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Minimizing Energy Consumption with New Coloring Scheduling in Wireless Sensor Networks

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Abstract

We propose a novel approach to design a coloring Wakeup Schedule (CWS) for the radio of the nodes in wireless sensor networks, in order to reduce the end-to-end latency with energy efficient data transmission. In this letter, a novel Coloring Wake-up Schedule (CWS) is presented for the radio of the nodes in the wireless sensor networks. The aim of this approach is reducing the end-to-end latency and energy consumption in the data transmission. In the CWS, a particular color is assigned to each cell of the nodes. By this, the packet of the node can transfer along the shortest path to the sink node; the nodes find their neighbour according to their transmission range and choose the neighbour that is near than any nodes to the sink node. Therefore the mentioned-schedule decreases the useless activities of the nodes which caused to save the energy. Also, a specific grid is defined for the situation of the CWS nodes to improve the routing. The various simulations prove the usefulness of the proposed CWS compared to the other schedules in wireless sensor networks.

Keywords: Coloring, Wake-up Schedule, energy consumption

Introduction

In a wireless sensor networks, lowering energy consumption is a critical issue in the lifetime of the network sensors. Energy conservation algorithms can be implemented at the lower layers of the protocol stack to enhance the longevity of the nodes [2]. Scheduling algorithm is required for wakening the sleeping nodes in the presence of the pending transmission. A wake-up schedule is defined to maintain network connectivity while decreasing the idle state energy consumption. In traditional wake-up schedules, like SMAC [1], all nodes can choose their own listen/sleep schedules and neighbor nodes synchronize together. However, it is prone to height overhead and suffers from non-optimized contention period, which consumes more energy and causes more loss time [4]. The AWS [2] is another protocol which uses the coloring graph. In this algorithm, each node has a chart which includes color and details of the neighbours. The main problem of the algorithm is time-waste when a specific node tries to discover its neighbours with their color.

In this Letter, a coloring wake-up scheduling (CWS) method for WSNs is introduced, which uses a grid divided to a number of coloring cells where the nodes is distributed on that grid. For any node, a wake-up schedule is kept in each node according to their coloring. Be aware of the situation of the each node to the others, causes decreasing the latency and energy consumption in data transmission for large-scale networks.

Proposed Coloring wake-up scheduling

In this session a coloring pattern for a wake-up schedule is introduced where a cell of the grid is selected and colored based on graph coloring algorithm. A graph in which every vertex has been assigned a color according to a proper coloring that is called a *k*-chromatic coloring graph [3]. An example of the coloring of the grid is shown in Fig. 1 for *k*=4.

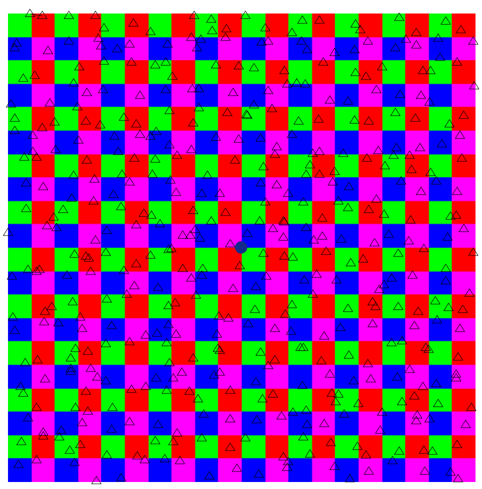

Fig. 1 Four-coloring graph for a wake-up pattern

According to this, a grid with specific dimensions is selected and divided into different cells in the same size which colored them based on the coloring graph.

Furthermore, the nodes are distributed in the grid. There is a possibility to place more than one node in a single cell. The nodes are informed of the position of the other nodes with regard to their own geographical positioning. With informed of the cell coloring, each node can predict the own wake-up pattern and the other nodes wake-up pattern. A node finds its neighbour in a transmission range and selects the neighbour that nearer to the sink node. So the data send in the shortest path to the sink node. The nodes of a cell spend some time in sleep mode and some time in wake-up mode.
In this grid, the sink-tree is used. Therefore, in all of the routes ending to the sink node, it can inhibit the creation of unnecessary and extra routes. As illustrated in Fig. 2, the specified route for a certain node to the sink node is drawn.

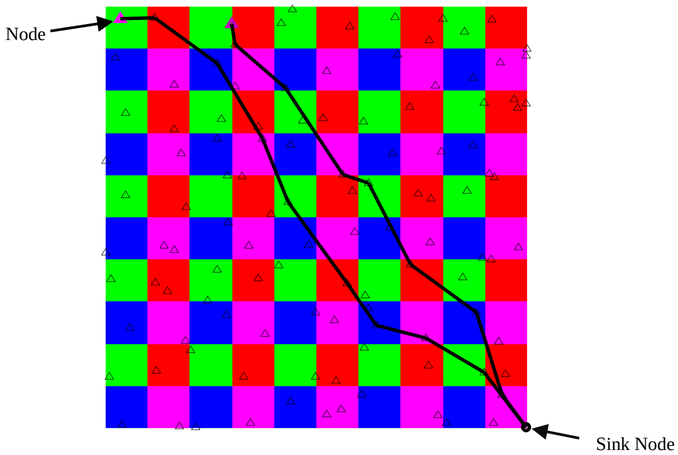

Fig. 2 Routing for a certain node in the four-coloring grid

Fig. 3 shows the sleep schedule for the radio of the nodes. A packet will be transmitted from a node of the cell-colored to a neighbor that belongs to another cell-colored by checking the active states of the neighbors at the time of transmission. In data transmission, node that belongs to C_i takes place to the active neighbour that belongs to C_j where the j=i+1.

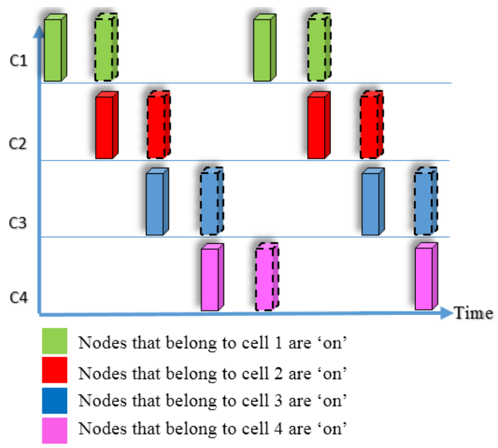

Fig. 3 Wake-up pattern when there is data transmission

In the AWS pattern, the value of the latency, L, is calculated as follow [2]:

$$L = [(T_s / G) + T_a] * (N + N_{ex}) \qquad (1)$$

Where G, N, N_{ex} are respectively the number of colors , the number of hops and the number of excess hops related to the coloring pattern. Also, T_s and T_a are sleeping time and active time for the nodes. The equation (1) can be used for the proposed CWS pattern too. The difference is that the latency of the CWS becomes less because the number of the nodes in a certain cell of the CWS are at least one. Also, knowing about the place of the node can will decrease the amount of N_{ex}.

Simulation Results and analysis

We have provided and analysed the results from the simulations of the new suggested wake-up pattern using MATLAB software. For better comparison, beside the 4-coloring pattern, the 2-coloring is also considered for simulating along the AWS [2], and the SMAC [1] patterns. Two main measurement criteria are end-to-end delay and the consumed energy in the simulations. In the implemented algorithm, the nodes are distributed accidentally throughout the grid and the parameters of the nodes are considered as shown in the Table 1.

Table 1: Simulation parameters

Parameters	Values
Transmitting power	14 mW
Receiving power	13 mW
Power consumption in idle mode	12 mW
Power consumption in sleep mode	0.016 mW
T_{active}	300 ms
T_{sleep}	4.7 s
Transmission range (radio)	125 meter

As shown in Fig. 4, the Latency has been measured for all the mentioned patterns by varying the hop length between the source to destination and considering its effect on end-to end latency. In general, the latency increases for all the patterns as the hop length enhances. The proposed 2 and 4 coloring patterns have a better performance against the others because in the proposed patterns, the nodes select their neighbours based on the cell coloring schedule and awareness of the geographical positioning of them.

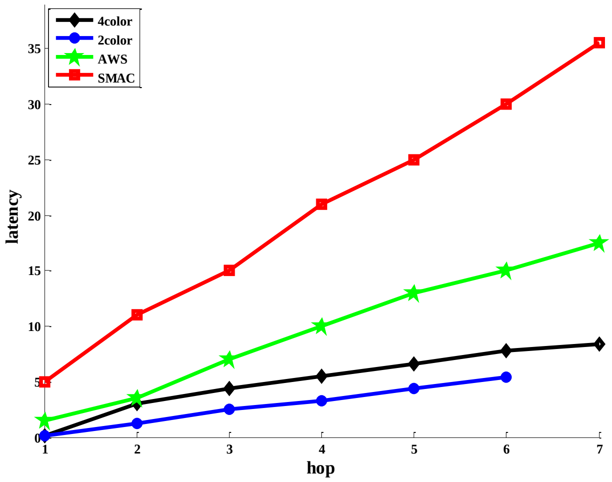

Fig.4 Latency versus the number of hops

As expected, the two patterns, SMAC and AWS, have more latency for the transmission packets when the hop length increases. In the SMAC, waiting time at every hop causes more latency for the transmission packets. However in the AWS, the latency becomes less due to reduction of the waiting time by dynamically selecting the forwarding node which it also aware the neighbour's color.

The total energy consumption against the number of the nodes has been illustrated for all mentioned patterns in Fig. 5. In this figure, the average energy consumption of the 4-coloring proposed pattern is less because the nodes are allowed to sleep more. Also, they traverse the shortest path in the grid by using the sink-tree.

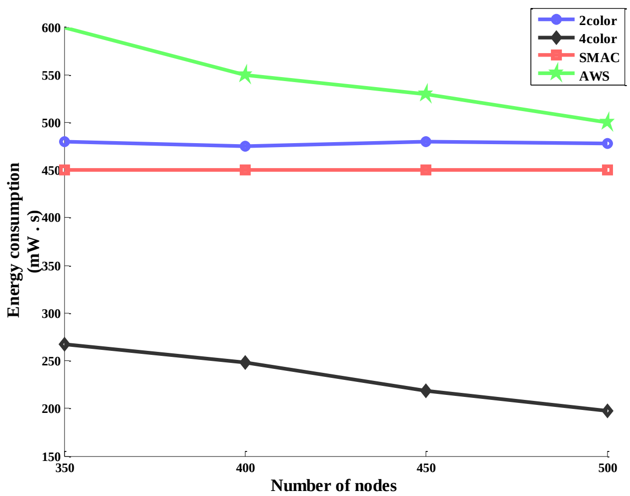

Fig. 5 Energy consumption versus number of nodes

Conclusion

A novel Coloring Wake-up Schedule has been introduced for the radio of the nodes in a wireless sensor network. A grid was defined with a number of cells, which a particular color was assigned to each cell of the nodes. In addition, the routing between the nodes to the sink is improved because the situation of the each nodes is approximately distinguished by the other neighbours. Behavioural simulations show that the proposed CWS has better latency and lower energy consumption compared to the traditional similar patterns. Therefore it is suitable to apply the proposed pattern in the wireless sensor networks.

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