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Improving Security In Wireless Sensor Networks Through Machine Learning –Based Intrusion Detection System

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Abstract
Intrusion detection is one of the important ap- plications of Wireless Sensor Networks (WSNs).Prior research indicated that the barrier coverage method combined with Mobile Sensor Networks (MSNs) can enhance the effectiveness of intrusion detection by mitigating coverage holes commonly appeared in stationary WSNs. However, the trajectories of moving sensors and moving intruders have not been investigated thoroughly, where the impact between two adjacent moving sensors and between a moving sensor and a moving intruder are still under- determined. In order to address these open problems, in this paper, we firstly discuss the virtual potential field between sensors as well as between sensors and intruders. We then propose to formulate the mobility pattern of sensor node using elastic collision model and that of intruder using point charge model. The point charge model describes an hitherto-unexplored mobility pattern of empowered-intruders, which are capable of acting upon the virtual repulsive forces from sensors in order to hide them away from being detected. With the aid of the two models developed, analytical expressions and simulation results demonstrate that our proposed design achieves a higher k- barrier coverage probability in intrusion detection when compared to that of the conventional designs. It is also worth mentioning that these improvements are achieved with shorter average displacement distance and under the much more challenging MSNs settings.

Index Terms—*Mobile sensor networks, intrusion detection,*

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I. Introduction

Intrusion detection can be defined as the technique to detect unapproved entrance into specific territory and it has become the basis of other monitoring applications such as border surveillance and sabotage detection. Traditional radar systems can be utilized in intrusion detection tasks but face the limitations of high cost and high false alarm rates. Moreover, radar systems need to be built in security areas with a long construction cycle. Therefore, distributed target detection systems are proposed in order to address the above problems and provide better performance. Wherein , wireless sensor networks (WSNs) have been widely applied as a kind of flow-cost and easy-deployed distributed intrusion detection systems through continuously sensing and transmitting environmental- related data. Multiple sensors may collaboratively judge whether an intrusion event occurs based on decision fusion and local voting; and multiple sensors also may collaboratively detect the intruder's movement and crossing trajectory by trans-location and coverage optimiza- tion, which is exactly the concern of this paper. This issue usually focuses on how to effectively deploy sensor nodes on a specific zone boundary in order to capture an intruder with high probability.

Prior research indicated that the coverage optimization methods, especially the barrier coverage method, are capable of improving the intrusion detection capability in WSNs. Barrier coverage was firstly introduced in for stationary WSNs, where sensors deployed over a belt region are used to carry out intrusion detection and the region is said to provide *k*-barrier coverage if every path that crosses the width of the belt is covered by at least *k* distinct fixed sensors(k 1).In stationary WSNs, there may exist exposed paths for intruders which cannot be covered by any deployed sensor owing to their' static 'nature. Hence, it is believed that Mobile Sensors Networks (MSNs), where every sensor can move to an appropriate position according to coverage requirements, are capable of enhancing coverage and of avoiding exposed paths appeared in stationary WSNs .However, if the trajectories of moving sensors and moving intruders were completely stochastic, it would every challenging to justify whether MSNs still provide *k*-barrier coverage. As a result, it becomes highly desirable to develop rigorous model for characterizing the *k*-barrier coverage probability of MSNs.

In this context, virtual potential field based modeling Between moving sensors and moving intruders appears to be attractive. This model was firstly adopted in , where the field is constructed in such a way that each sensor is repelled by both obstacles and other sensors, thereby forcing the network to spread itself throughout the environment. However, the existing studies of only considered general MSNs setting, where the intruder's crossing trajectories were not taken into account comprehensively. Furthermore, some intruders who are probably equipped with sensing magnetic field scanner may strategically hide them away from sensors. And this intruder s are called as empowered intruders who achieve the dodging when acting upon the virtual repulsive forces between sensors and them. Little existing research considers such scenario with the empowered intruders, and meanwhile the barrier coverage probability obtained from current approaches may be further improved. This motivates us to study this hitherto-unexplored problem with novel system models and powerful intrusion detection strategies, where both of them will be treated in this paper.

Related work

Intrusion detection was first introduced in sensor-based robotic systems. It has been an important branch of the coverage pro blem, which can be divided into two categories: full coverage and barrier coverage. Full coverage needs to ensure the connectivity and maximize the detection rate of the coverage area, while barrier coverage needs to minimize the probability of undetected enemy penetration through the barrier.

The problem of full coverage has been extensively studied in and among which the approach based on virtual potential field attracts considerable attention. and respectively consider the enhanced virtual potential field algorithm and the optimal mobile sensor redeployment strategy, for the purpose of the minimum nodes and the maximal coverage. H. Mahboubi et al. combine the Voronoi diagram with virtual force algorithm and propose a distributed approach of coverage optimization . F. J. Parrado-Garcia et al. study the WSNs deployment configuration for in-situ lunar surveys in which simulated annealing algorithm is used to solve a constrained coverage optimization problem in this application scenario. However, it is difficult for full coverage to thoroughly address the intrusion detection problem due to lack of considerations of moving trajectories of sensors or intruders, and subsequently plenty of research contents have begun to explore barrier coverage in WSNs.

Based on distinctive views of barrier coverage, many solutions are proposed to adapt to different requirements in stationary WSNs. B. Liu et al. present an efficient distributed algorithm to construct sensor barriers on long strip areas of irregular shape without any constraint on crossing paths.

Chen et al. design a set of metrics in order to measure the quality and performance of barrier coverage in. Taking the moving trajectory, speed and location of moving target(i.e. moving intruder)into account, respectively provide the effective proposal, where S. Kumar et al. consider the movements of intruder are likely to follow a shorter path when the intruder crosses a belt region and J. M. Chenet al. restrict the farthest distance that an intruder can move without being detected , both of which motivating the pattern of intruder's pass-through in this paper. The existence of the exposed path in stationary WSNs hinders it from being the ideal solution in critical intrusion detection tasks where any unmonitored crossing is intolerable.

Currently, mobile WSNs have gradually become the con- cern of barrier coverage, which are investigated in. Where andillustrate that node mobility may improve the coverage performance of WSNs.

H.Xuetal. design a barrier coverage method in a hybrid sensor networks where the mobile sensors with adjustable sensing ranges can efficiently mend the barrier gaps produced by the stationary nodes. S.J.Lietal. suggest a barrier coverage method which minimizes the maximum sensor movement distance by characterizing critical permutation switches. M. Rout et al. propose two distributed deployment schemes where mobile sensor nodes are randomly deployed over a rectangular belt to form sensor barriers by self-adjustment. Particularly for the scenario of sparse WSNs, S.B.Heetal. design a periodic monitoring scheduling (PMS)algorithm in which each point along the barrier line is monitored periodically by mobile sensors to guarantee the high coverage

. D. Van et al. extend the traditional virtual force algorithm with interest-driven virtual force to provide monitoring of a moving phenomena in an unknown and open area

.G.Y.Keungetal. Introduce the gas kinetic theory and mean free path from physics to facilitate the study regarding the intrusion detection problem. Based on these physics models, it derives the inherent relationship between the *k*-barrier coverage performance and a set of crucial dynamic aspects of MSNs and calculates the detection probability format least *k* number of sensor coverage. Nevertheless, the movement pattern of sensor nodes in is purely stochastic so that their sensing area may overlap, which results in a decreased overall detection probability.

Furthermore, literatures focus on developing algorithms to reposition mobile sensors. C. Shen et al. formulate the problem of minimum-energy barrier-coverage, and realize the energy-efficient sensor relocation by utilizing fewer mobile sensors than stationary sensors to achieve barrier coverage. N. Bartolini et al. focus on the vulnerabilities of the deployment based on Voronoi diagrams and put for- ward a solution to coordinate mobile sensors and guide their movements to new positions . Z. B. Wang et al. mainly study how to efficiently use the reposition of mobile sensors to achieve *k*-barrier coverage in directional sensor networks. B. Xu et al. investigates the potential of using mobile sensor nodes to strengthen the barrier coverage of WSN by adopting the first- order grey model to determine the vulnerable part of the barrier and relocate mobile nodes to cover the possible loopholes, Particularly, for the bistatic radar (BR) sensor networks, and respectively consider the placement and deployment problem in order to maximize the coverage and minimize the vulnerability of a barrier. However, current deployment strategies of MSNs do not take empowered intruders into consideration and the obtained barrier coverage probability needs to be further improved by designing an effective mobility model of sensor.

To the best of our knowledge, we are the first to study the arrier coverage probability in intrusion detection scenario with empowered intruders in MSNs. Based on the virtual potential field, by leveraging the elastic collision model and the point charge model from physics, we investigate the dynamic relationships between moving intruders and mobile sensors and then evaluate the *k*-barrier coverage performance in intrusion detection tasks with empowered intruders.