Incentive Compatible Mechanisms for Group Ticket Allocation in Software Maintenance Services

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Abstract

A customer reported problem (or Trouble Ticket) in software maintenance is typically solved by one or more maintenance engineers. The decision of allocating the ticket to one or more engineers is generally taken by the lead, based on customer delivery deadlines and a guided complexity assessment from each maintenance engineer. The key challenge in such a scenario is two folds, un-truthful (hiked up) elicitation of ticket complexity by each engineer to the lead and the decision of allocating the ticket to a group of engineers who will solve the ticket with in customer deadline. The decision of allocation should ensure Individual and Coalitional Rationality along with Coalitional Stability.

In this paper we use game theory to examine the issue of truthful elicitation of ticket complexities by engineers for solving ticket as a group given a specific customer delivery deadline. We formulate this problem as strategic form game and propose two mechanisms, (1) Division of Labor (DOL) and (2) Extended Second Price (ESP). In the proposed mechanisms we show that truth telling by each engineer constitutes a Dominant Strategy Nash Equilibrium of the underlying game. Also we analyze the existence of Individual Rationality (IR) and Coalitional Rationality (CR) properties to motivate voluntary and group participation. We use Core, solution concept from co-operative game theory to analyze the stability of the proposed group based on the allocation and payments.

1 Introduction

A trouble ticket (or synonymously a ticket) is a software problem as reported by a customer to be analyzed and fixed by a team of maintenance engineers. A basic model currently being followed in software maintenance process is shown in Figure 1. The problem ticket can come to the organization through different interfaces such as web interface system, call centers, emails etc. The ticket received through any such interface will then be channelized to a lead. The lead in turn takes the responsibility to allocate the ticket to one of the reporting engineers. The complexity of the reported problem actually propagates from the bottom layer (engineer) to the top (lead) where as the allocation and the payment happens in the opposite direction.

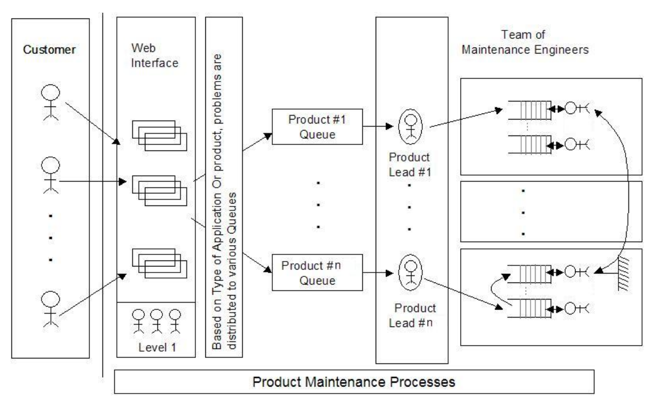

Figure 1. Typical Software Maintenance Work flow

In this case an engineer may not find it in his best interest to report the ticket complexity truthfully and hence boost the reported value of ticket complexity for individual selfish benefits, which may lead to in-efficient ticket allocation. Hence, the central objective of the ticket allocation problem is to ensure that every individual participating in the allocation does not improve his payoff by revealing ticket complexities untruthfully.

Often the problem tickets are solved in groups rather

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than by individual engineers [1]. The reason for such collaboration may be due to technical complexity or a specific customer delivery (time) deadline. In such cases the ticket has to be allocated to a group of engineers (called *proposed group*) such that, each engineer in the *proposed group* makes partial contribution to solve the ticket. The engineers in the proposed group get paid [2] for their portion of contribution to the overall problem. The decision of deciding the *proposed group*, their contribution and payments is called as a "*Group Ticket Allocation Problem*".

The key challenge in this problem is two fold; (1) Ensure truth elicitation by each engineer and (2) Decide the *proposed group* that will solve the reported problem and the payments to engineers in the *proposed group*. Along with the above decisions we should ensure that proposed group is stable and all the engineers are motivated to participate in the game and the proposed group (i.e. they should not incur loss by participating in the game or the group).

In this paper we focus our attention to solve the *Group Ticket Allocation* problem and propose two interesting mechanisms. We analyze the following four desirable properties for each of the proposed mechanism.

- Incentive Compatiblity (IC): Each engineer finds in his best interest to reveal truth.
- Individually Rational (IR): Each engineer is not worse off by participating in the game
- Coalitionally Rational (CR): Each engineer is not worse off by participating in the coalition (or group).
- Stability: The stability of the mechanism ensures that any subset of players from the proposed coalition will *not* have any benefits to break-away from the proposed coalition.

1.1 Review of Relevant Work

A few analytical approaches have been explored to improve the efficiency of the software maintenance process. The work by Kulkarni et al. [2] models the maintenance process using queueing theory and identifies the optimal number of engineers to be allocated for the task of maintenance during a specific time period. The work by Antoniol et al. [3] models the maintenance organization as a queueing network to assess staffing, evaluate service level, and finds the probability of meeting the maintenance deadlines. Many authors also use statistical and empirical techniques [4],[5] to analyze and improve the software maintenance process.

The problem of ticket allocation (or bug assignment) is also been looked upon using a recommender system based approach. The work of Anvik [6], [7], proposes an recommender system which reveals a set of possible developers to whom a trouble ticket (or bug) might possibly be assigned, based on the past history of tickets resolved. In work by Duggan et al. [8] task allocation in software construction is looked upon as multi-objective optimization problem and provide a set of time and quality optimal solutions for the decision maker.

The thrust of the above relevant papers has been primarily on analyzing the maintenance data for improving the maintenance process. All the above papers implicitly make a crucial assumption, namely, that the data is truthfully reported by all the agents and the agents are loyal to the organization. However, the rationality of the engineers may induce them to report the complexity of a ticket in an untruthful way so as to increase their payoffs. This leads to non-optimal ticket allocation, increased payments and time to resolve. *This paper addresses the problem of truthful elicitation of ticket complexities using a game theoretic approach for "Group Ticket Allocation".*

1.2 Contribution and Organization

The paper offers the following contributions:

- The problem of "*Group Ticket Allocation*" is modelled as that of designing an *incentive compatible mechanism*, that is a mechanism which makes truth revelation an optimal (or best response) strategy for the players. This is the subject of Section 2.
- We propose a *Dominant Strategy Incentive Compatible (DSIC)* [9] mechanism called *Division of Labor* (DOL) for this problem, which ensures that truth revelation is optimal for each player (or engineers) irrespective of other players reported type. We show that this mechanism does not motivate the group to solve the problem (i.e., *not CR*) even though every engineer is motivated for a *voluntary participation* (*IR*) . This is topic of discussion in Section 3.
- We propose a second mechanism *Extended Second Price* (ESP) which is *DSIC* [9] and IR. We show that this mechanism also satisfies the most desired property of group formation, *CR*. We show that the proposed allocation and payment for this mechanism lies in the *core* of the game. We discuss this in Section 4.

[1] In our earlier work [1] we have addressed the problem of truth eliciting mechanisms for *Individual Ticket Allocation* problem in software maintenance.

[2] payment in this case is not necessarily a country currency, it could as well be a virtual utility or a score which can be later converted for monetary or other benefits

2 The Model

The approach that we take for analyzing the ticket allocation for groups is based on both non-cooperative and co-operative game theory. In this section we formulate a strategic form game and apply auction mechanism to induce desired properties in the proposed game.

The model as shown in Figure 2 will include a lead and a set of reporting engineers, $N = \{1, 2, ..., n\}$. The auction is conducted by lead in which all engineers in N participate. Let the type announced by each engineer $i \in N$ be θ_i. This type value θ_i denotes the amount of days spent by engineer i to solve the problem independently.The valuation of each engineer i is v_i is the amount of value ascertained, if the ticket is allocated to i, and have been asked to work for d days. The payment to each engineer i is represented by t_i and the utility is $u_i = t_i - v_i$.

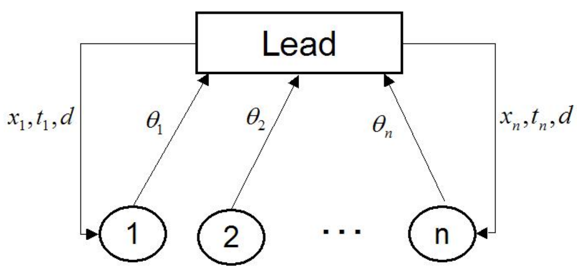

Figure 2. The Model

2.1 How Auction Works?

The lead receives the reported ticket and the number of days $\bar{d}$ within which the customer demands the ticket to be solved. The $lead$ announces the reported customer problem to all the engineers in N (and retains the customer delivery deadline as private information). In turn the lead receives individual type values θ_i from each engineer i in terms of number of days required to solve the problem. The lead uses the *Optimization Problem* (defined in Section 2.3) to determine the number of days d within which the problem can be solved and the group g that can solve the ticket. Using d and g lead computes the payment for each player. This is depicted in Figure 3.

Further in each of the proposed mechanism we will explain the payment rule used and will prove the desired properties satisfied by the mechanism. Now we will explain the notations that will be used to state and prove our propositions.

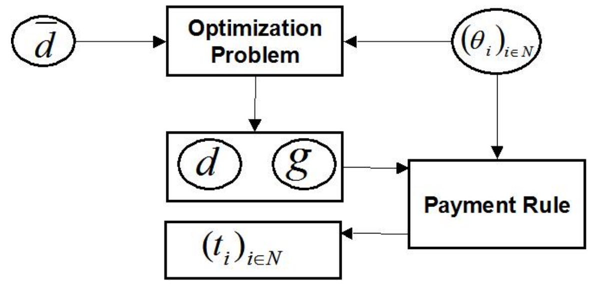

Figure 3. Working Model of Auction

2.2 Notations

The following table contains all the notations that will be used in further sections.

N	$= \{1, 2, ..., n\}$, Set of n engineers
Θ_i	Type set of player i
θ_i	Actual type reported by player i which is number of days required by i to solve the problem individually, where $\theta_i \in \Theta_i$
θ_{max}	$= \max_{i \in N} \theta_i$
θ_{-max}	$= \theta \backslash \theta_{max}$
i_{max}	$= \arg\max_{i \in N} \theta_i$
N_{-max}	$= N \backslash \{i_{max}\}$
$\bar{d}$	Customer announced delivery deadline in number of days
x_i	= 1, denotes presence of player i in the proposed group; 0 otherwise.
g	$= \{i : x_i = 1, i \in N_{-\max}\}$, Proposed group to which the problem is allocated
g_{-i}	$= g \backslash \{i\}$, a subset of group g where player i is excluded g
d	Number of days in which the problem will be fixed by proposed group
t_i	Payment made to player i, for solving the

problem in the proposed group, g.

θ_g $= \max_{i \in g} \theta_i$, max type value in g.

ρ $= \min_{i \in N \setminus g} \{\theta_i : \theta_i \geq \theta_g\}$

w daily wage of every player; $w = 1$ is the value of w in this paper.

v_i $= dx_i w$, valuation of player $i \in N$

u_i $= t_i - v_i, i \in N$

θ_c $= \max_{i \in c} \theta_i, \forall c \subseteq g$

$\overline{\theta}_{-c}$ $= \min_{i \in N \setminus c} \theta_i, \forall c \subseteq g$

t_i^{vcg} Payment to player i using the Vickrey-Clarke-Grove payment rule.

$\vartheta(c)$ Worth of coalition $c, \forall c \subseteq N$

2.3 Optimization Problem

In this section we have listed the optimization problem that is depicted in Figure 3. The optimization problem decides the group g and the number of days d required by the group to solve the ticket. The formulation aims to minimize the number of days given the given customer delivery deadline. The factor $\frac{1}{\theta_i}$ is the percentage of work engineer i would complete in one day.

Objective $\min d$
Subject To

$$\sum_{i \in N_{-max}} \frac{x_i d}{\theta_i} = 1$$

$$x_i \in \{0, 1\}$$

$$d \leq \overline{d}$$

3 Division of Labor Mechanism

The fundamental idea behind this mechanism is *"Every one should get what they are capable of"*. We split the total amount of money based on the amount of contribution by each engineer for d days. Even though all players in g might have worked for same number of days d, player i might be more capable than j, that is $\frac{1}{\theta_i} \geq \frac{1}{\theta_j}$. Hence payment for all players in group g will include the capability factor of $\frac{1}{\theta_i}, \forall i \in g$. The individual contribution of player i in this case is $\frac{d}{\theta_i}$. All players who are not in group g will receive zero payment.

The problem of deciding the group g will be solved using the optimization problem proposed in section 2.3. The problem of "*How much to pay?*" will be addressed in this section. Now we will formally define the payment rule for this mechanism,

$$t_i = \frac{d}{\theta_i}\rho, \forall i \in g$$
$$t_i = 0, \forall i \notin g$$

Where ρ is the lowest bid of the player who is not in the group g (See notations). Now we shall show in the following propositions that this payment mechanism is indeed DSIC and IR.

Proposition 1: DOL Mechanism is DSIC.
Proof: Let θ_i be the true type of player i and θ_i^+ [3] be the type of player i when i lies. Similarly d, d^+ be the number of days given by optimization problem for θ_i and θ_i^+ announcements respectively. Likewise g, g^+ is the proposed group given by optimization problem for θ_i, θ_i^+ type announcements $\forall i \in N$ respectively. Also we know that $\theta_i^+ \geq \theta_i$ and $d^+ \geq d$.

The optimization solution ensures that d and d^+ will obey the following condition for a subset of g and g^+ players respectively.

$$\sum_{i \in g} \frac{d}{\theta_i} = 1 \tag{1}$$

$$\sum_{i \in g^+} \frac{d^+}{\theta_i^+} = 1 \tag{2}$$

We know that,

$$g \setminus \{i\} \quad \subseteq \quad g^+ \setminus \{i\}$$

because all people in g other than i will remain in g^+ because other than i none of them lie.

(2)-(1) gives (3)

$$\sum_{i \in g^+} \frac{d^+}{\theta_i^+} - \sum_{i \in g^+} \frac{d}{\theta_i} = 0 \tag{3}$$

Let us now look at four cases,

1. player i is in g and also in g^+

[3] we have purposefully chosen θ_i^+ as the notation for false type, as the possible lie in software maintenance can be only greater than θ_i. The symbol + denotes the increase in value compared to θ_i

2. player i is not in g and in g^+
3. player i is in g and not in g^+
4. player i is not in g and not in g^+

Let us show that in all four cases, player i cannot better off by revealing theta untruthfully as θ_i^+.

More formally, $u_i \geq u_i^+, \forall i \in g$.

Case 1: Player i is in g and also in g^+. Now let us take a look at the utility of player i in both g and $g+$ proposed groups.

$$u_i = \left(\frac{d}{\theta_i}\rho\right) - d$$
$$u_i^+ = \left(\frac{d^+}{\theta_i^+}\rho^+\right) - d^+$$

The increase in utility by lie can be depicted as,
$u_i^+ - u_i = \left[\left(\frac{d^+}{\theta_i^+}\rho^+\right) - \left(\frac{d}{\theta_i}\rho\right)\right] - (d^+ - d)$

If i is the player who lies, and the player is in both g and g^+ proposed groups then only one case is possible where $g = g^+$ and $\rho = \rho^+$.

We also know,

$$u_i^+ - u_i = \left[\left(\frac{d^+}{\theta_i^+} - \frac{d}{\theta_i}\right)\rho\right] + d - d^+ \tag{4}$$

In this case all players including i remain in both g and g^+ hence $d^+ \geq d$. Hence the second component of equation (4), $d - d^+ \leq 0$. We can prove that there is no raise in utility for player i in this case, if the first component is also less than zero.

$$u_i^+ - u_i = \left[\left(\frac{d^+}{\theta_i^+} - \frac{d}{\theta_i}\right)\rho\right] + d - d^+$$

But we know that, (from equation (3))

$$\sum_{i \in g^+} \frac{d^+}{\theta_i^+} - \sum_{i \in g} \frac{d}{\theta_i} = 0$$

From which we can say,

$$\left(\frac{d^+}{\theta_i^+} - \frac{d}{\theta_i}\right) = \sum_{j \in g_{-i}} \frac{d}{\theta_j} - \sum_{j \in g_{-i}^+} \frac{d^+}{\theta_j^+}$$
$$= \sum_{j \in g_{-i} \cap g_{-i}^+} \frac{d - d^+}{\theta_j} - \sum_{j \in g_{-i}^+ \setminus g_{-i}} \frac{d^+}{\theta_j} \leq 0$$

This clearly shows that for **Case 1**,

$$\Rightarrow u_i^+ - u_i \leq 0$$

Case 2: Player i is not in g and in g^+. This case is not possible as player i can never enter g^+ by saying lie, when he could not have entered g (when he reveals truth), when all other players other than i continue to reveal same type value.

Case 3: Player i is in g and not in g^+.
The utility of player i when he is in the group g is $u_i \geq 0$ and when he is not in the group g^+ is $u_i^+ = 0$. Hence, increase in utility by lying for player i is, $u_i^+ - u_i \leq 0$

Case 4: player i is not in g and not in g^+. In this case the increase in utility of player i (by a lie) is zero, because the utility of player i while revealing truth and lie is zero. Formally,

$$u_i^+ - u_i = 0$$

Thus we have shown in all the above four cases, DOL mechanism is DSIC.

Proposition 2: DOL mechanism is Individually Rational.
Proof: We need to show that every player $i \in N$ by participating in the game gets more or the same as against not participating in the game. We need to show, $u_i \geq 0, \forall i \in N$.

For all players $i \in g$,$u_i = \frac{d}{\theta_i}\rho - d$

For all player $i \notin g$, $u_i = 0$

By definition we know, $\rho > \theta_i, \forall i \in g$. From which we can see, $u_i \geq 0, \forall i \in g$.

Proposition 3: DOL mechanism is *not* CR.
Proof: The DOL mechanism is Coalitionally Rational can be countered with the following example. The bids placed by $1, 2, 3$ and 4 are 14, 28, 29 and 30 respectively. Say customer delivery deadline is 8 days. The players 1, 2 and 3 collaborate to solve the problem in 7.06 days. The payments are 15.13, 7.56, 7.30 and 0 for engineers $1, 2, 3$ and 4 respectively. The utilities for players 1,2,3 and 4 are 8.06, 0.5, 0.24 and 0 respectively. If player 1 would have solved the ticket separately he would obtained payment of 28 and an utility of 14. Here by collaborating 1 receives utility of 8.06 instead of 14. Hence DOL mechanism is *n*ot CR.

Now we shall analyze the stability of the proposed allocation and payment scheme. We use *core* [10] the most fundamental solution concept from cooperative game theory for this purpose. The *core* of the game, is defined as,

$$core(N,\vartheta) = \Big\{(t_i)_{i\in N} : \sum_{i\in N} t_i = \vartheta(N), \sum_{i\in C} t_i \geq \vartheta(C), \forall c \subset N\Big\}$$

We define the characteristic function $\vartheta(.)$ in the following manner,

$$\vartheta(C) = \begin{cases} 0 : if \min_{i\in N\setminus C} \theta_i < \max_{j\in C} \theta_j \\ \min_{i\in N\setminus C} \theta_i : if \min_{i\in N\setminus C} \theta_i \geq \max_{j\in C} \theta_j \end{cases}$$

For the case, when $N = C$, we define $\min_{i\in N\setminus C} \theta_i = \theta_{\max}$. The valuation of coalition C, $\vartheta(C)$, is the amount of value that the coalition can generated by knowing the true bid value of every other player in the coalition. By knowing every other players true valuation, they can bid the maximum true bid value known with-in the coalition in order to gain maximum advantage, as the payment to the group will be the second highest bid value (if they win, zero otherwise).

Proposition 4: DOL mechanism is *not* in *core*.
Proof: The DOL mechanism is not CR from proposition 3. The Coalitional Rationality is an necessary condition as seen from the definition of core. Since, DOL mechanism does not have Coalitional Rationality, we can comfortably conclude the allocation and payment by this mechanism does not lie in the core of the game, and hence not stable.

We have so far shown that DOL mechanism has IR and *DSIC* properties and does not hold *core* and CR properties that are very essential for coalitional stability. In order to achieve *core* and CR properties we extend our discussion to our next mechanism, *Extended Second Price* (ESP).

4 ESP - Extended Second Price

In this mechanism, we propose a payment rule, which has two components unlike the previous mechanism which has only one. The first component is motivated from the famous VCG payment rule [11], [9] and the second term is inherited from DOL mechanism. The payment rule we propose is as follows,

$$t_i = \begin{cases} t_i^{vcg} + \frac{d}{\theta_i}\rho, \forall i \in g \\ 0, \forall i \notin g \end{cases}$$

Proposition 5: ESP Mechanism is DSIC.
Proof: We know that the first component in the payment equation of this mechanism maps to Second Price Auction, which is DSIC [11]. The second component is the payment of DOL mechanism, which is also DSIC. Hence under-bidding or a lie of player i will not increase the utility of i through either of the components. Hence, this mechanism is DSIC.

Proposition 6: ESP Mechanism is Coalitionally Rational.
Proof: Let us define u_i^g, for the utility of player if he participates in the proposed group, and u_i^{-g}, if i is not participating the proposed group. For all players $i \notin g$, do not have any impact to group g as they are asked not to participate anyway. So, only for players $i \in g$ it matters to participate or not in the proposed group g. If $u_i^g \geq u_i^{-g}$ then participating in the group as proposed is always a good choice for player i and it is Coalitionally Rational. Here we will show that $\forall i \in g, u_i^g \geq u_i^{-g}$. We know that,

$$\begin{aligned} u_i^g &= u_i \\ u_i^{-g} &= t_i^{vcg} - \theta_i \end{aligned}$$

So $u_i^g \geq u_i^{-g}$, iff,

$$\begin{aligned} & t_i^{vcg} + \tfrac{d}{\theta_i}\rho - d \geq t_i^{vcg} - \theta_i \\ \Leftrightarrow\ & \tfrac{d}{\theta_i}\rho - d \geq \theta_i \\ \Leftrightarrow\ & \tfrac{d}{\theta_i}\rho - d \geq 0 \\ \Leftrightarrow\ & d\left(\tfrac{\rho}{\theta_i} - 1\right) \geq 0 \\ \Leftrightarrow\ & \tfrac{\rho}{\theta_i} \geq 1 \Leftrightarrow \rho \geq \theta_i \end{aligned}$$

But, we know by definition, $\rho \geq \theta_i$, hence we prove ESP mechanism is CR.

Proposition 7: ESP Mechanism is Individually Rational.
Proof: We need to show that $u_i \geq 0, \forall i \in N$. We know that $\forall i \notin g, u_i = 0$. But, $\forall i \in g$, $u_i = t_i^{vcg} + \frac{d}{\theta_i}\rho - d$. We know that,

$$\begin{aligned} & t_i^{vcg} \geq 0 \\ & d\left(\tfrac{\rho}{\theta_i} - 1\right) \geq 0 \end{aligned}$$

Hence, we can say, $\forall i \in g, u_i \geq 0$.

Proposition 8: The solution of ESP mechanism is in *core*.
Proof: With out loss of generality, let us assume the players are arranged in the increasing magnitude of their bid values. Hence player 1 has the lowest bid and player n has the highest bid. Now, the characteristic function ϑ, can simply be stated as, $\vartheta(p) > 0, p \in P$, where $P = \{(1,...k) : k = 2,\ldots,n\}$, whereas for all other coalitions, not in P, the characteristic value is zero. This is because at least one player whose not in the coalition will outbid the coalition bid (see definition of characteristic function).

We essentially need to show that the core condition is true for all coalitions $c \in P$. For rest of the coalitions $c \notin P$, the sum over payments of players in c, may be greater than equal to zero, because the mechanism is IR. For the coalitions $c \in P$, we can say,

$$\sum_{i \in c} t_i = t_1 + ... + t_k, k = 2, \ldots, n$$
$$= \sum_{i \in c} \left(\frac{d}{\theta_i}\rho + t_i^{vcg} \right) = \left(\sum_{i \in c} \frac{d}{\theta_i}\rho \right) + t_1^{vcg}$$
$$= \vartheta(c) + t_1^{vcg} \geq \vartheta(c)$$

Hence, we show that the proposed payments and allocation in ESP mechanism lie in $core$ of the game.

Now after showing the existence of desired properties for these two mechanisms we further proceed to experimentally show the effect of IC and CR properties using the ESP mechanism for a selected set of engineers.

5 Experimental Evaluation

5.1 The Setup

We have considered a game consisting of 10 engineers N={1,2,...,10}, who will announce their bids to a lead, who decides the allocation and payments based on the social choice function defined for the ESP mechanism. The type sets for each engineer is randomly generated from a uniform distribution over the interval [0,20]. For every unit time we have generated a random ticket and agents bid for the ticket, and an allocation happens. For the next new ticket, which arrives in the next unit time the ticket is auctioned. We assume the interval between any two tickets arriving into the system are reasonably high, such that every engineer will have no ticket in his queue while placing bid for a new ticket.

5.2 Experiment

We perform two experiments to analyze the performance of our mechanism. The first experiment (*Truth Elicitation Analysis*) is to compare the utility of players when one of the players reveals their bid untruthfully (a lie). For the purpose of experiment we have considered player 2 will be the liar. We depict this in Figure 4, where the curve $clui$, represents the cumulative utility (utility accrued over every ticket solved) of player i when θ_2 is a lie. The curve cui, represents the utility of player i when all players in the system reveal truth. For the purpose of clarity (of the graph), we show only the utility curves for player 1 and 2 in Figure 4. From the figure it is evident that player 2 gets lower utility when he lies, as the ESP mechanism is incentive compatible. This implies that it is always best for every player to reveal truth under this mechanism. As a side effect, we see the utility of player 1 has increased when player 2 reveals a lie. This is just the case of this experiment and not always true. But our mechanism guarantees that the utility of player 1 will never decrease (not at loss) because of untruthful revelation of player 2. In our second experiment (*Core Condition Analysis*), we group n-1 random players from the system, and apply our allocation and payment rules from ESP mechanism. We compare the utility of player 1 and 2 when the grouping of n-1 players is based on (i) some (random) rational decision by the lead (curves $crui$ in Figure 5) $versus$ (ii) the grouping is based on our proposed optimization function in Section 2 (curves cui in Figure 5). We find that it is always best to group the players as proposed by the optimization function, as it provides increased utility for every player $i \in N$ than any random grouping. We also found from the experiment that it is essential to have the first (n-1) players in group in order to achieve a core condition, under ESP payment scheme.

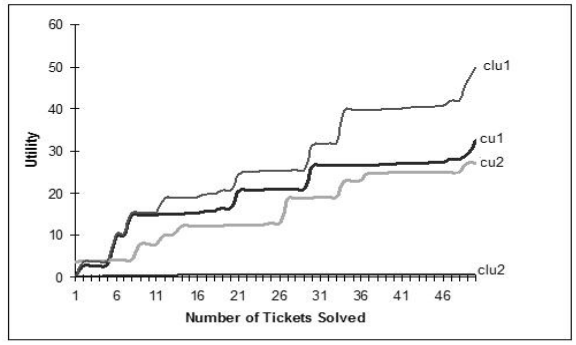

Figure 4. Truth Elicitation Analysis

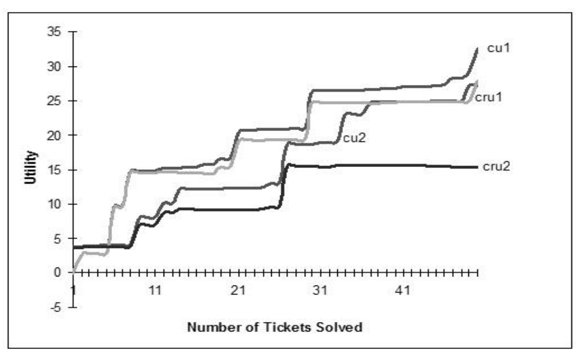

Figure 5. Core Condition Analysis

6 Conclusion

"*Group Ticket Allocation*" is one of the critical problems faced by many managers/leads in software maintenance. The decisions made by the leads/managers are purely based on their rationality of fairness and are not fair to all players, also not motivating for many participating engineers. This results in loss of productivity in many maintenance organization.

In this paper we address this issue by proposing two Incentive Compatible mechanisms for solving group ticket allocation problem with customer delivery deadlines. We showed that these mechanisms motivate engineers individually and also in groups. We have also established that the second mechanism ESP is superior to DOL in terms of CR and $core$ properties. Thus, the total cost incurred in ESP is higher than DOL, in order to satisfy these additional properties. The decision of choosing one of these mechanisms is basically making a trade-off between total cost vs rationality/stability. We leave this choice to the discretion of implementing maintenance organizations. One can also extend this model for hierarchical organizations, where the grouping spans hierarchies.

We are also currently working on software infrastructure to facilitate such auctions, grouping and payments for software maintenance services.[4].

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