Link LAB
Dept. of Computer Science
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TRUST: A General Framework for Truthful Double Spectrum Auctions

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Addressing Inefficient Spectrum Distribution

- Legacy wireless providers own the majority of spectrum
  - But cannot fully utilize it

- New wireless providers are dying for usable spectrum
  - But have to crowd into limited unlicensed bands

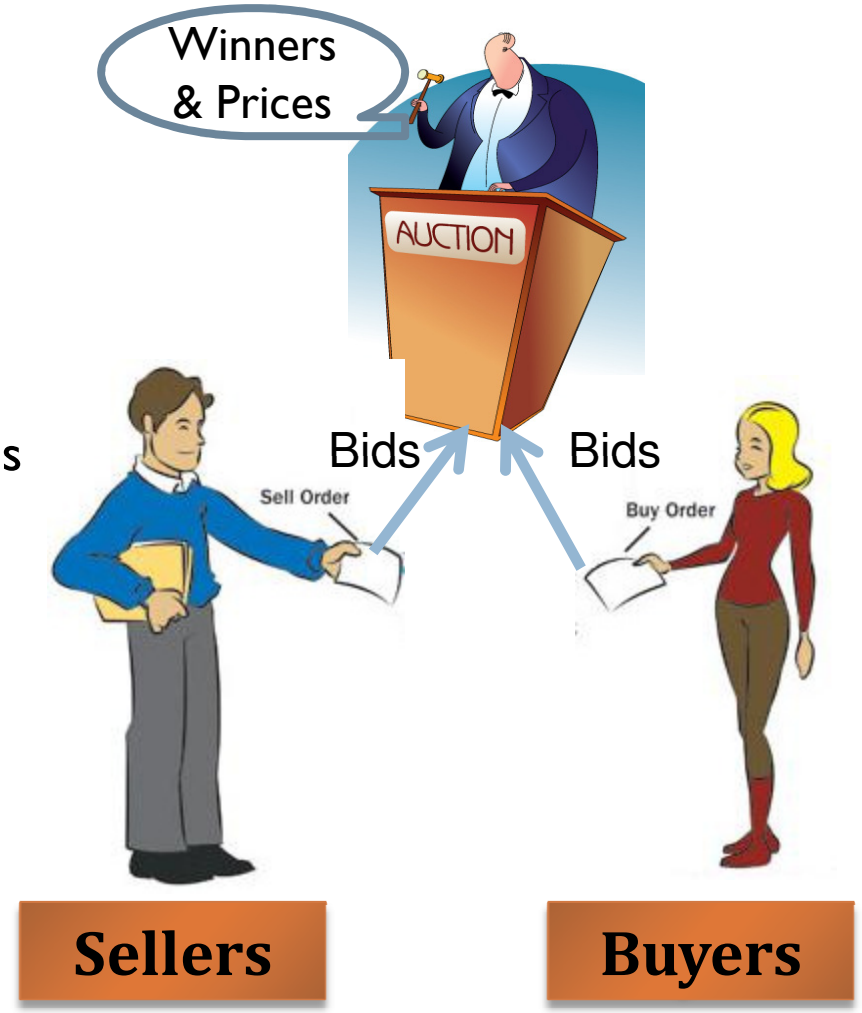
→ **Sellers**

→ **Buyers**

Market-based Spectrum Trading

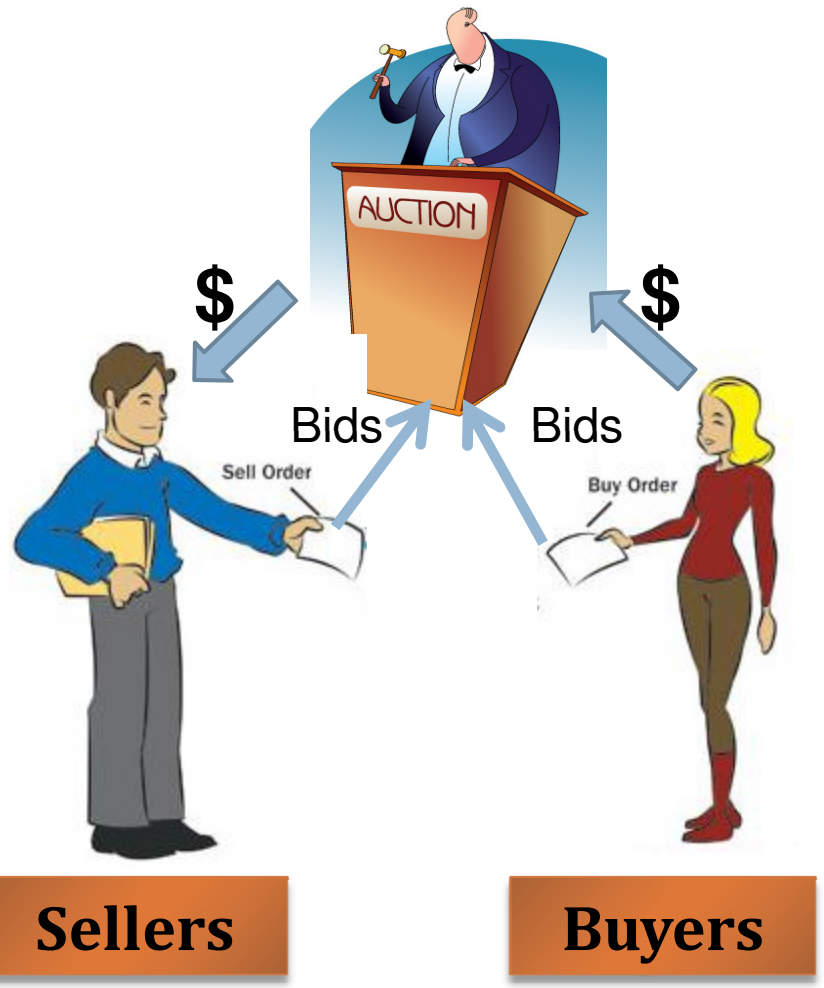
Enabling Trading by Double Auctions

- Double Auctions:
  - **Sellers** and **buyers** are bidders
    - Seller's bid: the minimal price it requires to sell a channel
    - Buyer's bid: the maximal price it is willing to pay for a channel
  - Auctioneer as the match maker
    - Select winning buyers and sellers



Need Judicious Auction Designs

- **Need to achieve 3 economic properties**
  - Budget balance: Payment to sellers <= Charge to buyers
  - Individual rationality:
    - Buyer pays less than its bid
    - Seller receives more than its bid
  - Truthfulness: bid the true valuation
- **Need to provide efficient spectrum distribution**



Our Contribution

- Enable **spectrum trading** by economic robust double auctions

- Achieving the three economic properties:
  - Budget balance
  - Individual rationality
  - Truthfulness

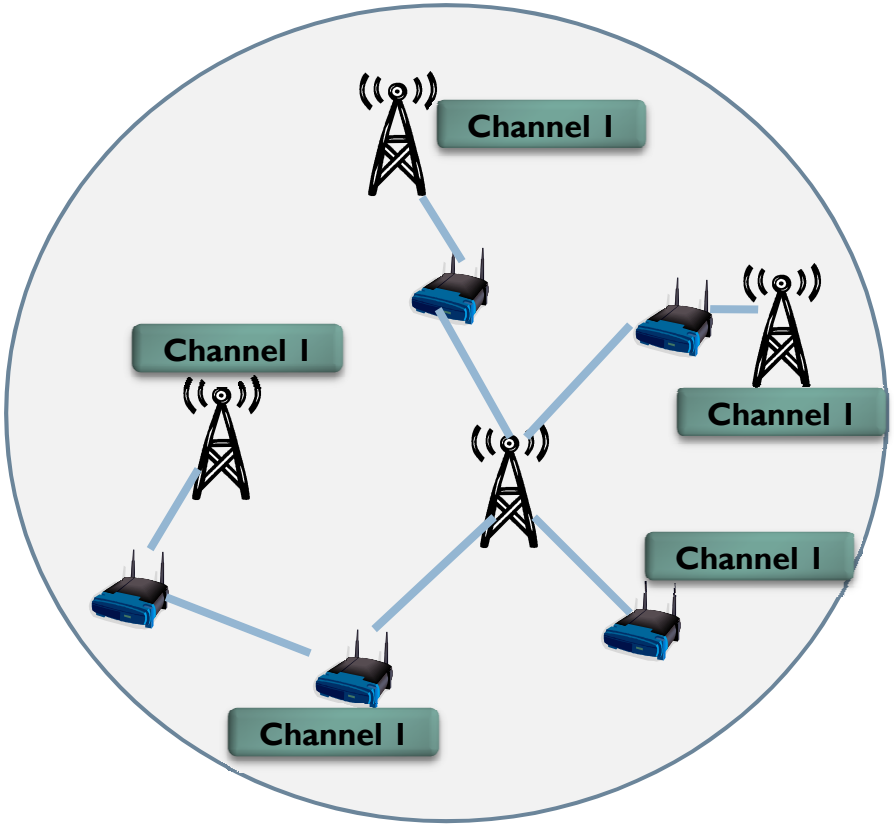
  while trying to maximize spectrum efficiency
  - **Achieve spectrum reuse among non-conflicting buyers**

Outline

- Motivation of TRUST
- Challenges of enabling double spectrum auctions
- TRUST design & auction properties
- Evaluations
- Conclusions & Future extensions

What Makes Double Spectrum Auctions Different?

- Must exploit spectrum reuse
  - One seller can support multiple buyers
- Traditional auction
  - 1 channel → 1 buyer
- Spectrum auction
  - 1 channel → a set of buyers



Existing Solutions No Longer Apply

	Truthfulness	Individual Rationality	Budget Balance	Spectrum Reuse
McAfee's Double Auction	√	√	√	X
VCG Double Auction	√	√	X	X
Extension of Single-sided Truthful Auction	X	√	√	√
Our Goal	√	√	√	√

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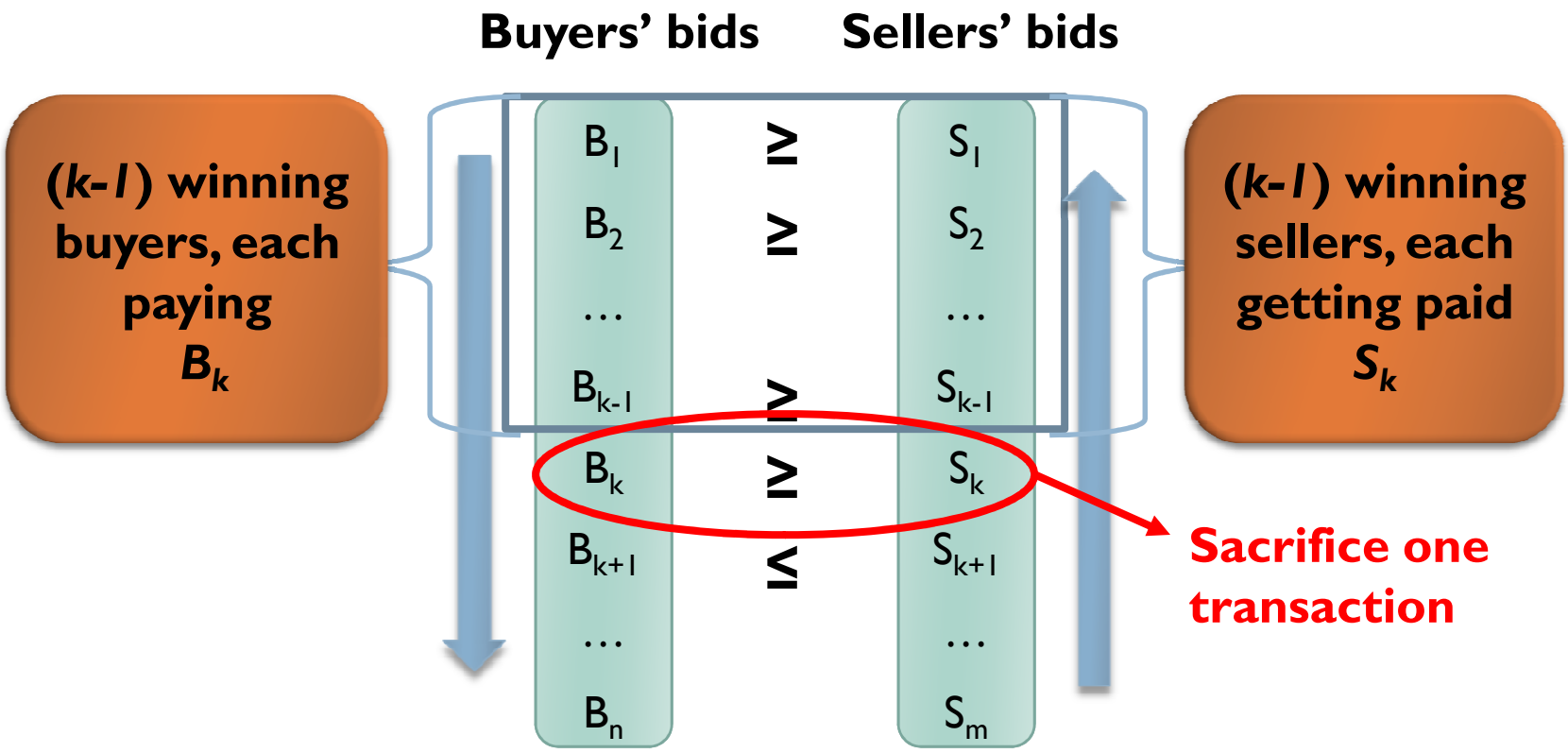
Design Guidelines

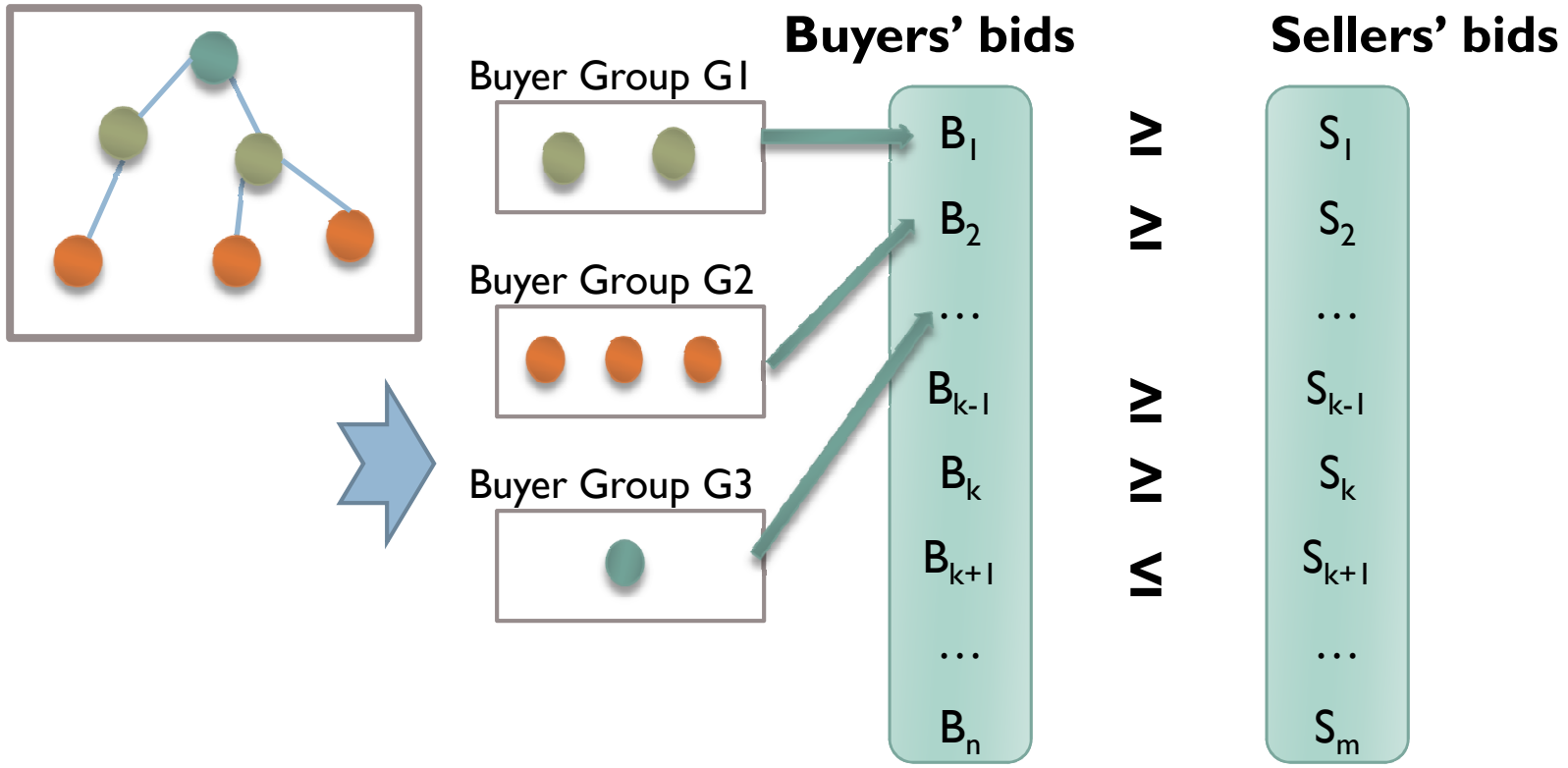
- Start from the McAfee design: the most popular truthful double auction design
  - Achieve all three economic properties without spectrum reuse
- Extend McAfee to assign multiple buyers to each single seller
  - Enable spectrum reuse among buyers
- Design the procedure judiciously to maintain the three economic properties

McAfee Double Auction



- Achieve budget balance, truthfulness, individual rationality without spectrum reuse

Enabling Spectrum Reuse



- Map a group of non-conflicting buyers to one seller

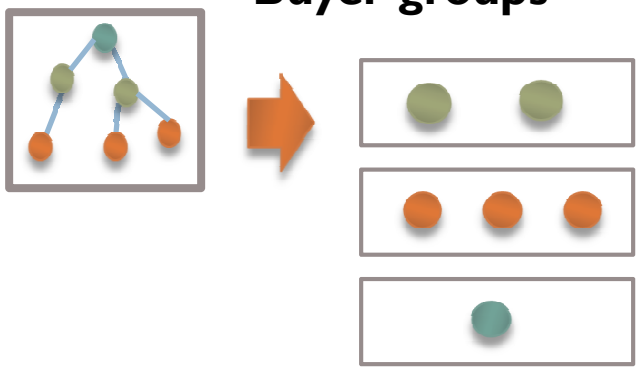
TRUST: Design

Form buyer group | **Decide the bid of each buyer group** | **Charge individuals in a winning buyer group**

Bid-independent Group Formation

1. Allocate one virtual channel to each buyer
2. Group buyers allocated with the same channel together

Buyer groups



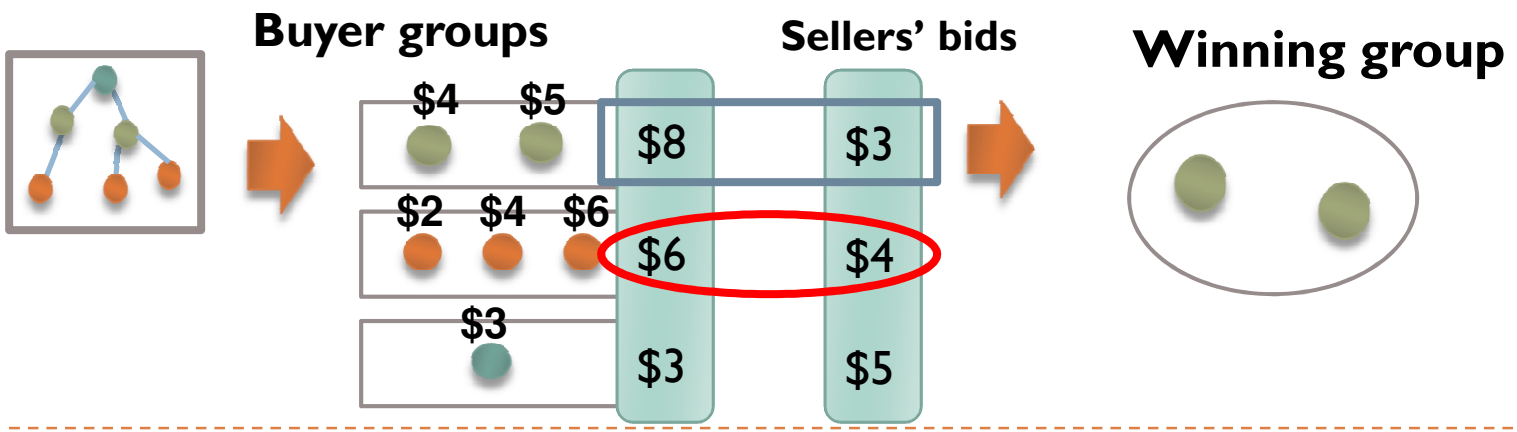
TRUST: Design

Form buyer group

Decide the bid of each buyer group; Apply McAfee

Charge individuals in a winning buyer group

Buyer group i's bid =
The lowest bid in group i * #of bidders in group i



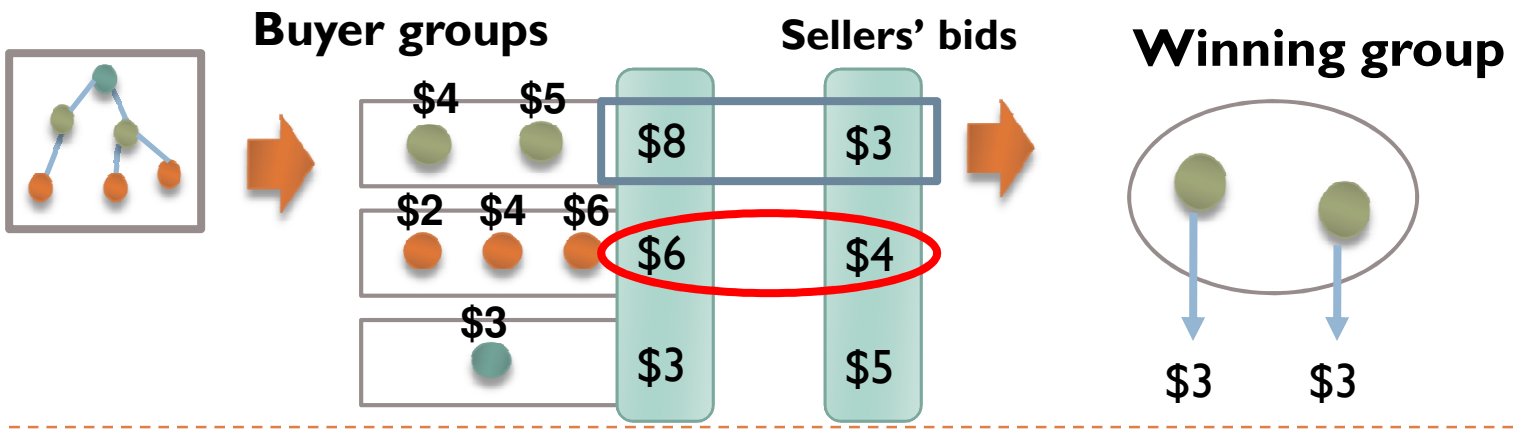
TRUST: Design

Form buyer group

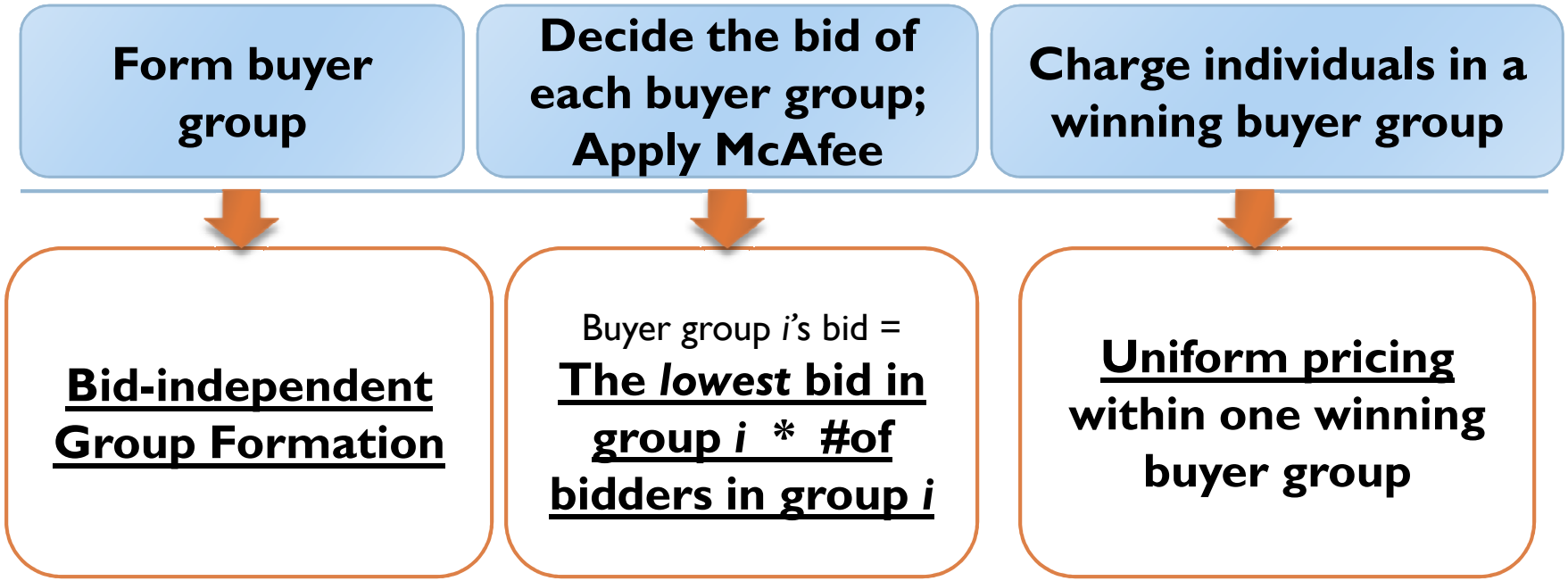
Decide the bid of each buyer group; Apply McAfee

Charge individuals in a winning buyer group

<u>Uniform pricing</u> within one winning buyer group

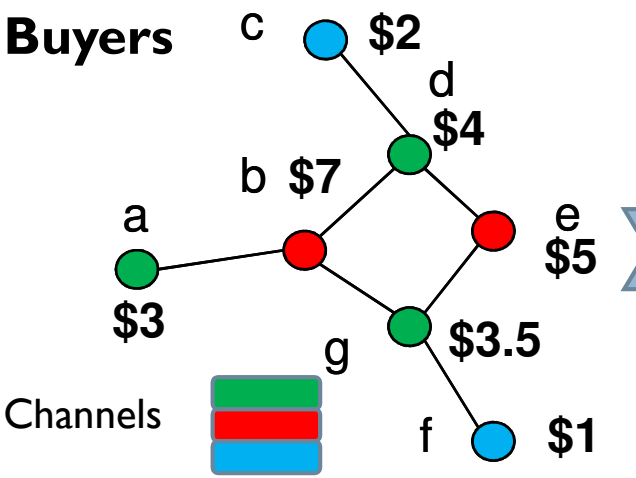


TRUST: Auction Properties



Theorem 1. TRUST is ex-post budget balanced, individual rational, and truthful.

TRUST: Example

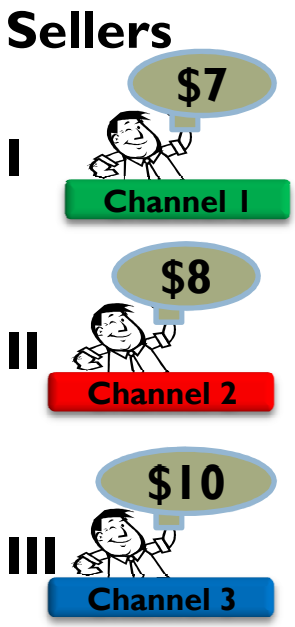


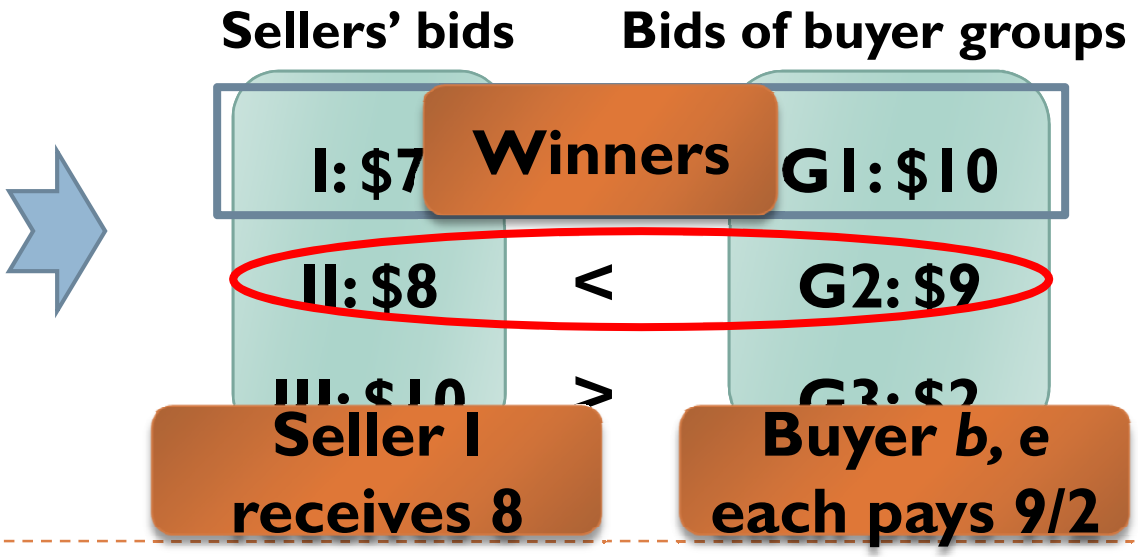
Buyer groups:

-- G1: {b, e} → $10

-- G2: {a, d, g} → $9

-- G3: {c, f} → $2





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TRUST: Evaluations

- Impact of **economics** on spectrum distribution
- Impact of **topologies of buyers**
- Impact of **bid patterns (variance)**

Allocation Algorithms

- Max-IS
- Greedy-U
- Greedy
- RAND

Topologies

- Random topology
- Cluster topology

Bid Distribution

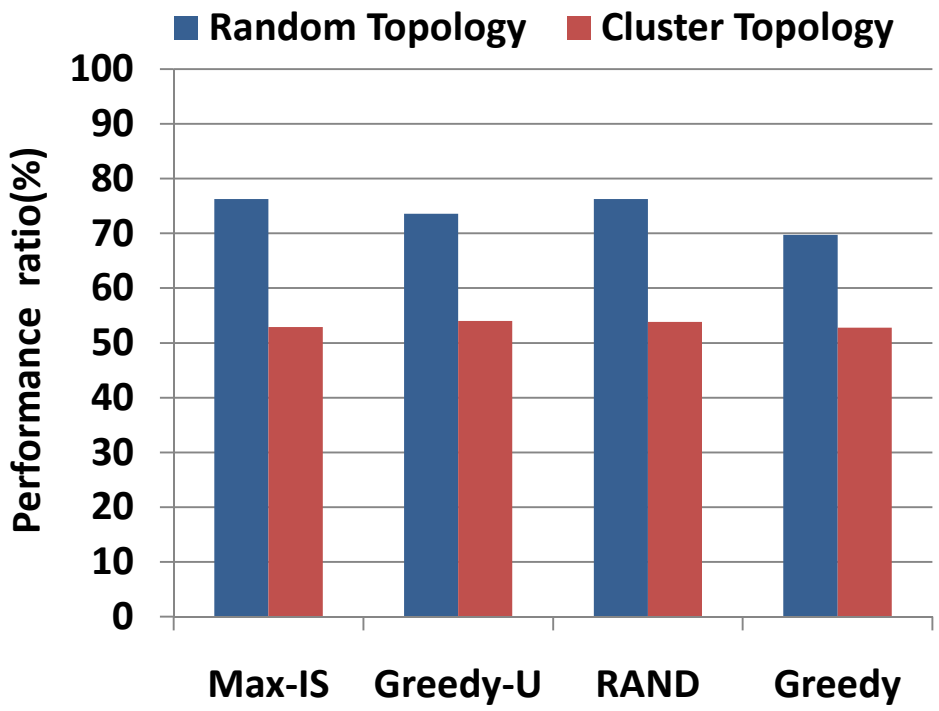
Bid b is generated by:

$$b = v \cdot \alpha + (1 - v)$$

- v : range of variance
- α: ~ U[0,1]

TRUST: Economic Impact

- Comparing to traditional spectrum allocation algorithms without economic factors, they choose groups by **sizes**
  - Performance ratio = $\frac{\text{Utilization of TRUST}}{\text{Utilization of spectrum allocations}}$



- **TRUST chooses buyer group by the lowest bid * group size**
- **In cluster topology, larger fraction of small groups, larger discrepancy in group sizes**

Conclusions

- Dynamic spectrum trading using double auctions
  - The first work on truthful double spectrum auction while enabling spectrum reuse
    - Work with any spectrum allocation algorithm
  - Examine the impact of economic designs on spectrum distribution
    - Must tradeoff spectrum efficiency for economic robustness
- Extensions
  - Allow each bidders to buy / sell multiple channels
  - How the auctioneer obtains interference conditions
  - Achieve other economic properties i.e. collusion resistance

- Thank You!

Additional information at

http://link.cs.ucsb.edu

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