Application of Game Theory in the Self-Organizing Network

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Abstract

The dynamic of self-organizing network led to the instability of the network, posing a challenge to the node trust mechanism. In this article, based on the related theory of self-organization of game between nodes in a network of trust management mechanism is improved, through multiple game process analysis, game strategy of nodes is given, puts forward a kind of incentive mechanism, was used to solve the incentive conditions, to improve the usability and effectiveness of the trust management system are proposed.

Keywords

Ad Hoc network, Game Theory, Trust management.

1. Introduction

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your Self-organizing wireless network is a set of two or more device for wireless communication[1] and network connection. Its characteristic is no center node, self-organization; multiple hops routing, network topology dynamically[2]. Self-organized wireless network is formed by self-organization and adaptive means that the networks can dynamically refactoring without the need for any system management[3], so the network topology is dynamically change. The communication between nodes depends on not the infrastructure, but on the collaboration with each other and maintain network inter connection between nodes[4].

At present, there are many researches on trust management mechanism in mobile ad hoc network [5-6], including the study of trust management mechanism[7-8] and process of trust setting up[9].Along with the promotion of game theory, creating the trust incentive management mechanism based on the game[10-11].Article[12] analysis the game theory to enhance the role of joint collaboration. Cooperative forwarding model based on repeated game in Ad hoc networks by Huangpeng Zhang[13].Article[14] study physical layer security collaboration algorithm based on evolutionary game theory.In article[15]game model is proposed for analyses forward grouping of selfishness,

Since each node in the network for its own benefit maximization, they will try their best to save their own resources, and extends his live times to maximization their service. The management of trusting provide a mechanisms to evaluate a nodes' reliability, because the height of the self-organizing network topology dynamics, in previous studies mostly by observation and indirect trust recommendation from neighbor nodes to calculate a node's trust, when most nodes pursuit self-interest maximization， it can affect the operation of trust management system and lead to nodes make the wrong choice. So it needs to study a related incentive mechanism to restrict the selfish behavior of each other and ensure that each node only pains, only gains.

According to the above problem, this paper proposes a game incentive model based on trust mechanism, based on the hypothesis that the nodes are rational, this paper proposes a punishment mechanism to motivate network node based on evolutionary game voluntarily participate in the process of indirect trust recommendation.

2. The establishment of the incentive game

The game's standard formula is expressed as:

$$G = < N, A, \{u_i\} > \forall s_i \in S_i, \forall i \in N$$

Where N is the set of N nodes, s_i is in the policy set of participate node i,{ u_i } is a set of the expected utility function for each participating node i to maximizing. For each participating node, the choice of the utility function is chosen by the strategy set of node i and the neighbor node selected strategy.

Nash equilibrium for each of the participants, is the set of optimal reaction between strategy, for each individual participant, the choice of strategy is selected for all other participants of the optimal response, each participant cannot unilaterally through from the policy set and additional revenues, namely

$$\forall s_i \in S, \forall i \in N, u_i(s_i*, s_{-i}*) \geq u_i(s_i*, s_{-i}*)$$

2.1 Indirect trust game model of information

Mobile ad-hoc network dynamic topology determines the nodes in a network needs to send indirect trust information request and expected to receive positive response to make the decision result more accurate when calculating the evaluation of other nodes' trust.
When node i received the indirect information requests from others, the node will choose the best strategy works for him (response or ignore).The time node i continue to activities and the benefits of indirect trust information from other nodes should be considered. Therefore, the activity time and indirect trust for node information can be consider design flexible punishment mechanisms, so to reduce the selfish node's benefits to contribute cooperation.

In the process of the nodes' trust on network, the node will analysis other points trust according to direct and indirect observations to calculation and analysis for other' trust, indirect trust information from other nodes in the network information recommendation. However, in practice, concerns the limited resources and protection privacy. Its behavior can present a certain rational trend, as refused to respond to the request of the other nodes, while other nodes are available to respond to a request for the issue to the pursuit of self-interest maximization, when a large number of nodes in a selfish behavior orientation, the game will also fall into prisoner's dilemma. So by repeated game many times, the nodes of indirect information acquisition process as a repeated game, establish a game model, to solve the Nash equilibrium.

The dynamic of the mobile network determines the nodes must send indirect information request message to its neighbor nodes and expect neighbor nodes to send positive response, and make the decision result more accurate. So we can expect active time and indirect trust information impact factor to be design the punishment mechanism, to reduce the benefits of selfish nodes to facilitate the cooperation between nodes.

2.2 Single stage game

The modeling process of indirect between nodes information acquisition, first put forward the following hypothesis:

The entire mobile self-organized network consists of N rational node, the node will send its adjacent nodes of one node of indirect trust information request.

The whole system is composed of a series of discrete time slot t time, in each time silt, single stage game happens, each node will send a indirect trust information request message to neighbor nodes at least one time, at the same time slot, network routing status will not change.

The energy consumption of each node sends a message is C, the energy consumption of receives the message is ignored.

The basic type single stage of indirect trust information game as a triad, G=(Q,S,u) , S is the strategies that each node can be choice, S={cooperation(C), not cooperation(N)},u for the node is the utility function, the Q respents the game players, Q={i, j}is the set of two neighbor nodes,i,j.∈N.

The utility function for a node in a slot time as follow:

$$u_i\left(s_i^t,s_j^t\right)=b_i-(cn_i^s+g(a_i))$$

The s_i^t, s_j^t are respectively node i and j at a slot time choice of game strategy, b_i is benefit of node i when neighbors select cooperation strategy, $b_i=\delta e^{\theta}$,δ is the node can get best interest when neighbor cooperative, θ is the impact factor of indirect information node, n_i^s is the number of node i sending message for response the indirect information from other nodes. $g(a_i)$ is the loss of privacy exposing when node chose cooperation strategy, a_i represents the extent of node's effort for forwarding message in grouping.at this time S_i =1,otherwise, the node ignore the message do not anything, S_i =0. When two neighbor nodes for single stage game, the pay-off matrix as shown in table 1;

Table 1 single-stage game payoff matrix

game nodes(i,j)	j cooperation(C)	j non-cooperation(N)
i cooperation(C)	$(b_i-cn_i^s-p,b_j-cn_j^s-g(a_i))$	$(-cn_i^s-g(a_i),b_j)$
i non-cooperation(N)	$(b_i,-cn_i^s-g(a_i))$	$(0,0)$

The table shows, when $b_k>cn_k^s+p$,k∈{i,j},game strategies are not cooperation for each other, the game to achieve Nash equilibrium. All nodes in network are unable to obtain indirect trust information from its neighbor's trust management mechanism of indirect trust there isn't a role, the benefits of all nodes is zero, it formed a typical prisoner's dilemma.

2.3 Repeated game

To break the dilemma, we must introduce reasonable punishment strategy, in the time t, if one node choice non-cooperation, then in the next time t, all its neighbor will not cooperation with it as punishment, in the period of punishment, the node must be choice cooperation unconditional, otherwise the punishment will be indefinite. At the end of the punishment, selfish behavior of nodes will be forgotten.

If s node still exist in the network after one game, so it will continuous game, the before behavior bound be consider in the follow actions.G(m) represent indirect trust repeated game, m is the expected time to node in the network activities on the number of time slots, One node in G (m) the revenue income for each period is the sum of the discounted value then the node i in the game in the expected return can be expressed as

$$U_i=\sum_{t=0}^{m}\lambda^t u_i(s_i^t,s_j^t)$$

σis the discount factor,0≦λ≦1，the longer expected active time of node i, the node will focus on more long-term benefits.,σwill be larger, otherwise,σbe smaller, making $\lambda=\frac{1}{1\text{-m}}$, In general, the relative stability of the network nodes corresponding to σis large, and to build temporary, dynamic and strong network σ smaller.

Assume that the node is equal in each time slot inside of the number of messages sent, if the rational nodes in the current time slot i chose non- cooperation strategy, so its expected return for three rusults.

If node choice do not accept punishment and continute choose non- cooperation

$$U_i^{N(1)}=u_i(N,C)+\lambda\sum_{t=1}^{\text{m}}\lambda^t u_i(N,N)=u_i(N,C)=b_i$$

If i accept punishment, but continue to choose not to cooperation after the punishment.

$$U_i^{N(2)}=u_i(N,C)+\sum_{t=1}^{T}\lambda^t u_i(C,N)+\lambda^{T+1}(u_i(N,C)+\sum_{t=1}^{T}\lambda^t u_i(C,N))+\text{m}$$
$$=\sum_{k=0}^{m/(T+1)}\lambda^{k(T+1)}(u_i(N,C)+\sum_{t=1}^{T}\lambda^t u_i(C,N))$$

If rational node i in the network choose cooperation continues. Its earnings is

$$U_i^C=\sum_{t=0}^{m}\lambda^t u_i(C,C)$$

In order to stimulate the rational nodes choose cooperation strategy, we must insure the benefit when nodes choosing cooperation larger than choosing not cooperation, we can get the following inequality:

$$\sum_{t=0}^{m}\lambda^t u_i(C,C)\ge b_i$$
$$\sum_{t=0}^{m}\lambda^t u_i(C,C)\ge\sum_{k=0}^{m/(T+1)}\lambda^{k(T+1)}(u_i(N,C)+\sum_{t=1}^{T}\lambda^t u_i(C,N))$$

Before node i make a decision, it will compare the benefits of two options, if the above inequality set up, the node will choose cooperation, otherwise will choose not cooperation. So need to choose appropriate parameters to ensure that the above inequality was set up to encourage cooperation between nodes, the solution of inequality is

$$\frac{-u_i(\text{C},UN)}{u_i(UN,C)}=\frac{|u_i(C,UN)|}{u_i(UN,C)}\le\frac{(\lambda-\lambda^{T+1})}{(1-\lambda)}$$

Above equation is the consistency condition to encourage repeated game, ensure that in each single stage game, players choose (cooperation, cooperation) as the perfect Nash equilibrium.

2.4 The process of the repeated game

The benefits of game as shown in table 2

Table 2 repeated game payoff matrix

Game nodes (i,j)	J cooperation(C)	J non-cooperation(N)
I cooperation(C)	U(C,C),U(C,C)	U(C,N),U(N,C)
I non- cooperation(N)	U(N,C),U(C,N)	U(N,N)

$$U(C,C)=U_i^c=\sum_{t=0}^{m}\lambda^t u_i(C,C)=\frac{1-\lambda^m}{1-\lambda}u_i(C,C)$$
$$U(C,N)=\frac{1-\lambda^m}{1-\lambda^{T+1}}\left(u_i(C,N)+\frac{\lambda-\lambda^{T+1}}{1-\lambda}u_i(N,C)\right)$$
$$U(N,C)=U_i^{N(2)}=\frac{1-\lambda^m}{1-\lambda^{T+1}}\left(u_i(N,C)+\frac{\lambda-\lambda^{T+1}}{1-\lambda}u_i(C,N)\right)$$
$$U(N,N)=\sum_{t=0}^{m}\lambda^t u_i(N,N)=0$$

When U(C,N)=0，we can get m=0 or $\frac{-u_i(c,N)}{u_i(N,C)}=\frac{\lambda-\lambda^{T+1}}{(1-\lambda)}$ .If m=0,the node will leave the current game immediately, don’t care about cooperation or non-cooperation selection strategy to seek more interests, the strategy of nodes will not change. If m≠0,from $\frac{-u_i(c,N)}{u_i(N,C)}=\frac{\lambda-\lambda^{T+1}}{(1-\lambda)}$ we can get the second inequality established, the same as of the benefits of cooperation and non-cooperation, so the node has no desire to change the current policy, the system will be in a stable state.

When U(C,N)>0,as $\frac{-u_i(c,N)}{u_i(N,C)} > \frac{\lambda-\lambda^{T+1}}{(1-\lambda)}$,the node will get more benefit than under cooperation, also the current choose is not cooperation, but after several rounds of the game, the node will choose cooperation strategy to get the biggest profit.

When U(C,N)<0,chosing non-cooperation get more interest than choose cooperation, no matter how many nodes choose cooperation ,the final choice of the node will be no cooperation.

Therefore trust management system must meet U (C, N)> 0, to motivate nodes choosing cooperation strategy, so as to ensure the security and stability of the network. The remaining two states should be avoided, otherwise the node will not change the current state or choosing non-cooperation as the steady state after several games, then the communication between nodes will be meaningless.

3. Validation of encourage consistency condition

(1) The effects of selfish node on trust management system.

With the increase of selfish nodes, indirect trust information acquisition rate reduced, lead to the whole trust management mechanism of indirect trust evaluation.

(2)The node parameters (m) of expected active time effect on collaborative.

When other parameters identical, the average number of nodes in the network and nodes indirectly trusted inversely proportional to the rate of access to information, the cause of this phenomenon is increased as the number of nodes in the network, each node will receive the corresponding increased indirect trusted message within a timeslot. The penalties(T)does not change, and therefore reduced the deterrent capacity of the node, causing part of node selecting strategy of non-cooperation, indirect trust information node gets down. In addition, when the networks are the same, increasing penalties, indirectly trusted access to information rates also increased, when l is not large enough, limited effects to punitive measures, because future benefits attractive to node is not strong enough. The node pays more attention to the immediate interests, so the node will select a non-cooperation policy to maximize the current.

4. Conclusion

In this paper, we present an incentive trust model based on games, analysis the influence factors of selfish behaviors of node, by encouraging the promotion of cooperation between nodes, providing better protection for wireless Ad hoc networks of data transmission and packet forwarding..

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