False Data Filtering Strategy in Wireless Sensor Network Based on Neighbor Node Monitoring

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Abstract—The injection attack of false data is a common attack form in wireless sensor network. This attack form achieves the purpose of consuming limited network resources and severely threatens the safety of wireless sensor network through consistent sending false data. This paper proposes a type of false data filtering strategy based on neighbor node monitoring. The idea of this strategy is to enable each node to store the neighbor node's information within the two-hop range. In the meantime, the data package determines whether the upstream node is original node or data forwarding intermediate node through whether ACK package is remitted by the upstream node to avoid the impersonation of wireless sensor network node by malicious node. The false data package of malicious node will be filtered within one hop. The simulation experiment verifies the filtering performance and anti-capture performance of this strategy, thus guaranteeing the safety of wireless sensor network.

Keywords—wireless sensor network; wastewater monitoring system; ZigBee network; PH parameters

1 Introduction

Wireless sensor network (WSN) is a newly-emerging field which is combination of sensor technology, network communication and information perception. Wireless sensor network is a type of wireless network composed of static or mobile self-organizing and multi-hop sensors, which can monitor, process and transmit the information within the area in real time, proving users with the information needed [1-3]. Wireless sensor network is regarded as one of the most important technologies in the 21st century, which fuses the logical information world with the objective physical world. It brings revolutionary changes to the technology of information perception, acquisition and processing and is widely applied in national defense and military, environmental monitoring, medical and health care, intelligent buildings and space exploration [4].

The structure of wireless sensor network is shown in Figure 1. We can see from Figure 1 that sensors and nodes are densely arranged in the monitoring area and the sensing data is aggregated to the sink node. The interaction with data of task manage node is achieved through the external network (Internet, satellite-net).

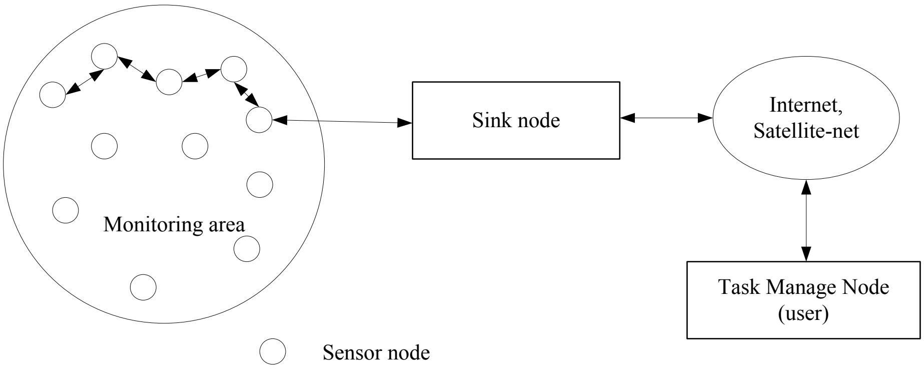


Fig. 1. Structure Diagram of Wireless Sensor Network

We can see from the structure diagram that wireless sensor network nodes and the route in the transmission process are exposed to the outside and thus it is very easy for malicious attackers to capture or forge sensor nodes. Once capturing the node, the confidential information will be stolen and this node will be reformed to malicious node [5]. To attack wireless sensor network, attacks will constantly inject false data through the malicious node, thus occupying network bandwidth and increasing communication overhead. On the one hand, the request by normal nodes will not be responded; on the other hand, the limited power of nodes will be wasted by false data, resulting in the paralysis of wireless sensor network. Therefore, the filtering technology of false data has attracted more and more attention [6].

Some scholars first proposed SEF strategy to tackle the filtering of false data in wireless sensor network. The basic idea is: in the deployment phase of network nodes, each node selects k key storages in the partitions of key pool. Each node is authenticated through the Message Authentication Code (MAC) with pre-stored perception information [7]. After receiving the data package, the node will check the key index corresponded to the MAC. Then, we use this key to verify the validity. If it is illegal, then we can judge that this is false data package and this data package will be discarded. With the proposal of gradual cross-certification, key distribution scheme LBRS based on geographical location information and one-way hash chain authentication, we have made some process in terms of data filtering. However, it is not capable of defending against malicious nodes [8-10]. The fundamental cause why it is very difficult for above strategies to defend against malicious nodes to fabricate false information is that the node receiving data package cannot identify the source of this data package. That is to say, the node cannot identify whether upstream nodes are generated or forwarded. Applying false data filtering strategy based on neighbor node monitoring, this paper can identify the source of this data package through ACK package. Thus, it can guarantee that the captured nodes cannot forge the false information in other regions and the false data package will be filtered within one hop in most cases.

2 False Data Filtering Strategy in WSN Based on Neighbor Node Monitoring

2.1 Basic Idea of this Strategy

In traditional filtering solutions, if attackers capture T nodes in different regions in the network, they will forge false data package in any region through storage keys in captured nodes. The downstream nodes cannot distinguish this data package is generated or forwarded by upstream nodes, so they can only verify or forward passively [11]. Therefore, if we can identify that the data package is generated by upstream nodes, and then downstream nodes can know whether the node at further distance is the neighbor of this node or not, thus identifying this data package is forged.

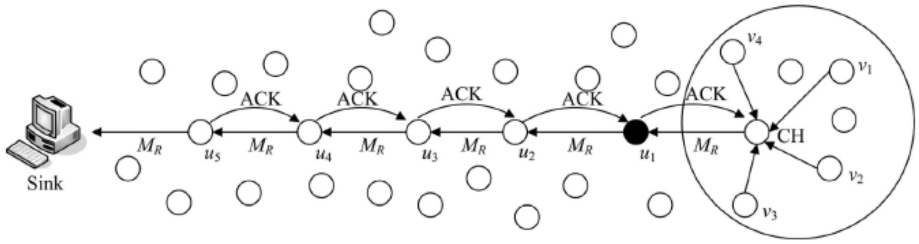
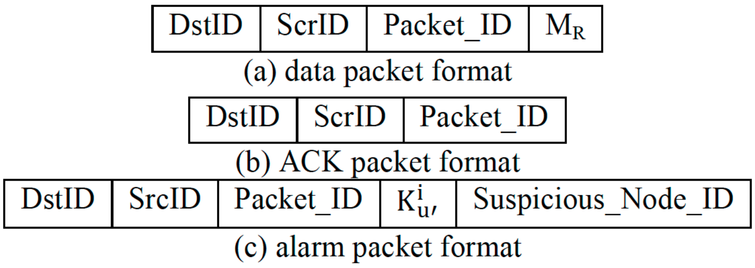


Fig. 2. Schematic Diagram of System Model

Strategy provisions: the neighbor node information within two hops is stored in the node. Each intermediate node, like the cluster-head node, not only needs to forward data package to downstream nodes, but also needs to transmit ACK package to upstream nodes. The model diagram is shown in Figure 2, when a node u_2 in the network receives the data package M_R forwarded by upstream nodes u_1, u_2 forwards ACK package to judge the data package generated is cluster-head node or forwarding node through monitoring. If a node makes the judgement that the node in the last hop is cluster-head node, then it can judge whether each ID in the data package is the neighbor node of the node in the last hop by applying the stored two-hop neighbor node information. If it is not, then it can judge this data package false data package; neighbor nodes can identify malicious nodes use them to generate data package and will automatically send alarming information to downstream nodes [12]. If a node (like u_2) monitors that the ACK package returned by the node u_1 in the last hop is node u_0, then we can identify that the node u_1 is the forwarding node. In this case, u_1 and u_0 also monitor ACK package and check in the Packet_ID in the data package stored buffering area to judge whether there is Packet_ID which is the same as that in ACK package. If there exist, then we can identify the ACK message as legitimate. Or else, we identify the ACK message as abnormal and send abnormal results to node u_2 in the form of alarm package. When the number of alarm packages in the data package received by node u_2 exceeds the threshold value w, then we can identify the data package received is false data package. In the transmitting process of alarm package, the real identity of nodes can be guaranteed by one-way chain technology. Sink nodes possess relevant keys of all nodes and small number of escaped false data packages will be detected by nodes after reaching the sink node [13-14].

The format of data package M_R, ACK package and alarm package is shown in Figure 3. Information like Packet_ID of false data package, its newest one-way chain key and ID of suspicious nodes is contained in the alarm package. Assume u_1 transmits the false data package to node u_2 of next hop and their common neighbor u' judges that it is a false data package applying ACK package. The neighbor node will transmit the data package stored within the two-hop range to u_2. If u_2 and u' are direct neighbors, the alarm package will be directly transmitted to node u_2; if u_2 and u' are neighbors of two-hop range, then it needs other nodes to forward the alarm package to u_2 or it will not transmit any data package. After receiving alarm package, u_2 will use the stored one-way chain key $K_{u'}^{i}$ of node u' to verify the validity of keys in alarm package. If it passes the verification, then u_2 will count the number of different nodes in alarm package and update the one-way chain keys corresponded to node u'.



DstID	ScrID	Packet_ID	M_R

(a) data packet format

DstID	ScrID	Packet_ID

(b) ACK packet format

DstID	SrcID	Packet_ID	$K_{u'}^{i}$	Suspicious_Node_ID

(c) alarm packet format

Fig. 3. Various Data Packet Formats

2.2 Mode of Key Distribution and Initializing Network

Similar to SEF strategy, we set a public key pool with N space as G and $G = \{k_i: 0 \leq i \leq N-1\}$. i is key index and the key pool is divided into n nonoverlapping key partitions $N_i: 0 \leq i \leq n-1\}$. Each partition contains m keys and thus N=n*m. Each key partition can be divided according to $N_i = \{K_j \middle| im \leq j \leq (i+1)m - 1\}$.

Before the deployment of nodes, each node will store L keys in public key pool randomly and give unique ID showing its identity, a global one-way key generation function F(x), parameter ub, lb, w and T_{wait}. Ub and lb represent the credibility threshold of nodes; w represents the quantity threshold of alarm packages needed in the authentication of certain node; T_{wait} represents the time u_l needed to wait for message monitoring after receiving the data package.

After the deployment of nodes in the monitoring area, each node uses random number R_u and node ID to generate keys $K_u^m = F(R_u, ID_u)$ and then uses function $K_u^j = F(K_u^{j+1})$ to generate m+1 one-way chain keys $< K_u^0, K_u^1, \dots, K_u^m, >$ corresponded to each node. Each node stores [m/d_1]+d_2 one-way chain keys calculated through its own ID. [m/d1] represents several keys $K_u^{d1}, K_u^{2d1}, \dots, K_u^{kd1}, \dots, K_u^m$ with the interval of d_1 and d_2 one-way chain keys to be used are stored, which are initialized as $K_u^0, K_u^1, \dots, K_u^{d2-2}, \dots, K_u^{d2-1}$. After the usage of first group of keys, the second group of keys are generated and stored into d_2 unit by applying neighboring one-way chain keys. Similarly, each node contains its own ID_u and the data package of K_u^0 message. After receiving, the neighboring node will record the ID_u and K_u^0 of its neighboring node and set the credibility of each neighboring node as 1. And then, it will send the ID_u and K_u^0 of its neighboring node to other neighboring nodes for storage. In this way, each node in the network not only records the ID_u, K_u^0 and credibility of its neighboring node, but records the ID_u and K_u^0 of its neighboring node within two-hop range.

2.3 Generation of Data Package

When the data information needed by users is generated, several sensor nodes around the information will sense this information and transmit this data information to neighboring nodes. When a node receives the data transmitted by more than T different key group nodes, this node informs its neighboring nodes that it is a cluster header node and forms fusion data package M according to corresponding fusion policies. The data package M is transmitted to each node in the cluster and they judge the conformity between this data and the data detected based on the application requirement of users and the precision of sensors. If the conformity is good, then randomly select a key K_i to generate M_i and send it to cluster head node. M_i=MAC(K_i, $M||ID_v||i$), ‖ represents the successful connection of data and MAC represents the authentication code of data generated by applying key K_i. The detailed process is as follow:

$$v \rightarrow CH: ID_v, i, MAC\big(K_i, M\big||ID_v|\big|i\big) \tag{1}$$

When cluster head nodes receive the data fed back by nodes, they will firstly refer to list of neighbor nodes to judge whether this ID is its neighbor node. If it is not, discard this data package and then select T data packages M_R generated by data from different key partitions. After that, transmit the data package to sink node. Then format of data package M_R is:

$$CH_j \xrightarrow{M_R} sink: M, ID_{CH}, K\,{}^{j}_{CH}, ID_{v1}, \dots, ID_{vi}, i_1, \dots i_t, M_{i1}, \dots, M_{it} \tag{2}$$

2.4 Sink Node Verification

After the halfway filtering algorithm, the data complete halfway screening and then the data will be transmitted to sink nodes. After receibving the data package, sink nodes will first check whether the number of keys, ID and MAC in the data package equals to T. If not, then discard this data package; if there exist two key indexes orginated from the same key partition, then discard this data package; finally, because sink node has the ID and corrresponding keys of all nodes, small number of false data escaping the filtering of halfway nodes will be regognized and filtered.

2.5 Analysis of Specific Attacking Identity Strategy of malicious nodes

Malicious cluster head nodes applying non-neighboring nodes in the network to forge false data package: When malicious nodes apply non-neighboring nodes to transmit false data to downstream nodes, through ACK package, downstream nodes can judge whether it is false data and discards it by the node ID with the two-hop range; if malicious nodes transmit ACK package to neighboring nodes, the neighboring nodes can identify it is illegal data package if the by comparison of Pcaket_ID shows inconsistent results. Moreover, it will transmit alarm package to downstream nodes. When the number of alarm packages from different nodes reach w, this data package will be identified as false data package.

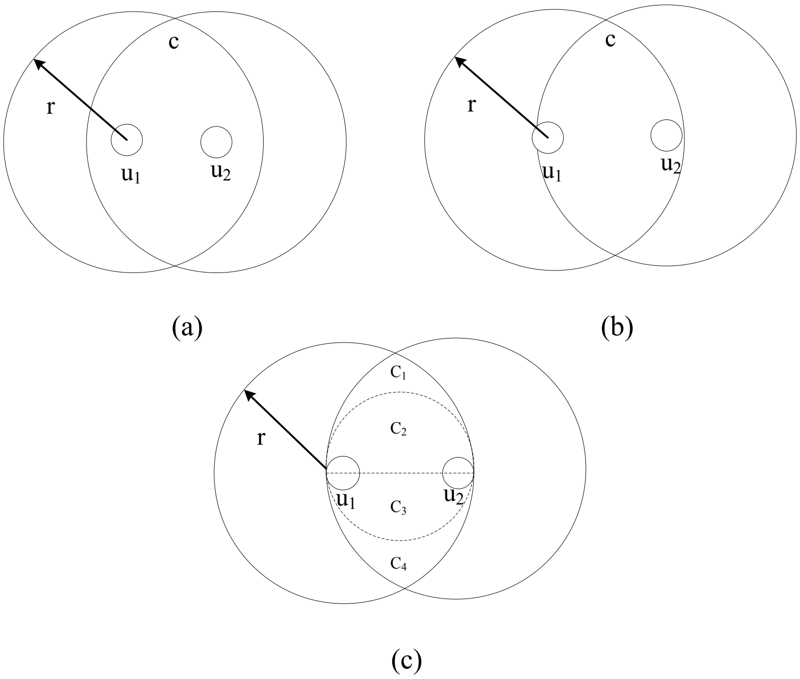
Malicious cluster head nodes applying neighboring nodes to forge false data package: If malicious nodes are captured by neighboring nodes, there will be two identical ID originated from the node from the same partition when transmitting the data package, which is contradictory. This data package will be filtered by downstream nodes and downstream nodes and downstream nodes will receive the alarm package.

Conspiracy attack by malicious cluster head nodes and captured downstream nodes: Many alarm packages will be forwarded when cluster head nodes and captured nodes transmit false data package to each other. During this time, the neighboring area will receive certain number of alarm packages. In this way, false data packages will be filtered.

The above three identity strategies can filter malicious nodes through one hop.

3 Strategy Performance and Analysis of Simulation Experiment

3.1 Monitoring Capacity of Neighboring Nodes



(a)

(b)

(c)

Fig. 4. Public Neighboring Area of Nodes

Analysis of the number of public monitoring nodes: In terms of nodes that can directly communicate with each other, the number of public neighboring nodes is assocated with distance. The larger the distance, the fewer the public neighboring nodes, as is shown in (a) and (b) in Figure 4. When the interval between u_1 and u_2 is the largest communication distance of nodes, the number of public neighboring nodes is the fewest. Assume that the largest communication distance of nodes is r and C area is the public area of nodes u_1 and u_2, so the minimal area of C is:

$$\mathrm{C} = \frac{2}{3}\pi \mathrm{r}^2 - \frac{\sqrt{3}}{2}\mathrm{r}^2 \tag{3}$$

In Figure (b), the proportion of C area in node communcation area is 40%. Assume the number of neighboring nodes is 20 and these nodes are distributed evenly, and there will be 7 public neighboring nodes for two nodes. Therefore, the number of public monitoring nodes can be guaranteed even under the premise of minimal public area.

Analysis of the number of alarm packages received by nodes in public area C: When the distance between nodes is the largest commnictaion distance, the overlapping area is divided into C_1, C_2, C_3 and C_4 shown in Figure (c). when node u_2 receives the alarm package transmitted by upstream monitoring nodes, this data package must be transmitted or forwarded by certain node in these 4 areas. When u_2 receives the alarm package, certain node in C_2 at least receives the alarm package of u_2 transmitted or forwarded by other 3 areas. This area occupies 83% in C area. Certain node in C_1 at least receives the alarm package of C_1 and C_2, occupying 50% of the node communication area. When u_2 receives m alarm packages transmitted by upstream monitoring nodes, it can be deduced that C_2 and C_3 at least receives 0.83m alarm packages and C_1 and C_4 at least receives 0.5m alarm packages.

The transmission delay of data package in this startegy is low, which exerts little impact on the decision-making of sink nodes. Meanwhile, there will not be great communication overhead and storage overhead, thus satisfying the requiremnet of users.

3.2 Simulation Experiment

The parameter configuration is shown in Table 1. We identify that the attack mode is random and take the mean value of 1000 data as the final result. We obtain the filtering capacity, anti-capture performance and algorithm performance by the comparison between SEF and NWFFS through simulation experiment.

Table 1. Parameter Configuration Table

Parameter	Parameter Value
Simulation area	500*500m^2
Number of nodes	2000
Communication radius	29.8m
Sensing radius	29.8m
Global key pool size	400
Number of key partitions	20
The number of keys node stored	10
Node trust upper threshold ub	0.8
Node trust Lower threshold lb	0.1
Alarm package threshold w	5
Number of key partitions in data package T	5

Analysis of Filtering Performance: Figure 5 shows that interms of the average number of hops, the average number of transmission hops of false data package in SEF strategy is significnatly higher than that in NWFFS strategy under two different strategies. Morever, the average number of transmission hops increases with the increase of malicious nodes. In NWFFS strategy, the average number of transmission hops is almost a constant value, which shows that the false data filtering strategy in wireless sensor network based on neighbor node monitoring proposed in this paper can effectively mitigate the harm by the attack of false data.

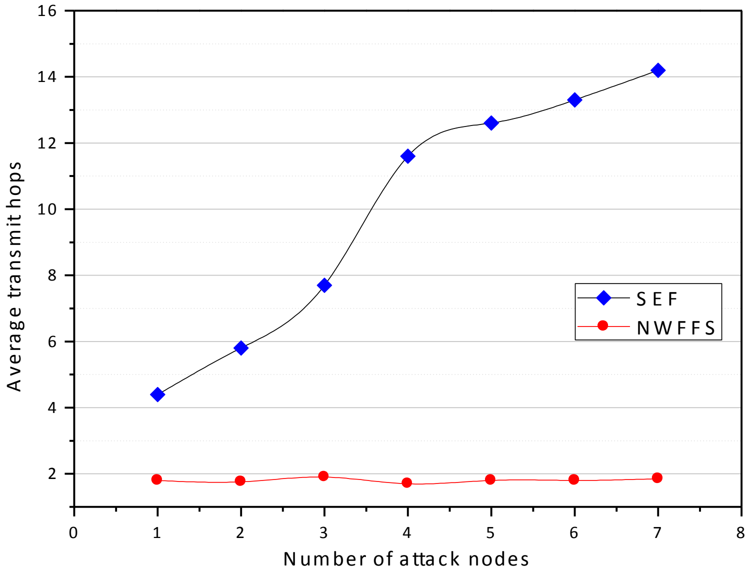


Fig. 5. Average Number of Transmission Hops Before False Data Filtering

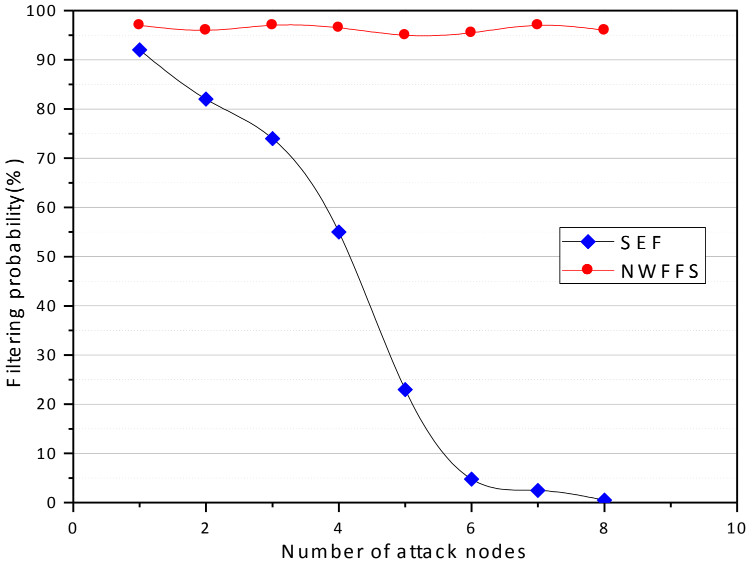


Fig. 6. Filtering Probability of False Data Package

Figure 6 is the comparison between the performance of false data package filtering of two strategies. When the number of captured nodes is relatively less (<3), SEF has good performance. However, with the increase of captured nodes, the filtering capability of SEF declines dramtically. When the number of captured nodes reaches

8, SEF almost loses its filtering capability. Compared with SEF, NWFFS strategy has almost maintained a good filtering capability of false data package.

Analysis of anti-capture performance: The number of captured nodes is directly proportional to the forgery area of malicious nodes. Therefore, we can use the proportion of area of false data package successfully forged by malicious nodes in total deployement area to measure the anti-capture performance of nodes in this strategy. we can see from Figure 7 that when the number of captured nodes is 5, malicious nodes in SEF strategy can forge 61.3 area events. In NWFFS strategy, malicious nodes can barely forge any area event. When the number of malicious nodes is 49, malicious nodes in SEF strategy can almost forge any area event while malicious nodes in NWFFS strategy can only forge 3.4% of area events.

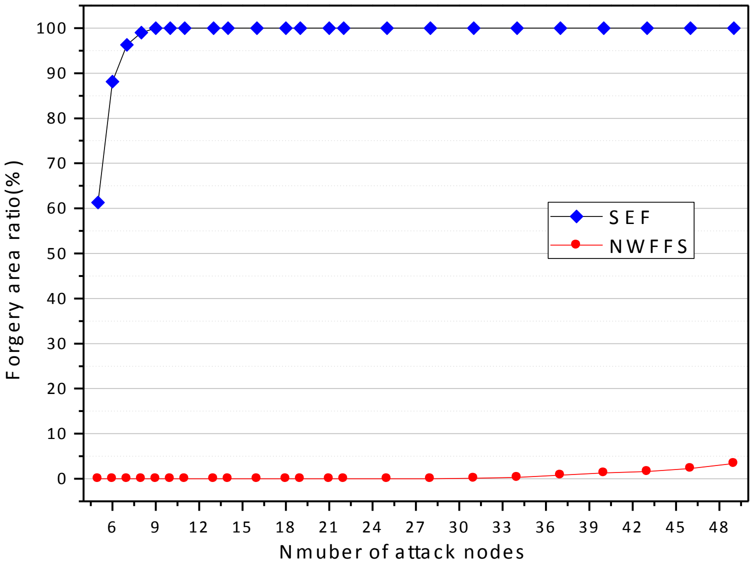


Fig. 7. Proportion of Forgery Area in Total Deployment Area

4 Conclusion

This paper proposes a type of false data filtering strategy based on neighbor node monitoring and describes the baisc strategic ideas in detail. After the establishment of the model and analysis of simulation experimental results, we discover that compared with peevious SEF strategy, this strategy has improved significantly in terms of filtering performance and anti-capture capacity, which indicates that this strategy effectively reduces the possibility that malicious nodes apply captured nodes to forge false data. In this way, the impact of malicious nodes on wireless sensor network is reduced and the security of wireless sensor network is further enhanced.

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