Spectrum Auctions and Valuation in the 4G Era

The Second Annual Americas Spectrum Management Conference
Pre-Conference Workshop – October 22, 2012
Washington Marriott Hotel, Washington, D.C.

Lemay-Yates Associates Inc.
2015 Peel Street, Suite 980, Montreal (Quebec) H3A 1T8 CANADA
Tel /Fax: (1) 514-288-6555 • www.LYA.com • Email LYA@LYA.com

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AGENDA

• 13:15-14:15 – Session 1 – Introduction, context and key topics:
  – How much spectrum is needed per carrier;
  – Translating customer demand to MHz;
  – Worldwide spectrum prices in the 4G Era;
  – Impacts of auction design on prices.
• 14:15-14:45 – Session 2 – Auction preparation:
  – Basics of CCA Auctions;
  – Preparation for bidding using LYA Auction Platform.
• 14:45… 15 minute break
• 15:00-16:45 – Session 3 – Auction bidding:
  – Bidding in a live Combinatorial Clock Auction (CCA);
  – Review of bidding results and wrap up.
Introduction

• Lemay-Yates Associates Inc. (LYA®) is a boutique consulting firm founded in February 1993 to provide management consulting services and market research to support the telecommunications industry:
  – LYA has completed approximately 500 different projects for 150 client organizations and has published 16 independent research reports
• LYA has participated in all of the Canadian auction processes held to date, including bid room participation in three SMRA auctions and support for award of spectrum in a Vickrey (second-price) process:
  – LYA also worked for the regulator in providing license valuations for cellular and PCS licenses supporting policy development prior to conducting auctions;
  – LYA has developed expert evidence in public consultations and participated in other licensing processes.
• In 2012, LYA independently developed a CCA Auction Platform to support bidders in upcoming spectrum auctions;
• LYA has conducted extensive international research on spectrum prices, available in published c-Ahead® Reports;
• LYA has conducted Spectrum Strategy and Auction Seminars to support bidders in auctions since 2003.
LYA Spectrum Auction Toolkit

- Financial modeling and license valuation
- LYA® CCA Auction Platform
- Spectrum Strategy and Auction Seminars
- Expert Evidence in Public Consultations
- Game Analysis
- Tactical support, competitor analysis, bidder training
- LYA® c-Ahead® Reports on Spectrum Pricing
- Market research and segmentation
- Assessment of bands and technologies
- Post auction review and opportunity assessment
- Auction Round Tracking Tools

LYA® Spectrum Auction Toolkit
Key Topics for Today’s Workshop

- Participation in auction requires bidders to know “everything”
- Today, our focus will be on key components of planning for participation in an auction:
  - How much spectrum do you need?
  - How to value it…
  - What have been values in other auction processes?
  - How to “play” in a CCA process.
- Key elements of spectrum policy and planning going forward:
  - Question of how much spectrum central to market structure and policies (e.g. caps in place in many Lat. Am. Countries; new FCC process in US FCC 12-119 – NPRM on Spectrum Holdings Policies – case by case versus absolute limits, etc.)
  - Tradeoffs in processes and relationships to outcomes… new FCC 12-118 – NPRM on Incentive Auctions – next wave of auctions – may be CCA in “reverse” (declining price) and “forward” (ascending price) directions.
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Data demand... Driving the Need for Spectrum

Cisco VNI, May 30, 2012
Data demand... Driving the Need for Spectrum

US wireless network data traffic – up 104% (CTIA June 2011-June 2012)

Cisco VNI, May 30, 2012

Mobile, 83% CAGR
Fixed, 30% CAGR

Million GB (PB) per month


- 10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000

32% CAGR
Mobile Video Trends Expected to Accelerate…

- Based on LYA consumer research – Mobile-connected tablets are growing three-times faster than WiFi-only tablets.

<table>
<thead>
<tr>
<th>Tablets</th>
<th>% Increase (2011-2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WiFi Only</td>
<td>32%</td>
</tr>
<tr>
<td>With Mobile Connection</td>
<td>207%</td>
</tr>
<tr>
<td>Total</td>
<td>73%</td>
</tr>
</tbody>
</table>

See LYA "WiFi Usage and Trends in Canada" Report for more details

- Following Apple announcement June 2012, FaceTime now available on mobile networks (not just using WiFi);
  - Similar capability was already available using Skype mobile
- Randall Stephenson (Pres., AT&T – in WSJ June 11, 2012): demand for spectrum will exceed supply by 2013 (quoting FCC)… and AT&T’s 30,000 WiFi hotspots offload only 1% of data traffic… half of American adults own a Smartphone and data usage continues to explode.
Approach to Assessing How Much Spectrum

- LYA developed an analytical model used to estimate future demand for spectrum:
  - Provides a long term view considering increasing speed and usage offered to customers and scenarios of spectral efficiency, service quality, availability;
  - Driven by variation of customer take-up rates for different theoretical service speeds and using approximate average numbers of customer per site;
  - Focused on estimating MHz needs in urban areas where typically more capacity constrained... *Not just that you need “more” but how much more.*

- Provides broad perspective on need for spectrum:
  - Not “optimized” from an engineering perspective, so provides an upper bound;
  - Not band specific – for illustration, provides view of total needed “around” a typical cell site – assumes spectral efficiency same across all bands (not the case in reality) – get top speeds using channel aggregation.
Customer Usage – Translated into Spectrum

- **Analytical scenario for illustrative purposes...** Data customers assumed on average to use data for 20 minutes per day, spread over six busy hours. Network usage in terms of MB per month are possible average subscriber usage, assuming use of peak rates for 3% to 5% of total usage.
  - Some subscribers will have very high usage and others very low. Cisco, for example, recently reported that 1% of mobile data subscribers account for 20% of mobile data traffic.
  - The large user could be thought of as streaming data at 100 Mbps for a continuous 20 minutes each day... 12.5 Mbytes per second for 20 minutes for each of 30 days results in 450 GB per month.

- **Overall consumer video usage is much higher per day than that seen on mobile... watching it all somewhere – on TV, on WiFi, on PC, etc.**

- It should be kept in mind as well that the customer’s device may limit its ability to consume data, depending on processor speed, memory availability, etc. Video sources also come with varying bit rates tailored to the device.
Business Models Impact Spectrum Needs
Using LYA Spectrum Needs and Business Plan Model

![Graph showing total MHz required at 5 bps/Hz for different business models]

© Lemay-Yates Associates Inc., 2011
Spectrum Needs – LYA Approach

• LYA uses an innovative and holistic approach to business modeling – essentially an LYA business model is a simulation tool where “everything” moves
  – Support development of auction budget from different bidder perspectives
• Test different bands, technologies, subscriber segments, deployment options, coverage/geographies, operational assumptions
  – E.g. Variation of business case values with different LTE throughput drivers (bps/Hz, FDD vs. TDD, offset with WiFi)… impacts amount of spectrum needed; “base case” 3 bps/Hz.
• **Strong linkage of subscribers to network**
  – Model network “deploys” based on subscriber drivers – subscriber forecast, data usage, technology parameters
  – And vary based on type of operator– large data-centric vs. small voice centric, etc.
• Provides direct determination of value of incremental spectrum and relative value of different bands – how much spectrum is needed.
Network Model Overview
(portion of business case model)
Example – Spectrum Needs Model

• Different band possibilities – frequency and capacity; small case to illustrate approach – carrier with only 10 MHz capacity.
• Few hundred thousand customers in suburban/regional area; “small” carrier model;
  – No high density urban areas.
• Increasing data ARPU and usage – targeting long term 100 Mbps objective;
• Model tested business case against deployment options in different spectrum bands and with varying bandwidth available per band;
  – Focused on N.Am. bands 1900 MHz, 700 MHz, 2500 MHz and in combinations with 10 MHz or 20 MHz bandwidth.
• Shows value of business case considering scenarios of deployment, take rates, usage levels, level of competition, etc.
Model Run - example

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sites in service (cumulative)</td>
<td>400</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>NPV (normalized)</td>
<td>$</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Data driven customer model... 10 MHz capacity in 2500 MHz band – requires build out to 800 sites and $NPV = $100 (normalized)
### Model Run - example

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<td>$100</td>
<td>$118</td>
<td></td>
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</tbody>
</table>

**Add 10 MHz more in 2500 MHz band**

- still requires build out to 800 sites
- due to coverage need – but add capacity later... NPV = $118 (normalized) – business case is 18% better than with only 10 MHz (probably relatively better in reality – likely over deployed at start)
Model Run - example

<table>
<thead>
<tr>
<th>Model Run</th>
<th>10 MHz in the 2500 MHz band(s) with FDD</th>
<th>20 MHz in the 2500 MHz band(s) with FDD</th>
<th>10 MHz in the 800 MHz band(s) with FDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
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Do same business plan, but with 800 MHz spectrum – now only need 300 sites (but grows to 800 for capacity later) – NPV improves to $165 – 800 MHz spectrum is worth more than 2500 MHz
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<td>100</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>NPV (normalized)</td>
<td>$234</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*If could get 20 MHz in 800 MHz band – would be even better... twice as good as 2500 MHz alone*
## Model Run - example

<table>
<thead>
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<th>Year</th>
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<th>5</th>
<th>10</th>
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<tbody>
<tr>
<td>Big data 10 MHz in the 2500 MHz band(s) with FDD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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Model Results – “Need” for Spectrum

• In absolute – Low frequency business plan is better than 2500 MHz business plan to do the same thing – NPV of 700 MHz plan 65% better;

• Tradeoff is that with 2500 MHz – have to build more sites.
  – If have 10 MHz in 700 MHz range, NPV = $165 – add 10 MHz in 2500 MHz range, NPV = $204… added spectrum worth $39 and improved value of business by 25%.

• On the other hand, if have 10 MHz in 2500 MHz first, NPV = $100 – add 10 MHz in 700 MHz range, NPV = $204… added spectrum worth $104 and improved value by 200%.

• More spectrum always improves value:
  – 2500 MHz – adding 10 MHz increases NPV by 18%;
  – 700 MHz – adding 10 MHz increases NPV by 40%.

• But if cannot get “enough” 700 MHz… then combination of 700/2500 is 70% more valuable than a bigger 2500 MHz plan (i.e. 20 MHz).
Other Technology Issues/Variations

• Change FDD technology to TDD…
  – Low spectrum cases (10 MHz) yield % improvement in value and in some cases fewer sites over the longer term;
  – Technology risk with TDD not explicitly accounted for and assume can carry all traffic.

• Can do similar exercise with WiFi deployment – trade-off of offload using WiFi access points relative to incremental mobile sectors (if the sectors can be deployed);
  – And WiFi business case focus on broader traffic opportunity.

• Re-run using less efficient technology… e.g. FDD at lower bps/Hz
  – Increases Hz/customer required to assure same service level.
  – *Can see clear need for more spectrum – 10 MHz cases are negative and many more sites are required.*
Implications for Auctions

- For same business case – e.g. big data 20 MHz – 700 MHz value should be about double that of 2600 MHz.
- Adding 700 MHz spectrum to an existing business built on 2600 MHz is three times more valuable than adding more 2600 MHz spectrum.
- Auction valuations from Europe though indicate a much higher value for 800 MHz digital dividend relative to 2600 MHz (in processes where they were awarded in the same auction).
- Model values can vary significantly with subscriber forecasts, density/geography etc... But does tend to indicate that Digital Dividend spectrum has been overpriced in auctions… *Could be hidden value in other bands – 2600 MHz, but also 1800 MHz band*
Spectrum Needs Approach - Summary

- Proven approach used in previous auction processes;
- Provides way of assessing auction dynamic from different bidder perspectives on spectrum value and to define auction envelope:
  - Compared to auction results for similar spectrum;
  - Combined with other analyses needed to develop bidding strategy.
- Approach being proven out from observed results of 4G auctions… incremental value of added 2.6 GHz spectrum is lower than if auctioned standalone.
Do Carriers Really “Need” More?

- Engineered solutions at a more granular level can offset spectrum needs – DAS, cell splitting, WiFi offload, overbuilding hot-spots;
- *LYA approach/model:* provides an “envelope” of spectrum requirements enabling carriers to focus on long-term needs and to assess tradeoffs of more spectrum relative to other solutions.
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“The price of spectrum currently available for high value uses such as PCS, cellular and mobile data will fall as the supply of such spectrum increases.”

“The price of spectrum currently available for high value uses such as PCS, cellular and mobile data will fall as the supply of such spectrum increases.”


“The report of my death was an exaggeration”

Mark Twain, 1897
Why is Valuation Important?

• For auctioneers, to ensure a successful auction:
  – Meet policy objectives;
  – Attract bidders;
  – Setting proper initial bid prices and reserve prices if applicable;
  – Managing expectations… ?

• For bidders, to come away fulfilling strategic and operational needs… without overpaying:
  – Calibration of business plans versus competitors;
  – Support in development of bidding strategy.
## What Impacts Spectrum Value?

1. Relevance of comparatives amongst countries – influences of market structure, economy, penetration – $/MHz-pop per auction per band within country provides a common basis for quick comparison;
2. Scarcity and uncertainty as to the next opportunity to acquire spectrum;
3. Which bands – “core” mobile spectrum (3G, digital dividend) with attractive characteristics for deployment have higher value;
4. Availability and scope of technology ecosystem;
5. Difficulties that may encountered in acquiring competitors in highly concentrated industries;
6. Auction structure and mechanism;
7. Eligibility criteria for auction participation;
8. Timing of auction process – with respect to economic cycle.
Pricing trends in the 4G era…
In Some Cases Prices have Declined from 3G to 4G

But in Others Prices have Increased…

$-$ $0.20 $0.40 $0.60 $0.80 $1.00 $1.20 $1.40 $1.60


US Spain Sweden

US Auctions, then and now

2G/3G prices declined as supply increased

- US PCS A and B blocks (Mar-95)
- US PCS C block (May-96)
- US PCS C block reauction (Jul-96)
- US PCS D, E, F blocks (Jan-97)
- US PCS C, D, E, F (Apr-99)
- US PCS C, F reauction (Jan-01)
- US PCS (Feb-05)
- US AWS-1 (Sep-06)
- US 700 MHz (Feb-08)
US Auctions, then and now

But the overall trend…?

2G/3G

4G

$2.50

$2.00

$1.50

$1.00

$0.50

$-

US PCS A and B blocks
Mar-95

US PCS C block
May-96

US PCS C block reaction
Jul-96

US PCS D, E, F blocks
Jan-97

US PCS C, D, E, F
Apr-99

US PCS C, F reaction
Jan-01

US PCS
Feb-05

US AWS-1
Sep-06

US 700 MHz
Feb-08

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What is the Trend?

- In some cases, pricing follows a downward trend, consistent with the notion that prices should decline as supply increases:
  - E.g. from US Auction history – prices peaked in 1996 with the C Block auction and followed a declining trend up to the 2006 AWS Auction – effectively ending the 2G/3G era.
- 4G – not just an extension of the 2G/3G “market” but new: mobile broadband focused on tablets, iPhones, Android devices, MTM, etc.
- As spectrum supply increases, prices may not be decreasing… contradiction? Not really… because the supply is different from the earlier supply (2G/3G) and focused on a different market.
  - And not all bands (and hence not all technology ecosystems) are created equal – although some can be re-farmed.
- But hard to conclude: Digital dividend in 4G era is higher than before – but only US examples are available; 2600 MHz in 4G era… less evident.
Evolution of Prices for Digital Dividend

<table>
<thead>
<tr>
<th>Region</th>
<th>Price</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Upper 700 MHz</td>
<td>$0.20</td>
<td>Sep-00</td>
</tr>
<tr>
<td>US Upper 700 leftovers</td>
<td>$0.40</td>
<td>Feb-01</td>
</tr>
<tr>
<td>US Lower 700 C, D blocks</td>
<td>$0.60</td>
<td>Aug-02</td>
</tr>
<tr>
<td>US Lower 700 C, D blocks</td>
<td>$0.80</td>
<td>May-03</td>
</tr>
<tr>
<td>US 700 MHz</td>
<td>$1.00</td>
<td>Jul-05</td>
</tr>
<tr>
<td>Germany Digital Dividend</td>
<td>$1.20</td>
<td>May-10</td>
</tr>
<tr>
<td>Hong Kong 700 MHz mobile TV</td>
<td>$1.40</td>
<td>Jun-10</td>
</tr>
<tr>
<td>Sweden Digital Dividend</td>
<td>$1.60</td>
<td>Mar-11</td>
</tr>
<tr>
<td>Spain Digital Dividend</td>
<td>$1.00</td>
<td>Jul-11</td>
</tr>
<tr>
<td>US 700 leftovers</td>
<td>$1.00</td>
<td>Sep-11</td>
</tr>
<tr>
<td>Italy Digital Dividend</td>
<td>$1.60</td>
<td>Jul-11</td>
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<tr>
<td>Portugal Digital Dividend</td>
<td>$1.40</td>
<td>Nov-11</td>
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<tr>
<td>France Digital Dividend</td>
<td>$1.00</td>
<td>Feb-12</td>
</tr>
<tr>
<td>Switzerland multiband</td>
<td>$0.40</td>
<td>Jun-12</td>
</tr>
<tr>
<td>Denmark Digital Dividend</td>
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</tr>
<tr>
<td>Romania multiband</td>
<td>$-</td>
<td></td>
</tr>
</tbody>
</table>

**4G ERA**
Evolution of Prices for Digital Dividend

Shown for reference – cannot separate out price per band
Digital Dividend – Observations

- Unlike pre-DTV transition licensing, the digital dividend licenses for freed up spectrum have been established as having a clear tangible value. *Clear demarcation before/after 4G…*

- In the larger economies the value is tops out at US$1 per MHz-pop range on average.
  - With multiple licenses, values may vary by region.
  - Prices per bidder may vary a lot with CCA auction processes.

- Since the French process was one-round sealed bid with a reserve price per block, the French regulator likely calibrated the reserve price to previous auctions. This may in part explain the similar result to neighboring Germany, although the winning bidders in France all paid greater than the reserve price in any case.
Evolution of Prices for 4G/2600 MHz Spectrum

4G Deployment begins Dec 2009 in Scandinavia

4G ERA

Evolution of Prices for 4G/2600 MHz Spectrum

Increasing?
Evolution of Prices for 4G/2600 MHz Spectrum

Increasing?
Decreasing?
4G/2600 MHz – Observations

• Less clear distinction before/after 4G – *perhaps business case still not overly clear…*

• Average prices in the licensing processes shown are in the range of 7 cents (US) per MHz-pop. Trending auction values since 1996 shows a likely increase to above the 8-cent range.

<table>
<thead>
<tr>
<th>2.6 GHz Auctions</th>
<th>US$/MHz-pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple average</td>
<td>$ 0.0704</td>
</tr>
<tr>
<td>Pop-weighted average</td>
<td>$ 0.0434</td>
</tr>
<tr>
<td>Highest value</td>
<td>$ 0.3121</td>
</tr>
<tr>
<td>Lowest value</td>
<td>$ 0.0015</td>
</tr>
<tr>
<td>Trend forecast value</td>
<td>$ 0.0824</td>
</tr>
</tbody>
</table>
4G/2600 MHz – Combined vs. Standalone

• One factor that appears to influence 2.6 GHz valuations is the nature and timing of the award process itself. Notably licenses have been awarded as part of an auction process combined with digital dividend or other spectrum. ... pay more if it is your “only” chance to get 4G spectrum?

• The highest pre-4G era price was seen in Hong Kong in early 2009; a very densely populated market – value of added spectrum there is quite high.
  – There are five mobile incumbents in Hong Kong (no new entrants participated) and the process was for only three licenses of 30 MHz each.

• The Swedish process in May 2008 was the precursor to the initial deployment of 4G in Scandinavia in late 2009 providing early recognition of the potential value of 2.6 GHz spectrum for broadband service deployment.
## European Auction Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 4G auction</td>
<td>$0.187</td>
<td>$0.349</td>
<td>$0.191</td>
<td>$0.158</td>
<td>$0.244</td>
<td>$0.379</td>
<td>$0.196</td>
</tr>
<tr>
<td>Digital Dividend spectrum</td>
<td>$0.910</td>
<td>$1.136</td>
<td>$0.679</td>
<td>$0.570</td>
<td>n/a</td>
<td>$0.917</td>
<td>$0.370</td>
</tr>
<tr>
<td>2600 MHz paired</td>
<td>$0.028</td>
<td>$0.083</td>
<td>$0.056</td>
<td>$0.038</td>
<td>n/a</td>
<td>$0.148</td>
<td>$0.171</td>
</tr>
<tr>
<td>2600 MHz unpaired</td>
<td>$0.026</td>
<td>$0.034</td>
<td>unsold</td>
<td>$0.015</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Other 2G/3G</td>
<td>$0.065</td>
<td>$0.366</td>
<td>$0.269</td>
<td>$0.085</td>
<td>n/a</td>
<td>n/a</td>
<td>$0.013</td>
</tr>
</tbody>
</table>

(1) *In Spain the 900/1800 MHz ("2G/3G") spectrum was awarded in a separate process in June 2011*
(2) *The Swiss auction included 2G, 3G and 4G spectrum*
(3) *In France the 2.6 GHz was awarded Sept 2011: Digital dividend awarded Dec 2011*
(4) *In Denmark, three processes were run: 2.6 GHz in May 2010, 900/1800 MHz in Sept 2010 and Digital Dividend in June 2012*

## European Auction Results

<table>
<thead>
<tr>
<th>4G Auction values</th>
<th>Combined auctions</th>
<th>Separate auctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>USS per MHz-pop</td>
<td>Germany</td>
<td>Italy</td>
</tr>
<tr>
<td>Total 4G auction</td>
<td>$0.187</td>
<td>$0.349</td>
</tr>
<tr>
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</tr>
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</tr>
</tbody>
</table>

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Observations from Auction Results

• Some consistent trends across countries – digital dividend highest value and most of the proceeds. US 700 MHz auction “led the way” and still the highest.

• Paired spectrum in other bands is much less expensive. Hidden values in “other” bands (i.e. not digital dividend) – considering business case modeling and technology ecosystem (e.g. 1800 MHz, 2600 MHz).

• No clear trend for unpaired spectrum yet – sometimes highly valued, sometimes no value… possible source of hidden value.

• 4G Era pricing across all bands tends to be higher – reversed a post-3G downward trend – reflected in consumer device growth and data usage – driving need for new and different spectrum.
Spectrum Auctions and Valuation in the 4G Era

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• 13:15-14:15 – Session 1 – Introduction, context and key topics:
  – How much spectrum is needed per carrier;
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• 14:45… 15 minute break

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Values and Formats

- Review a few cases to see how value and format may “play”;
- Keeping in mind that observable outcomes are what bidders actually did pay, not what they may have been willing to pay.
- *Auction mechanism should not be a determinant of value* – all trying to do the same thing… BUT… some cases of interest where format plays a role:
  - SMRA with Set-Aside used in Canada (2008) and UK (2001);
  - 2.6 GHz in combined versus standalone processes;
  - Swiss CCA Multiband Auction (2012).
SMRA with Set-Aside used in Canada (2008) and UK (2001)
## UK vs. Canada Set-Aside Comparison

<table>
<thead>
<tr>
<th></th>
<th>UK 3G 2000 National licenses</th>
<th>Canada AWS-2GHz 2008 Regional licenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licenses awarded per market</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Licenses set aside per market</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Number of national incumbents</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Number of qualified new entrant bidders</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Amount spectrum MHz set aside *</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Set aside MHz as % of total auction</td>
<td>25%</td>
<td>38%</td>
</tr>
<tr>
<td>Set aside $ bid as % of auction proceeds</td>
<td>20%</td>
<td>36%</td>
</tr>
<tr>
<td>$/MHz-pop relative to non-set aside</td>
<td>-27%</td>
<td>-29%</td>
</tr>
</tbody>
</table>

* UK was 30 MHz paired and 5 MHz unpaired spectrum

In Canada, set aside was 44% of AWS spectrum

© Lemay-Yates Associates Inc., 2011
Set-Aside Impact

• Reduces spectrum available to largest operators with greatest ability to pay – lower amount available pushes up prices for largest operators;

• “Entrants” pay less – spectrum in any case is worth less as entrant than incumbent;
  – Influences on bidding – both in Canada and UK – entrants could also bid on non-set aside licenses, contributing to increased bidding activity;

• Policy impetus to increase number of players in the market – licensing is the only instrument to ensure there will be entry.

• In-auction spectrum caps can also serve to ensure a minimum number of licensees per market.
2.6 GHz in Combined versus Standalone Processes
Differences in Valuations for 2.6 GHz Spectrum

- 2.6 GHz value in combined 4G auction
- 2.6 GHz standalone auction value

Germany | Spain | Italy | Portugal | Sweden | Denmark | France | Austria

$0.30

$0.25

$0.20

$0.15

$0.10

$0.05

$-

Combined versus Standalone

• In combined auctions… bidders tended to bid up the more valued digital dividend spectrum, then move bidding over to other bands. With the bulk of the money – usually in the range of 85% - going on digital dividend, the remainder on other bands is relatively small.

• In a standalone process… bidders may be uncertain about future spectrum availability (particularly if digital dividend auction has not been scheduled) – hence possibly creates a higher demand for other bands in the meantime – having “4G” spectrum is a necessity.
  – To date, 2.6 GHz has been awarded in advance of digital dividend spectrum.
  – Some prices though influenced by reserve price – e.g. France 2.6 GHz value is high, but the reserve price value was about 64% of the total – bidders had to bid over the reserve price to win at all (single round sealed bid process). Thus the price in France may have been artificially high.
Swiss CCA Multiband Auction (2012)
## Swiss CCA Auction – Very Different Outcomes

- **160 MHz for 14 cents vs. 42 cents**
- **255 MHz for 20 cents per MHz-pop**

### Frequency Band

<table>
<thead>
<tr>
<th>Frequency band</th>
<th>Orange</th>
<th>Sunrise</th>
<th>Swisscom</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 MHz</td>
<td>20 MHz</td>
<td>20 MHz</td>
<td>20 MHz</td>
</tr>
<tr>
<td>900 MHz</td>
<td>10 MHz</td>
<td>30 MHz</td>
<td>30 MHz</td>
</tr>
<tr>
<td>1800 MHz</td>
<td>50 MHz</td>
<td>40 MHz</td>
<td>60 MHz</td>
</tr>
<tr>
<td>2.1 GHz FDD</td>
<td>40 MHz</td>
<td>20 MHz</td>
<td>60 MHz</td>
</tr>
<tr>
<td>2.1 GHz TDD</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2.6 GHz FDD</td>
<td>40 MHz</td>
<td>50 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>2.6 GHz TDD</td>
<td>0</td>
<td>0</td>
<td>45 MHz</td>
</tr>
<tr>
<td>Adjudication price</td>
<td>154‘702‘000</td>
<td>481‘720‘000</td>
<td>359‘846‘000</td>
</tr>
</tbody>
</table>

**Total Revenue:** CHF 996 M  
**Revenue/Reserve = 1.65**

**Total Sold:** 530 MHz FDD, 45 TDD.
Swiss Multiband Auction

- Very clear relationship between format and values;
- In CCA – winners pay second price – with only three bidders and vast amounts of spectrum, and many caps… each bidder's contribution was close to the total possible contribution to the auction;
  - E.g. combining cap on 800/900 and 900-alone meant, with only three bidders, they were essentially dividing 800 MHz spectrum by three – for second price calculation, since other two bidders could not exceed cap, taking one bidder out would reduce auction revenues by the amount of that bidder (i.e. “second” price is effectively zero, or reserve bid).
- Outcome would have likely been different had there been more bidders and hence more competition for the licenses;
  - Bidders had no way of knowing that in the auction process.
Format – Implications for Bidding

• Bidding strategy for any auction regardless of format has to start with a good understanding of license value – your own “max” bid, the estimates for other bidders, and comparable valuations from past auctions.

• Format does play a role:
  – Set asides – lower price for set-aside buyers – price of entry?
  – Combined versus standalone – as bidder should not look at an auction as “last chance” - may account for high digital dividend prices even though other bands may do the “job” (eventually);
  – CCA auctions – more complicated process – need to design bidding to get best outcome – targeting same general outcome as SMRA but values can vary dramatically.

• Many other issues as well… e.g. Reserve prices – for the auctioneer – potential for distorting bidding by setting the floor too high – importance of benchmarking given the auctioneer cannot know the max bids of the bidders.
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Basics of Auctions

- Award license to A and price of B… principle of standard English Ascending Auction process – final price is the price at which the 2nd highest bidder drops out – i.e. awarded at the 2nd highest price.
Basics of Auctions

- Award license to A and price of B… principle of standard English Ascending Auction process – final price is the price at which the 2\textsuperscript{nd} highest bidder drops out – i.e. awarded at the 2\textsuperscript{nd} highest price.

Auctions (CCA or SMRA) trying to get this result
Second Price – Vickrey

- Award license to A and price of B, i.e. “second price”
- “Social” benefit is maximized since license is awarded to A which sees the greatest economic value – but A pays at second price so retains the “profits” from bidding honestly
- With one lot, second price is clear… with multiple lots and combinations, the “second” price is the next best outcome for the group

$\begin{array}{c}
\text{Max bid price of A} \\
A \text{ wins at B's max price} \\
\text{Max bid price of B} \\
\text{Max bid price of C}
\end{array}$
Simultaneous Multiple Round Ascending Auctions (SMRA)

- Simultaneous – set of inter-related licenses all offered at the same time;
- All licenses remain open for bidding until there is no more activity;
- Bidding points – deposit to participate buys bidding “points”;
- Stages of bidding each with multiple rounds – have to progressively “play” more points as auction progresses;
- Non-discretionary bidding based on pre-determined bid increments;
- Auction “paced” by activity rule – eligibility points reduced as a result of inactive bidding;
- Activity rule waivers – each bidder starts the auction with 5 activity rule waivers – allows to pass a round without bidding and not losing points;
- Standing high bidders on licenses when bidding stops are the “provisional winners” of the licenses;
- **Easy to understand SMRA process and most widely used to date… but…**
Combinatorial Clock Auction Format

• Intended to “correct” flaws of SMRA auctions:
  – First phase clock auction provides bidders with opportunity to bid on packages of licenses in multiple round – submit bid for one package per round – auctioneer raises prices for blocks with excess demand, but all packages from any round remain eligible;
  – Second phase – one round sealed bid – bidders submit multiple bids for desired combinations (within constraint of activity rule from first phase);
  – Winner determination to find maximum revenue out of set of minimum Vickrey outcomes, considering all bids from both phases.

• CCA provides for the auction itself to determine the winning combinations of licenses;
  – Winner determination is complex and difficult to explain.
The CCA Format

- The CCA consists of the following phases:
  (1) Clock Phase.
  (2) Sealed-Bid Phase.
  [ (3) Allocation Phase for generic items.]
The Clock Phase

- The Clock phase in CCA is similar to that in SMRA except:
  - There are no standing high bidders.
  - **Package Bids:** A bid for package S is a bid for S, and not for subsets of S as well.
- Clock phases were originally introduced to help bidders **price discover**.
Item Pricing

- The clock phase uses **item pricing**.
- In any round $t$, each item $i$ has an individual price $p_i^t$.

\[
\begin{array}{ccccccc}
A & B & C & D & E & F \\
\bullet & \bullet & \bullet & \bullet & \bullet & \bullet \\
8 & 2 & 5 & 7 & 7 & 4 \\
p_A^t & p_B^t & p_C^t & p_D^t & p_E^t & p_F^t \\
\end{array}
\]

- So the **price of a package** $S$ is the sum of the prices of the items in $S$:

\[
p^t(S) = \sum_{i \in S} p_i^t
\]

\[
p^t(ABF) = 8 + 2 + 4 = 14
\]
Package (Combinatorial) Bids

- Bidders make user-defined package bids.
- Given the item prices, they bid for exactly the package S that they want.
  - **No Exposure Problem**: A bid for package S is not a bid for any subset R of S.
  - **No Specification Problem**: Bids for two packages S and T do not constitute a bid for the package S union T.
- In the clock phase a bidder can bid for only one package per round.
  [In the sealed-bid phase a bidder can bid for many packages.]
Clock Phase: Price Incrementation

- **Demand Packages.** In round $t$, given prices $p^t$ each bidder $j$ chooses her best package $S^t_j$.

- **Excess Demand.** The price of an item that is in more than one* demand package is increased for round $t+1$.
  
  [Price increments are set by auctioneer - e.g. To control the length of the auction.]
  
  [*Or more than supply for a generic slot.]

- This process is repeated until no prices rises are required.

- **Feasible Allocation:** Thus, on termination, the Demand packages together form a feasible allocation: *each item is sold at most once.*
Clock Phase: Provisional Winner Determination

- So at the end of the clock phase, each item has at most one bidder.
- Thus, Bidder $j$ is the **provisional winner** of every item for which she is the unique bidder.
- **Provisional Packages.** Let $S_j*$ be the package that $j$ provisionally wins.
- **IMPORTANT:**
  - The CCA is designed so that bidders should win their provisional package *after* the sealed-bid phase.
  - There is a simple strategy to ensure this.
A Clock Run

- Six items for sale A, B, C, D, E, F;
- One quantity of each item available;
- Three bidders: Blue, Green and Red.
A Clock Run

ROUND 1

ROUND 2

ROUND 3

ROUND 4: TERMINATION
### Revealed Preference Hybrid – A Numerical Example

<table>
<thead>
<tr>
<th>Round</th>
<th>A (10 pts)</th>
<th>B (25 pts)</th>
<th>C (30 pts)</th>
<th>Eligibility /Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>250</td>
<td>300</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>300</td>
<td>300</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Reducing Round</td>
</tr>
<tr>
<td>3</td>
<td>144</td>
<td>300</td>
<td>300</td>
<td>30</td>
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<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td>360</td>
<td>30</td>
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<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Using RP (35 pt. Package)</td>
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<tr>
<td>5</td>
<td>173</td>
<td>360</td>
<td>360</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Pricing

• The aim in CCA is to use Vickrey pricing to encourage truthfulness and, thus, give economic efficiency:
  – Actually Vickrey-Clark-Groves (VCG) pricing that reflect multiple goods and multiple bidders.

• But VCG can result in pricing that is too low… this can be addressed by Core pricing.

• So the CCA uses core prices that are as close to VCG as possible.
Fairness

• **An Example.** The VCG outcome is \{A, B\} with value $180.
• Without Blue the optimal allocation is \{A, B\} with value $100.
  – *So Blue’s contribution is $80 and her price is $10.*
  – *Green also pays $10 because they bid the same amount.*
  – *So the total revenue is $20.*
• But Red is willing to pay $100. Is this fair?
We call **Red** a *blocking coalition*.

**Blocking Coalition**: a set of prices is *blocked* if there is a coalition of bidders that can propose an alternative feasible allocation with higher revenue and that makes the coalition members better off.

To avoid this problem, the auctioneer raises prices until there is *no* possible blocking coalition.
**The Core**

A pricing scheme which can’t be blocked is said to be **Core Pricing**. As well as fairness, core pricing solves many other problems, such as collusion, shrill bidding, that can arise in auctions.

The collection of all core price schemes is called the **Core**.

Pay-as-bid is always in the Core, but VCG prices are not.

Which set of prices in the core should we choose?

[In this example, we could charge prices (0, 50, 50), (0, 40, 60), or even (0, 11, 89).]

<table>
<thead>
<tr>
<th>Bidders</th>
<th>A</th>
<th>B</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>-</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>Blue</td>
<td>90</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Green</td>
<td>-</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>
The Minimum Revenue Core

- A set of prices in the Core yields the minimum total revenue for the auctioneer out of all core points: the **Minimum Revenue Core**, or MRC.
- **Nearest-Vickrey Pricing.** To obtain a unique set of prices, the standard method is to choose the point which minimizes the distance between the Minimum Revenue Core and the VCG Prices.
- A variant is to minimize the *weighted* distance between Minimum Revenue Core and the VCG Prices, where each bidder is given a weight inversely proportional to the opening price of their winning package.
- Weighted Nearest-Vickrey pricing ensures that bidders who win larger packages pay more of the difference between MRC revenue and VCG revenue.
### A Picture

#### Bidders:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blue</td>
<td>-</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Green</td>
<td>-</td>
<td>-</td>
<td>32</td>
</tr>
<tr>
<td>Orange</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black</td>
<td>-</td>
<td>12</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Graph:

- $b_3(AB) = 32$
- $b_4(A) = 14$
- $b_1(A) = 28$
- $b_2(B) = 20$
- $b_5(B) = 12$

**Figure 1:** The core point closest to VCG payments

---

Taken from Day and Cramton, “Quadratic Core-Selecting Payment Rules for Combinatorial Auctions” Operations Research, 2012 (forthcoming)
The allocation stage of the auction determines the winning bidders and the number of licence blocks that they have won. The allocation stage is divided into two phases: the clock rounds and the supplementary round. All valid bids submitted during both phases of the allocation stage are used to determine the winning packages and base prices.

1. The clock rounds allow for price discovery, helping to reduce a bidder's uncertainty regarding the value of the licences. Bidders are able to respond to the changes in prices accordingly, shifting their bids to licences that continue to be consistent with their business objectives.

2. During each clock round, bidders are only able to bid on one package of licences; however, there may be other packages that they would be interested in winning. The supplementary round provides bidders with an opportunity to improve bids that they placed in the clock rounds and/or to submit bids that they were eligible to bid on but unable to submit in the clock rounds.

3. Excess demand for any product?

4. Source: Industry Canada
A Few Basics of Bidding in CCA

• Bidding in clock rounds – means identifying quantity of items at non-discretionary price;
• Start auction with set of eligibility (bidding) points – points reduced as you reduce demand;
  – Can “play” clock phase like SMRA;
  – Can temporarily increase eligibility with a revealed preference bid.
• Bidding on individual licenses (items) – but only the package considered;
• Each round bid counts in winner determination;
  – There are no standing high bidders.
• **Important to end clock rounds on a preferred package… the “final clock packages” are the provisional winners;**
• Difficult to predict end of the clock rounds – occurs when there are no overlapping packages amongst all the bids;
• Sealed bids – Start by increasing value of FCP – creates “room” to bid on other packages (including value of unallocated items as safety strategy).
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Live bidding and discussion of results…
Background – Lemay-Yates Associates Inc.
Lemay-Yates Associates Inc.

- Lemay-Yates Associates Inc. (LYA®) is a boutique consulting firm founded in February 1993 to provide management consulting services and market research to support the telecommunications industry:
  - LYA has completed approximately 500 different projects for 150 client organizations and has published 16 independent research reports
- LYA has participated in all of the Canadian auction processes held to date, including bid room participation in three SMRA auctions and support for award of spectrum in a Vickrey (second-price) process:
  - LYA also worked for the regulator in providing license valuations for cellular and PCS licenses supporting policy development prior to conducting auctions;
  - LYA has developed expert evidence in public consultations and participated in other licensing processes in Canada and worldwide.
- In 2012, LYA independently developed a CCA Auction Platform to support bidders in upcoming spectrum auctions;
- LYA has conducted extensive international research on spectrum prices, available in published c-Ahead® Reports;
- LYA has conducted Spectrum Strategy and Auction Seminars to support bidders in auctions since 2003.
LYA Wireless and Auction Services

- LYA has a unique ability to integrate all key elements to support business plans and winning game plans for participation in spectrum auctions.
- LYA’s services can be grouped into three categories – pre-auction services, support in preparation for and during auction, and post-auction and other services:
  - Pre-Auction Services;
  - Support in Preparation for and during the Auction;
  - Post Auction and Other services.
- Outlined on next charts…
LYA Wireless and Auction Services

1. Pre-auction services
   - Initial Development or as Independent Review for Board, Investors, etc.
   - Market and Revenues: Assessment of the evolution of technology and services, market research, competitive assessment, service and customer segmentation, forecasting of customers, services and revenues,
   - Spectrum and Network Deployment: assessment of total and new spectrum needs, development and assessment of network deployment scenarios (the pros and cons of different bands), usage parameters,
   - Overall Business Case Development: operational and financial modeling to finalize business plan, assess alternatives including acquisitions and due diligence.
LYA Wireless and Auction Services, continued

2. Support in preparation for and during the auction:
   – **Government consultations**: Expert evidence on technical issues, competition and auction processes prior to the auction,
   – **License Valuation and Initial View on Auction Strategy**: Development of valuation scenarios for the spectrum licenses, both internal and external views, game analysis, development of auction strategy; assessment of budgets for various bidders or types of bidders,
   – **Auction Support Including Bid Room Support and Auction Management Tool**: Auction budgeting, development of detailed auction strategies and bidding tactics. LYA provides on-site bid room support to auction participants; including support in implementation of bidding strategy,
   – **LYA Auction Management Tool**: LYA developed an Auction Management Tool that has been used by bidders in a number of Canadian spectrum auctions including AWS. The LYA Auction Management Tool can be provided with or without LYA bid room support. LYA provides training to clients for the Auction Management Tool.
LYA Wireless and Auction Services, continued

3. Post auction and other services:
   – **Auction post mortem**: bidding strategy success/fail for different bidders, end values relative to initial budget estimates by bidder,
   – Potential for license swaps, transfers, acquisitions,
   – Competitive environment and market landscape analysis post auction,
   – Key take-aways for future spectrum auctions.
LYA Spectrum Auction Toolkit

- Financial modeling and license valuation
- LYA® CCA Auction Platform
- Spectrum Strategy and Auction Seminars
- Expert Evidence in Public Consultations
- Game Analysis
- Tactical support, competitor analysis, bidder training
- LYA® c-Ahead® Reports on Spectrum Pricing
- Market research and segmentation
- Assessment of bands and technologies
- Post auction review and opportunity assessment
- Auction Round Tracking Tools
LYA Resources

• Johanne Lemay, BScA, ing., MBA, Co-President:
  – Previous employment at Nortel – product management and marketing;
  – Education – Engineering Physics (Laval) and Executive MBA (Concordia).

• Robert K. Yates, BASc., M.Eng, ing., MBA, Co-President:
  – Previous employment with Bell Canada and Nortel;
  – Education – Electrical Engineering (Toronto), Operations Research/Management Science (Toronto) and Executive MBA (Concordia).

• In-house staff supporting research and analysis:
  – Sam Birnbaum, BA (Math and Philosophy) with LYA since mid-2012; programmer supporting the LYA CCA Auction Platform; has provided analytical support for market research and
  – Alexander Huot, B.Comm; with LYA since early 2010 including participating in assessment of mobile business case in Canada and expert in analysis of large datasets; research into auction and license processes and auction results worldwide.

• Team of Associates – specialized experts in Spectrum Auctions.
Examples of Recent LYA Projects

- Independent development of LYA Auction Game Simulator (2012);
- Support in assessment of auction formats and related rule set issues in CCA Auctions in context of Industry Canada’s consultation on 700 MHz (2012);
- International benchmarking (32 OECD countries) of fixed broadband speed performance and costs (2011);
- Mobile business case development, market entry and technology assessment and financial modeling for a regional operator (2011);
- Regulatory support and expert evidence in the context of Internet backbone costs, telecom competition and interconnection (2011-2012);
- Assessment of spectrum requirements for mobile broadband deployment (2010/2011);
- Research of mobile service pricing comparing Canada-US by carrier for voice and data, including evolution of basket costs using historical pricing information tracking from late 1990s to 2010 for voice and data (2010);
- Review of mobile technologies and standards for the 700 MHz and BRS frequency ranges (2010);
- Assessment of Performance of Canada’s Consumer Broadband Networks, including international comparisons of fixed and mobile data consumption (2010);
- Development of business plan and support for application to Industry Canada’s Broadband Canada program (2009);
- Modeling and assessment of network capacity for television over Internet, comparison to fixed and mobile broadband traffic and trends (2010);
- Review of broadband for small/medium businesses in Canada, including assessment of availability, speed objectives, traffic growth, use of e-commerce, web sites (2010).
The LYA CCA Auction Platform

- LYA's CCA Auction Platform, provides a way to test the impacts of different rules and their implementation as well as bidding tactics in a realistic setting.
- Provides a mock auction platform for bidders to bid against each other or against a set of robots; robotic simulation of game outcomes:
  - Bidders can be humans and/or robots;
  - Robots bid based on selecting from 10-12 behaviors;
  - Bidding is blind and replicates CCA auctions following Australian/Canadian rules;
  - Reflects Canadian 700 MHz band plan, spectrum caps and generic lots;
  - Auctions come to a natural conclusion including clock and sealed bid phases.
- Current status – at final prototype stage… supports analytical work to evaluate impact of competitive landscape for an upcoming auction and possible winning strategies, auction format different rule sets, and bidding rules, caps, etc.
Thank you…