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An energy-efficient SDN based sleep scheduling algorithm for WSNs

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ABSTRACT

Energy efficiency in Wireless Sensor Networks (WSNs) has always been a hot issue and has been studied for many years. Sleep Scheduling (SS) mechanism is an efficient method to manage energy of each node and is capable to prolong the lifetime of the entire network. In this paper a Software-defined Network (SDN) based Sleep Scheduling algorithm SDN-ECCKN is proposed to manage the energy of the network. EC-CKN is adopted as the fundamental algorithm when implementing our algorithm. In the proposed SDN-ECCKN algorithm, every computation is completed in the controller rather than the sensors themselves and there is no broadcasting between each two nodes, which are the main features of the traditional EC-CKN technique. The results of our SDN-ECCKN show its advantages in energy management, such as network lifetime, the number of live nodes and the number of solo nodes in the network.

1. Introduction

Wireless Sensor Networks (WSNs) have been widely adopted to collect, process, transmit and receive on-the-spot data instead of human labors, especially in hush environment. Normally, nodes in a WSN are very hard or even impossible to be recharged or replaced. Moreover, for a sensor node, usually limited energy is supplied with batteries. These challenges need high level of autonomy and self-organization of each sensor node in the network (Baccour et al., 2012). Hence, each node must be capable to acquire some other nodes' information deployed in the same region of interest. By processing these information, nodes are able to automatically make decisions and change their sleep status. In recent research, many literatures about Energy balancing techniques for WSNs have been discussed (Zhangbing et al., 2014a; Kai et al., 2012) and the fusion of WSNs and other network techniques is increasingly studied (Zhangbing et al., 2014b; Luís et al., 2014; Joel and Paulo, 2010).

Sleep Scheduling mechanism is currently an efficient method to manage the entire network and make the energy management more efficient (Zhu et al., 2014). To save the energy, the key point of Sleep Scheduling mechanism is to automatically and deliberately shut down subsets of nodes while remain other nodes alive in each given time interval. By applying SS mechanism, each node in the network has opportunity to "sleep" instead of "being awake" all the time, while the connectivity of the entire network is not affected during the lifetime of the network (Zhu et al., 2012). However, the discovery of other nodes is implemented by broadcasting the relevant information from each node, which is called beacon data, to all its neighbors, and all neighbors must then broadcast their information back in every time interval, which cost a lot of communication energy. Furthermore, in WSNs, the energy consumption of sending a single bit of data is at least 480 times as much as performing one addition instruction by CPU (Kimura and Latifi, 2005), which means if the total transmission times of a network during its lifetime is reduced by one, 480 addition instructions can be completed. How to reduce the transmission times of a network while keeping the network connectivity becomes a difficulty in the study of energy management in WSNs.

Motivated by the challenges above, in this paper we propose a Software-Defined Network (SDN) based SS algorithm to reduce the total transmission time of a network during its lifetime while maintaining the network connectivity, hence prolong the network lifetime. EC-CKN algorithm is regarded as the prototype of our algorithm since the residual energy is the criterion considered by each node when judging its status in the current interval. The rest of this paper is organized as follows. In Section 2, the related work including EC-CKN algorithm and SDN technology will be briefly

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introduced. Then in Section 3, the proposed SDN based SS will be presented in detail. The results and analysis are shown in Section 4. Finally, we conclude the paper in Section 5.

2. Related work

It is important to prolong the lifetime of the entire network and manage the energy of the network more efficient. Multiple Sleep scheduling algorithms have been proposed by researchers in recent study to balance the energy consumption and prolong the lifetime of the network.

2.1. Sleep scheduling mechanisms

Yaxiong and Jie (2010) proposed a generic duty-cycling scheduling method based on stochastic theory; Chih-fan and Mingyan (2004) presented specific scheduling algorithms within each approach and analyzed their coverage and duty cycle properties. In Nath and Gibbons (2007) and Zhuxiu et al. (2011), two famous Sleep Scheduling algorithms were designed, which are called Connected K-Neighborhood (CKN) algorithm and an improved CKN: Energy Consumed uniformly-Connected K-Neighborhood (EC-CKN) algorithm, respectively. Both Sleep Scheduling algorithms can efficiently close the relatively low-power nodes while maintaining both network connectivity and reasonable routing latency. In CKN algorithm, each node is K-connected which means that for any node in the network, if it has more than K alive neighbors, then it decides to close itself; and if its number of neighbors is less than K, the node remains awake. CKN algorithm is a distributed SS algorithm which can effectively prolong the lifetime of each node and the entire network. However, the energy in CKN algorithm cannot guarantee to be uniformly consumed (Zhuxiu et al., 2011). Different from CKN algorithm, EC-CKN algorithm considered the remaining energy of each node on the basis of CKN, which can balance the energy consumption of the entire network and simultaneously keep the network K-connected.

Detailed procedure of EC-CKN is shown in Fig. 1 (Zhuxiu et al., 2011). We decide to choose EC-CKN as the fundamental algorithm of our SDN based algorithm because its judgement criterion is relevant to the nodes' residual energy, which can directly reflect the energy consumption of the entire network. In our SDN-ECCKN algorithm, SDN based architecture is adopted instead of traditional WSN to remove the broadcasting procedures and hence reduce the total transmission times. In Table 1, from step 2 to step 3, each node broadcasts twice to obtain its 1-hop and 2-hop nodes' status, which are used for the later judgement of its own status. These two broadcasting procedures for each node in each interval cost a lot of communication energy.

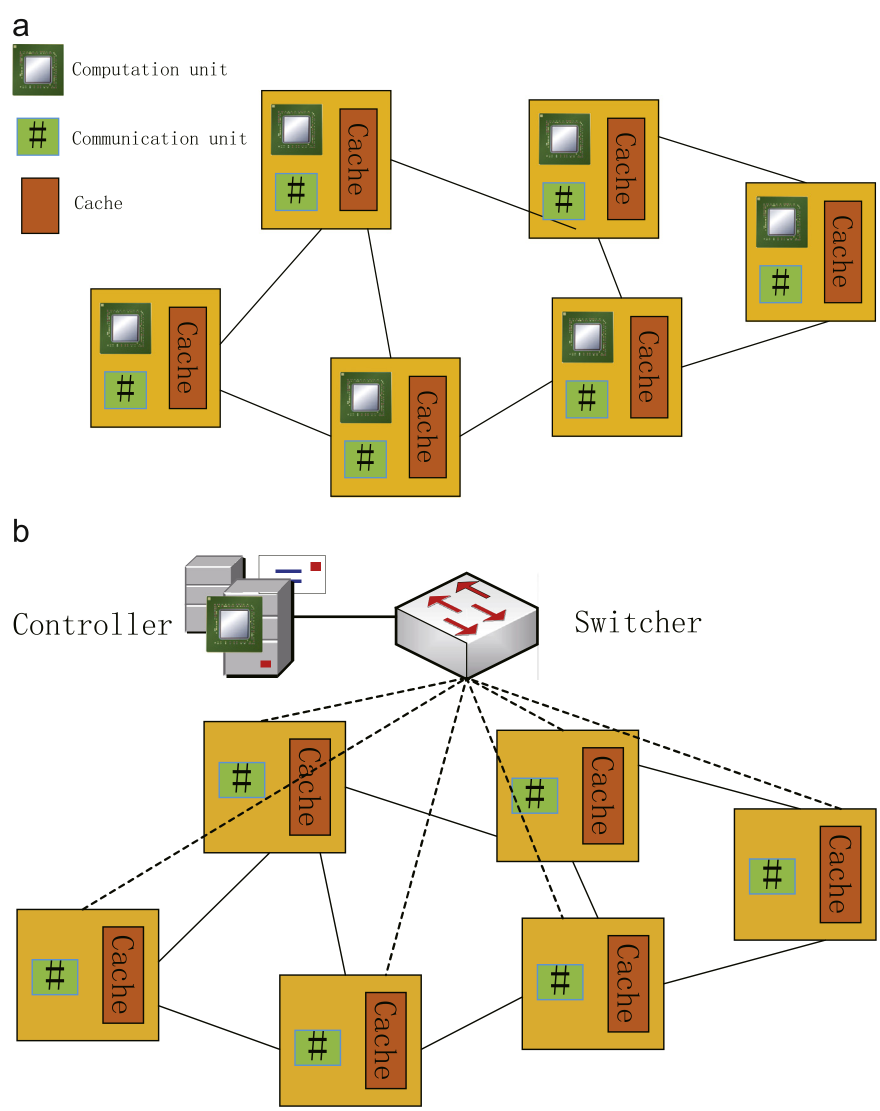

Fig. 1. Differences between traditional and SDN architecture. (a) Traditional WSN architecture. (b) SDN architecture.