

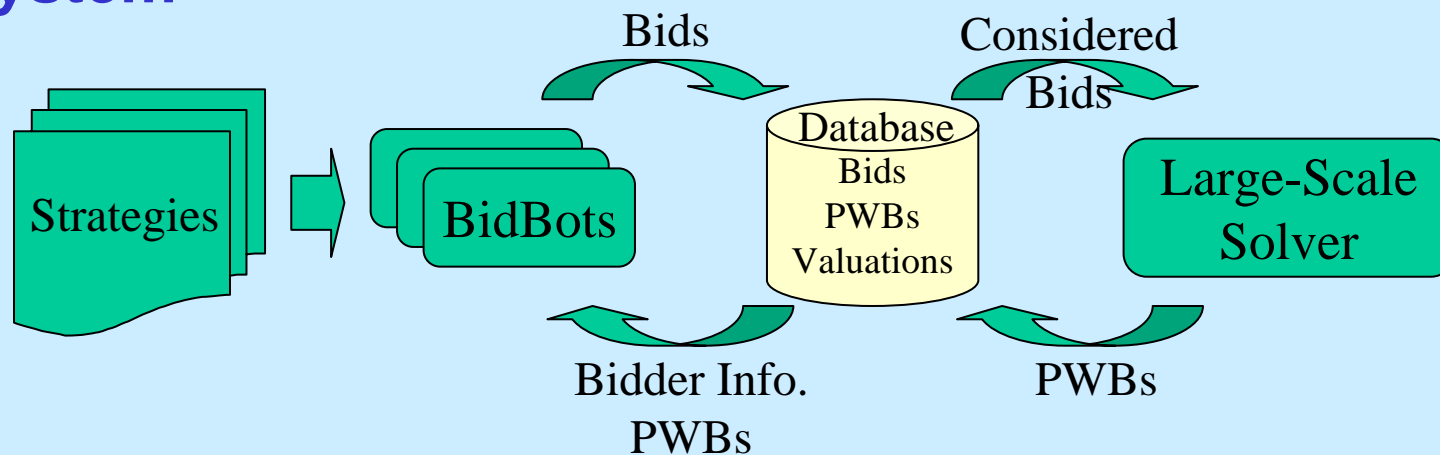


BidBots

A Combinatorial Auction Testing Platform

- » **Automated Auction Simulation Program**
 - Control Auction Sequence
 - Impose Pre-determined Auction Rules
 - Vary Size of Auction
 - Licenses
 - Bidders
 - Packages per Bidder
 - Provide Platform for Strategic Bidding Entities
- » **Program Concurrently Developed With And For The Large-Scale Solver**

» Not Integrated Into Auction #31 Package Bidding System



» *BidBots (Bidder Robots)*

– Ambiguous Term

- Auction Simulation (Software or Version)
- Automated Bidders (Personified Context)

Introduction – Purposes & Advantages

» Fundamental Purposes Include

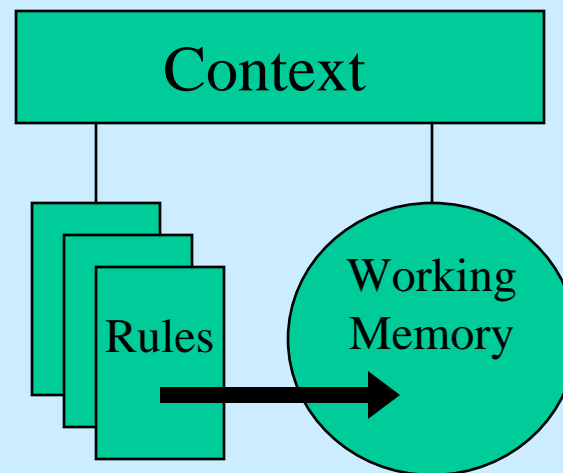
- Primary: Provide Large Data Sets To Test Large-Scale Solver
- Secondary: Provide A Means To Analyze Effects Of Auction Rules

» Realized Advantages

- Relieve Burden Of Human Participation
 - Time Requirements
 - No User Interface Requirements
- Perform “As Fast As It Can Run” Testing
 - Bidding takes approximately 1 second per active bidder
 - Multiple auctions can be run in 1 day
- Strategies are interpreted at the time of execution
 - Stored text files
 - ILOG JRules

» ILOG JRules

- Each bidder (BidBot) is a context
- Licenses and Packages comprise the working memory
- Rules define a bidding strategy



Introduction – Example



- » If a Package exists where
 - the MAB is less than the Valuation
- » Then place a Bid at the MAB



Version 1 Implementation – Fundamentals

- » **Auction Rules Mimic Auction #31**
 - No Last And Best Bidding
- » **Provides Basic Bidder Functionality**
 - Dynamically Create New Packages
 - Place New Bids (With Increments)
 - Renew Previous Bids
 - Utilize Activity Waivers
 - Reduce Eligibility



Version 1 Implementation – Strategic Participation

» Four Initial Strategies

- Parking
- Random
- Straightforward
- Value

» No Use Of Bid Renewal

» Non-Strategic Use of Activity Waivers and Eligibility Reduction

Parking – Bidding Rule

- » **Compile a List of Packages(Licenses) where**
 - the MAB is Less Than the “Going Rate”
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Loop Over the List**
 - Place a Bid at the MAB on the Package(License)
 - with the Largest Delta Between the MAB and “Going Rate”
 - that Does Not Overlap Any Packages(Licenses) Already Bid
 - Quit Bidding when
 - activity Requirement Has Been Met
 - no More Packages(Licenses) Remain In List

Parking – Create Package Rule

- » **If there does not exist a Package(License) where**
 - the MAB is Less Than the “Going Rate”
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Then**
 - Create a New Package where
 - the MAB is Less Than the “Going Rate”
 - the MAB is Less Than the Valuation
 - Place a Bid at the MAB on the New Package

Random – Bidding Rule

- » **Compile a List of Packages(Licenses) where**
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Loop Over the List**
 - Choose a Package(License)
 - at Random
 - that Does Not Overlap Any Packages(Licenses) Already Bid
 - Place a Bid on the Package(License)
 - at a Randomly Chosen Increment
 - Quit Bidding when
 - activity Requirement Has Been Met
 - no More Packages(Licenses) Remain In List

Random – Create Package Rule

- » **If there does not exist a Package(License) where**
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Then**
 - Create a New Package where
 - the MAB is Less Than the Valuation
 - the Licenses In the Package Are Chosen at Random
 - Place a Bid at a Randomly Chosen Increment on the New Package

Straightforward – Bidding Rule

- » **Compile a List of Packages(Licenses) where**
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Loop Over the List**
 - Place a Bid on Every Package(License)
 - at the MAB
 - Quit Bidding when
 - no More Packages(Licenses) Remain In List

Value – Bidding Rule

- » **Compile a List of Packages(Licenses) where**
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Loop Over the List**
 - Place a Bid at the MAB on the Package(License)
 - with the Largest Delta Between the MAB and Valuation
 - that Does Not Overlap Any Packages(Licenses) Already Bid
 - Quit Bidding when
 - activity Requirement Has Been Met
 - no More Packages(Licenses) Remain In List

Value – Create Package Rule

- » **If there does not exist a Package(License) where**
 - the MAB is Less Than the Valuation
 - is Not a Provisionally Winning Bid From the Last Round
- » **Then**
 - Create a New Package where
 - the MAB is Less Than the Valuation
 - Place a Bid at the MAB on the New Package



Version 1 Test Results – Test Auction Description

» Auction Size Defined By

- 200 Licenses
 - 100 Licenses Contain 840,000 BUs
 - 100 Licenses Contain 1,680,000 BUs
- 50 Bidders
 - 14 Parking
 - 10 Random
 - 11 Straightforward
 - 15 Value
 - 80% Receive Full Eligibility (252,000,000 Bus)
 - 20% Receive 50-100% of Full Eligibility
- 25 Packages Per Bidder



Version 1 Test Results – Test Auction Description

» Each Bidder is Provided (Pre-Auction)

- Valuations on All Of the Licenses They Value
 - License Valuations Equal the License's Bidding Units Multiplied By a Randomly Chosen Number Between Four and Six
- A Synergy Factor
 - Random Number Between One and Two
- Valuations on Up To 10 Packages (Up To 25 Packages For Straightforward BidBots)
 - Package Valuations Equal the Sum of the Valuations on the Package's Licenses Multiplied By the Package Synergy
 - The Package Synergy is a Randomly Chosen Number Between One and the Bidder's Synergy Factor



Version 1 Test Results – Test Auction Results

- » **Maximum Revenue = \$2,187,676,000**
- » **137 Rounds**
- » **18 Provisionally Winning Bids**
 - 1 Package Bid on 183 Licenses
 - 17 Individual License Bids
- » **Total Runtime = 1 hour 37 minutes, 1.5 min/round**
- » **BidBots Did Not**
 - Complain About Not Winning Anything
 - Get Tired of Bidding Midway Through the Auction
 - Exceed Their Valuations on Packages(Licenses)
- » **SUCCESS!**



Version 1 Test Results – Discoveries

» Anomalous Bidding Behavior Found

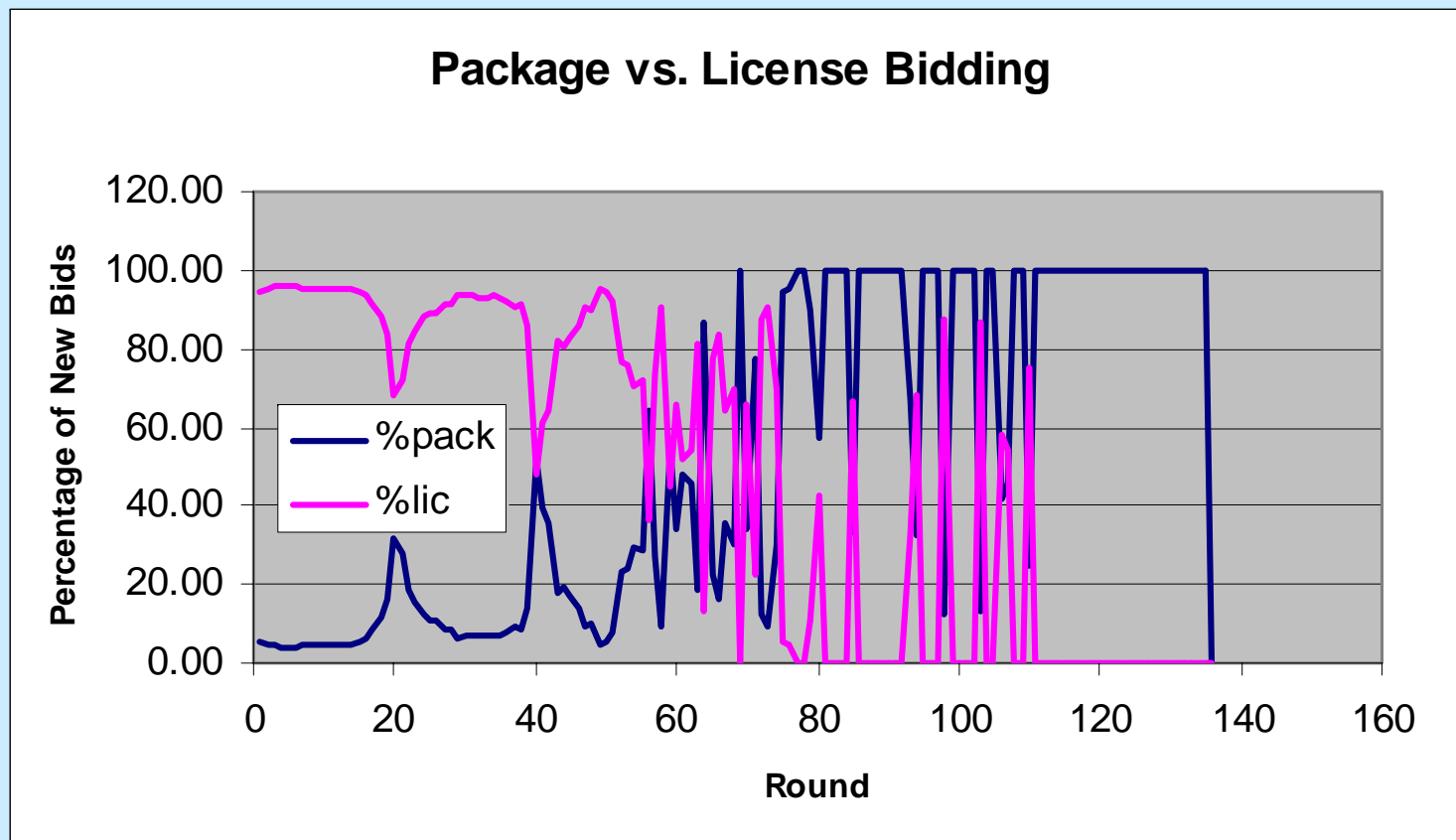
- Package Bidding vs. License Bidding
- Composition Of Provisionally Winning Set
- Parking Bidder Drop-Out
- 110 Round Revenue Plateau
- New Bid Spikes

» Deficiencies of Implementation

- Simple, Inflexible Bidding Strategies
- Small-Auction Paradigm

Version 1 Test Results – Package / License Bidding

» Mid-Auction Shift From Licenses to Packages





Version 1 Test Results – Package / License Bidding

- » **BidBots Do Not Differentiate Between Packages and Licenses**
- » **During First Half of the Test Auction**
 - Straightforward BidBots 10:1 Bids on Licenses vs. Packages
 - Random BidBots 20:1 Chance of Choosing a License to Bid On
 - Parking/Random/Value BidBots Place Complementary Bids
 - Large Packages Create High Probability of Overlap
 - Licenses Can Be Used to Meet Activity Requirement
- » **At Mid-Auction**
 - Most BidBots Approach Their Respective Valuations on Licenses
 - BidBots Begin Creating New Packages to Meet Activity Requirement

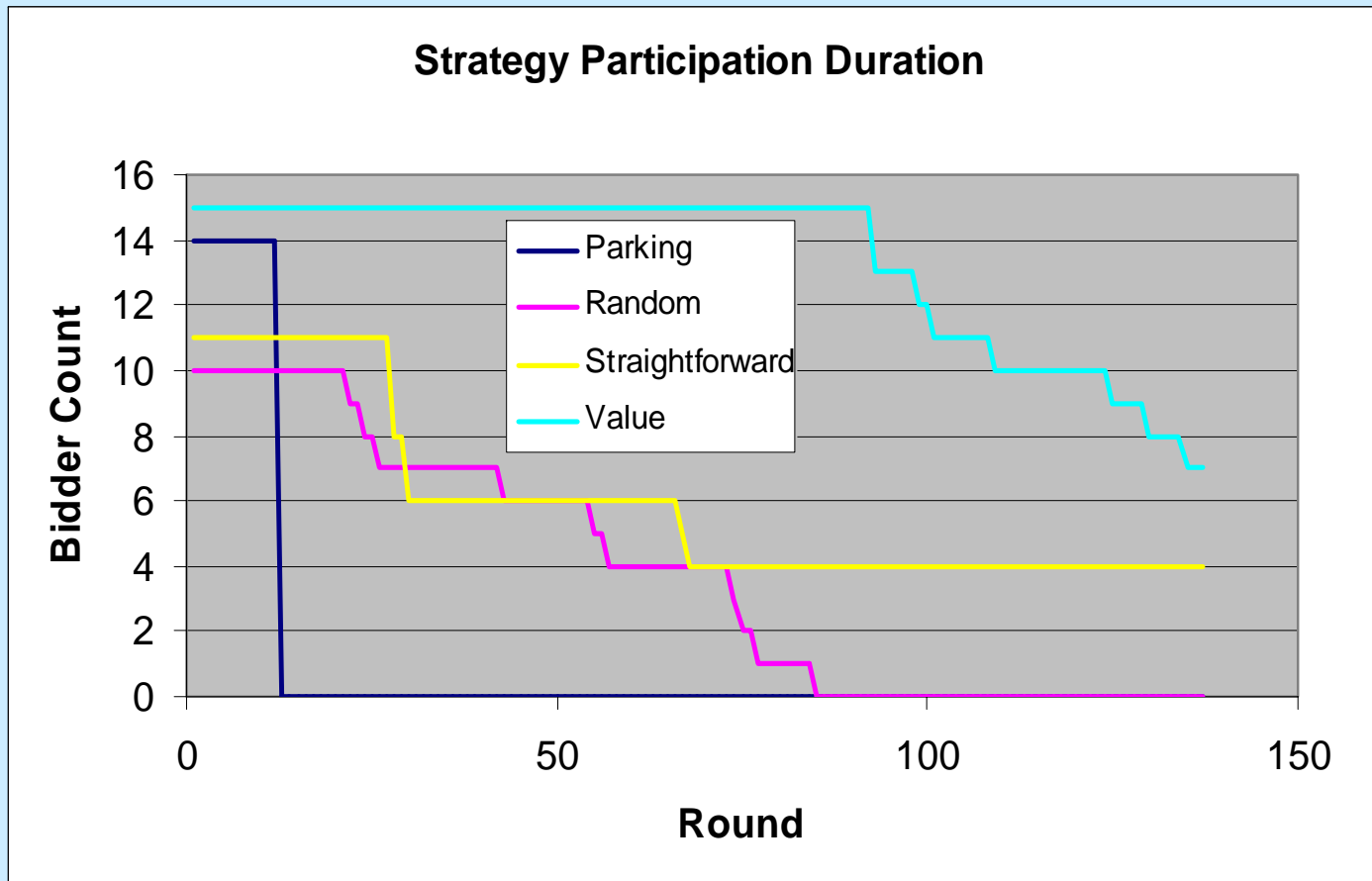


Version 1 Test Results – Provisionally Winning Set

- » **Early Rounds Were All Individual License Winners**
- » **After Round 17, Packages Were Present in PWB Set**
 - PWB Set Never Contained More Than One Package
 - Package Never Contained Fewer Than 107 Licenses
- » **After Round 23, One Package of 183 Licenses**
- » **Packages In Auction Were Generally Large**
 - BidBots Are Not Limited In Size of New Packages
 - Size of Packages Chosen Randomly (Uniform Distribution)
 - Average Package Size In Auction Was 80 Licenses
 - High Probability That Packages Overlap
 - Two Packages, Each Containing 80 Licenses Are All But Guaranteed to Overlap One Another, 99.9999999999999999...99999%
 - One Package With 183 Licenses, Second Package With 2 Licenses Will Overlap 99.999867% of the Time

Version 1 Test Results – Parking BidBot Dropout

» All Parking BidBots Dropped Out in Round 13





Version 1 Test Results – Parking BidBot Dropout

» First Seven Rounds of Bidding

- 95% of Bids Placed Were Individual License Bids
- 85% of the Individual License Bids Were at the MAB
- Provisionally Winning Set Was 200 Individual License Increment Bids

» “Going Rate”

- Average Bid Value on Each of the Licenses From Last Round
- Kept Low Since Majority of Bids Were at the MAB

» MABs Rose Quickly From Lowest \$/BU in the Provisionally Winning Set

» By Round 8 MABs Began Exceeding “Going Rates”

- Could Not Bid on Packages(Licenses)
- Could Not Create New Packages

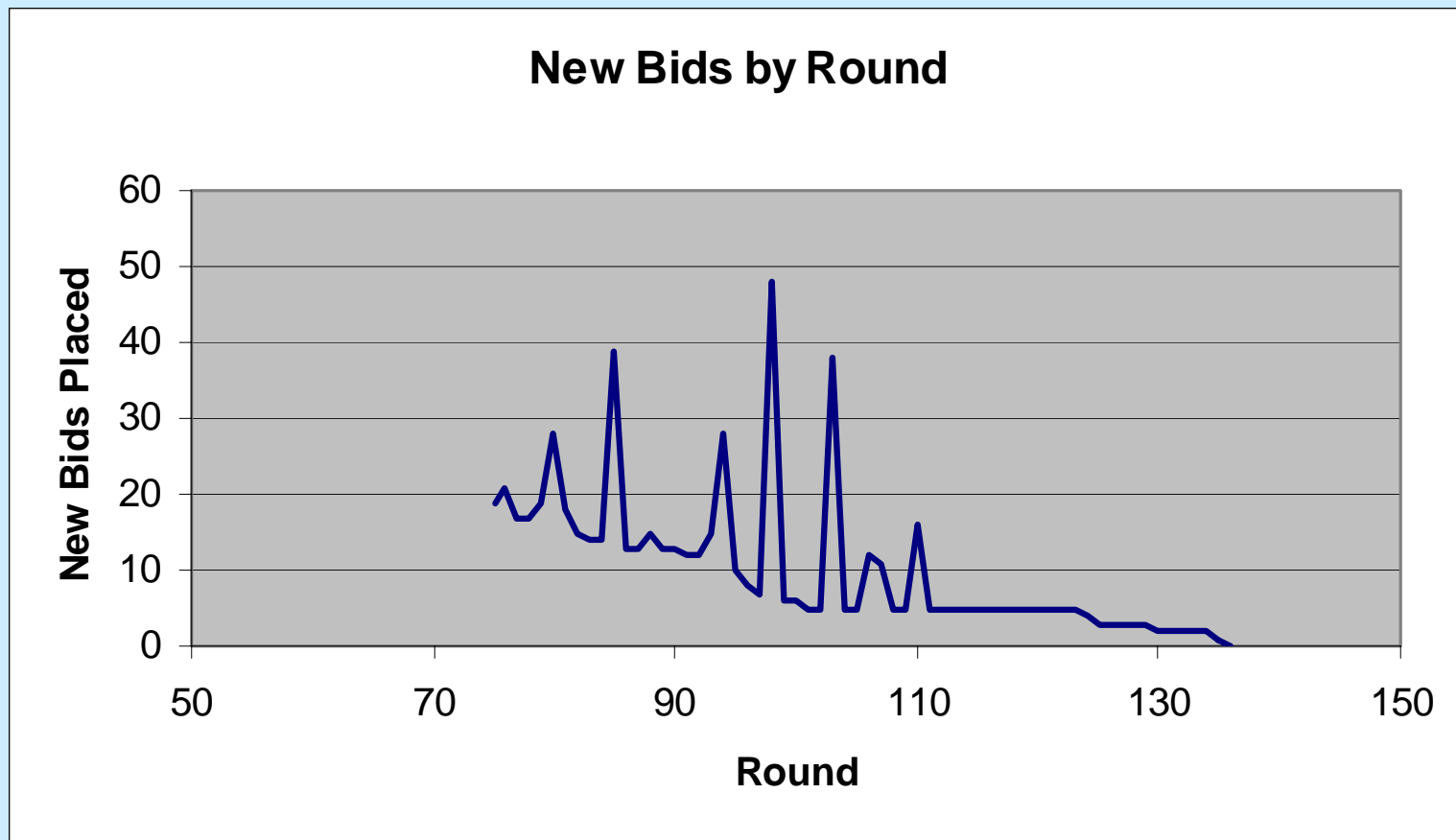


Version 1 Test Results – 110 Round Revenue Plateau

- » **99.7% of Revenue Was Generated By Round 25**
 - 110 Rounds of Bidding Followed
 - 9800 New Bids Were Placed
- » **Composition of Provisionally Winning Set Remained 94% Unchanged (By Bidding Units)**
 - 183 License PWB in Round 24, High Valued
 - Bidders Reached Their Values on Licenses From Extensive License Bidding in Early Rounds
 - New Packages Could Not Compete
 - High Probability of Overlap
 - No Bid Renewals, Good Partnering Bids Were Lost
- » **Use of New Packages Acted as a Parking Strategy**
 - Bidders Could Stay in Auction For 60+ Rounds Without PWBs

Version 1 Test Results – New Bid Spikes

» Drastic Spikes in Bidding in Mid To Late Rounds





Version 1 Test Results – New Bid Spikes

- » Value BidBot Chooses Package(License) With Largest Delta Between Valuation and MAB
- » MABs Approach Valuations of Packages in Later Rounds
 - For One BidBot, Value Delta of a Package May Become Smaller Than That of 50 or More Licenses
 - The 50 or More Licenses Will Then Be Bid to Meet Activity Requirement
- » Value BidBots Alternate Bidding on Packages and Licenses Repeatedly as the Value Deltas Approach Zero



Version 1 Test Results – Conclusions

» Suggested Improvements

- Strategic Prioritization Of Package/License Collections
- Package Size Limitation/Distribution
- Intelligent Creation Of Packages
 - Partnering Considerations
 - Interrelationships Among Licenses
 - Frequency Adjacency
 - Geographic Adjacency
- Normalization Of Value Deltas By Bidding Units
- Research Into Historic Bidding Practices



Version 2 Requirements – Operational Modifications

» Functional Improvements and Modifications

- Budget Constraints
- Last And Best Bidding
- Imposition Of Package Size Distribution
- License Adjacency Matrix
- Strategic Focus/Prioritization (Business Plans)
- Bidder Analysis Of Auction State

» BidBots-Auction Administrator Interface

- Auction Control Mechanisms
 - Start, Pause, Restart, Stop Features
 - Auction Rule Parameter Settings
- Auction Monitoring Mechanisms
 - View Round Results
 - Query Database



Version 2 Requirements – Strategy Improvements

» Additional Strategies

- Bi-Modal
- Gaming
- McCaw
- Thief

» Strategic Use of Embedded Functionality

- Bid Renewals
- Activity Waivers
- Eligibility Reduction
- Last and Best Bidding
- Strategic Focusing

Bi-Modal BidBots

- » **Will Alternate Focus on Two Different Business Plans From Round To Round**
- » **Will Retain Focus on a Business Plan When Provisionally Winning Bids Exist From a Prior Round**
 - **Will Use Renewals to Compose a Complete Set of Non-Mutually Exclusive Bids**
- » **Will Create Packages as Derivatives of Current Business Plans That Appear to Have Stronger Partnering Potentials Given the Current Composition of the Provisionally Winning Set**

Gaming BidBots

- » Will Attempt to Stay In the Auction Without Exposing Their True Interest or Losing the Eligibility Required to Bid on Their True Interest
- » Will Later Bid on Those Packages(Licenses) That They Truly Value In a Straightforward Manner While Attempting to Win a Predefined Percentage of Bidding Units From Their True Interest
- » Will Create Packages to Support Their Initial Parking Strategy and Their Later Straightforward Strategy
- » Packages Created During Straightforward Approach Will Focus on Derivatives of the Packages(Licenses) of Interest to Them so as to Better Partner With Incumbent Provisionally Winning Bids.

McCaw BidBots

- » Will Participate Only From the Standpoint of Pushing the Auction Towards the True Valuations on the Licenses Being Offered
- » Will Create Packages That Replicate Those Created By Other Bidders
- » Will Engage in Mock Competition With Other Bidders in Order to Drive the Values on Packages(Licenses) Nearer to the True Valuations the Other Bidders Have on Those Packages(Licenses)
- » Will Attempt to Not Win Anything
- » Will Exceed Their Package Valuations and Budget Constraints in Cases Where They Do Not Risk Their End Objective of Winning Nothing

Thief BidBots

- » Will Idly Participate in the Auction Until Evidence of Incumbency Exists in the Provisionally Winning Bid Set
- » Will Attempt to Steal a Package By Jump Bidding a Current Provisionally Winning Bid
- » Will Supplement Their Objective Bids With Nominal Bids on Other Packages(Licenses) in Order to Maintain Eligibility
- » Will Shift Objectives As Incumbency in the Provisionally Winning Bid Set Changes
- » May Place a Last and Best Bid For \$1000 More Than a Last and Best Bid That is Incumbent in the Provisionally Winning Bid Set in Order to Win it Away

- » **Human vs. BidBots Auctions**
- » **BidBots-Auction Network Interface**
 - Strategy Development
 - Auction Monitoring
- » **Intelligence**
 - Decision Support Through Optimization
 - Trend Recognition/Analysis
- » **Auction as a JRules Context**
 - Rules of the Auction are the rules of the Context
 - Working Memory would be composed of the Bidders