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(54) SYSTEM AND METHOD FOR WHITELISTING APPLICATIONS IN A MOBILE NETWORK ENVIRONMENT

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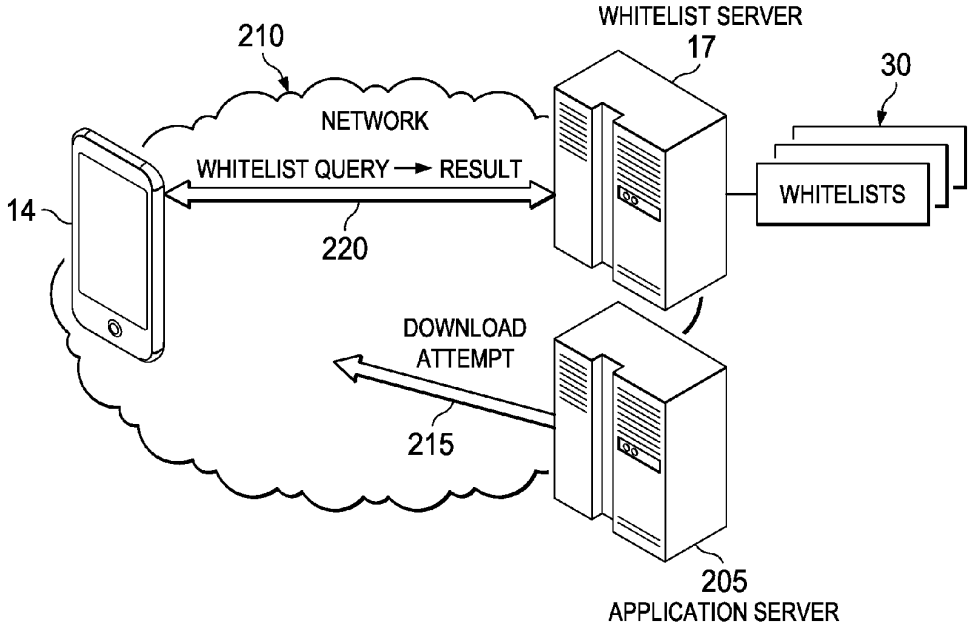
(57) **ABSTRACT**

An application is identified as installed on a particular mobile device. An action involving the application is identified, the action to be performed using the particular mobile device. It is determined whether the action is an approved action based on at least one policy associated with the particular mobile device. A determination that the action is unapproved can results in an attempt to prevent the action. Further, in certain instances, a whitelist or blacklist can be generated based on determinations of whether identified application actions conform to one or more policies associated with the particular mobile device.



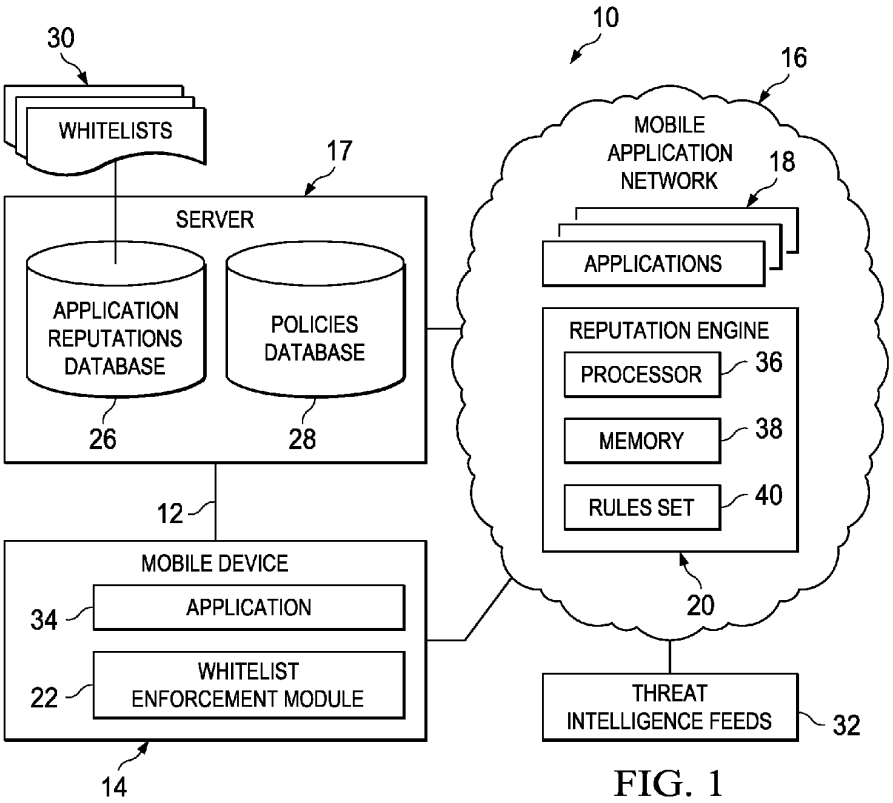

10
30
WHITELISTS
17
SERVER
APPLICATION REPUTATIONS DATABASE
POLICIES DATABASE
26
28
12
MOBILE DEVICE
34
APPLICATION
22
WHITELIST ENFORCEMENT MODULE
14
16
MOBILE APPLICATION NETWORK
18
APPLICATIONS
REPUTATION ENGINE
PROCESSOR
36
MEMORY
38
RULES SET
40
20
THREAT INTELLIGENCE FEEDS
32

FIG. 1

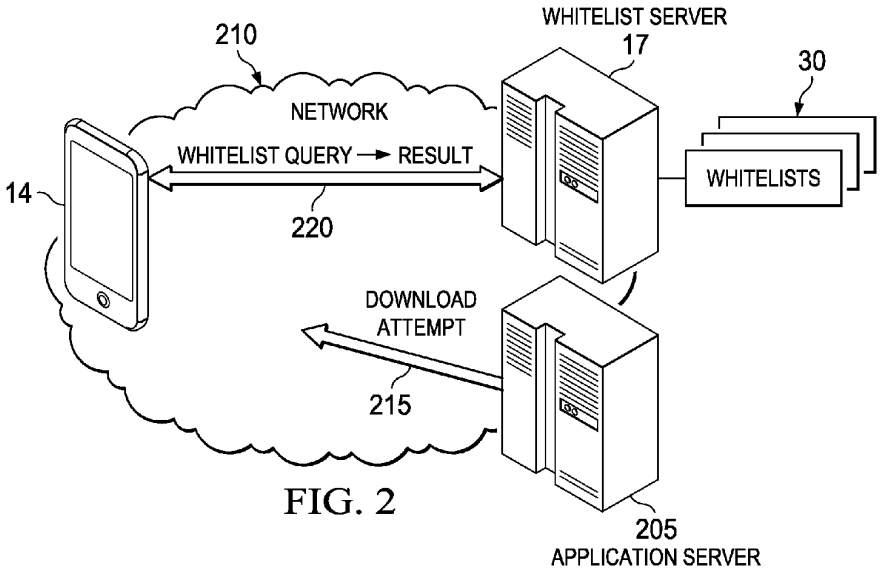

WHITELIST SERVER
17
210
30
NETWORK
WHITELIST QUERY → RESULT
WHITELISTS
14
220
DOWNLOAD
ATTEMPT
215
205
APPLICATION SERVER

FIG. 2

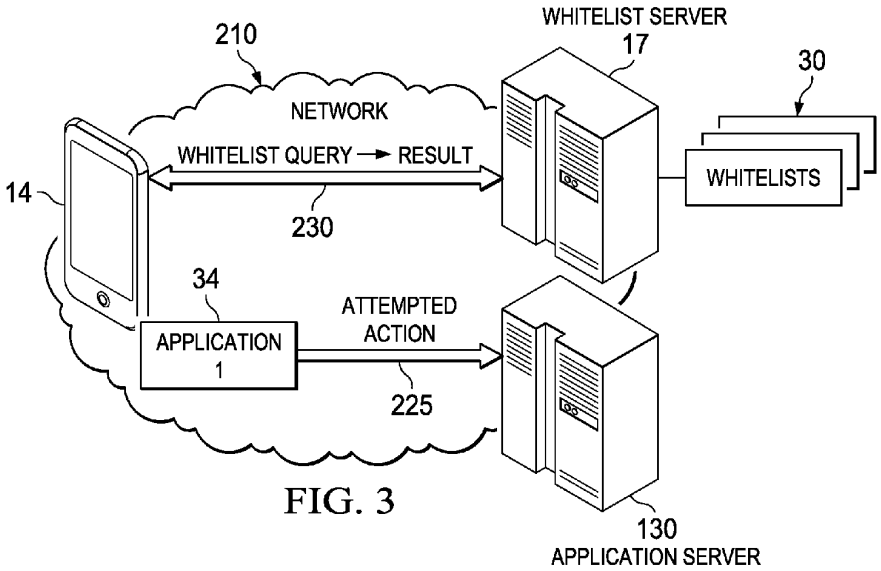

WHITELIST SERVER
17
210
30
NETWORK
WHITELIST QUERY → RESULT
WHITELISTS
14
230
34
ATTEMPTED
ACTION
APPLICATION
1
225
130
APPLICATION SERVER

FIG. 3

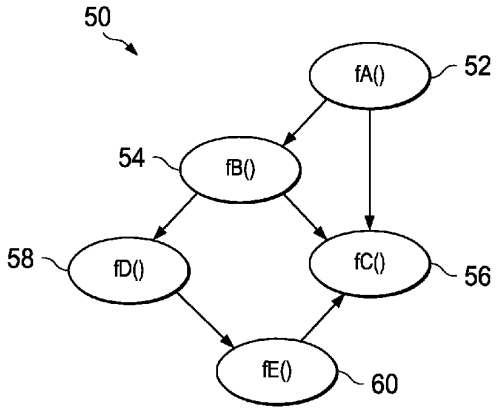

50
fA()
52
54
fB()
58
fD()
fC()
56
fE()
60

FIG. 4

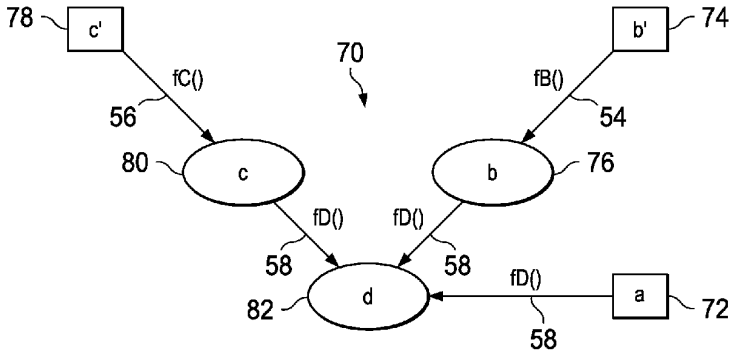

78
c'
b'
74
70
fC()
fB()
56
54
80
c
b
76
fD()
fD()
58
58
fD()
82
d
a
72
58

FIG. 5

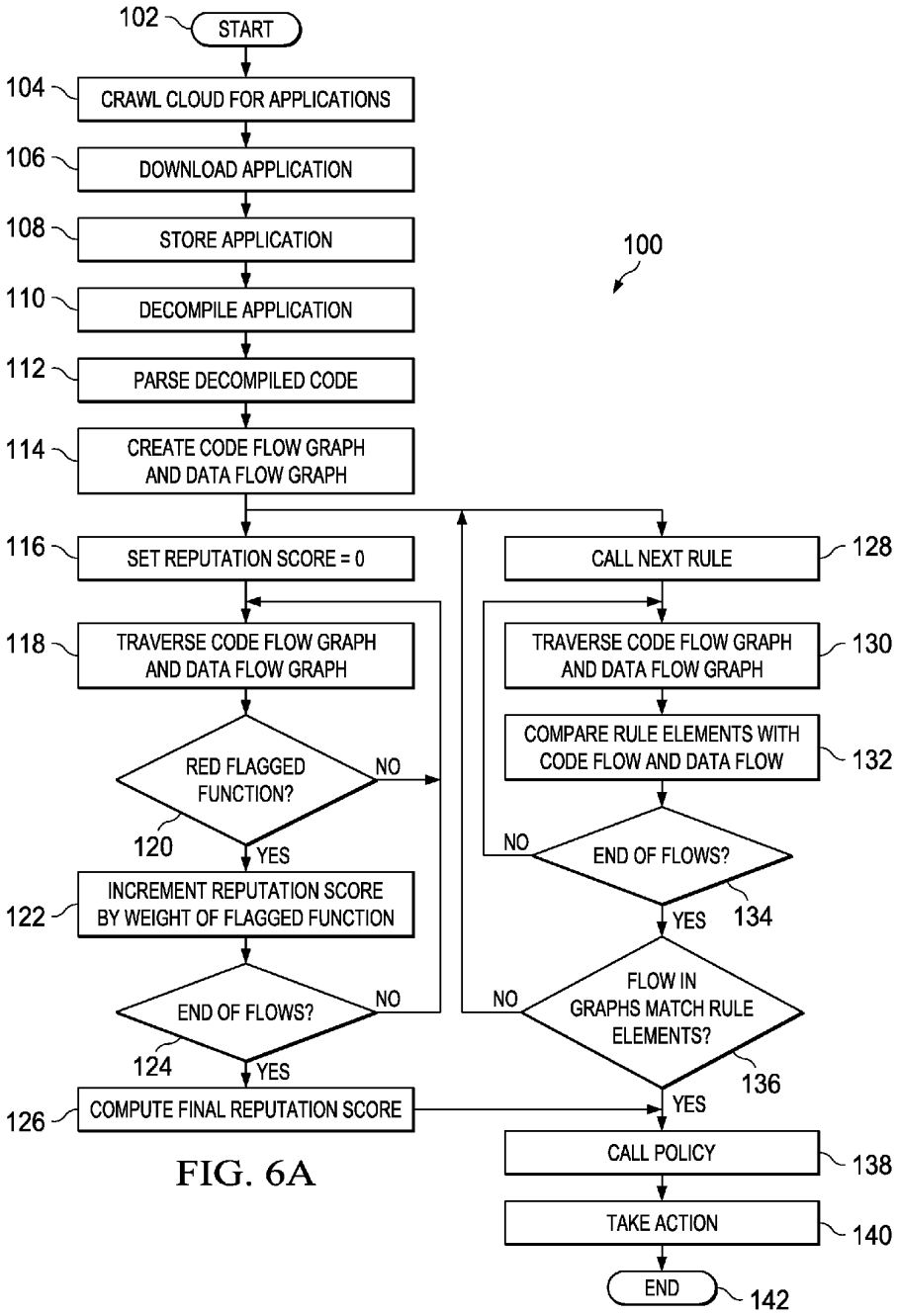

102
START
104
CRAWL CLOUD FOR APPLICATIONS
106
DOWNLOAD APPLICATION
108
STORE APPLICATION
100
110
DECOMPILE APPLICATION
112
PARSE DECOMPILED CODE
114
CREATE CODE FLOW GRAPH AND DATA FLOW GRAPH
116
SET REPUTATION SCORE = 0
118
TRAVERSE CODE FLOW GRAPH AND DATA FLOW GRAPH
RED FLAGGED FUNCTION?
NO
120
YES
122
INCREMENT REPUTATION SCORE BY WEIGHT OF FLAGGED FUNCTION
END OF FLOWS?
NO
124
YES
126
COMPUTE FINAL REPUTATION SCORE
128
CALL NEXT RULE
130
TRAVERSE CODE FLOW GRAPH AND DATA FLOW GRAPH
132
COMPARE RULE ELEMENTS WITH CODE FLOW AND DATA FLOW
NO
END OF FLOWS?
YES
134
NO
FLOW IN GRAPHS MATCH RULE ELEMENTS?
136
YES
138
CALL POLICY
140
TAKE ACTION
END
142

FIG. 6A

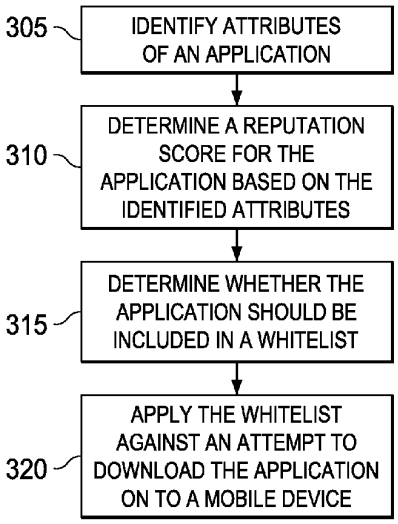


FIG. 6B

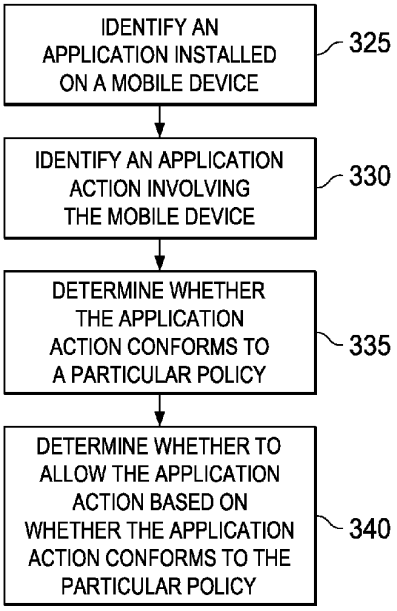


FIG. 6C

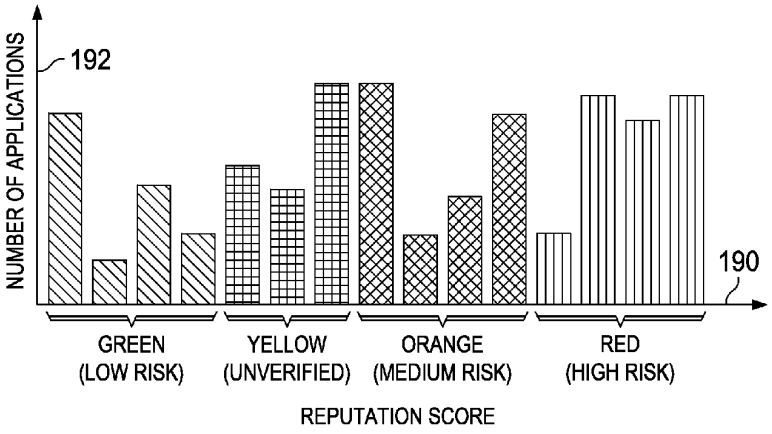


FIG. 7

SYSTEM AND METHOD FOR WHITELISTING APPLICATIONS IN A MOBILE NETWORK ENVIRONMENT

TECHNICAL FIELD

[0001] This disclosure relates in general to the field of computer networks and, more particularly, to a system and a method for whitelisting applications in a mobile network environment.

BACKGROUND

[0002] The field of computer network security has become increasingly important and complicated in today's society. Computer network environments are configured for virtually every enterprise or organization, typically with multiple interconnected computers (e.g., end user computers, laptops, servers, printing devices, etc.). Furthermore, computer and communications networks today encompass mobile devices such as smartphones, tablet computers and the like, which allow users to download and install applications on these devices quickly and with minimal oversight. However, unrestricted access to mobile resources and application programming interfaces by applications of unknown or untrusted origins could result in damage to the user, the device, and the network, if not managed by suitable security architectures and network precautions. Thus, innovative tools are needed to assist IT administrators in the effective control and management of applications on mobile devices within computer and communication network environments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] To provide a more complete understanding of the present disclosure and features and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying figures, wherein like reference numerals represent like parts, in which:

[0004] FIG. **1** is a simplified block diagram illustrating components of a system for whitelisting applications in a mobile network environment according to an example embodiment;

[0005] FIG. **2** is a simplified diagram illustrating an example application of whitelist in a mobile network environment according to at least one example embodiment;

[0006] FIG. **3** is a simplified diagram illustrating another example application of whitelist in a mobile network environment according to at least one example embodiment;

[0007] FIG. **4** is a simplified diagram illustrating an example code flow graph according to the present disclosure;

[0008] FIG. **5** is a simplified diagram illustrating an example data flow graph according to the present disclosure;

[0009] FIGS. **6A-6C** is a simplified flow-chart illustrating example operational steps that may be associated with embodiments of the present disclosure; and

[0010] FIG. **7** is a bar chart showing an example scenario of a number of applications against reputation score in accordance with this specification.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

[0011] In general, one aspect of the subject matter described in this specification can be embodied in methods that include the actions of identifying an application installed on a particular mobile device, identifying an action involving the application to be performed using the particular mobile device, and determining whether the action is an approved action based on at least one policy associated with the particular mobile device. A determination that the action is unapproved can results in an attempt to prevent the action.

[0012] In another general aspect of the subject matter described in this specification can be embodied in systems that include at least one processor device, at least one memory element, and a reputation engine. The reputation engine, when executed by the at least one processor device, can identify an application installed on a particular mobile device, identify an action involving the application to be performed using the particular mobile device, and determine whether the action is an approved action based on at least one policy associated with the particular mobile device. Determining that the action is unapproved can result in an attempt to prevent the action.

[0013] These and other embodiments can each optionally include one or more of the following features. Determining whether the action is an approved action can include identifying whether the action is included in a whitelist of approved actions, the whitelist based on conformance of actions with the at least one policy. The whitelist can include a listing of a plurality of actions, each action paired to at least one application. Approval of an action can be based on a reputation of the paired application. The reputation of a particular application can be based at least in part on user feedback data received for the particular application identifying user security assessments of the particular application. Approval of the action can be approved for a first application, and unapproved for a second application. The whitelist can be maintained by a whitelist server and at least a portion of the whitelist can be downloaded to one or more mobile devices remote from the whitelist server. An update to the whitelist can be identified and the update can be automatically downloaded to the one or more mobile devices. The whitelist can be one of a plurality of whitelists, each whitelist associated with a corresponding set of policies, and each set of policies associated with a corresponding entity. The whitelist can govern a set of mobile devices in a system of an entity, the set of mobile devices including the particular mobile. The set of mobile devices can include the particular mobile device utilizing a first operating system and at least one second mobile device utilizing a second operating system.

[0014] Further, these and other embodiments can also each optionally include one or more of the following features. Determining whether the action is an approved action can include identifying whether the action is included in a blacklist of unapproved actions, the blacklist based at least in part on failures of actions to conform with the at least one policy. An action can include a function of an application, and at least some functions of an application remain allowed during prevention of a particular action determined to be unapproved. An action can include an attempt to update the application, and unapproved updates are prevented from being downloaded to the particular mobile device. An action can include an attempt to initiate, start, or run the application on the particular mobile device, and the application is prevented from running based on a determination that the application violates the at least one policy. An action can include an attempt to communicate with at least one remote computing resource, and determining whether to prevent the applica-

tion's communication with the at least one remote computing resource can be based on a reputation of the at least one computing resource. The action can be identified in connection with an attempt to perform the action using the particular mobile device. A determination of a particular unapproved action of a particular application causes downloading of the particular application to be blocked for mobile devices whereon the particular application is not yet installed.

[0015] Some or all of the features may be computer-implemented methods or further included in respective systems or other devices for performing this described functionality. The details of these and other features, aspects, and implementations of the present disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

Example Embodiments

[0016] FIG. **1** is a simplified block diagram illustrating an example implementation of a system **10** for whitelisting applications in a mobile network environment. The exemplary environment illustrates a network **12** connecting one or more mobile devices **14** with mobile application network **16**. Mobile application network **16** may include one or more computing devices including devices serving one or more mobile applications **18** for download by one or more mobile devices. Mobile application network **16** can further include one or more networks, subnetworks, and connections including shared computing resources, Internet-based servers and network elements, cloud-based computing environments, data centers, enterprise networks, etc. For ease of discussion and illustration, only one mobile device is shown in the FIG. **1**. Any number of mobile devices may in fact be connected over network **12** within the broad teachings of the present disclosure. Mobile devices (e.g., mobile device **14**), are inclusive of mobile phones, smart mobile phones (smartphones), e-book readers, tablets, iPads, personal digital assistants (PDAs), laptops or electronic notebooks, portable navigation systems, multimedia gadgets (e.g., cameras, video and/or audio players, etc.), gaming systems, other handheld electronic devices, and any other similar device, component, element, or object capable of initiating voice, audio, video, media, or data exchanges within system **10**.

[0017] In one example embodiment, mobile device **14** may communicate with mobile application network **16** and access one or more applications **18** available in or from mobile application network **16**. Mobile applications **18** may be provided, for example, in connection with one or more application software distribution platforms such as Google® Android Market, Apple® App Store, Palm® Software Store and App Catalog, RIM® App World, etc., as well as other sources.

[0018] As used herein, "application" or "mobile application" encompasses application software that runs on (or is capable of running on) mobile devices and performs specific tasks for the mobile device's user. In general, applications encompass any software file comprising instructions that can be understood and processed on a computing device, such as for example, executable files, library modules, object files, script files, interpreter files, executable modules and the like. In general, an application may be capable of being decompiled (decompiling is a process of translating a file, such as an executable file, containing information at a relatively low level of abstraction, such as assembly language, into a higher level of abstraction which may be human readable, such as a programming language like C++). Applications may include native applications pre-installed on the mobile device, such as address books, calendars, calculators, games, maps and Web browsers. Applications may also be downloaded from various application software distribution platforms in mobile application network **16**. According to embodiments of the present disclosure, application **18** includes any new application and any update to native or downloadable applications. Examples of such mobile applications can include video game applications (or "apps"), map apps, productivity apps, news apps, web browser apps, email apps, e-reader apps, social networking apps, among potentially limitless other examples.

[0019] Mobile application network **16** may include a reputation engine **20** for assessing application reputations, also referred to herein as "reputation scores" or "trust scores" (both terms may be interchangeably used throughout the Specification). A reputation score is a value (e.g., numeric, textual, pictorial, etc.) that denotes a relative level of trustworthiness or security of the application on a spectrum (e.g., continuous or discrete) from benign (e.g., reputable) to malicious or unsafe (e.g., non-reputable). The reputation score may indicate a probability that an application is malicious software or otherwise poses a threat to mobile devices or networks upon which it is installed. For example, applications that have a high probability of being malicious may have a high reputation score. In one example scenario, an application that automatically, and without authorization, turns on a camera and a microphone (or other recording device) of a mobile device may be deemed to be insecure, in violations of one or more policies, or malicious. On the other hand, an application that merely accesses the mobile device's processor and memory to facilitate a game of cards may be deemed to be benign.

[0020] According to the embodiment illustrated in FIG. **1**, each mobile device **14** may be provisioned with one or more whitelist enforcement modules **22** for use in enforcing, at the mobile device **14**, whitelists maintained by one or more servers (e.g., **17**). Whitelist server **17** may be provisioned with an application reputations database **26** and policies database **28**. Policies in policies database **28** may be defined, associated with, assigned or applied by a service provider, device manufacturer, an enterprise manager, or any other appropriate entity. In some embodiments, reputation engine **20** may calculate reputation scores and store the reputation scores in a suitable location along with other information to identify the application. For example, reputation engine **20** may push application reputations to server **17**, and server **17** may store the reputation scores and application identification information in application reputations database **26**. Server **17** may also support whitelists **30**, which may be stored in application reputations database **26**. Such whitelists **30** can be based on policies in policies database **28** and indicate applications and/or application actions determined to be in compliance with a corresponding entity's policies. In some embodiments, reputation engine **20** may analyze applications, characterize applications and application functions and other actions as trusted or untrusted, and store trusted applications in a suitable location (e.g., whitelists **30**).

[0021] In some embodiments, reputation engine **20** may crawl mobile application network **16** (e.g., Internet) for applications, and download and store them in a suitable location, for example, server **17**, or in a storage device in communication with reputation engine **20**. In other embodiments, repu-

tation engine **20** may collect and aggregate an inventory of applications fingerprints from a plurality of sources such as mobile device **14**, application software distribution platforms, threat intelligence feeds **32**, etc. As used herein, "application fingerprint" encompasses one or more characteristics of the application (e.g., obtained from the application's manifest, application code, etc.) and/or the application's behavior (e.g., application requests or actions, network activity, etc.) that uniquely identifies the application.

[0022] An application manifest includes one or more files that contain details about an application, such as application code, including application functions and variables; application code flow graphs and data flow graphs; unique application identification (ID) tag (e.g., iPhone® App ID number, Android Marketplace ID number, or other series of characters that can uniquely identify an application); application developer identity; application certificate; application name; application capabilities such as camera activation, network connectivity, phone activation, geolocation, etc.; ports and protocols usable by the application; application life span; a geographical origination of the application; a day and/or time of a first and/or latest appearance of the application on a mobile device; files and file hashes associated with the application; country/region where the mobile device is currently located; and geographical locations of subsequent appearances of the application, etc. The application's behavior may include network activity; attack history; ports and protocols actually used by the application; association with other known Internet Protocol (IP) addresses; application requests for resources; and application actions. It will be understood that these types of details are set forth herein for example purposes, and are not intended to be limiting in any manner.

[0023] Threat intelligence feeds **32** include threat information from one or more sources internal or external to network **12**, such as web reputation engines, file reputation engines, network threat information, internet protocol (IP) and sender reputation engine, vulnerability information, etc. Threat intelligence feeds **32** may be formatted as XML, CSV, simple text files, etc. and can provide real-time, dynamic, and up-to-date information on a variety of potential threats. Threat intelligence feeds **32** may be provided by independent third parties such as security service providers, or by the enterprise's (or the network's) security services. Threat intelligence feeds **32** may be provided to update reputation scores, and/or facilitate analysis of applications by reputation engine **20**.

[0024] In example embodiments, mobile device **14** may be provisioned with one or more applications **34**. Application **34** may be a native application, pre-installed on mobile device **14**. According to embodiments of the present disclosure, reputation engine **20** may include a processor **36** and memory **38** for analyzing each application (e.g., application **18**) against a rules set **40**. Mobile device **14** may be configured to send information to reputation engine **20** and/or permit reputation engine **20** to access information stored on mobile device **14**. In an example embodiment, a user may provide permissions to reputation engine **20** to access mobile device **14**. In another example embodiment, mobile device **14** may be configured to communicate with reputation engine **20** using authentication protocols, for example, when a user signs up on an Internet site to access services provided by reputation engine **20**.

[0025] The network environment illustrated in FIG. **1** may be generally configured or arranged to represent any communication architecture capable of electronically exchanging packets. In addition, the network may also be configured to exchange packets with other networks such as, for example, the Internet, or other LANs. Other common network elements (e.g., email gateways, web gateways, routers, switches, load-balancers, firewalls, etc.), may also be provisioned in the network.

[0026] For purposes of illustrating the techniques of system **10**, it is important to understand the activities and security concerns that may be present in a given system such as the system shown in FIG. **1**. The following foundational information may be viewed as a basis from which the present disclosure may be properly explained. Such information is offered earnestly for purposes of explanation only and, accordingly, should not be construed in any way to limit the broad scope of the present disclosure and its potential applications.

[0027] Typical network environments, both in organizations (e.g., businesses, schools, government organizations, etc.) and in homes include a plurality of devices such as end user desktops, laptops, servers, network appliances, and the like, with each device having an installed set of executable software. Users in organizations and homes may also use mobile devices to connect to various wired and/or wireless networks. One difficulty users face when managing their devices in a network environment is ensuring that only trusted and approved executable software files are present on the devices. Although devices in a network may initially be configured with trusted and approved executable software, continuous efforts (both electronic and manual) are usually necessary to protect against unknown and/or malicious software. In particular, users may connect to a network using mobile devices, which may have unique vulnerabilities that hackers may use to spy on the users, or compromise secure information stored on servers and related networked devices.

[0028] Certain applications may be unwanted, or even malicious, to a user or a network. Malicious software (malware) includes hostile, intrusive, or annoying programming (e.g., code, script, active content, etc.) that can disrupt or deny operation, gather information that leads to loss of privacy or exploitation, gain unauthorized access to system resources, and exhibit other abusive behavior. For example, an application on a mobile phone could be remotely controlled, and configured to turn on the phone's camera and microphone, permitting spying. In another example, an application may track a user's location and convey that information to unauthorized persons. In yet another example, malicious applications may provide a pathway for unauthorized access to critical and proprietary information, inappropriate use of resources, business interruptions, fraud, and security breaches. Research indicates that rogue applications (e.g., malware and spyware) may be a tremendous problem for the mobile security space.

[0029] A system for whitelisting applications outlined by FIG. **1** can resolve these issues, among others. Embodiments of the present disclosure seek to improve capabilities of existing technologies to allow for a more robust solution. Collection and analysis of reputation information may happen in the cloud (e.g., mobile application network **16**) for scale, efficiency, and pervasiveness. Mobile devices may be configured to permit access from the cloud to their agents and applications for calculating reputation scores. According to an embodiment of the present disclosure, malware prevention may be based on an updater concept, with reputation scores

from mobile application network **16** acting as an update rule. Reputation engine **20** may be included in a server in mobile application network **16**. A management console (e.g., running in server **17**) may aggregate and store application reputations from reputation engine **20**, for example, using an inventory trust synchronizing process. The management console may provide appropriate policies, whitelists (e.g., whitelists **30**), inventory exchange, corporate application reputation scores, etc. to suitable whitelist enforcement modules **22** on mobile devices (e.g., mobile device **14**).

[0030] According to embodiments of the present disclosure, components of system **10** may determine functions used by an application, calculate a reputation score of the application, and analyze the application against a rule set in a back-end process. On the front-end, components of system **10** may take suitable protective actions based on the reputation score and analysis of the application. In some other embodiments, components of system **10** may search a whitelist identifying trustworthy applications to determine whether an application in a mobile device is identified in the whitelist. The trust status of the application can be defined as untrusted if the application is not identified in the whitelist. Suitable action may be taken in the mobile device if the trust status of the application is untrusted.

[0031] In example embodiments, reputation engine **20** may determine a reputation score of application **18** by aggregating and evaluating one or more applications fingerprints of application **18** uploaded to reputation engine **20** by one or more sources. For example, the application fingerprint may be sent to reputation engine **20** as a 32-byte fingerprint. In another example embodiment, the aggregated application fingerprint may include application code, containing functions and variables. As used herein, a "function" includes a portion of code within a larger program that performs a specific task and is relatively independent of the remaining code, such as a subroutine, a procedure, a routine, a method, an operation, or subprogram. Examples of functions include: (a) functions that record audio (e.g., Media.RecordAudio( )); (b) functions that send out text messages (e.g., SmaManager.SendTextMessage( )); (c) functions that read contact lists (e.g., contacts.read( )); (d) functions that contact Internet servers (e.g., httpClient.postData( )); etc. In some instances, reputations of identified functions can themselves be assessed and whitelists generated including identified functions conforming to one or more mobile device policies.

[0032] In example embodiments, reputation engine **20** may decompile application **18**, parse the decompiled code, and create one or more code flow graphs and data flow graphs. In example embodiments, functions used by application **18** may be determined from the code flow graphs and data flow graphs. A code flow graph (also known as a call graph) represents calling relationships between subroutines in the application (e.g., application **18**). The code flow graph shows a graphical representation of paths that may be traversed through an application during its execution. A data flow graph represents data dependencies between a number of operations or functions used by the application (e.g., application **18**). Any suitable method may be implemented to create the code flow graphs and data flow graphs. For example, commercially available software may be used to generate these graphs. Reputation engine **20** may store the data flow and code flow graphs in a database (not shown) for later analysis. Reputation engine **20** may also associate the graphs with unique identifying information about the application, such as the application ID (e.g., package ID) and hash of the binary DEX file (Android OS application binaries are compiled as DEX files).

[0033] Turning to FIG. **2**, according to example embodiments, a reputation system can be utilized to control downloads of applications on mobile devices at least partially under the control of one or more entities, such as a network service provider, device manufacturer, or enterprise. For instance, an example reputation system can protect against end users downloading and/or installing applications onto particular mobile devices serviced by the reputation system that do not conform to policies of the controlling entity, such as applications that are not included in an approved list of applications (i.e., a whitelist). For example, when an end user attempts to download or install a particular application (e.g., at **215**) on a mobile device (e.g., mobile device **14**), the mobile device (e.g., through whitelist enforcement module **22**) may query whitelist server **17** to determine whether the application is included in a corresponding whitelist (e.g., **30**). In some examples, mobile device **14** may send the application's identifying information (e.g., application manifest) to server **17** in connection with the query/query result communication **220** between mobile device **14** and whitelist server **17**. Server **17** may identify a particular whitelist (i.e., from a set of different whitelists **30**) corresponding to the mobile device, its user, network, etc. and perform a whitelist look-up to determine whether the application is included in the whitelist. Accordingly, whitelist server **17** can return results to the mobile device **14**. If the query results returned for the application indicate that the application is not included in the whitelist, mobile device **14** (e.g., through whitelist enforcement module **22**) can terminate and/or block downloading of the application, terminate and/or block installation of the application, delete data relating to the application, among other remedies.

[0034] In some instances, a request to check an application (e.g., at **220**) may result in a determination that the application has not yet been assessed, for instance, to develop a corresponding reputation score or qualitative assessment of the application. Accordingly, in some examples, a copy of the requested application can be downloaded and assessed (for instance, using reputation engine **20**) to determine whether the application should be included in one or more whitelists **30** according to particular policies associated with the respective whitelists **30**.

[0035] In other implementations, query **220** can include alternate techniques to determine whether an application is in compliance with one or more policies and can be downloaded and/or installed on a mobile device. For example, blacklists can be used in addition to, or in lieu of one or more whitelists **30**. In other instances, a reputation system can perform a database lookup and return a reputation score, or a qualitative assessment (e.g., derived based on policies in policies database **28**) whether the application is trusted or untrusted. In another example embodiment, reputation engine **20** may provide the trust score and status to the mobile device **14** (e.g., using whitelist enforcement module **22**). Based on the information from server **17** (or reputation engine **20**), whitelist enforcement module **22** may take appropriate action (e.g., changing configuration of applications on mobile device **14**; deleting malicious applications from mobile device **14**; generating security alerts on a display of mobile device **14**; generating security beeps on speakers of mobile device **14**; preventing installation or execution of the malicious application;

preventing access to resources in mobile device **14**; not taking any security action, etc.) based on the reputation score and analysis data.

[0036] Turning to FIG. **3**, whitelists (e.g., at **30**) (or blacklists) can be used to protect mobile devices against activities, transactions, functions, and other actions performed in connection with one or more applications **34** already installed on a mobile device. While it may be desirable to prevent potentially harmful applications from being installed on mobile devices in a system **10**, at least some functionality and updates for existing applications can be prevented based on determinations that corresponding application actions are harmful, insecure, or malicious. For instance, whitelist **30** can maintain a listing of functions, software updates, calls to outside servers (e.g., with untrustworthy reputations or affiliated with known malicious content), and other actions of applications tracked by whitelist server **17**. Indeed, whitelists **30** can include a listing of particular actions of particular applications (i.e., identified actions paired with identified applications) that reputation engine **20**, for instance, has identified as conforming to one or more policies. Similarly, blacklists can be maintained for particular actions of particular applications that reputation engine **20** has identified as insecure, potentially harmful or malicious, or otherwise violating one or more policies.

[0037] Accordingly, in the example of FIG. **3**, in response to or prior to an attempt to perform a particular action by a particular application **34** installed on mobile device **14**, mobile device **14** can query (e.g., at **230**) whitelist server **17** to identify, in one or more whitelists **30**, whether the particular action of the particular application **34** is approved according to one or more corresponding policies. In response, whitelist server **17** can provide results of the query indicating if the particular attempted action **225** is allowed and can proceed. If it is determined that the particular action **225** is not included in a corresponding whitelist of approved application actions, the action can be blocked, for instance, at mobile device **14** using whitelist enforcement module **22**. Further, in some instances, it can be identified that a particular application action has not yet been assessed, resulting in a risk assessment of the particular application action being completed or scheduled.

[0038] In some instances, application actions can involve calls to or communications with outside computing resources, such as a backend application server (e.g., **130**). In one illustrative example, an application **34** may attempt to download an update for the application **34** or otherwise communicate data or receive data from an application server **130**. In one example, before downloading the update, mobile device **14** (e.g., through whitelist enforcement module **22**) can query a whitelist **30** to determine whether the application update is trustworthy. For instance, if the update is not included in a corresponding whitelist, downloading of the update can be terminated. A reputation of the application server **130** or entity associated with the application server **130** can also be considered in determining whether communications and data exchanges with the application server **130** should be whitelisted (and whether the communication is ultimately blocked).

[0039] In another example, an application **34** may possess multiple functions ancillary to its principle functions. Some of these functions may be whitelisted functions, while others are not (e.g., because they pose a threat to user privacy, overburden a communication network, are associated with introducing the mobile device to particular threats or vulnerabilities, etc.). Accordingly, portions of an installed application **34** may be approved while others are blocked according to one or more corresponding whitelists **30**. In still other examples, it can be identified that a particular application **34** installed on the device is not included in a whitelist of approved applications, and attempts by the application **34** to load into memory or otherwise start and run on the mobile device **14** can be blocked, based on the application's **34** exclusion from a corresponding whitelist **30**.

[0040] In either of the examples of FIG. **2** or **3**, in some instances, rather than querying whitelist server **17** to check actions or applications against a whitelist **30**, whitelist server **17** can provide at least a portion of the whitelist **30** to the mobile device **14** for storage or caching on the mobile device **14**. This can allow mobile device **14** to protect itself against potential policy violations even when the device is disconnected from a network, such as the Internet. Further, given the memory constraints of mobile devices, a select portion of the whitelist **30** can be identified that corresponds to attributes or use patterns of a particular mobile device or associated user. For instance, mobile device can identify to whitelist server **17** the set of applications installed on the mobile device **14** and whitelist server **17** can provide a customized whitelist to the mobile device outlining approved functions and actions of the set of applications installed on the mobile device **14**, among other examples. Further, updates to mobile devices' local whitelist copies can be identified and pulled or pushed to the mobile device to ensure that the mobile device's whitelist is kept current.

[0041] According to some embodiments of the present disclosure, the analysis of applications' and application actions' reputations may be rule-based, and may depend on rules set **40**. According to embodiments of the present disclosure, rules set **40** may be based on software development kit (SDK) or application programming interface (API) function calls (i.e., expressions consisting of functions and variables or arguments used by the functions). In general, applications (e.g., application **20**), may be written to interface with a specific operating system using an API. API is a particular set of rules and specifications including specifications for routines, data structures, object classes, and protocols used to communicate between various software programs. For example, an API can define the operating system's resource request conventions (e.g. function-calling conventions).

[0042] An SDK is typically a set of development tools that allows for the creation of applications for a certain software package, software framework, hardware platform, computer system, video game console, operating system, or similar platform. An SDK may include an API (e.g., in the form of files to interface to a particular programming language) and/or sophisticated hardware to communicate with a certain embedded system. Substantially all API function calls may end up in platform SDK function calls. In example embodiments, reputation engine **20** may populate a list with predetermined SDK functions, which a potential malicious user might use.

[0043] A rule in rules set **40** may identify paths that a data element (e.g., any named unit of data for processing) can take for a malicious purpose. For example, if a data element uses Media. RecordAudio( ) (i.e., records audio), SmaManager. SendTextMessage( ) (i.e., sends SMS text message), contacts. read( ) (i.e., reads contact list), and httpClient.postData( ) (i.e., contacts an Internet server), in that order, the application

may be exhibiting suspicious behavior. However, if a data element uses SmaManager.SendTextMessage( ), contacts. read( ), and httpClient.postData( ), but does not use Media. RecordAudio( ), the application may not be exhibiting suspicious behavior. In an example embodiment, the rules can comprehensively identify all paths that indicate suspicious behavior.

[0044] Reputation engine **20** may analyze an application (e.g., application **18**) by traversing nodes, including leaf nodes (functions that do not call any other function) in the data flow graph. A rule may include rule elements, which are functions indicating suspicious behavior. For the sake of illustration, assume that an SDK contains functions a( ) . . . z( ), and rules set **40** includes the following rules comprising the specified rule elements: Rule 1: a( ), b( ), p( ), q( ), s( ), t( ), and z( ); Rule 2: c( ), m( ), n( ), b( ), and t( ); Rule 3: e( ), o( ), and z( ). Reputation engine **20** may traverse the code flow and data flow graphs for application **18**. Each path in the graphs of application **18** typically traverse functions called by application **18**. For a given rule, if all rule elements match a path in the graphs (and vice versa), the program logic may be deemed to be suspicious. Such a match may trigger a policy violation for a suitable action. An example policy may include characterizing the application as high risk, or alternatively, setting a trust status as untrusted, and omitting the application or application function from a corresponding whitelist if one or more rule violations are detected.

[0045] Turning to calculating reputation scores, functions used by the application (e.g., application **18**) may be weighted based on their malice potential. For example, API functions that record audio (e.g., potentially violating users' privacy) may be weighted higher than API functions that read contact lists. Functions with a weighting factor larger than a predetermined threshold may be denoted as red-flagged functions. Such red-flagged functions can be specifically omitted from application action whitelists (or alternatively included in application activity blacklists). The threshold value may be any value chosen by the user or programmer as appropriate and based on suitable needs. According to embodiments of the present disclosure, a reputation score for an application (e.g., application **18**) may be set to 0 at the start of the analysis. Reputation engine **20** may traverse the code flow graph and data flow graph of application **18**. Each time the graph path traversal encounters a red-flagged function, the aggregate reputation score for an application may be incremented by the weighting factor of the red-flagged function. At the end of the calculation, the resulting aggregate score can denotes the malice potential of the function call sequence or an application itself. Reputation engine **20**, or mobile device **14**, may access policies database **28** to identify a suitable action that may be taken with respect to the application based on its reputation score and/or application analysis information.

[0046] Reputation scores can be used to build whitelists (and/or blacklists) used to protect against potentially untrustworthy, insecure, or malicious applications and application actions. While numerous servers may be connected to mobile application network **16**, server **17** can represent a service providing one or more databases or libraries of whitelists containing information related to applications evaluated for risk. For example, applications evaluated and determined to be untrustworthy (e.g., containing malicious code such as viruses, worms, and the like, etc.) may be included in a so-called "blacklist" (not shown). Applications evaluated and determined to be trustworthy (e.g., uncontaminated, free of malicious code, etc.) may be included in a so-called "whitelist" (e.g., whitelists **30**). Although whitelists and blacklists may be implemented separately, it is also possible for them to be combined in a database or library with each software program file being identified as either a whitelist file or a blacklist file. Indeed, libraries of whitelists and blacklists can be assembled and managed by a central reputation system, the whitelists applying to a plurality of different mobile devices, mobile operating systems, mobile device manufacturers, network service providers, enterprises, and other entities and groupings.

[0047] Whitelists (and blacklists) may be implemented using checksums where a unique checksum for each application is stored, which can be readily compared to a computed checksum of an application sought to be evaluated. A checksum can be a mathematical value or hash sum (e.g., a fixed string of numerical digits) derived by applying an algorithm to an application (e.g., application program file, application manifest, etc.). If the algorithm is applied to a second application that is identical to the first application, then the checksums should match. However, if the second application is different (e.g., it has been altered in some way, it is a different version of the first application, it is a wholly different type of software, etc.) then the checksums are unlikely to match.

[0048] In specific embodiments, a trust status (i.e. trusted or untrusted) of an application is defined as trusted if the application is included in whitelists **30** and untrusted if the application is not included in whitelists **30**. Whitelists **30** may include entries identifying each application or application action that is categorized as trusted. In an example embodiment, whitelists **30** may comprise a checksum of application or function fingerprints. In some embodiments, evaluation of applications to determine their respective trust status is performed in real-time for applications associated with an execution attempt in mobile device **14**. An execution attempt (e.g., **215** or **225**) as used herein in this Specification is intended to include any software process or instruction with an execute request and any attempt to access resources (e.g., processor, memory, camera, microphone, etc.) in the mobile device. When an application is associated with an execution attempt, the execution may be blocked if the trust status of the application is determined to be untrusted (e.g., based on a whitelist or blacklist query). In example embodiments, the trust status may be determined using one of the trusted software inventories (e.g., whitelists **30**) or may be determined using one or more trust evaluation techniques in real-time (e.g., using reputation engine **20** and other components). Any execution attempts by untrusted applications may also be logged and aggregated for reporting.

[0049] Databases with whitelists **30** in FIG. **1** may be provided by independent third parties and may be regularly updated to provide a comprehensive listing of trustworthy applications available to consumers. Similarly, blacklists (not shown) may be provided by independent third parties and may be regularly updated to provide a comprehensive listing of untrusted, malicious applications. Whitelists and blacklists may be external to network **12** and may be accessible through other networks such as mobile application network **16**, or through any other suitable connection that permits electronic communication between network **12** and whitelists **30**. Copies of all or portions of such whitelists (or blacklists) can also be provided to corresponding mobile devices **14** themselves for use, for example, by a whitelist enforcement module **22**.

[0050] According to embodiments of the present disclosure, whitelists **30** may be provisioned in application reputations database **26** (for example, as a local copy), or accessed by or through application reputations database **26**, or otherwise available to server **17** and/or mobile device **14** over network **12** (or other networks). Whitelists **30** may also contain information related to applications evaluated for risk and may identify such applications using checksums. Applications identified in whitelists **30** may be inclusive of applications from one or more external whitelists and/or may be customized to provide information on selected applications. In particular, applications developed internally within the organization, but not necessarily available to the general public, may be identified in whitelists **30**. Additionally, an internal blacklist could also be provided to identify particular applications evaluated and determined to be untrustworthy. Applications may be organized in any suitable manner in whitelists **30**, for example, grouped by publishers or by any other suitable groups.

[0051] In example embodiments, whitelist enforcement module **22** may access whitelists **30** (or local copies of whitelists **30**) to determine the trust status of application **34**. Alternatively, or additionally, whitelist enforcement module **22** may access application reputations database **26** to obtain reputation scores for application **34** (which is already installed in mobile device **14**) and application **18** (which is not yet installed in mobile device **14**). According to embodiments of the present disclosure, whitelist enforcement module **22** may send application identification (e.g., application manifest) to server **17**. In an example embodiment, agent **24** may connect to server **17** over the Internet and get a response over a data connection. In another example embodiment, whitelist enforcement module **22** may dial a predefined number, and send dual-tone multi-frequency (DTMF) tones to transmit application identification information. For example, a hash of the application's identification number (ID) may be computed and converted to an octal representation. The hash can then be transmitted using DTMF tones for numbers 0-7, with a tone for 8 signaling end-of-transmission. The dialed number can then respond with corresponding DTMF tones representing the reputation score that can be used by the agent to determine if the application is trusted or untrusted.

[0052] Whitelist enforcement module **22** may collect identification information (e.g., application manifest) of applications to be downloaded (or already downloaded) to mobile device **14**, and monitor behavior and activities of any one or more applications already installed on mobile device **14**. Whitelist enforcement module **22** may also access policies, which may be stored on mobile device **14** or in policies database **28** in server **17**, to determine if any application is malicious or vulnerable to particular threats, and determine any action to take based on reputation scores or application analysis data. Whitelist enforcement module **22** may also manage activities of applications on mobile device **14**, for example, by preventing installation of one or more applications or application updates or preventing execution of one or more applications or application actions based on the respective reputation scores of the applications, their updates, or actions. In example embodiments, whitelist enforcement module **22** may comprise a kernel module residing in (or be operable by) operating system (not shown) of mobile device **14**.

[0053] In an example embodiment, whitelist enforcement module **22** may include event detection capabilities, communication interfaces, policy manager, etc. In another example embodiment, whitelist enforcement module **22** may include software capable of communicating with reputation engine **20** and server **17**, and carrying out instructions from policy managers, event detection components, etc. Whitelist enforcement module **22** may be configured to receive queries or information from reputation engine **20** and/or server **17**. For example, reputation engine **20** may query whitelist enforcement module **22** for a status of one or more applications installed in mobile device **14**. Whitelist enforcement module **22** may provide application status to reputation engine **20** in response to the query. In another example, reputation engine **20** may provide whitelist enforcement module **22** with a reputation score of application **18**. In response, whitelist enforcement module **22** may lookup a policy and take a suitable action based on the reputation score.

[0054] In another example embodiment, application reputations database **26** may include whitelists **30** of trustworthy applications, for example, applications with a low reputation score, or trusted status. Whitelist enforcement module **22** may compare an application (e.g., application **34** or application **18**) with whitelists **30**. If the application is not found in whitelists **30**, the application may be deemed to be untrusted and may not be allowed to download (if not downloaded) or run (if already downloaded). In some embodiments, mobile device **14** may be booted to enable the functionalities described herein.

[0055] In some embodiments, the aggregated application fingerprints may include aggregated behaviors of the application that may also be evaluated to determine a reputation score of the application. As more information about an application or actions of applications are reported or otherwise made available to reputation engine **20**, a statistical confidence level of the reputation score may be higher. For instance, whitelist enforcement modules **22** operating mobile devices **14** in a system can detect security events relating to particular applications and application activities and report such events to reputation engine **20** or other modules for use in determining the trustworthiness of such applications and application activities. Indeed, knowledge gained from monitoring application activity on any one mobile device may be aggregated and analyzed against information about similar activity obtained from other mobile devices, and correlated with data from other vectors (e.g., file, web, message, network connections, and manual efforts) for substantially comprehensive information about the application. In an example embodiment, the data from other vectors may be derived from threat intelligence feeds **32**. Additionally, any threat or vulnerability may be temporal in nature (e.g., if an application is interacting with an IP address that is temporarily compromised), and components of system **10** may modify the application's reputation score appropriately in real time to remediate the threat to the host mobile device. For example, reputation engine **20** may incorporate and adjust reputation scores with each additional data point.

[0056] In an example scenario, if a new application pops up in a particular geographic location (e.g., China) and it spreads like wildfire within hours (e.g., application is downloaded and installed to an unusually large user base or user bases in atypical markets, for instance, installations on several hundred thousand mobile devices geographic locations, such as United States, Europe, Australia, India, etc. in a short span of time), such fast and atypical distribution may be interpreted to be an indicator of malicious behavior, and a reputation score

for the new application may be generated or updated to reflect this characteristic. Reputation engine **20** may aggregate such information, analyze it, and determine that a propagation factor (i.e., how quickly the application spreads to other mobile devices) of the application is high, indicating possible malicious behavior.

[0057] In another example scenario, an application on a particular mobile device may initiate a spying or snooping action. A whitelist enforcement module **22** may recognize the snooping action and convey the snooping action to reputation engine **20**. Consequently, reputation engine **20** may calculate an updated reputation score for the application. The updated reputation score may be distributed to all other mobile devices on which the application is installed, enabling respective agents to take suitable action.

[0058] Turning to the infrastructure of FIG. **1**, server **17** may be an enterprise server managing security and policies of a particular enterprise. In another embodiment, server **17** may be one or more intermediate servers provided, for instance, through a third-party computer security services vendor. FIG. **1** showing mobile device **14** communicating with mobile application network **16** through server **17** is merely representative. One or more servers may be used for one group of associated mobile devices (e.g., mobile devices on an enterprise, or having a common local communications carrier, etc.); and multiple enterprises or groups of associated mobile devices may connect to the cloud through their own one or more servers.

[0059] Network **12** represents networks, which can be a series of points or nodes of interconnected communication paths for receiving and transmitting packets of information that propagate through system **10**. Network **12** offers communicative interfaces between any of the components of FIG. **1**. Network **12** could be any local area network (LAN), wireless local area network (WLAN), wide area network (WAN), wireless wide area network (WWAN), metropolitan area network (MAN), wireless metropolitan area network (WMAN), wireless single hop or multi-hop network, virtual private network (VPN), Intranet, Extranet, or any other appropriate architecture or system that facilitates communications in a network environment. Network **12** may include any suitable communication link to reputation engine **20** such as wireless technologies (e.g., IEEE 802.11, 802.16, WiFi, Bluetooth, WiMax, DSRC, WiMAX, etc.), satellite, cellular technologies (e.g., 3G, 4G, etc.), etc., or any combination thereof. Network **12** may also include configurations capable of transmission control protocol/Internet protocol (TCP/IP) communications, user datagram protocol/IP (UDP/IP), or any other suitable protocol, where appropriate and based on particular needs.

[0060] Not shown in system **10** of FIG. **1** is hardware that may be suitably coupled to reputation engine **20** in the form of consoles, user interfaces, memory management units (MMU), additional symmetric multiprocessing (SMP) elements, peripheral component interconnect (PCI) bus and corresponding bridges, small computer system interface (SCSI)/integrated drive electronics (IDE) elements, etc. In addition, suitable modems, routers, base stations, wireless access points, and/or network adapters may also be included for allowing network access by components of system **10**. Any suitable operating systems may also be configured in components of system **10** to appropriately manage the operation of hardware components therein. Components of system **10** may include any other suitable hardware, software, components, modules, interfaces, or objects that facilitate the operations thereof. This may be inclusive of appropriate algorithms and communication protocols that facilitate the operations detailed herein. These elements, shown and/or described with reference to system **10** are intended for illustrative purposes and are not meant to imply architectural limitations. In addition, each element, including reputation engine **20**, agents **24** and mobile devices **14**, may include more or less components where appropriate and based on particular requirements.

[0061] Turning to FIG. **4**, FIG. **4** is an example code flow graph or call graph for use in some implementations of a reputation engine. A call graph can be a directed graph that represents calling relationships between functions in a computer program. A call graph can be used, for instance, to automatically parse, test, simulate, and otherwise examine application functions and identify untrustworthy, insecure, or other undesirable application features. Further, the identification of undesirable functionality within an application can serve as the basis for a lower overall reputation score for the application or the identified application functions. In some instances, a call graph can include nodes and edges. Specifically, each node represents a procedure and each edge (f, g) indicates that procedure f calls procedure g. For purposes of illustration, assume that functions named fA( ), fB( ), fC( ) etc. are called in a sequence as follows: fA( ) {fB( ); fC( );} (i.e., fA( ) calls functions fB( ) and fC( )); fB( ) {fD( ); fC( );} (i.e., fB( ) calls functions fD( ) and fC( )); fC( ){calculation} (i.e., fC( ) performs a calculation); and fD( ) {fE( ) {fC( )}} (i.e., fD( ) calls function fE( ), which calls fC( )).

[0062] The resultant call graph **50** may be as illustrated in FIG. **5**. Function fA( ) **52** may call functions fB( ) **54** and fC( ) **56**. Function fB( ) **54** may call functions fC( ) **56** and fD( ) **58**. Function fD( ) **58** may call function fE( ) **60**, which in turn calls fC( ) **56**. The code flow graph can have leaf nodes (functions that do not call any other function, like fC( ) **56** in above example). Leaf nodes can either be (a) an application writer's function that performs some calculation; or (b) system calls/SDK functions like those in the Android SDK. The SDK functions may not call internal functions within the application's code. In example embodiments wherein applications for Android OS are written using Java SDK, system calls may be discounted from the analysis, as in the example illustrated herein.

[0063] Turning to FIG. **5**, FIG. **5** is an example data flow graph **70** according to embodiments of the present disclosure. A data flow graph typically has nodes and edges. Nodes receive data or describe operations (e.g., nodes can be program statements), and transmit values to other nodes by way of edges. Edges may be considered to be channels of communication, for instance. A circle in a data flow graph typically represents a process (e.g., a set of program sets). An arrow directed towards the circle represents a data input (or set of inputs) and an arrow originating from the circle represents a data output (or a set of outputs). Data input along an input edge is considered as a token. Nodes consume tokens (e.g., of type Boolean, integer, real or character) on input edges and produce tokens on output edges. Mathematically, the following representation may be adopted:

$$G=\langle N,E\rangle$$

where G is the data flow graph, $N=\{n_1, n_2, \ldots, n_n\}$ is the set of nodes, and E is the set of edges.

[0064] Reputation engine **20** may parse the application under analysis (e.g., application **18**). Parsing is a process of

analyzing a source code of a computer program and creating some form of internal representation. In example embodiments, reputation **20** may parse the decompiled source code of application **18** and create data flow graph **70**, with a node for each variable that is encountered, and an edge for each operation. Variables may be operated on in a program to result in some other variable.

[0065] For example, according to FIG. **6**A, assume that application **18** comprises a code including functions fA( ) (not shown), fB( ) **54**, fC( ) **56** and fD( ) **58** operating on variables a **72**, b **76**, c **80** and d **82**, all of which are integers. Integer a **72** is assigned a value of 100. Integer b **76** may be obtained by operating another function fB(b') **54** on variable b' **74**. Integer c **80** may be obtained by operating yet another function fC(c') **56** on variable c' **78**. Integer d **82** may be obtained by operating yet another function fD(a, b, c) **58** on variables a **82**, b **76** and c **80**. Function fA( ) may be mathematically represented as follows:

```
fA( )
{
    Int a = 100;
    Int b = fB( );
    Int c = fC( );
    Int d = fD(a,b,c);
}
```

[0066] The set of nodes and edges defined by the above described variables can result in data flow graph **70** as illustrated in FIG. **5**.

[0067] Turning to FIG. **6**A, FIG. **6**A is a flow chart illustrating example operational steps that may be associated with embodiments of the present disclosure. Operations **100** start in **102**, when reputation engine **20** is activated. Reputation engine **20** may crawl mobile application network **16** for applications (e.g., application **18**) in **104**. In an example embodiment, reputation engine **20** may crawl the Internet for applications. In another example embodiment, reputation engine **20** may crawl an enterprise network for applications. In yet another example embodiment, reputation engine **20** may crawl known websites or application software distribution platforms for applications.

[0068] In **106**, reputation engine **20** may download application **18** and in **108**, reputation engine **20** may store application **18**. Reputation engine **20** may store application **18** in a file server, application server, network drive, or any other device or network element that may be suitable to store program files such as those contained in application **18**. In an example embodiment, reputation engine **20** may store a checksum of application fingerprints, rather than the entire application. In yet another example embodiment, reputation engine **20** may store the application manifest, rather than the entire application.

[0069] In **110**, reputation engine **20** may decompile application **18** by any known method. Decompiling may not reconstruct the original source code of application **18**; however, it may provide information about the operations and variables in application **18**, sufficient to perform the functions as described herein. In **112**, reputation engine **20** may parse the decompiled code and obtain functions used by application **18**. In **114**, reputation engine **20** may appropriate create code flow graphs and data flow graphs of application **18**.

[0070] In **116**, a reputation score of an application **18** (or identified application functions, operations, or other actions identified during decompiling **110** and parsing **112**) can be calculated. For instance, in one example, a reputation score can be initially set to 0 (or initialized in any suitable manner). In **118**, reputation engine **20** traverses the code flow graph and data flow graph, seeking red-flagged functions. Each time the graph path traversal encounters a red-flagged function, as determined in **120**, the reputation score may be incremented by the weighting factor of the red-flagged function. For example, if Media.RecordAudio( ) function is assigned a weighting factor of 10, and SmaManager.SendTextMessage( ) function is assigned a weighting factor of 8, and contacts.read( ) function is assigned a weighting factor of 5, an application that includes all three functions may have a reputation score of 23. On the other hand, an application that includes only contacts.read( ) function and the SmaManager.SendTextMessage( ) function may have a reputation score of 13. When an end-of-flow is encountered in **124**, reputation engine **20** may calculate a final reputation score, for example, by aggregating the weighting factors of all red-flagged functions encountered.

[0071] In **128**, reputation engine **20** may call a (next) rule from rules set **40**. In **130**, reputation engine **20** may traverse the code flow graph and data flow graph of application **18**. In **132**, application **18** may compare rule elements with the code flow and data flow graphs. In **134**, if an end-of-flow is encountered, reputation engine determines whether the flow in the graphs (i.e., code flow graph and data flow graph) match the rule elements in **136**. Operations continue to **128**, wherein the next rule is called. Reputation engine **20** may go through all rules in rules set **40** until the code flow graph and data flow graphs have been analyzed against all rules in rules set **40**.

[0072] If a match is found (indicating malicious behavior), a policy may be called in **138**. In example embodiments, the policy may be called by agent **24** in mobile device **14**. In another example embodiment, the policy may be called by reputation engine **20**, which may apply the policy on application **18** and place it in whitelists **30** if the reputation score is low. In **140**, any suitable action may be taken. For example, whitelist enforcement module **22** may cause mobile device **14** to uninstall the application (if it has already been installed). In another example, whitelist enforcement module **22** may cause a security alert to be displayed on a screen of mobile device **14**, indicating that the application is malicious. Any appropriate action may be taken based on suitable needs. The operations end in **142**.

[0073] Turning to FIG. **6**B, a flowchart is shown showing example techniques used to assess an attempt to download a particular application onto a mobile device. For instance, attributes of the application can be identified **305**, for example, in connection with the crawling of libraries of applications identified as operable with one or more mobile devices, such as smartphones, tablet computers, PDAs, electronic readers, and other mobile devices of various makes, models, and operating systems. The particular application can be assessed, along with every other application discovered during the crawling, to identify attributes of the application, including the developer of the application, an identity of the server of the application, functions of the application, backend computing resources used by the applications, reported events relating to the applications, among other attributes discoverable during crawling and analysis of the respective applications. In one illustrative example,

attributes, such as application functions and actions of an application can be identified, for instance, through simulation, testing, decompiling, and/or parsing of the application. Additional attributes for the application can be identified in connection with discovery of the application such as identification of the server or source of the application, the developer of the application, when the application was first made available, among other attributes. For instance, an identity of the application's seller, server, or developer can be identified. Further a reputation of the application's source or developer can be identified and considered along with other attributes in determining the application's trustworthiness or compliance with one or more mobile application policies enforced in a network or system.

[0074] Further, a reputation score can be determined **310** for the particular application (and all other identified applications) based on the identified attributes. A plurality of reputation scores can be determined **310** for the particular application according to various rules and policies, including rules and policy sets corresponding to different entities, such as network service providers, device manufacturers, enterprise system managers, and so on. The determined reputation score can be used to determine **315** whether applications should be included in one or more whitelists identifying, for example, whether the application conforms to a particular set of policies or rules. For instance, whether an application is added to a whitelist can depend on whether the determined reputation score meets a certain threshold of trustworthiness, satisfies various policies or rules, among other examples. The whitelist can be used to protect mobile devices from potentially untrustworthy applications and threats and vulnerabilities potentially introduced through such applications. In other instances, the whitelist can be used to enforce particular mobile device application policies, such as policies or rules of a particular service provider or other entity.

[0075] As an example, the whitelist can be used **320** to assess attempts to download an application onto a particular mobile device. For instance, if the application is included in a whitelist, downloading of the application onto the particular mobile device may proceed uninhibited. Alternatively, if the application is not included in the whitelist, downloading of the application can be blocked, for instance, at the mobile device, a network gateway used by the mobile device, or some other computing component. Multiple whitelists may be developed and maintained and in some instances a single application may be included on some whitelists but omitted from others, for instance, based on the particular policies governing applications' inclusion in a corresponding whitelist.

[0076] FIG. **6**C shown another flowchart illustrating example techniques for assessing the trustworthiness or policy compliance of one or more actions of applications installed on one or more mobile devices. An installed application can be identified **325** on a mobile device. An application action can be identified **330** involving the mobile device, for instance, in connection with an attempt to perform the action using the mobile device. A determination can be made **335**, for instance using a whitelist or a blacklist, whether the identified application action conforms with a particular policy. The policy can be included in a set of policies or rules of a particular entity. Based on the determination **335**, the application action can be allowed or blocked (at **340**). For instance, such application actions can include attempts to download a particular update, an attempt to access a particular outside computing resource or server (e.g., with its own respective reputation), an attempt to perform a particular function, string of functions, or operation, or even an attempt to begin running the application, among other examples.

[0077] Turning to FIG. **7**, FIG. **7** is a bar chart illustrating reputation score **190** on the X-axis against number of applications **192** along the Y-axis. Reputation score **190** may be classified into a plurality of categories. In an example embodiment, low reputation scores may be classified as low risk, and assigned a color green. Reputation scores reflecting an unverified status may be assigned a color yellow. Intermediate reputation scores may be classified as medium risk and assigned a color orange. High reputation scores may be classified as high risk and assigned a color red. For each reputation score (or range of reputation scores), there may be several corresponding applications. For example, a number of applications **192** may have an identical reputation score (or range of reputation scores), which may be different from another number of applications with a different reputation score.

[0078] Suitable actions may be taken based on the risk level. For example, applications with reputation scores in the high risk category may not be allowed to download, or install, or run. On the other hand, applications with reputation scores in the low risk category may be allowed to download, install, and run. Any number of suitable actions may be taken based on the risk categories of the applications. The colors are provided for illustrative purposes only. Any other classification labels, means, schemes and methods may be used without changing the scope of the present disclosure.

[0079] Although the embodiments described herein have referred to applications, it will be apparent that other sets of program files may be evaluated and/or remediated using system **10**. The options for whitelisting applications, as shown in FIGURES, are for example purposes only. It will be appreciated that numerous other options, at least some of which are detailed herein in this Specification, may be provided in any combination with or exclusive of the options of the various FIGURES.

[0080] Software for achieving the operations outlined herein can be provided at various locations (e.g., the corporate IT headquarters, end user computers, web servers, distributed servers in the cloud, software security provider cloud or datacenter, etc.). In some embodiments, this software could be received or downloaded from a web server (e.g., in the context of purchasing individual end-user licenses for separate networks, devices, servers, etc.) in order to provide this system. In one example implementation, this software is resident in one or more mobile devices, computers and/or servers sought to be protected from a security attack (or protected from unwanted or unauthorized manipulations of data).

[0081] System **10** may be implemented in hardware or software, and may be used to assess applications either remotely or locally. In an example embodiment, system **10** may be implemented as a cloud component and local agents on various mobile devices, wherein the local agents perform collecting information (e.g., application code information), monitoring (e.g., application behavior), and enforcing functions and the cloud component receives the application code information, determines reputation scores and pushes reputation scores back to the mobile devices. In another embodiment, system **10** may be implemented as a remote automated service that can scan a targeted mobile device according to a pre-determined schedule, for example, once every 24 hours. In yet another example embodiment, system **10** may be

implemented as a portable solution that can be temporarily loaded onto a network connected to a target mobile device. System **10** may perform a deep inspection of applications on myriad mobile devices. In yet another example embodiment, system **10** may be hosted on a mobile device.

[0082] In various embodiments, the software of the system for whitelisting applications could involve a proprietary element (e.g., as part of a network security solution with security management products), which could be provided in (or be proximate to) these identified elements, or be provided in any other device, server, network appliance, console, firewall, switch, information technology (IT) device, distributed server, etc., or be provided as a complementary solution, or otherwise provisioned in the network. In various embodiments, mobile application network **16** may include one or more servers running proprietary software.

[0083] In certain example implementations, the activities outlined herein may be implemented in software. This could be inclusive of software provided in reputation engine **20** and in other network elements (e.g., mobile devices **14**) including applications. These elements and/or modules can cooperate with each other in order to perform the activities as discussed herein. In other embodiments, these features may be provided external to these elements, included in other devices to achieve these intended functionalities, or consolidated in any appropriate manner. For example, some of the processors associated with the various elements may be removed, or otherwise consolidated such that a single processor and a single memory location are responsible for certain activities. In a general sense, the arrangement depicted in FIGURES may be more logical in its representation, whereas a physical architecture may include various permutations, combinations, and/or hybrids of these elements.

[0084] In various embodiments, some or all of these elements include software (or reciprocating software) that can coordinate, manage, or otherwise cooperate in order to achieve operations, as outlined herein. One or more of these elements may include any suitable algorithms, hardware, software, components, modules, interfaces, or objects that facilitate the operations thereof. In the implementation involving software, such a configuration may be inclusive of logic encoded in one or more tangible media, which may be inclusive of non-transitory media (e.g., embedded logic provided in an application specific integrated circuit (ASIC), digital signal processor (DSP) instructions, software (potentially inclusive of object code and source code) to be executed by a processor, or other similar machine, etc.).

[0085] In some of these instances, memory can store data used for the operations described herein. This includes the memory being able to store software, logic, code, or processor instructions that are executed to carry out the activities described in this Specification. A processor can execute any type of instructions associated with the data to achieve the operations detailed herein in this Specification. In one example, the processor could transform an element or an article (e.g., data) from one state or thing to another state or thing. In another example, the activities outlined herein may be implemented with fixed logic or programmable logic (e.g., software/computer instructions executed by a processor) and the elements identified herein could be some type of a programmable processor, programmable digital logic (e.g., a field programmable gate array (FPGA), an erasable programmable read only memory (EPROM), an electrically erasable programmable read only memory (EEPROM)), an ASIC that includes digital logic, software, code, electronic instructions, flash memory, optical disks, CD-ROMs, DVD ROMs, magnetic or optical cards, other types of machine-readable mediums suitable for storing electronic instructions, or any suitable combination thereof.

[0086] Reputation engine **20** and other associated components in system **10** can include memory for storing information to be used in achieving operations as outlined herein. These devices may further keep information in any suitable type of memory (e.g., random access memory (RAM), read only memory (ROM), field programmable gate array (FPGA), erasable programmable read only memory (EPROM), electrically erasable programmable ROM (EEPROM), etc.), software, hardware, or in any other suitable component, device, element, or object where appropriate and based on particular needs. The information being tracked, sent, received, or stored in system **10** could be provided in any database, register, table, cache, queue, control list, or storage structure, based on particular needs and implementations, all of which could be referenced in any suitable timeframe. Any of the memory items discussed herein should be construed as being encompassed within the broad term 'memory.' Similarly, any of the potential processing elements, modules, and machines described in this Specification should be construed as being encompassed within the broad term 'processor.' Each of the computers may also include suitable interfaces for receiving, transmitting, and/or otherwise communicating data or information in a network environment.

[0087] Note that with the numerous examples provided herein, interaction may be described in terms of two, three, four, or more network elements and modules. However, this has been done for purposes of clarity and example only. It should be appreciated that the system can be consolidated in any suitable manner. Along similar design alternatives, any of the illustrated computers, modules, components, and elements of FIG. **1** may be combined in various possible configurations, all of which are clearly within the broad scope of this Specification. In certain cases, it may be easier to describe one or more of the functionalities of a given set of flows by only referencing a limited number of network elements. It should be appreciated that the system of FIG. **1** (and its teachings) is readily scalable and can accommodate a large number of components, as well as more complicated/sophisticated arrangements and configurations. Accordingly, the examples provided should not limit the scope or inhibit the broad teachings of system **10** as potentially applied to a myriad of other architectures.

[0088] It is also important to note that the operations described with reference to the preceding FIGURES illustrate only some of the possible scenarios that may be executed by, or within, the system. Some of these operations may be deleted or removed where appropriate, or these steps may be modified or changed considerably without departing from the scope of the discussed concepts. In addition, the timing of these operations may be altered considerably and still achieve the results taught in this disclosure. The preceding operational flows have been offered for purposes of example and discussion. Substantial flexibility is provided by the system in that any suitable arrangements, chronologies, configurations, and timing mechanisms may be provided without departing from the teachings of the discussed concepts.

What is claimed is:

1. A method comprising:

identifying an application installed on a particular mobile device;

identifying an action involving the application to be performed using the particular mobile device; and

determining whether the action is an approved action based on at least one policy associated with the particular mobile device, wherein a determination that the action is unapproved results in an attempt to prevent the action.

2. The method of claim **1**, wherein determining whether the action is an approved action includes identifying whether the action is included in a whitelist of approved actions, wherein the whitelist is based at least in part on conformance of actions with the at least one policy.

3. The method of claim **2**, wherein the whitelist includes a listing of a plurality of actions, each action paired to at least one application.

4. The method of claim **3**, wherein approval of an action is based, at least in part, on a reputation of the paired application.

5. The method of claim **4**, wherein the reputation of a particular application is based at least in part on user feedback data received for the particular application identifying user security assessments of the particular application.

6. The method of claim **3**, wherein approval of the action is approved for a first application, and unapproved for a second application.

7. The method of claim **2**, wherein the whitelist is maintained by a whitelist server and at least a portion of the whitelist is downloaded to one or more mobile devices remote from the whitelist server.

8. The method of claim **7**, further comprising identifying an update to the whitelist and causing the update to be automatically downloaded to the one or more mobile devices.

9. The method of claim **2**, wherein the whitelist is a particular one of a plurality of whitelists, wherein each whitelist in the plurality of whitelists is associated with a corresponding set of policies, and each set of policies is associated with a corresponding entity.

10. The method of claim **9**, wherein the particular whitelist governs a set of mobile devices in a system of an entity, the set of mobile devices including the particular mobile.

11. The method of claim **10**, wherein the set of mobile devices includes the particular mobile device utilizing a first operating system and at least one second mobile device utilizing a second operating system.

12. The method of claim **1**, determining whether the action is an approved action includes identifying whether the action is included in a blacklist of unapproved actions, wherein the blacklist is based at least in part on failures of actions to conform with the at least one policy.

13. The method of claim **1**, wherein the action includes a function of the application, and at least some functions of an application remain allowed during prevention of a particular action determined to be unapproved.

14. The method of claim **1**, wherein the action includes an attempt to update the application, and unapproved updates are prevented from being downloaded to the particular mobile device.

15. The method of claim **1**, wherein the action includes initiating running of the application on the particular mobile device, wherein the application is prevented from running based on a determination that the application violates the at least one policy.

16. The method of claim **1**, wherein the action includes an attempt to communicate with at least one remote computing resource, wherein determining whether to prevent the application's communication with the at least one remote computing resource is based on a reputation of the at least one computing resource.

17. The method of claim **1**, wherein the action is identified in connection with an attempt to perform the action using the particular mobile device.

18. The method of claim **1**, wherein a determination of a particular unapproved action of a particular application causes downloading of the particular application to be blocked for mobile devices whereon the particular application is not yet installed.

19. Logic encoded in non-transitory media that includes code for execution and when executed by a processor is operable to perform operations comprising:

identifying an application installed on a particular mobile device;

identifying an action involving the application to be performed using the particular mobile device; and

determining whether the action is an approved action based on at least one policy associated with the particular mobile device, wherein a determination that the action is unapproved results in an attempt to prevent the action.

20. A system comprising:

a memory configured to store data; and

a processor operable to execute instructions associated with the data;

a reputation engine, adapted when executed by the at least one processor device to:

identify an application installed on a particular mobile device;

identify an action involving the application to be performed using the particular mobile device; and

determine whether the action is an approved action based on at least one policy associated with the particular mobile device, wherein a determination that the action is unapproved results in an attempt to prevent the action.

21. The system of claim **20**, further comprising generating a whitelist including a listing of each approved application action identified as conforming to the at least one policy.

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