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(54) **POLICY-BASED SELECTION OF REMEDIATION**

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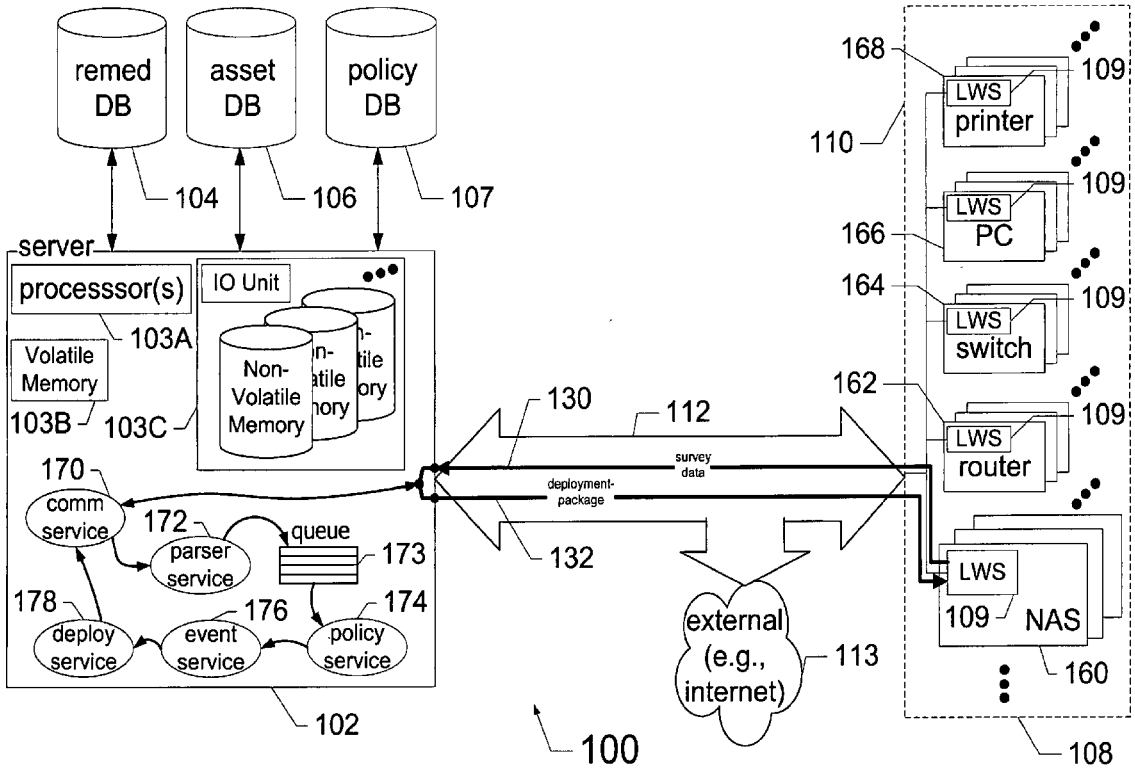
(57) **ABSTRACT**

Methods and systems for remediating a security policy violation on a computer system are provided. According to one embodiment, information is received by one computer system regarding a program-code-based operational state of another computer system at a particular time. It is determined whether the program-code-based operational state represents a violation of security policies that have been applied to or are active in regard to the computer system at issue by evaluating the received information with respect to the security policies. Each security policy defines at least one parameter condition violation of which is potentially indicative of unauthorized activity or manipulation to make the computer system at issue vulnerable to attack. When a security policy violation is detected, then a remediation is identified that can address the violation; and the remediation is caused to be deployed to the computer system at issue.



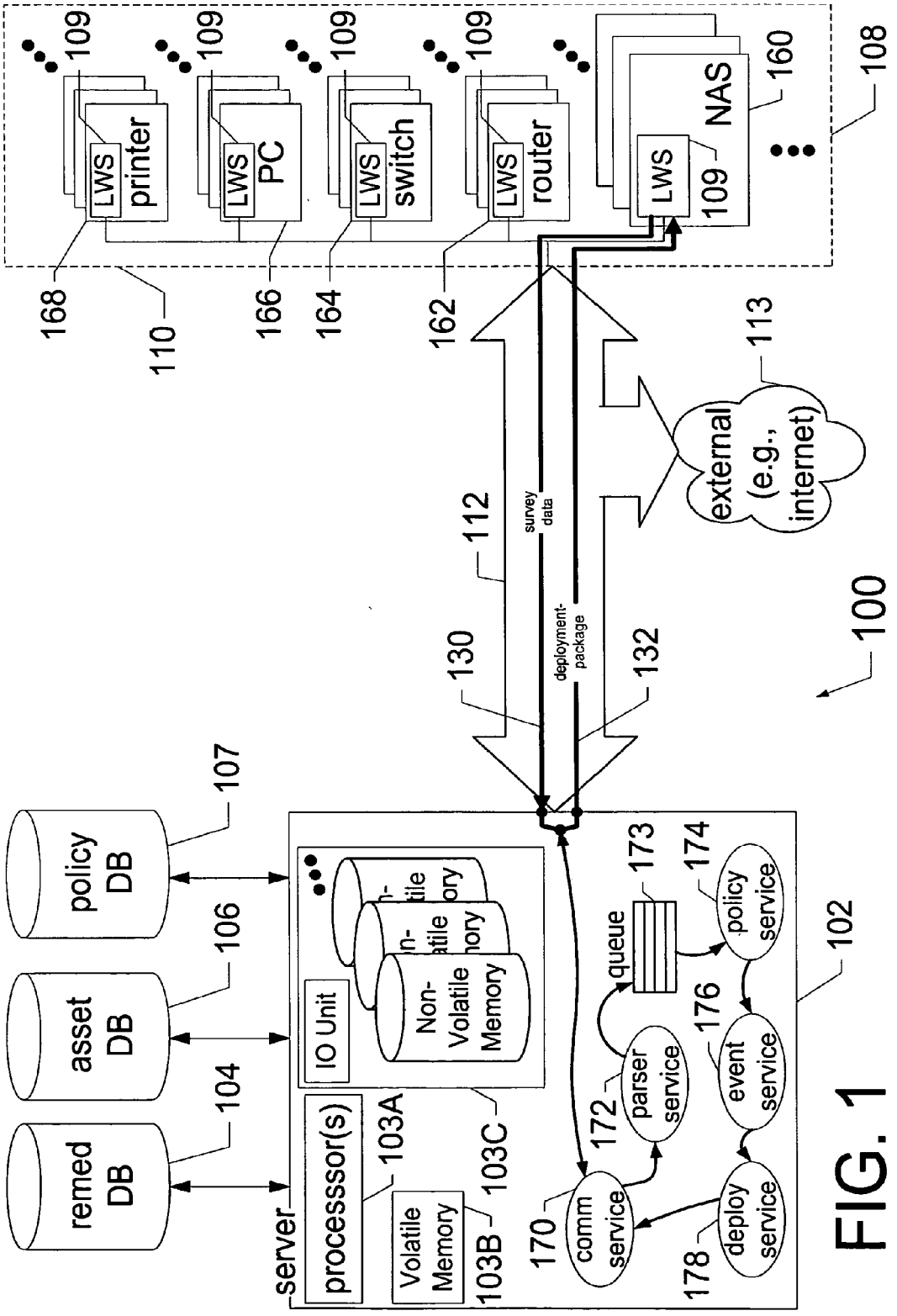

109
LWS
printer
LWS
PC
LWS
switch
LWS
router
LWS
NAS
160
108
168
110
166
164
162
113
external
(e.g.,
internet)
112
survey
data
deployment-
package
130
132
100
107
policy
DB
106
asset
DB
104
remed
DB
server
processor(s)
103A
IO Unit
Volatile
Memory
103B
Non-
Volatile
Memory
103C
queue
173
174
policy
service
172
parser
service
176
event
service
170
comm
service
178
deploy
service
102

FIG. 1

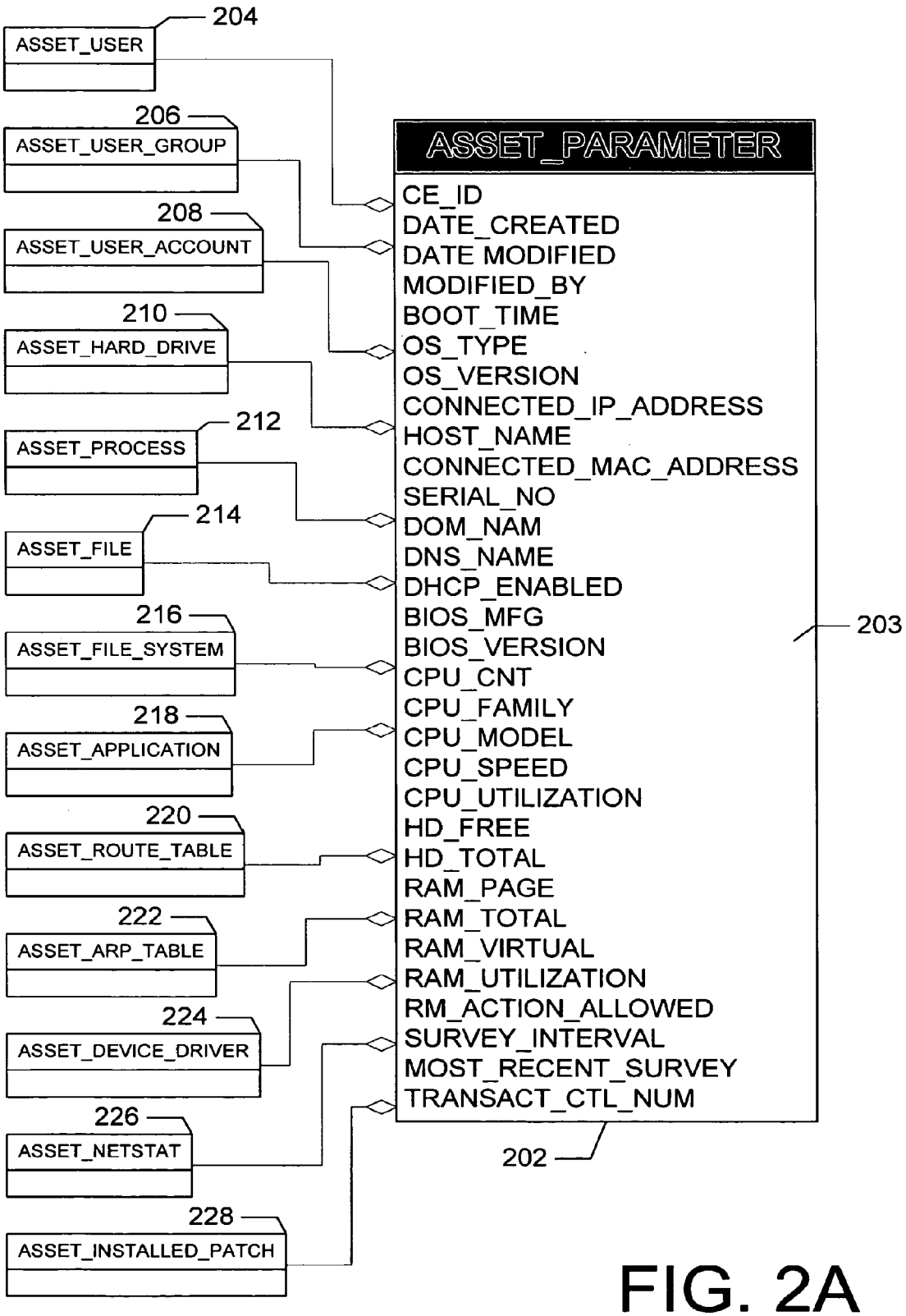

204
ASSET_USER
206
ASSET_USER_GROUP
208
ASSET_USER_ACCOUNT
210
ASSET_HARD_DRIVE
212
ASSET_PROCESS
214
ASSET_FILE
216
ASSET_FILE_SYSTEM
218
ASSET_APPLICATION
220
ASSET_ROUTE_TABLE
222
ASSET_ARP_TABLE
224
ASSET_DEVICE_DRIVER
226
ASSET_NETSTAT
228
ASSET_INSTALLED_PATCH
ASSET_PARAMETER
CE_ID
DATE_CREATED
DATE MODIFIED
MODIFIED_BY
BOOT_TIME
OS_TYPE
OS_VERSION
CONNECTED_IP_ADDRESS
HOST_NAME
CONNECTED_MAC_ADDRESS
SERIAL_NO
DOM_NAM
DNS_NAME
DHCP_ENABLED
BIOS_MFG
BIOS_VERSION
CPU_CNT
CPU_FAMILY
CPU_MODEL
CPU_SPEED
CPU_UTILIZATION
HD_FREE
HD_TOTAL
RAM_PAGE
RAM_TOTAL
RAM_VIRTUAL
RAM_UTILIZATION
RM_ACTION_ALLOWED
SURVEY_INTERVAL
MOST_RECENT_SURVEY
TRANSACT_CTL_NUM
203
202

FIG. 2A

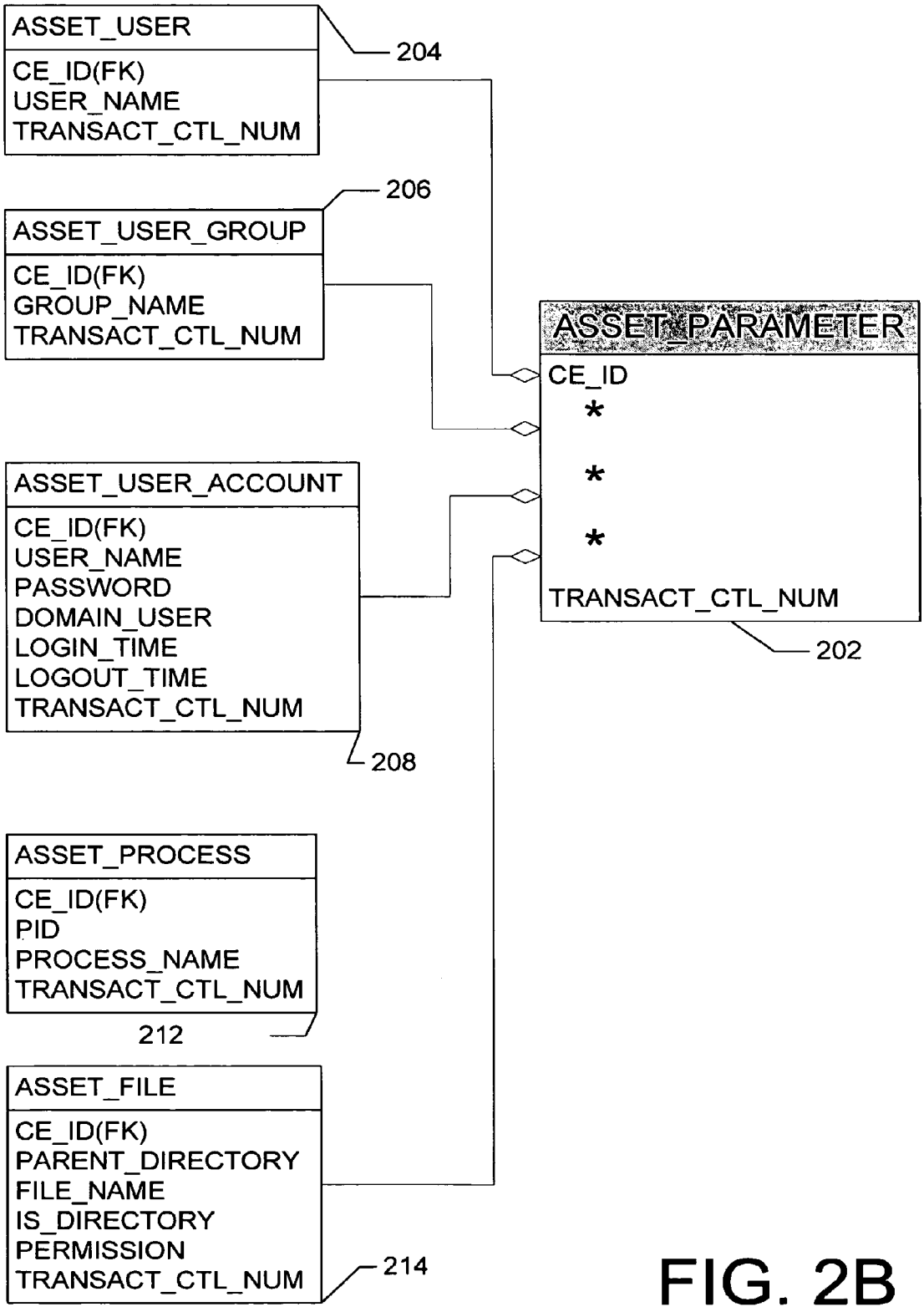

ASSET_USER
CE_ID(FK)
USER_NAME
TRANSACT_CTL_NUM
204
ASSET_USER_GROUP
CE_ID(FK)
GROUP_NAME
TRANSACT_CTL_NUM
206
ASSET_PARAMETER
CE_ID
*
*
*
TRANSACT_CTL_NUM
202
ASSET_USER_ACCOUNT
CE_ID(FK)
USER_NAME
PASSWORD
DOMAIN_USER
LOGIN_TIME
LOGOUT_TIME
TRANSACT_CTL_NUM
208
ASSET_PROCESS
CE_ID(FK)
PID
PROCESS_NAME
TRANSACT_CTL_NUM
212
ASSET_FILE
CE_ID(FK)
PARENT_DIRECTORY
FILE_NAME
IS_DIRECTORY
PERMISSION
TRANSACT_CTL_NUM
214

FIG. 2B

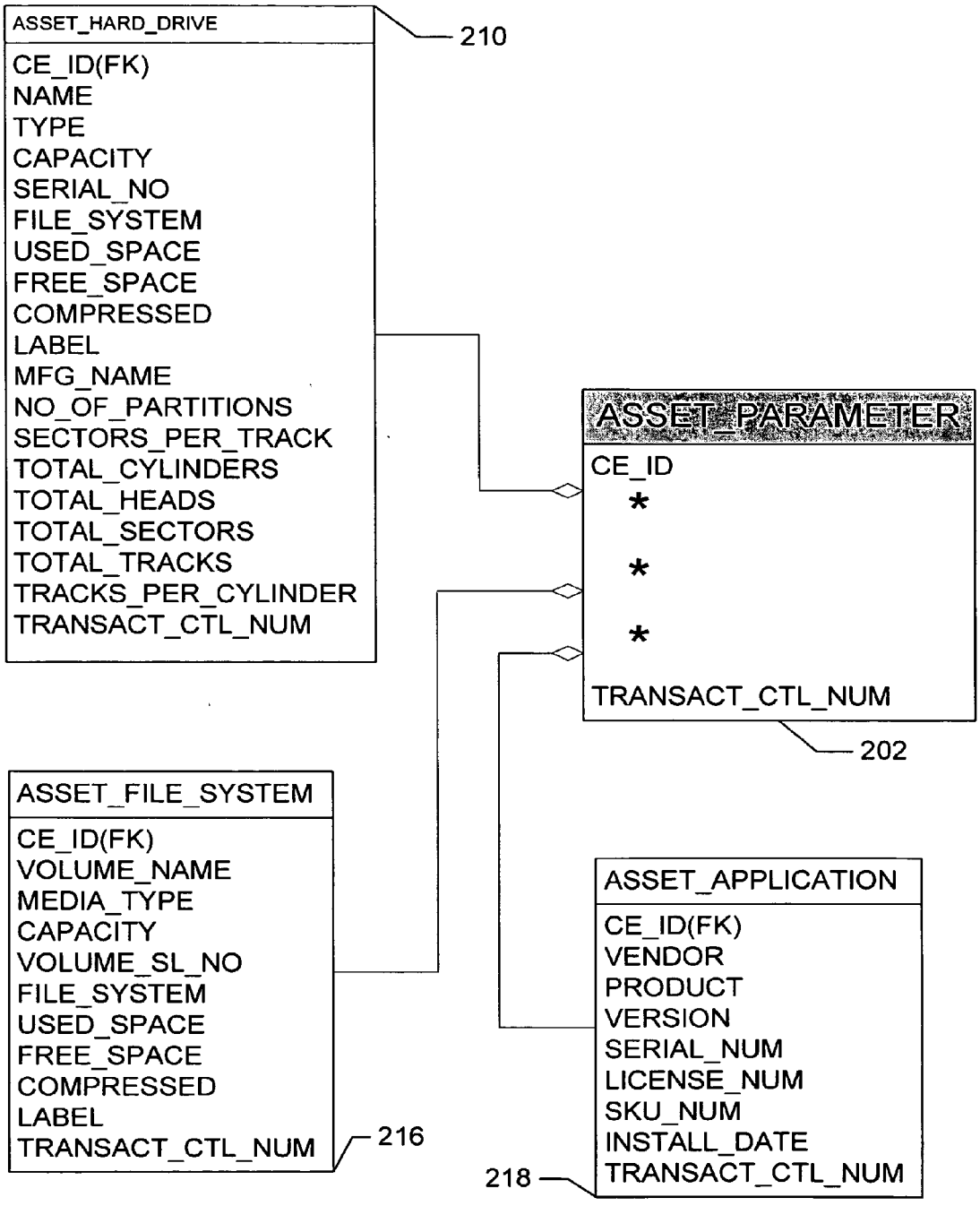

ASSET_HARD_DRIVE
CE_ID(FK)
NAME
TYPE
CAPACITY
SERIAL_NO
FILE_SYSTEM
USED_SPACE
FREE_SPACE
COMPRESSED
LABEL
MFG_NAME
NO_OF_PARTITIONS
SECTORS_PER_TRACK
TOTAL_CYLINDERS
TOTAL_HEADS
TOTAL_SECTORS
TOTAL_TRACKS
TRACKS_PER_CYLINDER
TRANSACT_CTL_NUM
210
ASSET_PARAMETER
CE_ID
*
*
*
TRANSACT_CTL_NUM
202
ASSET_FILE_SYSTEM
CE_ID(FK)
VOLUME_NAME
MEDIA_TYPE
CAPACITY
VOLUME_SL_NO
FILE_SYSTEM
USED_SPACE
FREE_SPACE
COMPRESSED
LABEL
TRANSACT_CTL_NUM
216
ASSET_APPLICATION
CE_ID(FK)
VENDOR
PRODUCT
VERSION
SERIAL_NUM
LICENSE_NUM
SKU_NUM
INSTALL_DATE
TRANSACT_CTL_NUM
218

FIG. 2C

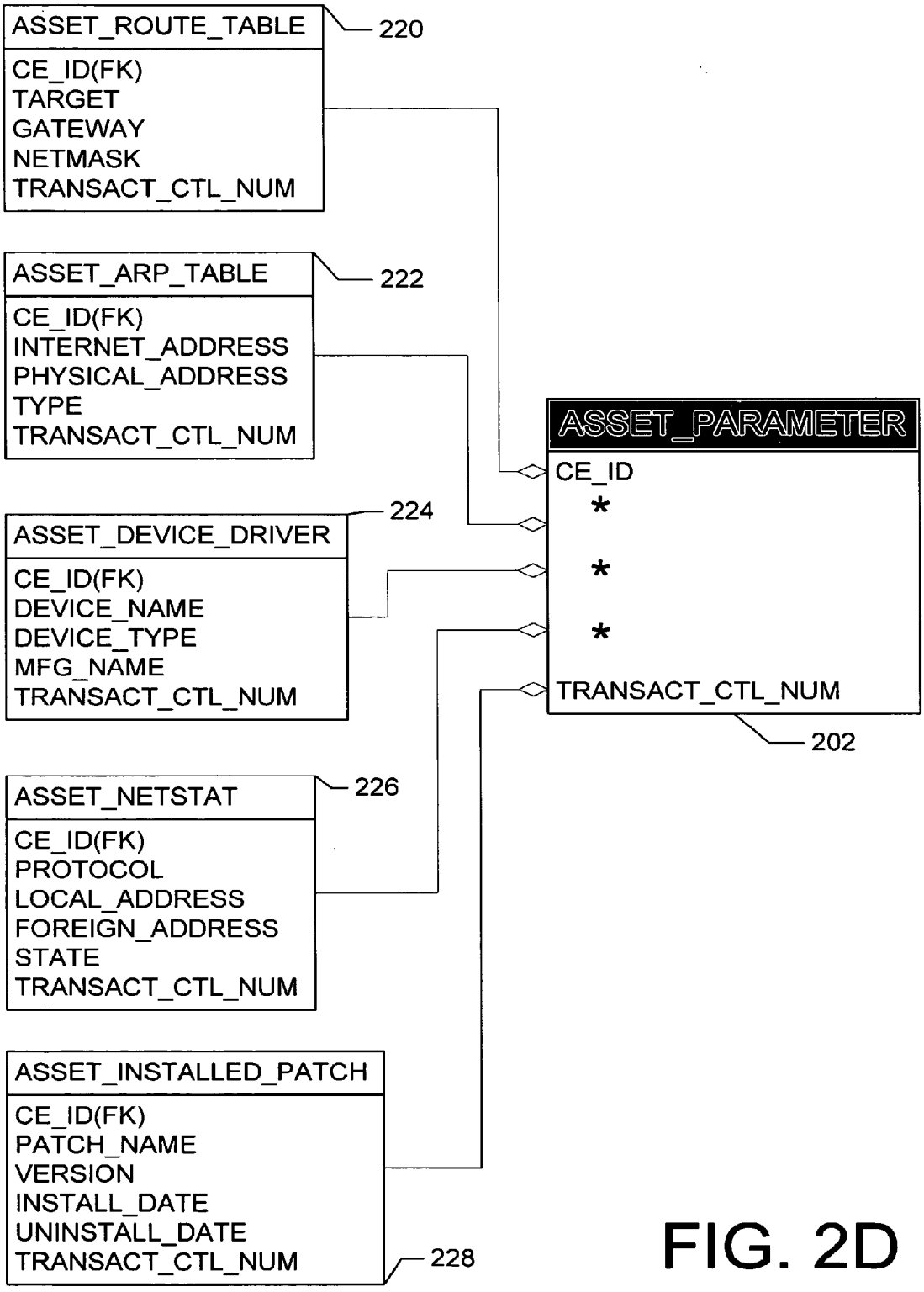

ASSET_ROUTE_TABLE
220
CE_ID(FK)
TARGET
GATEWAY
NETMASK
TRANSACT_CTL_NUM
ASSET_ARP_TABLE
222
CE_ID(FK)
INTERNET_ADDRESS
PHYSICAL_ADDRESS
TYPE
TRANSACT_CTL_NUM
ASSET_PARAMETER
CE_ID
*
*
*
TRANSACT_CTL_NUM
202
224
ASSET_DEVICE_DRIVER
CE_ID(FK)
DEVICE_NAME
DEVICE_TYPE
MFG_NAME
TRANSACT_CTL_NUM
226
ASSET_NETSTAT
CE_ID(FK)
PROTOCOL
LOCAL_ADDRESS
FOREIGN_ADDRESS
STATE
TRANSACT_CTL_NUM
ASSET_INSTALLED_PATCH
CE_ID(FK)
PATCH_NAME
VERSION
INSTALL_DATE
UNINSTALL_DATE
TRANSACT_CTL_NUM
228

FIG. 2D

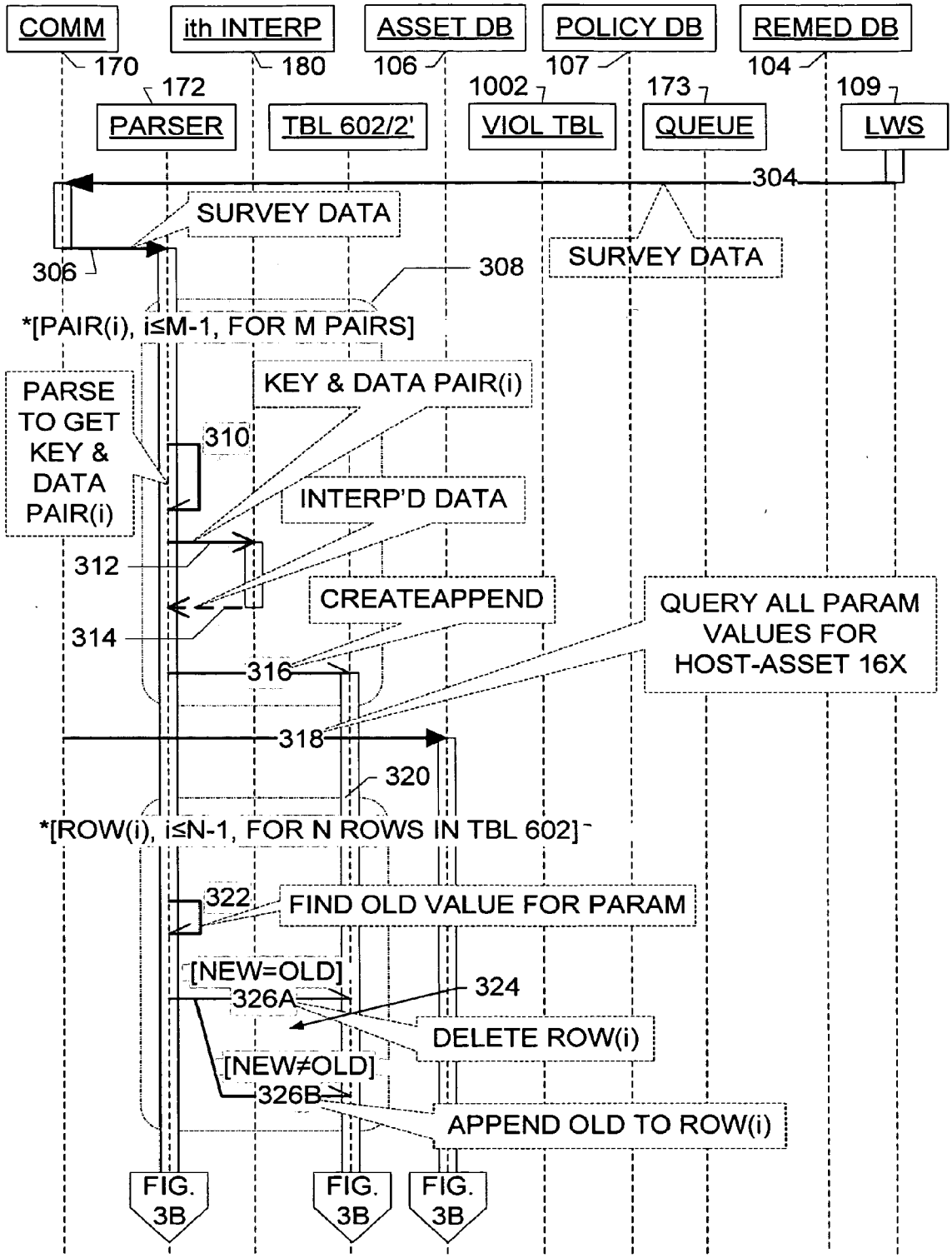

COMM
ith INTERP
ASSET DB
POLICY DB
REMED DB
170
180
106
107
104
172
1002
173
109
PARSER
TBL 602/2'
VIOL TBL
QUEUE
LWS
304
SURVEY DATA
SURVEY DATA
306
308
*[PAIR(i), i≤M-1, FOR M PAIRS]
KEY & DATA PAIR(i)
PARSE TO GET KEY & DATA PAIR(i)
310
INTERP'D DATA
312
CREATEAPPEND
QUERY ALL PARAM VALUES FOR HOST-ASSET 16X
314
316
318
320
*[ROW(i), i≤N-1, FOR N ROWS IN TBL 602]
322
FIND OLD VALUE FOR PARAM
[NEW=OLD]
326A
324
DELETE ROW(i)
[NEW≠OLD]
326B
APPEND OLD TO ROW(i)
FIG. 3B
FIG. 3B
FIG. 3B

FIG. 3A

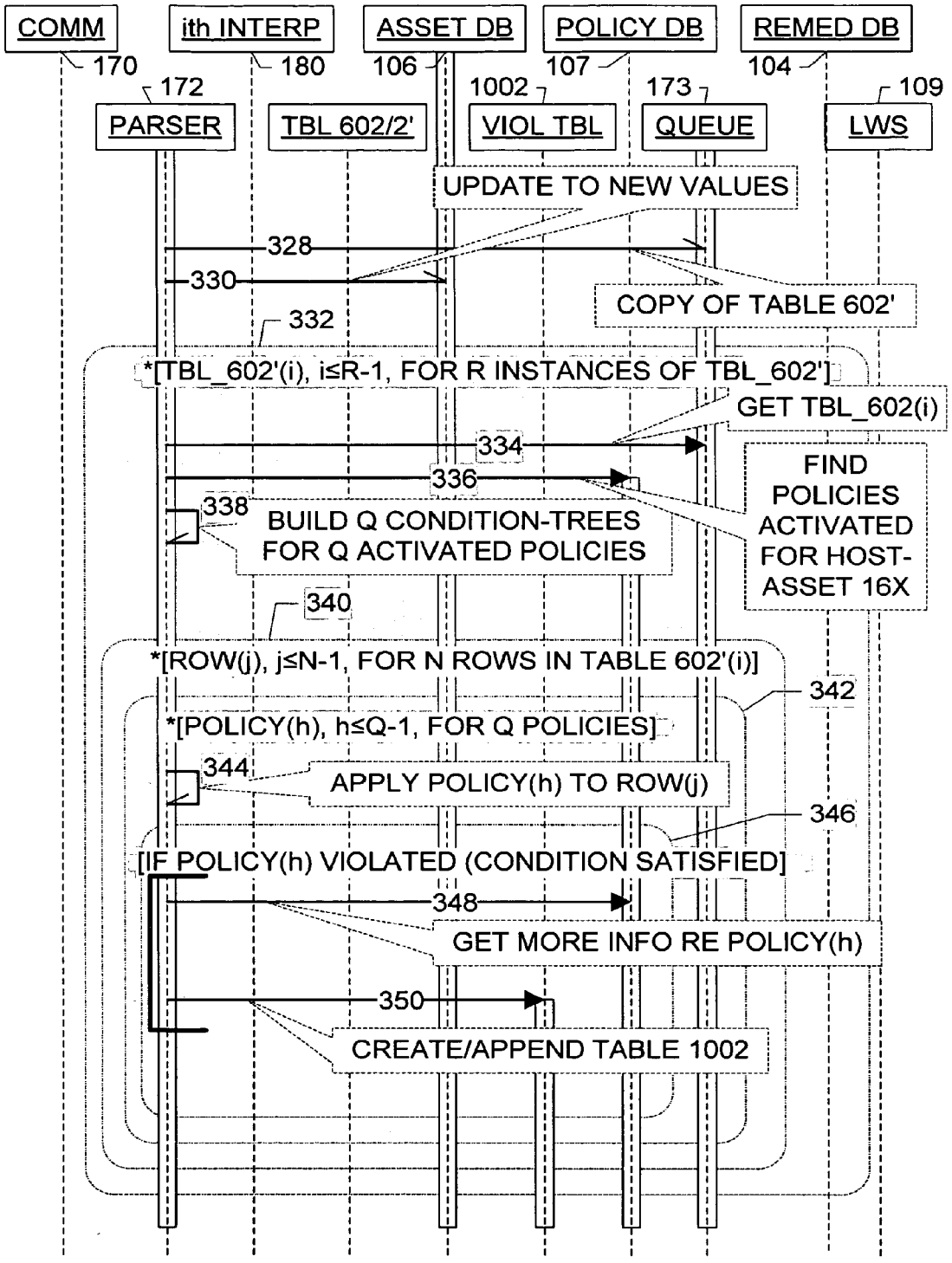

COMM
ith INTERP
ASSET DB
POLICY DB
REMED DB
170
180
106
107
104
172
1002
173
109
PARSER
TBL 602/2'
VIOL TBL
QUEUE
LWS
UPDATE TO NEW VALUES
328
330
COPY OF TABLE 602'
332
*[TBL_602'(i), i≤R-1, FOR R INSTANCES OF TBL_602']
GET TBL_602(i)
334
336
FIND POLICIES ACTIVATED FOR HOST-ASSET 16X
338
BUILD Q CONDITION-TREES FOR Q ACTIVATED POLICIES
340
*[ROW(j), j≤N-1, FOR N ROWS IN TABLE 602'(i)]
342
*[POLICY(h), h≤Q-1, FOR Q POLICIES]
344
APPLY POLICY(h) TO ROW(j)
346
[IF POLICY(h) VIOLATED (CONDITION SATISFIED]
348
GET MORE INFO RE POLICY(h)
350
CREATE/APPEND TABLE 1002

FIG. 3B

| R_ID | POL_ID | ACT_ID | CE_ID |
|---|---|---|---|
| R844 | P48765 | A20458 | CE768 |
| R844 | P48765 | A13423 | CE768 |
| R844 | P48765 | A54633 | CE768 |
| R945 | P49503 | A76464 | CE395 |
| R945 | P49503 | A98747 | CE395 |
| R844 | P09687 | A54633 | CE334 |
| R844 | P09687 | A75474 | CE334 |
| R873 | P09847 | A67321 | CE334 |

804

806

* * * *
* * * *
* * * *

FIG. 8

802

804

| R_ID | POL_ID | CE_ID | PARAM | NEW | OLD(K-1) | OLD(K-2) |
|---|---|---|---|---|---|---|
| R844 | P48765 | CE768 | CPU_CNT | 1 | 2 | |
| R873 | P09847 | CE334 | DOM_NAM | acct | eng | |

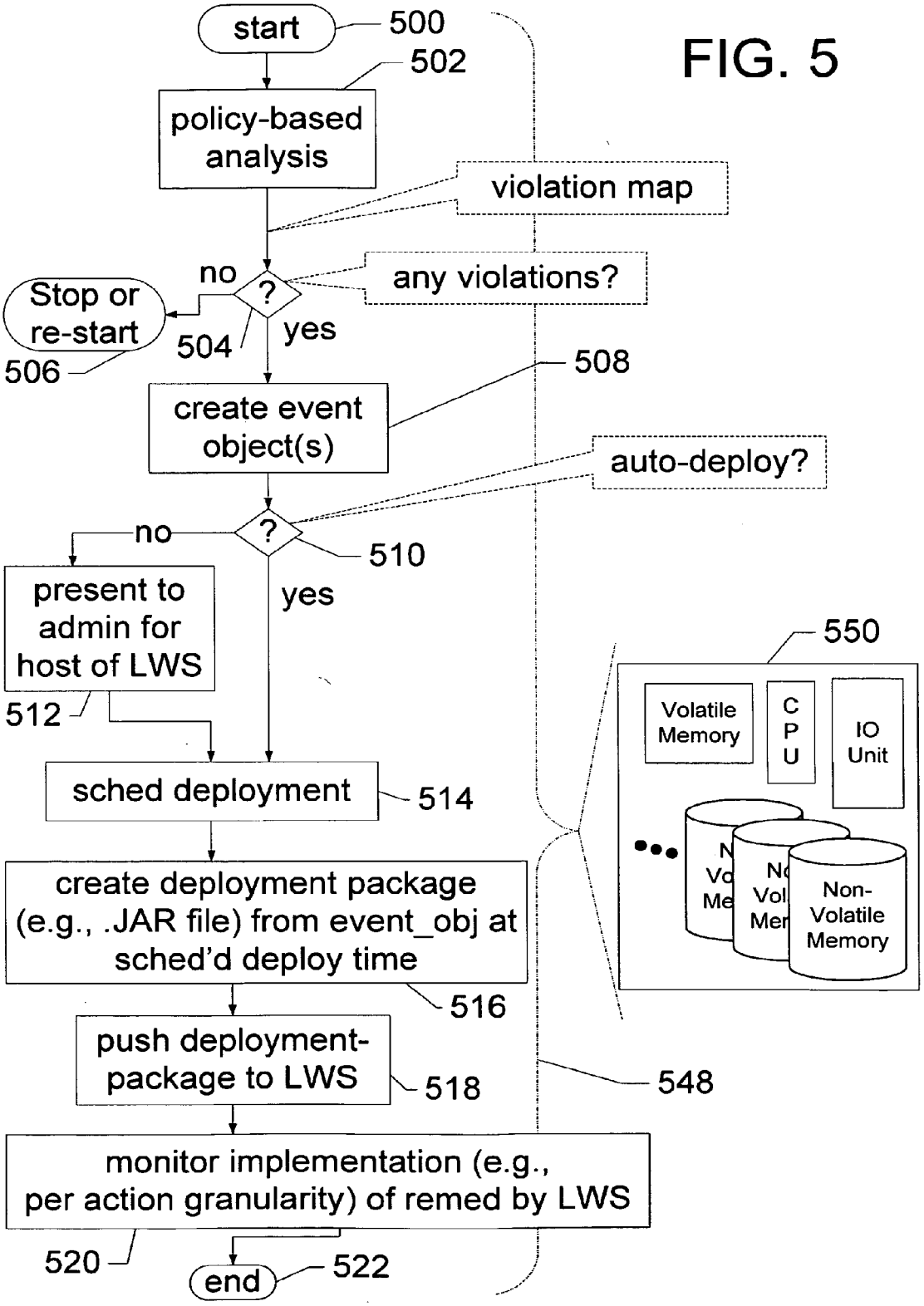
***

806

402

FIG. 4

FIG. 5


start
500
502
policy-based analysis
violation map
any violations?
no
?
yes
Stop or re-start
504
506
508
create event object(s)
auto-deploy?
?
no
yes
510
present to admin for host of LWS
512
sched deployment
514
create deployment package (e.g., .JAR file) from event_obj at sched'd deploy time
516
push deployment-package to LWS
518
548
monitor implementation (e.g., per action granularity) of remed by LWS
520
end
522
550
Volatile Memory
CPU
IO Unit
Non-Volatile Memory

| CE_ID | PARAM | NEW | OLD |
|---|---|---|---|
| 160_999 | CPU_CNT | 1 | null |
| 160_999 | PROCESS_NAME | Outlook® | null |
| 160_999 | DOM_NAM | acct | null |
| 160_999 | OS_TYPE | Windows® 2000 | null |
| * | * | * | |
| * | * | * | |
| * | * | * | |

602

FIG. 6A

| CE_ID | PARAM | NEW | OLD |
|---|---|---|---|
| 160_999 | CPU_CNT | 1 | 2 |
| 160_999 | DOM_NAM | acct | eng |
| 160_999 | OS_TYPE | Windows® 2000 | Windows® XP |
| * | * | * | * |
| * | * | * | * |
| * | * | * | * |

602'

FIG. 6B

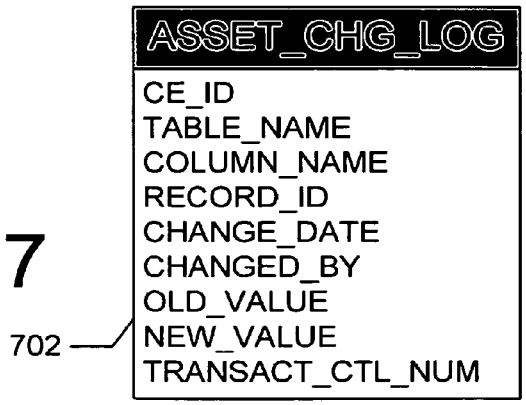



FIG. 7

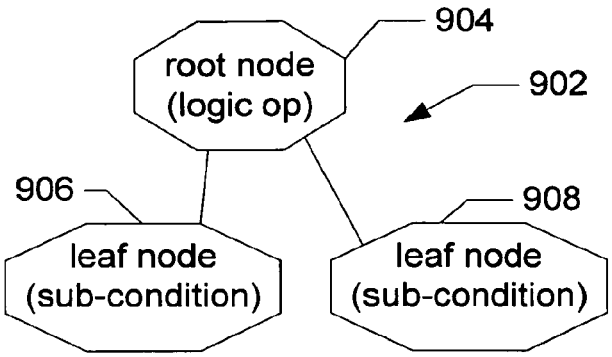

904
root node
(logic op)
902
906
908
leaf node
(sub-condition)
leaf node
(sub-condition)

FIG. 9A

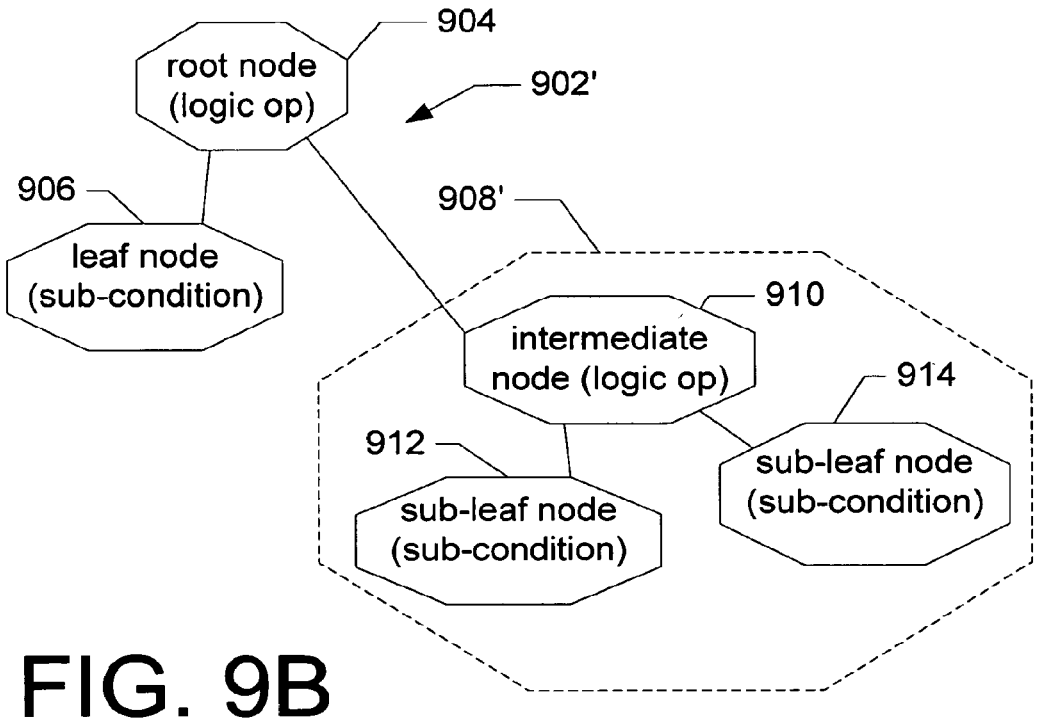

904
root node
(logic op)
902'
906
908'
leaf node
(sub-condition)
910
intermediate
node (logic op)
914
912
sub-leaf node
(sub-condition)
sub-leaf node
(sub-condition)

FIG. 9B

# POLICY-BASED SELECTION OF REMEDIATION

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of U.S. patent application Ser. No. 13/715,017, filed Dec. 14, 2012, which is a continuation of U.S. patent application Ser. No. 12/640,908, filed Dec. 17, 2009, now U.S. Pat. No. 8,341,691, which is a continuation of U.S. patent application Ser. No. 10/933,504, filed Sep. 3, 2004, now U.S. Pat. No. 7,665,119, all of which are hereby incorporated by reference in their entirety for all purposes.

## BACKGROUND

**[0002]** 1. Field

**[0003]** Embodiments of the present invention generally relate to the field of remediation. In particular, embodiments of the present invention relate to determining, based on received parameter values from a computer system at issue that collectively characterize an operational state of the computer system, the existence of a policy violation and responsive thereto automatically selecting and deploying one or more appropriate remediations to the computer system at issue.

**[0004]** 2. Description of the Related Art

**[0005]** Attacks on computer infrastructures are a serious problem, one that has grown directly in proportion to the growth of the Internet itself. Most deployed computer systems are vulnerable to attack. The field of remediation addresses such vulnerabilities and should be understood as including the taking of deliberate precautionary measures to improve the reliability, availability, and survivability of computer-based assets and/or infrastructures, particularly with regard to specific known vulnerabilities and threats.

**[0006]** Too often, remediation is underestimated as merely the taking of security precautions across a network. While remediation includes such taking of security precautions, it is more comprehensive. It is more accurate to view the taking of security precautions as a subset of remediation.

**[0007]** The taking of precautions is typically based upon policies. Such policies are typically based upon security best practices, e.g., a user shall not install his own software, and/or corporate best practices, e.g., a password must be 8 characters in length. To the extent that taking of precautions is automated, the automation typically samples the value of one or more parameters at a given point in time. Then the values of one or more parameters are presented to a user to assess whether the sampled values pose a cause for concern in the context of any policies which are in place.

## SUMMARY

**[0008]** Methods and systems are described for remediating a security policy violation on a computer system. According to one embodiment, information is received by a first computer system regarding a program-code-based operational state of a second computer system at a particular time. A determination is made regarding whether the program-code-based operational state of the second computer system represents a violation of one or more security policies that have been applied to or are active in regard to the second computer system by evaluating, by the first computer system, the received information with respect to the one or more security policies. Each security policy defines at least one parameter condition violation of which is potentially indicative of unauthorized activity on the second computer system or manipulation of the second computer system to make the second computer system vulnerable to attack. When the determination is affirmative, then a remediation is identified by the first computer system that can be applied to the second computer system to address the violation; and the first computer system causes the remediation to be deployed to the second computer system.

**[0009]** Other features of embodiments of the present invention will be apparent from the accompanying drawings and from the detailed description that follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** Embodiments of the present invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

**[0011]** FIG. **1** is a block diagram of an architecture for a policy-based remediation system into which embodiments of the present invention can be incorporated.

**[0012]** FIGS. **2**A, **2**B, **2**C and **2**D are linked database structures illustrating data relationships in a machine-actionable memory that represent parameters of a host-asset, according to an embodiment of the present invention.

**[0013]** FIG. **3**A is a UML-type sequence diagram depicting a first part of a method of determining which policies are violated, according to an embodiment of the present invention.

**[0014]** FIG. **3**B is a UML-type sequence diagram depicting a second part of a method of determining which policies are violated, according to an embodiment of the present invention.

**[0015]** FIG. **4** depicts a violation table illustrating data relationships in a machine-actionable memory that represent policies that have been violated, according to an embodiment of the present invention.

**[0016]** FIG. **5** is a flow diagram illustrating a policy-based method of remediation selection, and a method of remediation deployment, according to an embodiment of the present invention.

**[0017]** FIG. **6**A is a survey table illustrating data relationships in a machine-actionable memory that represent survey data from a current sample, according to an embodiment of the present invention.

**[0018]** FIG. **6**B depicts a new-vs-old table, according to an embodiment of the present invention.

**[0019]** FIG. **7** depicts a UML-type database structure, entitled ASSET_CHG_LOG (asset change log) that is used to keep a history of changes in the value of a parameter, according to an embodiment of the present invention.

**[0020]** FIG. **8** depicts a policy information table illustrating data relationships in a machine-actionable memory that represents which policies are active on which of the various host-assets, according to an embodiment of the present invention.

**[0021]** FIG. **9**A is a diagram of a condition-tree, according to an embodiment of the present invention.

**[0022]** FIG. **9**B is a diagram of another version of the condition-tree of FIG. **9**A, according to an embodiment of the present invention.

## DETAILED DESCRIPTION

**[0023]** Methods and systems are described for remediating a security policy violation on a computer system.

**[0024]** FIG. **1** is a block diagram of an architecture **100** for a policy-based remediation system into which embodiments of the present invention can be incorporated, making system **100** itself represent at least one embodiment of the present invention.

**[0025]** Architecture **100** can include: a server **102** (having one or more processors **103**A, non-volatile memory **103**B and other components **103**C); a database (DB) of remediations **104**; a DB of assets **106**; a DB of policies **106**; and a group **108** of networked assets. Generalized networked communication is represented by path **112**. Access to entities external to architecture **100**, e.g., the Internet (item **113**) is available via path **112**.

**[0026]** Server **102** can be a component of the network to which group **108** represents assets. Other components **103**B typically include an input/output (IO) unit, volatile memory (e.g., RAM, etc.), non-volatile memory (e.g., disk drives, etc.), etc. DBs **104**, **106** and **107** can be local non-volatile memory resources of server **102**.

**[0027]** Examples of assets in group **108** include network-attached storage (NAS) devices **160**, routers **162**, switches **164**, computers (also referred to as PCs) **166**, printers **168**, etc. Assets in group **108** will be generally be referred to as host-assets **16**X. In group **108**, host-assets **16**X can be generalized as devices having some measure of program-code-based operation, e.g., software, firmware, etc., which can be manipulated in some way via an instance of a communication, e.g., arriving via path **112**, and as such can be vulnerable to attack.

**[0028]** Each of the various host-assets **16**X in group **108** is depicted as hosting a light weight sensor (LWS) **109**. Each LWS **109** and server **102** adopt a client-server relationship. Operation of each LWS **109** can include gathering information about its host-asset **16**X and sending such information to server **102**; and receiving remediations in an automatically-machine-actionable format from server **102** and automatically implementing the remediations upon its host-asset **16**X.

**[0029]** An automatically-machine-actionable remediation can take the form of a sequence of one or more operations that automatically can be carried out on a given host-asset **16**X under the control of its LWS **109**. Such operations can be invoked by one or more machine-language commands, e.g., one or more Java byte codes.

**[0030]** Server **102** can evaluate the gathered-information regarding host-assets **16**X in terms of policies that have been applied, or are active in regard to, host-assets **16**X, respectively. Based upon the evaluations, server **102** can select remediations and then send them to host-assets **16**X, respectively.

**[0031]** Each host-asset **16**X is provided with local programs and/or services (hereafter, survey tools) that can collect values of a plurality of parameters (hereafter, survey data) which collectively characterize an operational state of host-asset **16**X at a particular point in time. Each LWS **109** can invoke such survey tools and/or cooperate with periodic scheduling of such survey tools to obtain the survey data. Then each LWS **109** can also transmit the survey data to server **102**.

**[0032]** For example, consider LWS **109** of NAS **160**, whose transmission of survey data to server **102** is indicated by a communication path **130** superimposed on path **112** in FIG. **1**. Continuing the example, once server **102** has selected one or more remediations for NAS **160**, server **102** deploys the selected remediation(s) to LWS **109** of NAS **160** as indicated by a communication path **132**. The selected remediations can take the form of a deployment package that can include one or more automatically-machine-actionable actions, e.g., a set of one or more Java byte codes for each automatically-machine-actionable action. It is noted that, for simplicity of illustration, only NAS **160** is depicted in FIG. **1** as sending survey data and receiving a deployment package. It is to be understood that instances of paths **130** and **132** would be present for all LWSs **109**.

**[0033]** Next, details as to the gathering of information will be discussed and examples of policies provided, followed by discussion of how violations of policies can be automatically determined, and how corresponding remediations can automatically be selected. To accompany the discussion, FIGS. **3**A-**3**B are provided.

**[0034]** FIGS. **3**A-**3**B are a UML-type sequence diagrams depicting a method of determining which policies are violated, according to at least one embodiment of the present invention.

**[0035]** Server **102** and each LWS **109** can, e.g., be provided with services (not depicted in LWSs **109** but see corresponding communication service **170** in server **102**), e.g., J2EE-type services, that carry out communication therebetween. For example, see message **304** in FIG. **3**A sent from a given instance of LWS **109** to communication service **170**.

**[0036]** Survey data from an instance of LWS **109** (which is transferred via path **130**) can be formatted in a variety of ways. For example, within the survey data, a portion representing a particular parameter can be preceded by a service key, e.g., a string of data that denotes the service on host-asset **16**X that collected the portion. Server **102** can be provided with a parser service **172**, a J2EE-type service, that can parse the survey data. In the context of FIG. **3**A, communication service **170** can pass the survey data to parser server **172** at message **306**.

**[0037]** Parser service **172** can sequentially examine the survey data, looking for pairs of service keys and associated data portions. Continuing the example, parser service **172** can recognize a service key (k), recognize as being associated therewith a data portion (k), e.g., found between service key (k) and a subsequent service key (k+1), and call an interpretation service (not depicted) corresponding to service key (k) to interpret data portion (k). Parser service **172** can take the output of the respective interpretation services and build a survey table of new parameter values. This can be an iterative process. One of ordinary skill in the art would understand that there are other ways to process the survey data.

**[0038]** In the context of FIG. **3**A, such an iterative loop is denoted by item No. 308 and is given the label "[PAIR(i), i.ltoreq.M−1, FOR M PAIRS]." In UML notation, the asterisk (*) denotes iteration, and iteration of loop **308** will continue while the statement within the square brackets is true. Here, the statement for loop **308** indicates that looping iterates for each PAIR(i) of a service key and its related portion of the survey data (or, in other words the i.sup.th PAIR) while (so long as) the variable, i, is less than or equal to M−1 (namely, i.ltoreq.M−1). The boundary M denotes the total number of pairs of service keys and related data present in the survey data.

**[0039]** At self-message **310** in FIG. **3**A, parser service **172** can parse the survey data to obtain the i.sup.th pair, also

known as PAIR(i). At message **312**, parser service **172** calls an interpretation service according to the value of the service key in PAIR(i). Hence, such an interpretation service is generally referred to as an i.sup.th interpretation service **180** in FIG. **3**A. At message **314**, i.sup.th interpretation service sends back interpreted data to parser service **172**. In response, at message **316**, parser service **172** can create survey table **602** if this is the first pass through loop **308** and survey table **602** does not yet exist. Otherwise, if survey table **602** already exists, then parser service **172** can append the interpreted data to survey table **602**.

**[0040]** FIG. **6**A is an example of a survey table **602** illustrating data relationships in a machine-actionable memory that represent new survey data from the present sample, according to at least one embodiment of the present invention.

**[0041]** More particularly, survey table **602** illustrates data relationships created by parser service **172**, e.g., in volatile memory **103**B, based upon the survey data, according to at least one embodiment of the present invention. As such, survey table **602** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0042]** Survey table **602** can be described as a CE_ID: PARAM:NEW:OLD mapping, where CE_ID is an acronym for an identification (ID) of a given LWS **109** loaded on a given host-asset **160**X, and where each instance of a host-asset **16**X can be described as a client environment (CE). Each row of table **602** can include: a CE_ID field; a PARAM field (name of parameter); a NEW field (new value of the parameter); and an OLD field (old value of the parameter). Each row of table **602** represents a mapping between a value for the CE_ID, a name or identification (ID) of a parameter, a new value thereof obtained during the present sampling (k) by the survey tool(s), and an old value thereof obtained during a preceding sampling (e.g., k−1).

**[0043]** Here, continuing the example of survey data from path **130**, it is assumed that NAS **160** has CE_ID=160.sub.--999 for (merely) the purposes of illustration. As will be discussed below, values of many different types of parameters are gathered from the various host-assets **160**X, respectively. Further continuing the example of survey data from path **130**, survey table **602** assumes that the survey data includes: the parameters CPU_CNT, PROCESS_NAME, DOM_NAM and OS_TYPE as being reported in the data; and the corresponding values 1, Outlook®, acct (abbreviation for account) and Windows®. 2000, respectively. Initially, null values are stored in the OLD fields. Typically, many other parameters will be present in the survey data and reflected in table **602**. Here, only four samples of parameters and values thereof are presented, for simplicity of illustration.

**[0044]** Server **102**, e.g., via parser service **172**, can then assess whether there has been a change in the values of the parameters in the survey data from the present sample (k) relative to a preceding sample, e.g., the immediately preceding sample (k−1). This can be done by server **102** querying asset DB **106** for all parameter records that pertain to a given host-asset **16**X, and then comparing the new values (k) against the old values (e.g., k−1) to identify those that have changed. An architecture for DB **106** will now be discussed.

**[0045]** FIGS. **2**A, **2**B, **2**C and **2**D are linked database structures illustrating data relationships in a machine-actionable memory, e.g., asset DB **106**, that represent parameter values for the various host-assets **160**X, according to at least one embodiment of the present invention.

**[0046]** More particularly, FIG. **2**A depicts an asset-parameter (ASSET_PARAMETER) database structure **202**. As such, database structure **202** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0047]** Unlike survey table **602**, database structure **202** (and also database structures **204**-**228**) are depicted as UML-type database structures. This should be understood to mean that database structure **202** represents an at least M×N array, e.g., M rows and N columns where M and N are integers. A row (not depicted) of the array denoted by database structure **202** corresponds to parameter values of a given host-asset **16**X. The columns (not depicted) of the array denoted by database structure **202** correspond to various parameters. The N labels in box **203** denote the parameters, and hence there is a column in the array denoted by database structure **202** for each label in box **203**.

**[0048]** Box **203** indicates that database structure **202** can include, e.g., the following parameters: CE_ID (again, the ID of the particular instance of LWS **109**); DATE_CREATED (date that the asset was created); DATE MODIFIED (last date that the asset was modified); MODIFIED_BY (who modified the asset); BOOT_TIME (time at which the most recent boot-up occurred); OS_TYPE (type of operating system); OS_VERSION (version of the operating system); CONNECTED_IP_ADDRESS (IP address assigned to host-asset **160**X); HOST NAME (name of host-asset **160**X); CONNECTED_MAC_ADDRESS (MAC address assigned to host-asset **160**X); SERIAL_NO (serial number assigned to host-asset **160**X); DOM_NAM (domain name of host asset **160**X); DNS_NAME (DNS name assigned to host asset **160**X); DHCP_ENABLED (is DHCP, namely dynamic host control protocol, enabled?); BIOS_MFG (name of the manufacturer of the BIOS); BIOS_VERSION (version of the BIOS); CPU_CNT (number of processors); CPU_FAMILY (processor's family of architectures, e.g., Centrino®; CPU_MODEL (model of processor); CPU_SPEED (speed of processor); CPU_UTILIZATION (percentage utilization of the processor); HD_FREE (free space on the hard disk); HD_TOTAL (total space of the hard disk); RAM_PAGE (page size for RAM); RAM_TOTAL (total size of RAM); RAM_VIRTUAL (amount of virtual RAM); RAM_UTILIZATION (percentage utilization of RAM); RM_ACTION_ALLOWED (remote actions allowed); SURVEY_INTERVAL (interval of at which sampling to obtain survey data takes place); MOST_RECENT_SURVEY (DTS, namely date-time stamp, of most recent survey data); and TRANSACT_CTL_NUM (a surrogate key to uniqueness of rows in database structure **202**).

**[0049]** One of ordinary skill in the art will recognize that values for those parameters listed by box **203** of database structure **202**, a subset thereof and/or other parameters can be gathered by the survey tools. Appropriate sets of parameters depend upon the nature of the technology found in host-assets **16**X, the granularity of information which an administrator of architecture **100** desires, etc. The same is true for database structures **204**-**228**.

**[0050]** FIG. **2**A also depicts UML-type database structures **204**-**228**. FIG. **2**B is a version of FIG. **2**A that depicts database structures **204**, **206**, **208**, **212** and **214** in more detail and database structure **202** in less detail. As such, each of database structures **204**, **206**, **208**, **212** and **214** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0051]** Consider, for example, database structure **204**, which is entitled asset-user (ASSET_USER). Each row in database structure **204** can include a CE_ID field (used as a foreign key relative to database structure **204**), a USER_NAME field (user's name), and a TRANSACT_CTL_NUM field. It should be understood that multiple users can potentially use a given host-asset **16**X, most with permission but some possibly without permission. Hence, different rows in the array represented by database structure **204** can identify different users of the various host-assets **16**X, respectively.

**[0052]** Database structure **204** is connected to database structure **202** via a path that terminates in a open diamond (.diamond.) at database structure **202**. The open diamond denotes aggregation. In terms of ASSET_USER database structure **204**, multiple instances or values of the parameter USER_NAME can exist for a given asset many of whose parameters are stored in ASSET_PARAMETER database structure **202**. Such aggregation also can include the characteristic that if rows for a given asset are deleted in ASSET_PARAMETER database structure **202**, then the corresponding one or more rows in ASSET_USER database structure **204** are not necessarily deleted as a consequence. Each of database structures **206-228** is also connected to database structure **202** via a path that terminates in a open diamond (.diamond.) at database structure **202**.

**[0053]** Database structure **206** is entitled asset-user-group (ASSET_USER_GROUP). Each row in database structure **206** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a GROUP_NAME field (user-group's name); and a TRANSACT_CTL_NUM field. Database structure **206** is an accommodation for the possibility that multiple user-groups can be given permission to use a given host-asset **16**X. Different rows in the array represented by database structure **206** can identify different user groups for the various host-assets **16**X, respectively.

**[0054]** Database structure **208** is entitled asset-user-account (ASSET_USER_ACCOUNT). Each row in database structure **208** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a USER_NAME field (user's name); a password (PASSWORD) field; a DOMAIN_USER field (user's domain); a LOGIN_TIME field (time of most recent login); LOGOUT_TIME field (time of most recent logout); and a TRANSACT_CTL_NUM field. Database structure **208** can store information about the activity of the multiple users that can be given permission to use a given host-asset **16**X. Different rows in the array represented by database structure **208** can store data regarding different users' activity on the various host-assets **16**X, respectively.

**[0055]** Database structure **212** is entitled asset-process (ASSET_PROCESS). Each row in database structure **212** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a P_ID field (ID of process); a PROCESS_NAME field (name of process); and a TRANSACT_CTL_NUM field. Database structure **212** is an accommodation for the possibility that multiple processes can be running on a given host-asset **16**X. Different rows in the array represented by database structure **212** can store data regarding different processes running on the various host-assets **16**X, respectively.

**[0056]** Database structure **214** is entitled asset-file (ASSET_FILE). Each row in database structure **214** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a PARENT_DIRECTORY field (path to file location); a FILE_NAME field (name of file); an IS_DIRECTORY field (is file actually a directory?); a PERMISSION field (read/write permission, DTS, etc.); and a TRANSACT_CTL_NUM field. Database structure **214** is an accommodation for the possibility of desiring to determine the presence of a particular file in a given location, the status of the file's permissions, etc. Hence, rows in the array represented by database structure **214** can store information about various files that are loaded on the various host-assets **16**X, respectively.

**[0057]** FIG. **2**C is a version of FIG. **2**A that depicts database structures **210**, **216** and **218** in more detail and database structure **202** in less detail. As such, each of database structures **210**, **216** and **218** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0058]** Database structure **210** is entitled asset-hard-drive (ASSET_HARD_DRIVE). Each row in database structure **210** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a NAME field (hard drive name); a TYPE field (type of hard drive); a CAPACITY field (storage capacity of the hard drive); a SERIAL_NO field (serial number assigned to the hard drive); a FILE_SYSTEM field (type of file system to which the hard drive is configured); a USED_SPACE field (amount of storage used); a FREE_SPACE field (amount of storage remaining unused); a COMPRESSED field (are the files compressed?); a LABEL field (label given to the hard drive); a MFG_NAME field (name of the hard drive's manufacturer); a NO_OF_PARTITIONS field (number of partitions into which the hard drive is divided); a SECTORS_PER_TRACK field (number of sectors per track); a TOTAL_CYLINDERS field (total number of cylinders or platters); a TOTAL_HEADS field (total number of heads); a TOTAL_SECTORS field (number of sectors per track); a TOTAL_TRACKS field (total number of tracks); a TRACKS_PER_CYLINDER field (number of tracks per cylinder); and a TRANSACT_CTL_NUM field. Database structure **210** is an accommodation for the possibility that there can be multiple hard drives on a given host-asset **16**X. Different rows in the array represented by database structure **210** can store data regarding various hard drives which form parts of the various host-assets **16**X, respectively.

**[0059]** Database structure **216** is entitled asset-file-system (ASSET_FILE_SYSTEM). Each row in database structure **216** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a VOLUME_NAME field (name of storage volume); a MEDIA_TYPE field (type of media); a CAPACITY field (storage capacity of the file system); a VOLUME_SL_NO field (volume serial number); a FILE_SYSTEM field (type of file system); a USED_SPACE field (amount of storage the file system that has been used); a FREE_SPACE field (amount of storage in the file system remaining unused); a COMPRESSED field (are the files compressed?); a LABEL field (label given to the file system); and a TRANSACT_CTL_NUM field. Database structure **216** is an accommodation for the possibility that there can be multiple file systems in use on a given host-asset **16**X. Different rows in the array represented by database structure **216** can store data regarding different file-systems used by the various host-assets **16**X, respectively.

**[0060]** Database structure **218** is entitled asset-application (ASSET_APPLICATION). Each row in database structure **216** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a VENDOR field (name of the application's vendor); a PRODUCT field (name of applica-

tion); a VERSION field (version of the application); a SERIAL_NUM field (serial number assigned to the application); a LICENSE_NUM field (number of license for the application); a SKU_NUM field (SKI, namely stock-keeping unit, number); an INSTALL_DATE field that the application was installed); and a TRANSACT_CTL_NUM field. Database structure **218** is an accommodation for the possibility that there can be multiple applications loaded on a given host-asset **16**X. Different rows in the array represented by database structure **218** can store data regarding different applications loaded on the various host-assets **16**X, respectively.

**[0061]** FIG. **2**D is a version of FIG. **2**A that depicts database structures **220**, **222**, **224**, **226** and **228** in more detail and database structure **202** in less detail. As such, each of database structures **220**, **222**, **224**, **226** and **228** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0062]** Database structure **220** is entitled asset-route-table (ASSET_ROUTE_TABLE). Each row in database structure **220** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a TARGET field (address to which communication directed); a GATEWAY field (gateway through which communication proceeds; a NETMASK field (bit mask used to tell how much of an IP address identifies the subnetwork that the given host-asset **16**X is on and how much identifies the host-asset **16**X itself); and a TRANSACT_CTL_NUM field. Database structure **220** is an accommodation for the possibility that there can be multiple routes by which communication can be sent from a given host-asset **16**X. Different rows in the array represented by database structure **220** can store information regarding various routes of communication being used by the various host-assets **16**X, respectively.

**[0063]** Database structure **222** is entitled asset-ARP-table (ASSET_ARP_TABLE). Each row in database structure **222** can include: a CE_ID field (used as a foreign key relative to database structure **204**); an INTERNET_ADDRESS field (internet address, e.g., IP address, of host-asset **16**X involved in a communication); a PHYSICAL_ADDRESS field (address of hardware on host-asset **16**X involved in a communication); a TYPE field (ARP mapping dynamic or static); and a TRANSACT_CTL_NUM field. Database structure **222** is an accommodation for the possibility that there can be multiple components on a given host-asset **16**X that are engaged in external communication. Different rows in the array represented by database structure **222** can store data regarding different various components on the various host-assets **16**X, respectively, that are engaged in communication.

**[0064]** Database structure **224** is entitled asset-device-driver (ASSET_DEVICE_DRIVER). Each row in database structure **224** can include: a CE_ID field (used as a foreign key relative to database structure **204**): a DEVICE_NAME field (name of driver); a DEVICE_TYPE field (type of driver); a MFG_NAME field (name of driver's manufacturer); and a TRANSACT_CTL_NUM field. Database structure **224** is an accommodation for the possibility that there can be multiple drivers loaded on a given host-asset **16**X. Different rows in the array represented by database structure **212** can store data regarding different processes running on the various host-assets **16**X, respectively. Different rows in the array represented by database structure **224** can store information regarding the various drivers loaded on the various host-assets **16**X, respectively.

**[0065]** Database structure **226** is entitled asset-netstat (ASSET_NETSTAT). Each row in database structure **226** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a PROTOCOL field (name of protocol, e.g., TCP, UDP, etc.); a LOCAL_ADDRESS field (port being used for an instance of communication by a given host-asset **16**X); a FOREIGN_ADDRESS field (an address of an entity with which the given host-asset **16**X is in communication): a STATE field (state, e.g., listening, of the communication in which an entity on a given host-asset **16**X is engaged); and a TRANSACT_CTL_NUM field. Database structure **226** is an accommodation for the possibility that there can be multiple instances of external communication in which components on a given host-asset **16**X can be engaged. Different rows in the array represented by database structure **226** can store information regarding various instances of communication in which the various host-assets **16**X, respectively, are engaged.

**[0066]** Database structure **228** is entitled asset-installed-patch (ASSET_INSTALLED_PATCH). Each row in database structure **228** can include: a CE_ID field (used as a foreign key relative to database structure **204**): a PATCH_NAME field (name of installed patch); a VERSION field (version of the installed patch): an INSTALL_DATE field (date that the patch was installed); an UNINSTALL_DATE field (date that the patch was uninstalled); and a TRANSACT_CTL_NUM field. Database structure **228** is an accommodation for the possibility that there can be multiple patches installed on a given host-asset **16**X. Different rows in the array represented by database structure **228** can store data regarding various patches installed on the various host-assets **16**X, respectively.

**[0067]** Discussion now returns to parser service **172**. To review, parser service **172** can query asset DB **106** for all parameter records pertaining to a given host-asset **16**X for which survey data has been received and parsed to form survey table **602**. In the context of FIG. **3**A, such a query is illustrated as a message **318** from parser service **172** to asset DB **106**.

**[0068]** Then parser service **172** can iteratively (e.g., row-by-row for survey table **602**) compare the new parameter values (k) against the old parameter values (e.g., k−1) to identify those that have changed. Such an iterative technique is illustrated in FIG. **3**A as loop **320**. The result of such an iterative technique (or, in other words, the result of loop **320**) is that table **602** is converted into what can be described as a new vs. old table.

**[0069]** Loop **320** of FIG. **3**A is given the label "*[ROW(i), i.ltoreq.N−1, FOR N ROWS IN TBL **602**]." Iteration of loop **320** will continue for each ROW(i) of table **602'** while (so long as) the variable, i, is less than or equal to N−1 (namely, i.ltoreq.N−1). The boundary N denotes the total number of rows in table **602'**.

**[0070]** In loop **320**, parser service **170** searches through parameter values obtained via message **318** for an old value corresponding to the parameter of row(i) of table **602**. Next, FIG. **3**A illustrates a branching message **324**. As indicated by the label "[NEW=OLD]," if parser service **170** finds a corresponding old value and if the old value equals the new value, then branch **326**A of message **324** is taken, by which parser service **174** deletes row(i) from table **602**. Else, as indicated by the label "[NEW.noteq.OLD]," if parser service **170** finds a corresponding old value and if the old value does not equal the new value, then branch **326**B of message **324** is taken, by

which parser service **174** appends the old value to the OLD field of row(i) in table **602**. If no corresponding old parameter value is found, then parser service **170** can ignore the new value. This could be handled by changing the label of branch **324**A to be [NEW=OLD or NEW=NULL].

**[0071]** FIG. **6**B depicts such a new versus old (hereafter, new-vs-old) table **602'** that illustrates a revised version of survey table **602**, according to at least one embodiment of the present invention. As such, survey table **602'** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0072]** Extending the example of survey data from path **130**, it is assumed in FIG. **6**B that parser service **172** has: recognized changes in the parameters CPU_CNT, DOM_NAM, and OS_TYPE; appended the corresponding old values thereof; determined that no change has occurred in the parameter PROCESS_NAME; and deleted the row for the unchanged parameter PROCESS_NAME.

**[0073]** After it finishes the iterative new vs. old comparison that results in new-vs-old table **602'**, parser service **172** can place a copy of new-vs-old table **602'** (or an object representing table **602'**) in an asynchronous queue **173**, e.g., a FIFO buffer, for a policy service **174** (to be discussed below). In the context of FIG. **3**B, this is illustrated as message **328** from parser service **172** to queue **173**. Queue **173** can absorb variations in the rate at which parser service **172** generates instances of new-vs-old table **602'**.

**[0074]** Substantially concurrently, parser service **172** can (according to those rows, if any, remaining in table **602'**) also overwrite corresponding records in database structures **202**-**228** with the new parameter values and append new records to an installment history, e.g., as embodied by a suitable database structure on asset DB **106**. In the context of FIG. **3**B, this is illustrated as message **330** from parser service **172** to asset DB **106**.

**[0075]** FIG. **7** depicts an example of a suitable UML-type database structure **702**, entitled ASSET_CHG_LOG (asset change log) that is used to keep the history of changes in the value of a parameter, according to at least one embodiment of the present invention. Each row in database structure **228** can include: a CE_ID field (used as a foreign key relative to database structure **204**); a TABLE_NAME field (name of the primary table in which the parameter is tracked); a COLUMN_NAME field (name of the parameter); a RECORD_ID field (value of the TRANSACT_CTL_NUM field in the primary table); a CHANGE_DATE field (DTS for change tracked by the given row in database structure **228**); a CHANGED_BY field (entity initiating change); an OLD field (value of the parameter as of the immediately preceding, relative to point in time indicated by the value in the CHANGE_DATE field, sample); a NEW field (value of the parameter as of the point in time indicated by the value in the CHANGE_DATE field); and a TRANSACT_CTL_NUM field. Structure **702** can be used to track the history of changes to each of parameters for all of the assets tracked in ASSET_PARAMETER database structure **202**.

**[0076]** The copies of the various instances of table **602'** in queue **173** can be sequentially processed by a policy service **174** of server **102**. Policy service **174** can obtain an instance of new-vs-old table **602'** from queue **173** and then evaluate the changed data in new-vs-old table **602'** against each policy that is activated for the given host-asset **16**X. This can be iterative. In the context of FIG. **3**B, such iteration is illustrated by loop **332**.

**[0077]** Loop **332** of FIG. **3**B is given the label "[TBL_**602'**(i), I.ltoreq.R−1, FOR R INSTANCES OF TBL_**602**]." Iteration of loop **332** will continue for each TBL_**602'**(i) of queue **173** while (so long as) the variable, i, is less than or equal to R−1 (namely, i.ltoreq.R−1). The boundary R denotes the total number of instances of table **602'** in queue **173**. Policy service **174** gets a copy of table **602'**(i) via message **334** to queue **173**.

**[0078]** Before discussing loop **332** further, a discussion of policies is provided. A policy can define as a condition of a given parameter either of the following: one or more potential values of a given parameter; or one or more values based upon the given parameter. When the condition of a policy is satisfied, this is potentially indicative of unauthorized activity or manipulation of the given host-asset **16**X upon which the policy has been activated.

**[0079]** As a first policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if the value of the CONNECTED_IP_ADDRESS parameter of ASSET_PARAMETER database structure **202** is not one of the IP addresses on an approved list. If such a policy is satisfied, it could potentially (though not necessarily) indicate unauthorized actively on the given host-asset **16**X.

**[0080]** As a second policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if an authorized user of a VPN (virtual private network) is logged in during normal business hours (where VPN usage is for this user is typically expected to be after business hours) and if the given host-asset is connected to the accounting wireless domain (where the user is authorized only to access the engineering and sales domains). If such a policy is satisfied, it could potentially indicate that a known user is engaging in unauthorized activity.

**[0081]** As a third policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if there is a change in the CPU_CNT parameter of ASSET_PARAMETER database structure **202**. If such a policy is satisfied, this could be indicative of one or more processors having been stolen from or added to the given host-asset **16**X, Either type of change can indicate potential unauthorized manipulation of the given-host **16**X, and the latter may potentially be a precursor of forthcoming unauthorized activity on the given host-asset **16**X.

**[0082]** Discussion now returns to loop **332** of FIG. **3**B and policy service **174**. To evaluate the changed data in new-vs-old table **602'** against each policy that is activated for the given host-asset **16**X, policy service **174** can do the following: it can query policy DB **107** for all policies activated for the given host-asset **16**X, e.g., by indexing according to the CE_ID value therefore; then it can build a condition-tree, e.g., in non-volatile memory **103**B, for the condition of each policy that is active for a given host-asset **16**X; and then it can evaluate each row of new-vs-old table **602'** according to each condition-tree, which results in a violation table. An example of a violation table is depicted in FIG. **8**. In the context of FIG. **3**B, policy service **174** queries for the activated policies via message **336** to policy DB **107**.

**[0083]** FIG. **8** depicts an activated policy table illustrating data relationships in a machine-actionable memory that represents which policies are active on which of the various host-assets **16**X, according to at least one embodiment of the present invention.

**[0084]** More particularly, FIG. **8** depicts a policy information (or, in other words, an R_ID:POL_ID:CE_ID) table **802**, illustrating data relationships in a machine-actionable

memory, e.g., in policy DB **107**, that maps policies to remediations, and also maps policies to assets. As such, policy information table **802** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0085]** Policy information (pol-info) table **802** includes the columns R_ID, POL_ID, ACT_ID and CE_ID. A value in the R_ID-column indicates an identification (ID) of a remediation (R_ID) suited to remediating the circumstances of a violated policy. A value in the POL_ID-column indicates an ID of a policy (POL_ID). A value in the ACT_ID-column indicates an ID of action or operation that automatically can be carried out on a given host-asset **16**X to at least in-part implement a remediation. A value in the CE_D-column indicates an ID of a given host-asset **16**X.

**[0086]** An example of constraints upon Pol-info table **802** would be as follows: each policy can map to only one remediation; a remediation, however, can map to one or more policies; each policy can map to one or more assets; etc. Pol-info table **802** can be created by the administrator of architecture **100**, and edited/expanded as policies change and/or are added. Extending the example illustrated via the specific details of new-vs-old table **602'** in FIG. **6**B, it is assumed in FIG. **9**A that records denoted by items **804** and **806** corresponding to the policies violated by the data of the new-vs-old table **602'**.

**[0087]** Returning to the context of FIG. **3**B, at self-message **338**, policy service **174** builds the condition trees for those policies indicated by Pol-info table **802** as being activated for the given host-asset **16**X. For the sake of discussion, it is assumed that each message **338** generates a total of Q condition trees for Q activated policies. Next, at loop **340**, policy service **174** evaluates each condition-tree according to the values of each row of new-vs-old table **602'**(i). Before discussing loop **340**, a discussion of condition trees is provided.

**[0088]** FIG. **9**A is a diagram of a condition-tree **902**, according to at least one embodiment of the present invention. Condition-tree **902** depicts data relationships in volatile memory **103**B. As such, condition-tree **902** depicts a particular type of machine-actionable memory, according to at least one embodiment of the present invention. Condition-tree **902** is an at least two-level hierarchical tree structure that includes: a root node **904**; and leaf node **906**; and one or more optional leaf nodes **908**. There can be N leaf nodes, where N is an integer and N.gtoreq.1. While not limited to a specific maximum value, N typically will fall in a range 2.ltoreq.N.ltoreq.10.

**[0089]** Root node **904** can represent a logical operator, e.g., logical AND, logical OR, logical NOT, etc. leaf nodes **906** and **906** can be statements representing subconditions of the policy's condition. Stated differently, condition tree **902** is a representation of a condition that itself is a collection of conditions. Evaluation of the statements representing the sub-conditions according to the values in a row of new-vs-old table **602'** yields an indication of the statement being true or false, e.g., a logical one or a logical zero.

**[0090]** FIG. **9**B is a diagram of a version **902'** of condition-tree **902**, according to at least one embodiment of the present invention. In FIG. **9**B, node **908** is depicted as a multi-part node **908'**, which can include: an intermediate node **910**, that reports to root node **904**; a sub-leaf node **12**; and one or more sub-leaf nodes **914**. There can be P sub-leaf nodes, where P is an integer and P.about.1. Similarly, sub-leaf nodes **912** and **914** can be statements representing sub-sub-conditions of the sub-condition represented by leaf node **908**. And similarly, evaluation of the statements representing the sub-sub-conditions according to the values in a row of the new-vs-old table **602'** yields an indication of the statement being true or false. One or more of sub-leaf nodes **912** and **914** can be themselves be multi-part nodes, respectively.

**[0091]** Via the use of a condition tree **902/902'**, a policy whose condition is satisfied when a collection of sub-conditions are coincidentally satisfied can be quickly evaluated. Moreover, such condition-trees **902/902'** can quickly and easily be configured and/or reconfigured.

**[0092]** In prior rule-based decision-making software, conditions of a rule are typically represented in source code as if-then-else constructs, rather than as a machine-actionable memory. Coding of such constructs is relatively more difficult, and as is revising such constructs. In addition, if-then-else constructs are sequential in nature. In contrast, condition-trees **902/902'** exploit the parallelism in a condition. Accordingly, condition trees **902/902'** are significantly faster on average to evaluate than a corresponding if-then-else construct.

**[0093]** Stated differently, condition-trees represent an object-oriented representation, where the level of granularity is at the node-level (nodes are the objects) into which a condition is decomposed. In contrast, while an if-then-else construct according to the Background Art might be coded using a high-level object-oriented programming language, at best the condition as a whole of the construct is treated as the sole object. If-then-else constructs are less granular representations of conditions than are condition-trees.

**[0094]** Returning to the first policy example, a corresponding condition-tree could have as simple leaf nodes reporting to the root node the sub-conditions CONNECTED_IP_ADDRESS=given_member_of approved_list for each member of the approved list. The root node for this condition tree could be a logical OR operator.

**[0095]** Returning to the second policy example, a corresponding condition-tree could have as the root node the logical AND operator, and as simple leaf nodes reporting thereto the sub-conditions VPN_CONNECTION (true or false) and USER_VPN_AUTHORIZED (true or false). The condition tree could also have the following multi-part nodes reporting to the root node: the logical AND operator as the intermediate node to which report simple sub-leaf nodes representing the sub-sub conditions DOM_NAM=given_member_of approved_list for each member on the list; and the logical operator NOT as the intermediate node to which reports a simple sub-leaf node representing the sub-sub condition NORMAL_VPN_WINDOW=time_range given_member_of approved_list.

**[0096]** Returning to the third policy example, a corresponding condition-tree could have as the root node the local NOT operator, and as a simple leaf node reporting thereto the sub-condition CPU_CNT_NEW=CPU_CNT_OLD.

**[0097]** The ordinarily-skilled artisan will recognize other ways to construct condition-trees for each of the first, second and third policy examples. In general, policy conditions are typically susceptible to a plurality of constructions.

**[0098]** Similar to how an appropriate set of parameters will vary (again, depending upon the nature of the technology found in host-assets **16**X, the granularity of information thereabout that is desired, etc.), so too will vary the nature and complexity (e.g., the number of sub-conditions whose satisfaction needs to coincide) of policy conditions. Moreover, the

complexity of policies will also vary according to the desired degree to which satisfaction of the policy is a precursor of forthcoming unauthorized activity on or manipulation of the given host-asset **16**X. In other words, condition complexity (and thus policy complexity) will vary according to how early a warning of potential forthcoming unauthorized activity or manipulation the administrator of architecture **100** desires to receive.

**[0099]** Patterns of seemingly unrelated parameter values or changes in the values thereof can warn of or foreshadow potential forthcoming unauthorized activity or manipulation. In this respect, identifying unauthorized activity or manipulation from a pattern of seemingly unrelated parameter values is analogous to the differential diagnosis of a patient's illness by a physician where the patient presents with a plurality of symptoms, many of which can seem unrelated.

**[0100]** Generally, the earlier the warning that is desired, the greater is the number of seemingly unrelated parameter values (or changes in the values thereof) that are included as factors of the condition. Hence, earlier warnings typically dictate policies whose conditions concern a relatively greater number of parameters.

**[0101]** It should be noted that there can be one or more policies which have as the sole condition, or as one or more of the sub-conditions thereof, either of the following definitions: one or more of the potential values defined for the given parameter represent aberrations from normal values of the given parameter; or one or more of the potential values defined for the given parameter represent normal values of the given parameter. Generally, the earlier the warning, the more likely it is that that the latter definition (in which potential values representing normal values) will chosen for one or more sub-conditions of the policy.

**[0102]** A condition for a policy can include as one or more factors (or, in other words, describe) at least one of the following concerning at least one parameter: existence; non-existence; a range of potential values thereof; change in the value thereof; no-change in the value thereof; a maximum amount of change in the value thereof; a minimum amount of change in the value thereof; a maximum potential value thereof; a minimum potential value thereof; being equal to a specific value thereof; not being equal to a specific value thereof; presence on a list; absence from a list; etc.

**[0103]** Some additional examples of policies will be briefly mentioned. Again, satisfaction of the conditions of such policies can potentially be indicative of unauthorized activity or manipulation of the given host-asset **16**X.

**[0104]** As a fourth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the BOOT_TIME parameter from of ASSET_PARAMETER database structure **202** is not consistent with the value of the MOST_RECENT_SURVEY parameter of ASSET_PARAMETER database structure **202**. Satisfaction of this condition potentially can indicate unauthorized manipulation of the system clock on the given host-asset **16**X.

**[0105]** As a fifth policy example, consider a two-sub-condition policy which is violated (or, in other words, whose condition is satisfied) if: the CPU_CNT parameter of ASSET_PARAMETER database structure **202** changes; and the DHCP_ENABLED parameter of ASSET_PARAMETER database structure **202** is true. Servers typically do not enable DHCP, using instead a static IP address. Where the given host-asset **16**X is a server, satisfaction of this condition potentially can indicate that that a malefactor who added the processor to the server desires to keep the extra processor invisible.

**[0106]** As a sixth policy example, consider a multi-sub-condition policy which is violated (or, in other words, whose condition is satisfied) if: the value of the CPU_UTILIZATION parameter of ASSET_PARAMETER database structure **202** exhibits a spike; and there is a pattern that the value of the RAM_UTILIZATION parameter of ASSET_PARAMETER database structure **202** exhibits a spike and then returns substantially to the previous value. Satisfaction of this condition potentially can indicate that a user is hiding use of some volatile memory and/or a rogue application is attempting to minimize the amount of time that it exposed.

**[0107]** As a seventh policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the RAM_TOTAL parameter of ASSET_PARAMETER database structure **202** is less than a previous value. Satisfaction of this condition potentially can indicate unauthorized removal (e.g., theft) of volatile memory device(s) from the given host-asset **16**X or that some of the volatile memory is deliberately being hidden. Alternatively, if the value of the RAM_TOTAL parameter increases, then this potentially can indicate unauthorized addition of volatile memory device(s) from the given host-asset **16**X.

**[0108]** As an eighth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of DOM_NAM parameter of ASSET_PARAMETER database structure **202** is a null value (indicating that the given host-asset **16**X does not belong to the domain); and the value of the USER_NAME parameter of ASSET_USER database structure **204** is not on a list of users approved for the given host-asset **16**X. Satisfaction of this condition potentially can indicate an unauthorized user.

**[0109]** As a ninth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the calculated value of a hard disk's size (which can be based upon the values of the SECTORS_PER_TRACK and TOTAL_TRACKS parameters of ASSET_HARD_DRIVE database structure **210**) does not substantially match the value of the CAPACITY parameter of ASSET_HARD_DRIVE database structure **210**. If there are a negligible number of bad sectors, then satisfaction of this condition potentially can indicate a portion of the hard disk storage space is being hidden.

**[0110]** As a tenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the GATEWAY parameter of ASSET_ROUTE_TABLE database structure **220** has changed from the preceding value, which is assumed to be a default value. Satisfaction of this condition potentially can indicate a communication which a malefactor hopes will go unnoticed.

**[0111]** As an eleventh policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the SERIAL_NUM parameter in ASSET_APPLICATION database structure **218** changes. Where the unit having the change serial number is a processor, satisfaction of the condition potentially can indicate an unauthorized swap of processors. Due to manufacturing tolerances, otherwise identical instances of processors can exhibit different tolerances to ambient temperature; here, a malefactor could have swapped a processor with a lower ambient temperature tolerance for a processor with higher ambient temperature tolerance.

**[0112]** As a twelfth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the DHCP_ENABLED parameter of ASSET_PARAMETER database structure **202** is false. As noted, servers typically do not enable DHCP, but all other computer-based devices typically do enable DHCP. Where the given host-asset **16**X is not a server, satisfaction of this condition potentially can indicate that that a malefactor has statically set the IP address of the given host-asset **16**X in order to login to the network fraudulently as another user.

**[0113]** As a thirteenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the PROCESS_NAME parameter in ASSET_PROCESS database structure **212** is not on a list of processes approved for the given host-asset **16**X. Satisfaction of this condition potentially can indicate processes that should not be running on the given host-asset **16**X.

**[0114]** As a fourteenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the PRODUCT parameter of ASSET_APPLICATION database structure **218** is on a list of applications not approved for the given host-asset **16**X. Satisfaction of this condition could indicate that an unwanted file-sharing program, e.g., KAZAA, is installed irrespective of whether it is running as a process.

**[0115]** As a fifteenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the LOCAL_ADDRESS parameter of ASSET_NETSTAT database structure **226** includes a port value that is not on a list of ports approved for listening by the given host-asset **16**X. Satisfaction of this condition could indicate that an unauthorized web server is running on the given host-asset **16**X.

**[0116]** As a sixteenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of the DEVICE_TYPE parameter of ASSET_DEVICE_DRIVER database structure **224** indicates that the driver is on list of unauthorized driver types, e.g., including USB-type drivers. Some information security best practices call for there to be no removable storage devices connected to networked computers. An common example of a small, easily concealed removable storage media is a USB-type memory stick. Satisfaction of this policy's condition potentially can indicate that a removable storage device, e.g., USB-type memory stick, is connected to the given host-asset **16**X.

**[0117]** As a seventeenth policy example, consider a policy which is violated (or, in other words, whose condition is satisfied) if: the value of a given parameter, e.g., the PRODUCT parameter of ASSET_APPLICATION database structure **218**, is absent from a list of permissible values; and the value of the given parameter is absent from a list of impermissible values. Satisfaction of this condition potentially can indicate the presence of an entity, e.g., an application, on the given host-asset **16**X which the administrator of architecture **100** has yet to encounter.

**[0118]** Discussion now returns to loop **340** of FIG. **3**B and policy service **174**. Nested within loop **340** is a loop **342**, and nested within loop **342** is a prerequisite-dependent group **346** of messages.

**[0119]** Again, at loop **340**, policy service **174** evaluates each condition-tree according to the values of each row of new-vs-old table **602'**(i). Loop **340** of FIG. **3**B is given the label "*[ROW(j), j.ltoreq.N−1, FOR N ROWS IN TABLE **602'**(i)]." Iteration of loop **332** will continue for each TBL_**602'**(i) of queue **173** while (so long as) the variable, i, is less than or equal to R−1 (namely, i.ltoreq.R−1). Again, the boundary N denotes the total number of rows in table **602'**(i).

**[0120]** Nested loop **342** of FIG. **3**B is given the label "*[POLICY(h), h.ltoreq.Q−1, FOR Q POLICIES]." Iteration of loop **342** will continue for each POLICY(h) for table **602**(*i*) while (so long as) the variable, h, is less than or equal to Q−1 (namely, h.ltoreq.Q-1). Again, the boundary N denotes the total number of rows in table **602'**(i). At self-message **344**, policy service **174** applies policy(h) to row(j) of table **602'**(i). Then nested group **346** is entered.

**[0121]** Group **346** of FIG. **3**B is given the label "[IF POLICY(h) VIOLATED (CONDITION SATISFIED)]," which represents the pre-requisite to group **346**. Messages **348** and **350** are included in group **346**. Messages **348** and **350** occur if the prerequisite is met. More particularly, if self-message **344** determines that policy(h) has been violated, then policy service can query policy DB **107** for more information regarding policy(h), as indicated by message **348**. Then policy service **174** can create a violation table (to be discussed in more detail below), e.g., in volatile memory **103**B, to represent the additional information regarding policy(h). Creation of the violation table is represented by message **350**. If the violation table has already been created in a previous iteration of loop **340**, then policy service **174** appends the additional information regarding policy(h) to the existing at message **350**.

**[0122]** An example of a suitable violation table can be an adaptation of new-vs-old table **602'**. Information that policy service **174** can add to new-vs-old table **602'** can include: an ID of the policy (POL_ID) that was violated; and an ID of a remediation (R_ID) suited to remediating the circumstances of the violated policy.

**[0123]** FIG. **4** depicts a violation table **402** illustrating data relationships in a machine-actionable memory that represent policies that have been violated, according to at least one embodiment of the present invention. In other words, violation table **402** illustrates a particular type of machine-actionable memory arranged according to a particular data structure.

**[0124]** In violation table **402**, each row can identify (and thus map between) a policy that has been violated, the one or more parameters whose value (or values or changes therein) violated the policy, the new value (k) and at least the preceding corresponding value (k−1). Each row of table **402** can include: a CE_ID field (as in new-vs-old table **602'**); at least one PARAM field (similar to new-vs-old table **602'**); a NEW field (as in new-vs-old table **602'**); at least one OLD field (similar to new-vs-old table **602'**); a R_ID field; and a POL_ID field.

**[0125]** As noted above, policy service **174** can produce violation table **402** by adapting new-vs-old table **602'**, e.g., appending IDs of the violated policies (POL_IDs) and IDs of the associated remediations (R_IDs) to the corresponding rows of the parameters responsible for the violations, respectively. Extending the example illustrated via the specific details of new-vs-old table **602'** in FIG. **6**B, it is assumed in FIG. **4** that policies concerning the parameters CPU_CNT and DOM_NAM have been violated. Accordingly, information from the records corresponding to items **904** and **906** in R_ID:POL_ID:CE_ID table **902** has been appended to new-vs-old table **602'** to form violation table **402**. For simplicity of

illustration, values for the column labeled OLD(K−2) have not been depicted, but such values could be present.

**[0126]** After completing violation table **402**, policy service **174** can pass violation table **402** to an event service **176**. Again, each row in violation table **402** can be described as representing a remediation for the given host-asset **16**X. Server **102** can send remediations to the given LWS **109** via event service **176** and a deployment service **178**, e.g., as follows.

**[0127]** For example, event service **176** can prepare an event object corresponding to each row of violation table **402**. Thus, each event object represents a remediation for the given host-asset **16**X. Event service **176** can pass each event object to a deployment service **178**, which can prepare a deployment package for each event object and then send the respective deployment package to the given LWS **109** via communication service **170**.

**[0128]** The above discussion can be summarized by referring to FIG. **5**. FIG. **5** is a flow diagram illustrating a policy-based method of remediation selection, and a method of remediation deployment, according to at least one embodiment of the present invention.

**[0129]** Flow in FIG. **5** begins at block **500** and proceeds to block **502**, which has the label "policy-based analysis." The preceding discussion has described a policy-based analysis that yields violation map **402**. This can be contrasted with what can be described as a vulnerability-based analysis.

**[0130]** Examples of vulnerability-based analysis are two related copending applications that are assigned to the same assignee as the present application. The two related copending applications are: U.S. patent application Ser. No. 10/897,399 having a U.S. filing date of Jul. 23, 2004; and U.S. patent application Ser. No. 10/897,402 that also has a U.S. filing date of Jul. 23, 2004. The entirety of the '399 patent application is hereby incorporated by reference. The entirety of the '402 patent application is hereby incorporated by reference.

**[0131]** From block **502**, flow proceeds in FIG. **5** to decision block **504**, where server **102** can, e.g., via event service **176**, check whether any policies activated for the given host-asset **16**X have been violated. For example, this can be done by event service **176** checking if violation table has any non-null rows. If not, then flow can proceed to block **506** where flow stops or re-starts, e.g., by looping back to block **500**. But if there is at least one non-null row in violation table **402**, then can flow proceed to block **508**, where event service **176** can create an event object (e.g., EVENT) corresponding to each non-null row in violation table **402**. Flow can then proceed to decision block **510**.

**[0132]** At decision block **510**, server **102**, e.g., via deployment service **178**, can determine whether to automatically deploy each event object. As each is produced, event service **176** can pass the event object EVENT(i) to deployment service **178**. Deployment service can then determine whether the object EVENT(i) should be automatically deployed, e.g., based upon an automatic deployment flag set in a record for the corresponding policy stored in policy DB **107**. Alternatively, a field labeled AUTO_DEP can be added to violation table **402**, which would be carried forward in each object EVENT(i). The administrator of architecture **100** can make the decision about whether the remediation for a policy should be automatically deployed.

**[0133]** If automatic-deployment is not approved for the remediation corresponding to the violated policy of object EVENT(i), then flow can proceed to block **512** from decision block **510**. At block **512**, deployment service can present information about object EVENT(i) to, e.g., the administrator of architecture **100**, who can then decide whether or not to deploy the remediation. Flow proceeds to block **514** from block **512**. But if automatic-deployment is approved for object EVENT(i), then flow can proceed directly to block **514** from decision block **510**.

**[0134]** At block **514** of FIG. **5**, at time at which to deploy object EVENT(i) is determined. Flow proceeds to block **516**, where a deployment package D_PAK(i) corresponding to object EVENT(i) is prepared, e.g., as of reaching the time scheduled for deploying object EVENT(i). Deployment package D_PAK(i) can represent the remediation in an automatically-machine-actionable format, e.g., (again) a sequence of one or more operations that automatically can be carried out on the given host-asset **16**X, e.g., under the control of its LWS **109**. Again, such operations can be invoked by one or more machine-language commands, e.g., one or more Java byte codes. After deployment package D_PAK(i) is created at block **516**, flow can proceed to block **518**.

**[0135]** At block **518**, deployment service **178** can send (or, in other words, push) deployment package D_PAK(i) to the given LWS **109**. For example, deployment service **178** can pass deployment package D_PAK(i) to communication service **170**. Then communication service **170** can send D_PAK (i) to the given LWS **109** over, e.g., path **132**. Flow can proceed from block **518** to block **520**.

**[0136]** At block **520** in FIG. **5**, deployment service **178** can monitor the implementation upon the given host-asset **16**X of the remediation represented by deployment package D_PAK (i). Such monitoring can be carried out via communication facilitated by communication service **170**.

**[0137]** More particularly, interaction between deployment service **178** and the given LWS **109** (via communication service **170**) can obtain more information than merely whether deployment package D_PAK(i) was installed successfully by the given LWS **109** upon its host-asset **16**X. Recalling that a remediation represents one or more operations in an automatically-machine-actionable format, it is noted that a remediation will typically include two or more such operations. LWS **109** can provide deployment service **178** with feedback regarding, e.g., the success or failure of each such operation.

**[0138]** From block **520**, flow proceeds to block **522**, where the flow ends.

**[0139]** It is noted that a bracket **548** is depicted in FIG. **5** that groups together blocks **500**-**522**. And bracket **548** points a block diagram of a typical computer (also referred to as a PC) **550**. Typical hardware components for computer **550** include a CPU/controller, an I/O unit, volatile memory such as RAM and non-volatile memory media such disk drives and/or tape drives, ROM, flash memory, etc. Bracket **548** and computer **550** are depicted in FIG. **5** to illustrate that blocks **500**-**522** can be carried out by computer **550**, where computer **550** can correspond, e.g., to server **102**, etc.

**[0140]** The methodologies discussed above can be embodied on a machine-readable medium. Such a machine-readable medium can include code segments embodied thereon that, when read by a machine, cause the machine to perform the methodologies described above.

**[0141]** Of course, although several variances and example embodiments of the present invention are discussed herein, it is readily understood by those of ordinary skill in the art that various additional modifications may also be made to the

present invention. Accordingly, the example embodiments discussed herein are not limiting of the present invention.

What is claimed is:

**1**. A computer-implemented method comprising:

receiving, by a first computer system, information regarding a program-code-based operational state of a second computer system at a particular time;

determining whether the program-code-based operational state of the second computer system represents a violation of one or more security policies that have been applied to or are active in regard to the second computer system by evaluating, by the first computer system, the received information with respect to the one or more security policies, wherein each security policy of the one or more security policies defines at least one parameter condition violation of which is potentially indicative of unauthorized activity on the second computer system or manipulation of the second computer system to make the second computer system vulnerable to attack; and

when a result of the determining is affirmative, then:

identifying, by the first computer system, a remediation that can be applied to the second computer system to address the violation; and

causing, by the first computer system, the remediation to be deployed to the second computer system.

**2**. The method of claim **1**, further comprising prior to said causing, by the first computer system, the remediation to be deployed to the second computer system, determining whether the remediation has been configured for automatic deployment.

**3**. The method of claim **1**, further comprising maintaining, by the first computer system, a policy database having stored therein a plurality of security policies, including the one or more security policies.

**4**. The method of claim **1**, further comprising maintaining, by the first computer system, a remediation database having stored therein information regarding a plurality of remediations including the remediation

**5**. The method of claim **1**, wherein the violation relates to presence of an unknown application or a rogue application on the second computer system.

**6**. The method of claim **1**, wherein the violation relates to existence or non-existence of a particular application on the second computer system.

**7**. The method of claim **6**, wherein the violation is based at least in part on the particular application being present on a list of prohibited applications.

**8**. The method of claim **6**, wherein the violation is based at least in part on a version of the particular application.

**9**. The method of claim **6**, wherein the violation is based at least in part on a status of the particular application.

**10**. The method of claim **9**, wherein the status is indicative of whether a patch associated with the particular application has been installed the second computer system.

**11**. The method of claim **1**, wherein the violation is based at least in part on an operating system test relating to an operating system being run by the second computer system.

**12**. The method of claim **10**, wherein violation is based at least in part on a version of the operating system or a type of the operating system.

**13**. The method of claim **1**, wherein the first computer system comprises a remote server coupled in communication with the second computer system via a public network, wherein the second computer system comprises a host asset of a plurality of monitored host assets within an enterprise and wherein the method further comprises receiving, by the remote server, information indicative of one or more files stored on the host asset.

**14**. The method of claim **13**, wherein the violation relates to existence or non-existence of a particular file on the host asset.

**15**. The method of claim **14**, wherein the violation is based at least in part on a location of the particular file on the host asset.

**16**. The method of claim **14**, wherein the violation is based at least in part on one or more permissions associated with the particular file.

**17**. The method of claim **1**, wherein the information regarding a program-code-based operational state comprises information indicative of one or more drivers installed on the second computer system.

**18**. The method of claim **17**, wherein the violation relates to existence or non-existence of a particular type of driver on the second computer system.

**19**. The method of claim **18**, wherein the particular type of driver comprises a universal serial bus (USB) driver.

**20**. The method of claim **1**, wherein the violation relates to whether a removable storage device is connected to the second computer system.

**21**. The method of claim **1**, wherein the violation relates to whether a particular process is running on the second computer system.

**22**. The method of claim **1**, the information regarding a program-code-based operational state comprises information indicative of one or more ports of the second computer system that are in use.

**23**. The method of claim **22**, wherein the violation relates to a state associated with the one or more ports.

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