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Secure Routing by using Authentication and Intrusion Detection in MANET

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ABSTRACT: Multimodal biometric technology provides potential solutions for continuous user-to-device authentication in high security mobile ad hoc networks (MANETs). Multimodal biometrics are deployed to work with intrusion detection systems (IDSs) to alleviate the shortcomings of unmoral biometric systems. Since each device in the network has measurement and estimation limitations, more than one device needs to be chosen, and observations can be fused to increase observation accuracy using Dempster–Shafer theory for data fusion. The system decides whether user authentication (or IDS input) is required and which biosensors (or IDSs) should be chosen, depending on the security posture. The decisions are made in a fully distributed manner by each authentication device and IDS.

KEYWORDAS: Secure routing, MANET security, Multimodal biometrics, Intrusion detection systems, Dempster–Shafer theory, Continuous authentication, Data fusion

I. INTRODUCTION

With recent advances in mobile computing and wireless communications, mobile ad hoc networks (MANETs) are becoming more attractive for use in military applications. Supporting security-sensitive applications in hostile environments has become an important research area for MANETs since MANETs introduce various security risks due to their open communication medium, node mobility, lack of centralized security services, and lack of prior security association. In high-security MANETs, user authentication is critical in preventing unauthorized users from accessing or modifying network resources. Because the chance of a device in a hostile environment being captured is extremely high, authentication needs to be performed continuously and frequently [1]. The frequency depends on the situation severity and the resource constraints of the network [1]. User authentication can be performed by using one or more types of validation factors: knowledge factors, possession factors, and biometric factors. Knowledge factors (such as passwords) and possession factors (such as tokens) are very easy to implement but can make it difficult to distinguish an authentic user from an impostor if there is no direct connection between a user and a password or a token. Biometrics technology, such as the recognition of fingerprints, irises, faces, retinas, etc., provides possible solutions to the authentication problem [2]. Using this technology, individuals can be automatically and continuously identified or verified by their physiological or behavioral characteristics without user interruption.

In addition, intrusion detection systems (IDSs) are important in MANETs to effectively identify malicious activities and so that the MANET may appropriately respond. IDSs can be categorized as follows [3]: 1) network-based intrusion detection, which runs at the gateway of a network and examines all incoming packets; 2) router-based intrusion detection, which is installed on the routers to prevent intruders from entering the network; and 3) host-based intrusion detection, which receives the necessary audit data from the host's operating system and analyzes the generated events to keep the local node secure. For MANETs, host-based IDSs are suitable since no centralized gateway or router exists in the network.

Some research has been done in continuous biometric-based authentication. In [1] biometric-based continuous authentication is addressed. Some research has been done in combining intrusion detection and continuous authentication in MANETs. In the framework proposed in [4], multimodal biometrics are used for continuous authentication, and the IDSs are modeled as sensors to detect the system's security state. The framework is shown to be effective as it combines an important prevention-based security approach and a detection-based approach. However, the scheme proposed in [4] is a centralized scheme, in which a centralized controller is needed to schedule authentication and intrusion detection, and is more suitable for a single node rather than a network with distributed nodes with random mobility. Since a centralized controller may not be available in MANETs and the centralized scheme can be

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computationally intractable, it is difficult to implement the scheme proposed in [4] for a MANET with distributed nodes.

Several distinct features of the proposed scheme are given here.
1) In the proposed scheme, multimodal biometrics are deployed to alleviate the shortcomings of unimodal biometric systems.
2) Since each device in the network has measurement and estimation limitations, more than one device can be chosen, and their observations can be fused to increase observation accuracy. Dempster–Shafer theory is used for data fusion.
3) The system decides whether a user authentication (or IDS) is required and which biosensors (or IDS) should be chosen, depending on the security posture. The decisions are made in a fully distributed manner by each authentication device and IDS. Since there is no need for a centralized controller, the proposed scheme is more generic and flexible than a centralized scheme in MANETs. Nodes can freely join and leave from the network.
4) Since a biometric authentication process requires a large amount of computation, the energy consumption is significant. Moreover, due to the dynamic wireless channels in MANETs, the energy consumption for data transmissions is dynamically changing (e.g., because of power control). Therefore, in the proposed scheme, energy consumption is also considered to improve the network lifetime.
Section II introduces multimodal biometric-based user authentication and intrusion detection in MANETs. Section III shows how to use Dempster–Shafer theory for the fusion of IDSs and biometric sensors. Section IV shows Conclusion and future work.

II. MULTIMODEL BIOMETRIC-BASED USER AUTHENTICATION AND INTRUSION DETECTION

A. Biometric-Based User Authentication

Biometric technology can be used to automatically and continuously identify or verify individuals by their physiological or behavioral characteristics. Biometric systems include two kinds of operation models: 1) identification and 2) authentication. In the proposed system, the biometric systems operate in authentication mode (one-to-one match process) to address a common security concern: positive verification (the user is whoever the user claims to be). Based on a comparison of the matching score between the input sample and the enrolled template with a decision threshold, each biometric system outputs a binary decision: accept or reject. In most real-world implementations of biometric systems, biometric templates are stored in a location remote to the biometric sensors. The frequency of FA errors and of FR errors is called FA rate (FAR) and FR rate (FRR), respectively. The FAR can be used to measure the security characteristics of the biometric systems since a low FAR implies a low possibility that an intruder is allowed to access the system/network. In tactical MANETs, failure in user authentication might result in serious consequences. Hence, more than one biometric sensor is used at each time period in our system to increase the effectiveness of user authentication.

B. Intrusion Detection Systems

Intrusion detection is a process of monitoring computer networks and systems for violations of security and can be automatically performed by IDSs. Two main technologies of identifying intrusion detection in IDSs are given as follows: misuse detection and anomaly detection [5]. Misuse detection is the most common signature-based technique, where incoming/outgoing traffic is compared against the possible attack signatures/patterns stored in a database. If the system matches the data with an attack pattern, the IDS regards it as an attack and then raises an alarm. The main drawback of misuse detection is that it cannot detect new forms of attacks. Anomaly detection is a behavior-based method, which uses statistical analysis to find changes from baseline behavior. This technology is weaker than misuse detection but has the benefit of catching the attacks without signature existence [5]. Multiple algorithms have been applied to model attack signatures or normal behavior patterns of systems. Three common algorithms are naive Bayes, artificial neural network (ANN), and decision tree (DT). A naive Bayes classifier is based on a probabilistic model to assign the most likely class to a given instance. ANN is a pattern recognition technique with the capacity to adaptively model user or system behavior. DT, which is a useful machine learning technique, is used to organize the attack signatures into a tree structure. Most of the IDSs only use one of the preceding algorithms. IDSs can make two kinds of errors: false positive (FP) and false negative (FN). FNs result in security breaches since intrusions are not detected, and therefore, no alert is raised. The false negative rate (FNR) can be used to measure the secure characteristics of the IDSs since a low FNR implies a low possibility that intrusion occurs without detection.

C. System Model

Assume that a MANET has a continuous biometric-based authentication system with $N - W$ biosensors and W Intrusion detection systems, which have the ability to detect intrusions. The IDSs are also modeled as sensors, bringing the total

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number of sensors to N. Without loss of generality, we assume that some nodes have one or more biosensors, and some have no biosensor due to the heterogeneity of network nodes in the MANET. Similarly, some nodes are equipped with the IDS, and some are not equipped with the IDS. The total number of network nodes in the MANET is not directly related to the number of sensors.

The system can perform two kinds of operations: 1) intrusion detection and 2) user authentication. The IDSs can operate at all time instants to monitor the system. Authentication may be executed at every time instant as well. However, intrusion detection and authentication may consume a large amount of energy, which is a concern for energy-constrained devices in MANETs. Moreover, performing authentication and intrusion detection may lead to security information leakage to an adversary monitoring communications and network behavior. Each sensor monitors its local environment and not other sensors'. Then, their observations can be fused to increase observation accuracy using Dempster–Shafer theory. The number of sensors chosen is determined by the required level of network performance.

III. DATA FUSION OF BIOMETRIC SENSORS AND INTRUSION DETECTION SYSTEMS

In the proposed scheme, L sensors are chosen for authentication and intrusion detection at each time slot to observe the security state of the network. To obtain the security state of the network, these observation values are combined, and a decision about the security state of the network is made. However, since there is some probability that a given sensor might either be in a compromised state or have made an inaccurate assessment, it is possible that this sensor has contributed an unreliable observation. It can be quite difficult to ascertain which observers are compromised. Type-I classifiers output single-class labels (SCLs). Majority voting and behavior-knowledge space are two most representative methods for fusing SCL classifiers. Majority voting can operate under the assumption that most of the observing nodes are trustworthy. Type-II classifiers output class rankings. Two major fusion methods of type-II classifiers' outputs are based on either a class set reduction (CSR) or a class set reordering (CSRR). CSR methods try to find the minimal reduced class set, in which the true class is still represented. CSRR methods try to increase the true class ranking as high as possible. Type-III classifiers produce so-called soft outputs, which are the real values in the range. Fusion methods for type-III classifiers try to reduce the uncertain level and maximize suitable measurements of evidence. Fusion methods include Bayesian fusion methods, fuzzy integrals, Its essential idea is that an observer can obtain degrees of belief about a proposition from a related proposition's subjective probabilities. The motivation for selecting Dempster–Shafer theory to solve the fusion problem in our proposed scheme is given as follows.

1) It has a relatively high degree of theoretical development for handling uncertainty or ignorance.
2) It provides a convenient numerical procedure for combining disparate data obtained from multiple sources.
3) It is widely used in various applications.

arbitrary node a. That is,Ω = {secure, compromised}, which presents that node a has two security states: 1) secure state and 2) compromised state. Any hypothesis H refers to a subset of Ω for which the neighboring biometric sensors and IDSs can present evidence. The set of all possible subsets of Ω, including itself and the null set, is called a power set and is designated as 2Ω.

IV. CONCLUSION AND FUTURE WORK

Combining continuous authentication and intrusion detection can be an effective approach to improve the security performance in high-security MANETs. In the proposed scheme, the most suitable biosensors for authentication or IDSs are dynamically selected based on the current security posture and energy states. To improve upon this concept, Dempster–Shafer theory has been used for IDS and sensor fusion since more than one device is used at each time slot. Further work is in progress to reduce the computation complexity of the proposed scheme by searching for some structured solutions to the distributed scheduling problem. In addition, plan to consider more nodes' states, such as mobility and wireless channels, in making the scheduling decisions in MANETs.

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