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Energy collection perception routing algorithm in wireless sensor networks

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Abstract. The lifetime of sensor networks is affected seriously by the depletion rate of power of sensor node. At present, many researchers focus on the Energy-aware routing to preserve the energy capacity of battery so as to prolong the lifetime of networks. The Paper proposes a multipath routing protocol with energy distance perception. According to the residual energy on each different path, the protocol sends the date on each path through probability select after the establishment of routing, and achieves the energy load balancing of the whole network, which can avoid premature death of partial nodes. The energy distance prediction function is added in the process of sending data, and the intermediate node can inform the possible link failure in the source node link in advance, so that the source node can be switched to the path without link failures in advance for data transmission. The simulation results show that the protocol has a certain improvement in the average packet delivery fraction, data transmission delay and energy efficiency.

Key words. Wireless Sensor Networks, Energy perception, Routing protocol, Lifetime, Electric quantity.

1. Introduction

Wireless Sensor Networks are a hot research field at present. The information about monitoring object in the coverage area can be real time monitored, perceived and collected through the sensor node in the Wireless Sensor Networks, and the data can be transmitted to sink-node by multi-hop self-organization. The wireless sensor nodes are usually powered by a limited capacity battery, and the limited energy is the prominent feature of the Wireless Sensor Networks. The optimization of the energy consumption of sensor nodes and the prolongation of the network lifetime are the key links that the wireless sensor network can be put into practical operation. As one of the key technologies in Wireless Sensor Networks, the routing protocol is responsible for transmitting the date collected by sensor nodes to the sink-node hop-by-hop, of which the performance play a key role. It is a very important method to design energy efficient routing protocol for prolonging network lifetime as communication

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energy consumption accounts for the vast majority of the total energy consumption of sensor nodes. Focused on the research of energy efficient routing protocol for Wireless Sensor Networks, the Paper designs and achieves multiple energy efficient routing protocols by multiple methods such as energy distance prediction, multipath mechanism, ant colony algorithm and event clustering mechanism from effectiveness and equilibrium of node energy consumption.

Supervisor. WSNs (Wireless Sensor Networks) consist of small, finite-energy wireless sensor nodes with wireless communication function. The node that is responsible for detecting the abnormal events in WSNs such as forest fire, or collecting data in environment [1], such as temperature and humidity, and transmitting these information (abnormal events and environmental data) to special nodes is called as Sink node. Then, Sink nodes transmit this information to the Supervisor through Internet. As shown in Fig. 1, the node e finds an exception and transmits such condition through multi-hop path ($e \to d \to c \to b \to a$) to the Sink node that transmits the information to the Supervisor by virtue of Internet.

In general, it is difficult to supply the sensor nodes in time once the energy is exhausted as sensor nodes are often in the field. When the power of the sensor nodes is exhausted, information cannot be transmitted and collected, arising from many problems such as Coverage hole resulting in failure communication [2-3]. For this purpose, the researchers are devoted to the study of how to preserve the energy of sensor nodes, that is, to effectively and reasonably use the energy of the nodes. For example, duty cycle scheduling is designed for nodes in order to make these nodes go into a dormant state periodically so as to preserve the node energy. Surely, the normal operation of nodes in WSNs cannot be affected in the process of preserving the node energy [4-5]. The energy consumption of sensor nodes is balanced by energy-efficient routing algorithm in literature [6-9].

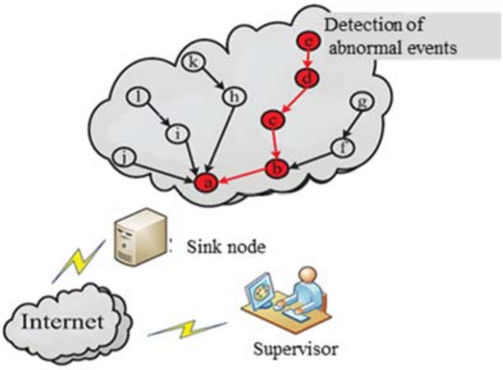

Fig. 1. Working diagram of sink node in WSNs

In addition to this, the node energy can be conserved by adjusting the location of sensor nodes [10]. Although this kind of scheme can prolong the lifetime of WSNs, it also consumes the extra energy of sensor nodes. For this purpose, the literature [11-15] proposes a compromise solution: to adjust the location of Sink node instead of sensor node, as shown in Fig.2.

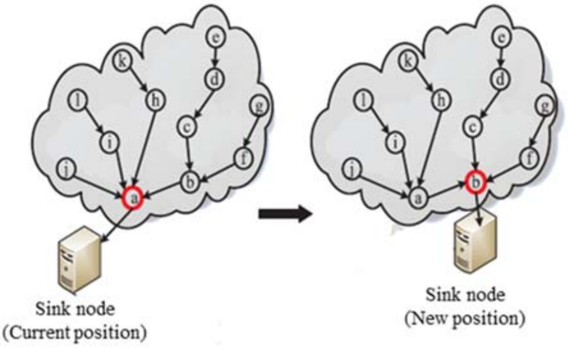

Fig. 2. Moving schematic diagram of sink node

As shown in Fig.2, the energy is depleted immediately after a few messages are forwarded by the nearest node a from the Sink node. Once the energy is depleted, Sink node will fail to receive new messages and the entire WSN stops working. The area where the node a is located is called hotspot. The load of node a can be reduced by adjusting the location of Sink node before the energy of node a in the hotspot is depleted. As shown in Fig. 2, the energy of node a can be conserved by moving the Sink node to near the node b that can share the task to transmit the messages to Sink node. Based on this, the lifetime of the whole WSN is prolonged.

For this purpose, the Paper proposes a new Sink node relocation scheme, that is, the energy-aware-based Sink node relocation scheme (EASR, Energy-aware sink relocation). The EASR scheme guides the time and place that the Sink node moves. Sink nodes perceive the energy of neighbor sensor nodes and move based on it to reduce the load of peripheral sensor node and preserve the energy of these sensor nodes. At the same time, the transmission range of the sensor nodes shall be adjusted in accordance with the energy level of sensor nodes. Numerical simulation shows that the proposed EASR scheme prolongs the lifetime of the whole WSNs effectively.

2. EASR

The transmission range of the nodes shall be adjusted according to the RBE (residual battery energy) of the sensor nodes in the EASR scheme, that is, adaptively change the transmission range. Battery energy decreases when a node has forwarded several messages or completed the detection task and the transmission range shall be reduced in order to preserve the energy. Then, the location of the Sink node is adjusted, and the MCP (Maximum Capacity Path) routing protocol [6] is implemented to propagate the message, thus prolonging the lifetime of the network. It is noted that the transmission message routing algorithm may affect the performance of the whole system (the adjustment of the location of the Sink node, and the forwarding of the message). Although the EASR scheme can be combined with existing multiple routing algorithms, the Paper only select the MCP routing protocol for reducing the influence on the system performance, because the parameters of the MCP routing protocol are consistent with the decisive parameters of the proposed EASR scheme.

The proposed EASR scheme is composed of two parts: adaptive changing transmission range and Sink node relocation.

2.1. Adaptive changing of transmission range

The greater the transmission range of the sensor nodes, the more the number of neighbor nodes in general. Accordingly, the quality of routing is also improved. However, the large transmission range also causes some deficiencies. The large transmission range will result in a long transmission distance for each hop and more consumption of battery energy. On the contrary, although the small transmission range is not helpful to the routing, it can preserve the energy of the battery.

Therefore, the sensor nodes are divided into three classes in accordance with the battery energy of sensor nodes in EASR as shown in Fig.3.

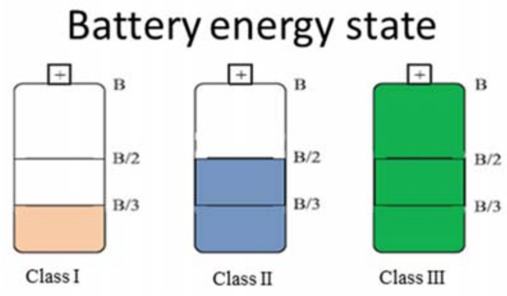

Fig. 3. Classification of sensor node in EASR

Assuming that B represents the total energy of the battery, and $r(u)$ means the current residual electricity of sensor nodes, the sensor node i is classified as three classes ($\Im^L$, $\Im^M$ and $\Im^H$) based on the value of $r(u)$.

(1) If $0 \le r(u) \le B/3$, the sensor nodes belong to the Class I ($\Im^L$), namely $i \in \Im^L$;

(2) If $B/3 \le r(u) \le B/2$, the sensor nodes belong to Class II ($\Im^M$), namely $i \in \Im^M$;

(3) If $B/2 \le r(u) \le B$, the sensor nodes belong to Class III ($\Im^H$), namely $i \in \Im^H$.

The transmission range of sensor nodes in $\Im^L$, $\Im^M$ and $\Im^H$ is different. Assuming that the maximum transmission range of sensor node is γ, and the transmission range of sensor node in $\Im^L$, $\Im^M$ and $\Im^H$ is $\gamma/4$, $\gamma/2$ and γ, respectively, the pseudo-code of adaptive changing transmission range algorithm is shown in Figure 4.

The above analysis shows that, when the energy of the sensor node is sufficient at first, the maximum transmission range γ is used to shorten the routing path. When the electric quantity falls, the transmission range is shortened to preserve the electric quantity. Therefore, this adaptive transmission range can effectively prolong the lifetime of the network.

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Adaptive changing transmission range algorithm
(sensor node $u$ )
Input: $\gamma$ in initial transmission range , initial battery energy $B$
       and current electricity $r(u)$
Output: transmission
        range $R$
If $0 \le r(u) \le B/3$ then
    $R = \gamma/4$
elseif $B/3 \le r(u) \le B/2$ then
    $R = \gamma/2$
elseif $B/2 \le r(u) \le B$ then
    $R = \gamma$
End
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Fig. 4. Adaptive changing transmission range algorithm

2.2. Sink node moving algorithm

The moving algorithm of Sink node implies two aspects. First decide whether to trigger the movement of the Sink node, that is, whether the detection is in line with the moving conditions of Sink nodes. Then determine the direction and distance of the Sink node movement.

(1) Moving conditions of Sink nodes

Sink nodes collect the electric quantity $r(u)$ of all sensor nodes in the networks periodically. After completion, Sink node calculates the maximum capacity path (P_{us}^{*}) by virtue of MCP routing protocol, where s represent the Sink node, and u means the neighbor node of Sink node. With regard to the maximum capacity path (P_{us}^{*}), the maximum capacity value $(c(P_{us}^{*}))$ [6] is defined. Assuming that the electricity information of N sensor node(s) is collected, the Sink node movement is triggered if one of the following two conditions is met. 1) The $c(P_{us}^{*})$ of any node in the N sensor node(s) is less than $B/2$; 2) average residual electric quantity $r(u)$ of N sensor node(s) is less than $B/2$. The formalized expression of the two conditions is as follows:

$$\exists u \in N, c(P_{us}^{*}) < B/2\,. \tag{1}$$

$$\sum_{u \in N} r(u)/|N| < B/2\,. \tag{2}$$

It means that dump energy of neighbor nodes around Sink nodes is less or the dump energy of some path is less than $B/2$ if any of the above two conditions are satisfied. Therefore, the Sink node is required to be moved to the proper position to prolong the lifetime of the network.

(2) Moving distance and direction of Sink node

The moving distance and direction shall be determined before the Sink node begins to move. The moving distance of Sink node each time is specified as r and the moving direction is divided into right, up, left and down. The moving destination of Sink node is set as S_{C1}, S_{C2}, S_{C3} and S_{C4} after four moving directions and distances are specified, as shown in Fig.5. The original Sink node is located in the central position, and can move along four directions, that is, right, up, left and down, of which the moving distance is r, and $r = \gamma$.

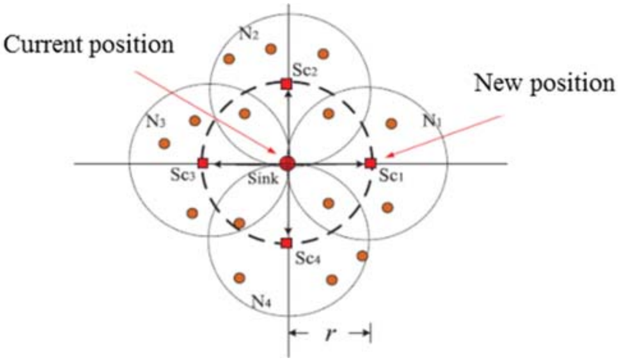

Fig. 5. Moving distance and direction of sink node

A neighbor subset N_k $(1 \leq k \leq 4)$ is defined to represent the number of neighbor of Sink node in a circle in r radius around itself. Accordingly, the weight coefficient ω_k is defined as follows:

$$\omega_k = \min \left\{ c\left(P_{us}^{*}\right) | u \in N_k \right\} . \tag{3}$$

Assuming that the destination of the Sink node is S_{Ck*}, it can be one of S_{C1}, S_{C2}, S_{C3} and S_{C4}. The moving direction of Sink node depends on four weight coefficients ω_k $((1 \leq k \leq 4))$. Therefore, the moving direction Dr is as follows:

$$Dr = \left\{ k | \max_{1 \leq k \leq 4} \{\omega_k\} \right\} . \tag{4}$$

As shown in Formula (4), the Sink node moves along the direction of the maximum weight coefficient ω_k. The pseudo-code of Sink node moving algorithm is shown in Fig.6.

3. Numerical analysis

Three different scenarios shall be set for simulation in order to fully analyze the performance of EASR scheme, and the EASR shall be compared with the One-Step Moving scheme [15] and stationary Sink node scheme. Sink node is always in a static state and cannot be moved in the Stationary scheme. These three schemes all use MCP routing protocols to forward messages. In addition, all sensor nodes in these schemes are in a static state after arrangement. In addition to the Stationary scheme, the Sink nodes in the rest two schemes are removable. The transmission range γ of sensor node and Sink node in the One-Step Moving and Stationary scheme remains

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Sink node moving algorithm

Input: $\gamma$ in initial transmission range , initial battery energy $B$ and
    current electricity $r(u)$ , and sensor node set $V$ in WSNs

Output: moving direction $Dr$

Collecting the residual battery energy $r(u), \forall u \in V$
Then, compute $c(P_{us}^{*}), \forall u \in V$
    If $\exists u \in N, c(P_{us}^{*}) < B/2$ or $\sum_{u \in N} r(u)/|N| < B/2$ is true
        Then ,compute $\omega_k = \min\{c(P_{us}^{*}) | u \in N_k\}$
        and ,compute $Dr = \{k | \max_{1 \le k \le 4}\{\omega_k\}\}$
    End
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Fig. 6. Pseudo-code of sink node moving algorithm

unchanged. However, the transmission range γ in the EASR scheme is adjusted in accordance with the electric quantity. Next, the lifetime performance of the network shall be analyzed from three scenarios.

(1) (Scenarios 1) Scenarios 1

The Scenarios 1 parameters are shown in the Table 1. The initial electric quantity of node is $B = 1000J$; transmission range γ is 25m and the sensor node changes from 50, 75, 100, 125, and 150. The simulation area is $100 * 100$. The simulation results are shown in Fig.7.

The Fig.7 shows that the performance of proposed EASR is superior to that of One-step moving and Stationary scheme within the change range of the whole sensor nodes. As is expected, the performance of Stationary scheme is the worst, because the position of Sink node is unchanged resulting in the fixation of its neighbor node (hot-spots) that forward the messages resulting in the quick energy consumption.

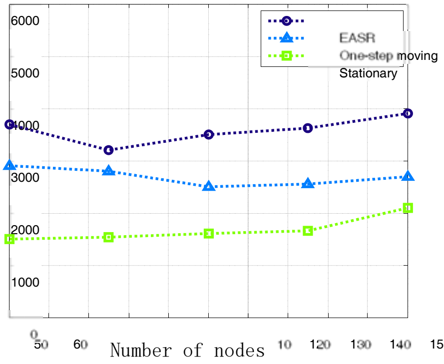

Fig. 7. Changes in network lifetime with number of sensor node

(2) Scenarios 2

The parameters of scenarios 2 are shown in Table 1. Different from the scenarios 1, the changed initial electric quantity is set to survey the influence of electric quantity on network lifetime.

Table 1. Parameters of scenarios 2

Parameters	Value
Initial energy (J)	600, 750, 1000, 1250, 1500
Transmission range (m)	25
Simulation area (m^2)	100×100
Number of node	100

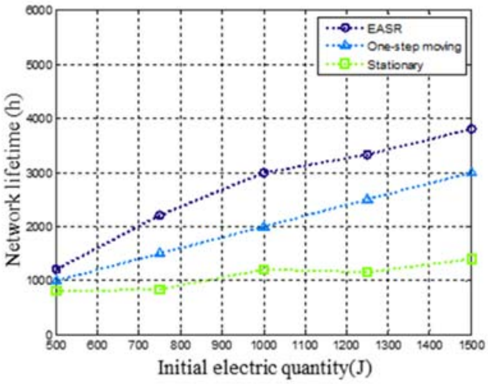

Fig. 8. Changes in network lifetime with initial electric quantity

The Fig.8 shows that the network lifetime rises with the increase in initial electric quantity of sensor nodes. Compared with One-step moving and Stationary scheme, the performance of the proposed EASR scheme is optimal, and the performance advantage is more obvious with the increase of the initial electric quantity. Similar to scenarios 1, the performance of Stationary scheme is the worst.

() Scenarios 3

The simulation parameters of scenarios 3 are shown in Table 2. The simulation is carried out to survey the influence on network lifetime of transmission range of nodes, and its results are shown in Fig.9.

Table 2. Parameters of scenarios 3

Parameters	Value
Initial energy (J)	100
Transmission range (m)	20, 25, 30, 35
Simulation area (m^2)	200×200
Number of node	400

As shown in Fig.9, the network lifetime is improved with the increase in the transmission range of the node, because the larger the transmission range, the length of the routing path is shortened. Accordingly, the number of neighbor nodes of the Sink node increases, promoting the increase of total number of residual energy in hot spots used for forwarding messages to Sink node. In addition, compared to One-step moving and Stationary scheme, the network lifetime of proposed EASR scheme is improved.

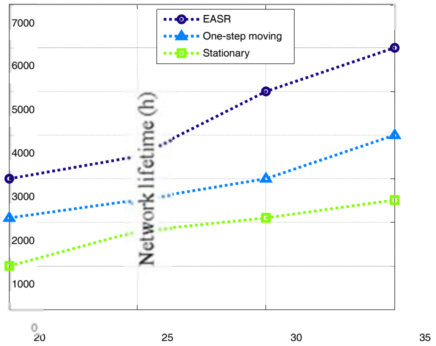

Fig. 9. Changes in network lifetime with transmission range of node

4. Conclusion

The energy of sensor node around the Sink node in WSNs (Wireless Sensor Network) is consumed faster. For this purpose, the position of Sink node shall be transferred properly to avoid excessive energy consumption of the sensor nodes around it. Based on this, the energy-aware-based Sink node relocation (EASR, Energy-aware sink relocation) scheme is proposed. The EASR scheme adaptively adjusts the transmission range in accordance with the energy of the sensor node. At the same time, the moving conditions of Sink node shall be established. If the moving condition is satisfied, the Sink node is triggered and the best moving direction is selected according to the energy status of the surrounding sensor nodes. The simulation results show that the proposed EASR scheme can prolong the network lifetime effectively.

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