

論文 / 著書情報  
Article / Book Information

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種別(和文)	論文要旨
Type(English)	Summary

## 論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	情報工学 知能情報	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(Philosophy)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words )

In this thesis, we consider a multi-agent resilient consensus problem, where some of the nodes are adversarial and transmit false data to the normal agents. As the applications of multi-agent systems widely used in the areas of wireless sensor networks, Internet of Things and distributed computing, the resiliency of the multi-agent systems needs to be improved. The goal of the resilient consensus problem is that normal agents should reach a common state value regardless of the misbehaviors taken by the adversary agents. Generally, there are two main approaches in this area: (i) mean subsequence reduced (MSR) algorithms, and (ii) detection-based algorithms. We develop several algorithms tackling this problem under different threat models. All of our approaches require the nodes to have the abilities to communicate with their multi-hop neighbors. Such multi-hop communication techniques are widely used in the wireless communication field as well as the computer science field. Yet, only a few works studied the application of the multi-hop techniques in the resilient consensus problem. One remarkable advantage of applying such techniques is that the requirement on the network connectivity can be reduced compared to the conventional one-hop algorithms.

In the literature, the adversarial agents are categorized into basically two types: Malicious agents and Byzantine agents. These agents are capable to manipulate their data arbitrarily. Malicious agents are limited as they must broadcast the same messages to all of their neighbors, while Byzantine agents can send individual messages to different neighbors.

First, we develop an MSR-based algorithm with multi-hop communication. We analyze the performance of the proposed algorithm under different threat models (i.e., malicious or Byzantine model). Moreover, we generalize the notion of graph robustness to the multi-hop setting, which is the necessary graph structure for the proposed algorithm to achieve resilient consensus. Taking account of time delays which are critical in the multi-hop communication environment, we also provide the analysis of the proposed algorithm when the agents update asynchronously and the communication is subject to time delays. This extension has broadened the scope of our algorithms. We find tight necessary and sufficient graph conditions for the proposed algorithm to guarantee resilient consensus under the malicious model as well as the Byzantine model. Moreover, our algorithm is of less computational complexity than the existing algorithm solving the asynchronous Byzantine consensus problem. So far, we only consider the real-valued consensus where agents take real values. Note that the integer-valued consensus is also widely used in the sensor networks especially when the sensors only have limited registers to store the integer values. Another advantage of taking integer values is that the communication resources can be saved compared to the real-valued case. Such integer-valued consensus is also considered for our algorithms.

Second, we develop an event-triggered algorithm based on the abovementioned algorithm. The event-triggered scheme is well known in the systems control area. Notably, it can reduce the communication loads while guaranteeing the given network control system to be stable. By introducing the event-triggered scheme to our algorithm, the transmissions between agents are heavily reduced compared to the non-event-triggered algorithms. We propose two relay

models for the event-triggered scheme under the multi-hop communication: the periodic relay model and the package relay model. We also highlight that through multi-hop communication, the necessary network connectivity for achieving resilient consensus can be reduced especially in comparison with the conventional one-hop communication case.

Lastly, we develop a detection-based algorithm solving the resilient consensus problem under the malicious attacks, where the two-hop communication is utilized. It is shown that the detection scheme becomes effective by requiring certain connectivity properties in the network so that the non-adversarial nodes can share enough information about their neighbors. In the second detection scheme, majority voting is used for normal agents to determine the identities of their neighbors (normal or adversarial). The detection function is realized by the verification of two consecutive information sets sent by the same neighbor. The proposed algorithm is more distributed and requires no additional authorized or centralized verification procedures compared to the existing detection method. Another important aspect of the proposed detection approach is that this method can achieve resilient consensus even when more than half of the agents in the network are adversarial. This is a case out of the capabilities of the MSR type of algorithms.

At the end of each chapter, numerical examples are provided to demonstrate the efficiency of the proposed methods. In the conclusion part, we provide several possible directions for future research.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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