Knowledge Sharing in Social Network Using Game Theory

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Abstract. Stimulating is an important mechanism in Virtual Community (VC) during the Knowledge Sharing (KS) process. In this paper, we combine the power of game theory and stimulating mechanism together to optimize the KS process in Social Network (SN). We first model the basic stimulating mechanism as a static game of complete information, under which the stimulating threshold for Nash Equilibrium (NE) is derived. Next, we modify the static model by introducing the KREPS-MILGROM-ROBERTS-WILSON (KMRW) reputation model, where the dynamic case is studied and the Perfect Bayesian Equilibrium is proved. We then propose a novel *rational stimulating* mechanism by combining the finitely repeated game with basic stimulating mechanism together. Theoretical analyzing indicates that, by introducing incomplete information, the *rational stimulating* achieves a lower cost; through stimulating, the Perfect Bayesian Equilibrium's condition is satisfied and the KS rate will approach 100% as long as the KS process is repeated enough. Finally, we extend our *rational stimulating* mechanism to the multi-person model.

Keywords: Social Network, Virtual Community, Knowledge Sharing, Stimulating, Game Theory.

1 Introduction

Social networks are built upon the idea that there exists a determinable structure to how people know each other, whether directly or indirectly [1] . In such networks, people are connected and cooperate through one or more specific types of interdependency through common social relationships [2–4].

As one of the kernel technology in SN, Knowledge Sharing concerns about how to turn individual knowledge into organizational knowledge [5,6]. Problems arouse during KS process involves how to increase the KS rate, how to avoid hitchhike and how to make most efficient utilization of knowledge [7–10].

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The game theory [11, 12] is a powerful tool to model the interaction among SN members and to analyze the optimal cooperation strategies. The static game of complete information based KS model can only be used to analyze member's one time KS behavior. In dynamic game of complete information, the finitely repeated game can not form collaboration behavior among members. Although we can achieve the Subgame Perfect Nash Equilibrium in infinitely repeated game, nevertheless, in real world SN, the KS process can not repeat endlessly. While in incomplete information case of KMRW model [13], the Perfect Bayesian Equilibrium can be achieved [14], however, the condition that equilibrium must satisfy is not easy to obtain and control [12].

While SN without coordination can not accomplish KS simply, the stimulating mechanism in VC [15] provides a feasible trick. A meticulously designed stimulating mechanism can greatly arouse member's enthusiasm as well as increase the KS rate. If we transfer different form of stimulating into numerical value defined as *stimulating cost*, then the key problem in stimulating mechanism is that how does the SN coordinator optimally set this value under the premise of guaranteeing a high KS rate among all the members in SN. Although a large *stimulating cost* can motivate the KS process, however, the cost to SN coordinator is non-neglectful; on the other hand, a small *stimulating cost* may not promote the members enough to join KS.

In this paper, we propose a novel *rational stimulating* mechanism by combining the finitely repeated game with basic stimulating mechanism together, who will optimize each other during the KS process. Through *rational stimulating*, Game helps Stimulating to reduce its cost; Stimulating guarantees the existing of Perfect Bayesian Equilibrium in return of Game's help.

The rest of paper is organized as follows: Section 2 describes the problem in KS process and gives out a basic solution using basic stimulating mechanism, where the *stimulating cost* is left as a problem to handle. In Section 3.1 and 3.2, we analyze the finitely repeated game of incomplete information and leave the Perfect Bayesian Equilibrium condition as another problem to solve. In Section 3.3, we propose and explore our *rational stimulating* mechanism. In Section 4, we extend the *rational stimulating* mechanism to multi-person case. Finally in Section 5, we conclude our paper.

2 Basic Stimulating Mechanism

2.1 Problem Description

In this section it is assumed that there are only two members in SN, named m_1 and m_2 respectively. They simultaneously choose actions and each member's payoff function is common knowledge between themselves. Further, we suppose that m_1 and m_2 are both rational and will take their dominant strategy as their best response to each other. The benefit of KS can be quantized, and so is the cost. We can obtain the following static game of complete information: the KS benefit for m_1 and m_2 are both of b; the KS cost is defined to be c, where $b, c > 0$ holds. As Table 1 shows, the KS process can be represented in the accompanying bi-matrix (We use the row of bi-matrix to indicate $m_1{'}s$ action, and m_2 is the column).

Table 1. Knowledge Sharing Based on Static Game of Complete Information

	sharing	not sharing
sharing	$(b-c, b-c)$	$(-c, b)$
not sharing	$(b, -c)$	$(0, 0)$

If both the two members choose *sharing* strategy, then the payoff for each one is $b - c$; if one of them (suppose m_i) chooses *not sharing*, then $m_j, j \neq i$ will get a negative payoff of $-c$ and m_i will get a b payoff; if neither of them chooses *sharing*, both will get nothing, represented as zero in the bi-matrix. Under assumption of rationality, both of m_1 and m_2's dominant strategy are *not sharing*, and the corresponding equilibrium is thus (*not sharing*, *not sharing*). While the SN coordinator expects a scenery of (*sharing*,*sharing*), the rationality brings the KS process into Prisoners' Dilemma.

2.2 Basic Stimulating Mechanism in Knowledge Sharing

To help SN members walk out of the Prisoners' Dilemma and arrive into the (*sharing*,*sharing*) equilibrium, the SN coordinator can take stimulating mechanism. Define SN coordinator's *stimulating cost* to be s. The payoff function by introducing stimulating mechanism can be represented by Table 2.

Table 2. Knowledge Sharing Based on Static Game of Complete Information with Basic Stimulating Mechanism

	sharing	not sharing
sharing	$(b+s-c, b+s-c)$	$(s-c, b)$
not sharing	$(b, s-c)$	$(0, 0)$

In basic stimulating mechanism, member m_i achieves an additional award s as long as he takes the *sharing* strategy. Under assumption of rationality, we can easily get the equilibrium of this improved KS process in the following two cases:

$$\text{NE} = \begin{cases} (N, N), & \text{if} \quad s < c \\ (S, S), & \text{if} \quad s > c \end{cases} \tag{1}$$

While in equations (1), S indicates *sharing*, N represents *not sharing.* The SN members can achieve the (*sharing*,*sharing*) equilibrium in condition that the *stimulating cost* provided by SN coordinator is larger than KS cost.

So much for this, we have derived the *stimulating cost* for SN coordinator. Providing $s > c$, the rational SN members can achieve their NE. However, as described in Section 1, a large *stimulating cost* results in an non-neglectful cost to SN coordinator. So the new problem arising here is that whether the threshold of s, which is c till now, can be further decreased under the premise of this decreased *stimulating cost* could still guarantee SN members' (*sharing*,*sharing*) equilibrium. In the following sections, we will find out an improved threshold by introducing SN member's uncertainty.

3 Rational Stimulating Mechanism

The static game of complete information discussed in Section 2 can only be used to analyze member's one time KS behavior. Although we can extend it to the dynamic model and analize the multi-stage KS process, however, the finitely repeated game can not form collaboration behavior among members. Further, if the game is repeated infinitely, the Subgame Perfect Nash Equilibrium can be achieved. Nevertheless, in real world SN, the KS process will not repeat endlessly. Fortunately, the KMRW reputation model [13] provides a Perfect Bayesian Equilibrium solution within some finite stages under incomplete information condition. In this section, we will explore the KMRW reputation model in our KS process with two SN members. Extension to multi-person KMRW model is discussed in Section 4.

3.1 Two Stage Knowledge Sharing

Suppose m_1, m_2 are a little of complex than in the previous section by introducing incomplete asymmetric information. To be concrete, we assume that m_1 has private information about his strategy with probability p of playing the *following* strategy and probability $1-p$ of *playing rationally*. Moreover, m_2 dose not know which type m_1 actually belongs to, the only thing he knows is $m_1's$ probability distribution $(p, 1-p)$. The *following* strategy provides that m_1 will first choose *sharing* then mimic $m_2's$ previous strategy; *playing rationally* means that the player will act according to its dominant strategy in the current stage. In an actual SN, the *following* member (referred as non-rational later in paper) can be explained as an *action echo*, who always follows other members' opinion in purpose of raising his status in SN.

The timing of m_1 and m_2 is described as follows:

- The SN coordinator knows the type for m_1, with probability p of non-rational and probability $1-p$ of rational.
- m_1 and m_2 choose *sharing* or *not sharing* in the first stage. The non-rational m_1 will choose *sharing* according to the *following* strategy; m_2 will choose his strategy rationally.
- On observing the result of the first stage, m_1 and m_2 choose *sharing* or *not sharing* in the second stage. The non-rational m_1 mimics $m_2's$ first step strategy; rational m_1 and m_2 play rationally.
- The payoff of the two stage KS is the sum of each stage's payoff.

Denote the rational and non-rational m_1 as m_1^r and m_1^n respectively. Similar to the finitely repeated game of complete information, *not sharing* is the dominant strategy for both m_1^r and m_2. So in the second stage of KS process, m_1^r and m_2 will play *not sharing*. Because m_2 will surely choose *not sharing* in the second stage, m_1^r is not necessary to hide his type in the first stage, so he will also choose *not sharing* in the first stage. Considering of m_1^n'*s following* strategy, the equilibrium path of two stage knowledge sharing can be represented by Table 3, where $X \in \{S, N\}$ according to the *following* strategy.

Table 3. Two Stage Knowledge Sharing with Incomplete Asymmetric Information

	$t = 1$	$t = 2$
m_1^n	S	X
m_1^r	N	N
m_2	X	N

If m_2 choose *sharing* in the first stage, then the average payoff (without stimulating) of m_2 in the two stage KS process is:

$$p \times (b - c) + (1 - p) \times (-c) + p \times b \tag{2}$$

If m_2 choose *not sharing* in the first stage, then the average payoff of m_2 in the two stage KS process is:

$$p \times b \tag{3}$$

From equations (2) and (3), we can solve the condition of m_2 sharing his knowledge in the first stage:

$$\begin{aligned} & p \times (b - c) + (1 - p) \times (-c) + p \times b > p \times b \\ \Rightarrow & p > \frac{c}{b} \end{aligned} \tag{4}$$

Inequality (4) indicates that according to m_2'*s* priori knowledge of m_1'*s* type, to promote knowledge sharing, the SN coordinator should guarantee $p > \frac{c}{b}$. However, given m_1, p is fixed; given m_2, b and c are fixed. It seems that the SN coordinator has nothing to do with adjusting inequality (4). We will solve this problem in Section 3.3 where the *rational stimulating* mechanism is discussed. Here, we continue our analysis in finitely repeated game of incomplete information in three stage case.

3.2 Three Stage Knowledge Sharing and the General T Stage Case

Suppose inequality (4) is satisfied, we will derive the sufficient condition for the equilibrium path of three stage KS as Table 4 shown. Under this equilibrium, m_1^r'*s* average payoff is $(b - c) + b$; m_2'*s* average payoff is $b - c + p \times (b - c) + (1 - p) \times (-c) + p \times b$. We will next prove that m_1 and m_2 has no incentive to derive the equilibrium path described in Table 4.

Table 4. Three Stage Knowledge Sharing with Incomplete Asymmetric Information

	$t=1$	$t=2$	$t=3$
m_1^n	S	S	S
m_1^r	S	N	N
m_2	S	S	N

If m_1^r chooses *not sharing* in the first stage, m_2 will know $m_1's$ type is m_1^r so as to choose *not sharing* in the following stages. To cope with m_2, m_1^r will also choose *not sharing*. The resulting KS process is shown in Table 5. According to Table 5, $m_1^r{}'s$ average payoff is b which is lower than the equilibrium path payoff $2b - c$ (assuming $b > c$ holds), so m_1^r will choose *sharing* in the first stage.

Table 5. Three Stage Knowledge Sharing: $m_1^r{}'s$ Deviation

	$t=1$	$t=2$	$t=3$
m_1^n	S	S	N
m_1^r	N	N	N
m_2	S	N	N

If m_2 chooses *not sharing* in the first stage, according to *following* strategy, m_1^n will mimic him and choose *not sharing* in the second stage. Considering that m_2 will surely choose *not sharing* in the third stage, m_1^r is not necessary to hide his type in the second stage, so m_1^r will take its dominant strategy *not sharing* in stage two. The resulting KS process is shown in Table 6.

Table 6. Three Stage Knowledge Sharing: $m_2's$ Deviation

	$t=1$	$t=2$	$t=3$
m_1^n	S	N	X
m_1^r	S	N	N
m_2	N	X	N

If m_2 choose *not sharing* in the second stage, the average payoff is b. So we can get the condition of m_2 having no incentive to deviate from equilibrium path:

$$\begin{aligned} & b - c + p \times (b - c) + (1 - p) \times (-c) + p \times b > b \\ \Rightarrow & p > \frac{c}{b} \end{aligned} \tag{5}$$

which is the same to inequality (4).

If m_2 choose *sharing* in the second stage, the average payoff will be $b - c + p \times b$. Once again, we can get the condition of m_2 having no incentive to deviate from equilibrium path:

$$\begin{aligned} & b - c + p \times (b - c) + (1 - p) \times (-c) + p \times b \\ & > b - c + p \times b \\ \Rightarrow & p > \frac{c}{b} \end{aligned} \tag{6}$$

which is the same to inequality (4) and (5).

Combine inequalities (4), (5) and (6), we conclude that under condition of $p > \frac{c}{b}$, there exists a Perfect Bayesian Equilibrium in the three stage KS process, which improves the KS rate in SN. To be general, we can have the following theorem:

Theorem 1 (T Stage Knowledge Sharing). *Given two SN members m_1 and m_2, who satisfy $p > \frac{c}{b}$. There exists a Perfect Bayesian Equilibrium in the T stage knowledge sharing process, under condition that m_1^r and m_2 both take the sharing strategy in the previous T-2 stages and the last two stages is taken as Table 3 shown.*

Theorem 1 indicates that according to $m_2's$ priori knowledge $(p, 1-p)$, to promote knowledge sharing, the SN coordinator should guarantee $p > \frac{c}{b}$. However, as referred in section 3.1, given m_1 and m_2, p, b and c are all fixed. The condition, $p > \frac{c}{b}$, Theorem 1 relying on, is not naturally satisfied. In the next subsection, we propose a novel *rational stimulating* mechanism, which contributes to both satisfying Perfect Bayesian Equilibrium condition and reducing the *stimulating cost* in SN's members KS process.

3.3 Rational Stimulating in Knowledge Sharing

Theorem 2 (Rational Stimulating with Two Members). *By introducing incomplete information in the basic stimulating mechanism, the optimal stimulating value s_{opt} satisfies:*

$$s_{opt} > \max\{c - pb, c - \frac{2}{3}b, c - 2(1-p)b\} \tag{7}$$

Moreover, as KS process's repeating times T increases, the KS rate $\eta(T)$ also increases, which will approache 100% in the limit case as equation (8) shown:

$$\lim_{T \to \infty} \eta(T) = 1 \tag{8}$$

Proof. If m_1, m_2 play the game according to Theorem 1, the KS rate $\eta(T)$ is computed as:

$$\eta(T) = \frac{(T-2)(b-c) + p(b-c) + (1-p)(-c) + pb}{T(b-c)} \tag{9}$$

According to $L'Hospital$ Rule, equation (8) can be easily achieved from equation (9). By taking the first derivative of equation (9) with respect to T, we have:

$$\eta'(T) = \frac{2b(1-p) - c}{T^2(b-c)} \tag{10}$$

Combining the Perfect Bayesian Equilibrium conditions (inequalities (4,5,6)) and the first derivative of $\eta(T)$ (equation (10)), we get the condition under which there exists Perfect Bayesian Equilibrium and the KS rate $\eta(T)$ increases as T increases:

$$\begin{cases} \frac{c}{b} < p < 1 - \frac{1}{2}\frac{c}{b} \\ c < b \\ \frac{c}{b} < 1 - \frac{1}{2}\frac{c}{b} \end{cases} \tag{11}$$

Notice that in inequality (11), given SN members m_1 and m_2, p, b, c are constants. We have already assumed that the KS cost is lower than benefit, so condition $c < b$ is naturally satisfied. The problem mentioned in the previous section still remains. That is, give m_1 and m_2, inequalities $\frac{c}{b} < p < 1 - \frac{1}{2}\frac{c}{b}$ and $\frac{c}{b} < 1 - \frac{1}{2}\frac{c}{b}$ can not be naturally satisfied.

Rewrite Table 2 as Table 7. Denote $c' = c - s$, then Table 1 and Table 7 jointly mean that the KS cost c under our *rational stimulating* mechanism can be variable, which is adjusted through *stimulating cost* provided by SN coordinator. Substitute c with c' in inequality (11), we finally get inequality (18).

Table 7. Another Form for Knowledge Sharing with Basic Stimulating Mechanism

	sharing	not sharing
sharing	$(b-(c-s), b-(c-s))$	$(-(c-s), b)$
not sharing	$(b, -(c-s))$	$(0, 0)$

The significance of Theorem 2 can be explained as follows: given SN members m_1 and m_2, although p, b, c are fixed, we can still achieve the finitely repeated KS process's Perfect Bayesian Equilibrium by coordinator optimally setting the *stimulating cost* as s_{opt}. On the other side, by modeling the KS process as an incomplete information dynamic game, compared to the basic stimulating mechanism, the SN coordinator can reduce its *stimulating cost* in management of SN activities. By adopting the *rational stimulating* mechanism, the SN coordinator uses a lower cost to achieve an prosperous scenery of knowledge sharing among different SN members.

4 The Multi-person Knowledge Sharing

In the original work of KMRW reputation model [13], only two players with incomplete asymmetric information were discussed. However, in real world SN, there are always more than two members sharing their knowledge. In this section, we extend both of KMRW reputation model and *rational stimulating* mechanism to the multi-person environment.

Suppose there are M members in SN, named $m_1, m_2, \ldots, m_M$ respectively. They simultaneously choose actions and each member's payoff function is common knowledge between themselves. Each of these M players is free to choose between *sharing* and *not sharing*. While the *sharing* strategy is taken by member m_i, a cost of c is accompanied with m_i and a potential benefit of b is ready for some players who will acquire m_i's knowledge. We further assume that every member in SN is seeking knowledge all the time, which means when m_i takes the *sharing* strategy, other $M-1$ players $(m_j, j \neq i)$ always obtain a benefit of b. While the *not sharing* strategy is taken by member m_i, no additional cost is needed. The payoff of m_i relies on the number of his neighbors who take *sharing* strategy.

4.1 *M*-Member Knowledge Sharing

Theorem 3 (Nash Equilibrium with M **Members).** *The Nash Equilibrium with M members in the KS process is a natural extension of two member Prisoner's Dilemma, which can be described as:*

$$NE^M = (N, N, \ldots, N) \tag{12}$$

Proof. Consider one possible strategy combination:

$$\mathbb{P} = (\mathfrak{p}_1, \mathfrak{p}_2, \ldots, \mathfrak{p}_M)$$

Where $\mathfrak{p}_i \in \{N, S\}, i = 1, 2, \ldots, M$ represents for $m_i's$ strategy. $m_i's$ payoff can be calculated as:

$$u_i = k_i \times b - c_i \tag{13}$$

Where $k_i \leq M-1$ denotes the number of $m_i's$ neighbors who take the *sharing* strategy and $m_i's$ cost c_i is defined as:

$$c_i = \begin{cases} c & if\ m_i\ shares\ knowledge, \\ 0 & otherwise \end{cases} \tag{14}$$

Notice that, the first part of equation (13) has nothing to do with $m_i's$ strategy. For a given k_i, $m_i's$ best response is surely *not sharing*. ■

4.2 *M*-Member Knowledge Sharing with Basic Stimulating

To help SN members walk out of the Prisoners' Dilemma and arrive into the $(S, S, \ldots, S)$ equilibrium, the SN coordinator can again take stimulating mechanism. As an improvement to Theorem 3, the basic stimulating mechanism in multi-person KS process can be described as

Theorem 4 (Basic Stimulating with M **Members).** *By introducing the stimulating mechanism, the Nash Equilibrium with M Members can be migrated to*

$$NE^M_{bs} = (S, S, \ldots, S) \tag{15}$$

Proof. In basic stimulating mechanism, $m_i's$ payoff can be calculated as:

$$u_i = k_i \times b - c_i + s_i \tag{16}$$

Where $k_i \leq M - 1$ denotes the number of $m_i's$ neighbors who take the *sharing* strategy and $m_i's$ cost c_i is defined according to equation (14), the *stimulating cost* s_i is defined as:

$$s_i = \begin{cases} s & if\ c_i = c, \\ 0 & otherwise \end{cases}$$

Given k_i, $m_i's$ best response is to be *sharing* under condition of $s > c$. ■

4.3 Multi-person Extension of KMRW and Rational Stimulating

In our model, all $m_i, i = 1, 2 \ldots, M$ are assumed to have private information about his strategy with probability p of being m_i^n and probability $1-p$ of being m_i^r. For any $j, j \neq i$, m_j dose not know which type m_i actually belongs to, the only thing he knows is $m_i's$ probability distribution $(p, 1-p)$. For a given m_i, it's assumed to have connection with all the other $M-1$ members in the SN, and an M-member game with incomplete asymmetric information is played. We have the following theorem:

Theorem 5 (T Stage Multi-person Knowledge Sharing). *Given M SN members $m_1, m_2, \ldots, m_M$, who satisfy $p > \frac{c}{b}$. There exists a Perfect Bayesian Equilibrium in the T stage knowledge sharing process, under condition that $m_j^r (j \neq i)$ and m_i both take the sharing strategy in the previous $T-2$ stages and the last two stages are taken as Table 8 shown, where $\bar{i} = \{1, 2, \ldots, i-1, i, \ldots, M\}$.*

Proof (Induction on T). Given that for each $\tau = 2, 3, \ldots, T-1$, Theorem 5 holds. Then for a τ=T stage game,

① $m_j^r, j \neq i$ **has no incentive to deviate from the equilibrium path in T stage game.** If m_j^r chooses *not sharing* in stage $\tau <$ T $- 1$, m_i will know $m_j's$ type is m_j^r and will choose *not sharing* in the following T $- \tau$ stages. The payoff from τ to T in equilibrium path and deviation path are $(\mathrm{T} - 2 - \tau + 1) \times (b - c) + b$ and b respectively. So $m_j^r, j \neq i$ has no incentive to deviate from the equilibrium path.

② m_i **has no incentive to deviate from the equilibrium path in T stage game.** According to equilibrium path, the payoff of m_i from stage $\tau <$ T to T to can be calculated as:

$$(M-1) \times \{2(b-c) + [(T-2) - (\tau+2) + 1](b-c) + p(b-c) + (1-p)(-c) + pb\} \tag{17}$$

If m_i chooses *not sharing* in stage τ. All $m_j^n, j \neq i$ will mimic this strategy and choose *not sharing* in stage $\tau+1$. m_j^r will also choose *not sharing* strategy for two reasons:

- *not sharing* dominates *sharing* in stage $\tau + 1$;
- *not sharing* hide $m_j's$ type and will achieve a payoff of at least zero from stage $\tau + 2$ to T; while *sharing* will expose himself to m_i who will choose *not sharing* in the rest stages and get a payoff of exactly zero.

Suppose this process for m_i continues until stage $\tau + \varphi, \varphi \geq 0$($m_i$ chooses *not sharing*, all m_j^n and m_j^r also choose *not sharing*). In stage $\tau + \varphi + 1$, m_i adopts the *sharing* strategy. The continuation game from stage $\tau + \varphi + 2$ to T thus constitute a $T - (\tau + \varphi + 2) + 1$ stage repeated game. According to our hypothesis, this game can be played according to the equilibrium path. We still need to discuss four different cases according to the $\tau + \varphi$ value:

- If $\tau + \varphi =$ T. $m_i's$ payoff is $(M-1) \times b$ in stage τ and zero in all the other stages. Notice that $p > \frac{c}{b}$, we have $pb > c$. Thus $m_i's$ payoff is less than equation (17);
- If $\tau + \varphi =$ T -1. $m_i's$ payoff is $(M-1) \times b$ in stage τ, $(M-1) \times (-c)$ in stage T and zero in all the rest stages, which is less than equation (17);
- If $\tau + \varphi =$ T -2. $m_i's$ payoff is $(M-1) \times b$ in stage τ, $(M-1) \times (-c)$ in stage T -1, $(M-1) \times pb$ in stage T and zero in all the rest stages, which is less than equation (17);
- If $\tau + \varphi <$ T-2. $m_i's$ payoff is $(M-1) \times b$ in stage τ, $(M-1) \times (-c)$ in stage $\tau + \varphi + 1$, $(M-1)[(T-2) - (\tau + \varphi + 2) + 1](b-c) + p(b-c) + (1-p)(-c) + pb]$ from stage $\tau + \varphi + 2$ to T and zero in all the rest stages, which is also less than equation (17). ■

Table 8. The Last Two Stages of T Stage Multi-Person Knowledge Sharing

	$t = 1$	$t = 2$
$m_{i_1}^n$	S	X
$m_{i_1}^r$	N	N
…	…	…
$m_{i_{M-1}}^n$	S	X
$m_{i_{M-1}}^r$	N	N
m_i	X	N

According to Theorem 5, we can get the optimal *stimulating cost* under M-member environment:

Theorem 6 (Rational Stimulating with Multi-person). *By introducing incomplete information in the basic stimulating mechanism, the optimal stimulating cost* s_{opt}^M *satisfies:*

$$s_{opt}^M > \max\{c - pb, c - \frac{2}{3}b, c - 2(1-p)b\} \tag{18}$$

The proof of Theorem 6 is similar with Theorem 2.

5 Conclusion

Knowledge Sharing is one of the kernel technology in SN. During the KS process, an efficient stimulating mechanism can greatly arouse member's enthusiasm as well as the KS rate. Although traditional stimulating mechanism can motivate the KS process, however, the cost to SN coordinator is non-neglectful. In this paper, a novel *rational stimulating* mechanism is proposed. By combining the power of game theory and basic stimulating mechanism together during the KS process, we successfully reduce the *stimulating cost*. We also solve the Perfect Bayesian Equilibrium condition problem and the KS rate is proved to approach 100% as long as the KS process is repeated enough. We also extend both of KMRW reputation model and *rational stimulating* mechanism to the multi-person environment.

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