Analyzing Asking/Bidding Price in Dynamic Game for Cooperative Authentication

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***Abstract*—With the problem that the non-cooperation of selfish nodes causes by location privacy leakage and resource consumption, some researchers proposed a bargaining-based game for cooperative authentication in MANETs. In this game, a fundamental issue is to study how the asking/bidding price affects the cooperative willingness of nodes. To address the problem that the improvement of cooperative willingness in dynamic decision-making, a bargaining-based dynamic game is proposed to analyze the dynamic behavior of the asking/bidding price of nodes. Further, the Subgame Perfect Nash Equilibriums and Perfect Bayesian Equilibrium are obtained to guide the player chooses its optimal strategy under complete and incomplete information, respectively. Finally, factors affect cooperative willingness have been analyzed and the simulation results indicate all positive factors, which cause a lower asking price and a higher bidding price, imply a higher cooperative willingness and a higher probability of successful cooperative authentication.**

***Index Terms*—location privacy, cooperative authentication, dynamic game, game theory, MANET.**

I. INTRODUCTION

In recent years, the cooperative authentication mechanism which requests lots of nodes to be cooperative has been proposed to cope with security threats (such as unauthorized access) [1]. Its advantages including enhancing positive authentication probability, mitigating verification overhead and decreasing global resource waste. With the problem that the non-cooperation of selfish nodes causes by location privacy leakage and resource consumption, a bargaining-based static game for cooperative authentication is proposed to help nodes decide whether to participate in authentication or not and the experiment results illustrate the expected effect [2]. In this kind of game, one fundamental problem is to study how the asking/ bidding price affects the cooperative willingness of nodes.

To analyze the affection of the asking/bidding price to cooperative willingness of nodes and improve the cooperative willingness in dynamic decision-making, a bargaining-based dynamic game, both with complete and incomplete information, is proposed to analyze the dynamic behavior of the asking/bidding price of nodes. Further, the Subgame Perfect Nash Equilibriums are obtained to guide the player chooses its optimal strategy to maximize its utility under complete information. Then the Perfect Bayesian Equilibrium with incomplete information is analyzed and established. Finally, the factors affecting the cooperative willingness have been analyzed and the simulation results indicate all positive factors, which cause a lower asking price and higher bidding price, imply a higher willingness of nodes to be cooperative and higher probability of successful cooperative authentication. Compared the scheme proposed in [3][4], the issue of privacy leakage is a major consideration in our strategy.

II. SYSTEM MODEL

The network model of cooperative authentication consists of a base station N_{bs} and lots of mobile nodes $MN = \{n_0, n_1 \ldots\}$. The authentication service of message, which the source node n_0 requests and its neighboring nodes $n_i (1 \le i \le N)$ provide, represents the "goods" for trades. If n_0 requires n_i to authenticate message *m*, n_0 must first calculate the *cost price* C_0, *reservation price* R_0, *bidding price* B_0 and the *loss of authentication failure* $LOAF_0$. Then, n_i also calculates the *cost price* C_i, *reservation price* R_i and *asking price* A_i. If the sum of A_i is less than B_0, then the bargain succeeds at *the agreeing price* AP, and sellers offer authentication services to the buyer and get *the allocation asking price* AS_i; Otherwise, the bargain fails. The price system is built according to [2].

Definition 1. Cooperative Authentication Game G is defined as a triple $G = (\boldsymbol{P}, \boldsymbol{S}, \boldsymbol{U})$:

1) ***Players***: $\boldsymbol{P} = \{P_i\}_{i=0}^N$ is the set of players, where P_0 denotes n_0 and P_i represents the i st NNs (n_i, $1 \le i \le N$).

2) ***Strategy***: $\boldsymbol{S} = \{s_i\}_{i=0}^N$ is the set of strategies of all players, where s_i ($0 \le i \le N$) is the strategy of P_i. Each P_i has two choices: *CooPeration*(*CP*) and *Non-Cooperation*(*NC*).

3) ***Payoff Function***: $\boldsymbol{U} = \{u_i\}_{i=0}^N$ is a set of utility functions, where $u_i(s_i, \mathbf{s}_{-i})$ denotes the utility function of P_i under the strategy s_i and given the strategies of other players. The $u_0(s_0, \mathbf{s}_{-0})$ and $u_i(s_i, \mathbf{s}_{-i})$ ($1 \le i \le N$) are defined as (1)(2):

$$u_0(s_0, \mathbf{s}_{-0}) = \begin{cases} R_0 - AP & \text{if } s_0 = CP \text{ and } \exists SC \\ -C_0 & \text{if } s_0 = CP \text{ and } \nexists SC \\ -LOAF_0 & \text{if } s_0 = NC \end{cases} \quad (1)$$

$$u_i(s_i, \mathbf{s}_{-i}) = \begin{cases} AS_i - R_i & \text{if } s_i = CP \text{ and } P_i \in SC \\ -C_i & \text{if } s_i = CP \text{ and } P_i \notin SC \\ 0 & \text{if } s_i = NC \end{cases} \quad (2)$$

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III. Analysis of Cooperative Authentication Game

A. Dynamic game with complete information

The players in the dynamic game with complete information conform to the "*Sequential Rationality*" which requires any player should make the decision according to the circumstances to make its strategy is optimal. Then we can define and obtain the *Subgame Perfect Nash Equilibrium* in *G*.

Definition 2. A strategy profile $\mathbf{S}^* = (\mathbf{S}_1^*,\ldots,\mathbf{S}_i^*,\ldots,\mathbf{S}_n^*)$ is a *Subgame Perfect Nash Equilibrium* if it represents a *Nash Equilibrium* of every subgame of the original game.

Theorem 1. Let C^k (where $C^k \subset (P-P_0)$.) be a set of cooperating players s.t. $\sum_{P_i\in C^k} A_i \le B_0$ and $|C^k| \ge minCNN$. Let SC be $\arg\min_{C^j\in C}\sum_{n_i\in C^j} A_i$. There is a strategy profile s_i^* achieves *Subgame Perfect Nash Equilibrium* if there exists such SC .

$$s_i^* = \begin{cases} CP & \text{if } P_i = P_0 \\ CP & \text{if } P_i \in SC \quad (\text{where } 1 \le i \le N) \\ NC & \text{else} \end{cases} \tag{3}$$

B. Dynamic game with incomplete information

In dynamic game with incomplete information, each player does not know which strategy type the action of other players belong to. It observes others' actions, then chooses its optimal strategy via adjusts its judgments. We define and obtain *Perfect Bayesian Nash Equilibrium* in *G*.

Definition 3. $\tilde{P}rob_i(\theta_{-i} \mid a_{-i}^h)$ denotes the belief of P_i observes the action a_{-i}^h at information set h . A strategy profile $\mathbf{S}^*=\{S_i^*(\theta_i)\}_{i=1}^n$ is *Perfect Bayesian Nash Equilibrium*, if for P_i : $S_i^*(\theta_i)|_h = \arg\max_{S_i(\theta_i)|_h} \sum_{\theta_{-i}} \tilde{P}rob\left(\theta_{-i} \mid a_{-i}^h\right) u_i\left(S_i(\theta_i)|_h, S_{-i}^*(\theta_{-i})\right), \forall \theta_i$.

Theorem 2. In the dynamic game with incomplete information, the following strategy results in the *Perfect Bayesian Nash Equilibrium* (where EAP^{f_1} is the except value of AP of player P_0 at given information set f_1, EAS_i is the except value of AS_i and $ISC \equiv A_i \le (B_0 - \sum_{P_j\in C^k, j\ne i} A_j)$.).

$$S_i^* = \begin{cases} CP \text{ if } P_0 \ \& \ BP_0 \equiv \begin{pmatrix} \tilde{P}rob_0\left(\theta_{i1} \mid CP_i^{f_1}\right) > \dfrac{C_0 - LOAF_0}{R_0 - EAP^{f_1} + C_0} \ \& \\ \tilde{P}rob_0\left(\theta_{i1} \mid NC_i^{f_2}\right) > \dfrac{C_0 - LOAF_0}{R_0 - EAP^{f_2} + C_0} \end{pmatrix} \\ CP \ \text{ if } P_0 \in NNs \ \& \ BP_i \equiv \begin{pmatrix} \tilde{P}rob_i\left(\theta_{01} \mid CP_0^{h_1}\right) > 0 \ \ \& \\ Prob_i\left(ISC\right) > \dfrac{C_i}{EAS_i - R_i + C_i} \end{pmatrix} \\ NC \ \ else \end{cases} \tag{4}$$

IV. Evaluation

The experiments have been implemented to evaluate how the asking/the bidding price affects the cooperative willingness of nodes and the probability of successful cooperative authentication. Fig.1 indicates that a lower asking price implies a higher willingness of nodes to be cooperative and higher probability of successful cooperative authentication. Fig.2 demonstrates that: a higher bidding price implies a higher willingness of neighboring nodes to be cooperative and higher probability of successful cooperative authentication. In future, we will design the cooperative authentication protocol to protect location privacy and save resources.

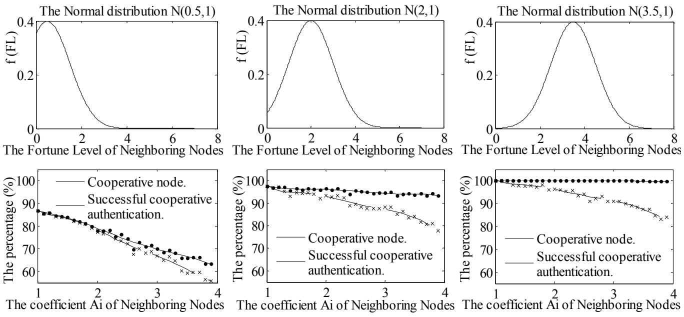

Fig. 1. The percentage of cooperative nodes and successful cooperative authentication varies with the fortune level and asking price coefficient of neighboring nodes.

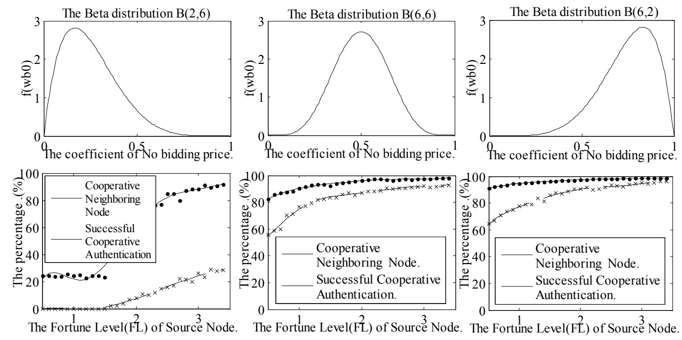

Fig. 2. The percentage of cooperative neighboring nodes and successful cooperative authentication varies with the bidding price coefficient and fortune level of neighboring nodes.

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