Int. J. Electron. Commun. (AEÜ) 69 (2015) 1464–1482

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

A novel joint logging and migrating traceback scheme for achieving low storage requirement and long lifetime in WSNs

Yuxin Liu, Anfeng Liu*, Sheng He

School of Information Science and Engineering, Central South University, ChangSha 410083, China

ARTICLE INFO

Article history:
Received 2 February 2015
Accepted 29 June 2015

Keywords:
Wireless sensor networks
Traceback
Packet logging and migrating
Lifetime

ABSTRACT

In this paper, a logging joint marking (LM) traceback scheme is proposed. The main point of LM scheme is: node marks each received packet; it logs the mark information until the times of packets marking reach v. If node's storage is deficiency for having log more mark, it will do migrating, that is, migrate the stored mark information to those nodes which are far away from sink and have large storage space left. Compared with previous traceback scheme, the advantages of LM scheme are as follows: (1) Longer network lifetime. (2) Less required storage capacity. (3) Higher safety performance. Since all the nodes are used to store marked packets, it will preserve more marked packets. As a result, the victims can acquire more information when backtracking and location the source of the malicious packet more rapidly and accurately. Our analysis show that compared with marking and logging scheme, LM scheme can increase network lifetime by 21%, reduce the storage capacity by 80%, and in the meantime reduce convergence time by 40%.

1. Introduction

Wireless sensor networks (WSNs) are emerging as a promising platform that enable a wide range of applications in both military and civilian domains such as battlefield surveillance, medical monitoring, biological detection, etc. [1,5–16]. Due to their operating nature, they are often unattended, hence prone to different kinds of novel attacks [1–4,15,21–25]. For instance, an adversary could capture nodes acquiring all the information stored therein – sensors are commonly assumed to be not tamper-proof. Therefore, an adversary may replicate captured sensors and deploy them in the network to launch a variety of malicious activities [15]. In the case of false data inject attack [3,23] or DoS/DDoS flooding attacks [23], malicious node consumes resources like energy, bandwidth, computing power, storage space etc. by sending large amount of false information in a short time, which terribly destroy the network [1,3,23]. Traceback in communication networks, is a promising solution to counter the spoofed attacks by determining the probable source of the malicious packet(s) or the attack path(s) [18], but the previous research are mostly concentrated on IP network which has sufficient energy and storage capacity [6–8], and due to limitation of energy and storage capacity in sensor network, it is inapplicable [18].

In sensor network, the method of traceback includes two categories: packet marking [29] and logging [19,22]. The method of packet marking is referred to as adding information of the nodes passed by in the packets head information (for example node ID information) [29], and logging is referred to as data packets marked and stored in the relay nodes in a suitable data structure [19,25]. In case of an attack, the victims consult upstream nodes to reconstruct attack paths by broadcasting the information of the malicious packet(s) in the traceback request to determine malicious node [18]. Packet marking requires extra bits in packet header, which increases the size of packets, the consumption and communication overhead increased [25], while the method of logging sends smaller data packets and requires larger storage space [25]. As for traceback scheme, the situation of sensor network is different from IP network which has no problem in energy and storage space, for that reason it is worth studying.

In the sensor network, there is a special phenomenon called "energy hole", that is, nodes near sink have to forward the data from the periphery region of the network, so they may consume far more energy than those in other area. Hotspots are formed in this way. After the premature death of nodes near sink area forming energy hole, the data cannot get to sink, which cause the whole network die in advance [29]. In the method of packet marking, the node nearer to the Sink has longer data packets, which leads to the nodes near Sink consume more energy [10,12–14]. For that reason, the method of packet marking deteriorates the phenomenon "energy hole" and reduces the lifetime of the network. While in the

* Corresponding author. Tel.: +86 0731 88879628.
E-mail address: afengliu@mail.csu.edu.cn (A. Liu).

http://dx.doi.org/10.1016/j.aeue.2015.06.016
1434-8411/

strategy of logging, the data packets are logged in the node when reaching certain length. In general speaking it also deteriorating the lifetime of the sensor network [19,23,25]. Besides the characteristic of many-to-one routing-to-Sink, which causes that the node nearer to Sink's hotspot area has larger probability of logging, requiring more storage space. While nodes far away from Sink area has large amount of storage space left, that is, the phenomenon of unbalance of storage capacity. The mix of packet marking and logging compromise the storage capacity and communication overhead to some extent [25], but in general it does not change the situation of large energy consumption and large requirement of storage capacity near Sink area, but much storage capacity left in area far from Sink area. That imposes negative affect to the performance of these strategies [30].

Aiming to solve the deficiency above, this paper proposes logging joint migrating (LM) traceback scheme. By making full use of the energy and storage space in the whole sensor network, compared with previous research the LM traceback scheme can improve three main indicators, that is, network lifetime, storage capacity required by nodes, convergence time. This paper has the following innovations:

(1) The LM scheme has longer network lifetime.
The hotspots area in sensor network determines the lifetime, therefore, the LM scheme logs or migrates marked packets to those nodes far away from Sink area in advance when routing data packets before reaching hotspots area. The amount of information forwarded by hotspots near Sink is reduced, which results in the increase of network lifetime. According to our theoretical analytical results, LM scheme increases network lifetime by 33% and 21% respectively compared with the method of packet marking and logging.
(2) The LM scheme requires less storage capacity, and storage among the nodes is balanced. It is a fair storage mechanism.
In the previous research in traceback scheme, nodes near Sink area have to store large amount of information, for the reason that in homogenous network, the nodes are deployed according to their maximum storage capacity. It wastes the storage capacity left in non-hotspots area, the LM scheme makes a critical difference from previous research, and that is, nodes without enough storage capacity do not store the real mark information but the ID number of the passed data packets and the ID of node who stores it. While the mark information required being stored is sent reversely to the node which has relatively large remaining storage capacity. Storing the two ID number spends far less capacity than the routing mark information, thus the storage space of the energy intensive hotspots area can be sharply cut down. Owing to the more abundant storage space and energy in non-hotspots area, reverse migrating the mark information do no harm to the network lifetime. On the contrary, it could make the storage of the node in the network relatively fair and reduce the required capacity and the cost of the network. Compared with the logging scheme, the storage space required in LM scheme is only 44.3–66.6% with the same amount of mark information.
(3) The LM scheme has higher security and is able to ascertain the source of the malicious packet in less time. Since the LM scheme makes the best of the energy and storage capacity left in non-hotspots area sufficiently accounting for 90% of the network, it can log more mark information. It has been calculated that LM scheme can store 1.71–3.17 times mark information that of marking and logging scheme. Convergence time can also be reduced because sufficient mark information collected can help victims to distinguish the source of attack after suffering less times of attack.

The rest of this paper is organized as follows: In Section 2, the related works are reviewed. The system model and problem statement are described in Section 3. In Section 4, a novel logging joint migrating (LM) traceback scheme is presented. Performance analysis is provided in Section 5. The experimental results and contrast is presented in Section 6. We conclude in Section 7.

2. Relevant researches

There are three traceback schemes, such as the logging traceback (hash-based) [21], ICMP-based traceback [24] and probabilistic packet marking [3] are widely used in conventional IP network to trace back varies attacks. Their main design goal is to locate the attacker by tracing back along the attacking path. Due to stringent resource constraint in WSNs, these algorithms cannot suitable to be applied in WSNs environments directly [2,3].

There are mainly two schemes apply to the traceback in WSNs. One is mark packets [29]. The method is: in the process of data routing, intermediate nodes add the route path information to the data packets so that routing path of packets (part or all of the routing path information) can be get by extracting the path information after receiving the malicious data packets. If the number of received malicious packets is enough, the information of the malicious source node can be completely known to realize the traceback of malicious node successfully. The advantage of adopting this scheme is that the protocol is simple, it almost no storage space requirements for the node, and it is easy to implement. Every node only has to add its own routing path to the packets. But the deficiency is that if the marked nodes are too many, the length of packets will increase, resulting in the packet has to be divided into pieces before sent. That may not only increases the clash of routing but also reduces the lifetime of sensor network severely. As a result, to improve the lifetime of network, packet is not always marked in the whole routing process generally (if so, the length of packets will be too long and affect the lifetime of the network). Instead, we qualify at most k nodes are marked in the routing path while other nodes are not marked [2,3]. This reduces the energy cost of the node, but requires the system to accumulate more packets to analyze comprehensively to determine malicious source node, which increases the convergence time. Besides, it is discovered by many research that in marking scheme, if every packet is limited to be marked k times at most, the node near Sink is to have higher probability to be marked while the node far from Sink is to have lower probability. This is because in such a scheme, every node determines if mark packet with a certain probability. But after the data packet is marked k times, the following nodes are to replace the information that has been marked. To overcome this deficiency, Ref. [2] presented a fair probability distribution mark scheme, which has a good effect.

The scheme based on logging is another method of back tracing malicious node [22]. The main point of the scheme is that the node marks the information of path of the packet. In this way, the attack path is rebuilt by acquiring the path information in the logging when back tracing. In the traceback scheme based on logging, the proportion of mark information in packets is relatively low. The node mainly forwards necessary packets, and that the routing path information is reserved in the node by logging. Once victims perceive the attack, or need a traceback, they are to send inquiry request to the required nodes. This information reserved in logging reduce the amount of data sent to the Sink. So the advantage of this scheme is high lifetime, and the deficiency that node requires large amount of energy to transmit the mark information in packets in the marking scheme leading to low lifetime is overcome to some extent. Logging scheme has the shortage that node requires large storage capacity to store the mark information, especially the area