Intrusion Detection System for Pervasive Computing Enviornments

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Abstract
Pervasive Computing Environment consists of various casually accessible, mobile embedded, handheld devices capable for enviornment sensing around it and reacting intelligently to simplify the User Interface. These devices are scattered everywhere at offices, homes, stores, classrooms etc and mostly they are connencted to ad-hoc networks and Internet works at backbone to provide 24x7 round the clock online connectivity. Various Access Control Mechanisms are sometimes unable to provide complete security to these pervasive computing devices as in infrastructure based networks. The addition of Pervasive Computing Devices to Infrastructure based networks makes the Intrusion Detection harder. In this Research Paper, the various challenges and charateristics of Intrusion Detection in Pervasive Computing Devices are discusses along with Mobile-Agent based solution for a network enviornment which consists both Pervasive and Infrastructure based computing devices.

Keywords
Pervasive Computing, Intrusion Detection, Network Security, Mobile Agents.

I. Introduction

In the past few years, Pervasive Computing [1] applications have grown tremendously because of recent developments in portable, low-cost, lightweight devices with faster short range and low power Wireless Communications networks. Pervasive Computing enviornment consists of various small, frequently mobile, handheld and portable smart devices connected to an ad-hoc network structure [2, 3]. These devices are fully efficient in sensing the enviornment around them and reacting intelligently to the changes in user context in order to simplify the user activities. Security issues increase in pervasive computing enviornments as it provides a user access to computing resources and services from any location and at any point of time [1, 4]. Lightweight Pervasive Computing Devices like PDAs (Personal Digital Assistants), Mobile Phones and Laptops are very portable devices and can be carried anywhere by the user. These portable devices can be connected to the Internet via Wired or Wireless Technology. Wireless Technology like Bluetooth [5], Wi-Fi-, WiMAX provide Internet access to handheld devices through various access points.

Various Access Control Mechanisms fail to protect these devices from all types of Information attacks making them vulnerable to attacks from the outside world. In addition to this, Pervasive Computing Devices are more prone to large types of Software Attacks like DoS Attacks (Denial of Service Attacks. When these devices are connected to Infrastruture based networks lik Office LANs, they also become vulnerable to attacks which are Infrastructure based. So there is an utmost requirement for Intrusion Detection System (IDS) to detect suck kinds of attacks. Various Researchers haveconducted various type of researches in Intrusion Detection carried out for Traditional Networks which comprise of Computers, Routers, Switeches, IP Phones, Firewalls. Addition of mobile, handheld and portable pervasive computing nodes into existing fixed infrastructure based networks increase the hetrogeneity of the resulting network making the problem of Intrucsion Detection even harder.

In this Research Paper, we discuss the various characteristics of Intrusion Detection for Pervasive Computing enviornments in addition to the detailed descption of Mobile Agent based Intrusion Detection System (IDS) to be deployed in Pervasive Computing Enviornment.

We develop a prototype of a Mobile Agent based distributed IDS [6] with special focus on Infrastructure based networks. In this paper, we extend the IDS for pervasive computing environments. In the infrastructure based network, the IDS uses a set of software entities called mobile agents that can move from one node to another node within a network, and perform the task of aggregation and correlation of the intrusion related data that it receives from another set of software entities called Static Agents. The Static Agents are installed on every node of the network to detect al types of suspicious activities in all nodes. But in remote and small pervasive computing nodes like PDSs, Handheld Devices, Static Agents are not installed. In them only Mobile Agents are installed. Mobile Agents have the ability to move the execution state of state of resource intensive intrusion detection functions from handheld/ portable pervasive computing nodes to other suitable nodes with sufficient memory and CPU speed. Mobile agents can operate autonomously and support heterogeneous platforms. The IDS discussed in this paper utilizes the above-mentioned beneficial features offered by mobile agent technology to perform intrusion detection for the pervasive computing environments.

This organization of this Research Paper is as follows. Section II presents other approaches related to the work done in this research. Section III describes the characteristics of IDSs for pervasive computing environments. Section IV presents our approach for intrusion detection. Section V concludes the paper and discusses some future work.

II. Related Work

The eBiquity-Research group [7, 8] views intrusion detection to be "Distributed and Collaborative" process. Their research work focus on enabling secure access and service discovery in pervasive computing using a security infrastructure built upon Public Key Infrastructure (PKI) for user authentication, non-repudiation, and access control. Distributed trust management is used to complement existing PKI and role based access control security mechanisms. This solution provides a flexible security framework for pervasive computing environments. The eBiquity research projects do not discuss about intrusion detection in pervasive computing devices like PDAs [9]. Agents for intrusion detection are placed in every node of the mobile ad-hoc network. These agents detect any anomaly in the node by using local audit traces and also communicate with agents of neighboring nodes to detect distributed attacks on the whole network. The focus in this work

is more on intrusions in mobile ad-hoc network routing protocols such as route logic compromise and traffic pattern distortion. In our work, we deal with intrusions on pervasive computing environments consisting of heterogeneous mobile and static nodes with varying device capabilities. We have used mobile agents in mobile wireless nodes that operate autonomously for intrusion detection instead of placing agents permanently in the nodes that collaboratively detect intrusion [9].

The following work are on mobile agent based IDSs but closely related to infrastructure based networks. They do not discuss about the intrusion detection on pervasive computing devices. The Intrusion Detection Agent (IDA) system [10] consists of sensors running in every monitored host that report Marks Left by Suspected Intruder (MLSI) and a central manager responsible for dispatching tracing agents to the host whose sensor reports an MLSI. The tracing agents gather information related to intrusion from the sensors and send it to central manager for analysis. In our IDS, mobile agents that are similar to tracing agents used in IDA system, have dual functions: gathering intrusion related data from every host and analyzing the gathered data by itself instead of sending it to a central manager for data analysis. Mobile agents are engaged to apply human immune system model for intrusion detection [11]. This IDS detects any deviation in normal behavior due to presence of foreign bodies in a host. The intelligent agents for intrusion detection project [12] have developed IDS using distributed multiple layers of lightweight intelligent mobile agents that apply data mining techniques to detect intrusions.

III. Intrusion detection system (ids) for pervasive computing-characteristics

This section of Research Paper discusses the security threats in pervasive computing environments that justify the need for IDS. We also discuss the challenges and different approaches for intrusion detection in pervasive computing environments.

Privacy, trust, and availability are important in pervasive computing [4, 14]. Handheld devices like PDAs [13] can be used as storage of important and confidential information of their users. A stolen PDA can reveal such private information to others. Physical attacks like loss/theft, tampering of hardware are more common with pervasive computing devices. Software attacks like exploiting a flaw such as buffer overflow in application software or security loopholes, computer viruses, DOS attacks, wireless packet sniffing, and unauthorized access are also targeted against pervasive computing devices. For example: a) macro viruses infecting Microsoft office running in PDAs, Palm OS viruses, b) misconFig.d Bluetooth PDA can allow any device to initiate connection to it due to ad-hoc communication between devices. The DOS attacks can make pervasive computing devices unavailable.

The constant interaction between pervasive computing devices also needs increased trust. However, some of these devices may also operate in a hostile or untrusted environment. Much of the research on security related to pervasive computing carried until now have been on providing secure infrastructure based on trust management and access control mechanisms like role based access control, public key infrastructure, and biometrics [7, 8]. The access control mechanisms, encrypted communication lines, and trust management offer first layer of defense that can sometimes fail to protect a device completely against the software attacks discussed earlier in this section. Hence, we need IDS to detect and respond to these attacks. The intrusion detection techniques used for infrastructure based networks cannot be directly applied to pervasive computing environments. The reasons are as follows: First, there is no single point in the network where IDS can be placed to monitor the network traffic since devices are distributed at different locations in a pervasive computing scenario. Fig. 1 shows an ad-hoc network of pervasive computing devices consisting of a laptop computer, PDA and mobile phone. All of these devices are mobile, may present at any location, and are connected to each other through short range wireless medium.

Second, normal desktop computers or servers have enough computing resources for hosting IDS sensors that monitors the host or the network. Most of pervasive computing devices have limited computing resources like memory, processor speed, network bandwidth, and are mostly battery powered devices. Hence, these devices are not capable of hosting a complete IDS sensor.

Third, the devices of pervasive computing environments run different context-aware applications. The IDS may have to consider the context in which the audit data were used to detect any anomalous behavior. Therefore, a pervasive computing environment requires a different approach for intrusion detection.

Some of these are: 1) mining of pervasive databases to detect intrusion patterns; 2) lightweight software entities placed in every device to monitor intrusion attempts; and 3) intrusion detection circuitry built to detect intrusion and corrupted sensors. We propose the usage of lightweight mobile software entities called mobile agents for performing intrusion detection. The detailed description of this approach along with the architecture of the proposed IDS is discussed in the next section.

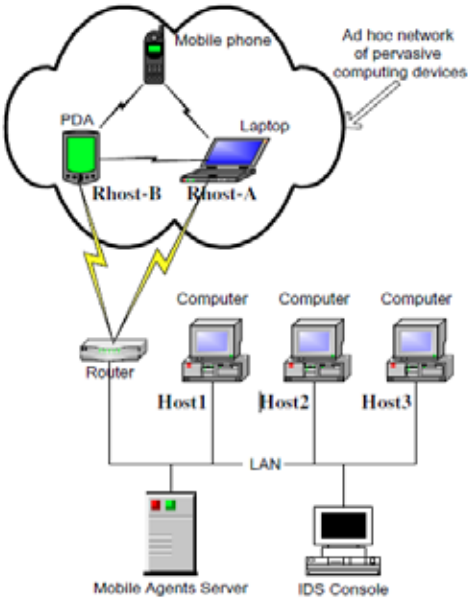

Fig.1: A typical pervasive computing environment with IDS

IV. Approach for this research paper

The presented Intrusion Detection System (IDS) is designed by keeping in mind the notion of heterogeneity and scarcity of computing resources in a pervasive computing environment. The proposed IDS operates in a computing environment consisting of a local infrastructure based network (desktop computers, servers, and routers), which is connected to a remote ad-hoc network of lightweight handheld or portable pervasive computing devices (PDAs, laptop computers, and mobile phones). Fig. 1 shows the operating environment of the IDS made up of computers

(Host1, Host2, Host3) connected to local network, remote laptop computer (Rhost-A), and remote PDA (Rhost-B). The proposed IDS is made up of static and mobile agents. The components are as follows: Static Agents (SA), Mobile Agents (MA), Mobile Agents Server (MAS), The Victim Host List (VHL), Mobile Hosts List (MHL), and Alerting Agent (AA). The architecture and the working environment of IDS are shown in Fig. 2. An SA installed in every host of the LAN (Host1, Host2, and Host3), generates an event when a suspicious activity is detected. The SA sends events related to such behavior of the host to the MAS, which then creates an MA to handle the task of detecting intrusions based on such activities. The MAS component resides in a separate mobile agent's server machine as shown in Fig. 1. The VHL stores the IP addresses of hosts of the LAN in which suspicious activity is detected. The MHL contains information of all the remote hosts that are currently connected to the local network as indicated by dotted lines in the Fig. 2. The MAs are of two types: Thick MA and Thin MA.

Thick MAS are meant for local nodes (Host1, Host2, and Host3) while thin MAS are used for remote nodes (Rhost-A, Rhost-B). A thick MA gathers data related to intrusion from SAs running in those hosts listed in VHL, correlates and aggregates the gathered data, generates alerts on the detection of any attack, and finally returns to the MAS. The solid lines with arrowhead in Fig. 2 shows the movement of MAS in the local network and its interaction with Sas installed in the hosts listed in the VHL. However, in remote (Rhost-A, Rhost-B) nodes, the SAs are not installed to avoid utilization of the limited resources like battery power, memory, and processor speed available in the remote nodes.

The MAs dispatches a thin MA to every host listed in the MHL. The MA dispatched to remote node is responsible for detecting any suspicious activity in the remote node. The MA gathers audit trail left by the applications along with any context information from the remote nodes for detecting any anomaly or intrusion at the remote node, and carries it back to the MAS. The MA performs the analysis of the gathered intrusion data at the MAS and thus reduces the resource utilization in the remote nodes. The dashed lines with arrowhead originating from the MAs in Fig. 2 show the movement of MAS through wireless medium to the nodes in the remote network. An AA module receives generated alerts from MAS and displays the alerts to the security administrator. The AA component resides in the computer that hosts the IDS console as shown in Fig. 1. After an MA is dispatched the MAS waits for that MA to return in order to prevent the MAS from dispatching the MA for the same task twice. The components of the IDS are described in detail in the following subsections.

A. Static Agents

Every monitored host in the LAN has a static agent component. Static agents act like host monitors generating events to indicate attacks, and these events are sent to MAS. Each event carries information ofthe probable type of attack. For example, an SA identifies failed password guessing attempts as a suspicious activity, and an event is generated to check for doorknob-rattling attack [15]. An SA is a multithreaded program where each thread monitors the host for different classes of attacks. These threads run at every administrator conFig.d time interval to check the log files for any trace of attack. The generated events are sent as a message to a remote object in the MAS whenever a trace of an attack is detected. An SA is responsible for triggering the movement of an MA within the local network. The threads of an SA run at a lower priority level and hence do not cause slowdown in the execution of other programs at the host system. The SA contains objects specific to attack(s) that are responsible for parsing the log files, checking for intrusion related data pattern in log files, separating data related to the attack from the rest of the data, and formatting the data as required by an MA.

B. MA Server (MAS)

The MAS is a repository of all the MAs used by the IDS. It is responsible for dispatching the MAs to target nodes both local and remote. An MAS component contains two other components MHL and VHL that decide the itinerary of an MA. In the local network, the MAS decide about the MA that has to be dispatched according to the attack event generated by SA. The object request broker module within the MAS contains objects that can receive messages from SA(s) about the detection of suspicious activities in some of the host(s) of the network. These objects are then responsible for creating an MA and sending it to the victim host(s).

Victim Host List (VHL) maintains separate lists to store the IP addresses of all the hosts that are subjected to the same types of attacks. For example, all the hosts subjected to doorknob rattling attack are maintained as a separate list in VHL. VHL provides the itinerary for the movement of an MA within the local network. When MAS receives an event message from an SA, the IP address of that SA host is added to the respective list in the VHL. All the MAs originate and return finally to this component. The MHL component within the MAS keeps track of all the remote hosts currently connected to the network using some third party applications that are used for management of remote mobile nodes. It stores the time of connection, device type, and IP address information of the remote node. The device type information helps in deciding if a thick or thin MA has to be dispatched. The MAS dispatches a thin MA to every remote node at regular interval of time. A security administrator depending on the device type can conFig. the interval at which the thin MAs are dispatched to remote nodes. These thin MAs use MAS for performing analysis of the audit data gathered from visited remote nodes.

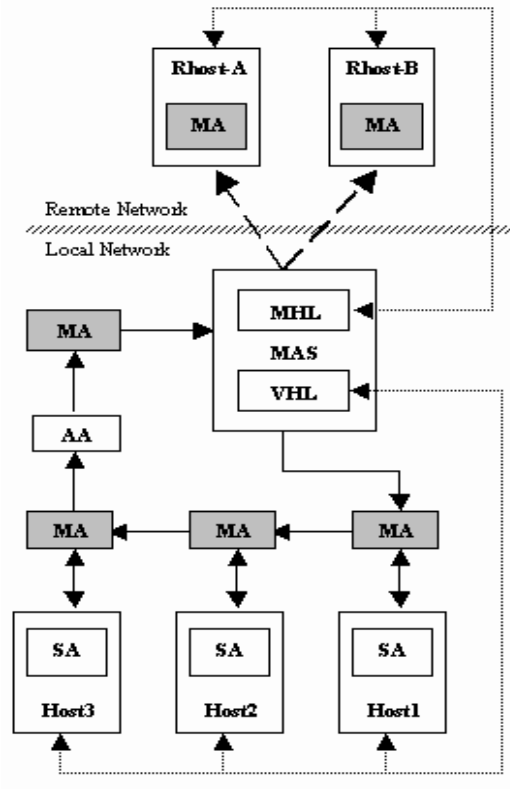

Fig. 2: The IDS architecture

C. Mobile Agent (MA)

Mobile agents are responsible for collecting evidences of an attack from all the attacked hosts and for further analysis of the gathered data. The advantage of using an MA is that it can function autonomously after it is dispatched without any control from other components. An MA can operate even if the network is disconnected. This property suits pervasive computing nodes that are usually intermittently connected to Internet or office LAN. The MAs are of two types: thick MA and thin MA. Thick MAs are for nodes with sufficient resources to support a mobile agent platform. In the local network, the thick MAs are used since the nodes are usually computers or servers capable of hosting an agent platform. The thick MAs take data from all the SAs running in the hosts listed in the VHL, correlate and aggregate the data, and generate any alerts on the detection of any intrusion activity in these hosts. Thin MAs have low system footprint and capable of running in small resource constrained nodes. Thin MAs are developed considering nodes like PDAs and mobile phones that have OS, memory and processor speed which cannot support a complete mobile agent platform. For remote networks, a separate thin MA is dispatched for every node present in the MHL list. Thin MAs contain only the code to parse audit trail left by application software, gather intrusion related data, format them, and move the data to MAS. The data gathered by a thin MA is analyzed at the server hosting the MAS component. Thus it relieves the remote nodes with limited memory and CPU speed from resource intensive intrusion data analysis. Alerts are generated on the detection of any traces of attack in the analyzed data.

D. Alerting Agent (AA)

An alerting agent receives alerts generated from both thick and thin MAs. It stores the information gathered from an MA in a separate log file for further analysis. An AA consists of an IDS console that can be used by the security administrator to view alerts generated from the MAs. The AA is responsible for preventing multiple alerts being generated for the same attack, and for suitably formatting the data to provide complete information about an attack to the administrator.

V. Implementation of MAs

Voyager [19] is used as the mobile agent platform for implementing the thick MAs, where each thick MA contains code only for detecting a specific type of attack resulting in small size code. Voyager supports only Desktop computers and is not suitable for implementing the thin MAs. A thin MA utilizes fewer resources in the remote node compared to a thick MA. The most widely used open source mobile agent platforms [5, 16, 17, 18] currently available for Handheld/Portable computing devices are JADELEAP and MicroFIPA-OS. MicroFIPA-OS is mainly targeted at "Compaq IPAQ handheld computers". JADE-LEAP supports large variety of devices and has the smallest system footprint. It currently supports PDAs, Java-enabled mobile phones in addition to desktop computers. JADE-LEAP supports TCP/IP over GSM and IEEE 802.11 Wireless LAN protocols. Therefore, JADE-LEAP is an intuitive choice for mobile agent platform for the pervasive computing devices of our IDS.

VI. Conclusions and Future Work

We have presented the architecture and operation of an IDS based on mobile agents technology for a network of pervasive computing devices connected to infrastructure based network. This IDS uses static and mobile intrusion detection agents. The static agents are confined to local devices but the mobile agents are used at both local (thick MA) and remote mobile nodes (thin MA). The main advantage of this approach is that mobile agents can move resource intensive intrusion detection functions from nodes with limited computing resources to other suitable nodes with sufficient memory and CPU speed. The IDS can be easily extended by adding new MAs for detecting new attacks, or the existing MAs can be modified for better detection capability, resulting in a highly modular and extendable architecture. A prototype IDS is being implemented using JADELEAP on Dell Axim X30 Pocket PCs and Voyager on desktop computers. In future, we will extend this prototype to support variety of other devices like Palm OS-based PDAs and Java enabled mobile phones.

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