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TOWARDS A ALGEBRAIC FRAMEWORK FOR BASIS ANONYMITY IN SENSOR NETWORKS

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Abstract

In certain applications, the positions of events reported by a sensor network need to remain anonymous. That is, unauthorized spectators must be unable to detect the origin of such events by analyzing the network traffic. Known as the source anonymity problem, this problem has emerged as an important topic in the security of wireless sensor networks, with variety of techniques based on different Reproachful assumptions being proposed. , a new framework for modeling, analyzing and evaluating anonymity in sensor networks. The novelty of the proposed framework is twofold: first, it introduces the notion of Intermission in distinguishability and provides a quantitative measure to model anonymity in wireless sensor networks; second, it maps source anonymity to the statistical Context problem of binary hypothesis testing with nuisance parameters. We then analyze existing solutions for designing anonymous sensor networks using the proposed model. We show how mapping source anonymity to binary hypothesis testing with nuisance parameters leads to converting the problem of exposing private source information into searching for an appropriate data transformation that removes or minimize the effect of the nuisance information. By doing so, we transform the problem from analyzing real-valued sample points to binary codes, which opens the door for coding theory to be incorporated into the study of anonymous sensor networks. Finally, we discuss how existing solutions can be modified to improve their anonymity.

Index Terms—Wireless Sensor Networks (WSN), source location, privacy, anonymity, hypothesis testing, nuisance parameters, coding Theory

1. Introduction

Wireless sensor networks have recently gained much attention in the sense that they can be readily deployed for many different types of missions. In particular, they are useful for the missions that are difficult for humans to carry out. For example, they are suitable for sensing dangerous natural phenomenon such as volcano eruption, biohazard monitoring, and forest fire detection. In addition to these hazardous applications, sensor networks can also be deployed for battle field surveillance, border monitoring, nuclear and chemical attack detection, intrusion detection, flood detection, weather forecasting, traffic surveillance and patient monitoring.

Sensor networks are deployed to sense, monitor, and report events of interest in a wide range of applications such as military, health care, and animal tracking. In many applications, such monitoring networks consist of energy constrained nodes that are expected to operate over an extended period of time, making energy efficient monitoring an important feature for unattended networks. In such scenarios, nodes are designed to transmit information only when a relevant event is detected (i.e., event-triggered transmission). Consequently, given the location of an event triggered node, the location of a real event reported by the node can be approximated within the node's sensing range.

The positions of the combat vehicle at different time Intermissions can be revealed to an adversary observing nodes transmissions. There are three parameters that can be associated with an event detected and reported by a sensor node the description of the event, the time of the event, and the location of the event. When sensor networks are deployed in untrustworthy environments, protecting the privacy of the three parameters that can be attributed to an event-triggered transmission becomes an important security feature in the design of wireless sensor networks

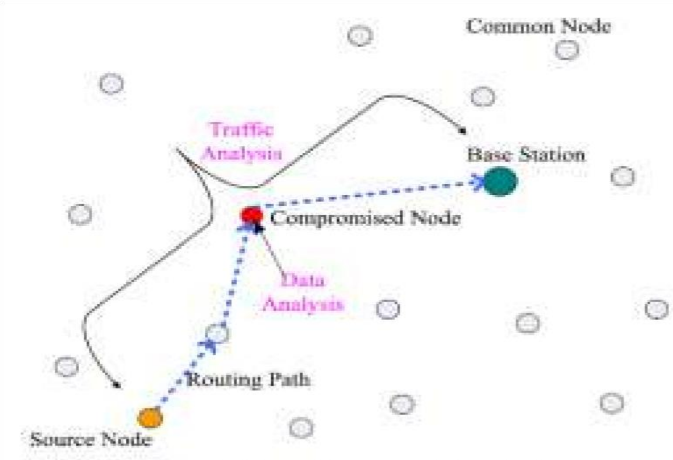
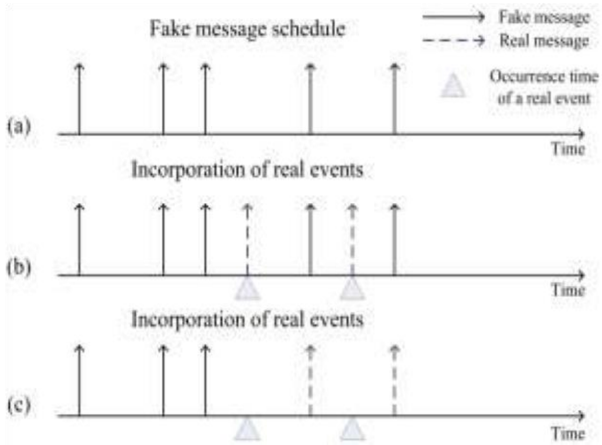


Fig. 2. Two scenarios for privacy attack in a WSN.

While transmitting the security of a message can be achieved via encryption primitives, hiding the timing and spatial information of reported events cannot be achieved via cryptographic means. Encrypting a message before transmission, for instance, can hide the context of the message from unauthorized spectators, but the mere existence of the cipher text is indicative of information transmission. The source anonymity problem in wireless sensor networks is the problem of studying techniques that provide time and location privacy for events reported by sensor nodes. (Time and location privacy will be used interchangeably with source anonymity throughout the paper.) In the existing literature, the source anonymity problem has been addressed under two different types of adversaries, namely, local and global adversaries. A local adversary is defined to be an adversary having limited mobility and partial view of the network traffic. Routing-based techniques have been shown to be effective in hiding the positions of reported events against local adversaries. A global adversary is defined to be an adversary with ability to monitor the traffic of the entire network. Against global adversaries, routing-based techniques are known to be ineffective in concealing location information in event-triggered transmission. This is due to the fact that, since a global adversary has full spatial view of the network, it can immediately detect the origin and time of the event-triggered transmission. The first step towards achieving source anonymity for sensor networks in the presence of global adversaries is to refrain from event-triggered transmissions. To do that, nodes are required to transmit fake messages even if there is no detection of events of interest (real events will be used to denote events of interest for the rest of the paper). When a real event occurs, its report can be embedded within the transmissions of fake messages. Thus, given an individual transmission, an observer cannot determine whether it is fake or real, assuming messages are encrypted. In the above approach, there is an implicit assumption of the use of a probabilistic distribution to schedule the transmission of fake messages.

However, the arrival distribution of real events is, in general, time-variant and unknown a priori. If nodes report real events as soon as they are detected(independently of the distribution of fake transmissions), given the knowledge of the fake transmission distribution statistical Context Context analysis can be used to identify outliers (real transmissions) with a probability higher than 1=2, as illustrated in Figure 1 (b)



Different approaches for embedding the report of real events within a series of fake transmissions; (a)shows the prespecified distribution of fake transmissions,(b) illustrates how real events are transmitted as soon as they are detected, (c) illustrates how nodes report real events instead of the next scheduled fake message.

In other words, transmitting real events as soon as they are detected does not provide source anonymity against statistical Context Context adversaries analyzing a series of fake and real transmissions.

One way to mitigate the above statistical Context Context analysis is illustrated in Figure 1(c). As opposed to transmitting real events as they occur, they can be transmitted instead of the next scheduled fake one. For example, consider programming sensor nodes to deterministically transmit a fake message every minute. If a real event occurs within a minute from the last transmission, its report must be delayed until exactly one minute has elapsed. This approach, however, introduces additional delay before a real event is reported. When real events have time-sensitive information, such delays might be unacceptable.

Reducing the delay of transmitting real events by adopting a more frequent scheduling algorithm is impractical for most sensor network applications since sensor nodes are battery powered and, in many applications, unchangeable. Therefore, a frequent transmission scheduling will drastically reduce the desired lifetime of the sensor network.

The Statistical Context Context Source Anonymity problem in sensor networks is the study of techniques that prevent global adversaries from exposing source location by performing statistical Context analysis on nodes transmissions. Practical SSA solutions need to be designed to achieve their objective under two main constraints: minimizing delay and maximizing the lifetime of sensors‟ batteries.

2. Model Conventions

2.1 Network Model

Communication is assumed to take place in a network of energy constrained sensor nodes. Nodes are deployed to sense events of interest and report them with minimum delay. Consequently, given the location of a certain node, the location of the reported event of interest can be approximated within the node’s communication range at the time of transmission. When a node senses an event, it places information about the event in a message and broadcast an encrypted version of the message. To obscure the report of an event of interest, nodes are assumed to broadcast fake messages, even if no event of interest has been detected. Nodes are also assumed to be equipped with a semantically secure encryption algorithm, so that adversaries are unable to distinguish between the reports of events of interest and the fake transmissions by means of cryptographic tests.1 Furthermore, the network is assumed to be deployed in an unreachable environment and, therefore, the. Conservation of nodes‟ energy is a design requirement

2.2 Reproachful Model

The Reproachful model used in this paper is external, passive, and global. An external adversary is an adversary who does not control any of the nodes in the network. As opposed to active adversaries injecting their own traffic or jamming the network, a passive adversary is only capable of observing the network traffic. A global adversary is an adversary who can monitor the traffic of the entire network and can determine the node responsible for the initial transmission reporting an event of interest. The adversary is assumed to know the positions of all nodes in the networks. The adversary is also assumed to know the distribution of fake message transmissions. Furthermore, the adversary is assumed capable of observing nodes transmissions over extended periods of times and performing sophisticated statistical Context analysis to compare the observed transmission with the known distribution of fake messages. The adversary, however, is not assumed able to break the security of the encryption algorithm and distinguish the report of event of interests via cryptographic tests.

3. Proposed Frameworks for Statistical Context Source Obscurity

Source anonymity model for wireless sensor networks is being introduced. Intuitively, anonymity should be measured by the amount of information about the occurrence time and location of reported events an adversary can extract by monitoring the sensor network. The challenge, however, is to come up with an appropriate model that captures all possible sources of information leakage and a proper way of quantifying anonymity in different systems.

3.1 Intermission In distinguishability

Currently, statistical Context anonymity in sensor networks is modelled by the adversary's ability to distinguish between real and fake transmissions by means of statistical Context Context analysis. That is, given a series of transmissions of a certain node, the adversary must be unable to distinguish, with significant confidence, which transmission carries real information and which transmission is fake, regardless of the number of transmissions the adversary may observe. Consider now an adversary observing a sensor network over multiple time Intermissions. Assume that, during a given time Intermission, the adversary is able to notice a change in the statistical Context behavior of transmission times of a certain node in the network. This distinguishable change in the transmission behavior of the node can be indicative of the existence of real activities detected and reported by that node during that Intermission, even if the adversary was unable to distinguish between individual transmissions. Consequently, in many applications, modelling source

Anonymity in sensor networks by the adversary's ability to distinguish between individual transmissions is insufficient to guarantee location privacy. It must be the case that an adversary monitoring the network over multiple time Intermissions, in which some Intermissions contain real event transmissions and the others do not, is unable to determine, with significant confidence, which of the Intermissions contain the real traffic. Formally, the notion of Intermission in distinguishability can be defined as follows.

Definition 1: Let IF denotes a time Intermission without any real event transmission, and IR denotes a time Intermission with real event transmissions. The two time Intermissions are said to be statistical Context indistinguishable if the distributions of inter transmission times during these two Intermissions cannot be distinguished with significant confidence.

3.2 Intermission versus Event In distinguishability

This section illustrates the relation between the traditional anonymity notion and the proposed anonymity notion First, observe that as the length of Intermissions decreases, Intermission in distinguishability approaches event in distinguishability. If each Intermission consists of a single transmission, Intermission in distinguishability is equivalent to event in distinguishability. However, in the more general scenario, in which Intermissions contain more than a single transmission, Intermission in distinguishability implies in distinguishability of individual transmissions. To see this, assume a system satisfying Intermission in distinguishability but does not satisfy individual event in distinguishability. Since real and fake transmissions are distinguishable, given a fake Intermission and a real Intermission, the real Intermission can be identified as the one with the real transmission; a contradiction to the hypothesis that the system satisfies Intermission in distinguishability. That is, if Intermissions are indistinguishable, then individual events within them must also be indistinguishable. In fact, the notion of Intermission in distinguishability is strictly stronger than the traditional notion individual event in distinguishability. That is, while Intermission in distinguishability implies individual in distinguishability, the converse is not true in general.

3.3 Mapping Statistical Context Source Anonymity to Binary Hypothesis Testing

In binary hypothesis testing, given two hypothesis, H0 and H1, and a data sample that belongs to one of the two hypotheses the goal is to decide to which hypothesis the data sample belongs. In the statistical Context strong anonymity problem under Intermission in distinguishability, given an Intermission of intertransmission times, the goal is to decide whether the Intermission is fake or real That is, given two hypotheses , the goal of the adversary is to determine to which hypothesis the observed data belongs

4. Statistical Context Goodness of Fit Tests and the SSA Problem

In the literature, statistical Context source anonymity is shown to be achieved via the use of statistical Context goodness of fit tests. In this section, we describe the current use of statistical Context goodness of fit tests in designing anonymous sensor networks.

4.1 SSA Solutions Based on Statistical Context Goodness of Fit Tests

The statistical Context goodness of fit of an observed data describes how well the data fits a given statistical Context model. Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the statistical Context model in question. Such measures can be used, for example, to test for normality of residuals, to test whether two samples are drawn from identical distributions, or to test whether outcome frequencies

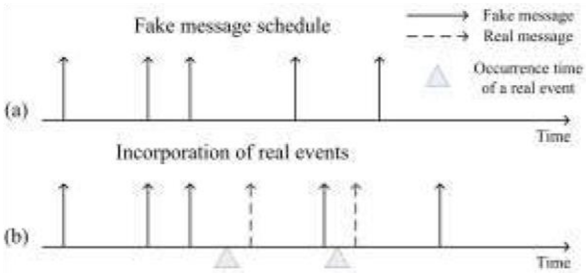
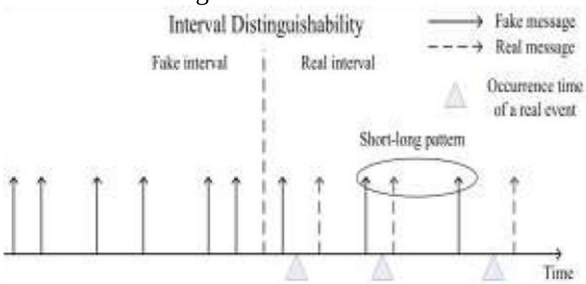


Fig. 3. Ref [1] B. Alomair, A. Clark, J. Cuellar, and R. Poovendran , 2010, (Fast Abstract).
An illustration of solutions based on statistical Context Goodness of fit tests. Nodes transmit fake messages According to a pre-specified probabilistic distribution and maintain a sliding window of inter-transmission times. When a real event occurs, it is transmitted as soon as possible under the condition that the samples in the sliding window maintain the designed distribution. The transmission following the real transmission is delayed to maintain the mean of the distribution of intertransmission times in the sliding window.



Fake events serve the same purpose they serve in algorithm AR, that is, they are used to hide the existence of real transmissions. Since there are no real events in fake Intermissions, however An illustration of Intermission distinguishability in the current state-of-the-art solutions based on statistical Context goodness of fit tests. Real events are transmitted sooner than what is determined by the probabilistic distribution, while the transmission following the real event is later than what is determined by the probabilistic distribution to fix the mean of the pre-defined distribution.

4.2 Correlation Analysis of Ssa Solutions Based On Statistical Context Goodness Of Fit Tests

The interpretation of the analysis is that each bit in a binary code representing a fake Intermission is independent of the all other bits, while bits in a binary code representing a real Intermission are correlated

4.3 Nuisance Parameters

In statistical Context decision theory, the term “nuisance parameters” refers to information that is not needed for hypothesis testing and, further, can preclude a more accurate decision making. When performing hypothesis testing of data with nuisance parameters, it is desired (even necessary in some scenarios) to find an appropriate transformation of the data that removes or minimizes the effect of the nuisance information before performing the hypothesis testing.

5. Projected Method

To improve anonymity, literature suggests introducing the same correlation of inter-transmission times during real Intermissions to inter-transmission times during fake Intermissions. That is, let the transmission procedure consists of two different algorithms AR and AF. In the presence of real events, algorithm AR is implemented. In the absence of real events (), algorithm AF is implemented. Algorithm AR is the same as the algorithm. In algorithm AF, the nodes generates two sets of events independently of each other: “dummy events”, dummy events are generated to be handled as if they are real events. That is, dummy events are generated independently of fake messages and, upon their generation, their transmission times are determined according to the algorithm. The purpose of this procedure is to introduce the same correlation of real Intermissions into fake Intermissions. That is, not only the two sequences of intertransmission times will be statistical Context indistinguishable means of statistical Context goodness of fit tests but also the binary codes representing fake and real Intermissions will have the same statistical Context behavior**.** The

Anderson-Darlington test is used in both algorithms, AR and AF, to determine the transmission times of real events and dummy events, respectively.

5.1 Anonymity Interpretations

a statistical Context framework using Java & MySQL. Since java is platform independent the same is used instead of traditional NS2 simulator. Using AD test in our algorithm AR and AF we have generated fake path by means of random values and real path will remain hidden. File will be encrypted and will be sent in various paths towards destination. Since message will be sent in various paths simultaneously adversaries will get confused. They will try to get the message and if they are on fake path they will fail in getting the message within a limited timeframe and message will reach destination successfully. Then adversary might try the other path thinking that it is real. Once message has been reached it will be useless decrypting it. Even if Adversaries are found to be on Real Path or if adversaries succeed in getting the real path they won't get the message since the code required to decrypt it, is with the recipient only and no one else. Message Packet Flow is encrypted in the binary format such that correlations analysis will fail to distinguish between real and fake path. Since the Message is sent at the same time via different paths events are indistinguishable resulting in anonymity of the node

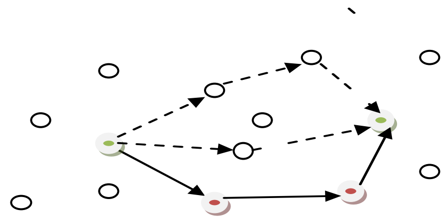


Fig4: Nodes in green color are Source and Destination respectively. All dotted lines are fake paths and the solid Line indicates the real path from source to destination.

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6. Conclusion

The Source Obscurity can be achieved using the given Framework and Binary hypothesis concept is being implemented.

This Statistical Context Framework can be improved further for a moving target using more efficient Cryptographic techniques.

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