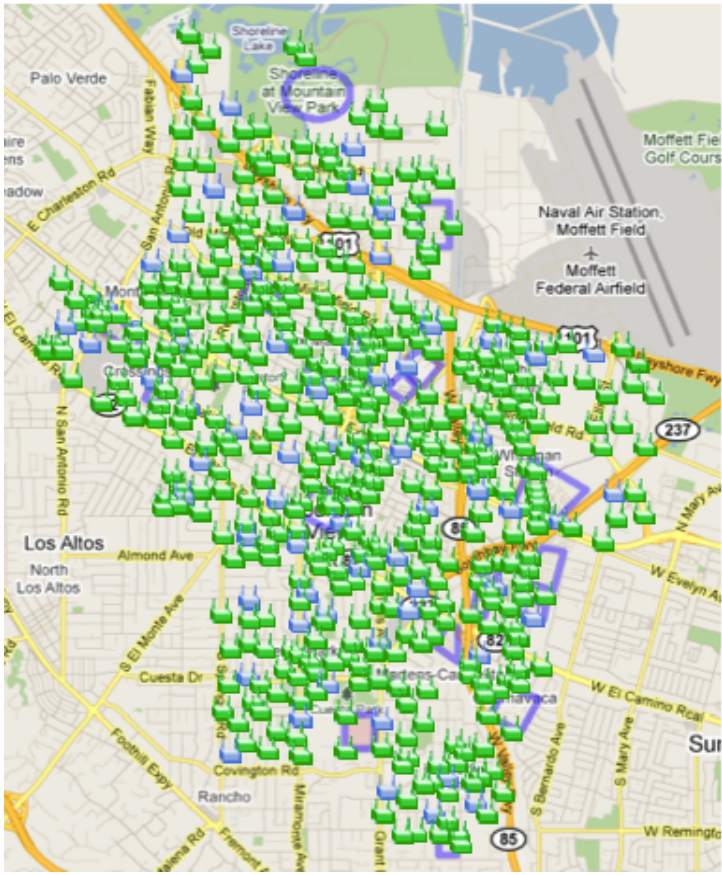

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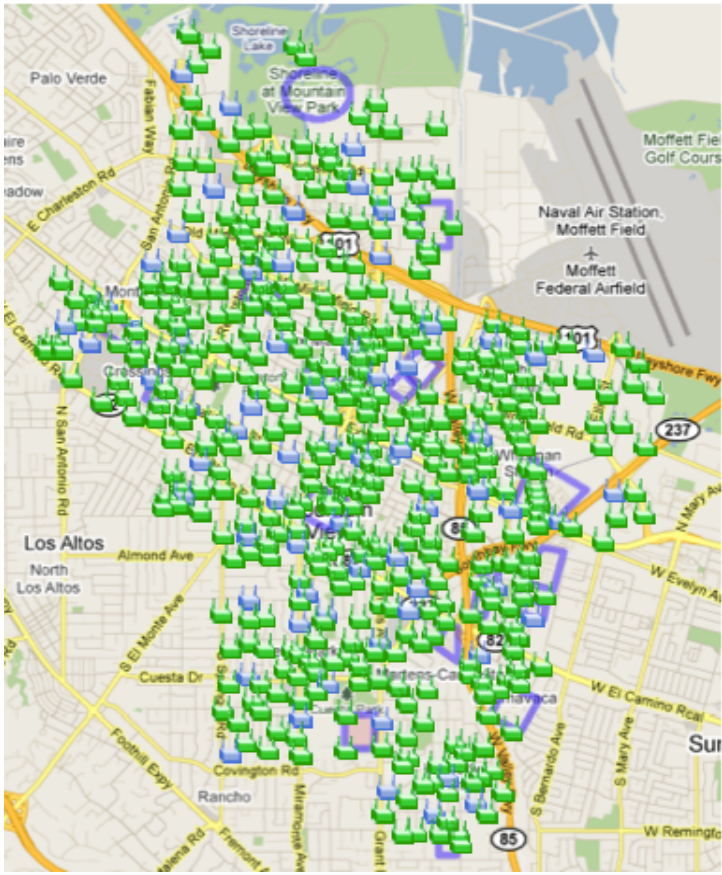
- Dynamic spectrum distribution with spatial reuse



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- Auctioneer auctions currently unused spectrum periodically
- Bidders bid for spectrum to match their needs

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- Key requirements:
  - Maximize spectrum distribution efficiency
    - Enabling spectrum reuse
  - Resist bidder cheating

Networking

Economics

A Closer Look at Bidder Cheating

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- Individual cheating
  - Change bid to gain unfair advantage
  - Solution: truthful spectrum auction designs
    - VERITAS [zhou08], TRUST[zhou09], [jia09]…

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- Individual cheating
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- Collusion
  - Cheat in groups, improving the group's utility
  - Popular in large-scale networks
    - Example: P2P networks
  - Few studies in dynamic spectrum auctions

Our Contributions

- **Understand the impact of bidder collusion in dynamic spectrum auctions**

- **Propose a collusion-resistant design for large scale spectrum auctions**

Outline

- Is bidder collusion a serious threat to spectrum auction?
- How to address bidder collusion?
- Evaluation
- Conclusion and future works

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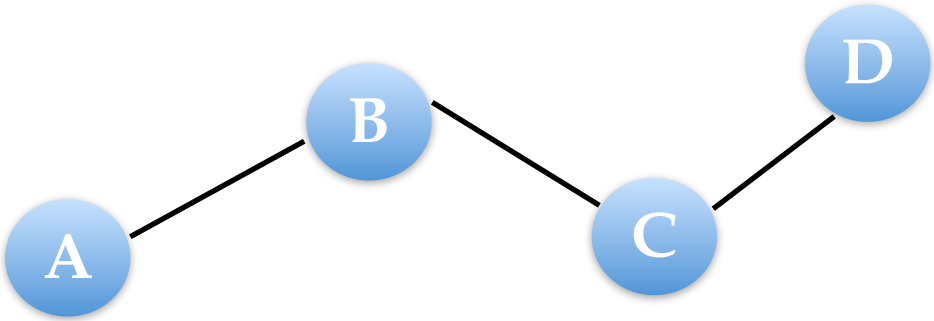

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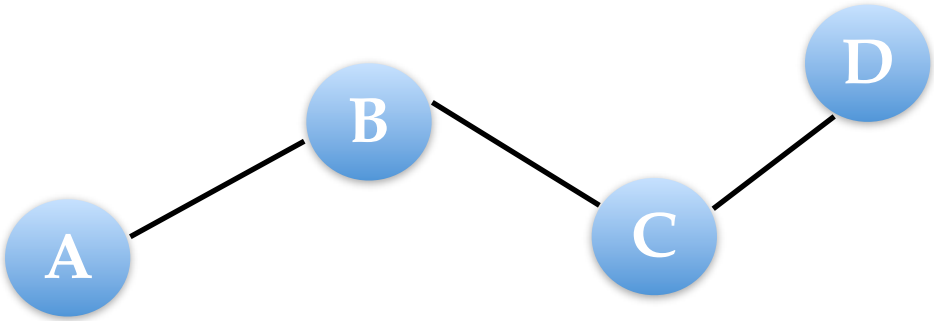

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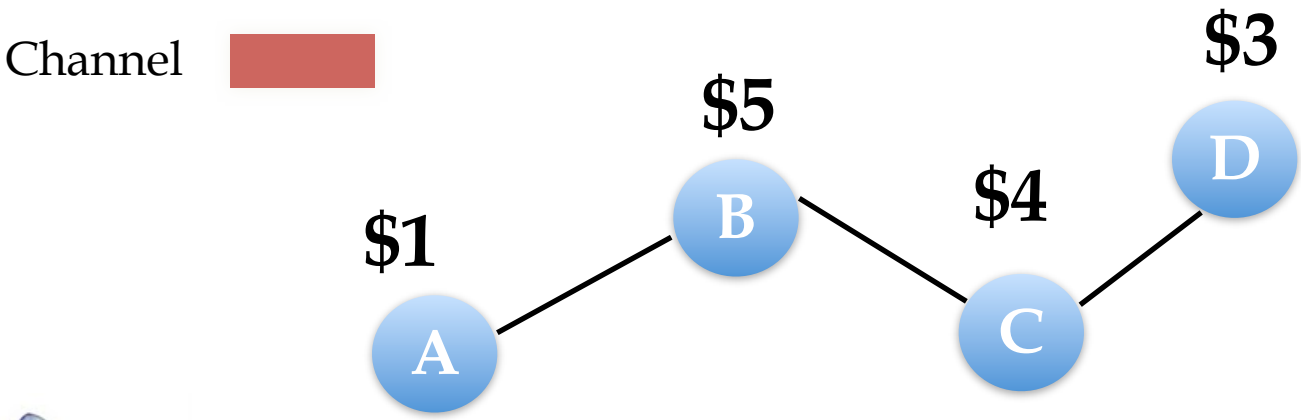

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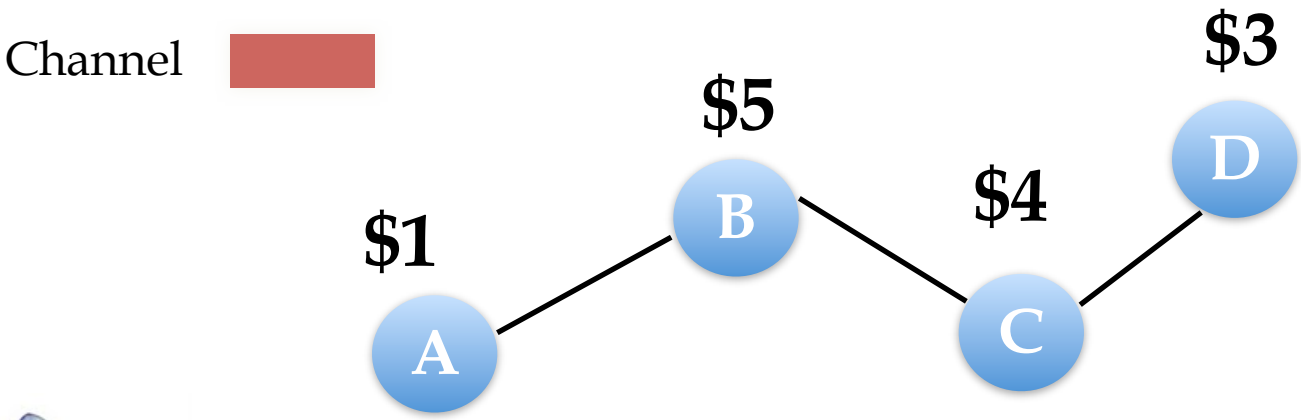

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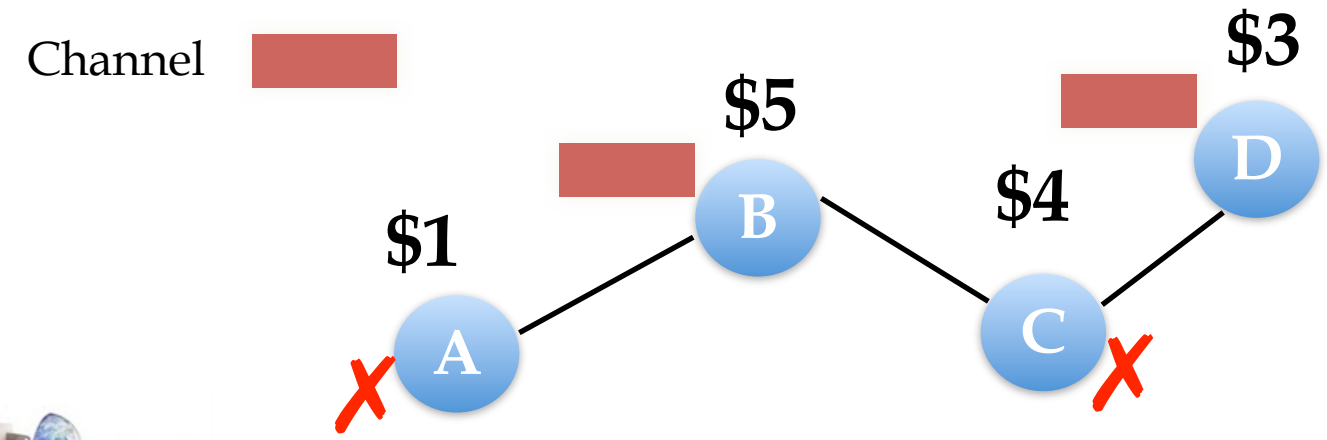

(Truthful) Spectrum Auctions 101

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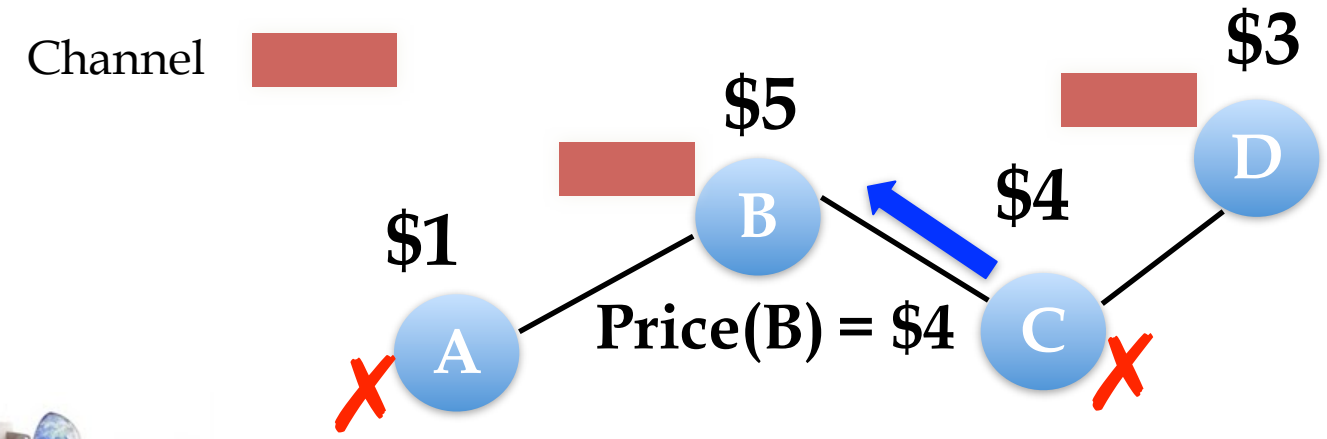
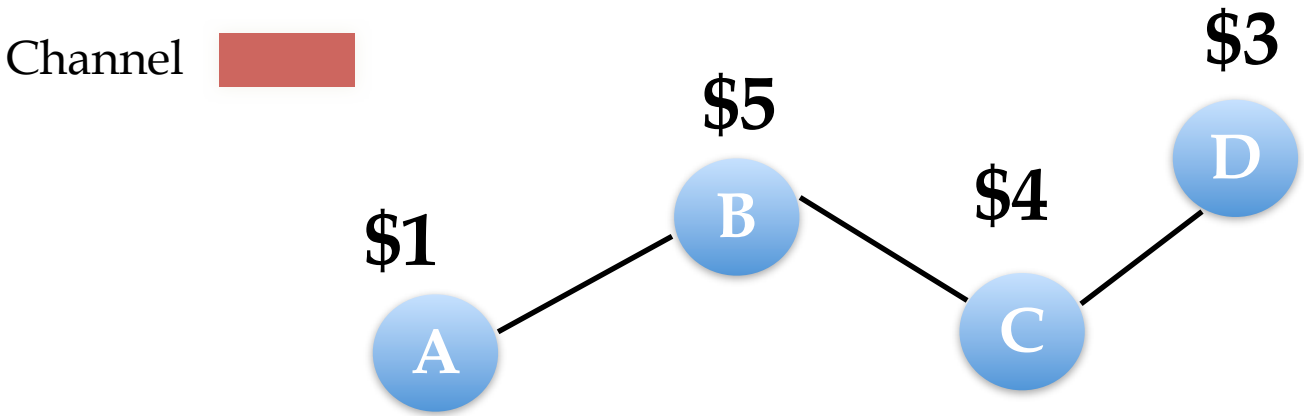
- Pricing
  - **Critical neighbor**: for bidder *i*, if *i* bids lower than its critical neighbor, then *i* cannot win the auction; otherwise it wins.



An Illustrative Collusion Example



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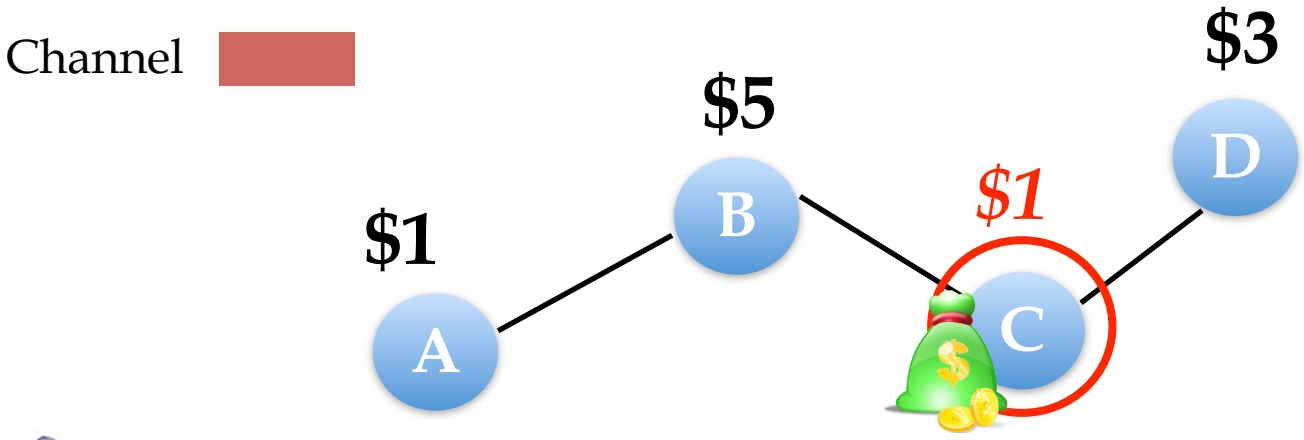

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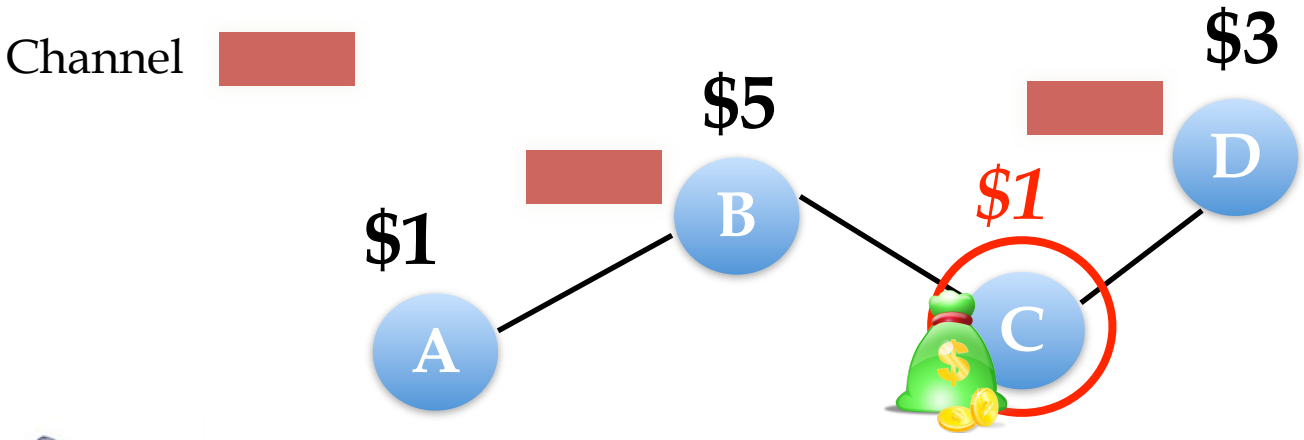

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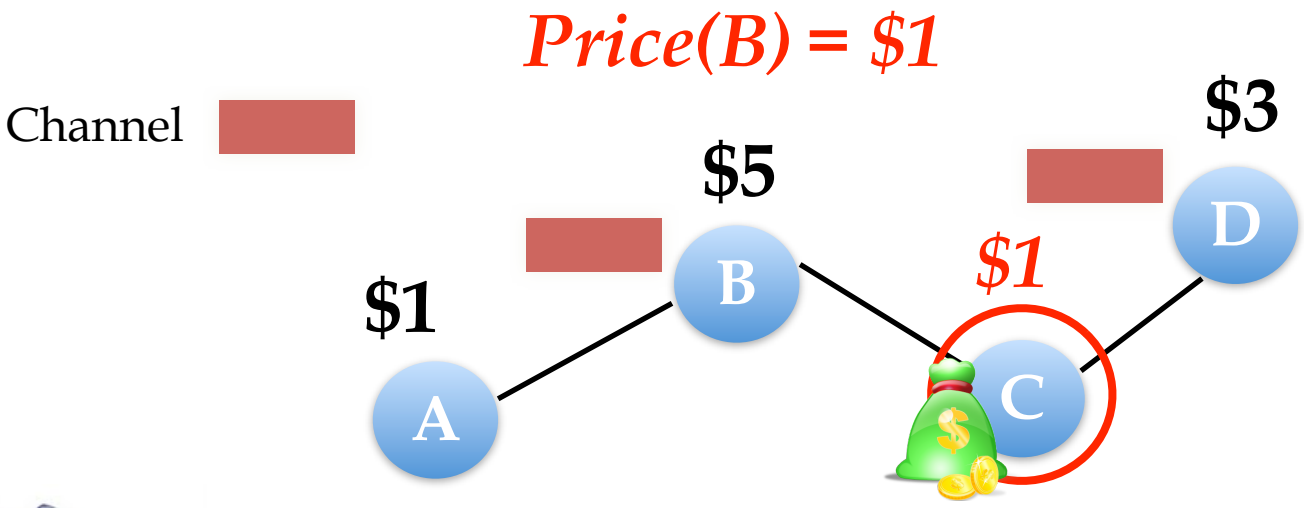

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- Impact on auction revenue
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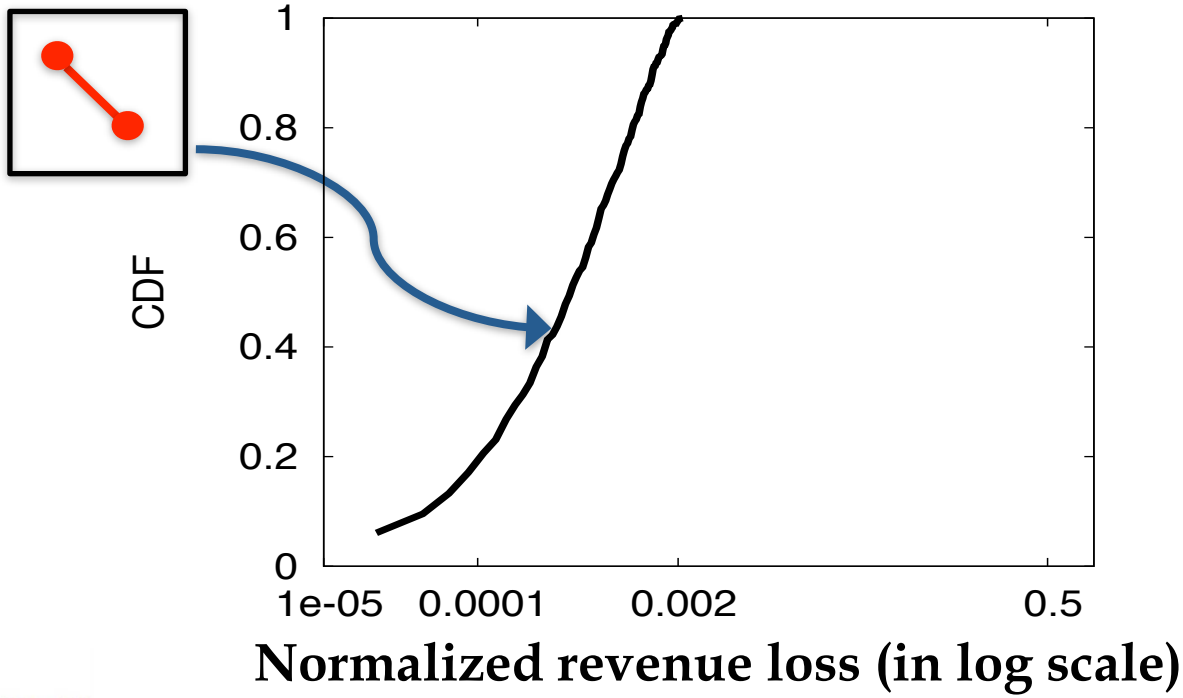

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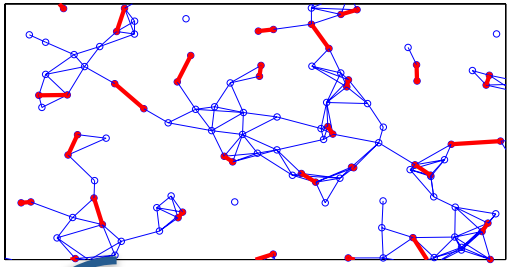
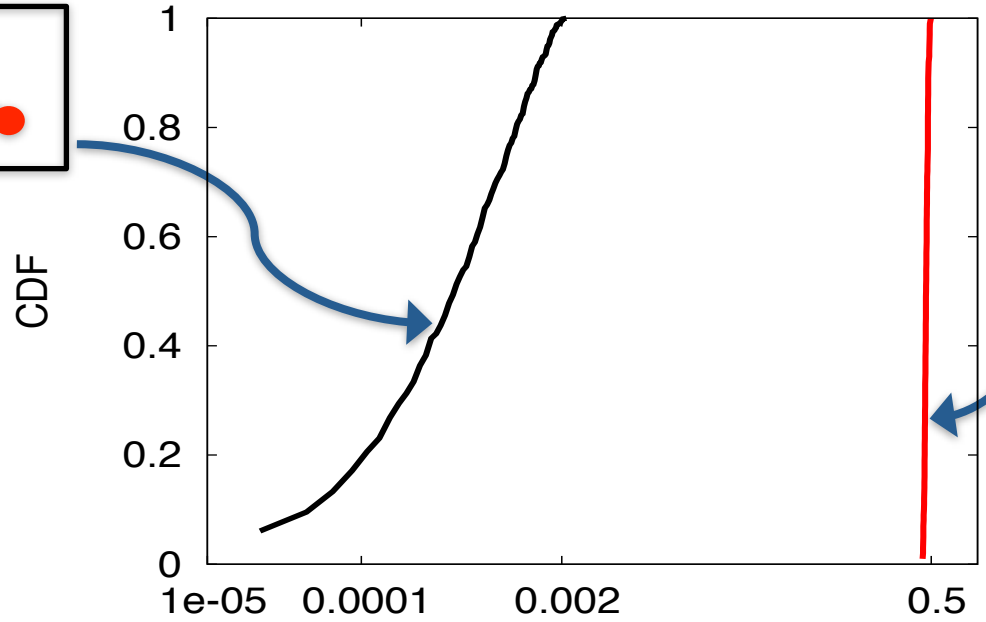
Multiple Collusion groups





Up to 50% revenue loss!

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- **Soft prevention while enabling spectrum reuse**
  - Existing designs assume "**all conflict**" or "**none conflicts**"
  - Need new design

Athena Spectrum Auctions

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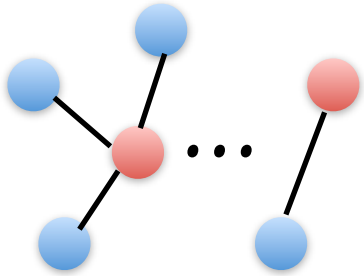

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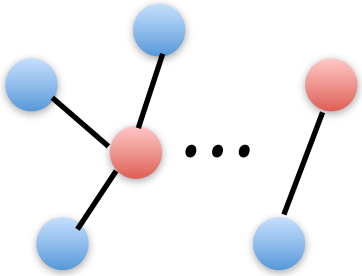

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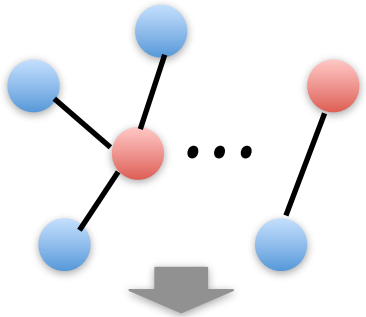

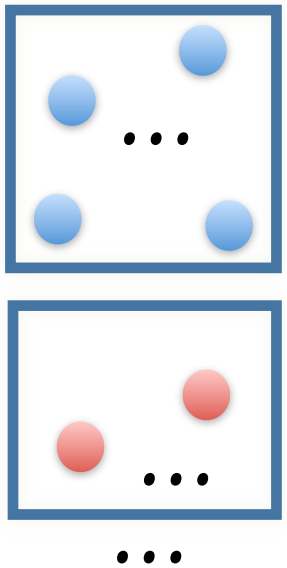

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  - Form bidder segments
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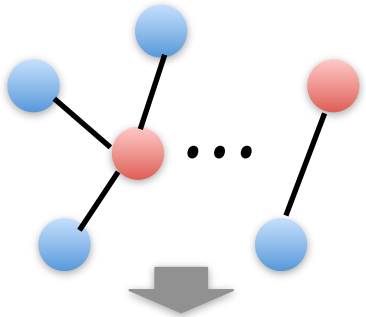

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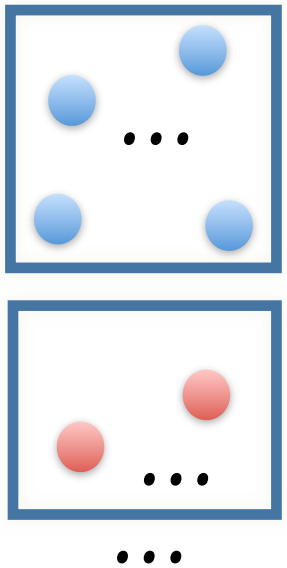

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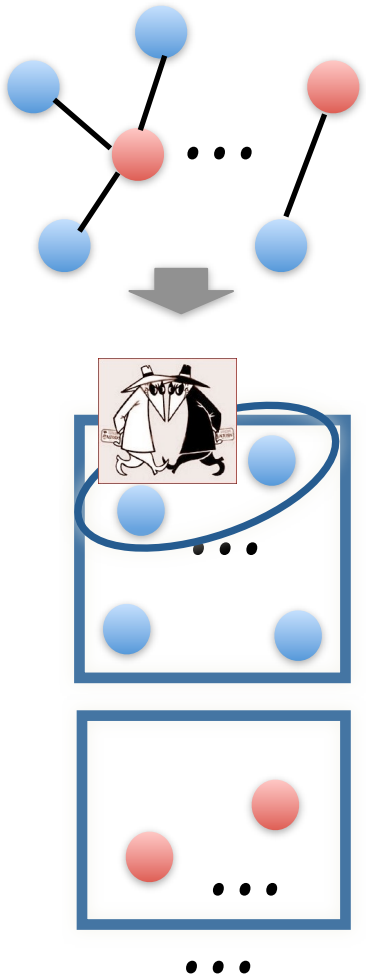

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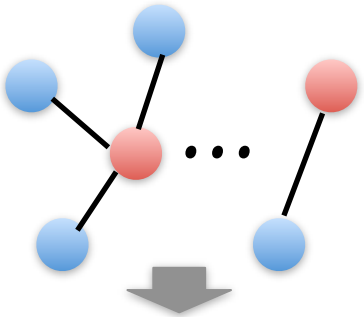

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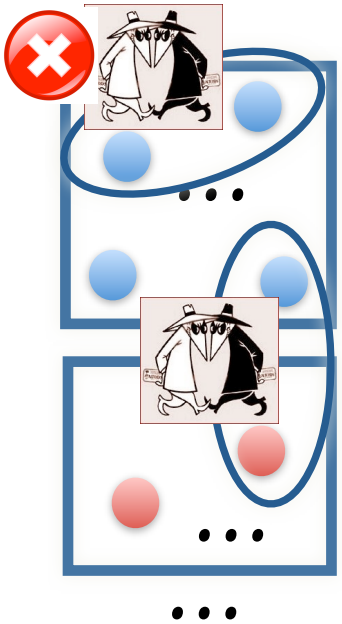

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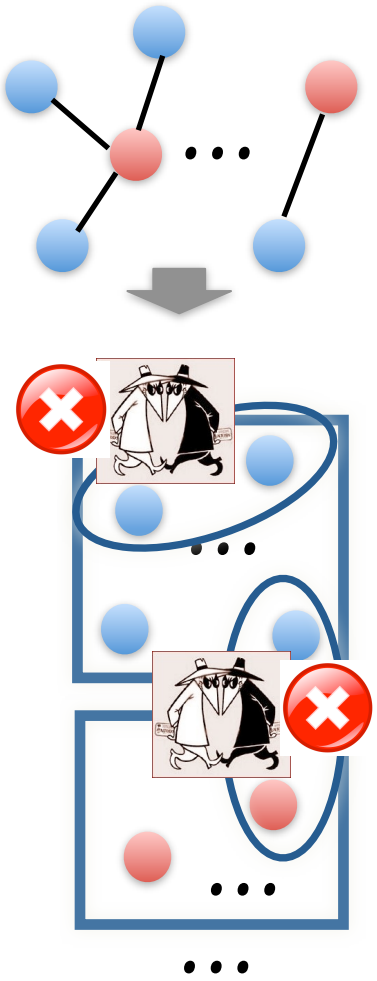

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Diminishing collusion gain

- Tackle collusion within a segment
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- Tackle collusion across segments
  - Add **randomness** to winning segment selection

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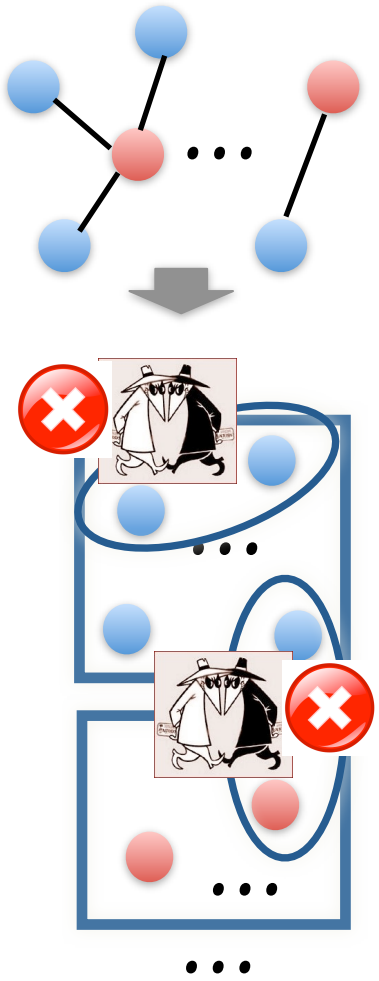

Enabling spectrum reuse

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Divide

Diminishing collusion gain

- Tackle collusion a segment
  - Use collusion- esign (tCP) to choose potential winn ch segment

Conquer

- Tackle collusion a segments
  - Add **randomn** ing segment selection

Combine

Detailed Design

Divide

Conquer

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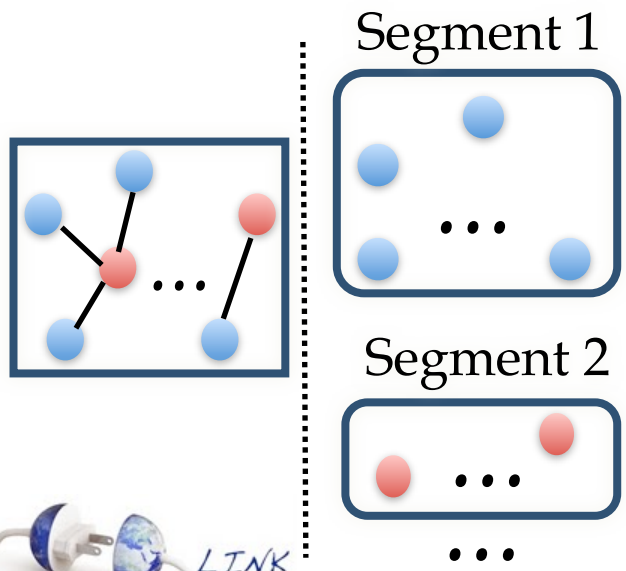
Detailed Design

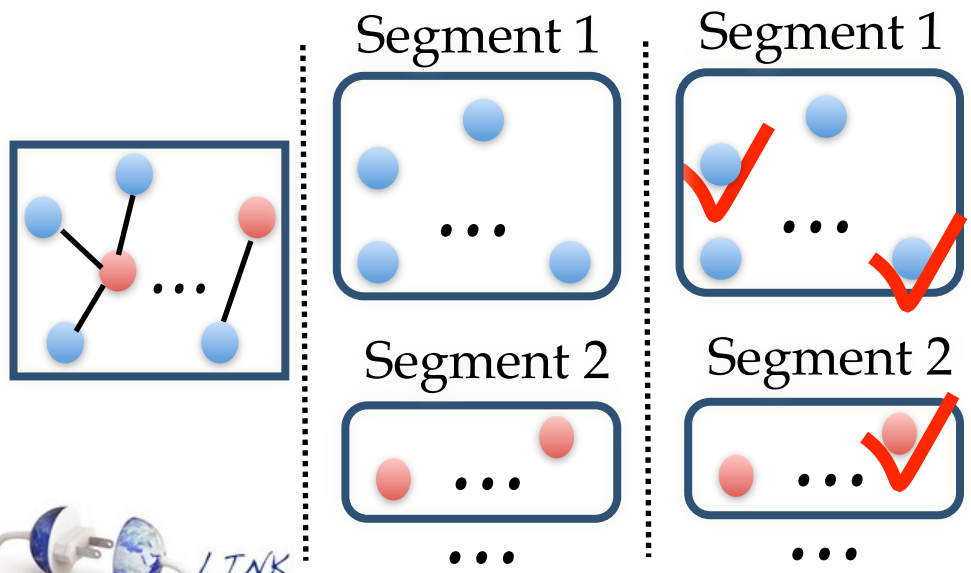
Divide | **Conquer** | **Combine**

- Divide bidders into segments
- Bidders in each segment do not conflict
- **Partition is bid-independent**



Detailed Design

Divide **Conquer** **Combine**

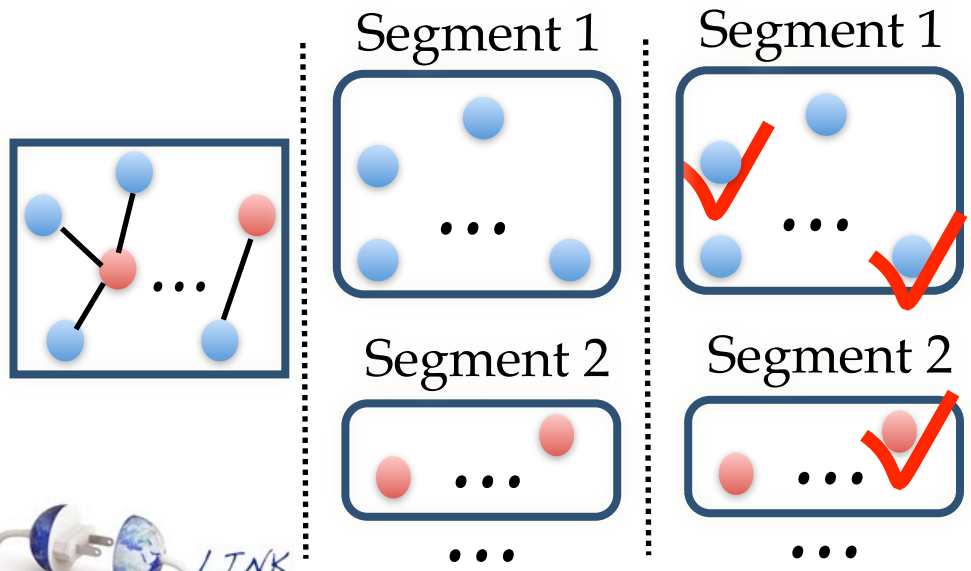


Detailed Design

Divide → **Conquer** → **Combine**

- For each segment i, select potential winners using a uniform price p_i
- **tCP** method[1]: make p_i **insensitive** to bid changes within segment i

  → **no gain for intra-segment collusion**



1: *[goldberg03]*

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- Estimate each segment's revenue
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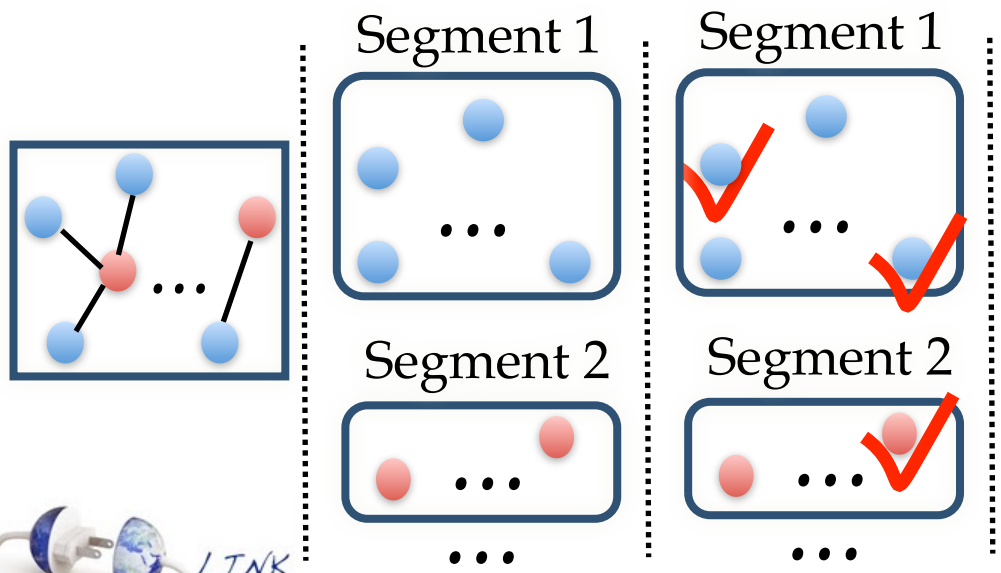
- **Add randomness in revenue estimation to diminish the impact of inter-segment collusion**



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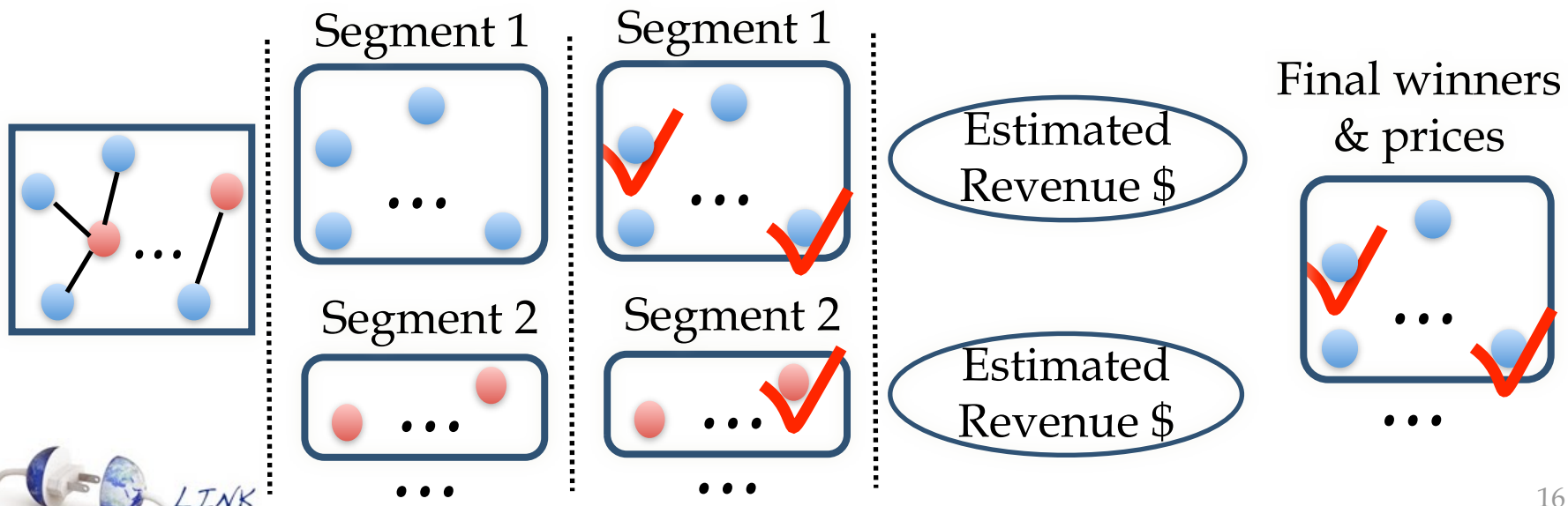


Summary

Divide

Spatial reuse by bid-independent partition

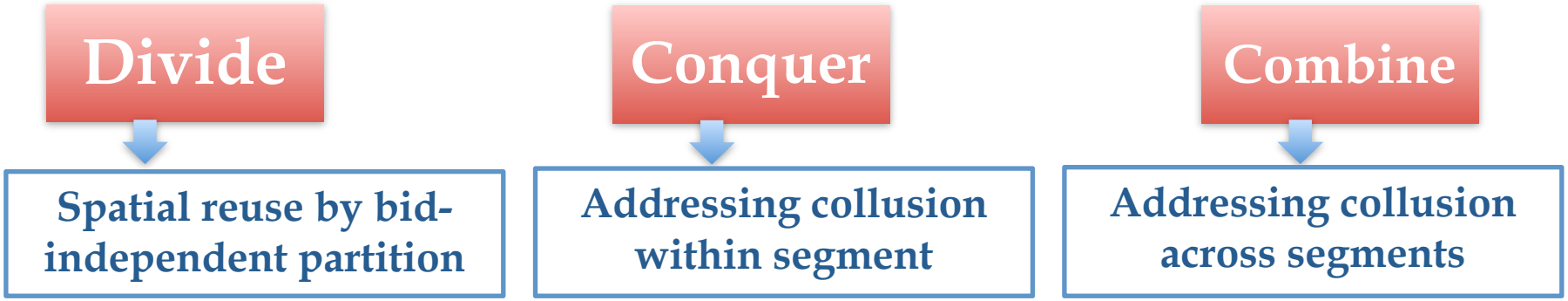
Conquer

Addressing collusion within segment

Combine

Addressing collusion across segments

Summary



- Athena's collusion resistance
  - ***(t, p)-truthfulness***: with probability ≥ p, no collusion group of ≤ t bidders can improve group utility by collusion
  - Athena achieves (t, p)-truthfulness, p depends on t and the #winners in the smallest segment

Fine-Tuning Athena

- ***Segment sizes*** affect the choice of the pricing scheme in 'Conquer' in order to maximize revenue given *(t, p)*
  - Uniform segment sizes
  - Non-uniform segment sizes
    - Carefully select segments running tCP and their configurations

- Athena's revenue bound
  - When all segments run tCP, the distance of Athena's revenue to the optimal is a function of ***t, p,* and segment sizes**

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- **Case study 1**: Effectiveness on resisting collusion
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- **Case study 2**: The cost of collusion resistance
  - How much revenue Athena needs to sacrifice for collusion-resistance?
  - Compare to VERITAS (truthful auctions)

Athena's Collusion Resistance

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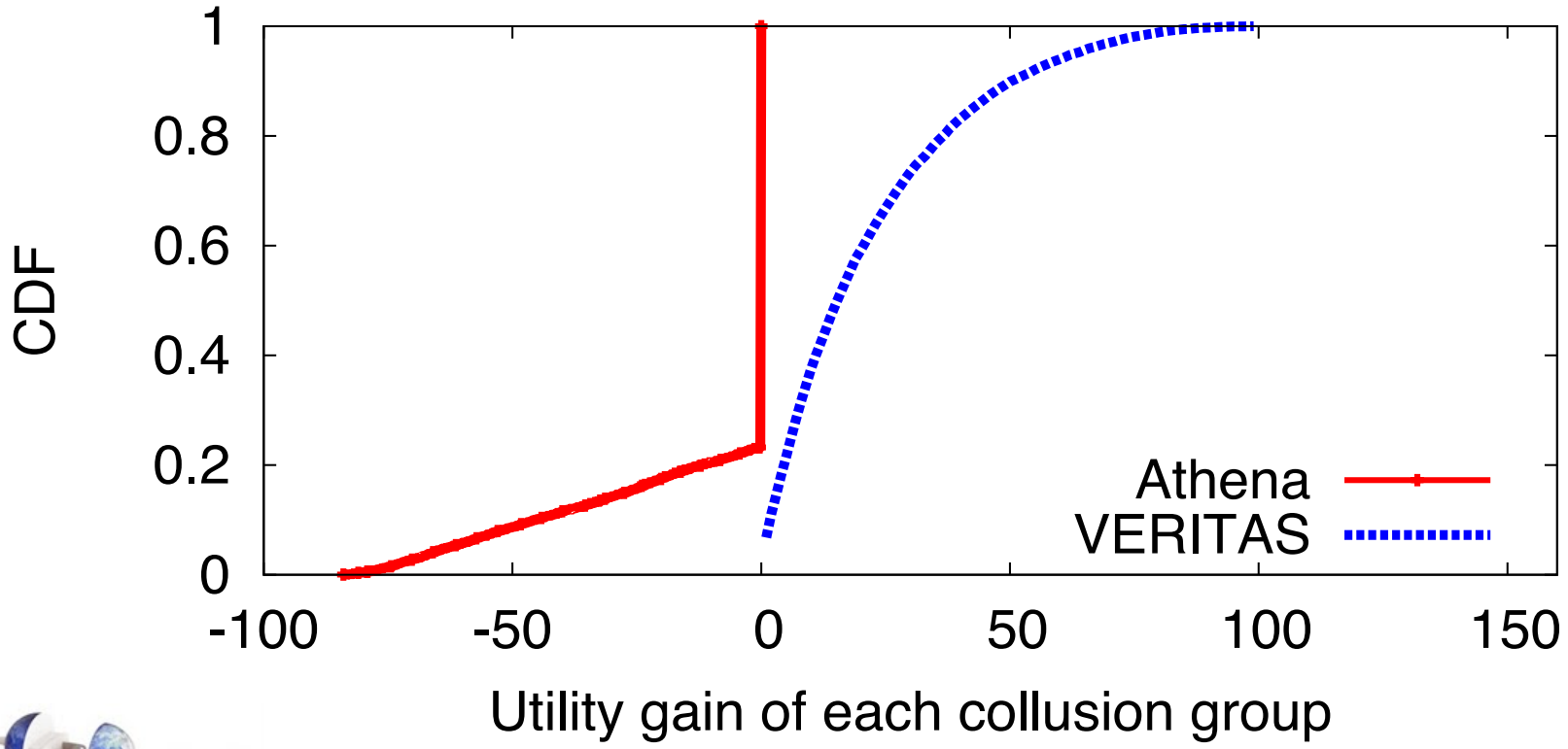
- Experimental result ($t = 2$, $p = 0.9$)
  - WCN collusion as an example



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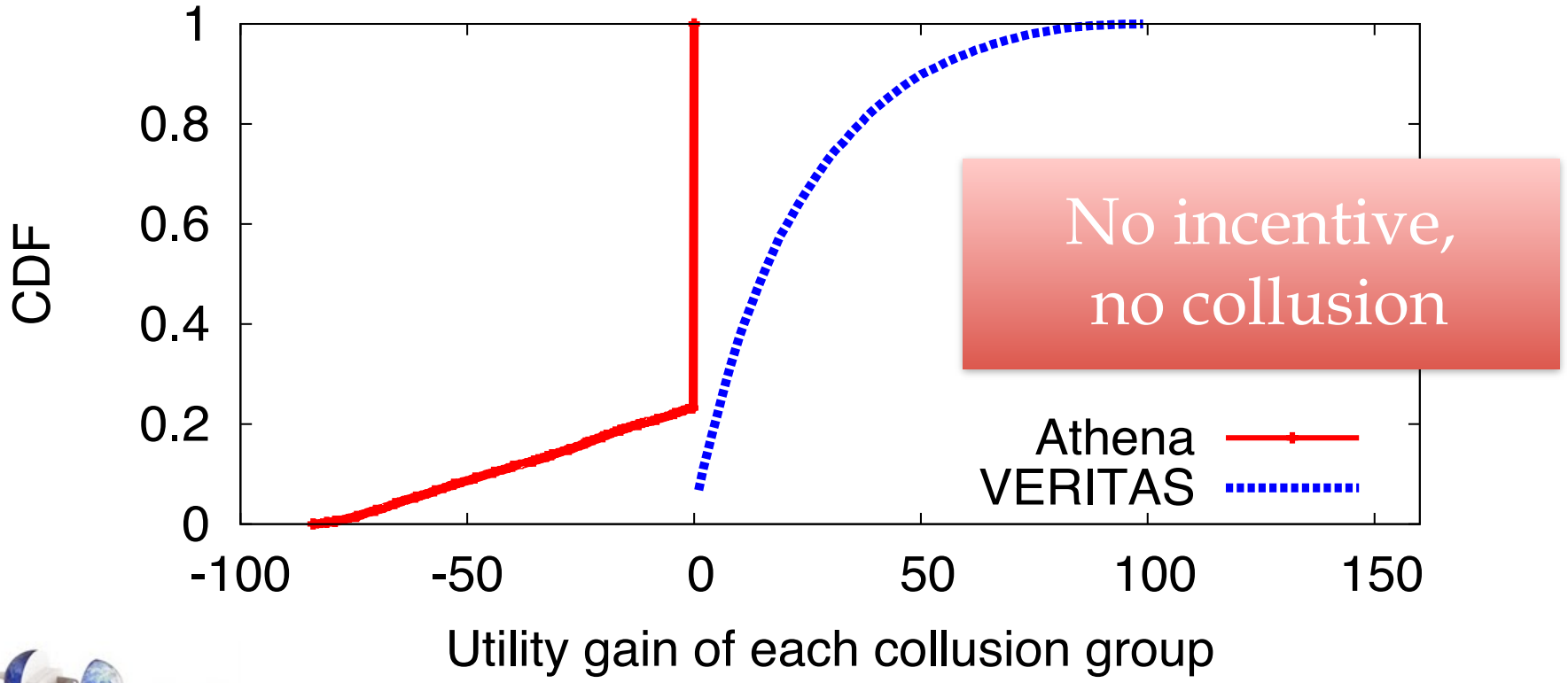

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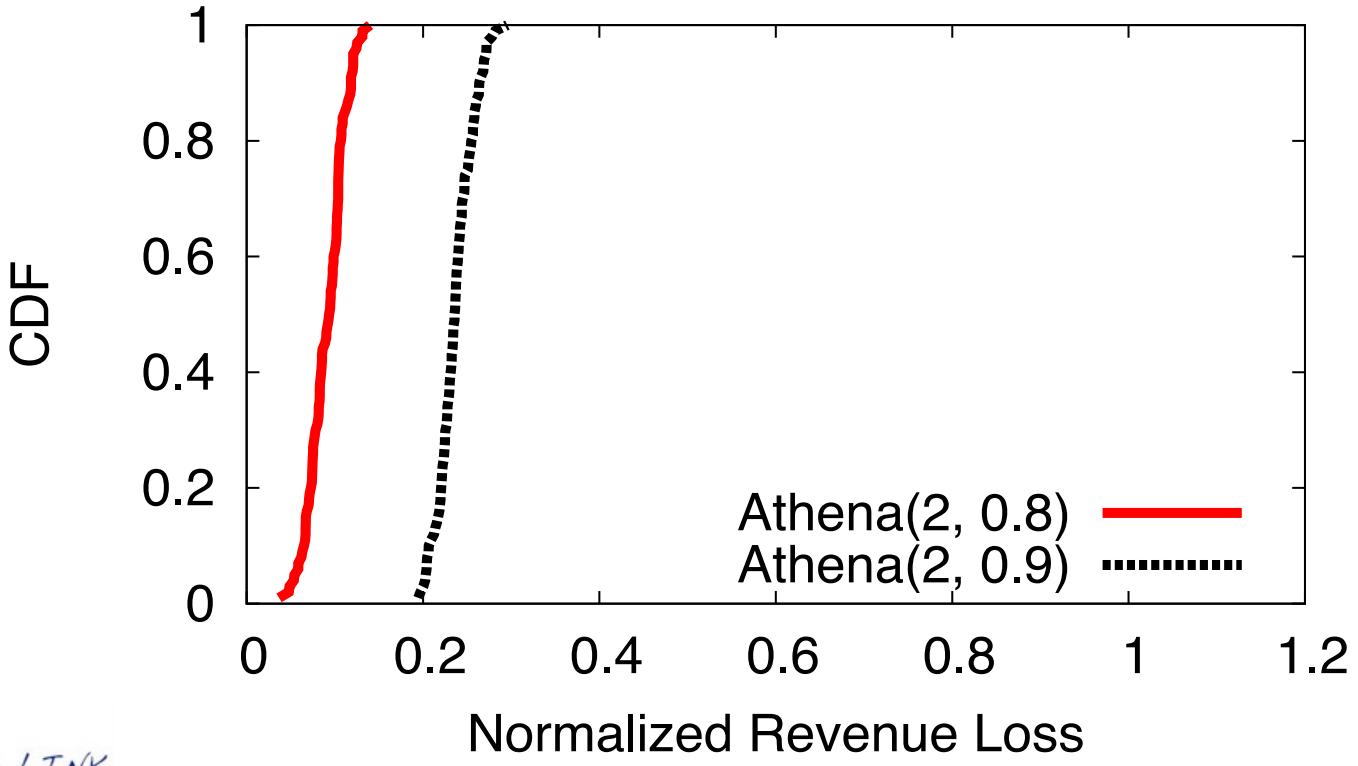

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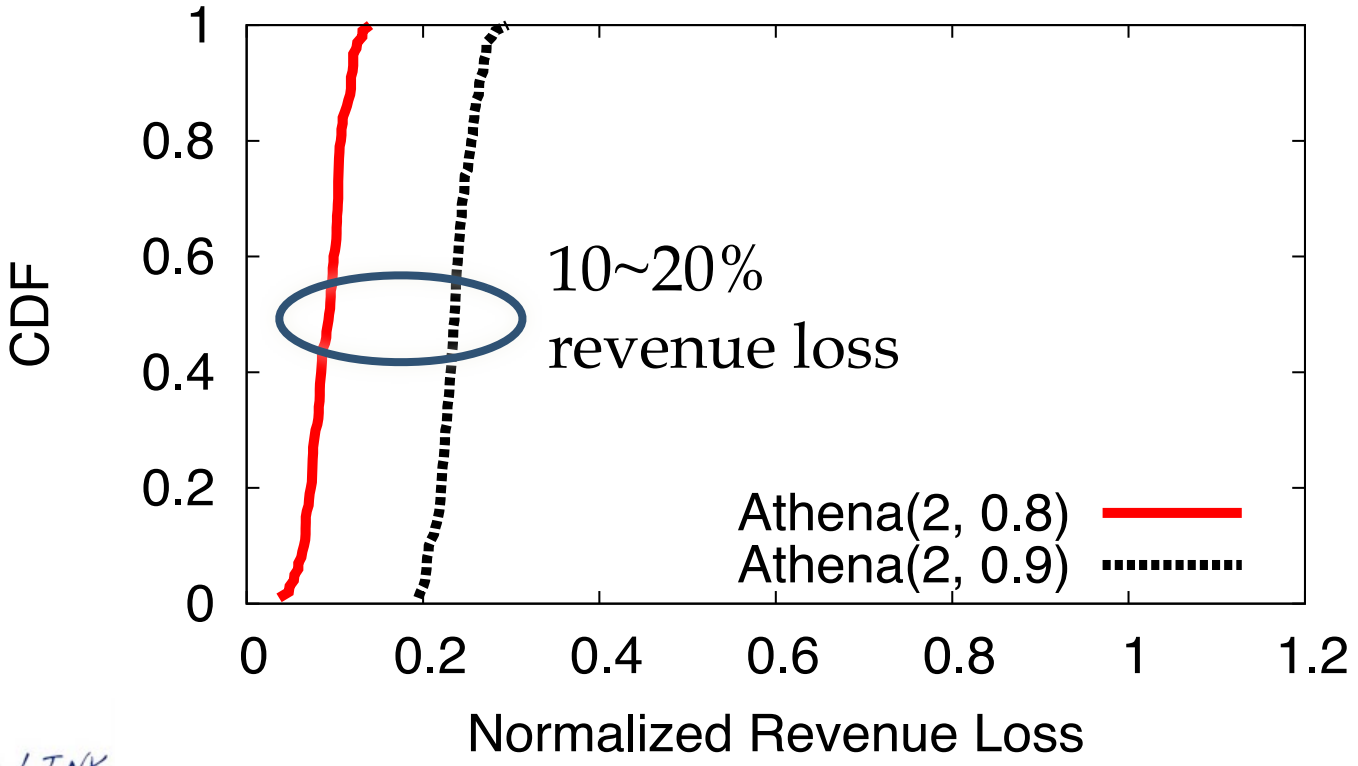

The Cost of Collusion-Resistance

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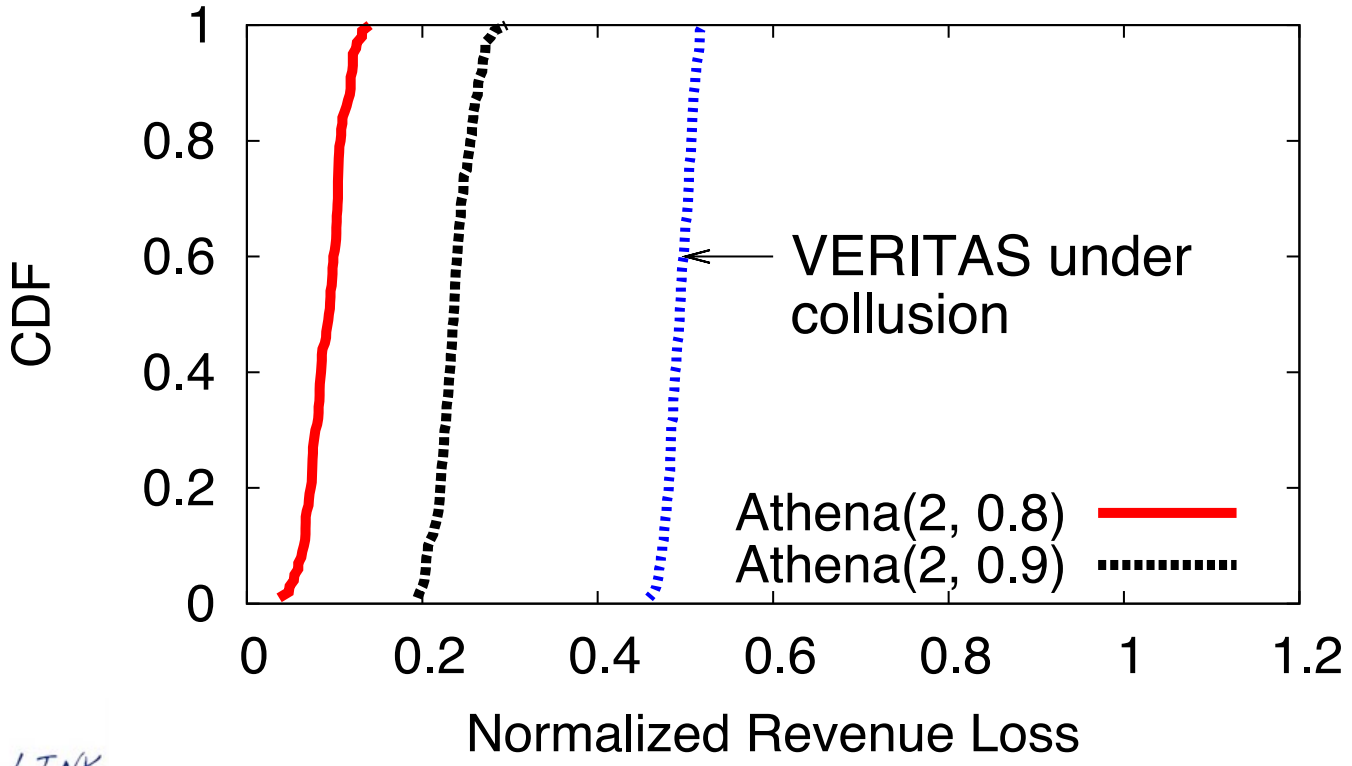

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  - Customizable collusion-resistance
- Future work
  - Extend to multi-channel request
  - Explore the optimal segment formation

Q & A

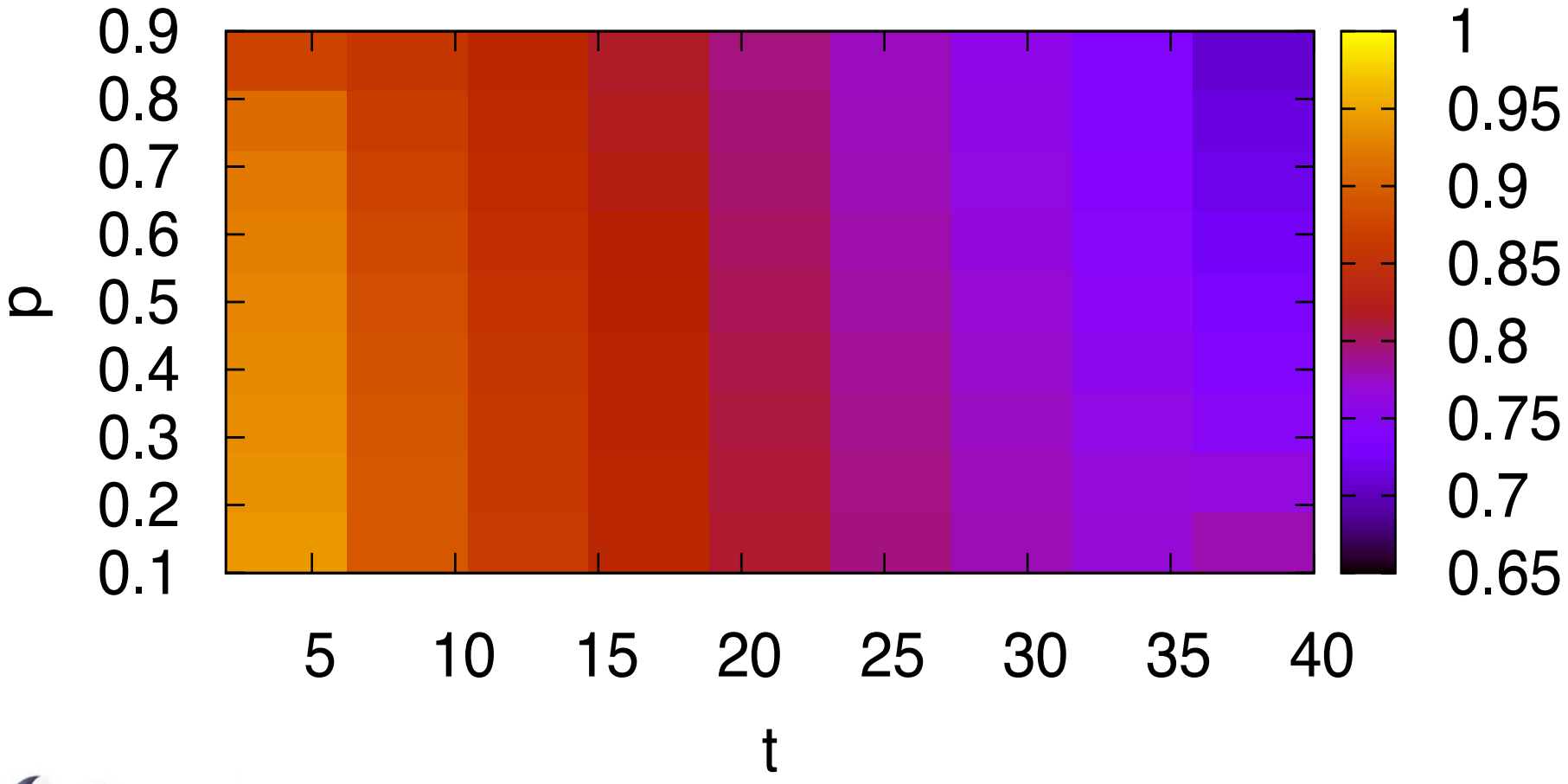
- Thanks!

For more information, please visit:

http://link.cs.ucsb.edu/project/mercury.html

BACK-UP SLIDES

For all (*t*, *p*)


p
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5
10
15
20
25
30
35
40
t
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65

Comparing to Posted Price

- Assuming no bidders collude due to the awareness of the design's collusion resistance

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