Mechanisms to incentivize shared use of spectrum

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Spectrum sharing will be

- System of licenses for exclusive use is inadequate for meeting future spectrum needs of the mobile industry:
  - Running out of traditional mobile spectrum below 3 GHz
  - UK and US want to make 500 MHz of spectrum available below 5 GHz for mobile use by 2020
  - Clearing incumbents time-consuming and in many cases impossible
  - Kassem and Marina (2015) estimate that 80% of spectrum made available for mobile use in the UK will be on a shared basis
  - 5G will rely heavily on higher-band spectrum with encumbered use

Opportunistic sharing (LAA)

- Spectrum “commons model” with standards and techniques in place to avoid interference
- If spectrum accessed by many different technologies, interference avoidance measures need to build into all of them which reduces spectral efficiency
- Quality of Service (QoS) not guaranteed for mobile industry

Licensed-shared access (LSA)*

- Exclusive secondary access to a band already used by an incumbent, on a coordinated basis
  - Voluntary:
    - Close collaboration between incumbent and secondary users
    - Incumbents participates voluntarily with appropriate financial incentives to share
  - Based on market supply and demand
    - Mobile industry relies on exclusive access to guarantee QoS
    - Exclusivity among secondary users at a given place and time, for a predictable future needed to support investment
  - Exclusive:
    - Simplifies coexistence measures and reduces incumbent’s vulnerability to harmful interference

*Criteria from CEPT, 2014, ECC Report 205
The market will sort it...or will it?

- LSA arrangement based on “voluntary” agreements:
  - Seller and buyer left to agree to mutually acceptable terms
  - Hope that financial incentive sufficient to induce incumbents to share when efficient

- Myerson-Satterthwaite impossibility theorem (1983) - under informational asymmetry there is no mechanism for a single buyer and seller that achieves the following three objectives at the same time:
  - Ex-post efficiency (a trade occurs when then seller’s cost is below the buyer’s willingness to pay)
  - Budget neutrality (the trade has to be funded by external sources)
  - Individual rationality (the mechanism never makes either seller or buyer worse off so both would want to opt in to it)

- If buyer and seller left to agree to a price:
  - Seller has an incentive to overstate its cost
  - Buyer has an incentive to understate its willingness to pay (WTP) to secure a better deal
  - Deal may break down as either may misjudge the true cost/WTP of the other party

- An efficient, individual rational mechanism:
  - Buyer needs to be guaranteed to only pay cost of seller to reveal its WTP
  - Seller needs to be guaranteed to be paid buyer’s willingness to pay to reveal its cost
  - Need external resources to finance trade
Our proposed linked mechanism

**LSA auction**

Establishes:
- Winner of LSA license (secondary user)
- Price for LSA license
- Willingness to pay for LSA license by winner of LSA license (WTP)

Incumbent asked whether it accepts auction outcome

Accepts

- Winner of auction pays LSA license price established in auction to incumbent
- LSA auction winner and incumbent share spectrum

Rejects

- Incumbent continues to use spectrum exclusively without sharing it
- Incumbent required to pay difference between WTP and price for LSA license as established in the LSA auction

In a thick market (many buyers and sellers), problem disappears (Rustichini, Satterthwaite & Williams (1994)):
- Competition on the sell side reduces the seller’s ability to get a higher price by overstating its true cost as it is in competition with other sellers
- Competition on the buy side reduces buyer’s ability to get a lower price by understating its willingness to pay as it is in competition with other buyers

Market characterized by thin sell side (in many cases only a single seller) and competition on the buy side – to enable all efficient trades:
- Make demand side as liquid as possible (lower transaction costs for seller by running an auction for LSA licenses)
- Remove seller’s incentive to trade outside the mechanism (in case it rejects the auction outcome, it is charged the highest possible price it could achieve outside the auction (WTP of auction winner) less the price it could achieve if it accepts the auction outcome)
Auction format for a single LSA license: Japanese auction

Clock rounds

- Bidders either accept or reject the current round price
- If rejected, bidders required to submit an exit bid (strictly lower than the current round price and at least equal to previous round price)
- If at least one bidder accepted the current round price (excess demand), next round scheduled with higher round price
- Excess demand cleared in a round in which no bidder accepted the current round price and clock rounds end

Winner and price determination

- Determine the highest bid submitted by each bidder
- Bidder with highest bid wins (ties broken at random)
- Winner pays bid from second highest bidder

Applications

Round 1

Further rounds

Excess demand

No excess demand

Excess demand

No excess demand

Auction moves to winner determination

Willingness to pay of winner

Price for LSA license
Efficiency

- Sharing efficient whenever $B > A$ or when the WTP of the auction winner is less than the cost of sharing.

- When asked to either accept or reject the auction outcome, incumbent compares total of $C$ (total payoff if it accepts) and $D$ (total payoff if it rejects):
  - If $D$ gives incumbent higher payoff than $C$, it is not efficient to share.
  - If $C$ gives incumbent higher payoff than $D$, it is efficient to share.
  - Incumbent maximizes payoff by selecting efficient outcome.

**Proof:**

- If $\text{Cost} < \text{WTP}$, then $\text{Cost} < \text{Price} + \text{License Fee}$
- $C = A - \text{Cost} + \text{Price}$, $D = A - \text{License Fee}$ => when $\text{Cost} < \text{WTP}$, then $A - \text{License Fee} < A - \text{Cost} + \text{Price}$ => $D < C$
Individual rationality

- If the price of the LSA license does not cover the incumbent’s cost of sharing, it would be worse off relative to A regardless of whether it chooses C or D.
- Although efficient (WTP > cost of sharing), the incumbent is not sufficiently remunerated in the mechanism and, if it could, would prefer not to take part in the mechanism.
- Incumbent’s true cost unknown, so no way to ensure that the price of the LSA license is “high enough”
Flexible to accommodate different types of incumbents

**Incumbent allowed to raise proceeds from sublicensing**

Case 1: Incumbent was assigned spectrum in an administrative procedure:
- Should be able to justify raising license fees in case incumbent does not want to share
- apply LSA model as is

Case 2: Incumbent was assigned spectrum in a competitive award:
- Difficult to justify raising license fees if incumbent does not want to share
- Could simply offer incumbent to share based on auction outcome (only route to market)
- May be impossible to deny incumbent to trade outside of mechanism though

**Incumbent not allowed to raise proceeds from sublicensing**

Case 3: Incumbent subject to license fee that are higher than WTP of auction winner:
- Propose to run an LSA auction that would determine a price for the LSA license and maximum WTP
- Reduce license fees by full WTP of the auction winner

Case 4: incumbent subject to license fee that is lower than WTP of auction winner or not currently subject to license fees at all:
- Propose to run an LSA auction that would determine a price for the LSA license and maximum WTP
- The incumbent can either agree to share and have its full annual license fee waived, or it can reject the auction outcome and pay a higher license fee (equal to the WTP of the winner of the auction)
Literature

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