A Frequency Hopping Game Model Based on Situation Awareness for Wireless Sensor Network

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Abstract. Wireless sensor networks (WSNs) are in an open environment which is complex and volatile, and often subject to inadvertent or intentional interference. Sensor networks can use frequency hopping technology to get away from the interference. How accurate and timely frequency hopping is particularly important issue. This paper built a Bayesian frequency hopping game model based on Nash equilibrium game theory, and made the formal definition and quantified description of the impact factors in the game model, and proved Bayesian Nash equilibrium. Through the simulation experiment, this model can improve the accuracy of the frequency hopping, make the time of frequency hopping become more rational, prolong the network lifetime and maintain the overall network connectivity.

Keywords: Wireless sensor networks, frequency hopping, Nash equilibrium game theory

1 Introduction

With the improvement of the security requirements of the WSNs, how to make WSNs avoid frequency band interference or congested attacks is the urgent problem needed to be studied and solved. Frequency hopping communication is a very effective method against frequency band interference and congested attack. We proposed a frequency hopping game mode based the Nash equilibrium game theory. Simulation experiment proved that the model had made the frequency hopping more rational and maintained the overall connectivity of WSNs.

2 Related Work

Based on the different hopping strategy, an analytical expression to compute the metric aggregate multi-hop information efficiency is derived in [1]. Literature [2] used the non-coordinated frequency hopping technology to be against interference. In [3], adaptive rapid channel hopping mechanism was proposed. In [4], EPA-based

Frequency Hopping Metric is proposed and applied to frequency-hopping algorithm. In [5], detection and avoidance mechanism for resisting the interference of the channel was proposed. Literature [6] proposed adaptive slot channel hopping (A-TSCH) which utilized blacklist technology.

3 Frequency Hopping Game Model (FHGM)

FHGM Foundation. The FHGM contains three elements: the players, the strategy space and the utility function.

Definition 1. FHGM is denoted by triples (P, S, U).

Players P: {P_h, P_{nh}} denote the nodes of WSNs. P_h denotes the nodes of proposing frequency hopping; P_{nh} denotes the nodes of not proposing frequency hopping.

Strategy space S: {S_h, S_{nh}} denote the strategy space of nodes. S_h denotes the strategy set of proposing frequency hopping. Each node has two strategies: (Hop, Non-Hop) which also be expressed as (H, NH).

Utility function U: {U_h , U_{nh}} denote the utility function of the game model U_h denotes the payoff after hopping. U_{nh} denotes payoff non-hopping.

The payoff matrix of frequency hopping game model is shown in Table 1 and Table 2. α and β represent the probability of frequency hopping in normal and false.

Table 1. Payoff matrix (Normal)

		Non-Hop	
		H	NH
Hop	H	{αC_h^i, αC_h^j}	{αC_h^i, $(1-\alpha) C_{nh}^j$}
	NH	{$(1-\alpha) C_{nh}^i$, C_h^j}	{$(1-\alpha) C_{nh}^i$, $(1-\alpha) C_{nh}^j$}

Table 2. Payoff matrix (False alarm)

		Non-Hop	
		H	NH
Hop	H	{βC_h^i, βC_h^j}	{βC_h^i, $(1-\beta) C_{nh}^j$}
	NH	{$(1-\beta) C_{nh}^i$, βC_h^j}	{$(1-\beta) C_{nh}^i$, $(1-\beta) C_{nh}^j$}

Theorem 1. There is Nash equilibrium in the frequency hopping game model.

Bayesian Nash equilibrium analysis. The priori probability of false alarm form intrusion detection system in WSNs is assigned.

Let p denotes the probability of false alarm from intrusion detection system. α denotes the probability of Player j selecting hopping strategy in normal condition. β denotes the probability of Player j selecting hopping strategy in false alarm condition. With the above assumption, the static Bayesian hopping game tree is shown in Fig. 1. Here N denotes the sensor nodes.

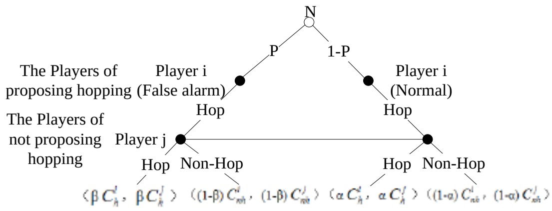

Fig.1. Bayesian hopping game tree

According to the Theorem 1, Nash Equilibrium is existent in the FHGM model. The two players, Player i and Player j, will both play the hopping strategy or not hopping strategy through weigh their payoff using themselves' utility function. Therefore, the final strategy of game in the FHGM model is only two, hopping or not hopping. Thus achieve equilibrium.

4 Simulation and Performance Evaluation

Performance Evaluation. The results of performance evaluation are shown in Fig.2.

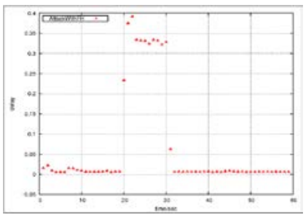

Fig.2 (a) Transmission delay

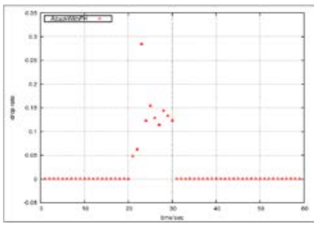

Fig.2 (b) Drop rate

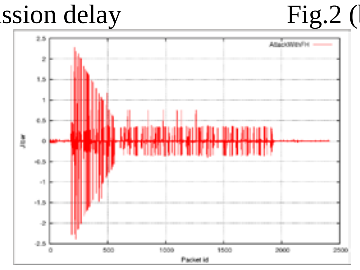

Fig.2 (c) Jitter

Fig.2. Performance Evaluation

Experimental environment is Fedora12 and NS2.34.

According to parameters of the FHGM model related about payoff, taking into account the Bayesian Nash Equilibrium, the simulation and performance evaluation of FHGM model is made in the same attack scene.

The transmission delay of the suffering attack network to resist the attack using the FHGM model is shown in Fig. 2(a). The drop rate of the suffering attack network to resist the attack using the FHGM model is shown in Fig. 2 (b). As shown in Fig. 2 (c), the jitter of the delay is larger when the network is under attack. Jitter back to normal level when using the FHGM model to resist attack. The effectiveness of FHGM model to resist the specified attack is fully proved.

5 Conclusions

This paper proposed a frequency hopping model based on incomplete information game. Firstly, the Frequency Hopping Game Model (FHGM) is modeled. And this paper built a static Bayesian hopping game tree. Existence of Bayesian Nash equilibrium in the FHGM mode is subsequently proved. Finally, the FHGM model is verified through simulation and performance analysis. The FHGM model is universal and adaptability.

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