Plan for Today

2/23 SD3
3/5 SD4
in class 3/10
paper 3/15
reviews 3/19

- FCC Incentive Auction
- Bitcoin

Spectrum

- Spectrum is used to transmit and receive information.
- FCC manages and allocates this spectrum.
  - Prevents devices from interfering each other by selling licenses
  - A license authorizes particular spectrum use on particular frequency bands in fixed geographic area.
- Finite resource – in 2012 insufficient amount left for next generation wireless (owned by TV broadcasters).
- Proposal: Run a double auction to buy back spectrum from TV broadcasters and sell to telecom companies.

F.C.C. Backs Proposal to Realign Airwaves

The New York Times

September 28, 2012 **By EDWARD WYATT**

WASHINGTON — The government took a big step on Friday to aid the creation of new high-speed wireless Internet networks that could fuel the development of the next generation of smartphones and tablets, and devices that haven't even been thought of yet.

The five-member Federal Communications Commission unanimously approved a sweeping, though preliminary, proposal to reclaim public airwaves now used for broadcast television and auction them off for use in wireless broadband networks, with a portion of the proceeds paid to the broadcasters.

The initiative, which the F.C.C. said would be the first in which any government would pay to reclaim public airwaves with the intention of selling them, would help satisfy what many industry experts say is booming demand for wireless Internet capacity.

Mobile broadband traffic will increase more than thirtyfold by 2015, the commission estimates. Without additional airwaves to handle the traffic, officials say, consumers will face more dropped calls, connection delays and slower downloads of data.

FCC Incentive Auction

Reverse auction: Where government buys back spectrum from their current owners.

Forward auction: Where government sells spectrum to telecom companies.

Repeatedly, set target for reverse auction.

Sell licenses in forward auction.

Repeat until revenue >= 0, decreasing the target each time.

How did it go?

Finished in March 2017

Government spent ~10 billion in reverse auction

Earned ~20 billion in forward auction.

Reverse auction

Interative ”descending clock” auction:

- In each round, each broadcaster is offered a buyout price.
- These prices decrease over time.
- If broadcaster accepts, moves to next round.
- If broadcaster rejects, exits and keeps license.
- Stop when target amount of spectrum has been cleared.
- Each broadcaster that did not exit sells its broadcast rights at the last price it had agreed to.

Reverse auction

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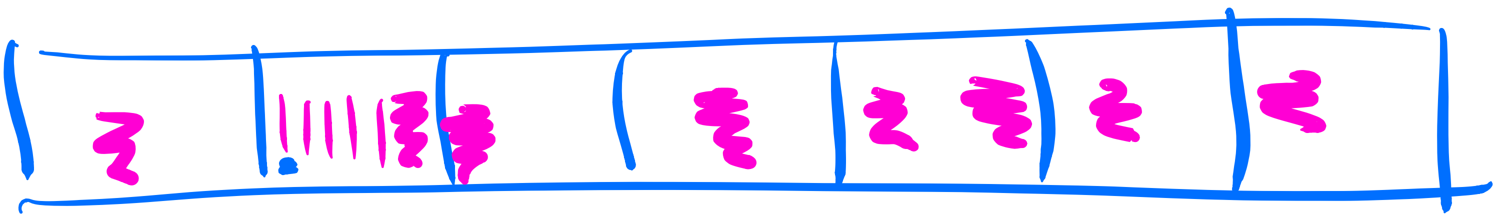
Assume that each TV station (broadcaster) has a value for their station.

What is their best strategy in the auction?

Problem

- Spectrum divided into channels – blocks of 6 MHz.
- Say targeted broadcasters are currently assigned to 16 channels and goal is to clear 12 of these.
- Clearing = clearing nationwide.
- Problem: bidders drop out in uncoordinated way.

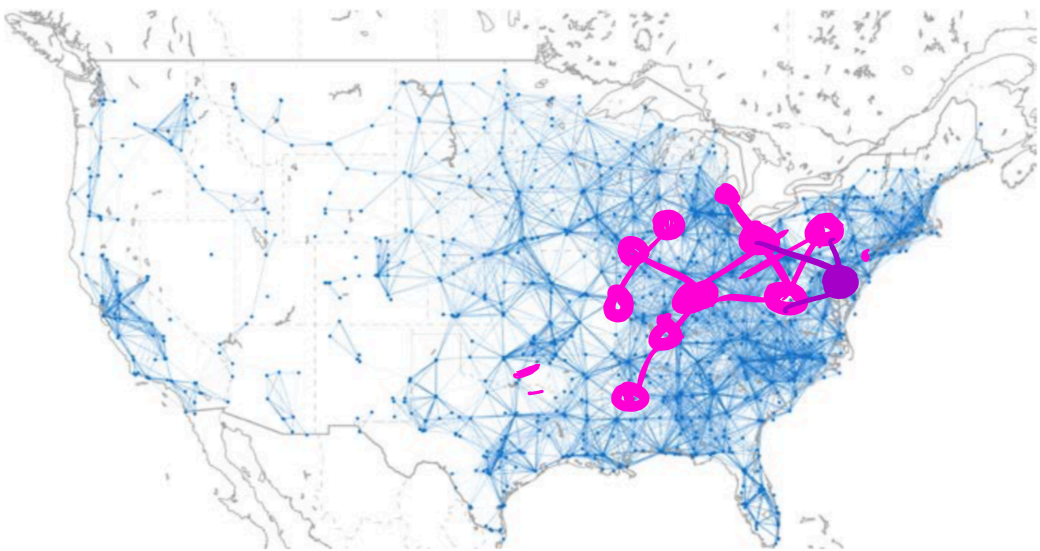


Problem

- Spectrum divided into channels – blocks of 6 MHz.
- Say targeted broadcasters are currently assigned to 16 channels and goal is to clear 12 of these.
- Clearing = clearing nationwide.
- Problem: bidders drop out in uncoordinated way.
- **Solution:** stations that drop out are guaranteed to retain a license, but not guaranteed to retain the same channel.
- Need to be able to assign dropped out broadcasters to 4 channels.

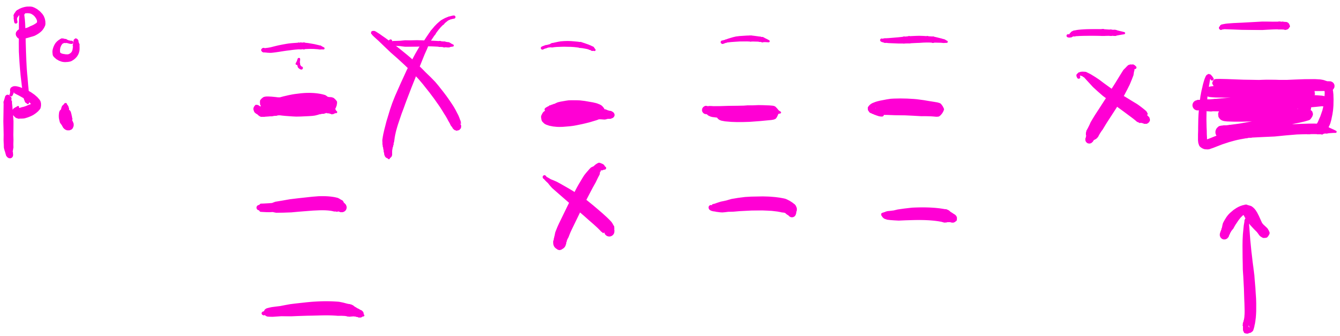
Need to maintain invariant that stations that have dropped out can be assigned to at most a target number of channels.

- Two stations with overlapping broadcasting regions cannot be assigned to the same channel.

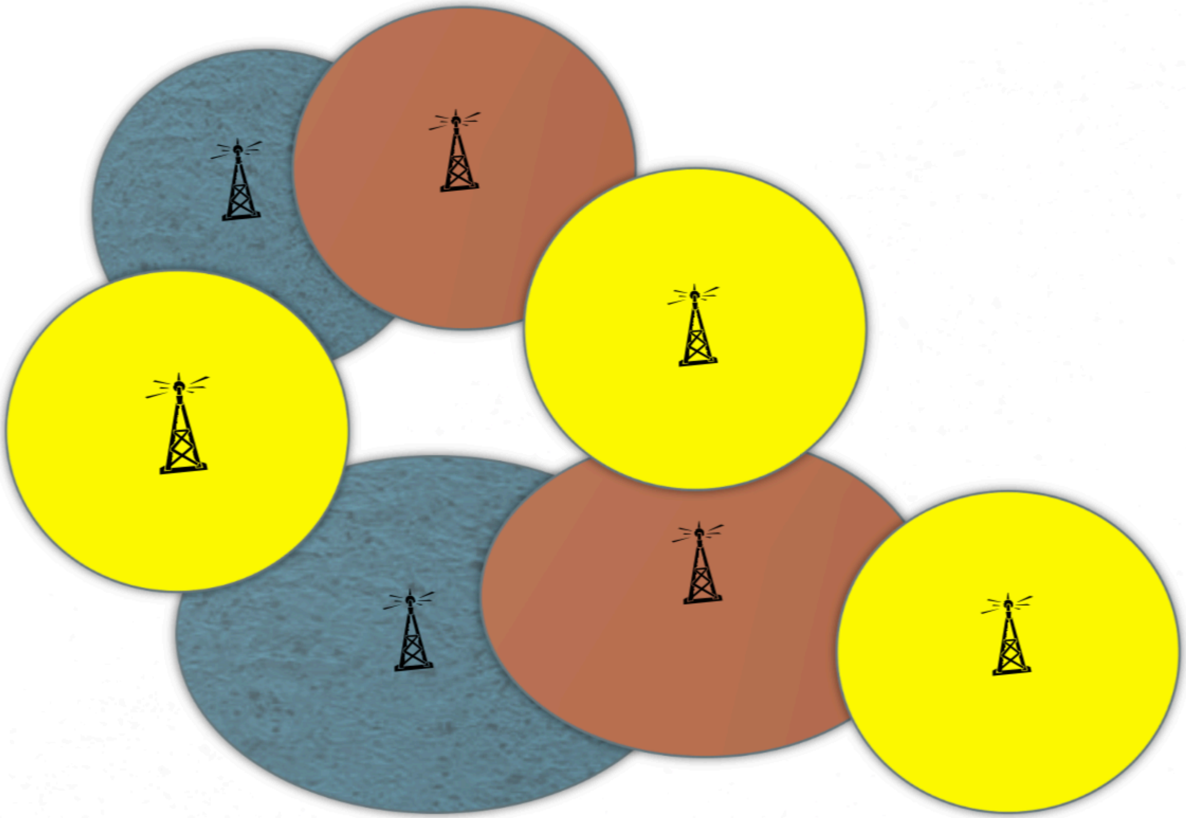


Repacking Problem

- Given a set of broadcasters, can they be packed into, say, 4 channels.



The Repacking Problem



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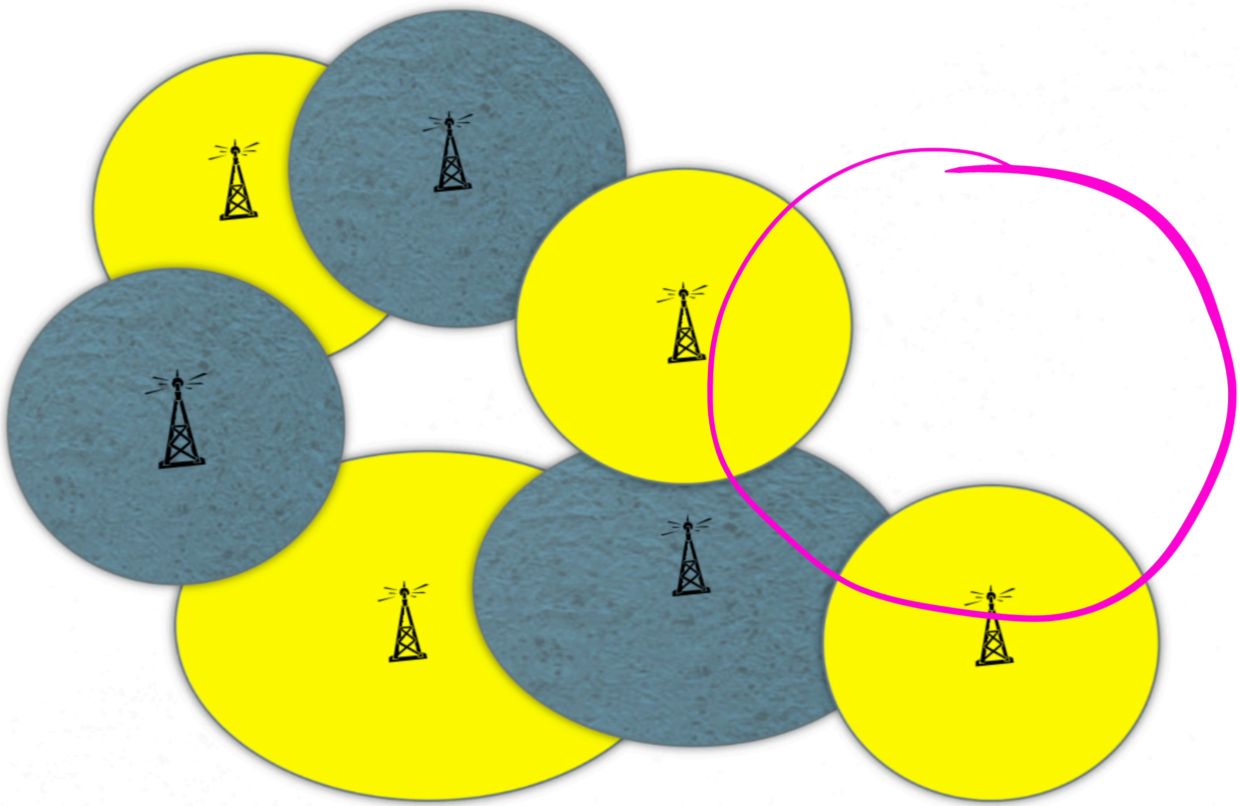

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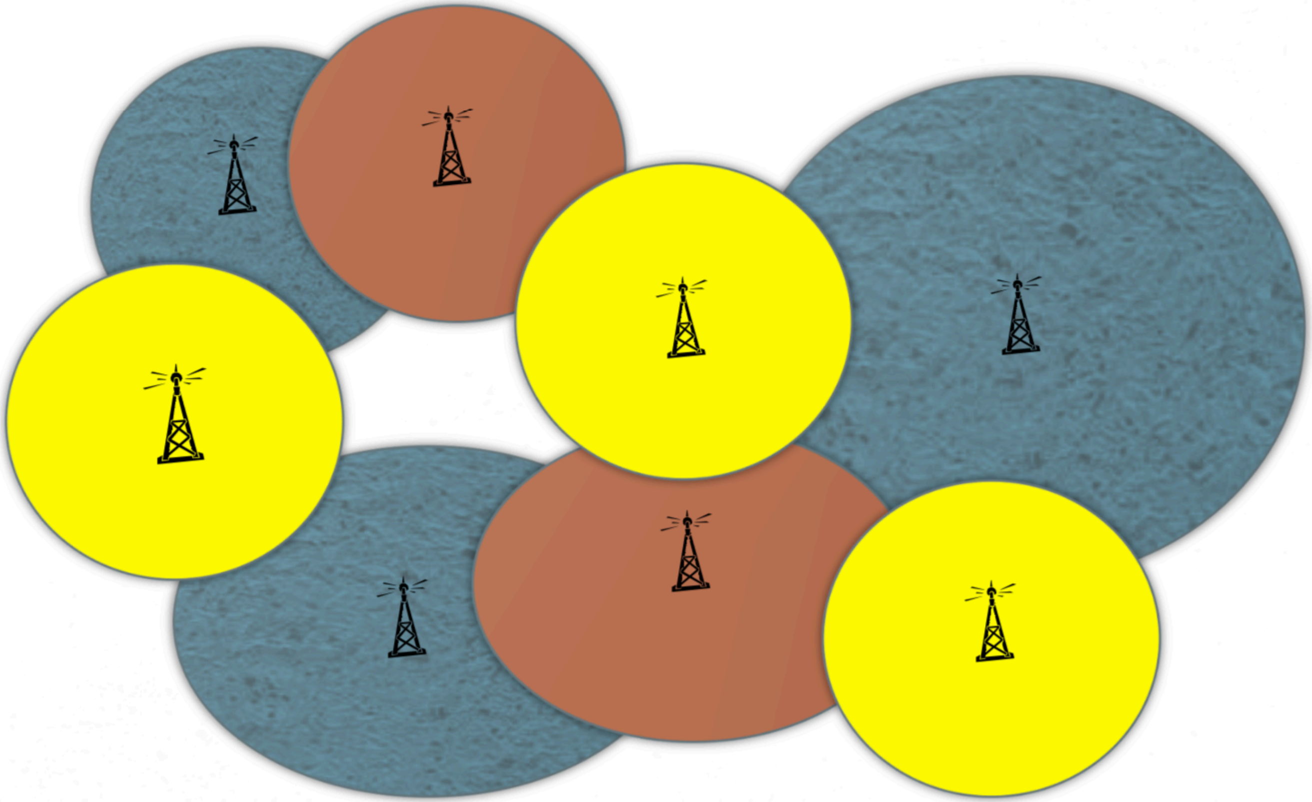

Key computational problem

- Before each station is processed in reverse auction, check that it's okay for that station to drop out.

- Testing the feasibility of a given repacking, based on interference constraints.
- Hard graph-coloring problem
  - 2991 stations (nodes)
  - 2.7 million interference constraints.
- Each problem was allotted 1 minute.

Lots of skepticism about whether this problem could be solved on such a scale.

Forward Auction

- Bidders are telecom companies like Verizon, ATT and regional carriers that want licenses for wireless spectrum.
- For each bundle of licenses, they have a value.
- Goal: welfare maximizing allocation.

combinatorial auction.

n bidders

m items

$v_i(S)$ S subset of m items.

Output of auction: $S_\phi, S_1, S_2, \ldots, S_n$

S_i set that bidder i gets

Goal: choose $(S_1 \ldots S_n)$ to max $\sum v_i(S_i)$

VCG auction

report $b_i(S)$ $\forall S$ $\forall i$

choose $S_1^*, \ldots, S_n^*$ that maximizes $\sum b_i(S_i^*)$

$$p_i = \max_{(S_1 \ldots S_n)} \sum_{j \neq i} b_j(S_j) - \sum_{j \neq i} b_j(S_j^*)$$

1 0

$$+ b_i(S_i^*) - b_i(S_i^*)$$

$$= b_i(S_i^*) - \left(\sum_j b_j(S_j^*) - \max_{S_1 \ldots S_n} \sum_{j \neq i} b_j(S_j) \right)$$

- hard computational problem
- bid elicitation unfeasable

$$= b_i(s_i^*) - \left(\sum_j b_j(s_j^*) - \max_{s_1 \ldots s_n} \sum_{j \neq i} b_j(s_j) \right)$$

1 2 1

More Problems with VCG

- Has some bad revenue and incentive properties in this "combinatorial auction setting".

	1	2	1&2
A	0	0	1
B	1	1	1
C	1	1	1

VCG outcome A & B.

A gets both

A's payment. 1 billion

VCG outcome w/ A, B, C.

B → 1
C → 2 payments are both 0

revenue is not necessarily monotonic in hidden values or participation.

Collusion

	1	2	1&2
A	0	0	1
B	0.25	0.25	0.25
C	0.25	0.25	0.25

if both bid 1 billion, both win at price of 0.

Common approach

- Use indirect mechanism: typically – sell each good in a separate single-item auction.

- Questions:
  - Simultaneous auctions or sequential auctions?
  - Sealed bid or open bidding?

Selling sequentially is a mistake

$k=2$ identical.

Example: Switzerland 2000

- Two identical 28 MHz blocks, followed by 56 MHz block.
- Sold in sequence of 2^{nd} price auctions.

28	28	56 MHZ
134 M	121 M	55 million.

Sealed bid is a mistake

10 identical licenses

sealed bid 2nd price auctions.

Example: New Zealand 1990

- Selling broadcast TV rights.
- Roughly 10 identical items.
- Used sealed bid simultaneous 2nd price auctions.

Current standard: simultaneous ascending auctions (SAA)

Feature 1: Price discovery

activity rule: # of items bidding on can only drop over time.

Current standard: simultaneous ascending auctions (SAA)

Feature 2: Valuation discovery

Conclusion

SAAs work well in combinatorial auctions where goods are mostly substitutes: $v(A+ B) <= v(A) + v(B)$

e.g. wants one license in one area, doesn't care which.

Not so good when goods are "complements",

$v(A+ B) > v(A) + v(B)$

e.g. want licenses in adjacent areas.

Strong theoretical results to back these claims up.