Accelerating the introduction of spectrum sharing using market-based mechanisms.

Fernando Beltrán
University of Auckland

ITU Kaleidoscope 2016
Bangkok
November 14-17, 2016
The paper

- Two jobs of Spectrum Management
  - Spectrum Allocation
  - Spectrum Assignment
- Spectrum Sharing
  - Technological enablers
  - UK’s Spectrum Sharing Framework (2016)
  - New Zealand’s Managed Spectrum Parks (2009)
- Effectiveness and Efficiency
- Market-based mechanisms: examples
  - Ofcom spectrum sharing options for 2013 2.6 GHz auction
  - FCC’s Licensed vs Unlicensed auction
Two jobs of Spectrum Management
(Cave, Doyle and Webb, 2007)

- Spectrum Allocation
- Spectrum Assignment
Spectrum Sharing
(PCAST, 2012)

- Technological enablers
  (Han et al, 2016), (Beltrán et al, 2016)
- UK’s Spectrum Sharing Framework (2016)
  (Ofcom, 2016)
- New Zealand’s Managed Spectrum Parks (2009)
  (MBIE, 2010), (Beltrán, 2015)
What is the best use that can be given to a given frequency band and who should be entitled – or licensed to use it?

If a Spectrum Authority puts spectrum to its best use, it will maximize the effectiveness of the allocation, and

If a Spectrum Authority puts the spectrum in the hands of those who value it the most, it will maximize the efficiency of the assignment.
Market-based mechanisms: examples

- FCC’s Licensed vs Unlicensed auction
  (Bykowsky, Sharkey and Olson, 2008)

  Ofcom spectrum sharing options for 2013 2.6 GHz auction
  (Ofcom, 2012)
FCC’s Licensed vs Unlicensed auction
(Bykowsky, Sharkey and Olson, 2008)

- FCC’s Licensed vs Unlicensed auction
Licensed vs Unlicensed bids

Find the efficient allocation of characteristics to blocks and the efficient assignment of those blocks to market participants.
2013 Ofcom’s 2.6 GHz auction
(Ofcom, 2012)

- Ofcom’s 2013 800 MHz & 2.6 GHz auction
Combinatorial Clock Auction, CCA

1. Auction Starts
2. Allocation Stage:
   - Clock rounds
   - Supplementary round
3. Assignment Stage:
   - Winning bidder(s) and base price determination
   - Generic licences?
     - Yes: Assignment Stage
     - No: Winning assignments and final price determination
4. Excess demand for any product?
   - Yes - Increase price of product(s) with excess demand
   - No: Auction Ends

Source: Industry Canada
# Clock Rounds Stage (aka Principal Stage)

<table>
<thead>
<tr>
<th>Round</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
<th>Prices</th>
<th>Supply --&gt;</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Clock Rounds stage

<table>
<thead>
<tr>
<th>Round</th>
<th>Prices</th>
<th>Supply --&gt;</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SA1 SA2 SA3 SA4 SA5</td>
<td>SA1 SA2 SA3 SA4 SA5</td>
<td>SA1</td>
<td>SA2</td>
<td>SA3</td>
<td>SA4</td>
</tr>
<tr>
<td>1</td>
<td>100 100 60 60 60</td>
<td>2 2 2 2 2</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The table represents the supply and prices for different rounds and stages.
# Clock Rounds stage

<table>
<thead>
<tr>
<th>Round</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prices</td>
<td>100</td>
<td>100</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>105</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>
## Clock Rounds stage

<table>
<thead>
<tr>
<th>Round</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>105</td>
<td>105</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>110</td>
<td>110</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

Supply --> 2 2 2 2 2
## Clock Rounds stage

<table>
<thead>
<tr>
<th>Round</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
<th>Supply --&gt;</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SA1</td>
<td>SA2</td>
<td>SA3</td>
<td>SA4</td>
<td>SA5</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>105</td>
<td>105</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>110</td>
<td>110</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>110</td>
<td>110</td>
<td>80</td>
<td>90</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>110</td>
<td>110</td>
<td>90</td>
<td>95</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>115</td>
<td>115</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>125</td>
<td>125</td>
<td>95</td>
<td>110</td>
<td>110</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>125</td>
<td>130</td>
<td>110</td>
<td>115</td>
<td>115</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Spectrum Sharing involves two operators with adjacent frequencies combining their respective smaller channels in a spectrum band in order to be able to use a wider channel from this combination (Ofcom 2012)

Auction design sought to facilitate:

- Joint bidding
- Spectrum Sharing (SS)
Auction preference expression

Design challenge: to allow bidders to express preferences for winning spectrum next to another bidder.

Two sources of potential benefits from SS:
- From pooling of capacity resources
- From gains available from larger channels

The latter requires channels to be contiguous.
Hence preference expression.
Goal: to allow bidders to reflect preferences for being both
- at particular frequencies, and,
- next to another specific bidder.

Example:
- 60 MHz (paired) of spectrum to be auctioned
- Blocks are 5 MHz each
- Coverage obligation imposed on a certain bidder
- Only the top four blocks of the upper band are suitable for meeting the coverage obligation
Example

Principal Stage resulted in
- A won 2 x 15
- B won 2 x 5
- C won 2 x 10
- C is the bidder with coverage obligation

Question: is there a range of feasible assignments that allows any bidder to be contiguous to any other bidder at least in one arrangement?
Example

Challenge:
To manage the tension between the objectives on coverage obligation and the options for SS

Blocks suitable for coverage obligation
Option for SS in the Assignment Stage

Assuming contiguity is important (highly valued):

- Principal Stage winners negotiate amongs themselves
- Allowing the creation of joint bidding vehicles in the Assignment Stage
- Allowing bids that are contingent on whether a bidder prefer to be next to another bidder
In conclusion ...

- Spectrum sharing can enhance the spectrum authority’s capabilities with a management scheme aimed to:
  - increase the effectiveness of allocations and
  - the efficiency of assignments.
- Market-based mechanisms that include auctions for the assignment of rights to share the spectrum are not only conceivable but possibly efficient ways to decide about the best use and user of the spectrum.
thank you
tēnā koutou
gracias

f.beltran@auckland.ac.nz
References


PCAST, Report to the President: Realizing the Full Potential of Government-held spectrum to spur economic growth, (2012).