



Wireless economics

S-38.041 Networking Business



Spectrum licencing

Big picture

- Governments can assign the national cellular spectrum licences through comparative evaluation (i.e. "beauty contest"), lottery, or auction
- Many governments rely on comparative evaluation because they want to keep control on the spectrum usage while supporting the investment capabilities of telecom industry
- Lotteries have been abandoned because of large overhead (huge number of bidders) and low hit rate (wrong kind of winners)
- Auctioning has gained popularity because of fairness, transparency, good hit rate, and remarkable revenues
- Statistics tell that a government favors auctioning when
 - the density of country's population is high (e.g. the Netherlands)
 - the government's budget deficit is large (e.g. the UK)
 - the number of licences is high (e.g. the US)



Auction theory

Basics

- Auctioning is economically efficient, i.e. maximizes the social welfare, if it allocates items to bidders who value them most
- Auction design for a particular situation is as much art as science, but the basic theory is still useful
- In tatonnement, prices adjust up-and-down to match demand and supply, while auctions typically allow prices to go one way, up or down



Auction theory

Types of auction (1/2)

- *Open* (oral) auctions often have several rounds while *sealed-bid* (written) auctions may only take a single round
- Descending (*Dutch*) auctions are typically faster than ascending (*English*) auctions because the auctioneer alone drives the price down (using a "*Dutch clock*")
- In a *first-price sealed-bid* auction the bidders decide off-line their claim \Rightarrow no information is revealed \Rightarrow result equals to Dutch auction (winner pays the highest bid = his own)
- In a *second-price sealed-bid* (or Vickrey) auction the bidders tend to bid their true valuations \Rightarrow result equals to English auction (winner pays the second highest bid)
- In a *multi-unit* auction bids are made on one or more units of the same object (e.g. communication bandwidth)



Auction theory

Types of auction (2/2)

- *Heterogeneous* multi-object auctions may be complex because of the possible dependences between the non-similar objects auctioned together (e.g. spectrum objects)
- In *simultaneous* auctions bids are initially sealed and later (partly) posted by the auctioneer (e.g. spectrum)
- In *sequential* auctions prices tend to decline in the later auctions due to fewer or poorer bidders (e.g. UMTS)
- In *double* auctions there are multiple bidders and sellers which are treated symmetrically (e.g. stock exchanges)
- *Simultaneous ascending* auction (SAA) is the most common approach for auctioning a set of spectrum licences



Auction theory

Simultaneous ascending auction: basics

- Simultaneous bidding on multiple heterogeneous objects (e.g. spectrum licences) occurs in rounds and continues until nobody posts a bid on any object
- In each round, bidders make sealed bids and the auctioneer posts the highest bid and bidder for each object
- *Minimum bid increments* are enforced to secure fast finish
- *Combinatorial bidding*, i.e. bundling of objects, can be allowed although it adds complexity
- Bidders gradually reveal information during rounds thus reducing the probability of *winner's curse* (i.e. a bid higher than value) and enabling more aggressive bidding
- Simultaneous bidding enables the bidders to efficiently consider *complementarity* between objects (e.g. adjacent bands of spectrum)



Auction theory

Simultaneous ascending auction: inefficient allocation

Bidder	v_A	v_B	v_{AB}
<u>1</u>	1	2	6
<u>2</u>	3	4	5

- Consider an auction of two spectrum licences, A and B, where
 - two bidders, 1 and 2, compete
 - individual valuations are v_A and v_B , and a combined valuation is v_{AB}
 - licences are complements for bidder 1, but substitutes for bidder 2
- Socially optimal allocation would be v_{AB} for 1, but there are no prices facilitating this
- A possible but complicated solution is to allow combinatorial bidding



Auction theory

Simultaneous ascending auction: incentive to delay bidding

Bidder	V_A	V_B	Budget
<u>1</u>	15	30	20
<u>2</u>	10	0	20
<u>3</u>	0	5 w.p. 0.9 15 w.p. 0.1	20

- Consider an auction where bidder 3 values B at 5 or 15, with probabilities 0.9 and 0.1, respectively
- This partial information on bidder 3 implies that 1 waits to see how 3 bids, and vice versa
- Deadends like this one are handled with proper *activity rules* enforcing bidders to continue



Auction theory

Simultaneous ascending auction: free rider problem

Bidder	v_A	v_B	v_{AB}	Budget
<u>1</u>	4	0	0	3
<u>2</u>	0	4	0	3
<u>3</u>	$1+\varepsilon$	$1+\varepsilon$	$2+\varepsilon$	2

- Consider that combinatorial bidding is allowed: bidder 1 bids 1 on v_A , 2 bids 1 on v_B , and 3 bids 2 on v_{AB} \Rightarrow seller announces that 3 wins if no further bids are made
- The combined bid of 3 wins with a socially suboptimal value 2 if 1 and 2 decide to wait for each others' bid in order to save money \Rightarrow 3 gets a free ride



Spectrum auctions

Advice to governments (the U.S. perspective)

- Allocating the spectrum is as important as its assignment
 - Avoid useless spectrum by listening to experts (e.g. interference issues)
 - Define cleaning rules for spectrum occupied by poor usage
- Use care when modifying successful auctioning rules (e.g. SAA)
- Allow adjusting the auction parameters between rounds
- Reduce effectiveness of bidders' revenue-reducing strategies
 - nationwide licences eliminate demand reduction due to spectrum split
 - anonymity eliminates retaliation ("you stay off my licence and I stay off your licence")
- Use spectrum caps to limit anticompetitive concentration
- Implement special treatment for designated entities with care
- Promote market-based tests in spectrum management



UMTS licence auctions

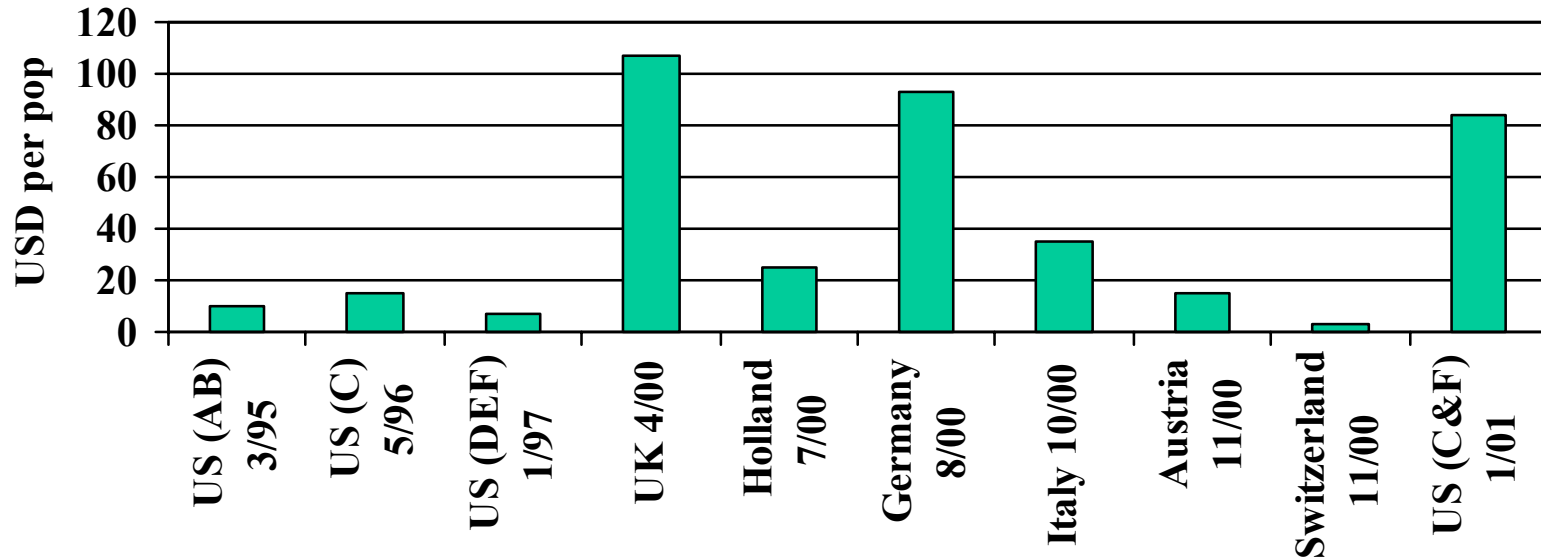
Case Europe

- European governments copied the american experience, i.e. the simultaneous ascending auction
- The UK and Netherlands chose a simple version where a bidder can win at most a single licence, while Germany allowed multiple bids
- In Holland, 5 licences and 5 incumbents \Rightarrow entrants allied with incumbents \Rightarrow price level remained low
- In the UK, 5 licences and 4 incumbents \Rightarrow tough competition lasting 150 rounds \Rightarrow price level record high (e.g. Vodafone paying 160USD per person for 2x15MHz)
- In Germany, 12 blocks (2x5MHz), 4 incumbents, and 4-6 possible winners \Rightarrow 173 rounds \Rightarrow 6 winners a 2x10MHz with record prices



UMTS auctions

Comparison: European 3G (2x10MHz) vs. the US 2G



- Auction revenue varies significantly due to context sensitivity of auction design
- UMS auction revenues decreasing over time (international operators running out of money?)
- Spectrum in the US has lately reached the European price levels (impact of allowing resalability?)



Spectrum allocation

Demand vs. supply

- International bodies (ITU-R) create global recommendations on spectrum allocations, but governments make decisions
- Governments consider spectrum as a scarce resource requiring extremely strict regulation
- Strong demand of mobility together with advances in mobile device technologies maintain demand for new spectrum
- When and how will the gap between demand and supply of spectrum be filled?
- The answer consists of new technologies, new regulation, and new business models



Spectrum allocation

New technologies

- Spectrum is not a concrete nor finite resource to be licenced. Instead, a licence simply allows deployment of particular transceivers/receivers
- Interference is not an inherent property of spectrum. Instead, it is a property of devices evolving rapidly
- *Digitalization* saves spectrum (e.g. 5:1 compression ratio in TV signals)
- Spectrum can be shared more efficiently through *spread spectrum* technologies (e.g. WCDMA)
- The low power levels of *ultrawideband* enable the local use of spread spectrum as an underlay for the pre-existing spectrum licences
- *Smart directional antennas* reduce interference between devices
- *Cooperative mesh networks* promise to reduce power levels further
- Better compression through optimal coding algorithms (e.g. turbo codes)
- Software radio and network intelligence enable exploitation of the above mentioned new technologies (when?)



Spectrum allocation

Sources of new spectrum (in the U.S.)

Assigned service	Frequency band	Usable MHz
Terrestrial (3G)	1.7-2.1 GHz, 0.7-0.8GHz	120, 84
MVDDS/ITFS (flexible use)	2.5-2.7 GHz	132
Satellite (MSS)	1.6-2.0 GHz	98
Terrestrial MVDDS	12.2-12.7 GHz	500
Broadcast digital TV (DTV)	54...698 MHz	294
Satellite (fixed service)	17.2-20.2 GHz, 27.5-30GHz	5500
Direct broadcast sat. (DBS)	12.2-12.7 GHz	240
Unlicensed (NII)	5.5-5.7 GHz	255
Broadband wireless, sat/terr	38.6-40GHz, 47.2-48.2 GHz	5600
Broadband video/data	71-76, 81-86, 92-95 GHz	13300

- New spectrum: 300MHz for mobile and 1500MHz for broadcast
- The GSM and WLAN success required less than 100 MHz, each

Source: G.Staple, K.Werbach, 2004



Spectrum allocation

Optimizing the rules (the U.S. view)

- Spectrum reallocation
 - scanning the licenced radio spectrum in urban areas shows that significant portions of spectrum are unused at any given point of time
 - more efficient reallocation can unleash spectrum for new services (e.g. MVDDS: terrestrial reuse of satellite spectrum)
- Spectrum leases
 - allowing the flexible use (e.g. hybrid use) of licences to speed up deployment of new technology
 - allowing the resell of licences to speed up the search for best exploitation of spectrum
- Spectrum sharing
 - the success of WLAN on unlicenced band has created a new paradigm
 - new spectrum at 5GHz has been reserved for unlicenced use
 - unlicenced use of underlays may be possible on licenced bands



Spectrum allocation

New business models

- Future mobile handsets with multiple radio interfaces (e.g. WCDMA, WLAN, and DVB-T) will necessarily connect to multiple traditionally separate radio-specific value chains
- Each existing value chain has its own merits and is likely to extend its life-cycle through the new multi-radio handsets
- New value chains/nets are likely to emerge based on new and multiple radio interfaces
 - digital TV (DVB-T) with return channel (WCDMA)
 - broadcast services over WLAN or WCDMA
 - seamless roaming (e.g. WLAN access when visiting a neighbor)
- An economically efficient market favors business models that attract traffic from bottleneck radios (e.g. WCDMA) to abundant radios (e.g. WLAN and DVB-T) when possible