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Introduction

This report is deliverable 1c under FCC Contract No. C-9854013. The report provides documentation for the simultaneous ascending auction with package bidding (SAAPB) being developed by Charles River Associates Incorporated (CRA), Market Design, Inc., and Professor Charles R. Plott of Caltech and Computerized Market Systems, Inc. The documentation addresses specifically the SAAPB system design, structure of the auction rules, operational parameters, and verification process. This report is structured as follows.

The section on documentation of the system design covers the structure of the software program and how the various components are integrated.

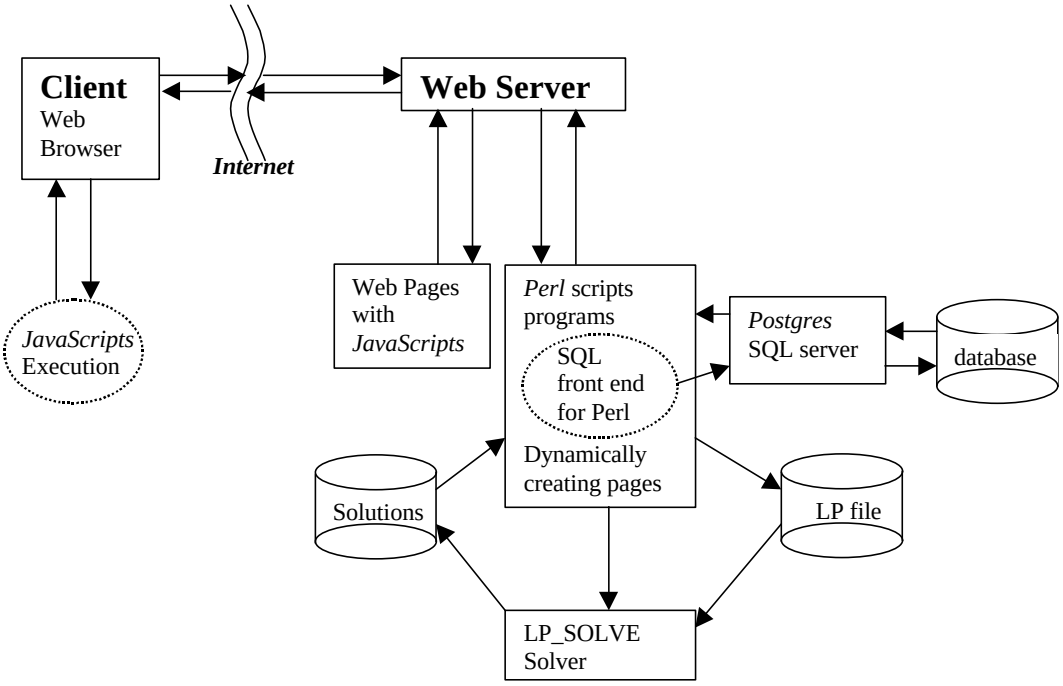
The section on the structure of the auction rules is a revision of a preliminary document supplied previously to the FCC. Definitions and the auction rules are described here, as are alternatives to be experimented with.

The section on operational parameters discusses some of the SAAPB parameter values that have been used and tested in experiments.

The section on verification process discusses the method by which the implementation of the SAAPB can be verified.

The last section of this report includes sample screens from the current version of the SAAPB.

2
System Design



Server Side:

*Hardware: Intel Pentium 350MHz, 32 MB memory, 2 GB HD

*Network: constant TCPIP connection to internet with permanent IP

*Operating System: RedHat Linux 5.1

*Database server: Postgres SQL server

*LP problem solver: LP_SOLVE package (C program, requires gcc if program modification is desired)

*Web Server: Apache Web Server

*Scripting Programming Language Support: Perl 5 (minor version requirements not explored) with Postgres for Perl Application Programming Interface

Client Side:

*Hardware/Software/Network: any platform with TCPIP connection to internet

*Web Browser: supporting Java Script

Processes

Setup:

The Web Server and SQL Server must be running. Perl5 must be installed. The DBI module and appropriate DBD modules for the SQL server must be installed. The program files are placed on the server. Appropriate ScriptAlias and Alias directives on the Web Server refer to the file locations.

Startup:

For Each 'Run', a new database is created in the DBMS. A file of SQL commands to initialize the new database (for Postgresql) is provided. The name of the new database is put into a config file so that scripts can access the proper database.

Server Tasks

Login:

1. The id and password are checked.

2. A record of the id, time, and remote host is logged.

3. An appropriate frameset web page is generated. The id and password are set as cookies.

New Bids:

1. The form submitted is checked to ensure that id, bid price, and the bid package make sense.

2. The weight of the bid is added to the weights of existing bids and must be less than a subject's total eligibility. Both the total weights of multiple package bids and total weights of locations receiving bids must not exceed total eligibility.

3. Single bids are checked and must be greater than the max single bid for the location.

4. A lock is obtained so that only one lp_solve calculation is performed at a time.

5. The MaxSet() price is calculated for the package and the bid price must exceed the MaxSet() * increment rule price.

6. If all of the above succeed, then the bid is inserted and the database updated.

7. If in the sealed bid phase, the lock is released and we are done.

8. A new solution is calculated from all active bids, the new bid, and any reserve bids tagged by the new bid. The new price and new set of winners are calculated. The maximum price is updated. The winning/nonwinning status is updated for all bids for which this changed and for the new bid. (note: Reserve bids are active only if they are winning. If a winning reserve bid becomes nonwinning, it automatically becomes inactive.)

9. The lock is released and the increment and query price are displayed.

New Reserve Bids:

1. The form submitted is checked as with new active bids.

2. The weight of the bid and existing bids and must not exceed reserve eligibility as with active bids.

3. A lock is obtained.

4. The MaxSet() price is calculated from active bids and the reserve bid price must exceed the MaxSet() * increment rule price.

5. If all of the above succeed, then the bid is inserted as a reserve bid.

6. The lock is released.

Queries:

1. The form submitted is checked to ensure that the bid package makes sense.

2. A lock is obtained so that only one lp_solve calculation is performed at a time.

3. If in the sealed bid phase, the bids at the beginning of the phase are retrieved. In the continuous phase, current bids are retrieved.

4. The MaxSet() price is calculated for the package and the MaxSet() * increment rule price is shown.

5. The solution is calculated from the existing bids and the new bid entered with 1 + the current maximum price as the bid price (to ensure that the new bid will be winning in this solution).

6. The Query price is calculated and shown as: max price + bid price - new price + 1 (to round up) or 2 * max price - new price + 2

7. The lock is released and the bidder is notified if the new bid is winning or nonwinning.

Cancellation:

1. The list of bids to be cancelled is checked. All bids must be nonwinning and owned by the canceller.

2. The expire time of each cancelled bid is set to make the bid inactive. The database is updated.

Cancelling winning (mistake) bids: (administrative command line utility)

1. The cancelled bid time is set to make the bid inactive.

2. Active bids are retrieved and a new solution is calculated.

3. The new price (less than the previous maximum price) is updated. Bids are updated if they become winning/nonwinning.

Show: Active bids, personal bids, morgue bids:

1. The appropriate data are retrieved from the database and displayed. See screen shots.

Change of phase:

1. A lock is obtained so new bids cannot be submitted.

2. Configuration and status areread from the database.

3. In the post-continuous bid phase, the bid log is queried so that we can tell if a bid was winning anytime during this phase.

4. In the post-sealed bid phase, a new solution is calculated, and the new price and bids are updated.

5. The current status is saved for reference.

6. The round, phase, and phase length areincremented and updated.

7. The bids from the beginning of the phase are retrieved so that the activity credit of active bids can be calculated. MaxSing prices are calculated.

8. All active bids are weighted and checked to determine their activity credit. (large sequence of conditionals)

9. For each id, the total activity credit is calculated from the credit of their bids and the parameters (betas, lambda).

10. In the post-sealed bid phase, the activity credit is stored.

11. In the post-continuous bid phase, the activity credit, stored activity credit, and eligibility are checked to determine the next round eligibility. The database is updated. If the new eligibility for an id is zero, and the id was not already in reserve, the id is marked as in reserve and all remaining active bids of the id are cancelled (none of them can be winning if the new eligibility is zero).

12. The current active bids are saved as the beginning of next phase bids for later reference.

13. The lock is released.

3
Structure of Auction Rules

INTRODUCTION

This section outlines some of the rules we have considered and implemented in our development of the prototype system of a simultaneous ascending auction with package bidding (SAAPB). These rules are not written at a level or in a form meant for bidders to understand easily. The description here is intended to facilitate discussion among project team members including the auction experts, economists, and software developers. This section is not a comprehensive discussion of all the auction rules or all the design features, although it is intended to include the major types of rules. The rules here are very preliminary and our work products continue to be works-in-progress.

OVERVIEW OF THE RULES

This section provides a synopsis of the rules of the simultaneous ascending auction with package bidding (SAAPB) system. The remaining sections discuss definitions and rules in more detail.

ROUND WINNER SELECTION PROCESS. Bids for packages of licenses are submitted in two phases of each round: a sealed bid phase and a continuous bidding phase. (A special case of a package is a single license.) The bidding system finds the set of bids that maximizes the revenue that would result from an actual sale. The selected bids have no licenses in common. That is, each license is allocated to only one bidder. In this case, the set of bids is a consistent collection of bids. The selected packages in the "winning set" are called the round winners or temporary winners, depending on the context.

RULES 1 and 2. These rules limit the number and types of bids so the system does not attempt computational problems that are too big to solve in reasonable time.

RULES 3 and 4. Round winners can be neither cancelled nor withdrawn. Bids that are not round winners can be cancelled whenever bids can be submitted (i.e., in any phase).

RULE 5-7. The sum of the activity weights (measured in points) of the bids that a bidder has in the system cannot exceed the bidder's eligibility for that round.

RULES 8 and 9. A bidder's activity for a round (which will be used to determine the bidder's eligibility level of the next round) is determined by the maximum of its activity in the sealed bid

phase and the continuous bidding phase. The number of items in the package and aggressiveness of the bid determine measurement of this activity. Four levels of aggressiveness are developed: the bid is in the selected set; the bid was high enough to be in the selected set when tendered; the bid is more than the sum of the best bids for single items in the package; the bid is lower than the sum of best bids on singles. Thus, when activity credit is given to non-winning bids the number of activity points depends upon the size of package of items and how the bid amount is positioned relative to other bids in the system, e.g in the sealed bid phase the position is relative to the bids that exited at the end of the previous continuous phase.

RULE 10. Eligibility will drop from round to round unless the activity levels are at required levels.

RULE 11. New bids must meet a minimum "increment requirement" to be submitted to the system. (We are currently implementing the option that is listed as Rule 11.3 below.) Existing bids can remain in the system (and are subject to the activity tests of Rules 8 and 9) but new bids for a package must be z% above the highest bid amount for the consistent collection of bids that cover the package. For the purpose of the increment requirements bids on single items are considered to be a "package".

RULE 12. As an option to be experimented with, bidders with no eligibility remaining can place their final bids in a “reserve” of bids set aside for this purpose. These bids cannot be changed in any form. Bidders with eligibility can combine their own bids with one or more of these reserve bids, but if the combined bid does not become a winner then the reserve bids are returned to the bid reserve. (The bid of the eligible bidder must independently meet the increment requirement.)

RULE 13. Each bidder has a set of identifiers that allow other bidders to identify a collection of that bidder’s bids or allows the bidder to completely hide efforts if desired by the bidder.

DEFINITIONS: TIME LINE

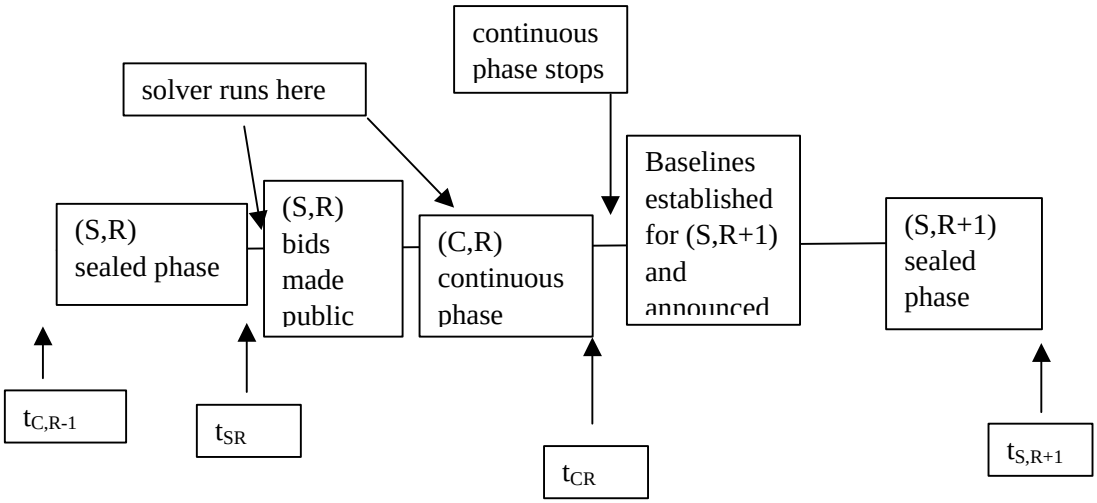
DEF. 1. R = round, P = phase (sealed bid or continuous bidding), t = clock time.

DEF. 2. A round has two phases, sealed bid and continuous bidding. This means that we have at least three measures of time (R, P, t) where R is the round, P is the phase in a round, and t is the clock time (sometimes meaning before the next change of phase or next round).

DEF. 3. “(S,R)” refers to the Sealed bid phase of round R. Bids submitted during this phase of the round are not observed by other bidders during the round (they may be observed by other bidders after the sealed bid phase is completed). “(C,R)” refers to the Continuous bidding phase of round R. Bids and the status of bids are public as they are entered.

DEF. 4. Typically the index of a phase means the end of a phase rather than the beginning of the phase.

The time line is as follows:



DEFINITIONS: STATE OF BIDS

Note: The time of measurements is exactly as stated. Typically those used for the sealed bid phase are just after the close of the previous continuous phase. Measurements during the continuous phase are at the instant a bid is submitted, except for the first measurement, which is at the instant the phase opens.

DEF. 5. AB(t) = set of active bids at time t. The active bids is the set of all bids examined by the system/solver whenever it calculates a winning set or whenever it computes the minimum it would take to become elements of the winning set. $AB_i(t)$ contains the active bids of agent i. Whether or not active bids are related to activity credits depends on the stage of the auction. In general the status of active bids, as defined below, will determine the nature of the activity credit they produce.

DEF. 6. W(t) = set of winning bids, those that would win if the auction stopped at instant t — shown as elements of a winning set in yellow in the preliminary version of the system that operates now. $W_i(t)$ are those of bidder i. The set of bids W(t) is a "consistent collection" of bids in which each license appears no more than once in all the single-license bids and package bids in the winning set.

DEF. 7. WH(t) = set of warehoused bids = Bids in AB(t) but not in W(t). Thus, AB(t) = $W(t) \cup WH(t)$ and so by definition $W(t) \cap WH(t) = \varnothing$. $WH_i(t)$ are those of bidder i at instant t. Unless stated otherwise, all bids submitted and not cancelled will be active bids. The exceptions are bids that exist in the "reserve." However, active bids might not receive activity credit.

It has been suggested that WH(t) might be allowed to contain only bids of single licenses. In the rules here, we make no such restriction. Non winning bids are important for "fitting". In addition the single-license markets might not be active if there are synergies in small sets.

DEF. 8. "Reserve bids" (last/best bids) can be made only once by a bidder and only after the bidder's eligibility falls to zero. These reserve bids cannot be modified and can become winners only if someone else picks them up from the reserve list and submits it along with their bid. They can be cancelled but once cancelled they cannot be resubmitted. Cancelling any part of one means canceling everything the bidder has in the reserve set of bids.

The purpose of the reserve is to capture the demand-revealing properties of last attempts to trade and to keep them around to be used by other, eligible bidders. The reserve will contain demand-revealing offers on packages of bids, which is typical of "final offers." They remain around to be used if possible and will help with the development of collections of bids to beat big packages.

DEF. 9. Other concepts that are needed for the SAAPB.

(a) $A_i(t)$ = the activity level (measured in points) of bidder i if measurements were made on the bids that i had in the system at the instant t. That is, the measurement considers all active bids, those in $AB_i(t)$.

(b) $A_i(t_{PR})$ = the activity level (in points) of bidder i measured at the end of phase P of round R.

(c) $A_i(R)$ = the activity level (in points) of bidder i in round R. Concept (b) implies two types of activity, activity in S and activity in C. This definition anticipates that they will be merged by Rule 8 below.

(d) minW(t) = the set of bids that satisfy the minimum it would take to be in the winning set given the bids in AB(t). The calculation is made on the basis of active bids, AB(t), that existed at the instant t. If the bid amount b(X) of a bid [X,b(X)] for package X submitted at time t′ is at least as great as would be required to be a member of W(t), then the bid [X,b(X)] is a member of minW(t). All bids in W(t) are also in minW(t).

(e) maxSing(X,t) = the sum of the maximum bid amounts from single-license bids on the single licenses included in the set of bids X. The calculation is made from bids that existed at the instant t. The notation maxSing(t_{PR}) denotes the set of single-license bids with the maximum bid amounts. The set maxSing(t_{PR})is a consistent collection of bids. (Note that the maximum bid amount for a single-license bid does not imply that the bid is a winning bid.)

(f) maxSet(X,t) = the maximum revenue that could be generated by sale of the set of licenses in the set X given the bids in the system at instant t. This concept means that the sum of bid amounts for each family of disjoint packages (consistent collection of single-license and package bids) of bids with union X has been calculated for all bids in the system at t. We use maxSet(X,t) to denote the revenue of the consistent collection with the highest revenue.

DEFINITIONS: ELIGIBILITY AND ACTIVITY

DEF. 10. Initial eligibility $E_i(0)$ is established for each bidder i. $E_i(t)$ is the eligibility of bidder i at instant t.

DEF. 11. Each object x is assigned an activity weight, aw(x). These weights will be measured in units of activity points, or just points.

DEF. 12. Each bid [X,b(X)] is assigned an activity weight (measured in activity points) of aw([X,b(X)]) equal to the sum of the points of each of the licenses in the package. That is aw([X,b(X)]) = sum of aw(x) for all x in X.

DEF. 13. $B_i(t)$ = "Bid budget" of bidder i at the instant t. The measure is in units of activity points.

DEF. 14. "Clusters." Objects are partitioned into clusters (like MTAs are clusters of BTAs). The definition of clusters will change depending upon the assumed complementarities among licenses, the computational power of the computer, the nature of the auction, the number of bidders, and the number of licenses.

RULES: BIDS AND COMPUTATIONAL CONSTRAINT

(All computational constraints are implicitly satisfied for all subsequent discussions below. Problems of restricting bids for computational speed will be covered separately by concepts such as clusters, Rule 1, and Rule 2. These are mentioned as a way to remove computation time constraints from consideration in the development of other rules.)

RULE 1. Bidder i is not allowed to have more than N_i total number of package bids in the set $AB_i(t)$ at any instant t. The number of bids an individual has active for single licenses might be unrestricted (this is being investigated).

RULE 2. An admissible bid can be for any subset of a cluster or for any set of clusters but cannot be for subsets of different clusters. The implementation of this depends on the definition of the clusters.

RULES: BIDS AND AUCTION CONVERGENCE SPEED

RULE 3. Bids in the set W(t) can be neither cancelled nor withdrawn. Bids selected for the winning set cannot be removed. (A rule that allows the bid price of a winning bid to be increased without meeting the increment rule is under consideration.)

RULE 4. Bids in the set WH(t) can be cancelled at any time that bids can be submitted.

Allowing cancellation of bids not in W(t) is needed because of the bid budget constraints on bids and because there may be no automatic discarding of bids from the system (which is being investigated). Automatic cancellation will require very specific policies.

An individual can cancel all reserve bids at any time. However, if any reserve bid is cancelled then all of the agent's reserve bids must be cancelled and nothing of the agent's can be replaced in the reserve. That is, the agent is completely out of the system. Further discussion of reserve bids will be needed when that is discussed below.

RULE 5. Bid budget constraints: Two constraints are active.

5.1 Constraint on package bids. $B_i(t) \geq$ aw(all bids for packages of two or more items that bidder i has in the set $AB_i(t)$) = sum of aw([X,b(X)]) over all bids [X,b(X)] in the subset of $AB_i(t)$ that are for two or more items. At any instant a bidder's bids in the active bid set must satisfy the bidder's package bid budget constraint. The sum of the activity points of all active bids for packages of two or more items must be less than or equal to the bidder's bid budget $B_i(t)$.

5.2 Constraint on items in bids. $B_i(t) \geq$ aw(all items in the union of bids in the set of bids bidder i has in the set $AB_i(t)$) = sum of aw(x) where x$\in$ union X such that [X,b(X)] is in the set of $AB_i(t)$. The bid budget cannot exceed the sum of the activity weights of all items that are in some bid tendered by the bidder.

The two budget constraints are imposed to allow complete freedom to bid on singles. The first constraint, when coupled with the definitions of eligibility gives an incentive to place package bids. Interestingly enough, preliminary tests suggests that bidders do not bid enough on packages. When they do bid they might not bid sufficiently aggressively. The combined impact is to give the bidder an incentive to place bids and to place them aggressively in order to maintain eligibility. On the other hand the constraint 5.1 can limit the bidder in the sense that eligibility might exceed the weights on licenses that might possibly win together. Thus, bids on singles are "free" up to the constraint that the number of licenses potentially purchased cannot exceed eligibility.

RULE 6. $B_i(t) = E_i(t)$. The bid budget $B_i(t)$ of the bid budget constraint of bidder i at an instant is defined to be the eligibility of the bidder at the instant. Alternatively, there could be a factor of proportionality here, such as $B_i(t) = M*E_i(t)$.

The distinction between B(t) and E(t) is made to avoid confusion about the dual role of eligibility (limiting bids and encouraging bids) and because this is a spot where an incentive condition could be added, such as through a proportionality factor.

RULE 7. $E_i(t \in R) = E_i(t_{SR}) = E_i(t_{CR}) = E_i(R)$.

This means that the eligibility of a bidder throughout all phases of a round is constant beginning with the eligibility that existed at the opening of the sealed bid phase. It is called "eligibility for the round." Thus, bidding during the seal bid phase or during the continuous phase of a round will not affect the individual's eligibility during that round. So, during a round the eligibility level of a bidder cannot change as a result of its own actions for that round.

RULE 8. $A_i(R) = \max\{A_i(t_{SR}), A_i(t_{CR})\}$

The activity credit a bidder gets for round R, that goes toward determining round R+1 eligibility, is the maximum of activity measured at the close of the sealed bid phase and the activity measured at the close of the continuous phase.

Obviously there are variations possible here including averages, different weights depending on phase, etc., that could be used in place of max{}. Using min{} here would place great incentive to be active in both phases but its full implications have not been studied yet.

RULE 9. Bid Aggressiveness Index and Activity measurement for phase P, continuous or sealed bid, within a round, R.

The definitions below identify four degrees of bid aggressiveness depending upon how close the bid is to becoming an actual winner. The first degree of aggressiveness is given to a bid that actually places itself in the set of potential winners that exist at the end of the particular phase in which the bid was tendered (Any carry over winner that remains a winner at the end of the phase qualifies as well.) The second degree is given to bids that were high enough to be placed in the winning set at the time the bid was tendered but were ultimately beaten by other bids during the phase. The third degree of aggressiveness is given to bids that were greater than the sum of the maximum bids as singles on the items contained in the bid. The lowest level of aggressiveness is given to bids that do no qualify as one of the first three. Expectations are that no credit will be given for the lowest level.

The notation t_{PR} denotes the phase at which the measurement was taken with $P \in \{C,S\}$. P-1 means the phase that ended just before (P,R), even if the phase just before P was in R-1. That is, if P was the sealed bid phase of R then P-1 would be the continuous phase of R-1.

$A_i(t_{PR})$ =

$\beta_1 \cdot$ [aw(.) of all bids of bidder i in $\{W(t_{PR})\}$] +

$\beta_2 \cdot$ [aw(.) of all bids of bidder i in $\{\text{minW}(t_{P-1,R}) \setminus W(t_{PR})\}$ that satisfy the increment rule] +

$\beta_3 \cdot$ [aw(.) of all bids of bidder i in $\{\text{maxSing}(t_{P-1,R}) \setminus \text{minW}(t_{P-1,R})\}$ that satisfy the increment rule] +

$\beta_4 \cdot$ [aw(.) of all bids of bidder i in $\{\text{AB}(t_{PR}) \setminus \text{maxSing}(t_{P-1,R})\}$ that satisfy the increment rule].

Thus:

β_1 corresponds to the activity credit given for bids that are winners at the end of the phase.

β_2 corresponds to the activity credit given to bids that are not winners but are in the system at the end of the phase and that are above the minimum it would take to get in the winner's set (at the beginning of the phase) but did not become winners in the phase.

β_3 corresponds to the activity credit given to bids in the system at the end of the phase and that are at or above the maximum bid amounts of single-license bids but below the minimum it takes to get in the winning set (at the beginning of the phase). Of course, W(t) is a subset of minW(t).

β_4 corresponds to activity credit given to bids that are below the maximum bid amounts of single-license bids.

Observation. Different rules and different auction stages imply different configurations of the β's. We will probably only consider rules with $\beta_4 = 0$ always (for all auction stages). At some of the later auction stages we might want only winning bids getting activity credit, which can be implemented by making β_1 positive and all other β's zero. However, giving credit only to bids that succeed in getting in the winning set could work to the disadvantage of bidders on small packages who are attempting to coordinate bids to overcome a single bid on a large package.

In the continuous phase the other bids are visible at the time a particular bid is submitted so fitting bids can be crafted with greater accuracy. By contrast bidding during the sealed bid phase suffers from a coordination problem. It is for this reason that the standby queue has been so important for the sealed bid combinatorial auctions. In the continuous versions the coordination problem is less difficult. Thus, a winners-only measurement of activity, the first level of aggressiveness, might not be too successful since it removes and discourages other bids that facilitate coordinated combos.

RULE 10. $E_i(R+1) = \min \{E_i(R), \lambda \cdot A_i(R)\}$

Suppose a bidder is required to establish an activity level of at least 50 percent of its eligibility in order to maintain its eligibility. Then $\lambda = 2$ *in this case.*

Now we have some parameters to control the speed of the auction: the β's and λ. These rules have the existing FCC rules as a special case where the clusters are single licenses and there is no continuous bidding phase.

RULE 11. SOME POSSIBLE INCREMENT RULES

Increment rules govern the amount by which bids must "increase" and are thus an important feature governing the speed of auction convergence. In the case of auctions for single items the natural increment rules involve some percentage increase over the current maximum bid - the current winner. In the case of packages it becomes more complex .

Increment rules can be applied to either (i) all non-winning bids or (ii) only all "new bids" (i.e., bids submitted in the just-finished phase would be allowed to stay unchanged in the system without meeting an increment test). There is a tradeoff because (i) will speed the auction while (ii) will increase efficiency by facilitating the package fitting problem. The rules below strike a compromise. The increment rules apply to new bids. That is, a "new bid" cannot be submitted unless it satisfies the increment rule, so for a new bid to get into the winning set it must meet the increment requirement. Bids that existed as active bids (AB(.)) at the end of the preceding phase can be resubmitted exactly as they were without meeting an increment test. In effect, old bids are resubmitted automatically unless cancelled. (Of course these old bids might not get activity credit if they are insufficiently aggressive.) Notice that in Rule 9 activity credit is given only if the bid satisfies the increment rule. Thus, the bid can stay in the system (which might be a good strategy if the bidder does not want to bid more) but the eligibility of the bidder will fall until the bider is finally forced into the bid reserve. Thus, a "close-out" bid can remain in the system for a while. Non-movement on the part of the bidder incurs a cost, which is consistent with the bid being a close-out bid.

The following are four alternative increment rules:

11.1 To satisfy increment rules for phase P of round R, a new bid amount must be at least z% above the bid amount of the corresponding bid in the set $\min W(t_{P-1,R})$.

Notice this does two things. First, it is conceivable that many bidders could make many bid submissions nearly simultaneously, requiring several calculations of minW(.). This computation can be distributed but it might be a problem in the continuous phase if there a large number of bidders making a large number of bid submissions simultaneously. Second, in combinatorial auctions one should hesitate to require that every bid be enough to get in the winning set, especially by some increment. The essence of the free rider problem is that small-packages bidders coordinate to overcome the bid of a big-package bidder. This coordination might require many unsuccessful bids an no bid except the last bid, which made the coordination complete, would be in the winning set. While this takes place the eligibility of the small bidders should not evaporate. So, keeping all non-winning bids out has a potential for reducing auction efficiency.

11.2 To satisfy increment rules for phase P of round R, a new bid X must be z% above $\max Sing(X,t_{P-1,R})$.

The problem here is that bidding on single licenses may not be very active. Thus, if there are few single-license bids, as might be the case if the bids for multiple-license packages were very high

relative to single-license bids, there might be very little push here. Bidders would not spend their activity on hopeless bids.

11.3 To satisfy increment rules for phase P of round R, a new bid for a set X must be z% above maxSet(X,$t_{P-1,R}$).

This is appealing. Since calculations like this are being made routinely anyway it might not be too difficult to make them here as well. It says that to meet the increment requirement for a bid on a set X you must bid more than the maximum bid amounts for the licenses in X at the end of the last phase. The procedure is to calculate the maximum bid amounts for all consistent collections of bids, where the union of each collection is X. We need to investigate the procedure if there is no collection of existing bids equal to the union of X.

11.4 Define a measure in terms of the average value of the prices held by the winning bids, as measured in dollars per point implied by the winning bids. A markup z% over this would be required of new bids.

The feasibility and utility of this is under consideration.

RULE 12. (The Reserve). When $E_i(R) = 0$, an individual has "y" rounds to submit bids to the bid reserve. Call these bidders "ineligible" as opposed to "eligible" bidders who still have eligibility. An ineligible bidder i can make K_i such bids as long as the total activity points do not exceed, say, $E_i(0)$ or some other suitable restriction. If the ineligible bidder cancels any of its reserve bids, all of its reserve bids are canceled and cannot be replaced.

For now we will assume that reserve bids are not part of the set of active bids AB(t) at any time because there may be a computational problem otherwise. If an eligible bidder wants to reactivate one of the reserve bids and submit it along with a legitimate bid, it can be done. The bid will be treated as a multiple-license package bid (a bid from the eligible bidder satisfying the eligible bidder's bid budget constraint, plus the reserve bid), and either the combined package bid is accepted in the winning set or the combined package bid is rejected and the reserve bid is restored to the reserve. Activity for the eligible bidder is computed as if the eligible bidder's bid were submitted alone. If the combined package meets the minW(t) requirement then activity credit is given to the eligible bidder for the eligible bidder's part of the combined package bid. If the combined package bid is accepted, rules must be developed to determine what happens to the other reserve bids of the ineligible bidder.

RULE 13. The individual has a set of public indexes that can be attached to bids or the individual can decide to attach no index at all. The public index will mean that other bidders can determine that a set of bids came from the same bidder but will not be able to identify who that bidder is. By using different public indexes the bidder can also hide patterns of bids or histories as desired. Further investigation is needed to determine whether a system of indexes can be implemented that promotes auction efficiency without providing an opportunity for unproductive signalling; particularly, we need to ensure that more sophisticated bidders do not take advantage of the information opportunities to their benefit but less sophisticated bidders do not.

OBSERVATIONS AND MISCELLANEOUS ISSUES

The various parameters set out above provide flexibility and will allow us to experiment with alternative bidding environments including alternative sources of complementarities.

Bidders will be updated continuously about their status and the status that will occur if they take various actions.

We will investigate whether dominated bids should be cancelled automatically by the system. It is possible that this is unnecessary because of the activity rules and budget constraints providing bidders incentives to cancel these bids.

Clusters. The definition here should be related to the underlying synergies that are suspected together with some understanding of the computational problems.

N_i = the maximum number of bids that bidder i can have in the active bid set AB(t) at any time. This might depend on initial eligibility and it may not be desirable to have single-license bids count against this total.

K_i = the number of bids an ineligible bidder can place in the bid reserve. We will need to investigate appropriate values for this parameter. They may be based on considerations of convenience or user-friendly computer screens.

We will investigate the feasibility of a public bid index set.

We will investigate discounts on single-license bids.

Alternative activity measurements exist and need to be considered. It is likely that any activity measurement will have tradeoffs.

(1) The rules above use bids as the vehicle for guiding and speeding bid activity as opposed to only the activity points of individual licenses that might be ultimately acquired. This feature can be seen in the formulation of the bid budget constraint and the activity credit measurements. The rules become more focused on the crafting of licenses by setting $\beta_4 = 0$. Alternative rules are still under investigation including computing activity only for consistent collections of bids, elimination of dominated bids, and elimination of multiple copies of bids.

(2) Some of the experimental work uses a measure based on the union of all bids.

4
Operational Parameters

Process parameters

In Rule 9 four levels of bid aggressiveness are outlined. With each is a weight. A single pattern of weights has been used in the experiments. These are:

$\beta_1 = 1.0$; $\beta_2 = 0.8$; $\beta_3 = 0.5$; $\beta_4 = 0$

So, full credit is given to a bid that ends the phase in the winning set. A bid that was enough to be in the winning set when tendered but emerged beaten by simultaneously submitted bids would get .8 of the activity as credit. Bids that are greater than the sum of the best price of singles in the package get .5. Notice that old bids left in the system can get activity credit even when a new bid submitted for the same amount would not meet the increment requirement and thus would get no credit. Bids fall below the sum of the singles prices get no credit. These would be old bids that have remained unchanged while the market moved up.

Rule 10 has a parameter, λ, defining the level of activity necessary before eligibility is lost from one round to the next. In the experiments conducted to date $\lambda = 2$.

The increment rule requires that bids are 5% above the amount that the set would bring from existing bids.

Phase lengths have varied depending upon experience. At first they are long, as bidders get to know the rules. At first bidders also tender more bids. As the system progresses the phase lengths shorten.

Initial eligibility has not constrained bidders. All bidders have had enough initial eligibility to buy all items.

The weights on items have been equal for all items at 100 each.

Bids are tendered in whole numbers. No fractions have been allowed.

The number of people and number of items has varied. Initial experiments were with five people and six items. More recent experiments have been with twelve people and sixteen items.

The structure of preferences has been selected to challenge the system with many difficult combinations to fit. In addition some items are included that will sell as singles. The latter are included as checks on the system and the understanding on the part of subjects.

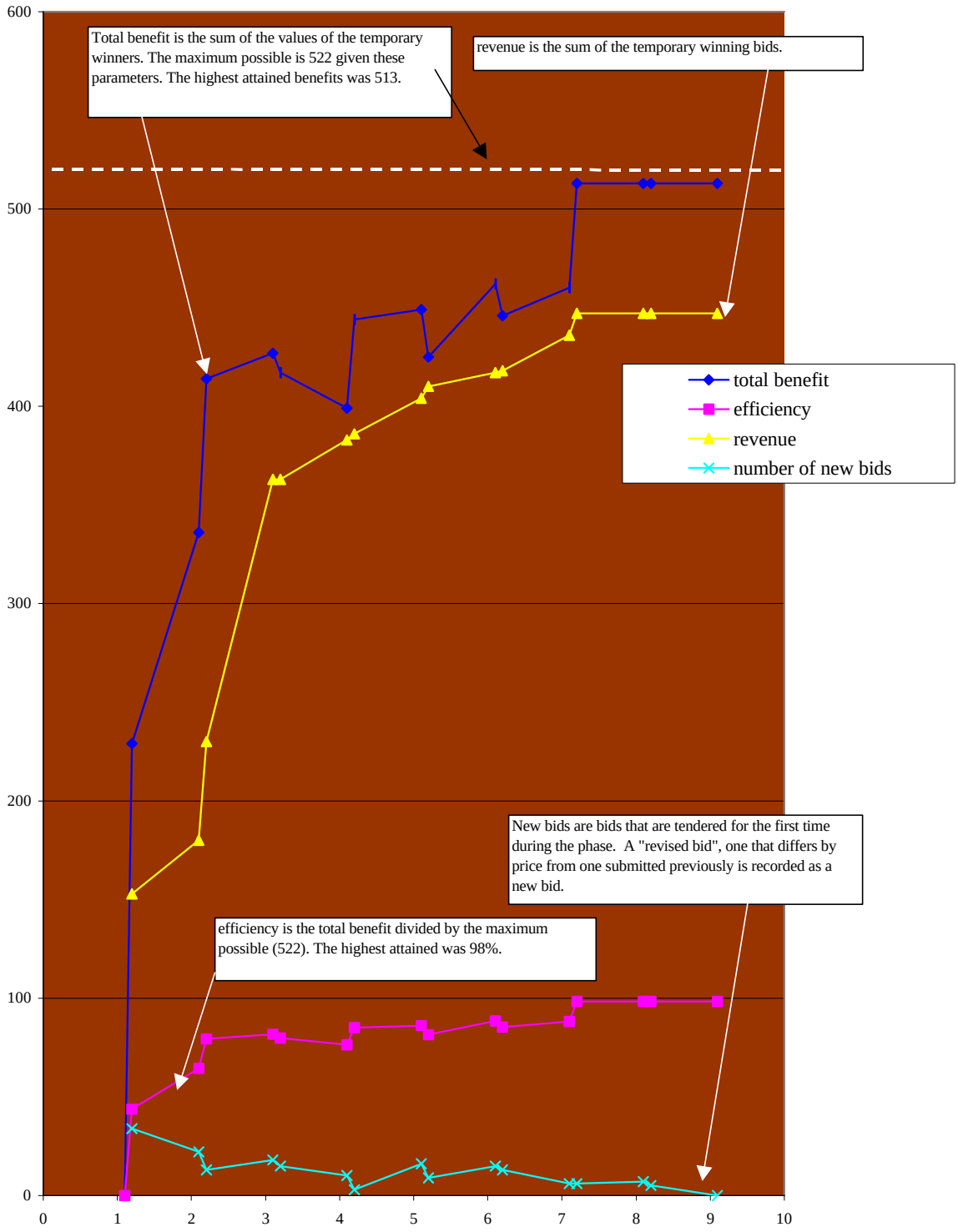
The following table and chart report example parameters and the results from one session of an example experiment.

Example parameters

Max benefits	#1	#2	#3	#4	#5
532	A 17	A 10	A 10	A 10	A 10
	B 10	B 18	B 10	B 10	B 10
	C 10	C 13	C 10	C 10	C 10
	D 11	D 10	D 10	D 10	D 10
	E 10	E 10	E 16	E 10	E 10
	F 10	F 10	F 10	F 10	F 19
	G 40	G 15	G 30	G 30	G 15
	H 22	H 33	H 28	H 25	H 24
	I 35	I 25	I 50	I 43	I 38
	J 8	J 7	J 7	J 25	J 10
	K 35	K 34	K 33	K 33	K 37
	L 50	L 35	L 40	L 40	L 37
	AEF 152	CE 40	BC 47	DE 41	CD 49
	CDF 157	AC 40	AE 45	EF 49	ADE 140
	ABCDEF 234	ABF 152	ADF 145	DEF 141	BEF 154
	HI 60	IJ 50	ABC 146	ABD 158	BDF 150
			JK 43		
	ACF 142	GH 49			
				GK 67	

The 2nd and 3rd best were calculated using only the first 6 items. When the next 6 are added new degrees of nonoptimality surface:

100% optimal	[4]DEF 141;[3]ABC 146;[1]G 40;[2]H 33;[3]I 50;[4]J 25;[5]K 37;[1]L 50
89.84% 2nd best{469}	[1]ABCDEF 234;[1]G 40;[2]H 33;[3]I 50;[4]J 25;[5]K 37;[1]L 50
87.10% 3rd best{455}	[1]G 40; [2]C 13;[4]EF 69;[4]ABD 158;[2]H 33;[3]I 50;[4]J 25;[5]K 37;[1]L 50



Example from experimental session.

5
Verification Process

Verification of the implementation of the SAAPB involves obtaining answers to many different questions. We are investigating these aspects of verification.

1. Do the rule in the computer correspond to the rules on paper? Even though the rules have a reasonably formal representation there are many ambiguities that surface when code is developed. The process of verification involves both review by theorists, experimentalists and by subjects who use the system after having been trained about the rules.

2. Will the system slow down considerably as size is increased? A process of adding bidders and items has been initiated. We are able to find examples in which the process is too slow but thus far that has only been with artificial bids. How and what causes slowness is still largely unknown except at very abstract levels.

3. Will the system be portable? We are undertaking a series of experiments in which different computer experts are responsible for operating the software. Operation has been successful. Less successful is the transfer of knowledge about how to recover if something goes wrong. This exercise continues with each experiment and with each experiment progress is made.

4. Can users understand the process? Of course this is a natural problem with any experimental project. The process must be understandable to subjects (users). As experiments progress the methods of explaining the system and the tools for helping bidders improve.

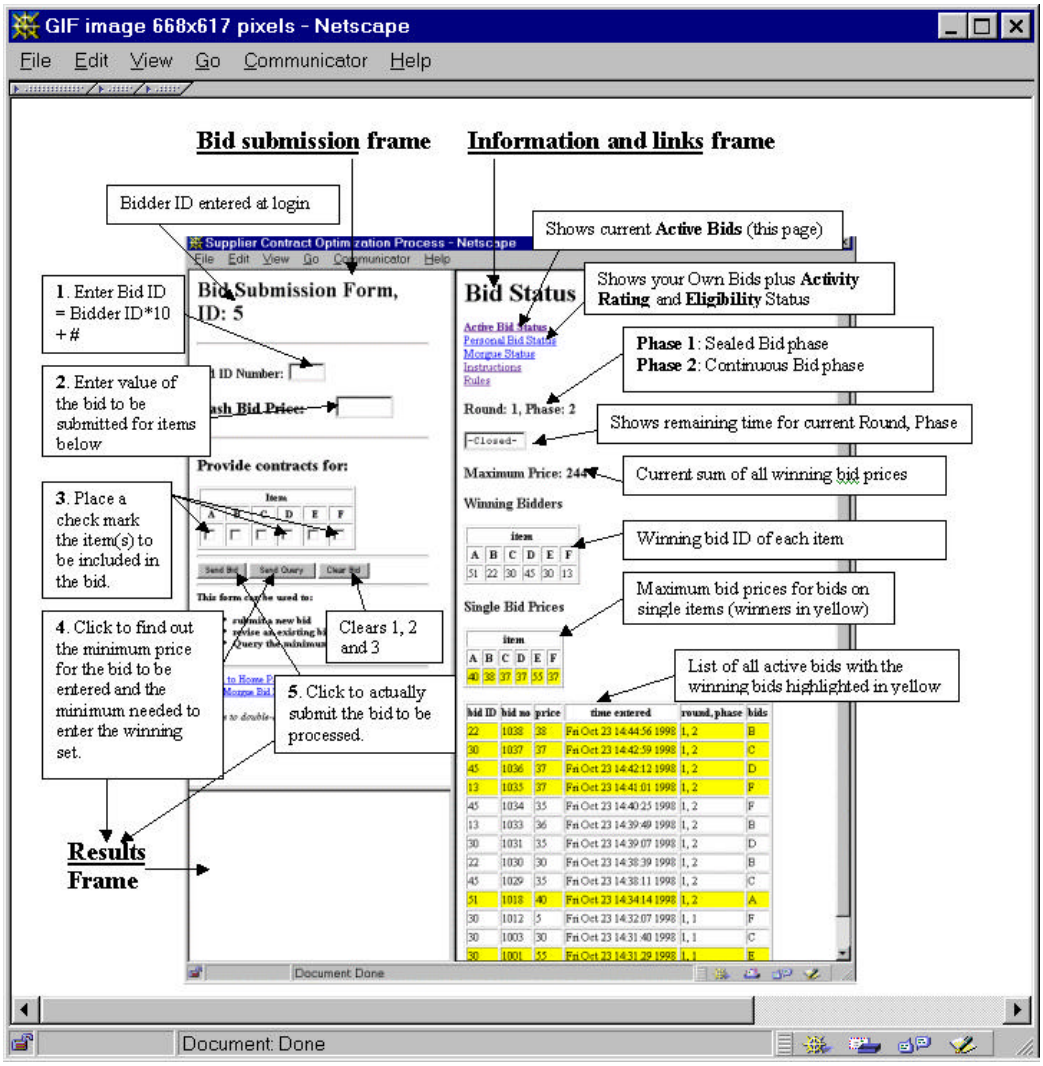
5. Does the system do a good job of finding optimal allocations? Tests are underway with increasingly difficult problems.

6. How fast is the convergence process? This is still under study, as are methods to speed it. The process is the same as above. Larger experiments are underway and are limited only by the logistics of managing a large experiment.

7. Some of the tools for conducting large tests have been successfully employed in this context. For example, subjects have an easy-to-understand tool for identifying their preferences over large numbers of sets. This technology is very similar to the technology used by bidders in determining what it might take to place a winning bid.

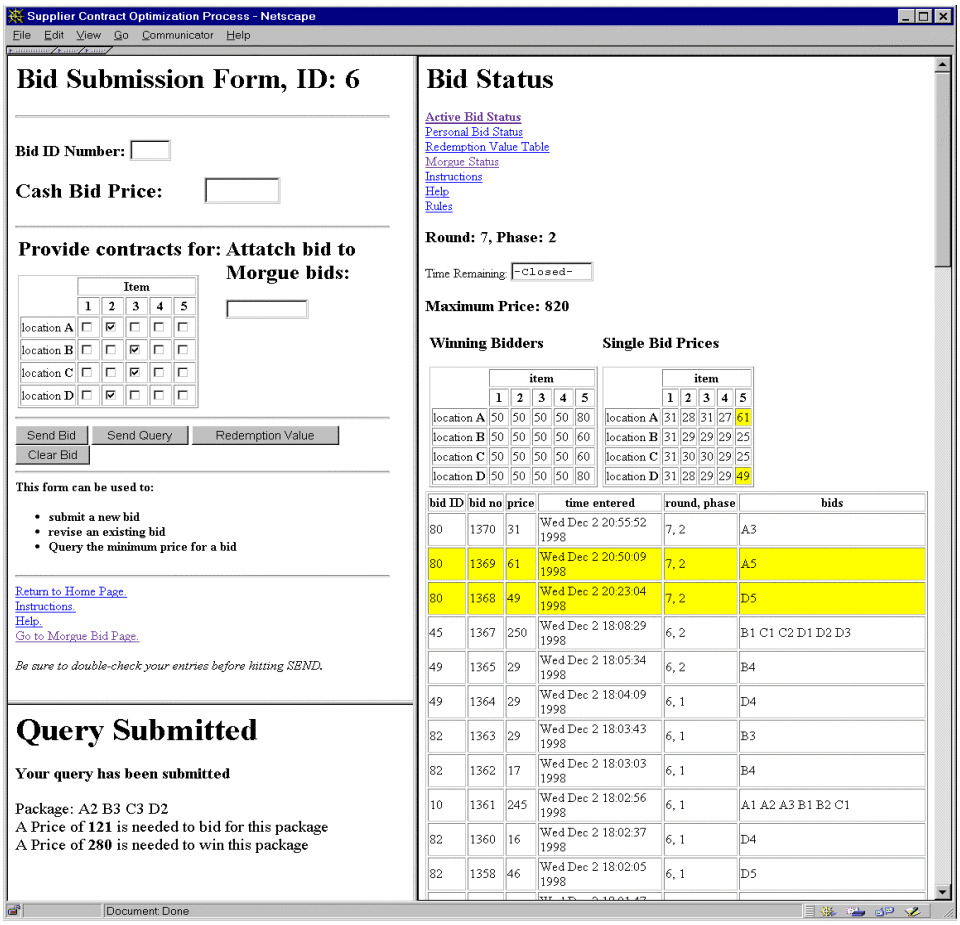
6
Sample Screens

This screen is an overview of bidders' screens. It is part of the instructions to bidders for using the system. It explains many of the links and sources of information available to bidders.



Sample Screens

This screen is similar to the screen above except that it is a twenty item example that was used in an experiment. On the right is the active bid status. Notice that at this stage a bid identified as 50 has captured sixteen of the items. Two items have been won through single bids (shown in yellow). There are many bids in the system, which are listed below. On the left a query has been submitted for the package {A2,B3,C3,D2}. The system response can be viewed. This query resulted from a computer examination of all bids in the system. The word "morgue" means "reserve" as used in the rules above.



Supplier Contract Optimization Process - Netscape

File Edit View Go Communicator Help

Bid Submission Form, ID: 6

Bid ID Number:

Cash Bid Price:

Provide contracts for: **Attatch bid to Morgue bids:**

	Item				
	1	2	3	4	5
location A	☐	☑	☐	☐	☐
location B	☐	☐	☑	☐	☐
location C	☐	☐	☑	☐	☐
location D	☐	☑	☐	☐	☐

Send Bid | Send Query | Redemption Value | Clear Bid

This form can be used to:

- **submit a new bid**
- **revise an existing bid**
- **Query the minimum price for a bid**

Return to Home Page.
Instructions.
Help.
Go to Morgue Bid Page.

Be sure to double-check your entries before hitting SEND.

Query Submitted

Your query has been submitted

Package: A2 B3 C3 D2
A Price of **121** is needed to bid for this package
A Price of **280** is needed to win this package

Bid Status

Active Bid Status
Personal Bid Status
Redemption Value Table
Morgue Status
Instructions
Help
Rules

Round: 7, Phase: 2

Time Remaining: -closed-

Maximum Price: 820

Winning Bidders

	item				
	1	2	3	4	5
location A	50	50	50	50	80
location B	50	50	50	50	60
location C	50	50	50	50	60
location D	50	50	50	50	80

Single Bid Prices

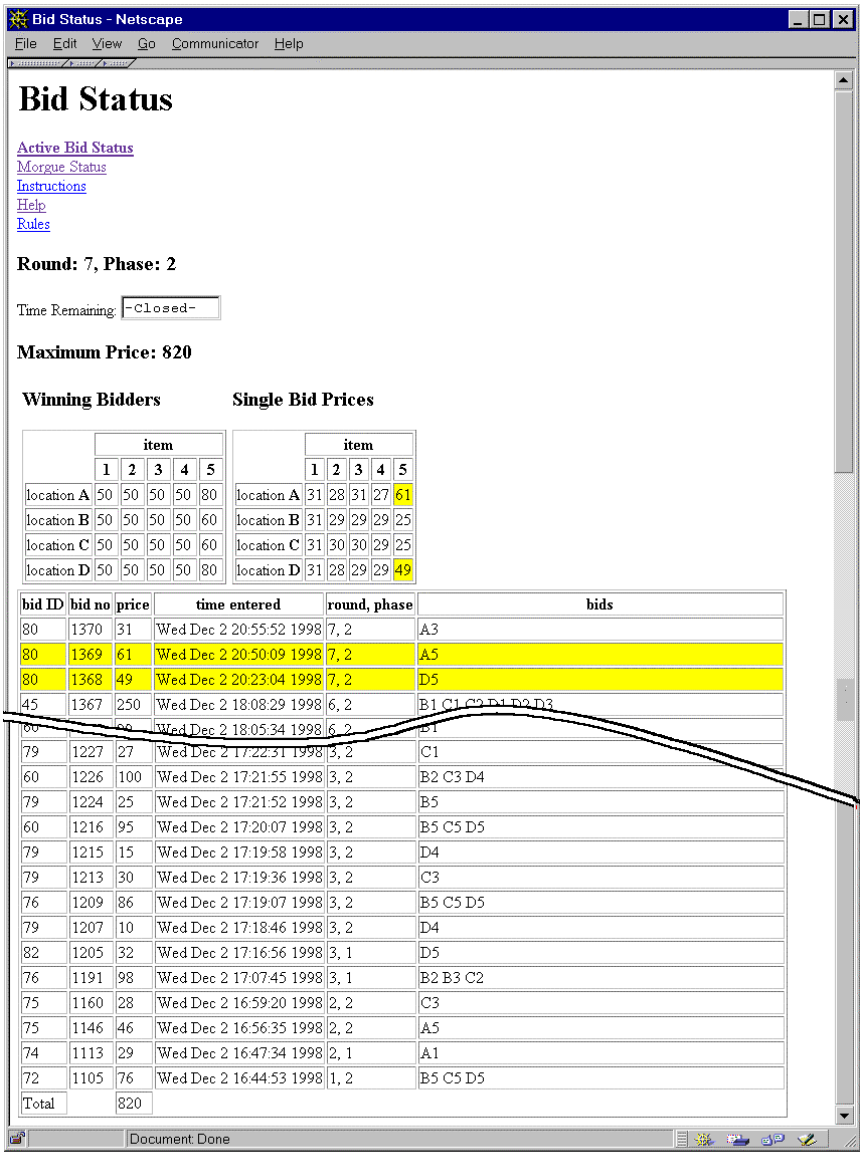
	item				
	1	2	3	4	5
location A	31	28	31	27	61
location B	31	29	29	29	25
location C	31	30	30	29	25
location D	31	28	29	29	49

bid ID	bid no	price	time entered	round, phase	bids
80	1370	31	Wed Dec 2 20:55:52 1998	7, 2	A3
80	1369	61	Wed Dec 2 20:50:09 1998	7, 2	A5
80	1368	49	Wed Dec 2 20:23:04 1998	7, 2	D5
45	1367	250	Wed Dec 2 18:08:29 1998	6, 2	B1 C1 C2 D1 D2 D3
49	1365	29	Wed Dec 2 18:05:34 1998	6, 2	B4
49	1364	29	Wed Dec 2 18:04:09 1998	6, 1	D4
82	1363	29	Wed Dec 2 18:03:43 1998	6, 1	B3
82	1362	17	Wed Dec 2 18:03:03 1998	6, 1	B4
10	1361	245	Wed Dec 2 18:02:56 1998	6, 1	A1 A2 A3 B1 B2 C1
82	1360	16	Wed Dec 2 18:02:37 1998	6, 1	D4
82	1358	46	Wed Dec 2 18:02:05 1998	6, 1	D5

Document: Done

Sample Screens

This is a closer look at the Active Bid Status Screen. Seventy two bids were in the system.



Bid Status - Netscape

File Edit View Go Communicator Help

Bid Status

Active Bid Status
Morgue Status
Instructions
Help
Rules

Round: 7, Phase: 2

Time Remaining: -Closed-

Maximum Price: 820

Winning Bidders

	item				
	1	2	3	4	5
location A	50	50	50	50	80
location B	50	50	50	50	60
location C	50	50	50	50	60
location D	50	50	50	50	80

Single Bid Prices

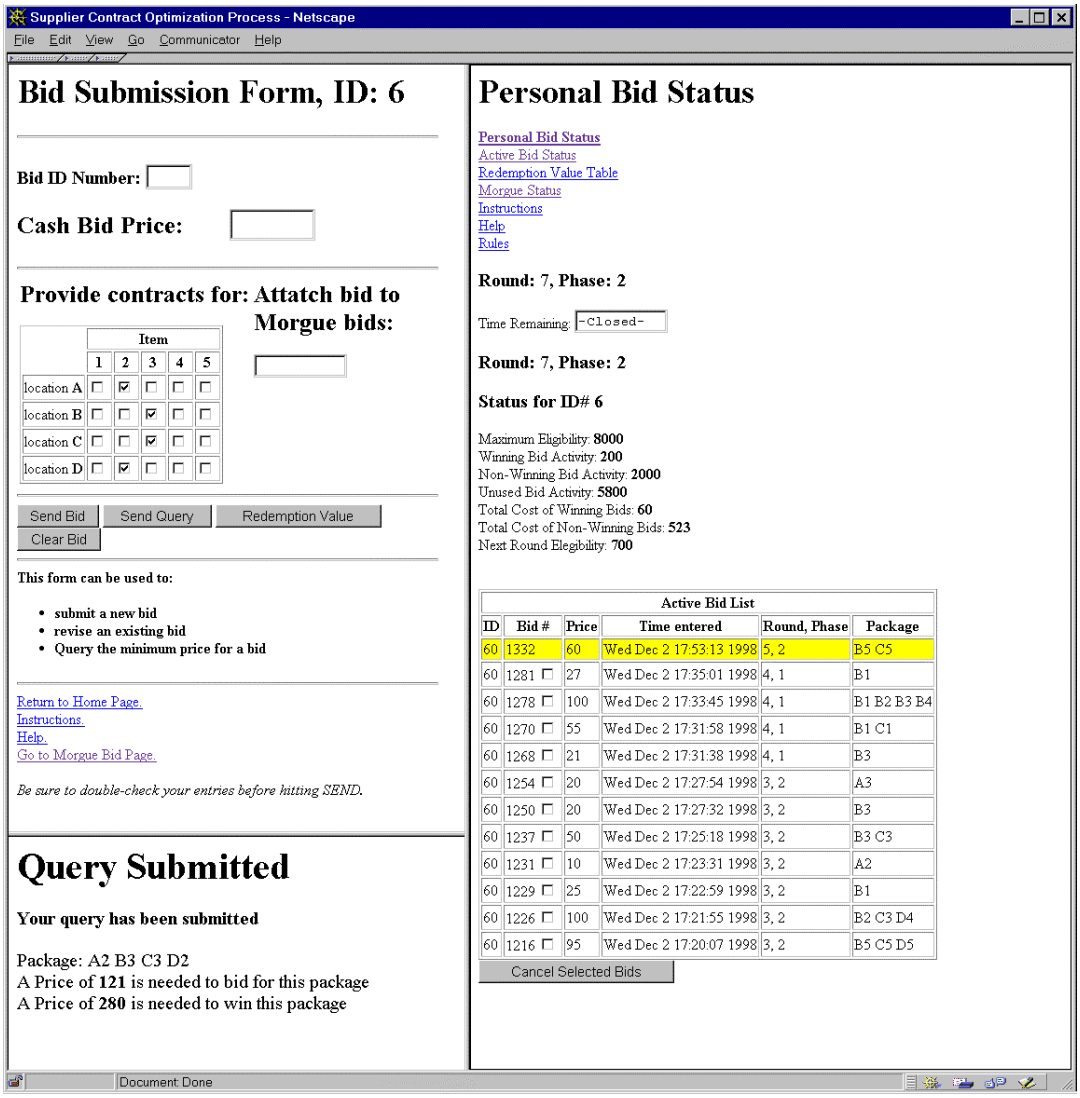
	item				
	1	2	3	4	5
location A	31	28	31	27	61
location B	31	29	29	29	25
location C	31	30	30	29	25
location D	31	28	29	29	49

bid ID	bid no	price	time entered	round, phase	bids
80	1370	31	Wed Dec 2 20:55:52 1998	7, 2	A3
80	1369	61	Wed Dec 2 20:50:09 1998	7, 2	A5
80	1368	49	Wed Dec 2 20:23:04 1998	7, 2	D5
45	1367	250	Wed Dec 2 18:08:29 1998	6, 2	B1 C1 C2 D1 D2 D3
60	[illegible]	[illegible]	Wed Dec 2 18:05:34 1998	6, 2	B1
79	1227	27	Wed Dec 2 17:22:31 1998	3, 2	C1
60	1226	100	Wed Dec 2 17:21:55 1998	3, 2	B2 C3 D4
79	1224	25	Wed Dec 2 17:21:52 1998	3, 2	B5
60	1216	95	Wed Dec 2 17:20:07 1998	3, 2	B5 C5 D5
79	1215	15	Wed Dec 2 17:19:58 1998	3, 2	D4
79	1213	30	Wed Dec 2 17:19:36 1998	3, 2	C3
76	1209	86	Wed Dec 2 17:19:07 1998	3, 2	B5 C5 D5
79	1207	10	Wed Dec 2 17:18:46 1998	3, 2	D4
82	1205	32	Wed Dec 2 17:16:56 1998	3, 1	D5
76	1191	98	Wed Dec 2 17:07:45 1998	3, 1	B2 B3 C2
75	1160	28	Wed Dec 2 16:59:20 1998	2, 2	C3
75	1146	46	Wed Dec 2 16:56:35 1998	2, 2	A5
74	1113	29	Wed Dec 2 16:47:34 1998	2, 1	A1
72	1105	76	Wed Dec 2 16:44:53 1998	1, 2	B5 C5 D5
Total		820			

Document: Done

Sample Screens

This screen shows personal bid status. Notice that activity is distributed across its various uses. In addition the bidder's bids are listed and can be cancelled easily. The query is tied directly to the personal status. If a bid violates a constraint the bidder is warned and the reason is explained by the system. This information is updated in real time during the continuous phase and system



responses have been fast. Tests with larger problems are being considered.