A Novel Approach for Probabilistic Dual Source Location Privacy Protection Scheme in Wireless Sensor Networks

Mrs.Christina Ranjitham M[1], Mrs. Angela Jennifa Sujana J[2], Ms. Mariya Rasathi Jeya A [3] , Ms. Santhana Selvi S[4], Ms.Mariammal M [5]

[1]*Assistant Professor, Department of Computer Science and Engineering, St. Mother Theresa Engineering College, Thoothukudi, India,*

[2]*Associate Professor, Department of Information technology, Mepco Schlenk Engineering College, Virudhunagar, India,*

[3,4,5] *UG Student, Department of Computer Science and Engineering, St. Mother Theresa Engineering College, Thoothukudi, India.*

Abstract

Wireless Sensor Networks (WSNs) have been widely deployed to monitor valuable objects. In these applications, the sensor node senses the existence of objects and transmitting data packets to the sink node (SN) in a multi hop fashion. The SN is a powerful node with high performance and is used to collect all the information sensed by the sensor nodes. Due to the open nature of the wireless medium, it is easy for an adversary to trace back along the routing path of the packets and get the location of the source node. Once adversaries have got the source node location, they can capture the monitored targets. In this project, we focus on the source location privacy problem in WSNs, a hot research topic in security, and propose a novel approach of two new cluster-based source location privacy protection schemes in WSNs called cluster-based dual phantom node source location privacy protection scheme (DPS) and probabilistic source location privacy protection scheme (PSLP) for WSNs. A more powerful adversary, which can use Hidden Markov Model (HMM) to estimate the state of the source, is considered in this study. To cope with this type of adversary dual phantom nodes and fake sources, which are responsible to mimic the behavior of the source, are utilized to diversify the routing path. Then, the weight of each node is calculated as criteria to select the next-hop candidate. In addition, two transmission modes are designed to transmit real packets. We evaluate our schemes through theoretical analysis and experiments. Experimental results show that compared with other schemes, our proposed schemes are more efficient and achieves higher Security, as well as keeping lower total energy consumption. Our proposed schemes can protect the location privacy of the source node even in resource-constrained wireless network environments.

Index Terms—Wireless sensor networks, source location privacy, phantom node, fake source.

I. Introduction

In recent years, WSNs have played an important role in a number of security applications, like remotely monitoring objects etc. In such applications, the location of the monitored object is tightly coupled with the sensor that detects it, called the data source. Therefore, preserving the location of data source is important for protecting the object from being traced. Such a preservation cannot be simply accomplished by encrypting the data packets as the location of the data source can be disclosed by analyzing the traffic flow in WSN. There have been extensive techniques proposed to **preserve** source-location privacy against different attack models:

Local-eavesdropping model - Local-eavesdropping assumes the attacker's ability to monitor the wireless communication is limited to a very small region, up to very few hops

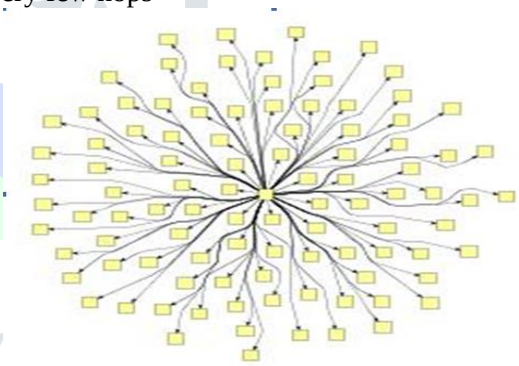


Fig. Distributed Sensor networks

Global-eavesdropping model - The attacker is assumed to be capable of monitoring the traffic over the entire network. Both being unrealistic, because the former stringently restricts the attacker's ability, while the latter exaggerates it, considering resources and cost required for launching such an attack. Semi-Global eavesdropping model - A more practical attack model, in this semi-global eavesdropping model, the attacker is able to eavesdrop on wireless communications in a substantial area that is much smaller than the entire monitoring network. This attack model allows the attacker to gather substantially more information than a local eavesdropper. Under the semi-global eavesdropping model, we explore a novel protocol for preserving source-location privacy by using data mules. Traditionally, data mules are used in WSNs for reducing energy consumption due to the data transmission between sensors and facilitating Communication in disconnected networks. A data mule picks up data from the data source and then delivers them directly to the base station. We adapt

the functionality of data mules so that they not only maintain their traditional functionality, but also facilitate the preservation of the location privacy of data sources. Wireless Sensor Networks (WSNs) are WSN networks comprised of a large number of small and costless devices (sensor nodes) which provide traditional computers with the ability to feel and reason about their surroundings, thus providing intelligence to the environment and enabling the Ambient Intelligence (AmI) paradigm. The reduced cost and size of sensor nodes is one of the main advantages of WSNs but it is also one of its main limitations, since it greatly constrains the capabilities of sensor nodes.

These devices must cope with a processor or memory equivalent to that of computers thirty years ago. Moreover, they are mainly battery powered and in most cases these are irreplaceable. Due to the lack of resources, sensor nodes are extremely vulnerable to different types of attacks, from the hardware to the application layer In general, privacy in AmI environments has traditionally been related to what is known as social privacy, that is, the need to prevent individuals from being tracked without their explicit consent. However, there are also network privacy considerations that must be taken into consideration. An attacker might analyze the network operation in order to retrieve information about the network itself and the data being collected.

II. Related Works

Meanwhile, wireless sensor networks vehicles also have to be prevented from the misuse of the private information and the attacks on their privacy. There is a number of research works focusing on providing the anonymous authentication with preserved privacy in VANETs [01]. They specifically provide a survey on the privacy-preserving authentication (PPA) schemes proposed for VANETs. We investigate and categorize the existing PPA schemes by their key cryptographies for authentication and the mechanisms for privacy preservation. In wireless sensor networks, it is important to provide confidentiality to the sensor's location. In this section, we describe previous proposed technologies that were designed to preserve the source location in wireless sensor networks. For a more comprehensive taxonomy of techniques of preserving privacy in WSNs, readers may refer to the state-of-the-art survey Fan et al. [02] preserve location privacy by using homomorphic encryption operations to prevent traffic analysis in network coding. In [03], each cluster header can filter the dummy packets received from the sensor nodes of its cluster to reduce the number of dummy packets. However, the scheme requires much computation overhead due to using asymmetric-key cryptography, and the packet delivery delay is long because the cluster header sends packets with a fixed rate regardless of the number of events it collects. Mehta et al. [04] formalize the location privacy problem using a global adversary model and compute a lower bound for the overhead required for achieving a given level of privacy protection. The proposed scheme by Alomair et al. [05] can guarantee event indistinguish ability by achieving interval indistinguish ability, where the adversary cannot distinguish between the first, the middle, or the end of the interval. In [06], dummy packets can be filtered at proxy nodes, and the lifetime of the WSN is analyzed at different proxy assignment methodologies. Hong et al. [07] propose a scheme that can thwart time correlation attack. In this attack, the adversary exploits the time correlation of transmissions in successive links to learn the end-to-end route. Zhou and Yow [08] propose an anonymous geographic routing algorithm which includes three components to avoid the explicit exposure of identity and location in communication. For local-eavesdropping based attack, flooding based approach was first introduced in [10], where each sensor broadcasts data that it receives to all its neighbors. However, this technique suffers from high communication overhead for sensors. In [09], each data packet is first relayed to a randomly selected intermediate sensor in the network and then is forwarded towards base station along the shortest path. In [01], FitProb Rate is proposed to maintain source anonymity, which is an exponentially distributed dummy traffic generation scheme. The Fitprob parameter decides the dummy traffic generated at a dynamic rate, which differs from other similar works. It is a great improvement over source simulation and fake sources but still has the drawback of having overhead due to dummy packet generation.

III. System Model

In this section, the system model contains the network model and the adversary model, and assumptions are interspersed in both two parts. The background application is the protection

of wild rare animals. In the wild environment, sensor nodes are randomly deployed. After being deployed, the locations of these sensor nodes keep unchanged. Then, sensor nodes monitor the acts of animals. the design features of the proposed network model and adversary model are familiarized, and assumptions are presented. The terrain of our underlying network is a finite two-dimensional grid, which is further divided into cells of equal size. The network is composed of one base station, static sensors, and mobile agents, called data mules. Static sensors - All static sensors are homogeneous with the same lifetime and capabilities of storage, processing as well as communication. They are deployed uniformly at random in the cells, and assumed to guarantee the connectivity of the network. Data mules - Data mules are the mobile agents which can be artificially introduced in the network [10]. We assume they move independently and do not communicate with each other. Also, they are assumed to know their own locations when they are moving all the time. Their mobility pattern can be modeled as a random walk on the grid, whereby in each transition it moves with equal probability to one of the horizontally or vertically adjacent cells.

After a data mule moves into a cell, it stays there for t_{pause} time period before its next transition. At the beginning of the pause interval, the data mule announces its arrival by broadcasting Hello Message. Only data source will respond and relay buffered data to the data mule. We assume the data mule does not communicate with sensors when moving. The data mule's communication range is larger than that of a sensor, thus a data source which cannot directly transmit data to the data mule will use multi-hop routing.

A. Network model :

The network model in this study is based on the typical Panda-Hunter model. A WSN which is composed of many sensor nodes is deployed to monitor the activities of pandas. Once a sensor node detects a panda, it becomes the source and sends packets to the sink through multiple hops. The essence of privacy protection is reducing the probability that the adversary finds the source location.

Therefore, we make the following assumptions:

1) Sensor nodes are randomly deployed. After being deployed, the location of each sensor node remains unchanged. What's more, all sensor nodes are homogenous, which means that they have the same initial energy, the same computing ability, and the same cache memory.

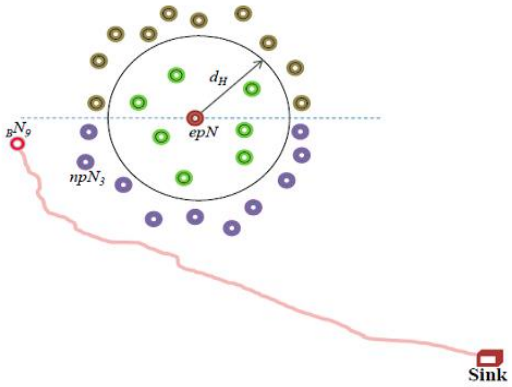
2) Routing is based on the weight. Each sensor node is assigned a weight that is updated regularly. The weight here represents the probability that this node is selected as the next hop, or it can be understood as the preference in selecting the next hop node, which is related to the residual energy, the communication quality, and the hop count to the sink. Details of this weight will be given later.

3) Only one sink exists in the network. As in other schemes or protocols, the sink remains in the network center.

4) Each sensor node has knowledge of its own adjacent neighbors. Packets sent by each sensor node are encrypted with an encryption algorithm.

B. Adversary model

Due to the potential value of the source, the adversary starts from the sink and tries his/her best to find the source location. The monitoring range of the adversary equals to a sensor node's radius, which means that the type of the adversary is a local adversary. The local adversary has a limited monitoring range, which is equal to or a little larger than the communication range of a common node. Thus, the local adversary can only monitor parts of the network. Commonly, the adversary performs passive attacks, such as eavesdropping and backtracking, to avoid being discovered by the network administrator. We consider a more powerful adversary in this paper. Apart from the passive attack, we assume that the adversary knows the packet type by checking the header of each packet. Then, the adversary can use the Hidden Markov Model (HMM) to infer the possible state of the source for a given time based on its observation. The intention of using HMM to infer the possible state of the source is that, comparing with wandering in the network, it is more effective for the adversary to find the source location from the estimation result of HMM. This is because the estimation of HMM can help the adversary reduce the scope of finding the source.



C. Attack Model

Due to the rarity of panda, the attacker is driven by interest and tries to use advanced equipment to capture the panda. During the panda's stay period, the source node will continually send data packets, and the hunter may use this to his advantage to track and hunt the panda. Similar to most other pieces in the literature on source node location privacy protection, we mainly consider the local passive attackers with the ability to eavesdrop on local trace of a WSN.

We make the following assumptions about the attack model:

(1) The attacker is equipped with wireless signal monitoring equipment, such as antenna and spectrum analyzers, and has sufficient computational capacity, storage capacity and energy resources. However, the attacker can only drop the network track in a local region; he cannot monitor the entire network. In fact, if the attacker can monitor the entire network, he can monitor the Panda directly without relying on the WSN. Also, he cannot decrypt the packet and tamper with the packet content;

(2) The attacker just wants to get the location of the source node, in order to ensure his own

Concealment , the attacker only passively listens to the packets and hops back and forth. The attacker does not initiate an active attack on the network, that is, he does not interfere with the normal functioning of the network, and otherwise intrusion detection measures might detect the attacker's presence;

(3) The initial position of the attacker is at the sink node. He waits until he hears a packet. Once the attacker hears a data packet, he can determine the packet sender via wireless locating technology and quickly move to its location. The monitoring radius of the attacker is the communication radius of sensor nodes. Although the attacker has strong mobility, he can sense only one hop transmission, and he moves only when he monitored a data packet, that is, the

attack tracks a packet only via hop-by-hop;
(4) We emphasize that the attacker cannot learn the origin of a packet by merely observing a relayed version of it. If the attacker does not overhead the data packet within a certain period of time, the will roll back hop-by-hop along the tracking path until he returns to the sink node;
(5) The monitored object can be captured when the attacker appears in the visible area of the source node.

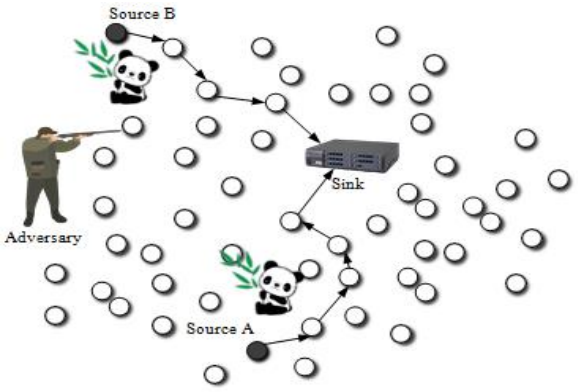


Fig. Panta-Hunter Model

D. Security Model

We make the following assumptions about the security of the network:
(1) The network has basic security measures, such as encrypting the data packet. The attacker cannot decrypt the packet, and can only capture the panda in the visible area of the source node via hop-by-hop backtracking. We will not discuss specific encryption and decryption algorithms and key management mechanisms, since they are beyond the scope of this paper.
(2) We assume that the source node includes its ID in the encrypted packets, but only the sink node can identify the source location from its ID. Even if the hunter can break the encryption in a reasonably short time, he cannot tell the source node's location.
(3) The sink node is absolutely safe, and the attacker cannot break the sink node.

IV. THE PROBABILISTIC SOURCE LOCATION PRIVACY PROTECTION SCHEME

In this section, a detailed description of PSLP is given. In the initialization process, the beacon message is periodically broadcasted by the sink to sensor nodes. When a node receives the message, it records the hop count stored in it, increase the hop count by one, repackages the packet, and sends to its neighbors. Each node only records the minimum hop count. Subsequently, all nodes know their hop count to the sink and their neighbors. Since the adversary may know the state of the source at a given time while the location of the source is still unknown, we intend to increase the possible locations of the source. PSLP contains three steps: the first step is the determination of phantom nodes; the second step is the determination of fake sources; the third step is the routing from the source to the sink. An overview of PSLP is shown in Fig.

As mentioned in the adversary model, the adversary can use HMM to estimate the state of the source and then perform targeted search. What we need to do is to increase more possible states of the source. Phantom nodes and fake sources perfectly match our needs. The phantom node refers to nodes around or nearby the source, which simulate the function of the source. The fake source also refers to nodes which simulate the function of the source. But the location of fake source is around the sink, which is far from the source. The motivation of combining the phantom node and the fake source together is to create the diversification of the transmission directions. Both phantom nodes and fake sources are selected in non-hotspot area, which has little influence on the network lifetime.

A. *The determination of phantom nodes*

As mentioned before, phantom nodes are nodes deployed around the source to simulate the function of the source. Considering the function of phantom nodes, we can see that the longer the distance between a phantom node and the source, the stronger the privacy protection is. The main purpose of this setup is to direct the adversary away from the real source. For more details, when the source appears, it sends packets to one of its neighbors within H hops via directed random walk. Then, the neighbor sends packets to a node in its far neighbor list and decreases H by one. When H becomes zero, the current node changes into a phantom node and forwards packets sent by the source. The phantom node changes during each data transmission. In addition, the phantom node must stay outside the visible area (circle around the source). Because when the adversary backtracks to the visible area, it recognizes the source immediately. Moreover, the source sends packets to the phantom node once during the initialization. So, the transmission between the source and the phantom node is assumed to be safe. Noted that the determination of phantom nodes relates to the distance between the source and the sink, which will be presented later.

B. *The determination of fake sources*

As described in previous definition, fake sources are gener- ated around the sink to increase directions from where packets come. The deployment range of a fake source is specified by angle θ_2 in Fig. 3. First of all, the sink divides the network into several rings. Then, these rings are divided into n sectors. For the sake of separating fake sources and the source, fake sources are only selected in the right part of the line which is perpendicular to the line linking the source and the sink. The number of fake sources is determined by the actual application. At the initialization, the fake source sequence is generated.

Each fake source is preferably to stay in different sectors, which guarantees that the direction of each

fake packet is different. Since the adversary knows the source state in aspecific time, it needs to analyze the packet flow to find the source. Therefore, by adopting fake sources to diversify the source location, source location privacy is protected. A node acts as a fake source for a fixed period. When the time period exhausts, another fake source appears. In order to alleviate the energy consumption of fake sources, we assume that there only exists one fake source for a certain period of time

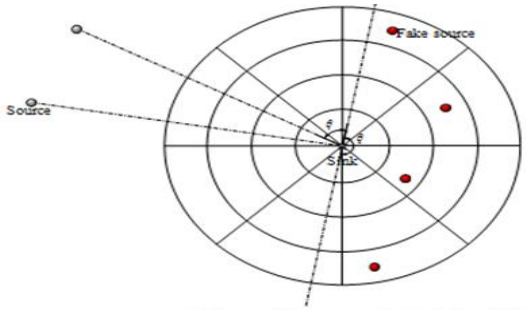


Fig. Ring areas around the sink.

C. The routing from the source to the sink

After the determination of phantom nodes and fake sources, the next step is the transmission between the real source and the sink. The source transmits a message to inform the sink when it appears. Then, the sink selects a fake source immediately after receiving this message. Considering that the source randomly appears, there exists a possibility that distance between the source and the sink is small. So, in response to this situation, we set a threshold between the source and the sink. Thereby, the routing process from the source to the sink contains two scenarios. The first case is that the hop count between the source and the sink is larger than the threshold.

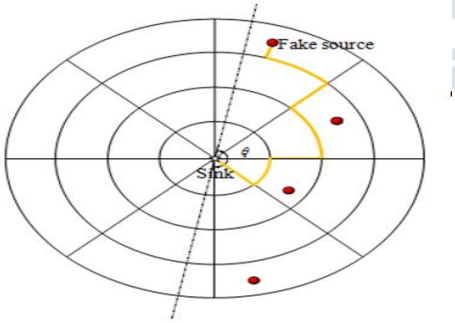


Fig. Possible transmission around the fake nodes

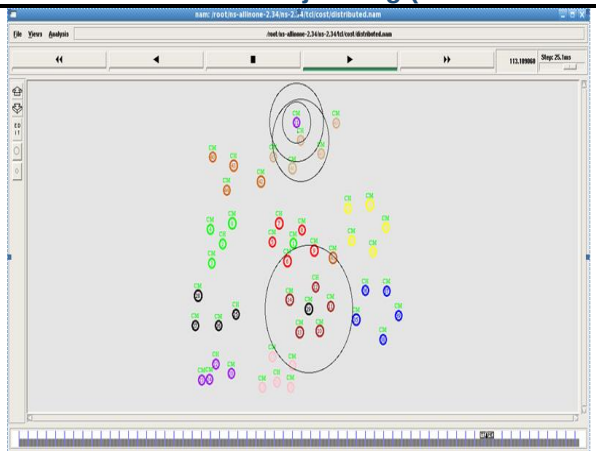


Fig. Sample result

V. PERFORMANCE EVALUATION

In this section, we evaluate the performance of PSLP. All the results provided in this section are the average values of the experimental data.

A. Overview

In this area, four metrics are evaluated in the simulation, namely, the safety time, the energy consumption, the network lifetime, and the transmission delay. First of all, we give the definition of each metric. The safety time is the difference between the time when the source sends the first packet and when the adversary finds the source's location. To be more specific, we use the hop count of backtracking taken by the adversary to represent the safety time. The energy consumption represents the average energy costed per simulation run. As control packets only take up very little energy, so we ignore this part and mainly focus on the energy consumption during packets transmission. The network lifetime refers to the time difference between the network establishment and the death of the first node. The transmission delay means the average packet transmission and the data processing time per simulation run. PSLP is compared with two other schemes, which are the dynamic single path routing algorithm (Dynamic SPR) and the enhanced protocol for source location protection (SLPE) [9]. Dynamic SPR uses fake sources to protect the source location, while the SLP-E adopts phantom nodes to implement this. These two methods are integrated in PSLP. Therefore, we choose Dynamic SPR and SLP-E for the comparison in NS2 tool.

B. Network lifetime

The network lifetime is influenced by many factors and the energy consumption of nodes occupies a large proportion. As there are two transmission modes in PSLP and the threshold T plays a vital role in this scheme, we intend to explore the relationship between the network lifetime and the distance between the source and the sink. The result is presented in Fig. 8. We can observe that with the increase of the hop count from the source to the sink, the average network lifetime increases with side length ranging from 300 m to 900 m for a fixed communication radius. Due to the existence of the

threshold T, the network life on both sides of the threshold T is completely different. When distance between the source and the sink is smaller than the threshold T, the transmission in this condition consumes more energy, and hence the network lifetime is not long. In addition, the network lifetime decreases with the increase of the network's side length. When the side length increases, a packet is delivered using more hops to the sink, which in turn influences the network lifetime.

C. Influence of the number of phantom nodes and fake sources

The influence of the number of phantom nodes and fake sources on the safety time and the average energy consumption is shown in Fig. As we can see in Fig. 9(a), the number of phantom nodes has a little influence on the safety time. This is because only one phantom node works per data transmission. Hence, the difference of the safety time in each transmission is not obvious, which is only related to the relative position between the phantom node and the source. There is a decrease when the number of phantom nodes is 4. This is due to the randomness of location between the source and the sink, and data transmission mode changes during each simulation run. The safety time increases with the number of fake sources. This is because fake source works in a relay. Thus, the more fake sources, the longer the safety time. In Fig. the number of phantom nodes has a little influence on the average energy consumption except the 4 phantom nodes case. This is because only one phantom node works in each simulation run. When there are 4 phantom nodes, the distance between the source and the sink tends to be larger than the threshold T. Thus, the length of routing path is not long and the average energy consumption decreases. The average energy consumption increases with the number of fake sources. The reason for the 4 fake sources case is the same as that of the 4 phantom nodes case.

D. Comparison

The comparison of the transmission delay is shown in Fig.10 and the communication radius of each node is fixed in this We use hop as the unit of delay. The reason is that the transmission delay is generated mainly due to the data transmission time and the data processing time, and the data transmission time is related to the length of routing path and the data rate. The data rate is a fixed value and thus we use the unit of routing path as the unit of transmission delay. In SLP-E and DynamicSPR, real packets are transmitted using the shortest path, and thereby the transmission delay in these two schemes is small. Although the side length of the network is growing, the impact is not very obvious. For a further elaboration, with the increase of network scale, the limited flooding area in SLP-E also increases. So the transmission delay in SLP-E gradually increases. Since two transmission modes exist in PSLP and the hop count between the source and the sink varies in each simulation run, this causes a little fluctuation in PSLP. In addition, with the increase of the side length, the routing path also increases, so does the transmission delay. The comparison of the safety time and the energy consumption are presented in Fig. The safety time relates to the routing path. We mainly compare these three algorithms from two aspects: the communication radius and the network size. The Safety time relates to the routing path. The longer the routing path, the more time an adversary will spend on tracking. In Fig., the safety time of PSLP fluctuates a lot. However, the safety time in SLP-E and Dynamic SPR increases at a lower rate with a given side length. This is because packets in SLP-E and Dynamic SPR are transmitted using the shortest path. When a node's communication radius increases, the average length of routing path reduces. Thereby, the safety time decreases with the communication radius. On the other hand, two transmission modes are considered in PSLP, with the increase of the communication radius, the case in which the hop count is smaller than the threshold occurs more often. So it is the threshold that makes the safety time of PSLP fluctuate with the communication radius. In Fig. 11(b), the safety time increases with the side length. As the side length increases, the average length of routing path increases. Thus, the safety time increases correspondingly. Since the equal hop count routing is adopted in PSLP, the safety time of PSLP is the largest. Also, when the network scale increases, it is more probable that the distance between the source and the sink is larger than the threshold. Thus, the safety time in this condition grows steadily. Many fake sources are deployed around the sink in Dynamic SPR, so the average safety time is larger than that of SLP-E. The energy consumption also relates to the routing path. In Fig. 11(c), the average energy consumption cost per simulation run in only one fake source lasts for a fixed period and packets are transmitted using the shortest path. The average energy consumption of PSLP and SLP-E increases with the communication radius for a given side of length. Energy in SLP-E is mainly consumed in the limited flooding area. With the randomness of random walk, the energy consumption fluctuates. Again, it is the two types of packets transmission that makes the energy consumption fluctuate. In addition, with the increase of the communication radius while the network scale keeps unchanged, the hop count between the source and the sink in PSLP may become small. Thereby it consumes more energy in this condition. The difference of the energy consumption between PSLP and Dynamic SPR lies in the use of phantom nodes and the equal hop count routing. As a result, the energy consumption in PSLP is a little larger than that in Dynamic SPR. In addition, parameters of the communication radius in PSLP is important. It is worth to mention that even though the energy consumption in Fig. is very smooth, if we change the communication radius into a different value, the result varies. In Fig., it seems that the communication radius used in the simulation makes

the transmission mode more biased towards the case in which the hop count between the source and the sink is larger than the threshold. The comparison of the network lifetime is presented in Fig. 12. Among the three schemes, the network lifetime of Dynamic SPR is the largest. This is because the fake source only appears in the furthest distance to the sink and only one fake source exists in the network for a fixed time. Moreover, real packets are routed to the sink using the shortest path, which consumes less energy and reduces the transmission delay. However, the distance between the sink and the fake source is different in each simulation, which makes the network lifetime fluctuate. In SLP-E, the limited flooding is repeated during each simulation run and, therefore, most of energy is consumed in the limited flooding step, which adds an extra burden on nodes in limited flooding area. In PSLP, even though there are two transmission modes in the simulation, the network lifetime of PSLP declines slowly and steadily. Given that we adopt the average value as final results, the difference between the two transmission modes is counteracted. Again, due to the use of fake packets, the network lifetime of PSLP is larger than that of Dynamic SPR. However, it is relatively small compared with SLP-E.

VI. CONCLUSIONS

Studying security in WSNs became increasingly important during the last decade. In this project, we focused on the source location privacy, a research hotspot in security, and proposed a probabilistic source location privacy protection scheme (PSLP) based on WSNs. A powerful adversary which utilizes Hidden Markov Model (HMM) is considered in this study. To cope with it, phantom nodes, fake sources, and weight are adopted to change the packets' transmission directions. Considering the
distance between the source and the sink, two types of routing modes are designed. Compared with Dynamic SPR and SLPE, the simulation results demonstrate that the proposed PSLP achieves a high safety time and balances the energy consumption of each node. Future studies will concentrate on protecting the source location by reducing the adversary's monitoring probability and secure communication among nodes.

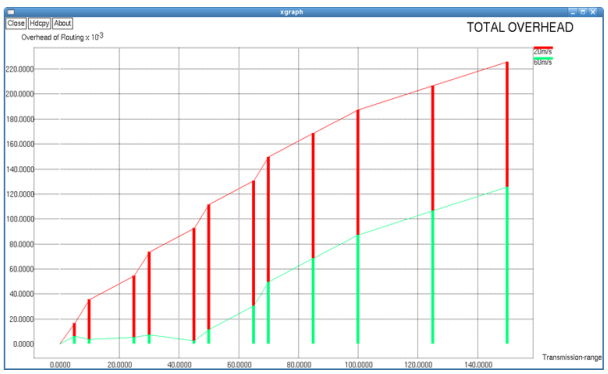


Fig. Total Overhead

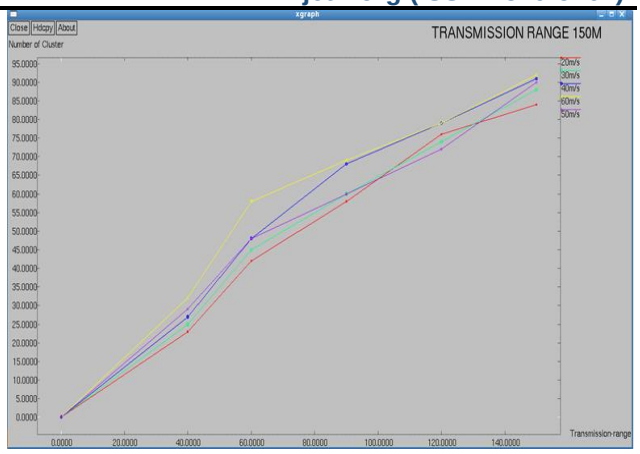


Fig. Transmission range

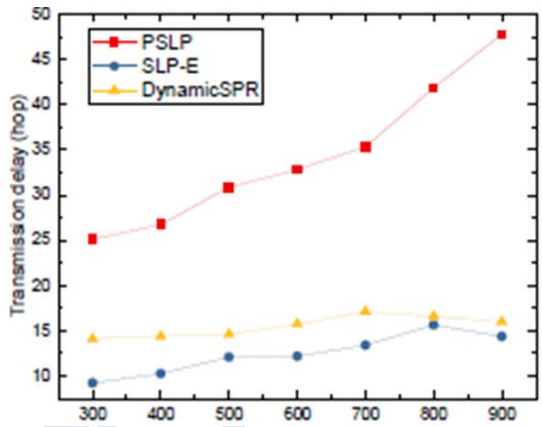


Fig.Transmission delay

REFERENCES

[1] H. Lu and J. Li, "Privacy-preserving authentication schemes for vehicular ad hoc networks: a survey," Wireless Communications and Mobile Computing, vol. 16, no. 6, pp. 643-655, Apr. 2016.

[2] G. Han, X. Yang, L. Liu, S. Chan, and W. Zhang, "A Coverage- Aware Hierarchical Charging Algorithm in Wireless Rechargeable Sensor Networks," IEEE Network Magazine, pp. 1-7, Nov. 2018, DOI: 10.1109/MNET.2018.1800197

[3] G. Han, H. Guan, J. Wu, S. Chan, L. Shu, and W. Zhang, "An Uneven Cluster-Based Mobile Charging Algorithm for Wireless Rechargeable Sensor Networks," IEEE Systems Journal, pp. 1-12, Nov. 2018, DOI: 10.1109/JSYST.2018.2879084

[4] G. Han, H. Wang, J. Jiang, W. Zhang, and S. Chan, "CASLP: A Confused Arc-Based Source Location Privacy Protection Scheme in WSNs for IoT," IEEE Communications Magazine, vol. 56, no. 9, pp. 42-47, Sept. 2018.

[5] H. Lu, J. Li, and M. Guizani, "Secure and Efficient Data Transmission for Cluster-based Wireless Sensor Networks," IEEE Transactions on Parallel and Distributed Systems, vol. 25, no. 3, pp. 750-761, Mar. 2014.

[6] G. Han, L. Zhou, H. Wang, W. Zhang, and S. Chan, "A Source Location Protection Protocol Based on Dynamic Routing in WSNs for Social Internet of Things," Future Generation Computer Systems, vol. 82, no. 5, pp. 689-697, Aug. 2018.

[7] H. Lu, J. Li, and H. Kameda, "A Secure Routing Protocol for Clusterbased Wireless Sensor Networks

Using ID-based Digital Signature," Proceedings of IEEE Global Communications Conference, Dec. 2010.
[8] M. Bradbury, A. Jhumka, and M. Leeke, "Hybrid online protocols for source location privacy in wireless sensor networks," Journal of Parallel and Distributed Computing, vol. 115, pp. 67-81, May 2018.
[9] J. Chen, Z. Lin, Y. Hu, and B. Wang, "Hiding the Source Based on Limited Flooding for Sensor Networks," Sensors, vol. 15, no. 11, pp. 29129-29148, Nov. 2015.
[10] G. Han, X. Miao, H. Wang, M. Guizani, and W. Zhang, "CPSLP: A Cloud-Based Scheme for Protecting Source-Location Privacy in Wireless Sensor Networks Using Multi-Sinks," IEEE Transactions on Vehicular Technology, vol. 68, no. 3, pp. 2739-2750, Jan. 2019.
[11] G. Han, H. Wang, M. Guizani, S. Chan, and W. Zhang, "KCLP: A kmeans Cluster-Based Location Privacy Protection Scheme in WSNs for IoT," IEEE Wireless Communications Magazine, vol. 25, no. 6, pp. 84-90, Dec. 2018.
[12] C. Ozturk, Y. Zhang, and W. Trappe, "Source-Location privacy in energy-constrained sensor network routing," ACM Workshop on Security of Ad Hoc and Sensor Networks, pp. 88-93, Jan. 2004.
[13] J. Wang, R. Zhu, S. Liu, and Z. Cai, "Node Location Privacy Protection Based on Differentially Private Grids in Industrial Wireless Sensor Networks," Sensors, vol. 18, no. 2, pp. 410-425, Jan. 2018.
[14] A. Boualouache, S. Senouci, and S. Moussaoui, "A Survey on Pseudonym Changing Strategies for Vehicular Ad-Hoc Networks," IEEE Communications Surveys & Tutorials, vol. 20, no. 1, pp. 770-790, First quarter. 2018.
[15] Y. Gong, C. Zhang, Y. Fang, and J. Sun, "Protecting Location Privacy for Task Allocation in Ad Hoc Mobile Cloud Computing," IEEE Transactions on Emerging Topics in Computing, vol. 6, no. 1, pp. 110-121, Mar. 2018.
[16] J. Du, C. Jiang, K. Chen, Y. Ren, and H.V. Poor, "Community-Structured Evolutionary Game for Privacy Protection in Social Networks," IEEE Transactions on Information Forensics and Security, vol. 13, no. 3, pp. 574-589, Mar. 2018.
[17] R. Manjula and D. Raja, "A novel source location privacy preservation technique to achieve enhanced privacy and network lifetime in WSNs," Pervasive and Mobile Computing, vol. 44, pp. 58-73, Feb. 2018.
[18] J. Koh, D. Leong, G. Peters, I. Nevat, and W. Wong, "Optimal Privacy- Preserving Probabilistic Routing for Wireless Network," IEEE Transactions on Information Forensics and Security, vol. 12, no. 9, pp. 2105-2114, Sept. 2017.
[19] C. Huang, M. Ma, Y. Liu, and A. Liu, "Preserving Source Location Privacy for Energy Harvesting WSNs," Sensors, vol. 17, no. 4, pp. 724-755, Mar. 2017.
[20] W. Chen, M. Zhang, G. Hu, X. Tang, and A. Sangaiah, "Constrained Random Routing Mechanism for Source Privacy Protection in WSNs," IEEE Access, vol. 5, pp. 23171-23181,sep 2017.