A Game Theoretical Based Self-Organization Scheduling Mechanism Mesh Networks in UAVs (unmanned aerial vehicles) cooperative multi-task assignment

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Abstract. The UAVs system is vigorously promoted in several fields. The Information Synchronization of Unmanned Aerial Vehicles is an important factor that affects the coordinated control of UAVs. We proposed a game theoretical based self-organization Scheduling mechanism (GTSS). The GTSS is applied to solve unmanned aerial vehicle (UAVs) cooperative multi-task assignment problem. It mainly sets a repeated game model in the communication scheduling among the UAVs.

1. Introduction

UAV (Unmanned Aerial Vehicle) plays a more and more important role in national defense and civil life. The high-altitude long-endurance uninhabited air vehicles (UAV) have a widely application and are being investigated actively. Game theory, with its self-organization dynamics collaboration, flexibility, has demonstrated its incomparable potential and advantages While there to be great space for researching game theory applying in solving multiple UAVs cooperative challenge.

We regard the UAVs scheduling communication as a mobile internet network communication process. The traditional communication mechanism is as showed in figure 1, a UAV is in charge of scheduling of the other UAV, so it to be a Cluster Head UAV of the whole UAVs. It unavoidable taking...
risk for the whole UAVs, when Cluster Head UAV taken down. So we suggest it take the mode of figure 2, adopting mesh form to build the UAVs communication system.

The similar research result is OLSR [5] which is proposed by Yang etc, while the low mobility network nodes bear low delay figured out in document [6]. The SINR routing metric arithmetic is proposed in document [7]. Yet it worked out a routing protocol based on the node’s reputation in document [8], while mainly consider more about path quality when routing in document [9]. We proposed GTSS mechanism: a game theoretical based self-organization dispatching mechanism. GTSS analysis the UAVs communication problem in a ad-hoc network thought.

2. Distributed Coordinate Scheduling

2.1. The Mesh Network Frame Structure
With fixed duration each time frame consists of a control sub-frame and a data sub-frame in TDMA mode. With fixed number the data sub-frame has 256 mini-slots (hereafter slots) which each is an chance to exchange data, being as link bandwidth resources. The control sub-frame consists of scheduling control sub-frame, network control sub-frame. In the mesh network with IEEE802.16 coordinate scheduling mode each node negotiates slots by broadcasting MSH-DSCH messages to its neighbor nodes in a three handshakes procedure.

![Mesh Network Frame Structure](image)

**Figure 3.** The mesh frame structure

2.2. Coordinate Scheduling
It allocates channel resources among nodes by distributed exchanging MSH-DSCH hop-by-hop in a collision-free style
Node A wanting some slots to send its data. Node A broadcasts MSH-DSCH to its neighbors, node B, node C, node D, node E. Node A requests one of its neighbors to reserve some slots for node A. One of node A’s neighbor return MSH-DSCH, based on itself present available slots. Finally, node A sends back MSH-DSCH to confirm the reserved slots.

3. Game Theoretical Based Self-Organization Scheduling Mechanism (GTSS)

We proposed a Game Theoretical Based Self-Organization Scheduling Mechanism (GTSS). We associate the communication between each UAV with the mobile internet network routing issue.

3.1. Self-Organization Scheduling

UAV’s communication buffer queue runs in queuing model being FCFS. We define every UAV businesses arriving with such characteristics:

1) Non-aftereffect characteristic: business arriving with a mutual independence way in overlap time interval.

2) Stability characteristic: during \([t,t+\Delta t]\) minimal \(\Delta t\) , there to be less correlation between \(t\) value and business’s arriving.

3) Generalization characteristic: probability of two or more businesses arriving is infinitesimal, for minimal \(\Delta t\).

We assume time scale span’ mean value of business arriving the UAV node’s queue to be a constant. Above all precondition, random process can be viewed as a Poisson process with \(\lambda\) density.

Every \(T\), GRSD making statistics about the arriving businesses:

\[
r(k) = (1 - d_r) \times \frac{Num}{T} + d_r \times r(k - 1)
\]

Where, \(d_r = e^{-\mu T}\), \(\mu\) is control parameter. \(k\) means statistics frequency; Num means arrival business numbers.

GTSS predicts about the probability of some kind of business arriving in next period:

\[
P_{\text{Num}} = \frac{r(k)^{\text{Num}} e^{-r(k)}}{\text{Num}!}
\]

Weighted smoothing algorithm preventing communication data bursting: (Based on historical experience where \(\zeta\) is set 0.3.)

\[
P_{\text{Num}} \times (i) = \zeta \times P_{\text{Num}} \times (i - 1) + (1 - \zeta) \times P_{\text{Num}} \times (i)
\]
Under the coordinate scheduling mode, every UAN node chooses its neighbor node with more available slots in the next hop. Based on the research result of document [4], we define the UAV node’s vacant degree to evaluate some UAV node’s available slots number:

\[ SC_i = \frac{r(k)}{RcvR_i^2} \]  

Where \( RcvR_i \) means one UAV node’s business arriving speed. The sampling period equal the sample statistics before (simulation experiment sets it 6s); \( r(k) \) means one UAV node’s business sending speed.

If \( RcvR_i \) is higher order than \( r(k) \) [4]. The UAV node’s with a large \( SC_i \) will have more available slots.

Every UAV node broadcasts its mainstream type of arriving business probability, vacant degree, identity, to its neighbor. UAV node to choose its neighbor nodes \{nRTer1, nRTer2, ..., nRTerq\} with minimum probability nRTer, sending MSH-DCSH to node(from{\{nRTer1, nRTer2, ..., nRTerq\}) with a biggest \( SC_i \). Receiving the MSH-DCSH, the UAV node will accomplish the three handshakes procedure.

UAV Node makes the next hop selection by exchanging QoS information, showed as figure 3.

![UAV node Select next hop node](image)

**Figure 5.** the next UAV node hop selection strategy

### 3.2. Cooperation-Oriented Repeated Game Model

We use document [12]'s repeated game model for reference. First one UAV node node send MSH-DCSH to its neighbor node. If its neighbor responds to the request, then sending back MSH-DCSH. It would unavoidable consumes slots resources. It would consume more slots to relay the other node’s data instead of transmitting own data. We define that the neighbor node deciding whether respond request to be a game action.: a cooperation-oriented repeated game model \( G(n,S,U) \).

1) \( N (i=1, 2, ..., n) \) nodes for each single game.

2) For every gamer UAV node, there existing two strategies, \( S_i = \{ZF, IG\} \); \( S_i = s_i(s_1, s_2, ..., s_n) \). Where the ZF meaning respondence probability \( s_{ZF} \), the IG meaning denying probability \( 1-s_{ZF} \).

3) For each strategy, the benefit \( u_i, U_i = u_i(u_1, u_2, ..., u_n) \) for each game.

We define \( PR_i \) to node’s competitiveness:

\[ PR_i = \frac{S_{db} + S_{dh}}{fT_{dur}} \]  

Where \( fT_{dur} \) represents the duration of the current frame.
Where the $S_{dn}$ represents answer slots numbers in $F_{dur}$ value the probability to respond quest. $fF_{dur}$ means the mean maximum continuous time slot length. The $S_{dr}$ means rejection slots numbers in $F_{dur}$ value the probability to refuse request.

UAV node with higher $PR_i$ has more slots to transmit its own data. **GTSS** We proposed a gaming rule increasing $PR_i$ encouraging more UAV node respond request actively:

$$u_{ci} = \left[ b_{PR} \times 256 \right]$$

(6)

Where, $u_i$ means node’s benefit responding the request. The $b_{PR_i}$ means reward income. Slot in total number is 256.

We adjust exp value to punish refusing cooperation node.

$$u_{rfi} = \alpha w\times \left\lfloor \exp^* \right\rfloor$$

(7)

Where, the $\left\lfloor \exp^* \right\rfloor$ means jitter of exp. The $\alpha w$ means jitter exp value. $u_{rfi}$ means benefit.

$$u_i = (u_{ci} - u_{ufi}) \times s_{ZF} - u_{rfi} \times (1 - s_{ZF})$$

(8)

Where $u_i$ means node’s exception profit, $u_{ufi}$ means node’s communication QoS consuming:

$$s_i(t + 1) = s_i(t) + \theta_i \times s_i(t) \times \frac{\partial u_i(s)}{\partial s_i(t)}$$

(9)

Where $s_i(t)$means presents node $i$’s strategy for each game. The $\theta_i$ means speed’s convergence parameter. It would automatic iterate node’s game strategy $s_i(t)$ based on historical information.

$$U_i(s_1^*, s_2^*, ..., s_i^*)$$

(10)

4. Conclusion

We abstract UAV node to the mobile network node. We proposed a repeated game research model **GTSS**. It improves the UAV node routing communication efficiency.

5. References

[1] I.F.Akyildiz.X.Wang, and W. Wang.Wireless mesh networks: A survey [J]. Computer Networks, Mar. 2005.47:445-487.

[2] Jianhua He.Kun Yang and Ken Guild.Application of IEEE802.16 mesh networks as the backhaul of multihop cellular networks,[J]IEEE Communications Magazine,2007.45(9):82-91.

[3] I F. Akyild. X.Wang and W. Wang.A Survey on Wireless Mesh Networks [J]. Communication Magazine ,Sept,2005.43:23-30.

[4] Sheng Cheng, Lu Yifei. Comprehensive assessment based routing protocol in wireless mesh network,[J]. Chinese Journal of Computers, 2010,33(12):2300-2311.

[5] Jacquet P, Muhlethaler P, Clausen T et al. Optimized link state routing protocol for ad hoc networks//Proceedings of the IEEE International Multi Topic Conference. Pakistan, 2001:62-68.

[6] Yang Yaling,Wang Jun. Design guidelines for routing metrics in multihop wireless networks//Proceedings of the 27th IEEE Communication Society Conference on Computer Communications. Phoenix, 2008:2288-2296.

[7] Elshaikh M, Kamel N, Awang A. High throughput routing algorithm metric for olsr routing protocol in wireless mesh networks//Proceedings of the 5th International Colloquium on Signal Processing&Its Applications. Kuala Lumpur, 2009:445-448.

[8] Ding Qing, Jiang Ming, Li xi, Zhou Xuehai. RePro:A reputation-baised proactive routing protocol for the wireless mesh backbone//Proceedings of the 5th International Joint Conference on INC, IMS and IDC. Seoul, 2009:516-521.

[9] De C Paschoalino R, Madeira E R M. Asclable link quality routing protocol for multi-radio
wireless mesh networks//Proceedings of the 16th International Conference on Communications and Networks, Honolulu, HI,2007:1053-1058.

[10] QoS Technology Introduction. [EB/OL]. (2008-05)[2013]:http://www.h3c.com.cn/Products___Technology/Technology/QoS/Other_technology/Technology_recommend/200805/605881_30003_0.htm.

[11] Kang Xiaojun. Coordinate oriented scheduling distributed with IEEE802.16 in Mesh network[D],hubei province wuhan , Huazhong University of Science and Technology, Communication and Information System,2007

[12] Fen Chenwei. Network routing and scheduling research in WiMAX mesh network [J] computer engineering, 2011, 37(4):93-95.

[13] CAO Min, MA Wen-chao, ZHANG Qian, et al.Modeling and performance analysis of the distributed scheduler inIEEE802.16 Mesh mode. Proceeding of the 6th ACM International Symposium on Mobile ad Hoc Networking and Computing, MobiHoc’05. NY, USA; ACM Press, 2005:78-89.

[14] You Lei, Wang Yifan, Zhang Yong, Mao Anfeng, Cai Jie, Song Junde. Functional model and simulation NS2 based with IEEE802.16 Mesh network [J], 2008 8(25):2505-2508.

[15] Cong Li. Wireless network resource dispatching research based on game. [D] Xi An. Xidian University2011.