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(54) SYSTEM CALL INTERCEPTION

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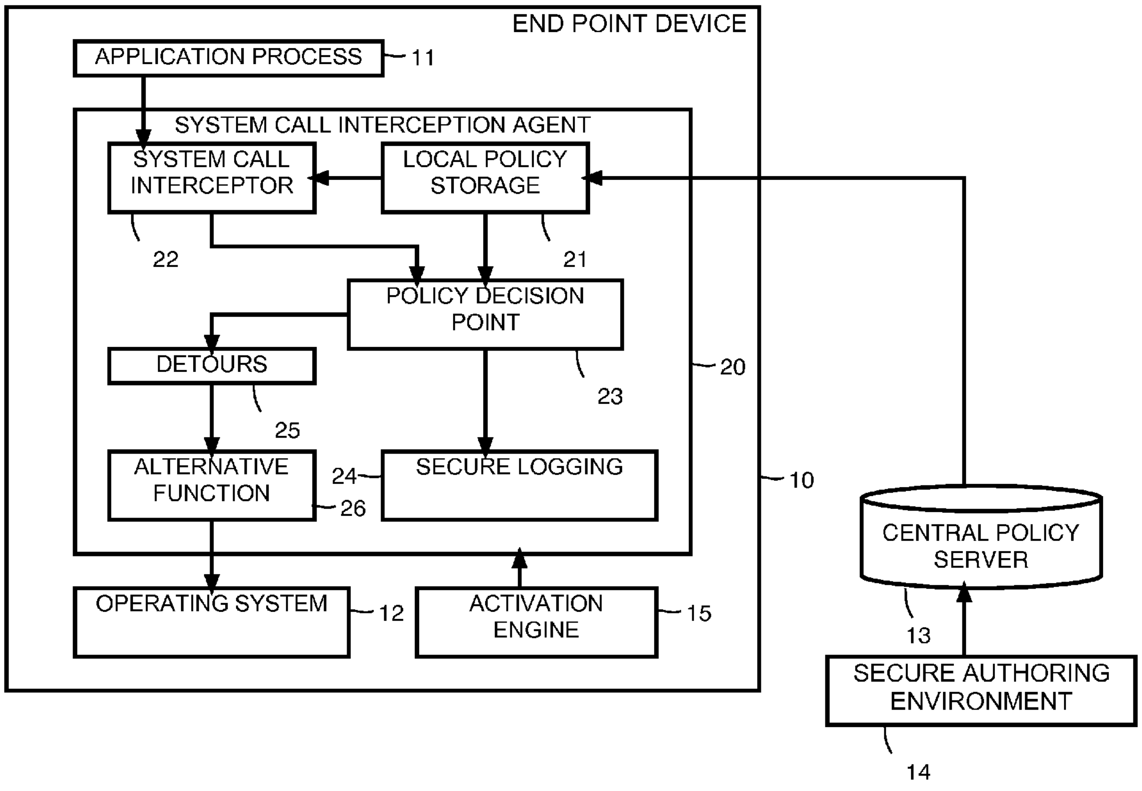
(57) **ABSTRACT**

System call interception is activated for an application process. It is recorded that system call interception is active for the application process. Ongoing checking is performed to determine whether system call interception remains active.



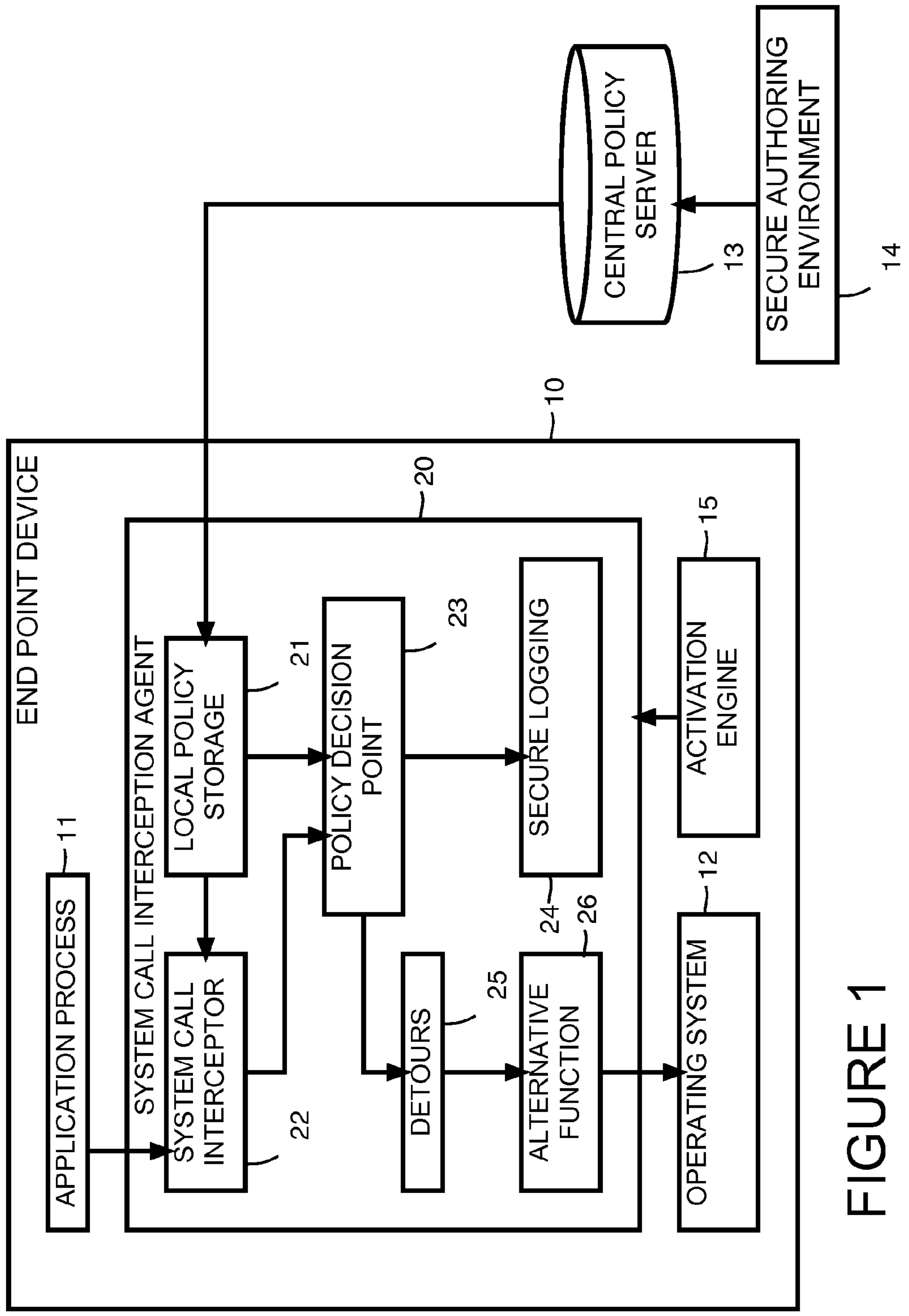

END POINT DEVICE
10
APPLICATION PROCESS
11
SYSTEM CALL INTERCEPTION AGENT
20
LOCAL POLICY STORAGE
21
SYSTEM CALL INTERCEPTOR
22
POLICY DECISION POINT
23
SECURE LOGGING
24
DETOURS
25
ALTERNATIVE FUNCTION
26
ACTIVATION ENGINE
15
OPERATING SYSTEM
12
CENTRAL POLICY SERVER
13
SECURE AUTHORING ENVIRONMENT
14

FIGURE 1

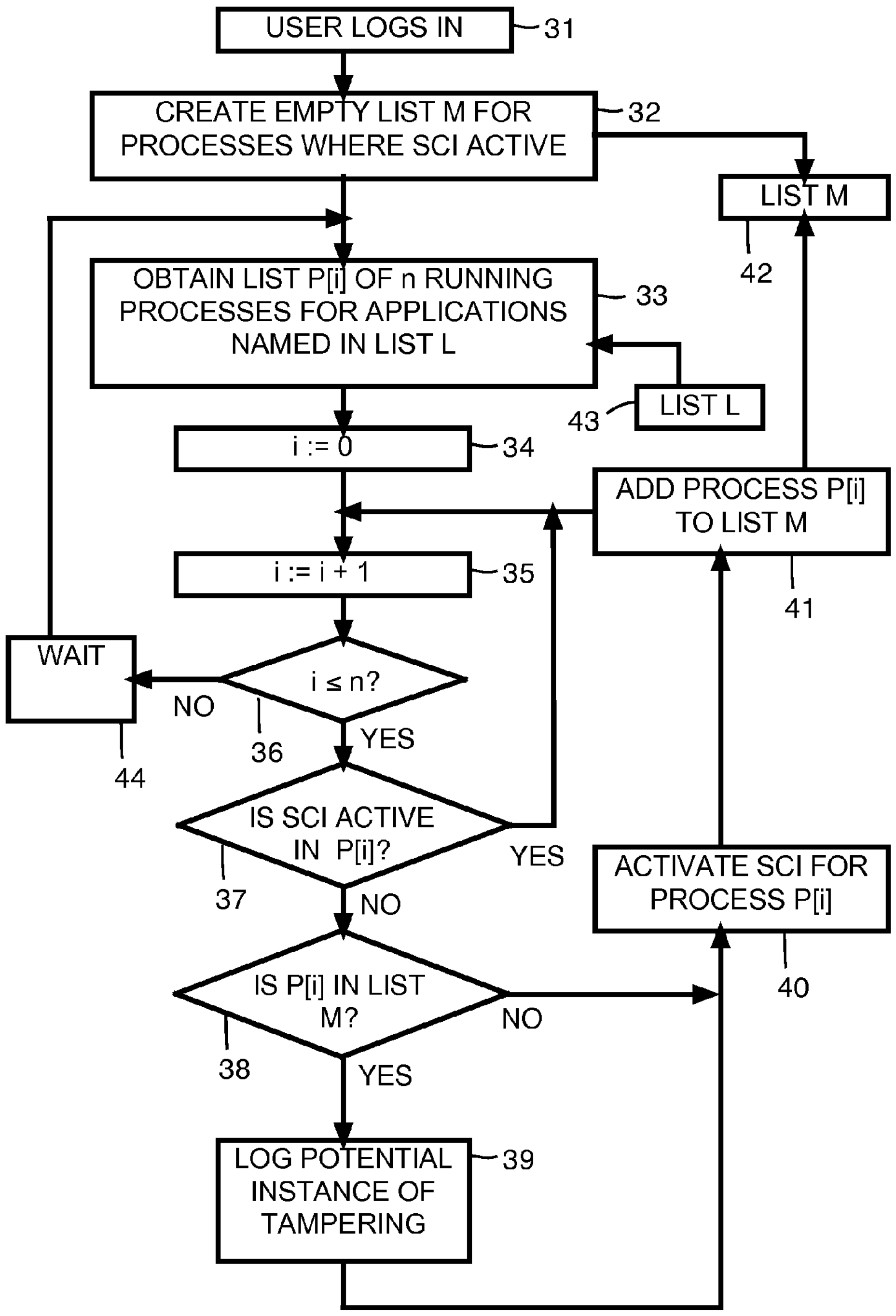

USER LOGS IN
31
CREATE EMPTY LIST M FOR PROCESSES WHERE SCI ACTIVE
32
LIST M
42
OBTAIN LIST P[i] OF n RUNNING PROCESSES FOR APPLICATIONS NAMED IN LIST L
33
LIST L
43
i := 0
34
ADD PROCESS P[i] TO LIST M
41
i := i + 1
35
WAIT
44
i ≤ n?
NO
36
YES
IS SCI ACTIVE IN P[i]?
YES
37
NO
ACTIVATE SCI FOR PROCESS P[i]
40
IS P[i] IN LIST M?
NO
38
YES
LOG POTENTIAL INSTANCE OF TAMPERING
39

FIGURE 2

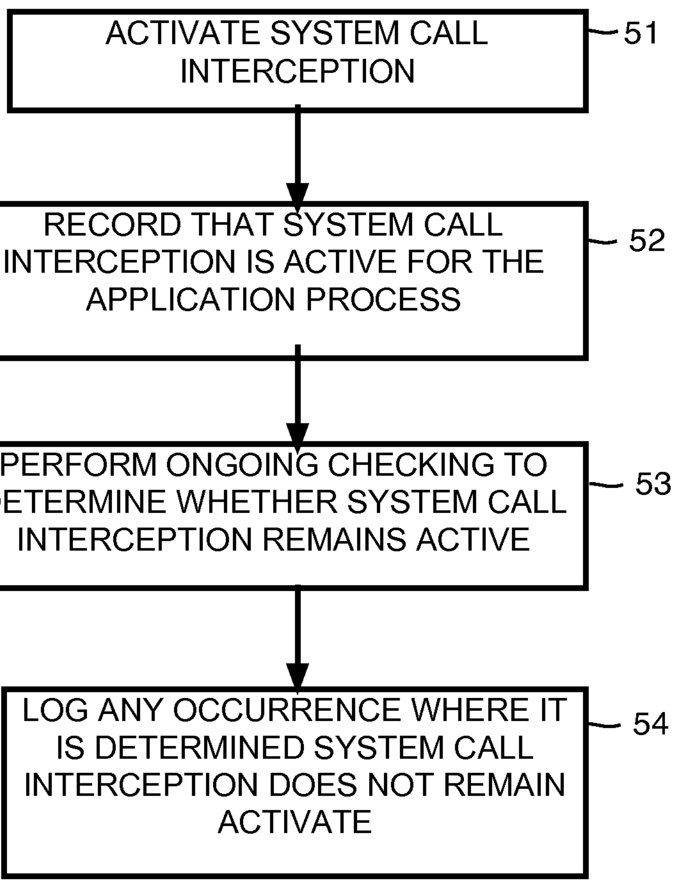

ACTIVATE SYSTEM CALL INTERCEPTION
51
RECORD THAT SYSTEM CALL INTERCEPTION IS ACTIVE FOR THE APPLICATION PROCESS
52
PERFORM ONGOING CHECKING TO DETERMINE WHETHER SYSTEM CALL INTERCEPTION REMAINS ACTIVE
53
LOG ANY OCCURRENCE WHERE IT IS DETERMINED SYSTEM CALL INTERCEPTION DOES NOT REMAIN ACTIVATE
54

FIGURE 3

SYSTEM CALL INTERCEPTION

BACKGROUND

[0001] The unintentional release or disclosure of sensitive information to an untrusted environment is a serious problem for any organization. Sensitive information at risk can include, for example, financial information, personal identity information, health information, intellectual property and so on. Unintentional release of information, also called data leaks, can occur in a wide variety of scenarios such as, for example, through the sending of a sensitive e-mail to the wrong address, uploading a confidential document instead of a conference submission, saving an unprotected document backup on an 'easy-to-lose' USB drive, printing and then leaving a sensitive document on a widely accessible printer and so on.

BRIEF DESCRIPTION OF DRAWINGS

[0002] FIG. **1** is a simplified block diagram showing a system call interception agent inserted between an application process and an operating system to prevent data leaks, in accordance with an implementation.

[0003] FIG. **2** is a simplified block diagram flow chart illustrating logic used to start and monitor operation of system call intercept agent, in accordance with an implementation.

[0004] FIG. **3** is a simplified block diagram flow chart illustrating logic used to start and monitor system call interception, in accordance with an implementation.

DETAILED DESCRIPTION

[0005] In order to prevent data leaks, an organization can develop a series of policies that determine, for example, which action of various users should be prevented or at least cautioned against.

[0006] For example, the policies may require prevention, or caution against, the exposure of sensitive data by such actions as transmission by e-mail, storage on portable drives, and printing on unsecure printers. The policies may depend, for example, on the sensitivity of data being accessed as well as the identity of the user accessing the data.

[0007] As shown in FIG. **1**, a secure authoring environment **14** can be used to develop and safeguard the policies. The policies can then be stored in a secure central policy server **13**. Central policy server **13** can be, for example, an organization-wide service implemented on a single server or a cluster of synchronized servers.

[0008] The policies stored within central policy servers are implemented within end point devices, for example, by a system call intercept (SCI) agent that intercepts system calls made from an application process to the operating system for the end point device. For example, an end point device is any device with processing capability, such as a server, a desktop computer, a laptop computer, computer tablet, a smart phone, a personal digital assistant and so on.

[0009] An application process is an instance of an application program that is being executed. An application process for which system call interception is activated may be, for example, a process for any application that performs actions that may result in a data leak. Examples of actions whose performance may result in a data leak are saving a file, copying a file, moving a file, uploading a file, sending e-mail, printing and so on.

[0010] A system call is any invocation of an operating system function by an application process. A system call intercept is any interception, for example by a SCI agent or another process, of a system call from an application process to an operating system.

[0011] FIG. **1** shows a SCI agent **20** inserted so as to capture system calls from an application process **11** to an operating system **12** within an end point device **10**. Operating system **12** can be any type of operating system that manages hardware resources of end point device **10** and provides common services for application processes. Application process **11** can be any computer process that performs operations in response to user interactions. SCI agent **20** includes local policy storage **21**. Local policy storage **21** stores at least a subset of the policies, stored in central policy server **13**, that apply to end point device **10**. For example, policies stored in local policy storage **21** are automatically synchronized with policies stored in central policy **13**. An alternative arrangement without local policy storage **21** may include a local policy enforcement mechanism where the policies are not stored within end point device **10**. In this case, for example, data could be uploaded to central policy sever **13** and evaluated for any potential breach of policies stored within central policy storage **13**. Then, for example, central policy server **13** instructs end point device **10** on how to handle any violation of a policy stored in central policy storage **13**.

[0012] When application process **11** makes a system call, a system call interceptor **22** intercepts the system call. A policy decision point **23** utilizes policies in local policy storage to determine how the system call should be handled. Some or all of the system calls and decisions made are stored within secure logging **24**.

[0013] When policies within local policy storage **21** indicate a system call should be intercepted, detour logic **25** and alternative function logic **26** take action before making system calls into operating system **12**. For example, if the user is identified as a trusted user, detour logic **25** may merely give a warning to the user that an operation is about to be performed that may compromise information. The trusted user will be given the chance to confirm if this is an action that is really to be taken. Upon confirmation from the trusted user, the system call requested by application process **11** is allowed to proceed.

[0014] In more secured environments, or with a less trusted user, detour logic **25** may issue a warning to the user that the action desired to be taken is not allowed. Function logic **26** may then prevent the system call from being executed and may even disable further user actions on end point device **10**. For example, function **26** may offer the user an alternative or modified action and then may assist the user in accomplishing the action. For example, function **26** may assist the user in encrypting data before the data is sent or stored.

[0015] For example, there is a secure communication channel between end point device **10** and central policy server **13**. Running of SCI agent **20** is mandatory. Policies from central policy server **13** must be updated within end point device **10** within a policy define interval time or default restrictive policies are applied. When end point device **10** appears on-line from an off-line mode, end point device **10** immediately communicates with central policy server **13** to receive the latest policies.

[0016] An activation engine **15**, shown in FIG. **1**, includes logic used to start and monitor operation of a system call intercept agent such as system call intercept agent **20**.

[0017] FIG. **2** is a simplified block diagram flow chart illustrating operation of activation engine **15** upon a user logging in. In a block **31**, a user logs in. In a block **32**, a list M is created. In another situation, a user might be logged in for a while, when due to change in monitoring level a system call intercept agent is activated and in block **32**, list M is created. In FIG. **2**, list M is identified by a reference number **42**. List M is initially empty when created, but will eventually identify all application processes operating in the user session for which a SCI agent will intercept system calls.

[0018] A list L, identified in FIG. **2** by a reference number **43**, contains a list of applications for which, according to policies stored within central policy server **13**, an SCI agent is to intercept system calls in order to guard against potential data leaks. In a block **33**, list L is referenced to determine processes corresponding to applications listed in list L, that are currently running in the user session. Into these processes a SCI agent will be injected for the purpose of intercepting system calls. What is meant by injecting of a SCI agent is to inject programming code—for example, in the form of a dynamic linked library—into an application process that implements a SCI agent that captures system calls sent from the process to the operating system. When the process makes a system call, the SCI agent intercepts the system call before the system call reaches the operating system. For example, if there are n processes running for applications named in list L, the n processes can be referred to as processes P[i], where i is an integer variable numbered from 1 to n.

[0019] While, depending on implementation, list L can be reasonably static, it is also possible that list L can be updated dynamically, for example, by central policy server **13**. For example, certain scenarios trigger central policy server to add or subtract applications from list L. For example, if it is suspected that an attack is underway against end point device **10**, or if a software virus is detected within end point device **10**, central policy server **13** may enter a heighted monitoring state and increase the number of applications in list L and/or may change policies to more restrictively and thoroughly guard against data leaks.

[0020] Also, for example, an audit of end user device **10** can be performed by activating system call interception for a larger number of processes and/or more thoroughly logging information about intercepted system calls. During the audit, the number of applications in list L may be increased, the policies for handling intercepted system calls can be changed and the amount of logging, etc, may be increased. After completion of the audit, the number of applications in list L and the information logged can be restored, for example, to pre-audit levels.

[0021] When the number of applications in list L is decreased and/or the implemented policies for processes may be changed to be less restrictive, system call interception may be ending or changing for certain processes. In this case care is exercised when, for example, removing an SCI agent from between the process and the operating system so that operation of the process is not adversely affected resulting in, for example, a crash of the process or some other deleterious result. This exercise of care may be achieved by leaving system call interception active for a time for a process until an opportune time occurs in which the system call interception can be inactivated for the process without any deleterious effects.

[0022] In a block **34**, the variable i is set equal to 0. In a block **35**, the variable i is incremented. In a block **36**, a check is made to see whether i is less than or equal to n. If so, this means traversing through all the n processes is not complete. In a block **37**, a check is made to determine if system call interception (SCI) is active for process P[i]. The check also, for example, confirms that the programming code implementing system call interception has not been tampered with. The confirmation that there has been no tampering can be performed, for example, on the basis of checking the authenticity of the programming code implementing system call interception, for example by checking the signature of the programming code implementing system call interception. For example if the programming code implementing system call interception is a dynamic linked library injected into process P[i], the signature of the dynamically linked library as it currently is in the file is compared with the signature of the dynamically linked library as it was when it was originally injected in process P[i]. If the signatures match, then the conclusion in the check in block **37** would be that system call interception (SCI) is active for process P[i]. If the signatures do not match, then the conclusion in the check in block **37** would be that system call interception (SCI) is not active for process P[i].

[0023] If in block **37** it is determined that system call interception (SCI) is active for process P[i], then in block **35**, the variable i is incremented and the next process is checked. If in block **37** it is determined that system call interception is not active for process P[i], in a block **38** a check is made to see if P[i] is in list M. If not, in a block **40** system call interception is activated for process P[i]. This means a SCI agent will intercept system calls from process P[i] and handle the system call in accordance with policies stored in central policy server **13**. In a block **41**, process P[i] is added to list M. Then, in block **35**, the variable i is incremented and the next process is checked.

[0024] If in block **38**, process P[i] is in list M, this indicates a potential incidence of tampering. That is, process P[i] was formerly put in list M indicating system call interception was activated for process P[i]. But the check in block **37** indicated system call interception is not currently active. This suggests system call interception has been turned off for process P[i], possibly as a result of tampering, for example, by a user of the end point device trying to circumvent policies stored in central policy server **13**. Also, if in block **37** signatures were checked and did not match, this would also indicate the possibility of tampering.

[0025] In a block **39**, any potential instance of tampering is logged. Depending on implementation additional or alternative actions can be taken in block **39**. For example, the system administrator can be alerted, for example by being sent an e-mail or by some other means. The user can be alerted, for example, by a pop-up window. In a very secure environment, a potential instance of tampering can be handled by deactivating end point device **10**, immediately increasing a monitoring level, and/or increasing restrictive policies, for example, including preventing any further traffic out of end point device **10**. And so on. Additionally, in block **40**, system call interception is again activated for process P[i].

[0026] If the process illustrated by blocks **31** through **41** in FIG. **2** is performed only when a user logs in and new processes start, it may be possible for a user to disable system call interception, perform actions not permitted by policies within central policy sever **13**, and then re-enable system call interception, thereby circumventing policies within central policy sever **13** possibly without detection.

[0027] In order to avoid such circumvention, the process illustrated by blocks **31** through **41** is performed periodically when the user remains logged in. Specifically, in block **36**, when i is greater than n, this means all the currently processes have been checked. Then, in a wait block **44**, a period of time is allowed to elapse. Then, beginning in block **33** the process is restarted by again obtaining a list of the n currently running processes P[i] for applications in list L. Because during the elapsed wait times, different processes may have started or stopped, n may be a different value than before.

[0028] The amount of elapsed time in wait block **44** is selected based on level of security and system performance. If the elapsed time in wait block **44** is too short, it may impact performance of some systems. If the elapsed time in wait block **44** is too long, it may allow tampering to occur in the interval without detection. One way to balance system performance with security is to vary the duration of the elapsed time in wait block **44** according to a predetermined pattern or according to some random or pseudo random pattern. In this way a user will not be able to predict whether tampering will be detected. This can discourage tampering and increase the likelihood of detecting tampering while minimizing the impact on system performance. For example, a maximum amount of elapsed time in wait block **44** may be chosen that is short enough to assure a malicious attacker does not have time, within the elapsed time in wait block **44**, to export undetected even the smallest sized sensitive document out of end point device **10**.

[0029] For example, the elapsed time in wait block **44** can be cut short whenever a new process is started that is for one of the applications listed in list L. Alternatively, in a separate process, activity on end point device **10** can be modified so that whenever a new process is started, a check can be made if it is for one of the applications listed in List L, and if so, system call interception can be activated for the process and the process added to list M.

[0030] FIG. **3** is a simplified block diagram flow chart illustrating logic used to start and monitor system call interception regardless of how system call interception is implemented. For example, the logic can be implemented using instructions within computer readable code stored on non-transitory computer readable medium.

[0031] In a block **51**, system call interception is activated for an application process running under a user session or under user sessions in a multi-user device. For example, if multiple users of a device are sharing use of an application, system call interception for the processes of the application may be used to prevent data leak from all the user sessions utilizing the application. In a block **52**, it is recorded that system call interception is active for the application process.

[0032] In a block **53**, ongoing checking is performed to determine whether system call interception remains active for the application process. The amount of elapsed time between each check may be constant or varied in accordance, for example, with a predetermined pattern or in accordance with some random or pseudo random pattern.

[0033] In a block **54**, any occurrence where an ongoing check discovers system call interception does not remain activated is logged. In addition to, or instead of, logging, other action may be executed. For example, an administrator may be informed of a potential breach of policy, a user may be alerted, a user's account may be deactivated, the device may be deactivated, a login session may be suspended, more restrictive policies implemented or another action or combination of actions taken to log, detect and/or protect against data leaks.

[0034] The disclosed subject matter may be implemented in other specific forms without departing from the spirit or characteristics thereof. Accordingly, the present disclosure is intended to be illustrative, but not limiting, of the scope of the following claims.

We claim:

1. Non-transitory computer readable medium storing computer readable code, the computer readable code comprising instructions for:

activating system call interception for an application process running under a user session;

recording that system call interception is active for the application process;

performing ongoing checking to determine whether system call interception remains active for the application process; and,

logging any occurrence where it is determined system call interception does not remain active.

2. Non-transitory computer readable medium as in claim **1** wherein the instructions are additionally for:

varying amount of time elapse between checking whether system call interception remains active for the application process.

3. Non-transitory computer readable medium as in claim **1** wherein the instructions are additionally for:

reactivating system call interception for any application process where it is determined system call interception did not remain active.

4. Non-transitory computer readable medium as in claim **1** wherein activating system call interception for application process running under a user session includes injecting a system call interception agent to intercept system calls.

5. Non-transitory computer readable medium as in claim **1** wherein activating system call interception for application process running under a user session includes using policies stored locally and automatically synchronized with policies stored in a central policy server to identify the application process for which to activate system call interception.

6. Non-transitory computer readable medium as in claim **1** wherein the instructions are additionally for:

handling intercepted system calls in accordance with policies stored in a central policy server.

7. Non-transitory computer readable medium as in claim **1** wherein performing ongoing checking to determine whether system call interception remains active for the application process includes checking authenticity of programming code used to perform system call interception.

8. Non-transitory computer readable medium as in claim **1** wherein the instructions are additionally for:

inactivating system call interception for the application process in response to a change in policy stroked in a central policy server.

9. A device comprising:

hardware resources;

an operating system to manage hardware resources and provides service for an application process;

a system call interception agent to intercept system calls from the application process to the operating system, so that each intercepted system call is handled by the system call interception agent in accordance with a predetermined policy; and, an activation engine to activate the system call interception agent to intercept system calls from the application process to the operating system and to perform ongoing checking that the system call interception agent remains active to intercept system calls from the application process to the operating system.

10. A device as in claim **9** wherein the activation engine varies amount of time elapse between checking that the system call interception agent remains active to intercept system calls from the application process to the operating system.

11. A device as in claim **9** wherein the activation engine reactivates the system call interception agent to intercept system calls from the application process to the operating system when it is determined system call interception did not remain active.

12. A device as in claim **9** wherein the activation engine increases a number of applications for which system call interception is activated in response to a heightened monitoring state.

13. A device as in claim **12** wherein the heighted monitor state occurs during at least one of the following:

a perceived attack is underway against the device;

a software virus has been detected within the device;

an audit is being performed.

14. A method comprising:

injecting a system call interception agent between a process and an operating system, the system call intercept agent intercepting calls from the process to the operating system and the call intercept agent taking actions in accordance with policies stored in a central policy server;

performing ongoing checking to determine whether the system call interception agent remains active between the process and the operating system; and,

reactivating the system call interception agent between the process and the operating system when it is determined that the system call interception agent has not remained active between the process and the operating system.

15. A method as in claim **14** additionally comprising:

performing at least one of the following actions when it is determined that the system call interception agent does not remain active between the process and the operating system:

logging that the system call interception agent did not remain active between the process and the operating system,

alerting an administrator,

alerting a user,

increasing a monitoring level,

deactivating a login session,

activating a more restrictive policy.

* * * * *