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Target-synchronization of the distributed wireless sensor networks under the same sleeping–awaking method

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Abstract

Based on the conflict and crosstalk avoidance mechanism (CCAM), we propose a sleeping–awaking method for wireless sensor networks (WSNs) in which the maximal degree node (MDN) and all its neighbors run sleep or wake simultaneously while other nodes run the CCAM. This method is said to be the same sleeping–awaking method (SSAM). The SSAM is motivated by the congestion and collision problems of cliques, MDN and its neighbor set in the communicating graph of the WSN. In this communication way, the related protocol about the SSAM is provided accordingly. Under the designed protocol, we get a Markovian switching WSN with both white noise disturbance and multiple time-varying delays. Based on the theory of exponential stability in pth moment, we show that the protocol ensures the WSNs to keep in synchronization with the target function. A numerical example shows that the WSN can keep its target-synchronization even with large time delays.

1. Introduction

In recent years, coordinated problems of network have attracted increasing attention of many researchers due to its wide applications, such as formation control [1], flocking [2], distributed sensor networks [3], etc.

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While the synchronization of the distributed network is one kind of the coordinated behaviors in networks and refers to the fact that all nodes of the network agree upon a common requirement value by the local communication. In many applications, synchronization is influenced by some uncertain factors, such as time-varying delays and noise disturbance. Recently, many researchers focus on the field of synchronization problems under time delay and noise surroundings, and there are many related literatures, such as communication in a directed way [4] and in an undirected way [5–7].

To demonstrate more realistically, there are some scholars to describe the networks with Markovian switching topologies or multiple time-varying delays [8–12].

Notice that all the listed literatures discussing the synchronization problems are under the fixed time-delay functions. In fact, in the different communication topology, time-delay functions may be different. Under such surroundings, the system may become unstable. Hence each node of the system cannot keep in synchronization with the target. So to study the related synchronization problem has the potential significance. Furthermore, the communication way which can save the energy of the maximal degree node (MDN) in the communicating graph has not attracted much attention.

Motivated by the above statements, the present work is to propose the basic theoretical analysis of target-synchronization problems for wireless sensor networks (WSNs) under the multiple time-varying delays and the noise surroundings. For saving the energy of the MDN, we propose a kind of sleeping–awaking method for the WSNs.

Different from the literatures [10–12], in this paper, the time-varying delay functions may differ from one topology to another. To demonstrate the Markovian switching topology more realistically, the switching topology presented in this paper is based on the conflict and crosstalk avoidance mechanism (CCAM) [13] which refers to the method that every sensor tries to avoid the conflict and crosstalk by taking the way of sleeping or awaking appropriately. Namely, if a sensor finds some of its neighborhood sensors exchanging information, then the sensor falls in sleeping; otherwise, the sensor falls awaking.

When the WSN runs the CCAM, the MDN has the most chance to communicate with other nodes and becomes invalid due to the frequency of communication. So for the communication graph of networks, the MDN is the most important member, because the connection of the network depends on the validity of the MDN largely. In general, the MDN exists in every WSN. In fact, according to the theory of random graph [14], for given n nodes, if every two of them connect with a constant probability p_0 $(0<p_0\leq 1)$, then there exists a MDN almost surely. So it will help for prolonging lifetime of the WSNs to reduce the communication frequency of the MDN.

To do so, we propose the same sleeping–awaking method (SSAM) for WSNs which can be expressed as follows. In a connected communication graph, every sensor makes sure its position and its neighbors set firstly and keeps a neighbor table supposed fixed next. According to the CCAM, the MDN and all its neighbors sleep or wake simultaneously, while each of the other nodes communicates with one of its neighbor randomly according to the related neighbor table. Hence the SSAM can reduce the communication frequency for the WSNs.

Moreover, to accelerate the synchronization of the state of the nodes for the WSNs, we make use of the theory of the pth moment exponential stability [15] which is widely used for the system stability analysis [16–18], where $p\geq 2$, $p\in Z$. Specially, when $p=2$, the pth moment exponential stability is the mean square exponential stability which is frequently used in different fields, such as [19–24].