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(54) **PREDICTING AND PREVENTING AN ATTACKER'S NEXT ACTIONS IN A BREACHED NETWORK**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(Continued)

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H04L 29/06	(2006.01)
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(52) **U.S. Cl.**

CPC ***H04L 63/1441*** (2013.01); ***G06F 21/55*** (2013.01)

(58) **Field of Classification Search**

CPC H04L 63/1441

See application file for complete search history.

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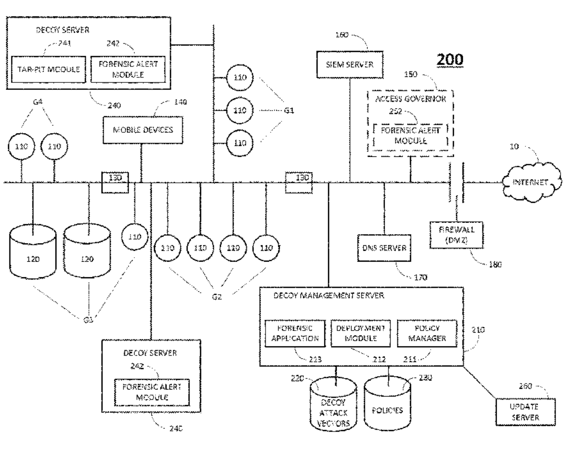
(57) **ABSTRACT**

A method for cyber security, including detecting, by a management server, a breach by an attacker of a resource within a network of resources, wherein access to the resources via network connections is governed by a firewall, predicting, by the management server, which servers in the network are compromised, based on connections created during the breach, and creating, by the management server, firewall rules to block access to the predicted compromised servers from the breached resource, in response to said predicting which servers.

10 Claims, 3 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/172,251, filed on Jun. 8, 2015, provisional application No. 62/172,253, filed on Jun. 8, 2015, provisional application No. 62/172,255, filed on Jun. 8, 2015, provisional application No. 62/172,259, filed on Jun. 8, 2015, provisional application No. 62/172,261, filed on Jun. 8, 2015.

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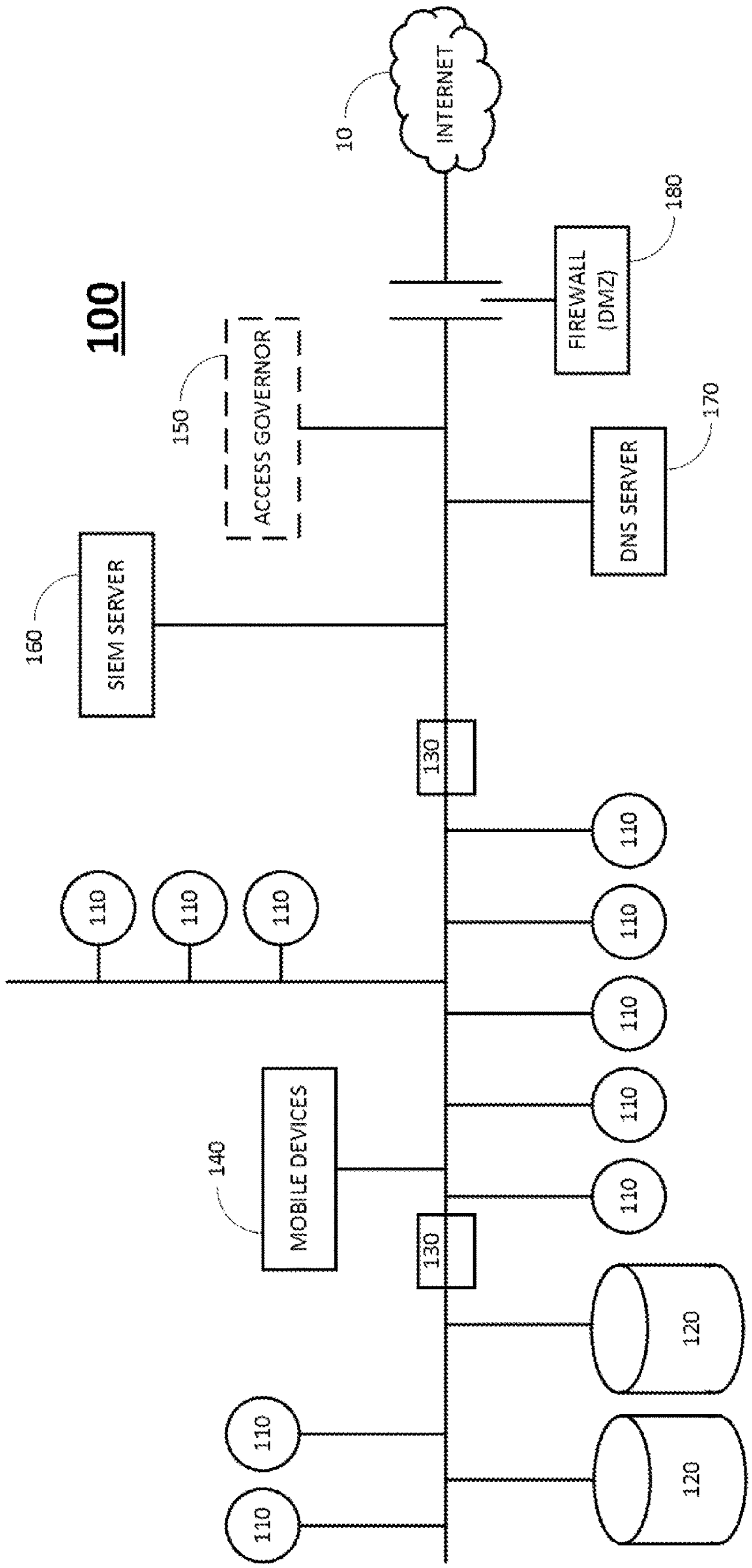

FIG. 1
(PRIOR ART)

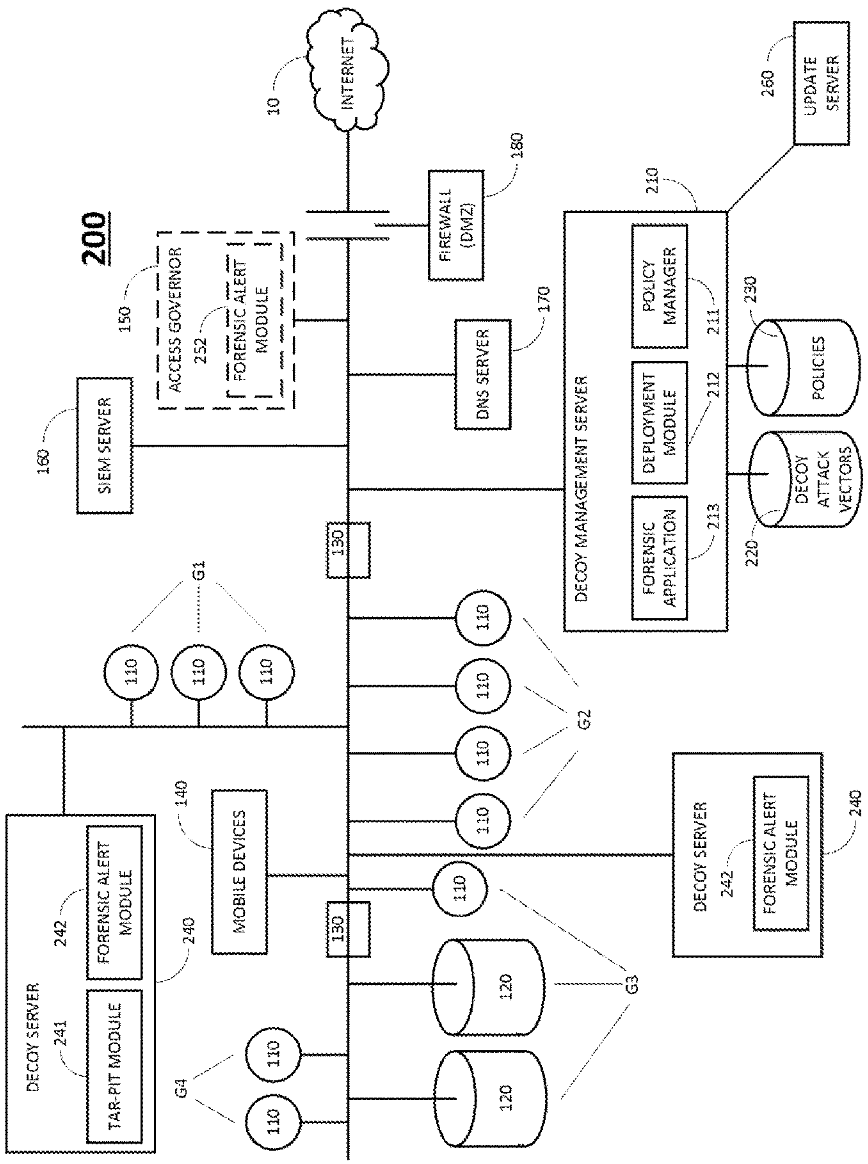
200
10
INTERNET
180
FIREWALL (DMZ)
150
ACCESS GOVERNOR
252
FORENSIC ALERT MODULE
160
SIEM SERVER
170
DNS SERVER
210
DECOY MANAGEMENT SERVER
211
POLICY MANAGER
212
DEPLOYMENT MODULE
213
FORENSIC APPLICATION
220
DECOY ATTACK VECTORS
230
POLICIES
260
UPDATE SERVER
130
110
G1
G2
G3
G4
120
140
MOBILE DEVICES
240
DECOY SERVER
241
TAR-PIT MODULE
242
FORENSIC ALERT MODULE

FIG. 2

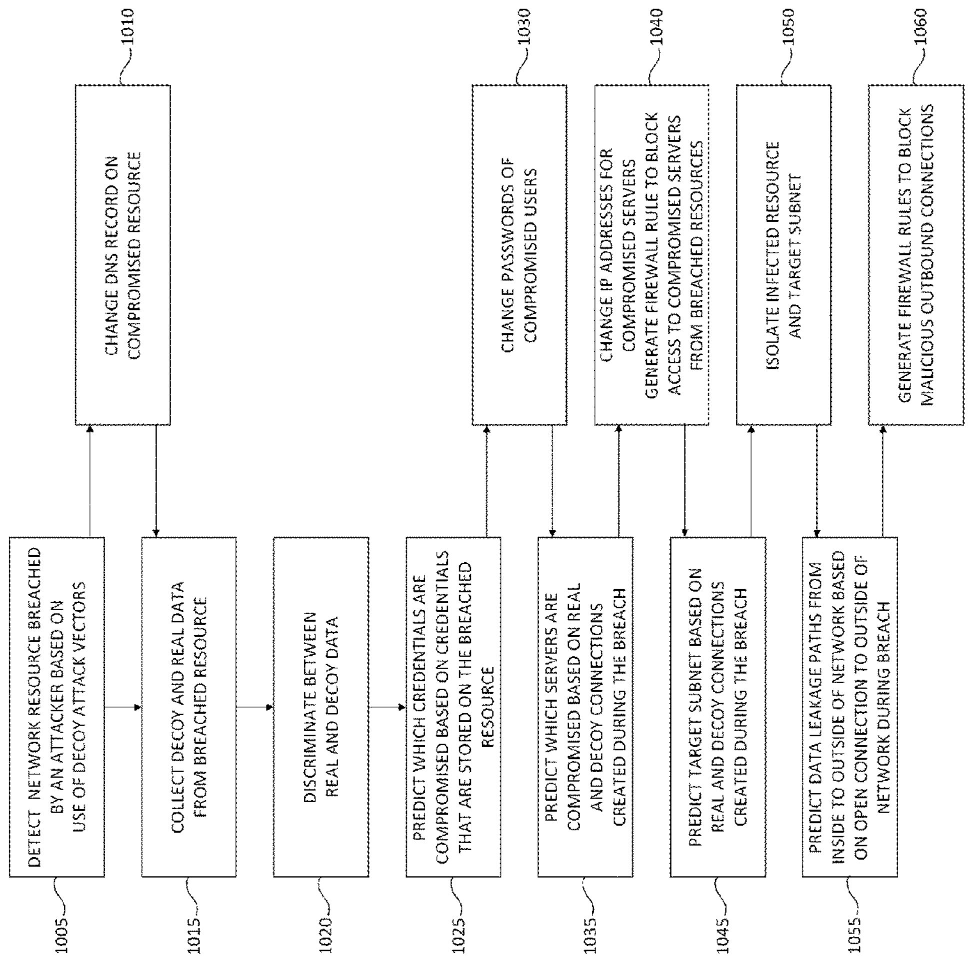
1005
DETECT NETWORK RESOURCE BREACHED BY AN ATTACKER BASED ON USE OF DECOY ATTACK VECTORS
1010
CHANGE DNS RECORD ON COMPROMISED RESOURCE
1015
COLLECT DECOY AND REAL DATA FROM BREACHED RESOURCE
1020
DISCRIMINATE BETWEEN REAL AND DECOY DATA
1025
PREDICT WHICH CREDENTIALS ARE COMPROMISED BASED ON CREDENTIALS THAT ARE STORED ON THE BREACHED RESOURCE
1030
CHANGE PASSWORDS OF COMPROMISED USERS
1035
PREDICT WHICH SERVERS ARE COMPROMISED BASED ON REAL AND DECOY CONNECTIONS CREATED DURING THE BREACH
1040
CHANGE IP ADDRESSES FOR COMPROMISED SERVERS
GENERATE FIREWALL RULE TO BLOCK ACCESS TO COMPROMISED SERVERS FROM BREACHED RESOURCES
1045
PREDICT TARGET SUBNET BASED ON REAL AND DECOY CONNECTIONS CREATED DURING THE BREACH
1050
ISOLATE INFECTED RESOURCE AND TARGET SUBNET
1055
PREDICT DATA LEAKAGE PATHS FROM INSIDE TO OUTSIDE OF NETWORK BASED ON OPEN CONNECTION TO OUTSIDE OF NETWORK DURING BREACH
1060
GENERATE FIREWALL RULES TO BLOCK MALICIOUS OUTBOUND CONNECTIONS

FIG. 3

PREDICTING AND PREVENTING AN ATTACKER'S NEXT ACTIONS IN A BREACHED NETWORK

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/175,054, now U.S. Pat. No. 9,690,932, entitled PREDICTING AND PREVENTING AN ATTACKER'S NEXT ACTIONS IN A BREACHED NETWORK, and filed on Jun. 7, 2016 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen, Sharon Sultan and Matan Kubovsky, the contents of which are hereby incorporated herein in their entirety. U.S. patent application Ser. No. 15/175,054 is a non-provisional of U.S. Provisional Application No. 62/172,251, entitled SYSTEM AND METHOD FOR CREATION, DEPLOYMENT AND MANAGEMENT OF AUGMENTED ATTACKER MAP, and filed on Jun. 8, 2015 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen and Sharon Sultan, the contents of which are hereby incorporated herein in their entirety.

U.S. patent application No. 15/175,054 is a non-provisional of U.S. Provisional Application No. 62/172,253, entitled SYSTEM AND METHOD FOR MULTI-LEVEL DECEPTION MANAGEMENT AND DECEPTION SYSTEM FOR MALICIOUS ACTIONS IN A COMPUTER NETWORK, and filed on Jun. 8, 2015 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen and Sharon Sultan, the contents of which are hereby incorporated herein in their entirety.

U.S. patent application Ser. No. 15/175,054 is a non-provisional of U.S. Provisional Application No. 62/172,255, entitled METHODS AND SYSTEMS TO DETECT, PREDICT AND/OR PREVENT AN ATTACKER'S NEXT ACTION IN A COMPROMISED NETWORK, and filed on Jun. 8, 2015 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen and Sharon Sultan, the contents of which are hereby incorporated herein in their entirety.

U.S. patent application Ser. No. 15/175,054 is a non-provisional of U.S. Provisional Application No. 62/172,259, entitled MANAGING DYNAMIC DECEPTIVE ENVIRONMENTS, and filed on Jun. 8, 2015 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen and Sharon Sultan, the contents of which are hereby incorporated herein in their entirety.

U.S. patent application Ser. No. 15/175,054 is a non-provisional of U.S. Provisional Application No. 62/172,261, entitled SYSTEMS AND METHODS FOR AUTOMATICALLY GENERATING NETWORK ENTITY GROUPS BASED ON ATTACK PARAMETERS AND/OR ASSIGNMENT OF AUTOMATICALLY GENERATED SECURITY POLICIES, and filed on Jun. 8, 2015 by inventors Shlomo Touboul, Hanan Levin, Stephane Roubach, Assaf Mischari, Itai Ben David, Itay Avraham, Adi Ozer, Chen Kazaz, Ofer Israeli, Olga Vingurt, Liad Gareh, Israel Grimberg, Cobby Cohen and Sharon Sultan, the contents of which are hereby incorporated herein in their entirety.

FIELD OF THE INVENTION

The present invention relates to cyber security, and in particular to computer network surveillance.

BACKGROUND OF THE INVENTION

Reference is made to FIG. **1**, which is a simplified diagram of a prior art enterprise network **100** connected to an external internet **10**. Network **100** is shown generally with resources including computers **110**, servers **120**, switches and routers **130**, and mobile devices **140** such as smart phones and tablets, for ease of presentation, although it will be appreciated by those skilled in the art that enterprise networks today are generally much more varied and complex and include other devices such as printers, phones and any Internet of Things objects. The various connections shown in FIG. **1** may be direct or indirect, wired or wireless communications, or a combination of wired and wireless connections. Computers **110** and servers **120** may be physical elements or logical elements, or a mix of physical and logical elements. Computers **110** and servers **120** may be physical or virtual machines. Computers **110** and servers **120** may be local, remote or cloud-based elements, or a mix of local, remote and cloud-based elements. Computers **110** may be client workstation computers. Servers **120** may be file transfer protocol (FTP) servers, email servers, structured query language (SQL) servers, secure shell (SSH) servers, and other database and application servers. A corporate information technology (IT) department manages and controls network **100** in order to serve the corporate requirements and meet the corporate needs.

Access to computers **110** and servers **120** in network **100** may optionally be governed by an access governor **150**, such as a directory service, that authorizes users to access computers **110** and servers **120** based on "credentials" and other methods of authentication. Access governor **150** may be a name directory, such as ACTIVE DIRECTORY® developed by Microsoft Corporation of Redmond, Wash., for WINDOWS® environments. Background information about ACTIVE DIRECTORY is available at Wikipedia. Other access governors for WINDOWS and non-WINDOWS environments include inter alia Lightweight Directory Access Protocol (LDAP), Remote Authentication Dial-In User Service (RADIUS), and Apple Filing Protocol (AFP), formerly APPLETALK®, developed by Apple Inc. of Cupertino, Calif. Background information about LDAP, RADIUS and AFP is available at Wikipedia.

Access governor **150** may be one or more local machine access controllers. For networks that do not include an access governor, authentication may be performed by other servers **120**. Alternatively, in lieu of access governor **150**, resources of network **100** determine their local access rights.

Credentials for accessing computers **110** and servers **120** include inter alia server account credentials such as <address> <username <password> for an FTP server, a database server, or an SSH server. Credentials for accessing computers **110** and servers **120** also include user login credentials <username> <password>, or <username> <ticket>, where "ticket" is an authentication ticket, such as a ticket for the Kerberos authentication protocol or NTLM hash used by Microsoft Corp., or login credentials via certificates or via another method of authentication. Background information about the Kerberos protocol and LM hashes is available at Wikipedia.

Access governor **150** may maintain a directory of computers **110**, servers **120** and their users. Access governor **150** authorizes users and computers, assigns and enforces security policies, and installs and updates software.

Computers **110** may run a local or remote security service, which is an operating system process that verifies users logging in to computers, to other single sign-on systems and to other credential storage systems.

Network **100** may include a security information and event management (SIEM) server **160**, which provides real-time analysis of security alerts generated by network hardware and applications. Background information about SIEM is available at Wikipedia.

Network **100** may include a domain name system (DNS) server **170**, or such other name service system, for translating domain names to IP addresses. Background information about DNS is available at Wikipedia.

Network **100** may include a firewall **180** located within a gateway between enterprise network **100** and external internet **10**. Firewall **180** controls incoming and outgoing traffic for network **100**. Background information about firewalls is available at Wikipedia.

One of the most prominent threats that organizations face is a targeted attack; i.e., an individual or group of individuals that attacks the organization for a specific purpose, such as stealing data, using data and systems, modifying data and systems, and sabotaging data and systems. Targeted attacks are carried out in multiple stages, typically including inter alia reconnaissance, penetration, lateral movement and payload. Lateral movement involves orientation, movement and propagation, and includes establishing a foothold within the organization and expanding that foothold to additional systems within the organization.

In order to carry out the lateral movement stage, an attacker, whether a human being who is operating tools within the organization's network, or a tool with "learning" capabilities, learns information about the environment it is operating in, such as network topology, network devices and organization structure, learns "where can I go from my current location" and "how can I go from my current location to another location (privilege required)", learns implemented security solutions, learns applications that he can leverage, and then operates in accordance with that data.

An advanced attacker may use different attack techniques to enter a corporate network and to move laterally within the network in order to obtain his resource goals. The advanced attacker may begin with a workstation, server or any other network entity to start his lateral movement. He uses different methods to enter the network, including inter alia social engineering, existing exploit and/or vulnerability, and a Trojan horse or any other malware allowing him to control a first node or nodes.

Once an attacker has taken control of a first node in a corporate network, he uses different advanced attack techniques for orientation and propagation and discovery of additional ways to reach other network nodes in the corporate network. Attacker movement from node to node is performed via an "attack vector", which is an object discovered by the attacker, including inter alia an object in memory or storage of a first computer that may be used to access or discover a second computer.

Exemplary attack vectors include inter alia credentials of users with escalated privileges, existing share names on different servers and workstations, and details including address and credentials of an FTP server, an email server, a database server or an SSH server. Attack vectors are often available to an attacker because a user did not log off of his workstation, did not log out of an application, or did not clear his cache. E.g., if a user contacted a help desk and gave a help desk administrator remote access to his workstation, and if the help desk administrator did not properly log off from the remote access session to the users workstation, then the help desk access credentials may still be stored in the user's local cache and available to the attacker. Similarly, if the user accessed a server, e.g., an FTP server, then the FTP account login parameters may be stored in the user's local cache or profile and available to the attacker.

Attack vectors enable inter alia a move from workstation A→server B based on a shared server host name and its credentials, connection to a different workstation using local admin credentials that reside on a current workstation, and connection to an FTP server using specific access credentials.

Whereas IT "sees" the logical and physical network topology, an attacker that lands on a first network node "sees" attack vectors that depart from that node and move laterally to other nodes. The attacker can move to such nodes and then follow "attack paths" by successively discovering attack vectors from node to node.

When the attacker implements such a discovery process on all nodes in the network, he will be able to "see" all attack vectors of the corporate network and generate a "complete attack map". Before the attacker discovers all attack vectors on network nodes and completes the discovery process, he generates a "current attack map" that is currently available to him.

An objective of the attacker is to discover an attack path that leads him to a target network node. The target may be a bank authorized server that is used by the corporation for ordering bank account transfers of money, it may be an FTP server that updates the image of all corporate points of sale, it may be a server or workstation that stores confidential information such as source code and secret formulas of the corporation, or it may be any other network nodes that are of value to the attacker and are his "attack goal nodes".

When the attacker lands on the first node, but does not know how to reach the attack goal node, he generates a current attack map that leads to the attack goal node.

One method to defend against such attacks, termed "honeypots", is to plant and to monitor bait resources, with the objective that the attacker discover their existence and then consume the bait resources, and to notify an administrator of the malicious activity. Background information about honeypots is available at Wikipedia.

Conventional honeypot systems operate by monitoring access to a supervised element in a computer network, the supervised element being a fake server or a fake service. Access monitoring generates many false alerts, caused by non-malicious access from automatic monitoring systems and by user mistakes. Conventional systems try to mitigate this problem by adding a level of interactivity to the honeypot, and by performing behavioral analysis of suspected malware if it has infected the honeypot itself.

After detection that a resource has been breached by an attack, conventional security systems react by isolating the breached resource. The breached resource may be isolated by manually unplugging it, or by running a system restore. Such reaction to detection of a breach has many drawbacks. In particular, an attacker may already have control over other resources of enterprise network **100**. The attacker may have obtained data, such as credentials, connection, and IP addresses, and can continue spreading through enterprise network **100** without requiring use of the specific resource that was isolated. Dependence upon manual isolation, which may be faulty, is very risky.

SUMMARY

Embodiments of the present invention overcome the drawbacks of conventional security systems that react to an attack by isolating a breached resource. Using the present invention, an attacker's movement inside an enterprise network is predicted, and prevented inter alia by changing compromised credentials and compromised IP addresses, and by adding firewall rules for compromised connections.

There is thus provided in accordance with an embodiment of the present invention a method for cyber security, including detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources in which users access the resources based on credentials, wherein each resource has a domain name server (DNS) record stored on a DNS server, wherein some of the resources are servers that are accessed via IP addresses, and wherein access to the network via connections that extend outside the network is governed by a firewall, changing, by the decoy management server, the DNS record for the breached resource on the DNS server, in response to the detecting, predicting, by the decoy management server, which credentials are compromised, based on credentials stored on the breached resource, changing, by the decoy management server, those credentials that were predicted to be compromised, in response to the predicting which credentials, predicting, by the decoy management server, which servers in the network are compromised, based on real and decoy connections created during the breach, changing, by the decoy management server, IP addresses of servers in response to the predicting which servers, predicting, by the decoy management server, a target subnet, based on real and decoy connections created during the breach, isolating, by the decoy management server, the target subject in response to the predicting a target subnet, predicting, by the decoy management server, data leakage paths from inside the network to outside the network, based on an open connection to outside the network during the breach, and creating, by the decoy management server, firewall rules to block outbound connections in response to the predicting data leakage paths.

There is additionally provided in accordance with an embodiment of the present invention a method for cyber security, including detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources, wherein access to the resources via network connections is governed by a firewall, predicting, by the decoy management server, which resources of the network were exposed to the attacker, based on address pointers stored on the breached resource, and generating firewall rules to block access to the predicted exposed resources from the breached resource, in response to the predicting which resources.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood and appreciated from the following detailed description, taken in conjunction with the drawings in which:

FIG. **1** is a simplified diagram of a prior art enterprise network connected to an external internet;

FIG. **2** is a simplified diagram of an enterprise network with network surveillance, in accordance with an embodiment of the present invention; and

FIG. **3** is a simplified flowchart of a method for prediction and prevention of an attacker's next action in a compromised network, in accordance with an embodiment of the present invention.

For reference to the figures, the following index of elements and their numerals is provided. Similarly numbered elements represent elements of the same type, but they need not be identical elements.

Table of elements in the figures

Element	Description
10	Internet
100	enterprise network
110	network computers
120	network servers
130	network switches and routers
140	mobile devices
150	access governor (optional)
252	forensic alert module
160	SIEM server
170	DNS server
180	firewall
200	enterprise network with network surveillance
210	deception management server
211	policy manager
212	deployment module
213	forensic application
220	database of credential types
230	policy database
240	decoy servers
242	forensic alert module
260	update server

Elements numbered in the 1000's are operations of flow charts.

DETAILED DESCRIPTION

In accordance with embodiments of the present invention, systems and methods are provided for responding to breach by an attacker of a resource within an enterprise network, by predicting and preventing the attacker's next actions.

Reference is made to FIG. **2**, which is a simplified diagram of an enterprise network **200** with network surveillance, in accordance with an embodiment of the present invention. Network **200** includes a decoy management server **210**, a database **220** of decoy attack vectors, a policy database **230** and decoy servers **240**. In addition, network computers **110** and servers **120** are grouped into groups G**1**, G**2**, G**3** and G**4**.

Database **220** stores attack vectors that fake movement and access to computers **110**, servers **120** and other resources in network **200**. Attack vectors include inter alia:

user of the form <username>

user credentials of the form <username> <password>

user credentials of the form <username> <hash of password>

user credentials of the form <username> <ticket>

FTP server of the form <FTP address>

FTP server credentials of the form <FTP address> <username> <password>

SSH server of the form <SSH address>

SSH server credentials of the form <SSH address> <username> <password>

share address of the form <SMB address>

Each decoy attack vector in database **220** may point to (i) a real resource that exists within network **200**, e.g., an FTP server, (ii) a decoy resource that exists within network **200**, e.g., a trap server, or (iii) a resource that does not exist. In the latter case, when an attacker attempts to access a resource that does not exist, access governor **150** recognizes a pointer to a resource that is non-existent. Access governor **150** responds by notifying decoy management server **210**, or by re-directing the pointer to a resource that does exist in order to survey the attacker's moves, or both.

The attack vectors stored in database **220** are categorized by families, such as inter alia

F**1**—user credentials
F**2**—files
F**3**—connections
F**4**—FTP logins
F**5**—SSH logins
F**6**—share names
F**7**—databases
F**8**—network devices
F**9**—URLs
F**10**—Remote Desktop Protocol (RDP)
F**11**—recent commands
F**12**—scanners
F**13**—cookies
F**14**—cache
F**15**—Virtual Private Network (VPN)
F**16**—key logger

Credentials for a computer B that reside on a computer A, or even an address pointer to computer B that resides on computer A, provide an attack vector for an attacker from computer A→computer B.

Database **220** communicates with an update server **260**, which updates database **220** as attack vectors for accessing, manipulating and hopping to computers evolve over time. Update server **260** may be a separate server, or a part of decoy management server **210**.

Policy database **230** stores policies for planting decoy attack vectors in computers of network **200**. Each policy specifies decoy attack vectors that are planted on the computers, in accordance with attack vectors stored in database **220**. For user credentials, the decoy attack vectors planted on a computer lead to another resource in the network. For attack vectors to access an FTP or other server, the decoy attack vectors planted on a computer lead to a decoy server **240**.

It will be appreciated by those skilled in the art the databases **220** and **230** may be combined into a single database, or distributed over multiple databases.

Decoy management server **210** includes a policy manager **211**, a deployment module **212**, and a forensic application **213**. Policy manager **211** defines a decoy and response policy. The decoy and response policy defines different decoy types, different decoy combinations, response procedures, notification services, and assignments of policies to specific network nodes, network users, groups of nodes or users or both. Once policies are defined, they are stored in policy database **230** with the defined assignments.

Deception management server **210** obtains the policies and their assignments from policy database **230**, and delivers them to appropriate nodes and groups. It than launches deployment module **212** to plant decoys on end points, servers, applications, routers, switches, relays and other entities in the network. Deployment module **212** plants each decoy, based on its type, in memory (RAM), disk, or in any other data or information storage area, as appropriate. Deployment module **212** plants the decoy attack vectors in such a way that the chances of a valid user accessing the decoy attack vectors are low. Deployment module **212** may or may not stay resident.

Forensic application **213** is a real-time application that is transmitted to a destination computer in the network, when a decoy attack vector is accessed by a computer **110**. When forensic application **213** is launched on the destination computer, it identifies a process running within that computer **110** that accessed that decoy attack vector, or identifies a DLL in memory injected into a process, that accessed that decoy attack vector, or identifies static data that accessed that decoy attack vector. Forensic application **230** logs the activities performed by the thus-identified process in a forensic report, and transmits the forensic report to decoy management server **210**.

Once an attacker is detected, a "response procedure" is launched. The response procedure includes inter alia various notifications to various addresses, and actions on a decoy server such as launching an investigation process, and isolating, shutting down and re-imaging one or more network nodes. The response procedure collects information available on one or more nodes that may help in identifying the attacker's attack acts, intention and progress.

Each decoy server **240** includes a forensic alert module **242**, which alerts management system **210** that an attacker is accessing the decoy server via a computer **110** of the network, and causes decoy management server **210** to send forensic application **213** to the computer that is accessing the decoy server. In an alternative embodiment of the present invention, decoy server **240** may store forensic application **213**, in which case decoy server **240** may transmit forensic application **213** directly to the computer that is accessing the decoy server. In another alternative embodiment of the present invention, decoy management server **210** or decoy server **240** may transmit forensic application **213** to a destination computer other than the computer that is accessing the decoy server. Access governor **150** also activates a forensic alert module **252**, which alerts decoy management server **210** that an attacker is attempting to use a decoy credential.

Notification servers (not shown) are notified when an attacker uses a decoy. The notification servers may discover this by themselves, or by using information stored on access governor **150** and SIEM **160**. The notification servers forward notifications, or results of processing multiple notifications, to create notification time lines or such other analytics.

Reference is made to FIG. **3**, which is a simplified flowchart of a method for prediction and prevention of an attacker's next action in a compromised network, in accordance with an embodiment of the present invention. At operation **1005**, decoy management server **210** detects breach of a resource of enterprise network **200**, based on an attacker's use of one or more decoy attack vectors. At operation **1010**, in response to detection of the breach at operation **1005**, decoy management server **210** changes one or more DNS records for the breached resource on DNS server **170**.

At operation **1015**, decoy management server **210** collects data from the forensic report received by forensic application **213**, the collected data including both decoy and real data for the breached resource. At operation **1020**, decoy management server **210** discriminates between the real and the decoy data collected at operation **1015**.

At operation **1025**, decoy management server **210** predicts which credentials are compromised, based on credentials that are stored on the breached resource. At operation

1030, in response to the prediction at operation 1005, decoy management server 210 changes passwords of compromised users.

At operation 1035, decoy management server 210 predicts which servers in network 200 are compromised, based on real and decoy connections created during the breach. At operation 1040, in response to the prediction at operation 1035, decoy management server 210 changes IP addresses for compromised servers. Optionally, in addition, firewall rules may be generated to block the compromised servers from being accessed from the breached resources.

At operation 1045, decoy management server 210 predicts one or more target subnets, based on real and decoy connections created during the breach. At operation 1050, in response to the prediction at operation 1045, decoy management server 210 isolates the infected resource and the one or more target subnets.

At operation 1055, decoy management server 210 predicts data leakage paths from inside network 200 to outside network 200, based on an open connection to outside of the network during the breach. At operation 1060, in response to the prediction at operation 1055, decoy management server 210 generates firewall rules to block malicious outbound connections. In an alternative embodiment, decoy management server 210 may generate firewall rules to re-direct outbound connections to a designated resource within network 200.

Each of the individual response operations 1010, 1030, 1040, 1050 and 1060 is itself optional, and may not be performed in some embodiments of the present invention. Moreover, response operations 1010, 1030, 1040, 1050 and 1060 may be performed automatically by decoy management server 210, or semi-automatically in conjunction with confirmation by an administrator, or manually whereby the method recommends each response operation to an administrator, but the administrator must manually perform the operation.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific exemplary embodiments without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A method for cyber security, comprising:

detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources in which users access the resources based on credentials, wherein access to the resources via network connections is governed by a firewall, wherein each resource has a domain name server (DNS) record stored on a DNS server, and wherein some of the resources are servers that are accessed via IP addresses;

changing, by the decoy management server, the DNS record for the breached resource on the DNS server, in response to said detecting;

predicting, by the decoy management server, which credentials are compromised, based on credentials stored on the breached resource;

changing, by the decoy management server, those credentials that were predicted to be compromised, in response to said predicting which credentials are compromised;

predicting, by the decoy management server, which servers in the network are compromised, based on connections created during the breach;

changing, by the decoy management server, IP addresses of the predicted compromised servers in response to said predicting which servers are compromised;

creating, by the decoy management server, firewall rules to block access to the predicted compromised servers from the breached resource, in response to said predicting which servers are compromised;

predicting, by the decoy management server, data leakage paths from inside the network to outside the network, based on an open outbound connection during the breach; and

creating, by the decoy management server, firewall rules to block that outbound connection in response to said predicting data leakage paths.

2. The method of claim 1 wherein said changing the DNS record and said changing the predicted compromised credentials are performed automatically.

3. The method of claim 1 wherein said changing the DNS record and said changing the predicted compromised credentials are performed semi-automatically wherein the decoy management server requests confirmation by an administrator of the network prior to changing the DNS record and the predicted compromised credentials.

4. The method of claim 1 wherein said changing the DNS record and said changing the predicted compromised credentials are performed manually wherein the decoy management server recommends these changes to an administrator of the network, who then performs the changes manually.

5. A method for cyber security, comprising:

detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources in which users access the resources based on credentials, wherein access to the resources via network connections is governed by a firewall, wherein each resource has a domain name server (DNS) record stored on a DNS server, and wherein some of the resources are servers that are accessed via IP addresses;

changing, by the decoy management server, the DNS record for the breached resource on the DNS server, in response to said detecting;

predicting, by the decoy management server, which credentials are compromised, based on credentials stored on the breached resource;

changing, by the decoy management server, those credentials that were predicted to be compromised, in response to said predicting which credentials are compromised;

predicting, by the decoy management server, which servers in the network are compromised, based on connections created during the breach;

changing, by the decoy management server, IP addresses of the predicted compromised servers in response to said predicting which servers are compromised;

creating, by the decoy management server, firewall rules to block access to the predicted compromised servers from the breached resource, in response to said predicting which servers are compromised;

predicting, by the decoy management server, data leakage paths from inside the network to outside the network, based on an open outbound connection during the breach; and creating, by the decoy management server, firewall rules to re-direct that outbound connection to a resource within the network, in response to said predicting data leakage paths.

6. The method of claim **5** wherein said changing the DNS record and said changing the predicted compromised credentials are performed automatically.

7. The method of claim **5** wherein said changing the DNS record and said changing the predicted compromised credentials are performed semi-automatically wherein the decoy management server requests confirmation by an administrator of the network prior to changing the DNS record and the predicted compromised credentials.

8. The method of claim **5** wherein said changing the DNS record and said changing the predicted compromised credentials are performed manually wherein the decoy management server recommends these changes to an administrator of the network, who then performs the changes manually.

9. A method for cyber security, comprising:

detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources, wherein access to the resources via network connections is governed by a firewall, wherein each resource has a domain name server (DNS) record stored on a DNS server, and wherein some of the resources are servers that are accessed via IP addresses;

predicting, by the decoy management server, which resources of the network were exposed to the attacker, based on address pointers stored on the breached resource;

generating firewall rules to block access to the predicted exposed resources from the breached resource, in response to said predicting which resources were exposed;

predicting, by the decoy management server, which servers in the network are compromised, based on connections created during the breach;

changing, by the decoy management server, IP addresses of the predicted compromised servers in response to said predicting which servers were compromised;

predicting, by the decoy management server, data leakage paths from inside the network to outside the network, based on an open outbound connection during the breach; and

creating, by the decoy management server, firewall rules to block that outbound connection in response to said predicting data leakage paths.

10. A method for cyber security, comprising:

detecting, by a decoy management server, a breach by an attacker of a specific resource within a network of resources, wherein access to the resources via network connections is governed by a firewall, wherein each resource has a domain name server (DNS) record stored on a DNS server, and wherein some of the resources are servers that are accessed via IP addresses;

predicting, by the decoy management server, which resources of the network were exposed to the attacker, based on address pointers stored on the breached resource;

generating firewall rules to block access to the predicted exposed resources from the breached resource, in response to said predicting which resources were exposed;

predicting, by the decoy management server, which servers in the network are compromised, based on connections created during the breach;

changing, by the decoy management server, IP addresses of the predicted compromised servers in response to said predicting which servers are compromised;

predicting, by the decoy management server, data leakage paths from inside the network to outside the network, based on an open outbound connection during the breach; and

creating, by the decoy management server, firewall rules to re-direct that outbound connection to a resource within the network, in response to said predicting data leakage paths.

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