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**Federschmidt et al.**

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(45) **Date of Patent: Aug. 19, 2025**

(54) **INTEGRATED DEVELOPMENT ENVIRONMENT EXTENSION FOR DEVELOPING INFORMATION TECHNOLOGY AND SECURITY OPERATIONS APPLICATION APPS**

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(73) Assignee: **Splunk Inc.**, San Francisco, CA (US)

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(51) **Int. Cl.**
***G06F 21/54*** (2013.01)
***G06F 21/57*** (2013.01)
***G06F 21/60*** (2013.01)

(52) **U.S. Cl.**
CPC .............. ***G06F 21/54*** (2013.01); ***G06F 21/57*** (2013.01); ***G06F 21/602*** (2013.01)

(58) **Field of Classification Search**
CPC ......... G06F 21/54; G06F 21/57; G06F 21/602
See application file for complete search history.

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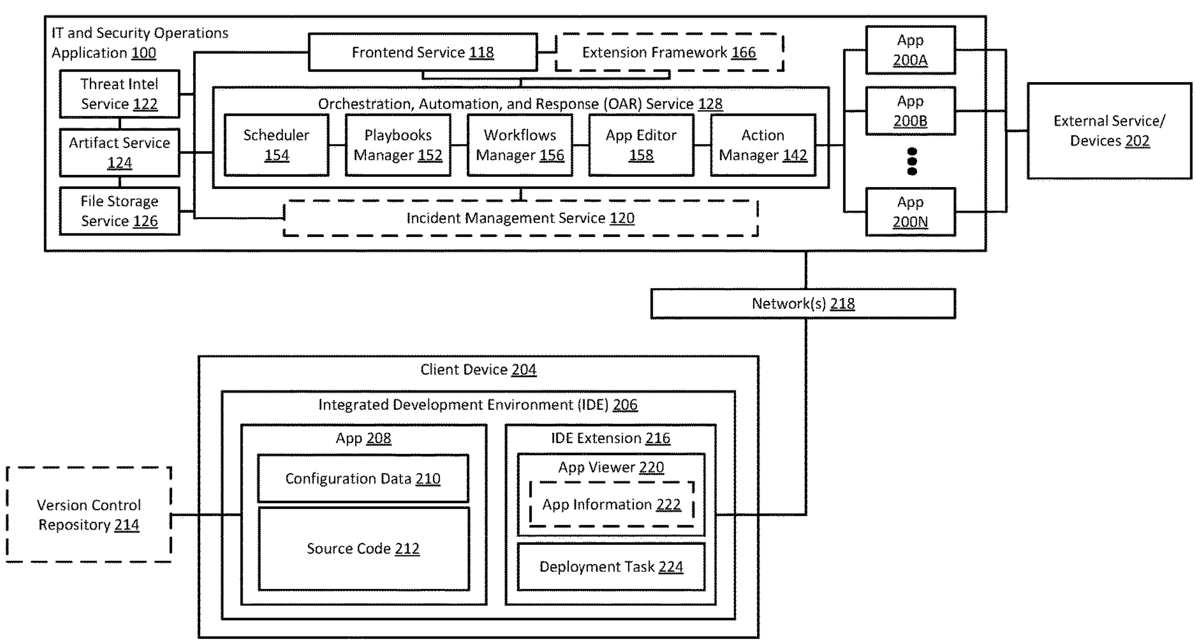
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(57) **ABSTRACT**

Techniques are described for providing an integrated development environment (IDE) extension that assists developers with many aspects developing apps for an information technology (IT) and security operations application. For example, the IDE extension includes functionality to assist with packaging and deploying apps to a remote IT and security operations application, viewing information about apps installed by a remote IT and security operations application, and testing app action implementations within their IDE. The IDE extension significantly increases developers' ability to create functional and stable IT and security operations application apps for interfacing with a wide variety of security technologies, thereby improving the security and stability of IT environments in which the apps are used.

**19 Claims, 18 Drawing Sheets**



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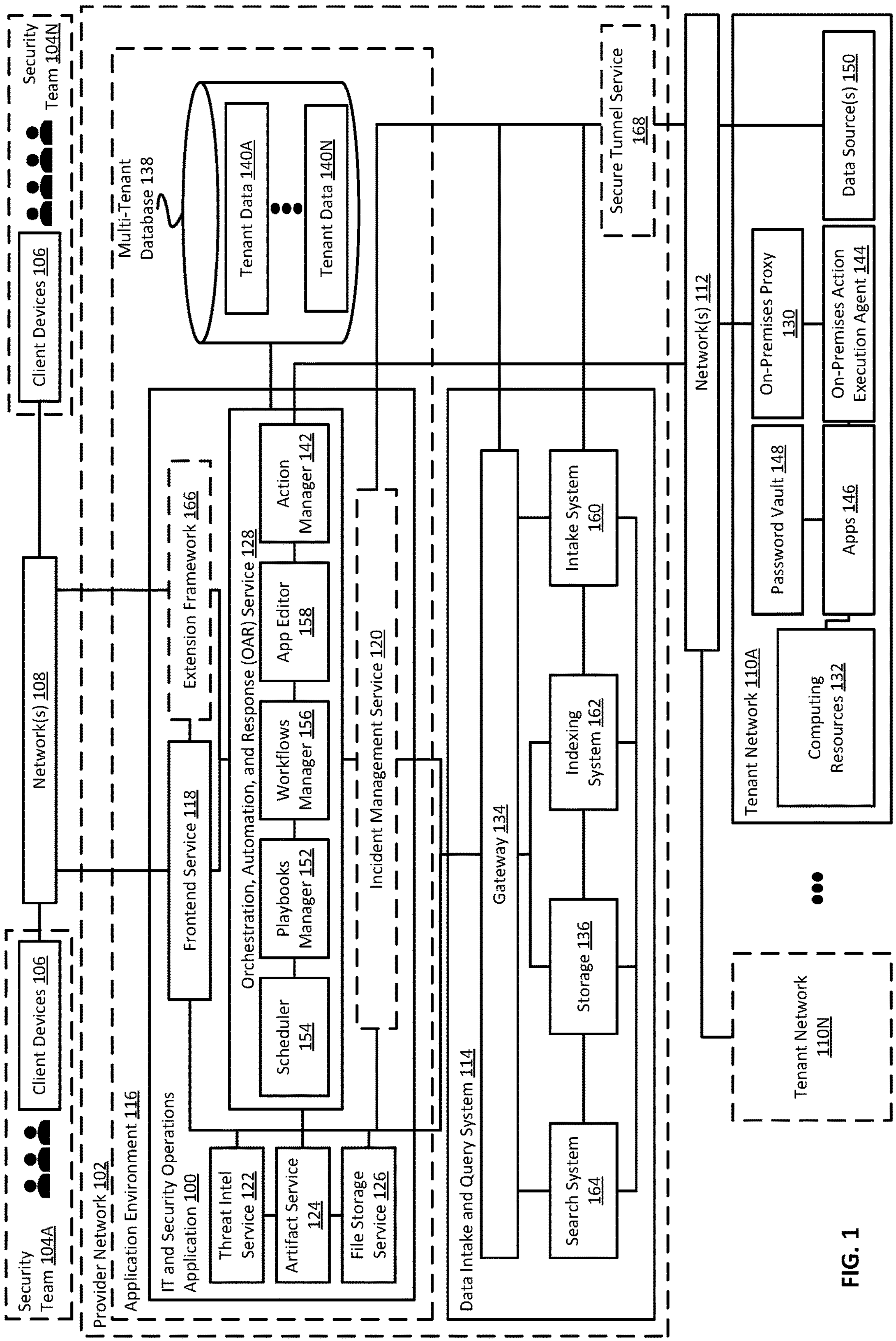

Security Team 104N
Client Devices 106
Multi-Tenant Database 138
Tenant Data 140A
Tenant Data 140N
Secure Tunnel Service 168
Network(s) 112
Data Source(s) 150
On-Premises Proxy 130
On-Premises Action Execution Agent 144
Password Vault 148
Apps 146
Computing Resources 132
Tenant Network 110A
Network(s) 108
Extension Framework 166
Orchestration, Automation, and Response (OAR) Service 128
Action Manager 142
App Editor 158
Workflows Manager 156
Playbooks Manager 152
Scheduler 154
Incident Management Service 120
Frontend Service 118
Gateway 134
Intake System 160
Indexing System 162
Storage 136
Search System 164
Tenant Network 110N
Security Team 104A
Client Devices 106
Provider Network 102
Application Environment 116
IT and Security Operations Application 100
Threat Intel Service 122
Artifact Service 124
File Storage Service 126
Data Intake and Query System 114

FIG. 1

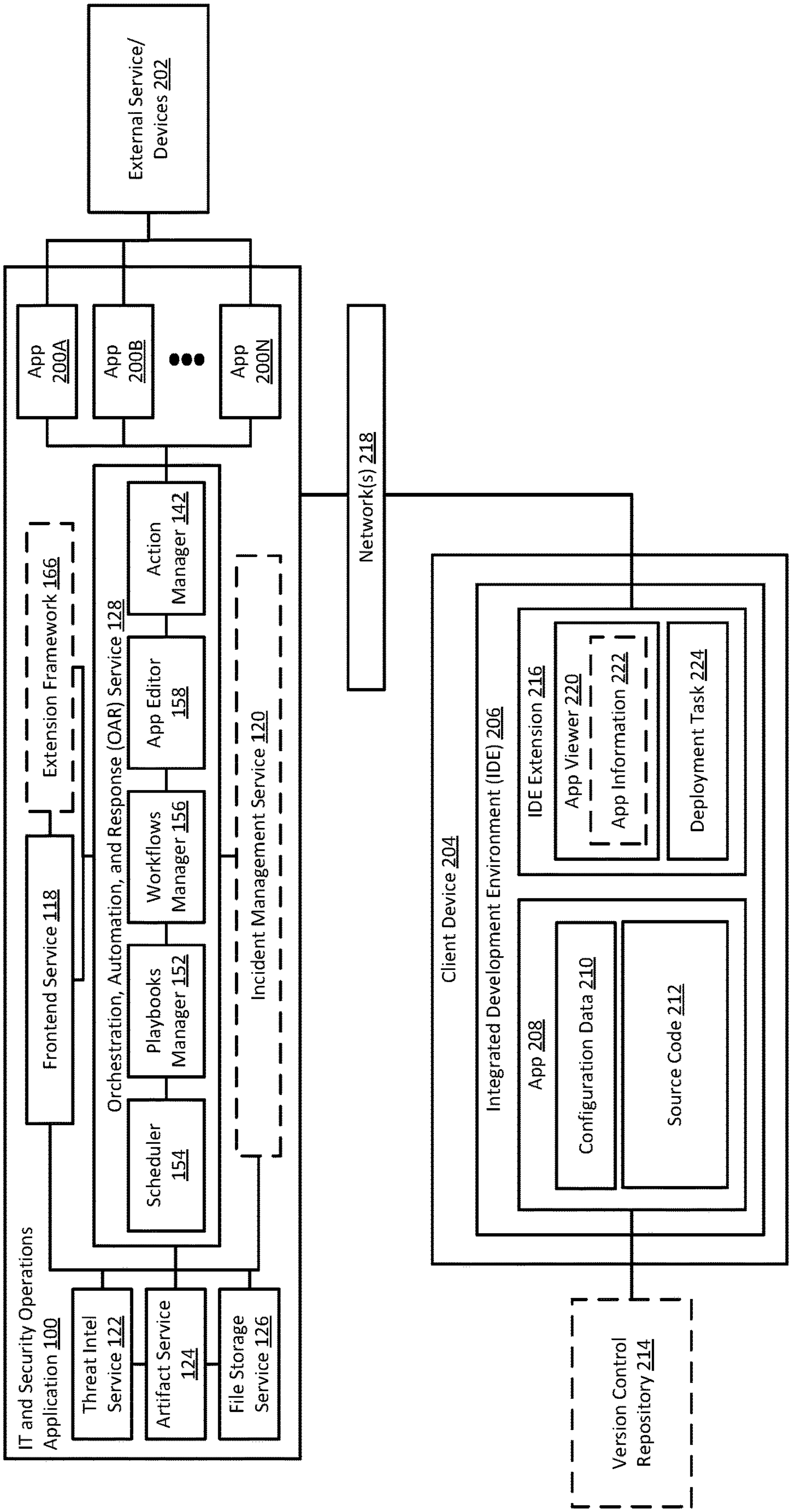

External Service/ Devices 202
App 200A
App 200B
App 200N
IT and Security Operations Application 100
Threat Intel Service 122
Artifact Service 124
File Storage Service 126
Frontend Service 118
Extension Framework 166
Orchestration, Automation, and Response (OAR) Service 128
Scheduler 154
Playbooks Manager 152
Workflows Manager 156
App Editor 158
Action Manager 142
Incident Management Service 120
Network(s) 218
Client Device 204
Integrated Development Environment (IDE) 206
App 208
Configuration Data 210
Source Code 212
IDE Extension 216
App Viewer 220
App Information 222
Deployment Task 224
Version Control Repository 214

FIG. 2

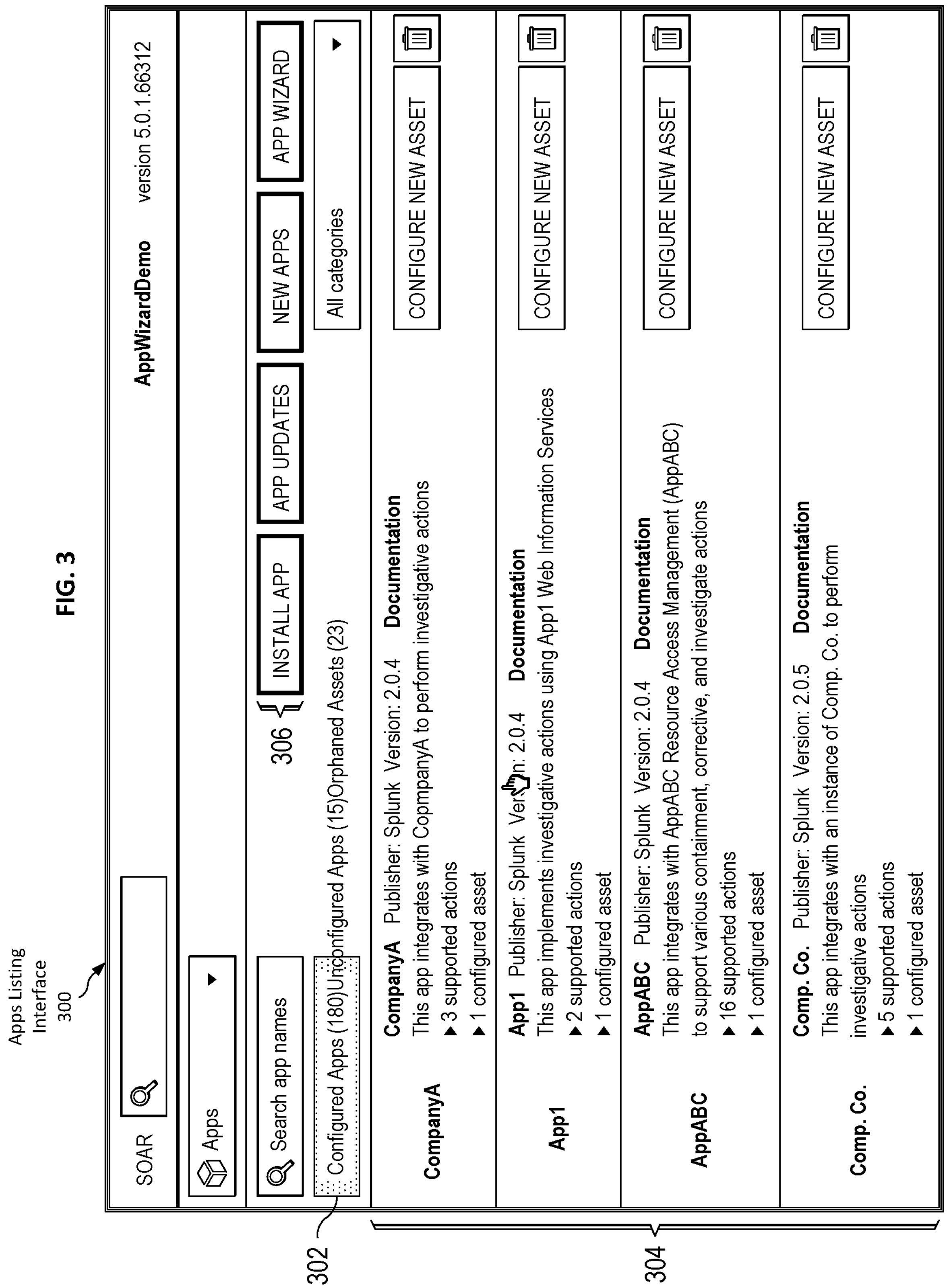

Apps Listing Interface 300
SOAR
AppWizardDemo
version 5.0.1.66312
Apps
Search app names
306
INSTALL APP
APP UPDATES
NEW APPS
APP WIZARD
All categories
Configured Apps (180)Unconfigured Apps (15)Orphaned Assets (23)
302
304
CompanyA
CompanyA Publisher: Splunk Version: 2.0.4 Documentation
This app integrates with CopmpanyA to perform investigative actions
3 supported actions
1 configured asset
CONFIGURE NEW ASSET
App1
App1 Publisher: Splunk Version: 2.0.4 Documentation
This app implements investigative actions using App1 Web Information Services
2 supported actions
1 configured asset
CONFIGURE NEW ASSET
AppABC
AppABC Publisher: Splunk Version: 2.0.4 Documentation
This app integrates with AppABC Resource Access Management (AppABC)
to support various containment, corrective, and investigate actions
16 supported actions
1 configured asset
CONFIGURE NEW ASSET
Comp. Co.
Comp. Co. Publisher: Splunk Version: 2.0.5 Documentation
This app integrates with an instance of Comp. Co. to perform
investigative actions
5 supported actions
1 configured asset
CONFIGURE NEW ASSET

FIG. 3

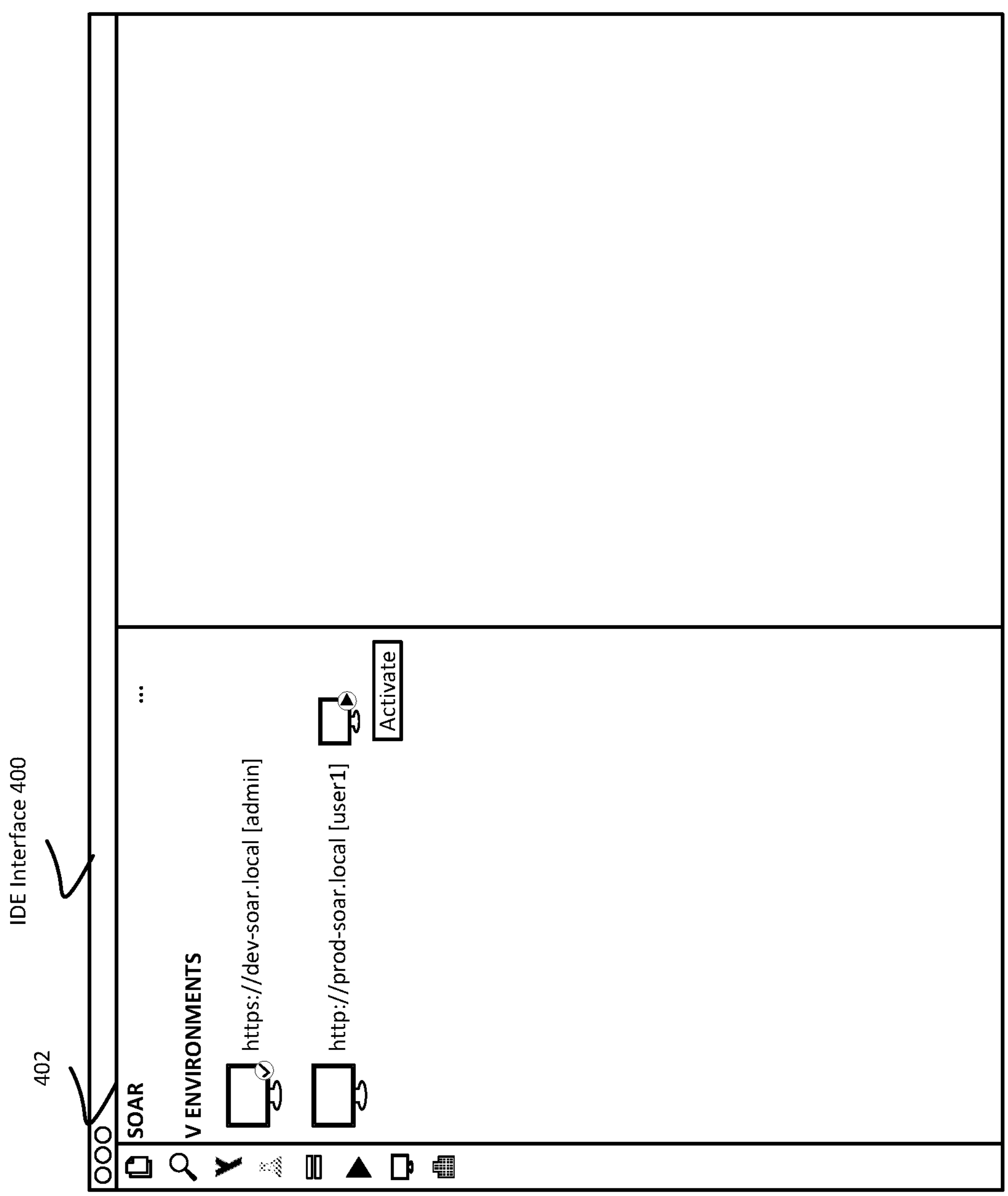

IDE Interface 400
402
SOAR
...
V ENVIRONMENTS
https://dev-soar.local [admin]
http://prod-soar.local [user1]
Activate

FIG. 4

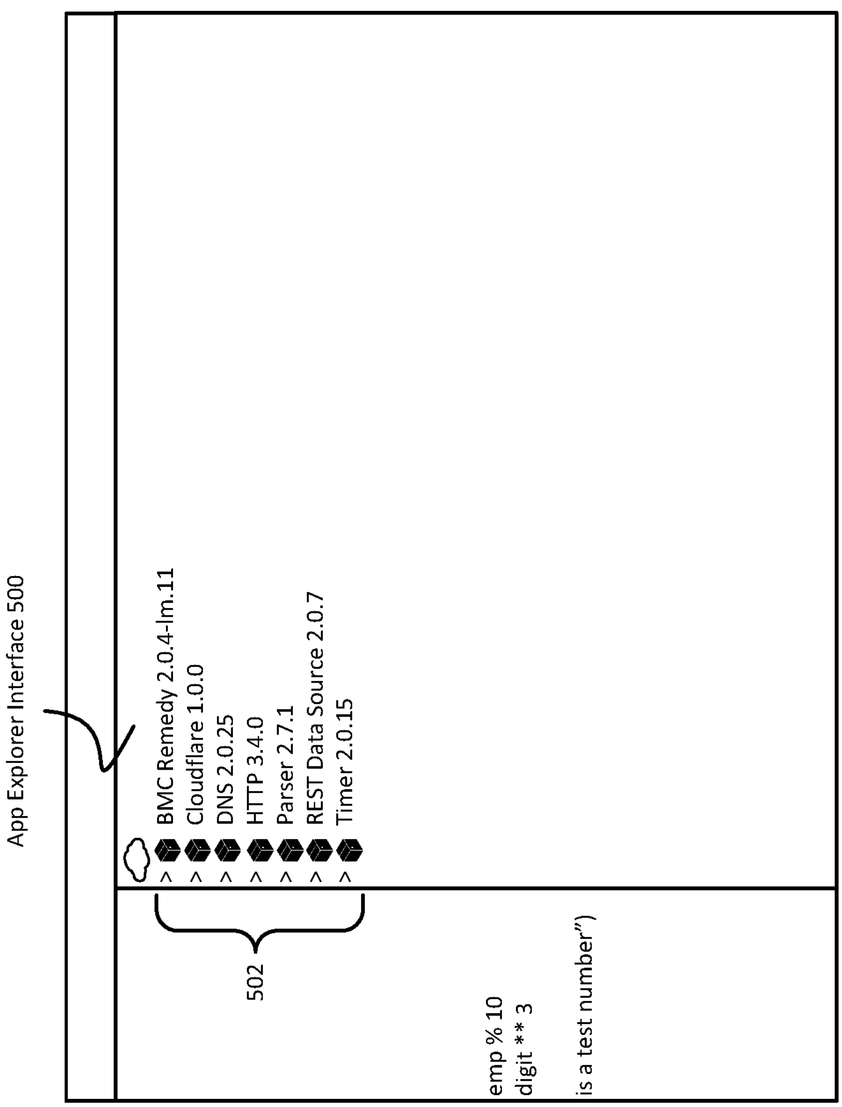
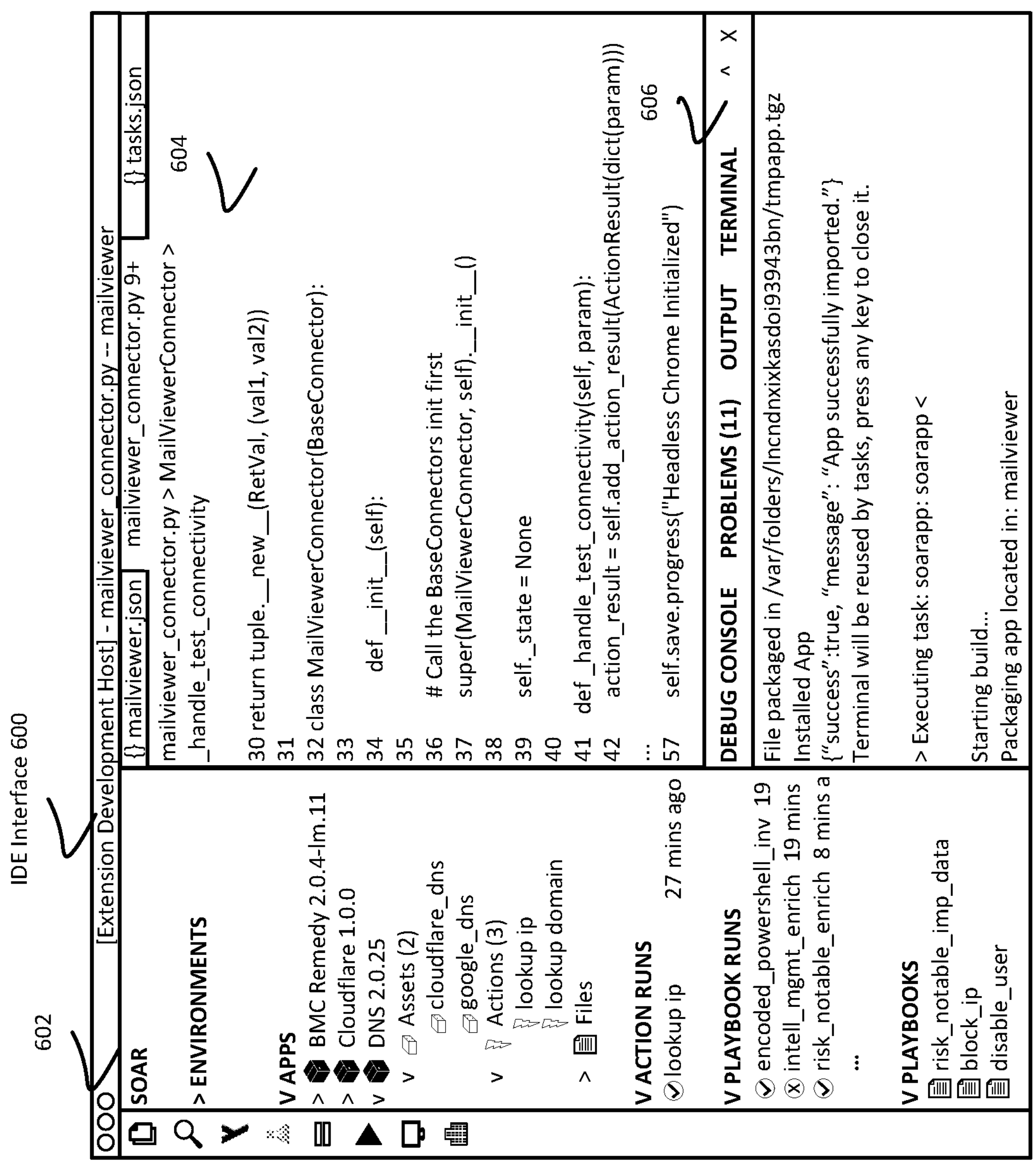

App Explorer Interface 500
BMC Remedy 2.0.4-lm.11
Cloudflare 1.0.0
DNS 2.0.25
HTTP 3.4.0
Parser 2.7.1
REST Data Source 2.0.7
Timer 2.0.15
502
emp % 10
digit ** 3
is a test number”)

FIG. 5



IDE Interface 600
602
604
606
[Extension Development Host] - mailviewer_connector.py -- mailviewer
SOAR
> ENVIRONMENTS
V APPS
> BMC Remedy 2.0.4-lm.11
> Cloudflare 1.0.0
v DNS 2.0.25
v Assets (2)
cloudflare_dns
google_dns
v Actions (3)
lookup ip
lookup domain
> Files
V ACTION RUNS
lookup ip 27 mins ago
V PLAYBOOK RUNS
encoded_powershell_inv 19
intell_mgmt_enrich 19 mins
risk_notable_enrich 8 mins a
...
V PLAYBOOKS
risk_notable_imp_data
block_ip
disable_user
{} mailviewer.json
mailviewer_connector.py 9+
{} tasks.json
mailviewer_connector.py > MailViewerConnector >
_handle_test_connectivity
30 return tuple.__new__(RetVal, (val1, val2))
31
32 class MailViewerConnector(BaseConnector):
33
34 def __init__(self):
35
36 # Call the BaseConnectors init first
37 super(MailViewerConnector, self).__init__()
38
39 self._state = None
40
41 def _handle_test_connectivity(self, param):
42 action_result = self.add_action_result(ActionResult(dict(param)))
...
57 self.save.progress("Headless Chrome Initialized")
DEBUG CONSOLE PROBLEMS (11) OUTPUT TERMINAL
File packaged in /var/folders/lncndnxixkasdoi93943bn/tmpapp.tgz
Installed App
{"success":true, "message": "App successfully imported."}
Terminal will be reused by tasks, press any key to close it.
> Executing task: soarapp: soarapp <
Starting build...
Packaging app located in: mailviewer


FIG. 6

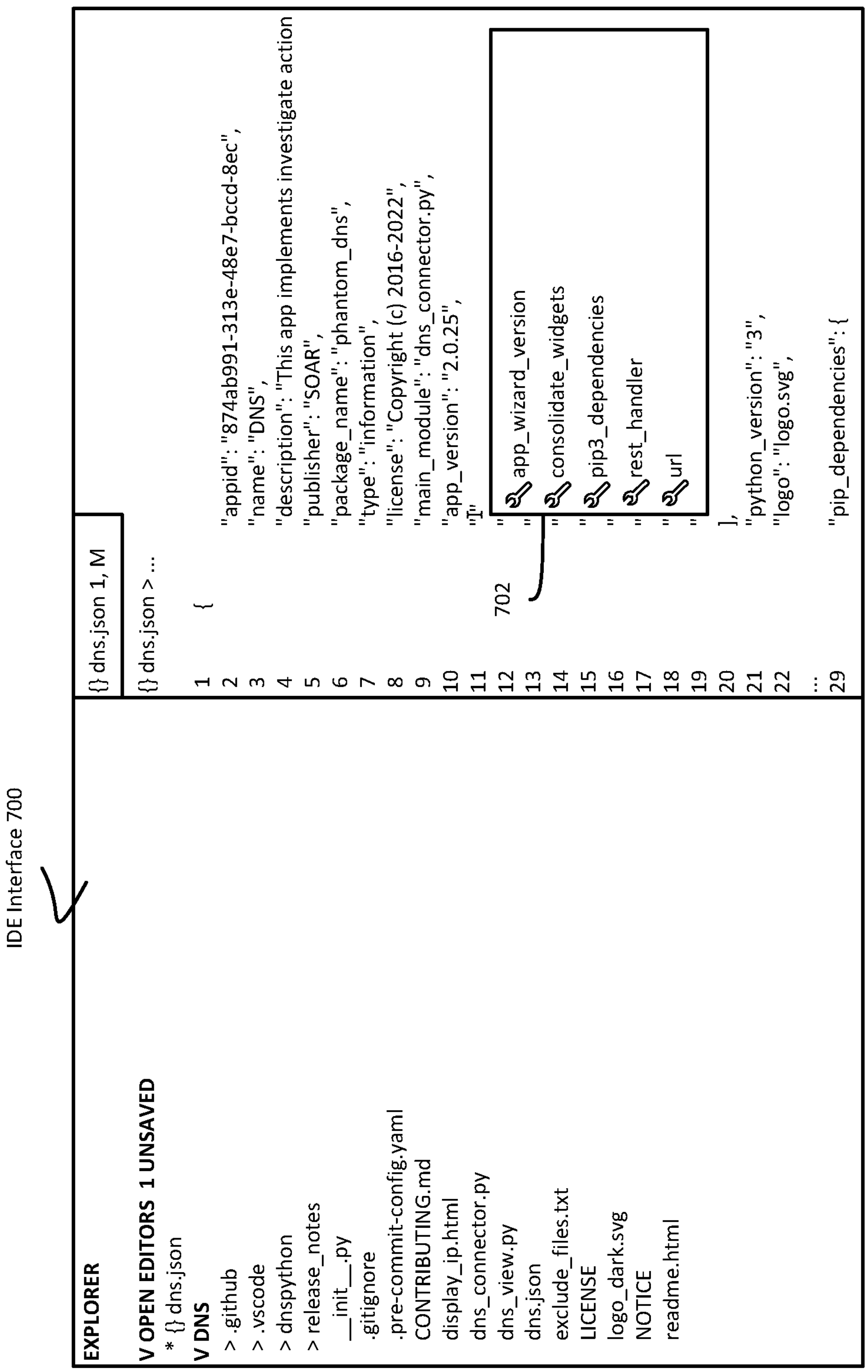

IDE Interface 700
EXPLORER
V OPEN EDITORS 1 UNSAVED
* {} dns.json
V DNS
> .github
> .vscode
> dnspython
> release_notes
__init__.py
.gitignore
.pre-commit-config.yaml
CONTRIBUTING.md
display_ip.html
dns_connector.py
dns_view.py
dns.json
exclude_files.txt
LICENSE
logo_dark.svg
NOTICE
readme.html
{} dns.json 1, M
{} dns.json > ...
1 {
2 "appid": "874ab991-313e-48e7-bccd-8ec",
3 "name": "DNS",
4 "description": "This app implements investigate action
5 "publisher": "SOAR",
6 "package_name": "phantom_dns",
7 "type": "information",
8 "license": "Copyright (c) 2016-2022",
9 "main_module": "dns_connector.py",
10 "app_version": "2.0.25",
11 "I"
12 " app_wizard_version
13 " consolidate_widgets
14 " pip3_dependencies
15 " rest_handler
16 " url
17 "
18 "
19 "
20 ],
21 "python_version": "3",
22 "logo": "logo.svg",
...
29 "pip_dependencies": {
702

FIG. 7

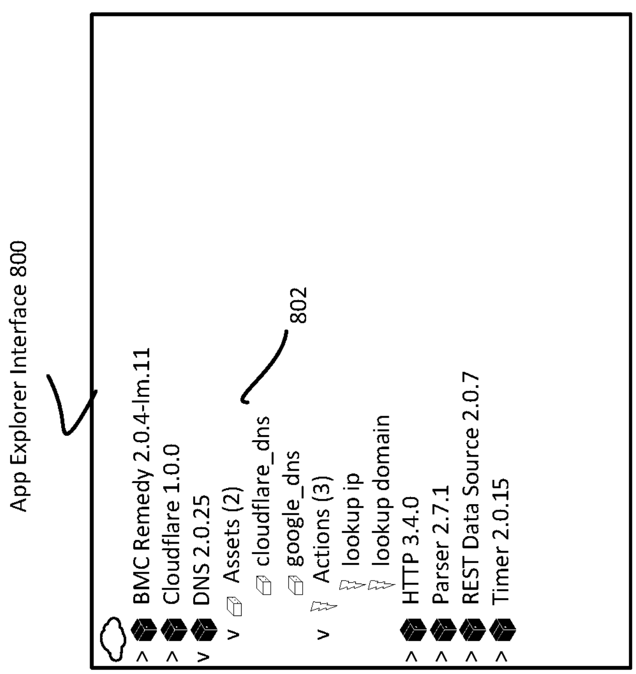

App Explorer Interface 800
802
BMC Remedy 2.0.4-lm.11
Cloudflare 1.0.0
DNS 2.0.25
Assets (2)
cloudflare_dns
google_dns
Actions (3)
lookup ip
lookup domain
HTTP 3.4.0
Parser 2.7.1
REST Data Source 2.0.7
Timer 2.0.15

FIG. 8

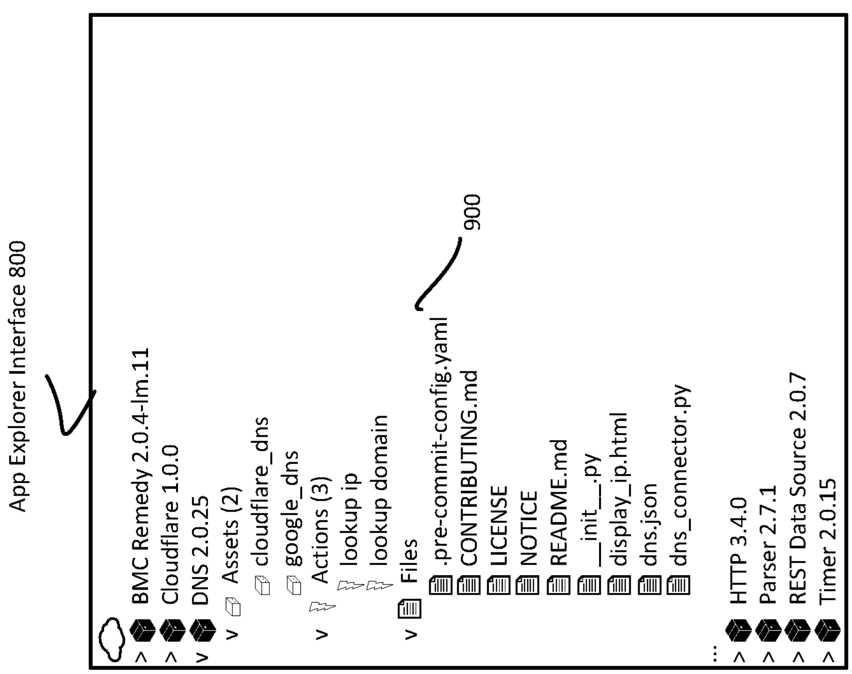

App Explorer Interface 800
900
BMC Remedy 2.0.4-lm.11
Cloudflare 1.0.0
DNS 2.0.25
Assets (2)
cloudflare_dns
google_dns
Actions (3)
lookup ip
lookup domain
Files
.pre-commit-config.yaml
CONTRIBUTING.md
LICENSE
NOTICE
README.md
__init__.py
display_ip.html
dns.json
dns_connector.py
HTTP 3.4.0
Parser 2.7.1
REST Data Source 2.0.7
Timer 2.0.15

FIG. 9

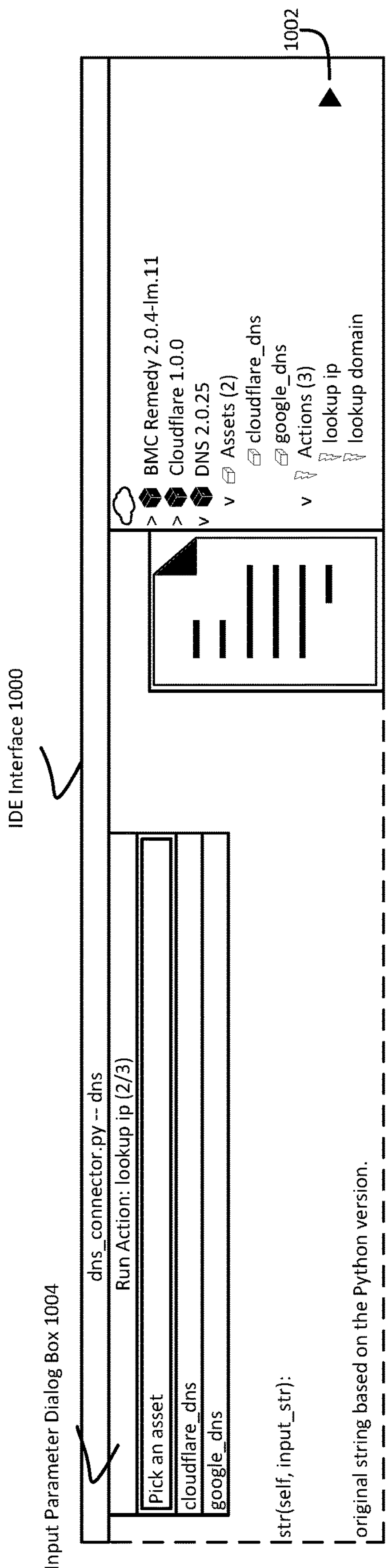

IDE Interface 1000
1002
Input Parameter Dialog Box 1004
dns_connector.py -- dns
Run Action: lookup ip (2/3)
Pick an asset
cloudflare_dns
google_dns
str(self, input_str):
original string based on the Python version.
BMC Remedy 2.0.4-lm.11
Cloudflare 1.0.0
DNS 2.0.25
Assets (2)
cloudflare_dns
google_dns
Actions (3)
lookup ip
lookup domain

FIG. 10

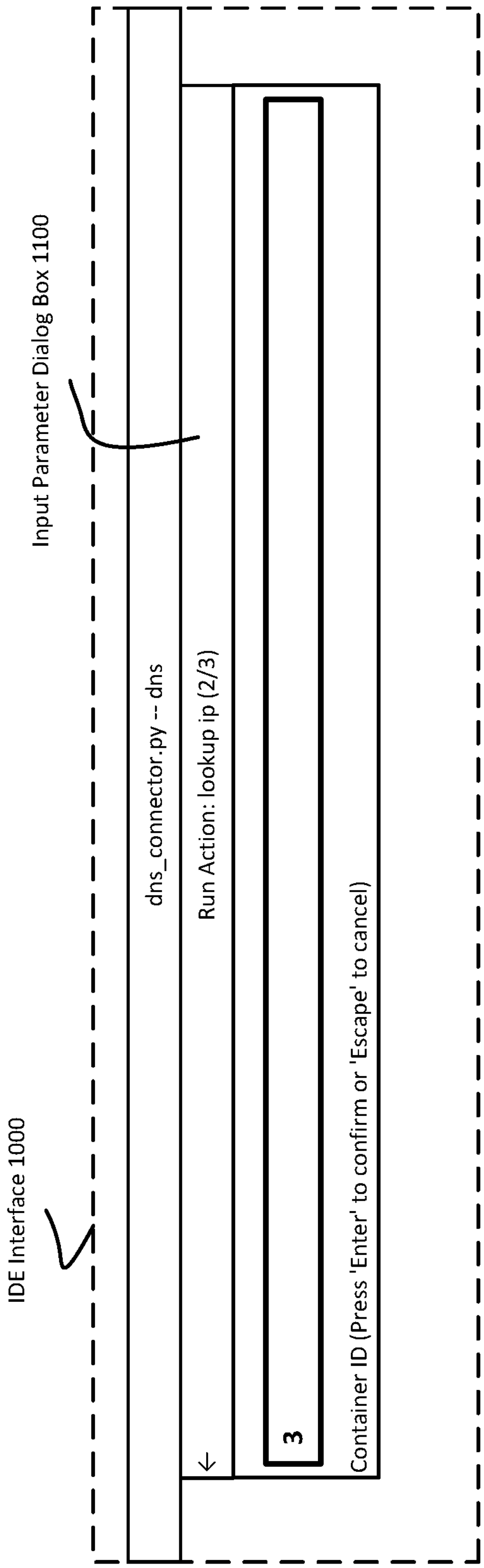

Input Parameter Dialog Box 1100
IDE Interface 1000
dns_connector.py -- dns
Run Action: lookup ip (2/3)
3
Container ID (Press 'Enter' to confirm or 'Escape' to cancel)

FIG. 11

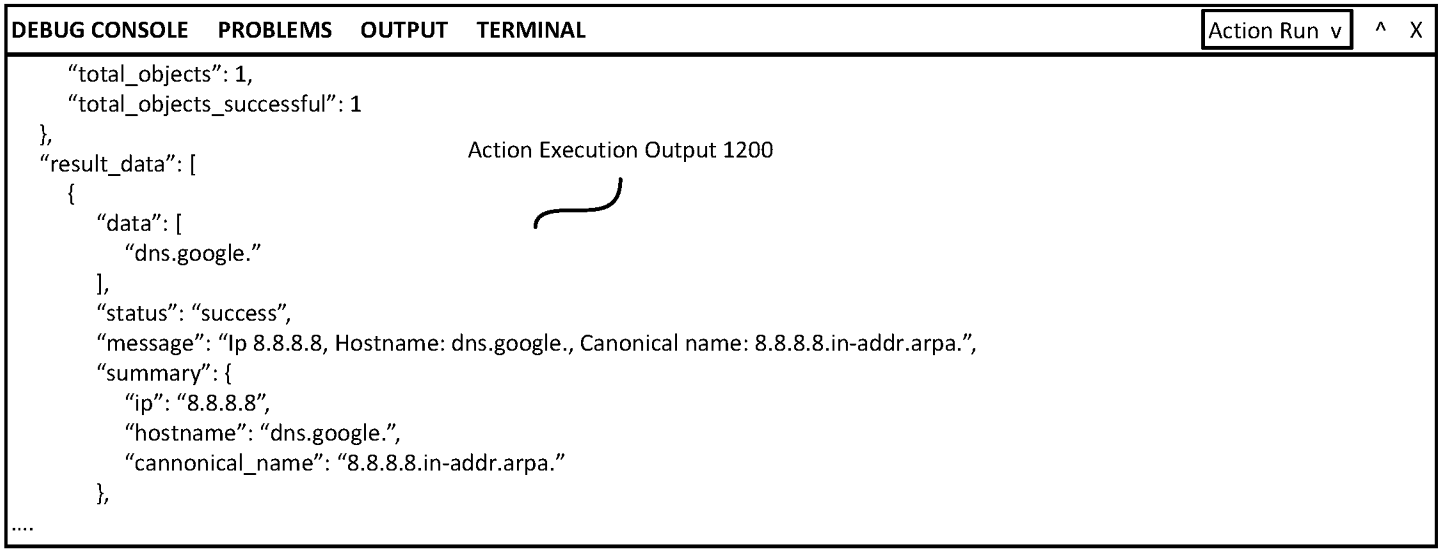

DEBUG CONSOLE PROBLEMS OUTPUT TERMINAL
Action Run v
^ X
"total_objects": 1,
"total_objects_successful": 1
},
"result_data": [
{
"data": [
"dns.google."
],
"status": "success",
"message": "Ip 8.8.8.8, Hostname: dns.google., Canonical name: 8.8.8.8.in-addr.arpa.",
"summary": {
"ip": "8.8.8.8",
"hostname": "dns.google.",
"cannonical_name": "8.8.8.8.in-addr.arpa."
},
....
Action Execution Output 1200

FIG. 12

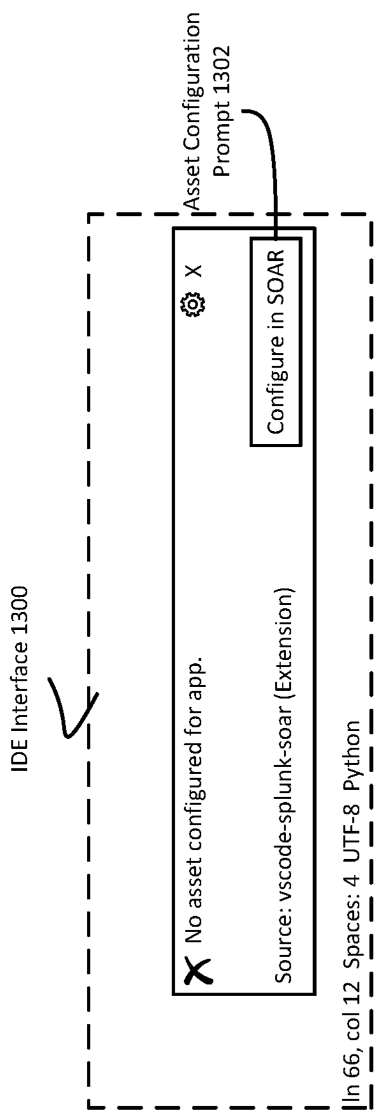

IDE Interface 1300
Asset Configuration Prompt 1302
No asset configured for app.
Source: vscode-splunk-soar (Extension)
Configure in SOAR
X
ln 66, col 12 Spaces: 4 UTF-8 Python

FIG. 13

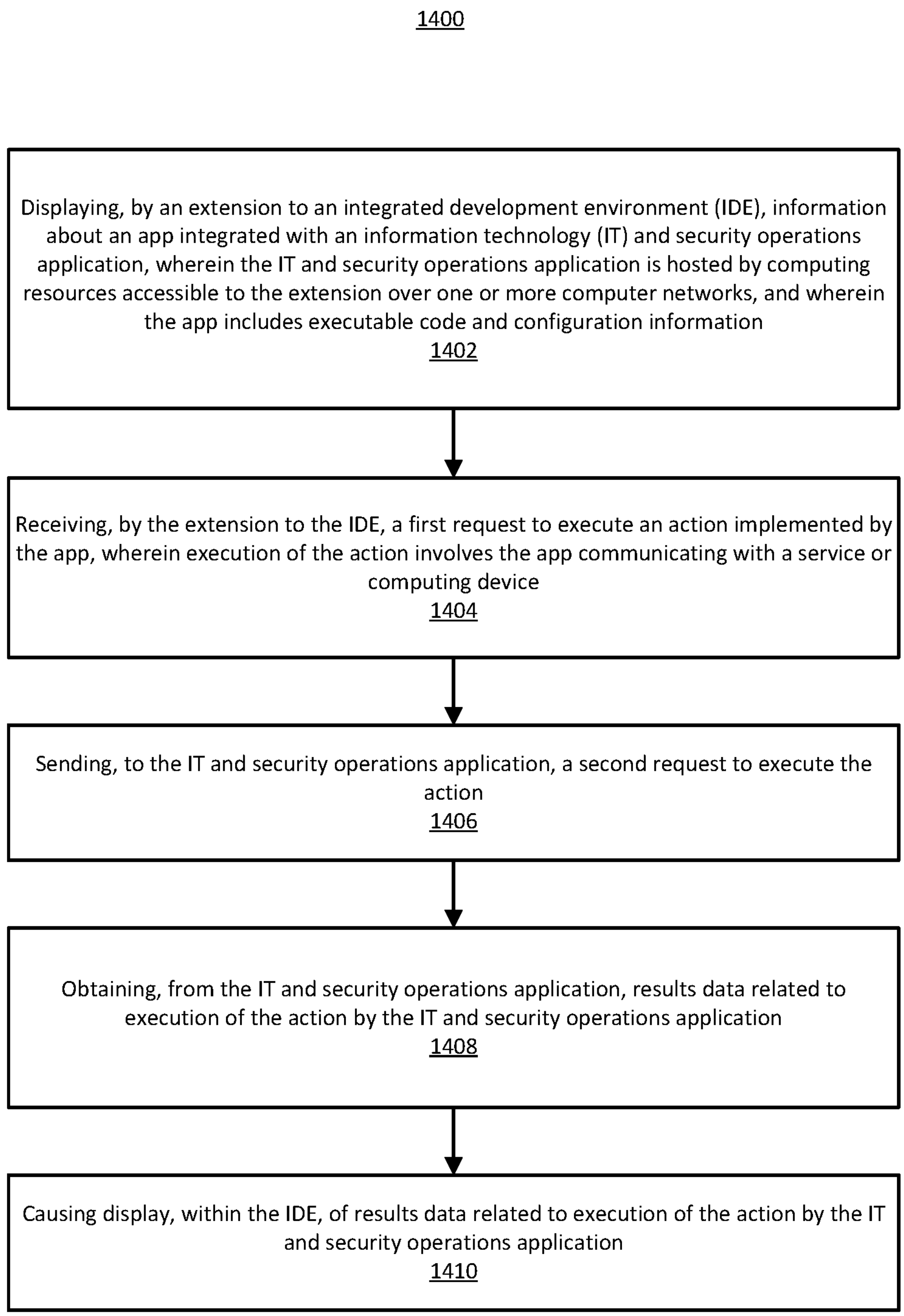

1400
Displaying, by an extension to an integrated development environment (IDE), information about an app integrated with an information technology (IT) and security operations application, wherein the IT and security operations application is hosted by computing resources accessible to the extension over one or more computer networks, and wherein the app includes executable code and configuration information
1402
Receiving, by the extension to the IDE, a first request to execute an action implemented by the app, wherein execution of the action involves the app communicating with a service or computing device
1404
Sending, to the IT and security operations application, a second request to execute the action
1406
Obtaining, from the IT and security operations application, results data related to execution of the action by the IT and security operations application
1408
Causing display, within the IDE, of results data related to execution of the action by the IT and security operations application
1410

**FIG. 14**

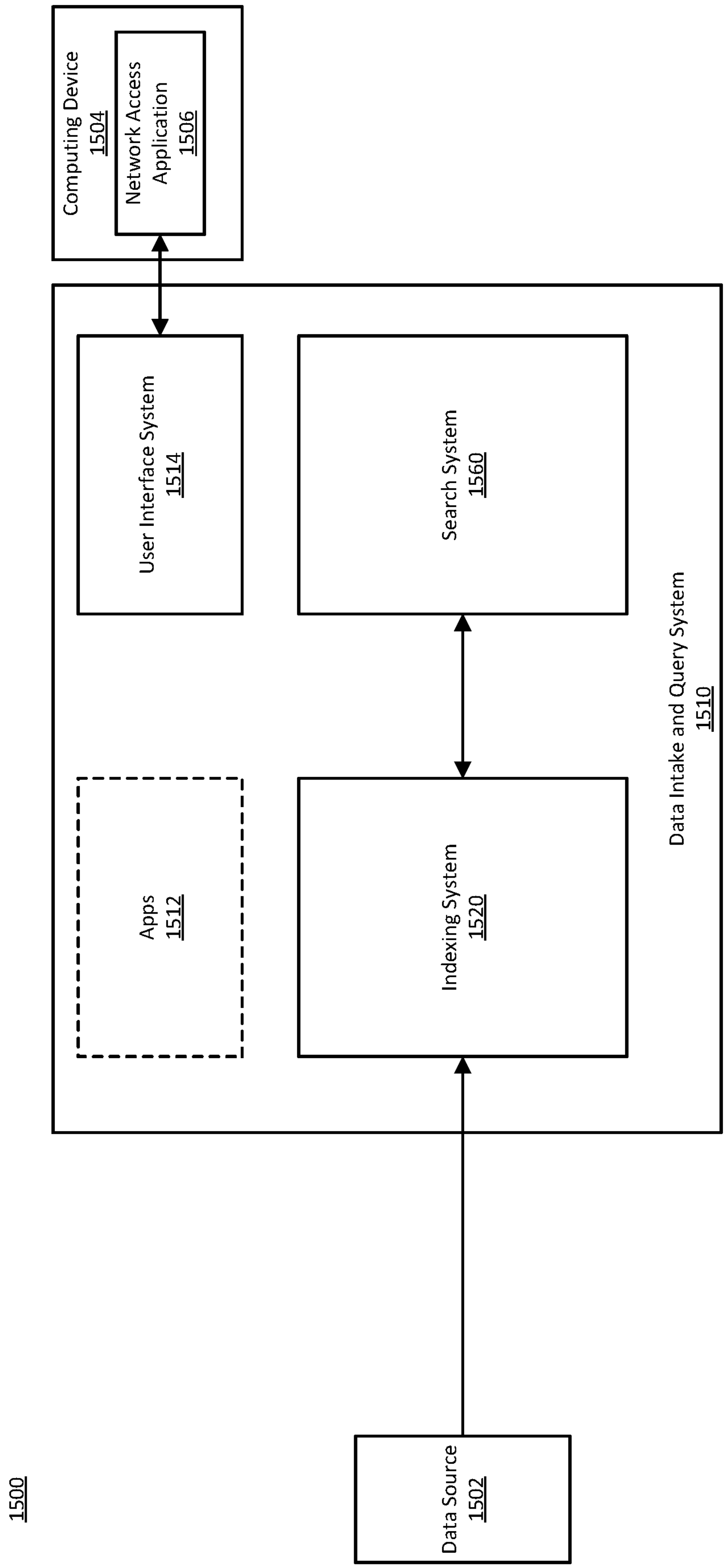

Computing Device
1504
Network Access Application
1506
User Interface System
1514
Search System
1560
Apps
1512
Indexing System
1520
Data Intake and Query System
1510
Data Source
1502
1500

FIG. 15

1620

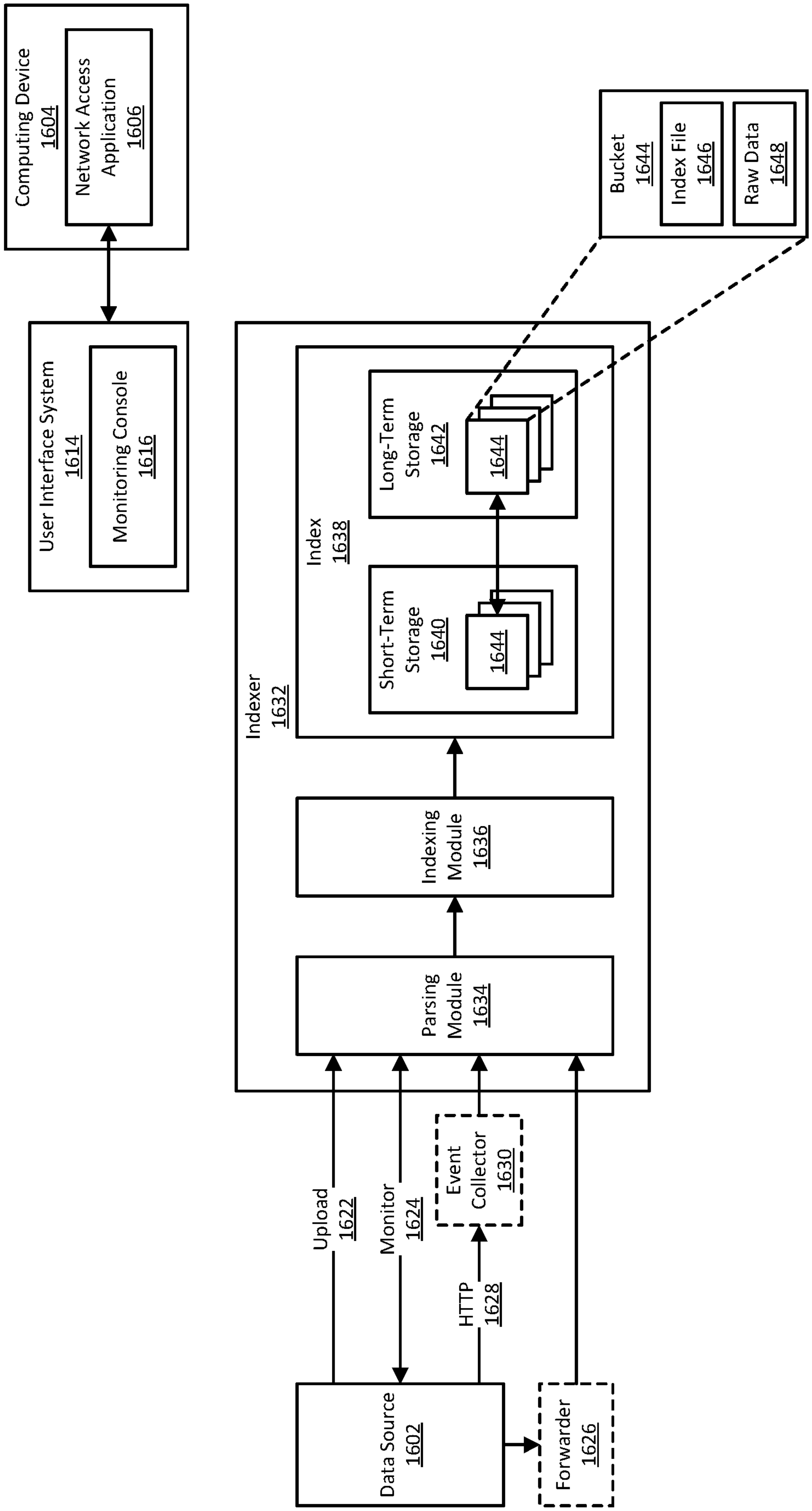

Computing Device 1604
Network Access Application 1606
User Interface System 1614
Monitoring Console 1616
Bucket 1644
Index File 1646
Raw Data 1648
Indexer 1632
Index 1638
Short-Term Storage 1640
Long-Term Storage 1642
1644
1644
Indexing Module 1636
Parsing Module 1634
Upload 1622
Monitor 1624
Event Collector 1630
HTTP 1628
Data Source 1602
Forwarder 1626

FIG. 16

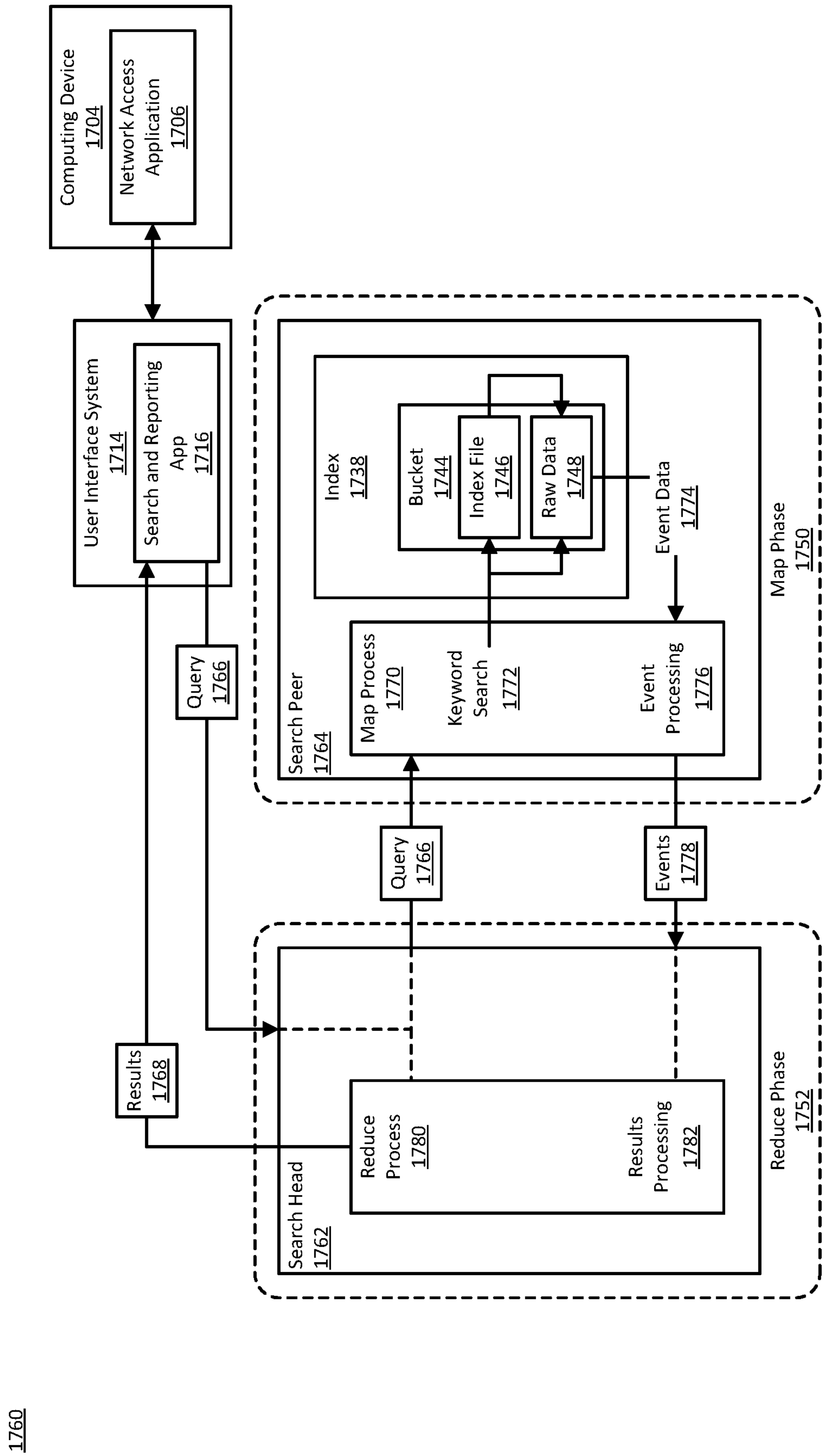

Computing Device
1704
Network Access Application
1706
User Interface System
1714
Search and Reporting App
1716
Query
1766
Results
1768
Search Peer
1764
Index
1738
Bucket
1744
Index File
1746
Raw Data
1748
Event Data
1774
Map Process
1770
Keyword Search
1772
Event Processing
1776
Map Phase
1750
Query
1766
Events
1778
Search Head
1762
Reduce Process
1780
Results Processing
1782
Reduce Phase
1752
1760

FIG. 17

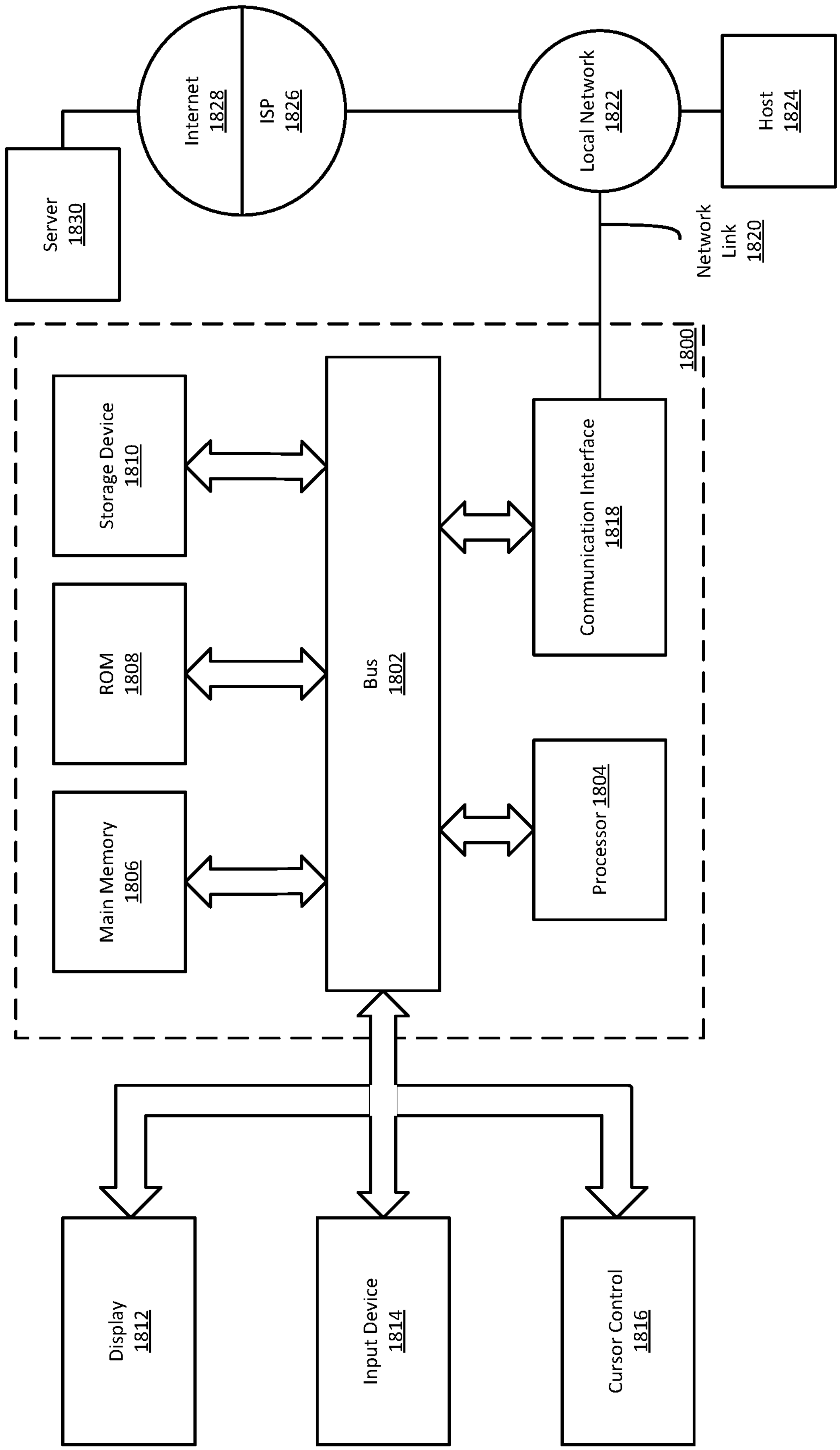

Server 1830
Internet 1828
ISP 1826
Local Network 1822
Host 1824
Network Link 1820
1800
Storage Device 1810
ROM 1808
Main Memory 1806
Bus 1802
Communication Interface 1818
Processor 1804
Display 1812
Input Device 1814
Cursor Control 1816

FIG. 18

# INTEGRATED DEVELOPMENT ENVIRONMENT EXTENSION FOR DEVELOPING INFORMATION TECHNOLOGY AND SECURITY OPERATIONS APPLICATION APPS

## RELATED APPLICATIONS

Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are incorporated by reference under 37 CFR 1.57 and made a part of this specification.

## BACKGROUND

Monitoring the operation and security of even a moderately complex computing environment typically involves a large number of tasks including, for example, investigating alerts generated by various operational and security monitoring applications, performing tasks to detect, triage, and respond to identified threats, and the like. To aid users and organizations with these and other tasks, some data intake and query systems provide users with a range of information technology (IT) and security-related applications (such as, e.g., security intelligence management services, Security Orchestration, Automation, and Response (SOAR) applications enterprise security applications, etc.). These applications broadly enable users to automatically monitor, detect, and investigate IT and security-related incidents, to automate repetitive tasks, and to strengthen defenses by connecting and coordinating complex workflows across security analyst teams and tools.

## BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative examples are described in detail below with reference to the following figures:

FIG. **1** is a block diagram of an example computing environment in which users can create apps used to integrate an IT and security operations application with third party services and devices according to some examples.

FIG. **2** is a block diagram illustrating an example computing environment in which users can obtain and use an extension for an integrated development environment (IDE) designed to assist users with the creation of apps for an IT and security operations application according to some examples.

FIG. **3** illustrates an example apps listing interface of an IT and security operations application according to some examples.

FIG. **4** illustrates an example interface enabling users to configure settings associated with an IDE extension for developing IT and security operations application apps according to some examples.

FIG. **5** illustrates an example graphical panel or window displaying information about apps installed at a remote IT and security operations application instance according to some examples.

FIG. **6** illustrates an example IDE interface in which a developer can create or modify an app for a remote IT and security operations application according to some examples.

FIG. **7** illustrates an example IDE interface in which an IDE extension provides autocompletion suggestions based on a configuration file schema according to some examples.

FIG. **8** illustrates an example IDE interface in which a developer can view asset configurations associated with an app installed by an IT and security operations application according to some examples.

FIG. **9** illustrates an example IDE interface in which a developer can view the files implementing an app installed at a remote IT and security operations application according to some examples.

FIG. **10** illustrates an example IDE interface in which a developer can invoke execution of an action implemented by an app installed at a remote IT and security operations application according to some examples.

FIG. **11** illustrates an example IDE interface generated by the IDE extension in which a developer can provide input for the execution of an action implemented by an app installed at a remote IT and security operations application according to some examples.

FIG. **12** illustrates an example IDE interface generated by the IDE extension in which the output is displayed from the execution of an action implemented by an app installed at a remote IT and security operations application according to some examples.

FIG. **13** illustrates an example IDE interface generated by the IDE extension in which a user is prompted to configure an asset to be used for executing an action implemented by an app installed at a remote IT and security operations application according to some examples.

FIG. **14** is a flow diagram illustrating operations of a method for using an extension for an IDE designed to assist users with the creation of apps for an IT and security operations application according to some examples.

FIG. **15** is a block diagram illustrating an example computing environment that includes a data intake and query system according to some examples.

FIG. **16** is a block diagram illustrating in greater detail an example of an indexing system of a data intake and query system according to some examples.

FIG. **17** is a block diagram illustrating in greater detail an example of the search system of a data intake and query system according to some examples.

FIG. **18** is a block diagram illustrating an example computer system that may be used in some embodiments.

## DETAILED DESCRIPTION

The present disclosure relates to methods, apparatus, systems, and non-transitory computer-readable storage media for software development tools including an "extension" or "plugin" to an integrated development environment (IDE) that can assist developers with the creation, deployment, and testing of "apps" for an information technology (IT) and security operations application. Some IT and security operations applications broadly provide mechanisms for adding connectivity between an IT and security operations application and third-party security technologies. For example, developers can use an app architecture of an IT and security operations applications to create new apps providing connectivity to external services used to find the geographical locations of IP addresses, enabling interactions with firewall products or other type of computing device in users' computing environments, or any of wide range of functionality. Among other features, the IDE extension described herein provides the ability for developers creating such apps to automatically deploy apps under development in the IDE to a remote IT and security operations application instance, allows developers to view information about apps installed on a remote IT and security operations application instance in the IDE, and enables developers to test actions implemented by various apps from directly within their IDE (e.g., by testing actions individually or as part of a playbook executed via the IDE).

An IT and security operations application "app" is typically developed in part by creating program code (e.g., written in Python or any other suitable programming language) used to create an interface between the IT security and operations application and other external services, applications, or computing devices. At a high level, an app is designed to receive action requests to be carried out on behalf of an IT and security operations application, to translate the action requests into specific commands used to interface with one or more types of external devices or services, to obtain any result data based on action executions, and to return results data to the IT and security operations application for further processing. To implement such functionality, an app generally includes several standard components including, e.g., source code files implementing the one or more actions provided by the app, optional code and display information used to specify how information related to the app is rendered and displayed within the IT and security operations application, and metadata describing the app and functionality that the app provides.

To create an app, developers can optionally write the program code for the app using a local code development tool (e.g., an IDE or other type of source code editor, possibly utilizing an app template provided by the IT and security operations application). Once the app is ready for deployment, a developer can import the code and associated metadata as a package into the IT and security operations application for installation. However, this process can be inefficient and error-prone for several reasons. As one example, users generally can detect errors in their source code or code dependencies only once an app is manually packaged in a user's local development environment, installed within the IT and security operations application, and the user attempts to execute the app and associated actions within the IT and security operations application. In these scenarios, debugging output might not also be readily available for users trying to understand why an app is failing to execute or otherwise not operating as intended. Furthermore, the manual packaging and installation of apps from a user's development environment lacks a consistent process for testing and publishing apps to general users only once a user confirms the expected operation of an app.

To address these challenges, among others, the described IDE extension assists developers with many aspects of the app development process including, for example, packaging and deploying apps to a remote IT and security operations application, viewing information about apps installed by a remote IT and security operations application, and testing app action implementations within their IDE. For example, the extension provides an executable task that can be invoked to automatically package and deploy apps, and further includes interfaces and functionality enabling developers to readily test actions and receive action execution output from directly within their IDE. Among other benefits, the IDE extension significantly increases developers' ability to create functional and stable IT and security operations application apps for interfacing with a wide variety of security technologies, thereby improving the security and stability of IT environments in which the apps are used.

FIG. **1** is a block diagram of an example computing environment including an IT and security operations application for which users can create apps using an IDE extension according to examples described herein. As shown in FIG. **1**, an IT and security operations application **100** comprises software components executed by one or more electronic computing devices. In some examples, the computing devices are provided by a cloud provider network **102** (e.g., as part of a shared computing resource environment). In other examples, an IT and security operations application **100** executes on computing devices managed within an on-premises datacenter or other computing environment, or on computing devices located within a combination of cloud-based and on-premises computing environments.

The IT and security operations application **100** broadly enables users to perform security orchestration, automation, and response operations involving components of an organization's computing infrastructure (or components of multiple organizations' computing infrastructures). Among other benefits, an IT and security operations application **100** enables security teams and other users to automate repetitive tasks, to efficiently respond to security incidents and other operational issues, and to coordinate complex workflows across security teams and diverse IT environments. For example, users associated with various IT operations or security teams (sometimes referred to herein as "analysts," such as analysts that may be part of example one or more of security team **104**A, . . . , security team **104**N) can use client computing devices **106** to interact with the IT and security operations application **100** via one or more network(s) **108** to perform operations relative to IT environments for which they are responsible (such as, for example, one or more of tenant network **110**A, . . . , tenant network **110**N, which may be accessible over one or more network(s) **112**, where network(s) **112** may be the same or different from network(s) **108**). Although only two security teams are depicted in the example of FIG. **1**, in general, any number of separate security teams can concurrently use the IT and security operations application **100** to manage any number of respective tenant networks, where each individual security team may be responsible for one or more tenant networks.

Users can interact with an IT and security operations application **100** and a data intake and query system **114** (described in more detail elsewhere herein) using client devices **106**. The client devices **106** can communicate with the IT and security operations application **100** and with data intake and query system **114** in a variety of ways such as, for example, over an internet protocol via a web browser or other application, via a command line interface, via a software developer kit (SDK), and the like. In some examples, the client devices **106** can use one or more executable applications or programs from an application environment **116** to interface with the data intake and query system **114**, such as the IT and security operations application **100**. The application environment **116** can include, for example, tools, software modules (e.g., computer executable instructions to perform a particular function), etc., that enable application developers to create computer executable applications to interface with an IT and security operations application **100** and/or data intake and query system **114**. The IT and security operations application **100**, for example, can use aspects of the application environment **116** to interface with the data intake and query system **114** to obtain relevant data, process the data, and display it in a manner relevant to the IT operations and security context. As shown, the IT and security operations application **100** further includes additional backend services, middleware logic, front-end user interfaces, data stores, and other computing resources, and provides other facilities for ingesting use case specific data and interacting with that data, as described elsewhere herein.

As an example of using the application environment **116**, the IT and security operations application **100** includes custom web-based interfaces (e.g., provided at least in part by a frontend service **118**) that optionally rely on one or more user interface components and frameworks provided by the application environment **116**. In some examples, an IT and security operations application **100** includes, for example, a "mission control" interface or set of interfaces. In this context, "mission control" refers to any type of interface or set of interfaces that broadly enable users to obtain information about their IT environments, to configure automated actions, playbooks, etc., and to perform operations related to IT and security infrastructure management. The IT and security operations application **100** further includes middleware business logic (including, for example, an optional incident management service **120**, a threat intelligence service **122**, an artifact service **124**, a file storage service **126**, and an orchestration, automation, and response (OAR) service **128**) implemented on a middleware platform of the developer's choice. Furthermore, in some examples, an IT and security operations application **100** can be instantiated and executed in a different isolated execution environment relative to the data intake and query system **114**. As a non-limiting example, in cases where the data intake and query system **114** is implemented at least in part in a Kubernetes cluster, the IT and security operations application **100** can execute in a different Kubernetes cluster (or other isolated execution environment system) and interact with the data intake and query system **114** via the gateway **134**.

In examples where an IT and security operations application **100** is deployed in a tenant network, the application can instead be deployed as a virtual appliance at one or more computing devices managed by an organization using the IT and security operations application **100**. A virtual appliance, for example, can include a VM image file that is pre-configured to run on a hypervisor or directly on the hardware of a computing device and that includes a pre-configured operating system upon which the IT and security operations application **100** executes. In other examples, the IT and security operations application **100** can be provided and installed using other types of standalone software installation packages or software package management systems. Depending on the implementation and user preference, an IT and security operations application **100** optionally can be configured on a standalone server or in a clustered configuration across multiple separate computing devices.

A user can initially configure an IT and security operations application **100** using a web-based console or other interface provided by the IT and security operations application **100** (for example, as provided by a frontend service **118** of the IT and security operations application **100**). For example, users can use a web browser or other application to navigate to the IP address or hostname associated with the IT and security operations application **100** to access console interfaces, dashboards, and other interfaces used to interact with various aspects of the application. The initial configuration can include creating and configuring user accounts, configuring connection settings to one or more tenant networks (for example, including settings associated with one or more on-premises proxies **130** used to establish connections between on-premises networks and the IT and security operations application **100** running in a provider network **102** or elsewhere), and performing other optional configurations.

A user (also referred to herein as a "customer," "tenant," or "analyst") of an IT and security operations application **100** can create one or more user accounts to be used by a security team or other users associated with the user. A user of the IT and security operations application **100**, for example, typically desires to use the application to manage one or more tenant networks for which the user is responsible (illustrated by example tenant networks **110**A, . . . , **110**N in FIG. **1**). A tenant network can include any number of computing resources **132** operating as part of a corporate network or other networked computing environment with which a user is associated. Although the tenant networks **110**A, . . . , **110**N are shown as separate from the provider network **102** in FIG. **1**, more generally, a tenant network can include components hosted in an on-premises network, in a provider network **102**, or combinations of both (for example, as a hybrid cloud network).

In general, any of the computing resources **132** in a tenant network can potentially serve as a source of incident data to an IT and security operations application **100**, a computing resource against which actions can be performed by the IT and security operations application **100**, or both. The computing resources **132** can include various types of computing devices, software applications, and services including, but not limited to, a data intake and query system **114** (which itself can ingest and process machine data generated by other computing resources **132**), a security information and event management (SIEM) system, a representational state transfer (REST) client that obtains or generates incident data based on the activity of other computing resources **132**, software applications (including operating systems, databases, web servers, etc.), routers, intrusion detection systems and intrusion prevention systems (IDS/IDP), client devices (for example, servers, desktop computers, laptops, tablets, etc.), firewalls, and switches. The computing resources **132** can execute upon any number separate computing devices and systems within a tenant network.

During operation, data intake and query systems, SIEM systems, REST clients, and other system components of a tenant network obtain operational, performance, and security data from computing resources **132** in the network, analyze the data, and may identify potential IT and security-related incidents from time to time. A data intake and query system in a tenant network, for example, might identify potential IT-related incidents based on the execution of correlation searches against data ingested and indexed by the system, as described elsewhere herein. Other data sources **150** can obtain incident and security-related data using other processes. Once obtained, data indicating such incidents is sent to the data intake and query system **114** or IT and security operations application **100** via an on-premises proxy **130**. For example, once a data intake and query system identifies a possible security threat or other IT-related incident based on data ingested by the data intake and query system, data representing the incident can be sent to the data intake and query system **114** via a REST API endpoint implemented by a gateway **134** or a similar gateway of the IT and security operations application **100**. As mentioned elsewhere herein, a data intake and query system **114** or IT and security operations application **100** can ingest, index, and store data received from each tenant network in association with a corresponding tenant identifier such that each tenant's data is segregated from other tenant data (for example, when stored in common storage **136** of the data intake and query system **114** or in a multi-tenant database **138** of the IT and security operations application **100**).

As mentioned, in some examples, some or all of the data ingested and created by an IT and security operations application **100** in association with a particular tenant is generally maintained separately from other tenants (for example, as illustrated by tenant data **140**A, . . . , tenant data **140**N in the multi-tenant database **138**). In some examples, a tenant may further desire to keep data associated with two or more separate tenant networks segregated from one another. For example, a security team associated with a managed security service provider (MSSP) may be responsible for managing any number of separate tenant networks for various customers of the MSSP. As another example, a tenant corresponding to a business organization having large, separate departments or divisions may desire to logically isolate the data associated with each division. In such instances, a tenant can configure separate "departments" in the IT and security operations application **100**, where each department is associated with a respective tenant network or other defined collection of data sources, computing resources, and so forth. Users and user teams can thus use this feature to manage multiple third-party entities or organizations using only a single login and permissions configuration for the IT and security operations application **100**.

Once an IT and security operations application **100** obtains incident data, either directly from a tenant network or indirectly via a data intake and query system **114**, the IT and security operations application **100** analyzes the incident data and enables users to investigate, determine possible remediation actions, and perform other operations. These actions can include default actions initiated and performed within a tenant network without direct interaction from user and can further include suggested actions provided to users associated with the relevant tenant networks. Once the suggested actions are determined, these actions can be presented in a "mission control" dashboard or other interface accessible to users of the IT and security operations application **100**. Based on the suggested actions, a user can select one or more particular actions to be performed and the IT and security operations application **100** can carry out the selected actions within the corresponding tenant network. In the example of FIG. **1**, an OAR service **128** of the IT and security operations application **100**, which includes an action manager **142**, can cause actions to be performed in a tenant network by sending action requests via network **112** to an on-premises proxy **130**, which further interfaces with an on-premises action execution agent (for example, on-premises action execution agent **144** in tenant network **110**A). In this example, the on-premises action execution agent **144** is implemented to receive action requests from an action manager **142** and to carry out requested actions against computing resources **132** using apps **146** (sometimes alternatively referred to as "connectors") and optionally a password vault **148** (e.g., to authenticate an app to one or more computing resources **132**).

To execute actions against computing resources in tenant networks and elsewhere, in some examples, an IT and security operations application **100** uses a unified security language that includes commands usable across a variety of hardware and software products, applications, and services. To execute a command specified using the unified security language, in some examples, the IT and security operations application **100** (possibly via an on-premises action execution agent **144**) uses one or more apps **146** to translate the commands into the one or more processes, languages, scripts, etc., necessary to implement the action at one or more particular computing resources **132**. For example, a user might provide input requesting the IT and security operations application **100** to remove an identified malicious process from multiple computing systems in the tenant network **110**A, where two or more of the computing systems are associated with different software configurations (for example, different operating systems or operating system versions). Accordingly, in some examples, the IT and security operations application **100** can send an action request to an on-premises action execution agent **144**, which then uses one or more apps **146** to translate the command into the necessary processes to remove each instance of the malicious process on the varying computing systems within the tenant network (including the possible use of credentials and other information stored in the password vault **148**).

In some examples, an IT and security operations application **100** includes a playbooks manager **152** that enables users to automate actions or series of actions by creating digital "playbooks" that can be executed by the IT and security operations application **100**. At a high level, a playbook represents a customizable computer program that can be executed by an IT and security operations application **100** to automate a wide variety of possible operations related to an IT environment. These operations—such as quarantining devices, modifying firewall settings, restarting servers, and so forth—are typically performed by various security products by abstracting product capabilities using an integrated "app model." Additional details related to operation of the IT and security operations application **100** and use of digital playbooks are provided elsewhere herein.

As mentioned, an IT and security operations application **100** may be implemented as a collection of interworking services that each carry out various functionality as described herein. In the example shown in FIG. **1**, the IT and security operations application **100** includes an incident management service **120**, a frontend service **118**, an artifact service **124**, a threat intelligence service **122**, a file storage service **126**, and an orchestration, automation, and response (OAR) service **128**. The set of services comprising the IT and security operations application **100** in FIG. **1** are provided for illustrative purposes only; in other examples, an IT and security operations application **100** can be comprised of more or fewer services and each service may implement the functionality of one or more of the services shown.

In some examples, an incident management service **120** is responsible for obtaining incidents or events (sometimes also referred to as "notables"), either directly from various data sources **150** in tenant networks or directly based on data ingested by the data intake and query system **114** via the gateway **134**. The frontend service **118** provides user interfaces to users of the application, among other processes described herein. Using these user interfaces, users of the IT and security operations application **100** can perform various application-related operations, view displays of incident-related information, and can configure administrative settings, license management, content management settings, and so forth. In some examples, an artifact service **124** manages artifacts associated with incidents received by the application, where incident artifacts can include information such as IP addresses, usernames, file hashes, and so forth. In some examples, a threat intelligence service **122** obtains data from external or internal sources to enable other services to perform various incident data enrichment operations. As one non-limiting example, if an incident is associated with a file hash, a threat intelligence service **122** can be used to correlate the file hash with external threat feeds to determine whether the file hash has been previously identified as malicious. In some examples, a file storage service **126** enables other services to store incident-related files, such as email attachments, files, and so forth. In some examples, an OAR service **128** performs a wide range of OAR capabilities such as action execution (via an action manager **142**), playbook execution (via a playbooks manager **152**), scheduling work to be performed (via a scheduler **154**), user approvals and so forth as workflows (via a workflows manager **156**), among other functionality described herein. According to examples described herein, an OAR service **128** includes an app editor **158** that enables users to create, modify, and test apps (e.g., including apps **146** utilized within a local tenant network, apps used by an IT and security operations application **100** running in a provider network **102**, or used elsewhere) using the built-in app editor, as described in more detail herein.

The operation of an IT and security operations application **100** generally begins with the ingestion of data related to various types of incidents involving computing resources of various tenant networks (for example, computing resources **132** or other data sources **150** of a tenant network **110**A). In some examples, users configure an IT and security operations application **100** to obtain, or "ingest," data from one or more defined data sources **150**, where such data sources can be any type of computing device, application, or service that supplies information that users may want to store or act upon, and where such data sources may include one or more of the computing resources **132** or data sources which generate data based on the activity of one or more computing resources **132**. As mentioned, examples of data sources include, but are not limited to, a data intake and query system such as the SPLUNK® ENTERPRISE system, a SIEM system, a REST client, applications, routers, intrusion detection systems (IDS)/intrusion prevention systems (IDP) systems, client devices, firewalls, switches, or any other source of data identifying potential incidents in tenants' IT environments. Some of these data sources may themselves collect and process data from various other data generating components such as, for example, web servers, application servers, databases, firewalls, routers, operating systems, and software applications that execute on computer systems, mobile devices, sensors, Internet of Things (IoT) devices, etc. The data generated by the various data sources can be represented in any of a variety of data formats.

In some examples, data can be sent from tenant networks to an IT and security operations application **100** using any of several different mechanisms. As one example, data can be sent to data intake and query system **114**, processed by an intake system **160** (e.g., including indexing of resulting event data by an indexing system **162**, thereby further causing the event data to be accessible to a search system **164**), and obtained by an incident management service **120** of the IT and security operations application **100** via a gateway **134**. As another example, components can send data from a tenant network directly to the incident management service **120**, for example, via a REST endpoint.

In some examples, data ingested by an IT and security operations application **100** from configured data sources **150** can be represented in the IT and security operations application **100** by data structures referred to as "incidents, "events," "notables," or "containers". Here, an incident or event is a structured data representation of data ingested from a data source and that can be used throughout the IT and security operations application **100**. In some examples, an IT and security operations application **100** can be configured to create and recognize different types of incidents depending on the corresponding type of data ingested, such as "IT incidents" for IT operations-related incidents, "security incidents" for security-related incidents, and so forth. An incident can further include any number of associated events and "artifacts," where each event or artifact represents an item of data associated with the incident. As a non-limiting example, an incident used to represent data ingested from an anti-virus service and representing a security-related incident might include an event indicating the occurrence of the incident and associated artifacts indicating a name of the virus, a hash value of a file associated with the virus, a file path on the infected endpoint, and so forth.

An incident of an IT and security operations application **100** can be associated with a status or state that may change over time. Analysts and other users can use this status information, for example, to indicate to other analysts which incidents an analyst is actively investigating, which incidents have been closed or resolved, which incidents are awaiting input or action, and the like. Furthermore, an IT and security operations application **100** can use the transitions of incidents from one status to another to generate various metrics related to analyst efficiency and other measurements of analyst teams. For example, the IT and security operations application **100** can be configured with a number of default statuses, such as "new" or "unknown" to indicate incidents that have not yet been analyzed, "in progress" for incidents that have been assigned to an analyst and are under investigation, "pending" for incidents that are waiting input or action from an analyst, and "resolved" for incidents that have been addressed by an assigned analyst. An amount of time that elapses between these statuses for a given incident can be used to calculate various measures of analyst and analyst team efficiency, such as measurements of a mean time to resolve incidents, a mean time to respond to incidents, a mean time to detect an incident that is a "true positive," a mean dwell time reflecting an amount of time taken to identify and remove threats from an IT environment, among other possible measures. Analyst teams can also create custom statuses to indicate incident states that may be more specific to the way the particular analyst team operates, and further create custom efficiency measurements based on such custom statuses.

In some examples, an IT and security operations application **100** also generates and stores data related to its operation and activity conducted by tenant users including, for example, playbook data, workbook data, user account settings, configuration data, and historical data (such as, for example, data indicating actions taken by users relative to particular incidents or artifacts, data indicating responses from computing resources based on action executions, and so forth), in one or more multi-tenant databases **138**. In other examples, some or all the data above is stored in storage managed by the data intake and query system **114** and accessed via the gateway **134**. These multi-tenant database (s) **138** can operate on a same computer system as the IT and security operations application **100** or at one or more separate database instances. As mentioned, in some examples, the storage of such data by the data intake and query system **114** and IT and security operations application **100** for each tenant is generally segregated from data associated with other tenants based on tenant identifiers stored with the data or other access control mechanisms.

An IT and security operations application **100** can define and implement many different types of "actions," which represent high-level, vendor- and product-agnostic primitives that can be used throughout the IT and security operations application **100**. Actions generally represent simple and user-friendly verbs that are used to execute actions in playbooks or manually through other user interfaces of the IT and security operations application **100**, where such actions can be performed against one or more computing resources in an IT environment. In many cases, a same action defined by the IT and security operations application **100** can be carried out on computing resources associated with different vendors or configurations via action translation processes performed by apps of the platform, as described in more detail elsewhere herein. Examples of actions that can be defined by an IT and security operations application **100** include a "get process dump" action, a "block IP address" action, a "suspend VM" action, a "terminate process" action, and so forth.

In some examples, an IT and security operations application **100** enables connectivity with various IT computing resources in a provider network **102** and in tenant networks **110**A, . . . , **110**N, including IT computing resources from a wide variety of third-party IT and security technologies, and further enables the ability to execute actions against those computing resources via apps (such as the apps **146** in tenant network **110**A and apps implemented as part of the IT and security operations application **100**). In general, an app **146** represents program code that provides an abstraction layer (for example, via one or more libraries, APIs, or other interfaces) to one or more of hundreds of possible IT and security-related products and services and which exposes lists of actions supported by those products and services. Each app **146** can also define which types of computing resources that the app can operate on, an entity that created the app, among other information.

As one example, an IT and security operations application **100** can be configured with an app **146** that enables the application **100** to communicate with a VM product provided by a third-party vendor. In this example, the app for the VM product enables the IT and security operations application **100** to take actions relative to VM instances within a user's IT environment, including starting and stopping the VMs, taking VM snapshots, analyzing snapshots, and so forth. To enable the app **146** to communicate with a VM manager or with individual VM instances, the app **146** can be configured with login credentials, hostnames or IP addresses, and so forth, for each instance with which communication is desired (or the app may be configured to obtain such information from a password vault **148**). Other apps **146** can be created and made available for VM products from other third-party vendors, where those apps may be configured to translate some or all the same actions that are available with respect to the first type of VM product. In general, apps **146** enable interaction with virtually any type of computing resource **132** in an IT environment and can be added and updated over time to support new types of computing resources. Additional details related to the creation and modification of apps is described elsewhere herein.

In some examples, computing resources **132** can include physical or virtual components within an organization with which an IT and security operations application **100** communicates (for example, via apps as described above). Examples of computing resources **132** include, but are not limited to, servers, endpoint devices, applications, services, routers, and firewalls. A computing resource **132** can be represented in an IT and security operations application **100** by data identifying the computing resource, including information used to communicate with the device or service such as, for example, an IP address, automation service account, username, password, etc. In some examples, one or more computing resources **132** can be configured as a source of incident information that is ingested by an IT and security operations application **100**. The types of computing resources **132** that can be configured in the IT and security operations application **100** may be determined in some cases based on which apps **146** are installed for a particular user. In some examples, automated actions can be configured with respect to various computing resources **132** using playbooks, described in more detail elsewhere herein. Each computing resource **132** may be hosted in an on-premises tenant network, a cloud-based provider network, or any other network or combination thereof.

The operation of an IT and security operations application **100** can include the ability to create and execute customizable playbooks. At a high level, a playbook comprises computer program code and possibly other data that can be executed by an IT and security operations application **100** to carry out an automated set of actions (for example, as managed by a playbooks manager **152** as part of the OAR service **128**). In some examples, a playbook is comprised of one or more functions, or codeblocks or function blocks, where each function contains program code that performs defined functionality when the function is encountered during execution of the playbook of which it is a part. As an example, a first function block of a playbook might implement an action that upon execution affects one or more computing resources **132** (e.g., by configuring a network setting, restarting a server, etc.); another function block might filter data generated by the first function block in some manner; yet another function block might obtain information from an external service, and so forth. A playbook is further associated with a control flow that defines an order in which the IT and security operations application **100** executes the function blocks of the playbook, where a control flow may vary at each execution of a playbook depending on particular input conditions (e.g., where the input conditions may derive from attributes associated with an incident triggering execution of the playbook or based on other accessible values).

In some examples, the IT and security operations application **100** described herein provides a visual playbook editor (for example, as an interface provided by a frontend service **118**) that allows users to visually create and modify playbooks. Using a visual playbook editor GUI, for example, users can codify a playbook by creating and manipulating a displayed graph including nodes and edges, where each of the nodes in the graph represents one or more function blocks that each perform one or more defined operations during execution of the playbook, and where the edges represent a control flow among the playbook's function blocks. In this manner, users can craft playbooks that perform complex sequences of operations without having to write some or any of the underlying code. The visual playbook editor interfaces further enable users to supplement or modify the automatically generated code by editing the code associated with a visually designed playbook, as desired.

An IT and security operations application **100** can provide one or more playbook management interfaces that enable users to locate and organize playbooks associated with a user's account. A playbook management interface can display a list of playbooks that are associated with a user's account and further provide information about each playbook such as, for example, a name of the playbook, a description of the playbook's operation, a number of times the playbook has been executed, a last time the playbook was executed, a last time the playbook was updated, tags or labels associated with the playbook, a repository at which the playbook and the associated program code is stored, a status of the playbook, and the like.

Users can create a new digital playbook starting from a playbook management interface or using another interface provided by the IT and security operations application **100**. Using a playbook management interface, for example, a user can select a "create new playbook" interface element and the IT and security operations application **100** causes display of a visual playbook editor interface including a graphical canvas on which users can add nodes representing operations to be performed during execution of the playbook, where the operations are implemented by associated source code that can be automatically generated by the visual playbook editor, and add connections or edges among the nodes defining an order in which the represented operations are to be performed upon execution.

In some examples, the creation of a graph representing a playbook includes the creation of connections between function blocks, where the connections are represented by edges that visually connect the nodes of the graph representing the collection of function blocks. These connections among the playbook function blocks indicate a program flow for the playbook, defining an order in which the operations specified by the playbook blocks are to occur. For example, if a user creates a connection that links the output of a block A to the input of a block B, then block A executes to completion before execution of block B begins during execution of the playbook. In this manner, output variables generated by the execution of block A can be used by block B (and any other subsequently executed blocks) during playbook execution.

Once a user has codified a playbook using a visual playbook editor or other interface, the playbook can be saved (for example, in a multi-tenant database **138** and in association with one or more user accounts) and run by the IT and security operations application **100** on-demand. As illustrated in the example playbooks above, a playbook includes a "start" block that is associated with source code that begins execution of the playbook. More particularly, the IT and security operations application **100** executes the function represented by the start block for a playbook with container context comprising data about the incident against which the playbook is executed, where the container context may be derived from input data from one or more configured data sources. A playbook can be executed manually in response to a user providing input requesting execution of the playbook, or playbooks can be executed automatically in response to the IT and security operations application **100** obtaining input events matching certain criteria. In examples where the source code associated with a playbook is based on an interpreted programming language (for example, such as the Python programming language), the IT and security operations application **100** can execute the source code represented by the playbook using an interpreter and without compiling the source code into compiled code. In other examples, the source code associated with a playbook can first be compiled into byte code or machine code the execution of which can be invoked by the IT and security operations application **100**.

In some examples, an optional IT and security operations application extension framework **166** allows users to extend the user interfaces, data content, and functionality of an IT and security operations application **100** in various ways to enhance and enrich users' workflow and investigative experiences. Example types of extensions enabled by the extension framework **166** include modifying or supplementing GUI elements (including, e.g., tabs, menu items, tables, dashboards, visualizations, etc.) and other components (including, e.g., response templates, connectors, playbooks, etc.), where users can implement these extensions at predefined extension points of the IT and security operations application **100**. In some examples, the extension framework **166** further includes a data integration system that provides users with mechanisms to integrate data from external applications, services, or other data sources into their plugins (e.g., to visualize data from any external data source in the IT and security operations application **100** or to otherwise enhance users' investigative experience with data originating outside of the IT and security operations application or data intake and query system **114**).

The types of users that might be interested in creating plugins using an IT and security operations application extension framework **166** include, for example, development teams associated with a data intake and query system **114**, developers of third-party applications or services relevant to the IT and security operations application **100** (e.g., developers of VM management software, cloud computing resource management software, etc.), and other general users of the IT and security operations application **100**. Users of the IT and security operations application **100** might, for example, desire to enhance their own workflows and other processes by enabling internal user information lookups, creating internal ticketing system postings, or enabling any other desired visualizations or actions at various points in the IT and security operations application. In some examples, the extension framework **166** enables users to create plugins using "No-Code" development tools, e.g., where users can define the specifications for custom visualizations, data integrations, and other plugin components without direct user coding (e.g., without the direct creation of JavaScript code, JSON specifications, or other data comprising a plugin), although users can also modify the underlying plugin components as desired.

As one example use case for a plugin, consider a cybersecurity company that provides security software that is known to be used by users of the IT and security operations application **100**. In this example, developers of the security software might desire for certain information collected or generated by the security software to be visible at various points within the IT and security operations application **100**, e.g., to create a tighter integration of the two software applications. The developers, for example, might desire for users of the IT and security operations application **100** to be able to view endpoint information, malware information, etc., collected by the security application when users view various visualizations or other incident information in the IT and security operations application **100** that is associated with the data collected by the security software.

In the example above, developers associated with the cybersecurity company can use the extension framework **166** to create a plugin that integrates the data collected by the security application with the IT and security operations application **100**. Users who subscribe to the plugin can then view relevant data or perform other actions when the users navigate to defined extension points of the IT and security operations application **100**. Numerous other such use cases exist for a wide variety of applications, data sources, and desired functionality related to an IT and security operations application **100**. Among other benefits, the ability to create and use plugins to an IT and security operations application **100** enables security teams to efficiently investigate and remediate a wide variety of incidents that occur from time to time in IT environments, thereby improving the overall security and operation of the IT environments.

In some examples, components external to the IT and security operations application **100** interface with an intermediary secure tunnel service **168** to send communications to, and to receive communications from, an IT and security operations application **100** running in a provider network **102**. In some examples, the secure tunnel service **168** operates as a service that establishes WebSocket or other types of secure connections to endpoint devices. As one example, the secure tunnel service **168** can establish a first secure connection to the IT and security operations application **100** and a second secure connection to an on-premises proxy **130** and an on-premises action execution agent **144** executing in a tenant network **110**A, where each connection is established using a handshake technique with the respective endpoints. Once established, the connection enables two-way communications between the IT and security operations application **100** (e.g., via a separate proxy implemented by the IT and security operations application **100**) and the on-premises action execution agent **144** without the need to open a port in a firewall or perform other configurations to a network associated with the tenant network **110**A. In some examples, the secure tunnel service **168** is a cloud-based service (e.g., executing using computing resources provided by a provider network **102**) configured to transfer data between an IT and security operations application **100** and computing devices located on networks external to the provider network **102**, including on-premises action execution agents, mobile devices, and the like. In other examples, the secure tunnel service **168** executes using computing resources located outside of a cloud-based environment.

In some examples, the secure tunnel service **168** performs authentication operations with other components (e.g., the IT and security operations application **100** and an on-premises proxy **130** or on-premises action execution agent **144**) to establish trust and then establishes secure communications channels with those components, where the secure tunnel service **168** and other components transmit secure communications using the secure communications channels. In some examples, the secure tunnel service **168** provides end-to-end encryption (E2EE) of communications between the IT and security operations application **100** and an on-premises action execution agent **144** via an on-premises proxy **130** by transmitting one or more encrypted data packets between the IT and security operations application **100** and the on-premises proxy **130**. In some examples, communications sent through the secure tunnel service **168** are in the form of data packets, where each data packet includes, for example, a payload and a device identifier for a destination device that is to receive the data packet. In other examples, the data packet can also include a device identifier for the source device or an instance identifier that indicates an IT and security operations application instance associated with the data packet. In some examples, the data packet is encrypted prior to being transmitted to the secure tunnel service **168**, e.g., using a public key of an asymmetric key pair generated by a receiving device. While in some examples, the secure tunnel service **168** decrypts the data packet before sending the data packet to its intended destination, in other examples, the secure tunnel service **168** forwards the encrypted data packet to its intended destination without performing a decryption process.

The IT and security operations application **100** and on-premises proxy **130** can communicate with the secure tunnel service **168** across network(s) **112**. As indicated herein, the networks **112** can be communications networks, such as a local area network (LAN), wide area network (WAN), cellular network (e.g., LTE, HSPA, 3G, 4G, and/or any other network based on cellular technologies), and/or networks using any of wired, wireless, terrestrial microwave, or satellite links. In some examples, after an on-premises action execution agent **144** is installed and executed within a tenant network **110**A, the on-premises action execution agent **144** uses an on-premises proxy **130** to initiate a process to establish a secure connection (e.g., a gRPC Remote Procedure Calls (gRPC) over HTTP/2 connection) with a secure tunnel service **168**. For example, the secure tunnel service **168** may establish the secure connection and associate the secure connection with a device identifier for the on-premises proxy **130**.

In some examples, the secure tunnel service **168** maintains a database that stores document data structures and optionally stores keys. This database, for example, can be a structure query language (SQL) database, or a NoSQL database, such as an AMAZON® DynamoDB. In some examples, the database includes a key store that stores encryption keys, including single-use session keys and long-term keys associated with devices that send E2EE communications. In other examples, the secure tunnel service **168** does not store encryption keys and routes messages without the use of a key store. In some examples, the database also includes a routing table that includes address information associated with devices registered with the secure tunnel service **168** with which the service has established secure communications. The secure tunnel service **168**, for example, can send queries to the database to determine, based on a device identifier in a particular data packet, the address of the intended recipient of the particular data packet.

As illustrated in FIG. **1**, the secure tunnel service **168** may not directly communicate with an on-premises action execution agent **144** but communicate instead through an on-premises proxy **130**. As indicated herein, the on-premises proxy **130** is a process executing in the tenant network **110**A and that operates as a gateway between the secure tunnel service **168** and the IT and security operations application **100**. The on-premises proxy **130** is configured to receive messages from the secure tunnel service **168** and forward the messages to the on-premises action execution agent **144** for processing. The on-premises proxy **130** can also be configured to generate and send messages (e.g., notifications, alerts, etc.) IT and security operations application **100** via the secure tunnel service **168**. In some examples, the on-premises proxy **130** can also send messages to configured mobile devices in accordance with a push notification service, such as the APPLE® Push Notification service (APN), or GOOGLE® Cloud Messaging (GCM). In some examples, the on-premises proxy **130** is configured to perform the management, generation, and registration of encryption keys used to communicate with the secure tunnel service **168**.

As indicated herein, an IT and security operations application **100** can provide an extensible architecture that enables users to create custom "apps" for the IT and security operations application. These apps, for example, broadly enable users to add connectivity to third party technologies, services, devices, or any other components external to an IT and security operations application **100** (including, e.g., technologies implementing various types of computing resources **132** within a tenant network or with services or devices external to a tenant network) through the implementation of custom actions. In many cases, a developer might desire to create such an app using an IDE running on a computing device local to the developer. For example, the

IDE might be one with which a developer is familiar with for the purposes of authoring, debugging, compiling, and deploying source code used to implement various types of software applications. According to examples described herein, an IDE extension is described that provides functionality enabling users to easily develop apps for an IT and security operations application within an IDE of their choice. FIG. **2** is a block diagram illustrating an example computing environment in which users can obtain an extension to an IDE designed to assist users with the creation of apps for an IT and security operations application according to some examples.

FIG. **2** again illustrates an IT and security operations application **100**, which can be hosted by computing resources located in any of a number of possible computing environments such as, e.g., a cloud-based computing environment, a user-managed datacenter or local computing environment, or any other computing environment or combination thereof. As shown, the IT and security operations application **100** currently has installed, or has accessible for installation, some number of apps including an app **200**A, app **200**B, . . . , app **200**N. As indicated, each of these apps can each be implemented to interface with a respective type of application, service, device, or other component that is external to the IT and security operations application **100** (represented as external services and devices **202** in FIG. **2**).

To view information about apps or to configure apps for a user's IT and security operations application **100** instance, in some examples, a user can access an apps listing interface provided by the IT and security operations application **100**. For example, a user can use a client device **204** to access a web-based console or other interface of the IT and security operations application **100** including an apps listing interface. FIG. **3** illustrates an example apps listing interface **300** of an IT and security operations application **100**. As shown, the apps listing interface **300** includes interface elements **302** enabling users to view previously configured apps, to view unconfigured apps, and to view other types of app-related information. The example apps listing interface **300** includes an app list **304** showing apps based on the user's selection of a type of app of interest. The example apps listing interface **300** shown in FIG. **3** further includes interface elements **306** enabling a user to provide input indicating that the user desires to install a new app, to discover updates to existing apps, or to create a new app (e.g., optionally beginning with an "app wizard" tool).

Returning to FIG. **2**, a developer using a client device **204** might often desire to create or modify these and other types of apps associated with an IT and security operations application **100** in a local development environment. For example, a user can use an IDE **206** (e.g., Microsoft® Visual Studio, Eclipse, PyCharm, etc.) running on the client device **204** (e.g., a personal desktop computer, laptop, etc.) to create and modify an app **208**, where the implementation of the app **208** can include associated configuration data **210**, source code **212**, among other possible app components. Some types of IT and security operations applications **100** provide an optional app "template" that can be used as a starting place for app development. The template can include skeleton copies of expected configuration files, source code files, etc., where a user can modify the template as desired to add custom functionality. The app **208** under development in the IDE **206** can represent a newly created app, an app created based on an app template, an existing app under further modification, or an app in any other state. In some examples, users can use version control software to manage changes to the source code **212**, configuration data **210**, and other app files over time, e.g., by storing and managing the app **208** files in a version control repository **214**. The version control repository **214** can be managed by a user of the client device **204**, provided by a separate version control service, or in some examples, provided by the IT and security operations application **100**.

FIG. **2** further illustrates the use of an IDE extension **216** for their IDE **206**, where the IDE extension **216** is configured to assist the user with various aspects of developing, deploying, and testing an app **208** to be installed by a remote IT and security operations application **100**. As indicated, the remote instance of the IT and security operations application **100** generally can be an instance of the application running anywhere outside of the IDE including, e.g., in a cloud-based computing environment, in a user-managed computing environment, or possibly even on a same computing device as the IDE in some examples. In examples where the IT and security operations application **100** is hosted on computing resources remote to the client device **204**, the IDE extension **216** can communicate with the IT and security operations application **100** over one or more network(s) **218**. Among other features, the IDE extension **216** includes an app viewer **220** that can be used to explore apps installed on a remote IT and security operations application instance (including, e.g., exploring implemented actions, configured assets, app files, and other app information **222**), a deployment task **224** that can be invoked to deploy an app under development in the IDE to a remote IT and security operations application **100** instance, and other functionality that enables users to test execution of individual actions from within their IDE **206**.

A user can obtain the IDE extension **216** for their IDE **206** from any of several possible sources. For example, some IDEs provide a built-in extension or plug-in marketplace through which extensions for an IDE can be downloaded and installed. In other examples, users can obtain the IDE extension **216** by downloading one or more installation files via a URL provided by a creator of the IDE extension. In general, the IDE extension **216** can include executable code, scripts, processes, or any other logic that can be invoked by users from within their IDE **206**. Once installed, in some examples, the IDE extension **216** provides one or more interfaces that can be used to configure settings associated with use of the IDE extension.

FIG. **4** illustrates an example interface enabling users to configure the IDE extension for developing apps for an IT and security operations application according to some examples. As shown, the IDE extension settings interface **400** includes several interface elements for configuring aspects of using the IDE extension such as, e.g., an interface element **402** used to configure and enable connections with remote IT and security operations application instances with which the extension is to interact over a computer network or other type of connection (e.g., an IT and security operations application **100**). For example, the interface **400** can include interactive dialogs that enable a user to provide authentication information to be used by an IDE extension **216** to access one or more remote IT and security operations application instances (including, e.g., a username, password, API key, or other type of authentication information). Other configurations can be used to customize the IDE extension **216** for a user's particular IDE environment and usage preferences. In some examples, the IDE extension enables users to connect to multiple IT and security operations application instances at once, but may restrict the user to selecting one "active" instance (e.g., where the active instance can serve as the instance used to populate other panels in the IDE).

Once a user has provided configuration settings for the IDE extension **216**, in some examples, a user can optionally use functionality provided by the IDE extension **216** to confirm that the extension can access an identified remote IT and security operations application **100** instance with the user-provided authentication information. As one example, an IDE extension **216** can provide a "version" command that can be invoked (e.g., using a command line interface provided by the IDE) to test whether the extension is able to successfully request version information associated with a remote IT and security operations application **100** instance. In this example, responsive to a user providing input invoking the "version" command, the IDE extension **216** sends an API request to the remote IT and security operations application **100** instance requesting information about a software version of the instance, where the request includes the authentication information provided by the user as part of the configuration settings. The remote IT and security operations application **100** validates the request using the provided authentication information and, if successfully authenticated, returns a response with the requested version information. The IDE extension **216** or IDE **206** can then display the results of the command in an output window to help the user confirm that the extension can successfully connect to the instance.

Once an IDE extension **216** is able to connect to a remote IT and security operations application **100**, in some examples, the IDE extension **216** can obtain and display information about apps currently installed by the remote IT and security operations application **100**. FIG. **5** illustrates an example graphical panel or window displaying information about apps installed at a remote IT and security operations application instance. For example, the app explorer interface **500** includes a list of apps **502** installed by an IT and security operations application **100** with which an IDE extension **216** has established a connection. To obtain the information, the IDE extension **216** can send an API request to the IT and security operations application **100** (e.g., using a "list apps" API or similar type of request supported by the application). The information about each app initially displayed in the app explorer interface **500** can include, for example, a name of the app, a version of the app, etc. As described in more detail hereinafter, users can expand the information displayed about one or more of the apps in the app explorer interface **500** to show, for example, information about actions implemented by each app, assets configured for each app, files associated with apps, and the like.

In some examples, a developer can use their IDE **206** to create or modify the source code **212**, configuration data **210**, or other implementation details related to an app **208**. As indicated, the files associated with an app **208** implementation can be obtained from a separate version control repository **214** or, in some examples, from the remote IT and security operations application **100** instance. For example, a user can optionally use the app explorer interface **500** or other component of the IDE extension **216** to select an app and request download of the associated files for viewing or for further modification in the IDE **206**.

FIG. **6** illustrates an example IDE interface in which a developer can create or modify an app for a remote IT and security operations application according to some examples. The IDE interface **600**, for example, includes project explorer panel **602**, a source code editor **604**, and a terminal window **606**. The example project explorer panel **602**, for example, enables a developer to view files associated with one or more apps or other projects under development in the IDE **206**, view information associated with one or more playbooks configured at an IT and security operations application instance, and view information about past action and playbook runs invoked via the IDE. In the example of FIG. **6**, a "MAILVIEWER" app is shown to include various files such as a "mailviewer_connector.py" Python file, a "mailviewer.json" JSON-formatted file, a "tasks.json" JSON-formatted file, and the like, each of which may contribute in part to the implementation of the app. A user can select any of files shown in the project explorer panel **602** to view the contents of the file in the source code editor **604**. The project explorer panel **602** further indicates instances of action runs (e.g., a "lookup ip" action was executed 27 minutes ago), playbook runs (e.g., an "encoded_powershell_inv" playbook was executed 19 minutes ago), and indicators of playbooks configured at a remote IT and security operations application instance.

The source code editor **604** provides text editing capabilities broadly enabling users to modify the content of files as part of a software development project. In the example of FIG. **6**, a user is currently editing the "mailviewer_connector.py" Python file as part of developing the "MAIL VIEWER" app. In some examples, the IDE extension **216** can provide autocompletion suggestions for keys in metadata files for apps based on schema information associated with the metadata files, provide autocompletion suggestions within app source code based on template definitions for the structure of app code, or any other types of configuration file or source code syntax assistance. The IDE extension **216** can also implement various types of validation checks for configuration files and source code files to identify possible issues with the contents or structure of an app implementation based on an expected app structure.

FIG. **7** illustrates an example IDE interface in which an IDE extension provides autocompletion suggestions based on a configuration file schema according to some examples. In FIG. **7**, the IDE interface **700** includes display of a file named "dns.json" in a source code editor panel. In this example, a user is adding a key-value pair to the file, where the key-value pair may be relevant to the app configuration, and the IDE extension **216** causes display of autocompletion suggestions **702** including a list of possible key names. These key names, for example, can be derived from a schema for the configuration file under modification and can help a user ensure that only valid keys are provided as input.

Returning to FIG. **6**, a terminal window **606** allows for the display of various types of information within the IDE, including output from an IDE extension **216** (e.g., to display the results of commands executed via the IDE extension **216**, information about app deployment processes performed by a deployment task **224**, information about app action executions invoked via the IDE, etc.). The project explorer panel **602** shown in FIG. **6** again includes a list of apps associated with a remote IT and security operations application **100** to which an installed IDE extension **200** has established a connection. In this example, the project explorer panel **602** further shows information about selected apps including information about configured assets, implemented actions, files, etc.

As indicated, a user can use an project explorer panel **602** to view a list of apps installed at a remote IT and security operations application **100** and to further selectively view more detailed information about selected apps. In some examples, information about the apps is obtained by the IDE extension **216** dynamically and in response to user requests for information about particular apps. For example, the IDE extension **216** can initially obtain from a remote IT and security operations application **100** a list of apps associated with the application instance and display the names of the app in an project explorer panel **602** (e.g., as expandable list items). Responsive to a user selecting one or more of the apps (e.g., by clicking on the name of the app in the list displayed in the project explorer panel **602**), the IDE extension **216** can send one or more subsequent requests to the IT and security operations application **100** to obtain more detailed information about the selected apps including, e.g., names of configured assets, actions implemented by the apps, etc. User selection of one or more of those items can then cause the IDE extension **216** to obtain additional information, e.g., including the details of an asset configuration, the contents of a file, etc., possibly for display in a source code editor **604** portion of the IDE. In other examples, an IDE extension **216** can obtain app information in batch and display the information without subsequent requests to a remote IT and security operations application **100**.

As indicated elsewhere herein, a user can author and modify an app **208** for an IT and security operations application **100** using an IDE **206**. Once a user has implemented some or all the functionality of an app **208**, the user typically desires to deploy the app **208** to an IT and security operations application **100** for testing and use. In some examples, a developer can invoke, using the IDE **206**, a deploy task **224** to deploy an app **208** under development in the IDE **206** to a configured remote IT and security operations application **100** instance. A user can invoke the deploy task **224** using a menu bar, terminal input, or any other interface element provided by the IDE **206** for invoking commands supported by an IDE extension **216**. In this example, a deploy task **224** packages the source code **212** and configuration data **210** of an app **208** into a format expected by a remote IT and security operations application **100** (e.g., a .zip file) and uses an API provided by the IT and security operations application **100** to send the packaged app for installation. For example, the deploy task **224** can include one or more scripts, processes, or other executable code that can be invoked within the IDE **206** to perform the desired functionality.

In some examples, an IT and security operations application **100** receiving a request to install an app **208** unpackages the app files and stores the files in a location at which the app code can be invoked on demand by the IT and security operations application **100**. The IT and security operations application **100** can optionally send a response or otherwise provide access to an IDE extension **216** regarding a status of the app install process. For example, the status information can indicate that a requested app install is pending, that an app install has completed successfully, that an app install has failed (e.g., because app files were missing, corrupted, or in an unexpected format, etc.), and the like. This information can be displayed in the IDE **206** by the IDE extension **216** to provide users with information about the app install process without needing to consult interfaces provided by the IT and security operations application **100**.

Once an app **208** is installed by a remote IT and security operations application **100** using the deploy task described above, the IDE extension **216** can update the display of apps in the IDE **206**. In the example shown in FIG. **8**, a user has used a deploy task **224** to install an app named "DNS" associated with a version number "2.0.24" (where the version number can be configured in the configuration data **210**). As shown by the list elements **802**, the installed "DNS" app is further associated with two assets that can be used to execute actions implemented by the app. As described elsewhere herein, an asset broadly represents a configuration, or instance, of an app and includes information used to communicate with an external service or device (e.g., including an IP address, an automation service account, username and password, etc.).

FIG. **9** illustrates an example IDE interface in which a developer can view the files implementing an app installed at a remote IT and security operations application according to some examples. Referring again to an example "DNS" app that a user has deployed to a remote IT and security operations application **100**, the app explorer interface **800** can further display, upon selection by a user, of a list of files **900** included as part of the deployed app. As indicated, these files can include source code files, configuration files, readme files, etc. Users can select one or more of the files for display and, optionally, for modification in the IDE **206**. In some examples, the plug-in enables users to compare a remotely deployed file to a locally opened file (e.g., to highlight any differences between the two files).

In addition to viewing information about apps installed at a remote IT and security operations application **100**, users can also use the IDE extension **216** to invoke actions implemented by an app for testing or other purposes. As described in more detail hereinafter, a user can request execution of an action in their IDE **206** and the IDE extension **216** can cause a remote IT and security operations application **100** to execute the requested action by sending one or more API requests to the IT and security operations application **100**. The IDE extension **216** can further cause the display of information resulting from the execution of the action directly within the IDE **206** such that a user can test action execution without leaving their IDE. FIG. **10** illustrates an example IDE interface **1000** in which a developer can invoke execution of an action implemented by an app installed at a remote IT and security operations application according to some examples. As shown, the information displayed about the "DNS" app includes a list of actions implemented by the app such as, e.g., a "lookup ip" action, a "lookup domain" action, etc. The interface **1000** further includes an interface element **1002** that a user can select to request execution of a particular action associated with the app, where the request to invoke the action causes the IDE extension **216** to optionally display one or more input parameter dialog boxes to obtain input parameters for the action execution.

In this example, a user requesting to execute the "lookup ip" action using the interface element **1002** results in the display of a dialog box **1004**, which initially prompts a user to select an asset against which the action is to be run. In some examples, the IDE extension **200** can optionally obtain metadata from a remote IT and security operations application **100** instance to help users provide input to the dialog boxes. For example, the IDE extension **200** can obtain metadata associated with the app to identify configured assets, valid parameter values, and the like. In FIG. **10**, the input parameter dialog box **1004** displays two options for assets that can be selected by a user (e.g., a "cloudflare_dns" asset or a "google_dns" asset).

Once a user provides input to the dialog box **1004** in FIG. **10**, the dialog box flow optionally proceeds to one or more additional dialog boxes depending on input parameters expected by the action. FIG. **11** illustrates an example IDE interface generated by the IDE extension in which a developer can provide additional input for the execution of an action implemented by an app installed at a remote IT and security operations application. In this example, the dialog box **1100** prompts a user to further provide a container identifier. The container identifier is a data object managed by an IT and security operations application and against which an action can be executed. In this example of the "lookup ip" action, a container can include a data artifact corresponding to an IP address which can serve as the IP the action looks up using the previously provided asset configuration. In some examples, the IDE extension **216** can dynamically verify whether an entered container identifier, or other input parameter, refers to a valid data object managed by the remote IT and security operations application **100** instance, e.g., by sending an API request to the application **100**. For example, if a user enters a container ID of "3" as in FIG. **11**, the IDE extension **216** can send a request to the IT and security operations application **100** to verify whether a container with the identifier exists. The IDE extension **216** can then either warn the user or prevent the user from proceeding if an invalid container identifier is provided. Assuming the provided container identifier is valid, in this example, the dialog box flow can optionally further proceed to one or more additional dialog boxes depending on the expected parameters of the action (e.g., a dialog box prompting a user to enter an IP address, an action execution timeout length, etc.).

In some examples, a user can request for the IDE extension **216** to save the input parameters provided for an action execution for subsequent reuse. For example, if a user uses their IDE **206** to request execution of a "lookup ip" action and provides input parameters specifying a container identifier, an IP address, etc., the user can optionally request to save the provided input parameters for subsequent reuse. Upon request, the IDE extension **216** can save the input parameters upon request and provide an option for a user to select a previously saved set of input parameters when requesting execution of an action. In this manner, a user can quickly perform multiple test executions of an action without needing to provide a series of input parameters each time execution of the action is requested.

Once a user has completed providing input to be used to invoke execution of an action, the IDE extension **216** can send a request to the IT and security operations application **100** to invoke execution of the action with the provided input parameters. The IT and security operations application **100** receives and authenticates the request and, in some examples, provides an action run identifier back to the requesting IDE extension **216**. The action run identifier can be used by the IDE extension **216** to request a status of an action execution, obtain action results data, cancel an action execution, or request other information associated with an action execution. For example, if a user provides additional input to the IDE **206** requesting to cancel execution of a previously requested action, the IDE extension **216** can send a request to the IT and security operations application **100** requesting cancellation of the action execution and including the action run identifier. As another example, to obtain results data based on execution of an action, the IDE extension **216** can periodically request the IT and security operations application **100** for the results data using the action run identifier until the data is available. In other examples, the IT and security operations application **100** can push results data to the IDE extension **216**, or a pub-sub messaging system can be used, etc.

As indicated, in some examples, the IDE extension **216** can display results information associated with execution of an action in the IDE interface. FIG. **12** illustrates an example IDE interface generated by the IDE extension in which the output is displayed from the execution of an action implemented by an app installed at a remote IT and security operations application according to some examples. As shown, the IDE extension **216** can display action execution output **1200** in a terminal window or other interface of the IDE **206**. The results data can include indications of whether the action execution was successful, how long the action it for the IT and security operations application **100** to execute the action, data obtained based on the action execution from one or more external devices or services, and the like. In this manner, an app developer can analyze and debug action executions performed by a remote IT and security operations application **100** directly from within their IDE. A developer can further iterate on the development of such actions, if desired, by further modifying source code used to implement an action, using the IDE extension **216** to re-deploy the app to an IT and security operations application **100**, and invoking execution of an updated action from the developer's IDE, where such processes can be repeated until an action performs as expected.

In addition to enabling users to invoke the execution of individual actions from their IDE **206**, in some examples, users can also invoke execution of playbooks that use one or more actions of interest. As indicated herein, a playbook managed by an IT and security operations application **100** can be used to automate a series of actions defined by a user-configurable data flow. The IDE extension **216** can cause display, e.g., in an app explorer interface or other interface of an IDE **206** of playbooks available for execution and actions associated with each of the playbooks. In some examples, users can further provide input using an IDE **206** interface to invoke execution of a playbook, the IDE extension **216** can send a request to a remote IT and security operations application **100** to execute the playbook, and the IDE extension **216** can display results data from the playbook execution in an output console.

In some cases, a user might attempt to execute an action implemented by an app **208** but for which no asset has yet been configured. Without the configuration of an asset, an IT and security operations application **100** may not be able to execute the action and interact with relevant external services or devices involved in the action. FIG. **13** illustrates an example IDE interface generated by the IDE extension in which a user is prompted to configure an asset to be used for executing an action implemented by an app installed at a remote IT and security operations application according to some examples. In FIG. **13**, for example, a user using an IDE interface **1300** attempts to run an action without a corresponding asset configuration and is prompted, within the IDE **206**, with an asset configuration prompt **1302**. In this example, the asset configuration prompt **1302** includes an interface element that directs the user to an external application (e.g., a web browser or other application) at which the user can configure an asset in connection with the IT and security operations application **100**. Once configured, the IDE extension **216** can update the information about the corresponding app (e.g., in an app explorer interface) and can enable users to request execution of the action using the configured asset as described above.

FIG. **14** is a flowchart illustrating an example process **1400** for using an extension for an IDE designed to assist users with the creation of apps for an IT and security operations application according to some examples. The example process **1400** can be implemented, for example, by a computing device that comprises a processor and a non-transitory computer-readable medium. The non-transitory computer readable medium can be storing instructions that, when executed by the processor, can cause the processor to perform the operations of the illustrated process **1400**. Alternatively or additionally, the process **1400** can be implemented using a non-transitory computer-readable medium storing instructions that, when executed by one or more processors, case the one or more processors to perform the operations of the process **1400** of FIG. **14**.

The process **1400** includes, at block **1402**, displaying, by an extension to an integrated development environment (IDE), information about an app integrated with an information technology (IT) and security operations application, wherein the IT and security operations application is hosted by computing resources accessible to the extension over one or more computer networks, and wherein the app includes executable code and configuration information.

The process **1400** further includes, at block **1404**, receiving, by the extension to the IDE, a first request to execute an action implemented by the app, wherein execution of the action involves the app communicating with a service or computing device.

The process **1400** further includes, at block **1406**, sending, to the IT and security operations application, a second request to execute the action.

The process **1400** further includes, at block **1408**, obtaining, from the IT and security operations application, results data related to execution of the action by the IT and security operations application.

The process **1400** further includes, at block **1410**, causing display, in the IDE, of the results data related to execution of the action by the IT and security operations application.

In some examples, the information about the app displayed by the extension includes at least one of: an identifier of the action implemented by the app, an identifier of a configuration associated with the service or computing device used by the app to access the service or computing device, or identifiers of one or more files stored by the IT and security operations application in association with the app.

In some examples, implementation of the app is based on two or more files accessible to the IDE, and the operations further include: receiving a request to deploy the app to the IT and security operations application; generating, by the extension to the IDE, a deployment package for the app based on the two or more files; and sending the deployment package to the IT and security operations application via the one or more computer networks.

In some examples, the operations further include causing display of an interface element associated with the IDE and used to obtain an input value associated the action, wherein the request to execute the action includes the input value.

In some examples, the request to execute the action implemented by the app is a first request to execute the action implemented by the app, and the operations further include: receiving, via an interface element of the IDE, an input value associated with the action, wherein the request to execute the action includes the input value; receiving, by the extension to the IDE, a request to save the input value for subsequent executions of the action; receiving a third request to execute the action implemented by the app, wherein the second request identifies the input value saved for subsequent executions of the action; and sending, to the IT and security operations application, a fourth request to execute the action, wherein the fourth request to execute the action includes the input value saved for subsequent executions of the action.

In some examples, the operations further include: receiving, by the IDE, input modifying the executable code or configuration information of the app to obtain an updated version of the app, wherein the updated version of the app includes an updated action implemented by the app; receiving a request to deploy the updated version of the app to the IT and security operations application; sending, to the IT and security operations application, a deployment package including the updated version of the app; receiving a third request to execute the updated action; and sending, to the IT and security operations application, a fourth request to execute the updated action.

In some examples, the operations further include causing display of source code associated with the app in a source code editor of the IDE, wherein the source code is displayed in a same interface as the information about the app integrated with the IT and security operations application.

In some examples, the operations further include receiving input selecting a file associated with the app, wherein the file is stored at a storage location accessible to the IT and security operations application; downloading, by the extension to the IDE, the file associated with the app; and causing display of contents of the file associated with the app in a source code editor of the IDE.

In some examples, the information about the app is displayed in an app explorer panel of the IDE, and the operations further include: receiving, by the extension to the IDE, input selecting the app in the app explorer panel; responsive to the input selecting the app, obtaining, from the IT and security operations application, information describing contents of the app, wherein the contents of the app includes at least one of: one or more assets configured for the app, one or more actions implemented by the app, or one or more files; and displaying the information describing contents of the app in the app explorer panel.

In some examples, the operations further include causing display of an interface element associated with the IDE and used to obtain an input value associated the action, wherein the extension to the IDE causes display of one or more suggested input values based on metadata associated with the app, and wherein the request to execute the action includes the input value.

In some examples, the executable code and configuration information enables the IT and security operations application to interface with a service or device that is external to the IT and security operations application.

In some examples, the operations further include causing display of a configuration file associated with the app in an editor interface of the IDE; receiving input to modify a portion of the configuration file, wherein the configuration file includes a plurality of key-value pairs, and wherein the configuration file is associated with a schema defining valid keys for the configuration file; and causing display of one or more suggested keys for the configuration file based on the schema.

In some examples, the operations further include receiving, via an app wizard interface, input corresponding to configurations for a new template app for the IT and security operations application; and generating, based on the input, one or more files corresponding to the new template app.

In some examples, the operations further include displaying information about one or more playbooks configured at the IT and security operations application, wherein a playbook, upon execution, automates a series of two or more actions in an IT environment.

In some examples, the operations further include receiving, via the extension to the IDE, a fourth request to execute a playbook, wherein a playbook, upon execution, automates a series of two or more actions in an IT environment; sending, to the IT and security operations application, a fifth request to execute the playbook; obtaining, from the IT and security operations application, results data related to execution of the playbook by the IT and security operations application; and causing display, in the IE, of the results data related to execution of the playbook by the IT and security operations application.

Entities of various types, such as companies, educational institutions, medical facilities, governmental departments, and private individuals, among other examples, operate computing environments for various purposes. Computing environments, which can also be referred to as information technology environments, can include inter-networked, physical hardware devices, the software executing on the hardware devices, and the users of the hardware and software. As an example, an entity such as a school can operate a Local Area Network (LAN) that includes desktop computers, laptop computers, smart phones, and tablets connected to a physical and wireless network, where users correspond to teachers and students. In this example, the physical devices may be in buildings or a campus that is controlled by the school. As another example, an entity such as a business can operate a Wide Area Network (WAN) that includes physical devices in multiple geographic locations where the offices of the business are located. In this example, the different offices can be inter-networked using a combination of public networks such as the Internet and private networks. As another example, an entity can operate a data center: a centralized location where computing resources are kept and maintained, and whose resources are accessible over a network. In this example, users associated with the entity that operates the data center can access the computing resources in the data center over public and/or private networks that may not be operated and controlled by the same entity. Alternatively or additionally, the operator of the data center may provide the computing resources to users associated with other entities, for example on a subscription basis. In both examples, users may expect resources to be available on demand and without direct active management by the user, a resource delivery model often referred to as cloud computing.

Entities that operate computing environments need information about their computing environments. For example, an entity may need to know the operating status of the various computing resources in the entity's computing environment, so that the entity can administer the environment, including performing configuration and maintenance, performing repairs or replacements, provisioning additional resources, removing unused resources, or addressing issues that may arise during operation of the computing environment, among other examples. As another example, an entity can use information about a computing environment to identify and remediate security issues that may endanger the data, users, and/or equipment in the computing environment. As another example, an entity may be operating a computing environment for some purpose (e.g., to run an online store, to operate a bank, to manage a municipal railway, etc.) and information about the computing environment can aid the entity in understanding whether the computing environment is serving its purpose well.

A data intake and query system can ingest and store data obtained from the components in a computing environment, and can enable an entity to search, analyze, and visualize the data. Through these and other capabilities, the data intake and query system can enable an entity to use the data for administration of the computing environment, to detect security issues, to understand how the computing environment is performing or being used, and/or to perform other analytics.

FIG. **15** is a block diagram illustrating an example computing environment **1500** that includes a data intake and query system **1510**. The data intake and query system **1510** obtains data from a data source **1502** in the computing environment **1500** and ingests the data using an indexing system **1520**. A search system **1560** of the data intake and query system **1510** enables users to navigate the indexed data. Though drawn with separate boxes, in some implementations the indexing system **1520** and the search system **1560** can have overlapping components. A computing device **1504**, running a network access application **1506**, can communicate with the data intake and query system **1510** through a user interface system **1514** of the data intake and query system **1510**. Using the computing device **1504**, a user can perform various operations with respect to the data intake and query system **1510**, such as administration of the data intake and query system **1510**, management and generation of "knowledge objects," initiating of searches, and generation of reports, among other operations. The data intake and query system **1510** can further optionally include apps **1512** that extend the search, analytics, and/or visualization capabilities of the data intake and query system **1510**.

The data intake and query system **1510** can be implemented using program code that can be executed using a computing device. A computing device is an electronic device that has a memory for storing program code instructions and a hardware processor for executing the instructions. The computing device can further include other physical components, such as a network interface or components for input and output. The program code for the data intake and query system **1510** can be stored on a non-transitory computer-readable medium, such as a magnetic or optical storage disk or a flash or solid-state memory, from which the program code can be loaded into the memory of the computing device for execution. "Non-transitory" means that the computer-readable medium can retain the program code while not under power, as opposed to volatile or "transitory" memory or media that requires power in order to retain data.

In various examples, the program code for the data intake and query system **1510** can execute on a single computing device, or may be distributed over multiple computing devices. For example, the program code can include instructions for executing both indexing and search components (which may be part of the indexing system **1520** and/or the search system **1560**, respectively), and can be executed on a computing device that also provides the data source **1502**. As another example, the program code can execute on one computing device, where the program code executes both indexing and search components, while another copy of the program code executes on a second computing device that provides the data source **1502**. As another example, the program code can execute only an indexing component or only a search component. In this example, a first instance of the program code that is executing the indexing component and a second instance of the program code that is executing the search component can be executing on the same computing device or on different computing devices.

The data source **1502** of the computing environment **1500** is a component of a computing device that produces machine data. The component can be a hardware component (e.g., a microprocessor or a network adapter, among other examples) or a software component (e.g., a part of the operating system or an application, among other examples). The component can be a virtual component, such as a virtual machine, a virtual machine monitor (also referred as a hypervisor), a container, or a container orchestrator, among other examples. Examples of computing devices that can provide the data source **1502** include personal computers (e.g., laptops, desktop computers, etc.), handheld devices (e.g., smart phones, tablet computers, etc.), servers (e.g., network servers, compute servers, storage servers, domain name servers, web servers, etc.), network infrastructure devices (e.g., routers, switches, firewalls, etc.), and "Internet of Things" devices (e.g., vehicles, home appliances, factory equipment, etc.), among other examples. Machine data is electronically generated data that is output by the component of the computing device and reflects activity of the component. Such activity can include, for example, operation status, actions performed, performance metrics, communications with other components, or communications with users, among other examples. The component can produce machine data in an automated fashion (e.g., through the ordinary course of being powered on and/or executing) and/or as a result of user interaction with the computing device (e.g., through the user's use of input/output devices or applications). The machine data can be structured, semi-structured, and/or unstructured. The machine data may be referred to as raw machine data when the data is unaltered from the format in which the data was output by the component of the computing device. Examples of machine data include operating system logs, web server logs, live application logs, network feeds, metrics, change monitoring, message queues, and archive files, among other examples.

As discussed in greater detail below, the indexing system **1520** obtains machine date from the data source **1502** and processes and stores the data. Processing and storing of data may be referred to as "ingestion" of the data. Processing of the data can include parsing the data to identify individual events, where an event is a discrete portion of machine data that can be associated with a timestamp. Processing of the data can further include generating an index of the events, where the index is a data storage structure in which the events are stored. The indexing system **1520** does not require prior knowledge of the structure of incoming data (e.g., the indexing system **1520** does not need to be provided with a schema describing the data). Additionally, the indexing system **1520** retains a copy of the data as it was received by the indexing system **1520** such that the original data is always available for searching (e.g., no data is discarded, though, in some examples, the indexing system **1520** can be configured to do so).

The search system **1560** searches the data stored by the indexing **1520** system. As discussed in greater detail below, the search system **1560** enables users associated with the computing environment **1500** (and possibly also other users) to navigate the data, generate reports, and visualize results in "dashboards" output using a graphical interface. Using the facilities of the search system **1560**, users can obtain insights about the data, such as retrieving events from an index, calculating metrics, searching for specific conditions within a rolling time window, identifying patterns in the data, and predicting future trends, among other examples. To achieve greater efficiency, the search system **1560** can apply map-reduce methods to parallelize searching of large volumes of data. Additionally, because the original data is available, the search system **1560** can apply a schema to the data at search time. This allows different structures to be applied to the same data, or for the structure to be modified if or when the content of the data changes. Application of a schema at search time may be referred to herein as a late-binding schema technique.

The user interface system **1514** provides mechanisms through which users associated with the computing environment **1500** (and possibly others) can interact with the data intake and query system **1510**. These interactions can include configuration, administration, and management of the indexing system **1520**, initiation and/or scheduling of queries to the search system **1560**, receipt or reporting of search results, and/or visualization of search results. The user interface system **1514** can include, for example, facilities to provide a command line interface or a web-based interface.

Users can access the user interface system **1514** using a computing device **1504** that communicates with data intake and query system **1510**, possibly over a network. A "user," in the context of the implementations and examples described herein, is a digital entity that is described by a set of information in a computing environment. The set of information can include, for example, a user identifier, a username, a password, a user account, a set of authentication credentials, a token, other data, and/or a combination of the preceding. Using the digital entity that is represented by a user, a person can interact with the computing environment **1500**. For example, a person can log in as a particular user and, using the user's digital information, can access the data intake and query system **1510**. A user can be associated with one or more people, meaning that one or more people may be able to use the same user's digital information. For example, an administrative user account may be used by multiple people who have been given access to the administrative user account. Alternatively or additionally, a user can be associated with another digital entity, such as a bot (e.g., a software program that can perform autonomous tasks). A user can also be associated with one or more entities. For example, a company can have associated with it a number of users. In this example, the company may control the users' digital information, including assignment of user identifiers, management of security credentials, control of which persons are associated with which users, and so on.

The computing device **1504** can provide a human-machine interface through which a person can have a digital presence in the computing environment **1500** in the form of a user. The computing device **1504** is an electronic device having one or more processors and a memory capable of storing instructions for execution by the one or more processors. The computing device **1504** can further include input/output (I/O) hardware and a network interface. Applications executed by the computing device **1504** can include a network access application **1506**, which can a network interface of the client computing device **1504** to communicate, over a network, with the user interface system **1514** of the data intake and query system **1510**. The user interface system **1514** can use the network access application **1506** to generate user interfaces that enable a user to interact with the data intake and query system **1510**. A web browser is one example of a network access application. A shell tool can also be used as a network access application. In some examples, the data intake and query system **1510** is an application executing on the computing device **1504**. In such examples, the network access application **1506** can access the user interface system **1514** without needed to go over a network.

The data intake and query system **1510** can optionally include apps **1512**. An app of the data intake and query system **1510** is a collection of configurations, knowledge objects (a user-defined entity that enriches the data in the data intake and query system **1510**), views, and dashboards that may provide additional functionality, different techniques for searching the data, and/or additional insights into the data. The data intake and query system **1510** can execute multiple applications simultaneously. Example applications include an information technology service intelligence application, which can monitor and analyze the performance and behavior of the computing environment **1500**, and an enterprise security application, which can include content and searches to assist security analysts in diagnosing and acting on anomalous or malicious behavior in the computing environment **1500**.

Though FIG. **15** illustrates only one data source, in practical implementations, the computing environment **1500** contains many data sources spread across numerous computing devices. The computing devices may be controlled and operated by a single entity. For example, in an "on the premises" or "on-prem" implementation, the computing devices may physically and digitally be controlled by one entity, meaning that the computing devices are in physical locations that are owned and/or operated by the entity and are within a network domain that is controlled by the entity. In an entirely on-prem implementation of the computing environment **1500**, the data intake and query system **1510** executes on an on-prem computing device and obtains machine data from on-prem data sources. An on-prem implementation can also be referred to as an "enterprise" network, though the term "on-prem" refers primarily to physical locality of a network and who controls that location while the term "enterprise" may be used to refer to the network of a single entity. As such, an enterprise network could include cloud components.

"Cloud" or "in the cloud" refers to a network model in which an entity operates network resources (e.g., processor capacity, network capacity, storage capacity, etc.), located for example in a data center, and makes those resources available to users and/or other entities over a network. A "private cloud" is a cloud implementation where the entity provides the network resources only to its own users. A "public cloud" is a cloud implementation where an entity operates network resources in order to provide them to users that are not associated with the entity and/or to other entities. In this implementation, the provider entity can, for example, allow a subscriber entity to pay for a subscription that enables users associated with subscriber entity to access a certain amount of the provider entity's cloud resources, possibly for a limited time. A subscriber entity of cloud resources can also be referred to as a tenant of the provider entity. Users associated with the subscriber entity access the cloud resources over a network, which may include the public Internet. In contrast to an on-prem implementation, a subscriber entity does not have physical control of the computing devices that are in the cloud and has digital access to resources provided by the computing devices only to the extent that such access is enabled by the provider entity.

In some implementations, the computing environment **1500** can include on-prem and cloud-based computing resources, or only cloud-based resources. For example, an entity may have on-prem computing devices and a private cloud. In this example, the entity operates the data intake and query system **1510** and can choose to execute the data intake and query system **1510** on an on-prem computing device or in the cloud. In another example, a provider entity operates the data intake and query system **1510** in a public cloud and provides the functionality of the data intake and query system **1510** as a service, for example under a Software-as-a-Service (SaaS) model. In this example, the provider entity can provision a separate tenant (or possibly multiple tenants) in the public cloud network for each subscriber entity, where each tenant executes a separate and distinct instance of the data intake and query system **1510**. In some implementations, the entity providing the data intake and query system **1510** is itself subscribing to the cloud services of a cloud service provider. As an example, a first entity provides computing resources under a public cloud service model, a second entity subscribes to the cloud services of the first provider entity and uses the cloud computing resources to operate the data intake and query system **1510**, and a third entity can subscribe to the services of the second provider entity in order to use the functionality of the data intake and query system **1510**. In this example, the data sources are associated with the third entity, users accessing the data intake and query system **1510** are associated with the third entity, and the analytics and insights provided by the data intake and query system **1510** are for purposes of the third entity's operations.

FIG. **16** is a block diagram illustrating in greater detail an example of an indexing system **1620** of a data intake and query system, such as the data intake and query system **1510** of FIG. **15**. The indexing system **1620** of FIG. **16** uses various methods to obtain machine data from a data source **1602** and stores the data in an index **1638** of an indexer **1632**. As discussed previously, a data source is a hardware, software, physical, and/or virtual component of a computing device that produces machine data in an automated fashion and/or as a result of user interaction. Examples of data sources include files and directories; network event logs; operating system logs, operational data, and performance monitoring data; metrics; first-in, first-out queues; scripted inputs; and modular inputs, among others. The indexing system **1620** enables the data intake and query system to obtain the machine data produced by the data source **1602** and to store the data for searching and retrieval.

Users can administer the operations of the indexing system **1620** using a computing device **1604** that can access the indexing system **1620** through a user interface system **1614** of the data intake and query system. For example, the computing device **1604** can be executing a network access application **1606**, such as a web browser or a terminal, through which a user can access a monitoring console **1616** provided by the user interface system **1614**. The monitoring console **1616** can enable operations such as: identifying the data source **1602** for indexing; configuring the indexer **1632** to index the data from the data source **1602**; configuring a data ingestion method; configuring, deploying, and managing clusters of indexers; and viewing the topology and performance of a deployment of the data intake and query system, among other operations. The operations performed by the indexing system **1620** may be referred to as "index time" operations, which are distinct from "search time" operations that are discussed further below.

The indexer **1632**, which may be referred to herein as a data indexing component, coordinates and performs most of the index time operations. The indexer **1632** can be implemented using program code that can be executed on a computing device. The program code for the indexer **1632** can be stored on a non-transitory computer-readable medium (e.g., a magnetic, optical, or solid state storage disk, a flash memory, or another type of non-transitory storage media), and from this medium can be loaded or copied to the memory of the computing device. One or more hardware processors of the computing device can read the program code from the memory and execute the program code in order to implement the operations of the indexer **1632**. In some implementations, the indexer **1632** executes on the computing device **1604** through which a user can access the indexing system **1620**. In some implementations, the indexer **1632** executes on a different computing device.

The indexer **1632** may be executing on the computing device that also provides the data source **1602** or may be executing on a different computing device. In implementations wherein the indexer **1632** is on the same computing device as the data source **1602**, the data produced by the data source **1602** may be referred to as "local data." In other implementations the data source **1602** is a component of a first computing device and the indexer **1632** executes on a second computing device that is different from the first computing device. In these implementations, the data produced by the data source **1602** may be referred to as "remote data." In some implementations, the first computing device is "on-prem" and in some implementations the first computing device is "in the cloud." In some implementations, the indexer **1632** executes on a computing device in the cloud and the operations of the indexer **1632** are provided as a service to entities that subscribe to the services provided by the data intake and query system.

For a given data produced by the data source **1602**, the indexing system **1620** can be configured to use one of several methods to ingest the data into the indexer **1632**. These methods include upload **1622**, monitor **1624**, using a forwarder **1626**, or using HyperText Transfer Protocol (HTTP **1628**) and an event collector **1630**. These and other methods for data ingestion may be referred to as "getting data in" (GDI) methods.

Using the upload **1622** method, a user can instruct the indexing system **1620** to specify a file for uploading into the indexer **1632**. For example, the monitoring console **1616** can include commands or an interface through which the user can specify where the file is located (e.g., on which computing device and/or in which directory of a file system) and the name of the file. Once uploading is initiated, the indexer **1632** processes the file, as discussed further below. Uploading is a manual process and occurs when instigated by a user. For automated data ingestion, the other ingestion methods are used.

The monitor **1624** method enables the indexing system **1620** to monitor the data source **1602** and continuously or periodically obtain data produced by the data source **1602** for ingestion by the indexer **1632**. For example, using the monitoring console **1616**, a user can specify a file or directory for monitoring. In this example, the indexing system **1620** can execute a monitoring process that detects whenever data is added to the file or directory and causes the data to be sent to the indexer **1632**. As another example, a user can specify a network port for monitoring. In this example, a monitoring process can capture data received at or transmitting from the network port and cause the data to be sent to the indexer **1632**. In various examples, monitoring can also be configured for data sources such as operating system event logs, performance data generated by an operating system, operating system registries, operating system directory services, and other data sources.

Monitoring is available when the data source **1602** is local to the indexer **1632** (e.g., the data source **1602** is on the computing device where the indexer **1632** is executing). Other data ingestion methods, including forwarding and the event collector **1630**, can be used for either local or remote data sources.

A forwarder **1626**, which may be referred to herein as a data forwarding component, is a software process that sends data from the data source **1602** to the indexer **1632**. The forwarder **1626** can be implemented using program code that can be executed on the computer device that provides the data source **1602**. A user launches the program code for the forwarder **1626** on the computing device that provides the data source **1602**. The user can further configure the program code, for example to specify a receiver for the data being forwarded (e.g., one or more indexers, another forwarder, and/or another recipient system), to enable or disable data forwarding, and to specify a file, directory, network events, operating system data, or other data to forward, among other operations.

The forwarder **1626** can provide various capabilities. For example, the forwarder **1626** can send the data unprocessed or can perform minimal processing on the data. Minimal processing can include, for example, adding metadata tags to the data to identify a source, source type, and/or host, among other information, dividing the data into blocks, and/or applying a timestamp to the data. In some implementations, the forwarder **1626** can break the data into individual events (event generation is discussed further below) and send the events to a receiver. Other operations that the forwarder **1626** may be configured to perform include buffering data, compressing data, and using secure protocols for sending the data, for example.

Forwarders can be configured in various topologies. For example, multiple forwarders can send data to the same indexer. As another example, a forwarder can be configured to filter and/or route events to specific receivers (e.g., different indexers), and/or discard events. As another example, a forwarder can be configured to send data to another forwarder, or to a receiver that is not an indexer or a forwarder (such as, for example, a log aggregator).

The event collector **1630** provides an alternate method for obtaining data from the data source **1602**. The event collector **1630** enables data and application events to be sent to the indexer **1632** using HTTP **1628**. The event collector **1630** can be implemented using program code that can be executing on a computing device. The program code may be a component of the data intake and query system or can be a standalone component that can be executed independently of the data intake and query system and operates in cooperation with the data intake and query system.

To use the event collector **1630**, a user can, for example using the monitoring console **1616** or a similar interface provided by the user interface system **1614**, enable the event collector **1630** and configure an authentication token. In this context, an authentication token is a piece of digital data generated by a computing device, such as a server, that contains information to identify a particular entity, such as a user or a computing device, to the server. The token will contain identification information for the entity (e.g., an alphanumeric string that is unique to each token) and a code that authenticates the entity with the server. The token can be used, for example, by the data source **1602** as an alternative method to using a username and password for authentication.

To send data to the event collector **1630**, the data source **1602** is supplied with a token and can then send HTTP **1628** requests to the event collector **1630**. To send HTTP **1628** requests, the data source **1602** can be configured to use an HTTP client and/or to use logging libraries such as those supplied by Java, JavaScript, and .NET libraries. An HTTP client enables the data source **1602** to send data to the event collector **1630** by supplying the data, and a Uniform Resource Identifier (URI) for the event collector **1630** to the HTTP client. The HTTP client then handles establishing a connection with the event collector **1630**, transmitting a request containing the data, closing the connection, and receiving an acknowledgment if the event collector **1630** sends one. Logging libraries enable HTTP **1628** requests to the event collector **1630** to be generated directly by the data source. For example, an application can include or link a logging library, and through functionality provided by the logging library manage establishing a connection with the event collector **1630**, transmitting a request, and receiving an acknowledgement.

An HTTP **1628** request to the event collector **1630** can contain a token, a channel identifier, event metadata, and/or event data. The token authenticates the request with the event collector **1630**. The channel identifier, if available in the indexing system **1620**, enables the event collector **1630** to segregate and keep separate data from different data sources. The event metadata can include one or more key-value pairs that describe the data source **1602** or the event data included in the request. For example, the event metadata can include key-value pairs specifying a timestamp, a hostname, a source, a source type, or an index where the event data should be indexed. The event data can be a structured data object, such as a JavaScript Object Notation (JSON) object, or raw text. The structured data object can include both event data and event metadata. Additionally, one request can include event data for one or more events.

In some implementations, the event collector **1630** extracts events from HTTP **1628** requests and sends the events to the indexer **1632**. The event collector **1630** can further be configured to send events or event data to one or more indexers. Extracting the events can include associating any metadata in a request with the event or events included in the request. In these implementations, event generation by the indexer **1632** (discussed further below) is bypassed, and the indexer **1632** moves the events directly to indexing. In some implementations, the event collector **1630** extracts event data from a request and outputs the event data to the indexer **1632**, and the indexer generates events from the event data. In some implementations, the event collector **1630** sends an acknowledgement message to the data source **1602** to indicate that the event collector **1630** has received a particular request form the data source **1602**, and/or to indicate to the data source **1602** that events in the request have been added to an index.

The indexer **1632** ingests incoming data and transforms the data into searchable knowledge in the form of events. In the data intake and query system, an event is a single piece of data that represents activity of the component represented in FIG. **16** by the data source **1602**. An event can be, for example, a single record in a log file that records a single action performed by the component (e.g., a user login, a disk read, transmission of a network packet, etc.). An event includes one or more fields that together describe the action captured by the event, where a field is a key-value pair (also referred to as a name-value pair). In some cases, an event includes both the key and the value, and in some cases the event includes only the value and the key can be inferred or assumed.

Transformation of data into events can include event generation and event indexing. Event generation includes identifying each discrete piece of data that represents one event and associating each event with a timestamp and possibly other information (which may be referred to herein as metadata). Event indexing includes storing of each event in the data structure of an index. As an example, the indexer **1632** can include a parsing module **1634** and an indexing module **1636** for generating and storing the events. The parsing module **1634** and indexing module **1636** can be modular and pipelined, such that one component can be operating on a first set of data while the second component is simultaneously operating on a second sent of data. Additionally, the indexer **1632** may at any time have multiple instances of the parsing module **1634** and indexing module **1636**, with each set of instances configured to simultaneously operate on data from the same data source or from different data sources. The parsing module **1634** and indexing module **1636** are illustrated to facilitate discussion, with the understanding that implementations with other components are possible to achieve the same functionality.

The parsing module **1634** determines information about event data, where the information can be used to identify events within the event data. For example, the parsing module **1634** can associate a source type with the event data. A source type identifies the data source **1602** and describes a possible data structure of event data produced by the data source **1602**. For example, the source type can indicate which fields to expect in events generated at the data source **1602** and the keys for the values in the fields, and possibly other information such as sizes of fields, an order of the fields, a field separator, and so on. The source type of the data source **1602** can be specified when the data source **1602** is configured as a source of event data. Alternatively, the parsing module **1634** can determine the source type from the event data, for example from an event field or using machine learning.

Other information that the parsing module **1634** can determine includes timestamps. In some cases, an event includes a timestamp as a field, and the timestamp indicates a point in time when the action represented by the event occurred or was recorded by the data source **1602** as event data. In these cases, the parsing module **1634** may be able to determine from the source type associated with the event data that the timestamps can be extracted from the events themselves. In some cases, an event does not include a timestamp and the parsing module **1634** determines a timestamp for the event, for example from a name associated with the event data from the data source **1602** (e.g., a file name when the event data is in the form of a file) or a time associated with the event data (e.g., a file modification time). As another example, when the parsing module **1634** is not able to determine a timestamp from the event data, the parsing module **1634** may use the time at which it is indexing the event data. As another example, the parsing module **1634** can use a user-configured rule to determine the timestamps to associate with events.

The parsing module **1634** can further determine event boundaries. In some cases, a single line (e.g., a sequence of characters ending with a line termination) in event data represents one event while in other cases, a single line represents multiple events. In yet other cases, one event may span multiple lines within the event data. The parsing module **1634** may be able to determine event boundaries from the source type associated with the event data, for example from a data structure indicated by the source type. In some implementations, a user can configure rules the parsing module **1634** can use to identify event boundaries.

The parsing module **1634** can further extract data from events and possibly also perform transformations on the events. For example, the parsing module **1634** can extract a set of fields for each event, such as a host or hostname, source or source name, and/or source type. The parsing module **1634** may extract certain fields by default or based on a user configuration. Alternatively or additionally, the parsing module **1634** may add fields to events, such as a source type or a user-configured field. As another example of a transformation, the parsing module **1634** can anonymize fields in events to mask sensitive information, such as social security numbers or account numbers. Anonymizing fields can include changing or replacing values of specific fields. The parsing component **1634** can further perform user-configured transformations.

The parsing module **1634** outputs the results of processing incoming event data to the indexing module **1636**, which performs event segmentation and builds index data structures.

Event segmentation identifies searchable segments, which may alternatively be referred to as searchable terms or keywords, which can be used by the search system of the data intake and query system to search the event data. A searchable segment may be a part of a field in an event or an entire field. The indexer **1632** can be configured to identify searchable segments that are parts of fields, searchable segments that are entire fields, or both. The parsing module **1634** organizes the searchable segments into a lexicon or dictionary for the event data, with the lexicon including each searchable segment and a reference to the location of each occurrence of the searchable segment within the event data. As discussed further below, the search system can use the lexicon, which is stored in an index file **1646**, to find event data that matches a search query. In some implementations, segmentation can alternatively be performed by the forwarder **1626**. Segmentation can also be disabled, in which case the indexer **1632** will not build a lexicon for the event data. When segmentation is disabled, the search system searches the event data directly.

Building index data structures generates the index **1638**. The index **1638** is a storage data structure on a storage device (e.g., a disk drive or other physical device for storing digital data). The storage device may be a component of the computing device on which the indexer **1632** is operating (referred to herein as local storage) or may be a component of a different computing device (referred to herein as remote storage) that the indexer **1638** has access to over a network. The indexer **1632** can include more than one index and can include indexes of different types. For example, the indexer **1632** can include event indexes, which impose minimal structure on stored data and can accommodate any type of data. As another example, the indexer **1632** can include metrics indexes, which use a highly structured format to handle the higher volume and lower latency demands associated with metrics data.

The indexing module **1636** organizes files in the index **1638** in directories referred to as buckets. The files in a bucket **1644** can include raw data files, index files, and possibly also other metadata files. As used herein, "raw data" means data as when the data was produced by the data source **1602**, without alteration to the format or content. As noted previously, the parsing component **1634** may add fields to event data and/or perform transformations on fields in the event data, and thus a raw data file **1648** can include, in addition to or instead of raw data, what is referred to herein as enriched raw data. The raw data file **1648** may be compressed to reduce disk usage. An index file **1646**, which may also be referred to herein as a "time-series index" or tsidx file, contains metadata that the indexer **1632** can use to search a corresponding raw data file **1648**. As noted above, the metadata in the index file **1646** includes a lexicon of the event data, which associates each unique keyword in the event data in the raw data file **1648** with a reference to the location of event data within the raw data file **1648**. The keyword data in the index file **1646** may also be referred to as an inverted index. In various implementations, the data intake and query system can use index files for other purposes, such as to store data summarizations that can be used to accelerate searches.

A bucket **1644** includes event data for a particular range of time. The indexing module **1636** arranges buckets in the index **1638** according to the age of the buckets, such that buckets for more recent ranges of time are stored in short-term storage **1640** and buckets for less recent ranges of time are stored in long-term storage **1642**. Short-term storage **1640** may be faster to access while long-term storage **1642** may be slower to access. Buckets may move from short-term storage **1640** to long-term storage **1642** according to a configurable data retention policy, which can indicate at what point in time a bucket is old enough to be moved.

A bucket's location in short-term storage **1640** or long-term storage **1642** can also be indicated by the bucket's status. As an example, a bucket's status can be "hot," "warm," "cold," "frozen," or "thawed." In this example, hot bucket is one to which the indexer **1632** is writing data and the bucket becomes a warm bucket when the indexer **1632** stops writing data to it. In this example, both hot and warm buckets reside in short-term storage **1640**. Continuing this example, when a warm bucket is moved to long-term storage **1642**, the bucket becomes a cold bucket. A cold bucket can become a frozen bucket after a period of time, at which point the bucket may be deleted or archived. An archived bucket cannot be searched. When an archived bucket is retrieved for searching, the bucket becomes thawed and can then be searched.

The indexing system **1620** can include more than one indexer, where a group of indexers is referred to as an index cluster. The indexers in an index cluster may also be referred to as peer nodes. In an index cluster, the indexers are configured to replicate each other's data by copying buckets from one indexer to another. The number of copies of a bucket can configured (e.g., three copies of each bucket must exist within the cluster), and indexers to which buckets are copied may be selected to optimize distribution of data across the cluster.

A user can view the performance of the indexing system **1620** through the monitoring console **1616** provided by the user interface system **1614**. Using the monitoring console **1616**, the user can configure and monitor an index cluster, and see information such as disk usage by an index, volume usage by an indexer, index and volume size over time, data age, statistics for bucket types, and bucket settings, among other information.

FIG. **17** is a block diagram illustrating in greater detail an example of the search system **1760** of a data intake and query system, such as the data intake and query system **1510** of FIG. **15**. The search system **1760** of FIG. **17** issues a query **1766** to a search head **1762**, which sends the query **1766** to a search peer **1764**. Using a map process **1770**, the search peer **1764** searches the appropriate index **1738** for events identified by the query **1766** and sends events **1778** so identified back to the search head **1762**. Using a reduce process **1782**, the search head **1762** processes the events **1778** and produces results **1768** to respond to the query **1766**. The results **1768** can provide useful insights about the data stored in the index **1738**. These insights can aid in the administration of information technology systems, in security analysis of information technology systems, and/or in analysis of the development environment provided by information technology systems.

The query **1766** that initiates a search is produced by a search and reporting app **1716** that is available through the user interface system **1714** of the data intake and query system. Using a network access application **1706** executing on a computing device **1704**, a user can input the query **1766** into a search field provided by the search and reporting app **1716**. Alternatively or additionally, the search and reporting app **1716** can include pre-configured queries or stored queries that can be activated by the user. In some cases, the search and reporting app **1716** initiates the query **1766** when the user enters the query **1766**. In these cases, the query **1766** may be referred to as an "ad-hoc" query. In some cases, the search and reporting app **1716** initiates the query **1766** based on a schedule. For example, the search and reporting app **1716** can be configured to execute the query **1766** once per hour, once per day, at a specific time, on a specific date, or at some other time that can be specified by a date, time, and/or frequency. These types of queries may be referred to as scheduled queries.

The query **1766** is specified using a search processing language. The search processing language includes commands that the search peer **1764** will use to identify events to return in the search results **1768**. The search processing language can further include commands for filtering events, extracting more information from events, evaluating fields in events, aggregating events, calculating statistics over events, organizing the results, and/or generating charts, graphs, or other visualizations, among other examples. Some search commands may have functions and arguments associated with them, which can, for example, specify how the commands operate on results and which fields to act upon. The search processing language may further include constructs that enable the query **1766** to include sequential commands, where a subsequent command may operate on the results of a prior command. As an example, sequential commands may be separated in the query **1766** by a vertical line ("|" or "pipe") symbol.

In addition to one or more search commands, the query **1766** includes a time indicator. The time indicator limits searching to events that have timestamps described by the indicator. For example, the time indicator can indicate a specific point in time (e.g., 10:00:00 am today), in which case only events that have the point in time for their timestamp will be searched. As another example, the time indicator can indicate a range of time (e.g., the last 24 hours), in which case only events whose timestamps fall within the range of time will be searched. The time indicator can alternatively indicate all of time, in which case all events will be searched.

Processing of the search query **1766** occurs in two broad phases: a map phase **1750** and a reduce phase **1752**. The map phase **1750** takes place across one or more search peers. In the map phase **1750**, the search peers locate event data that matches the search terms in the search query **1766** and sorts the event data into field-value pairs. When the map phase **1750** is complete, the search peers send events that they have found to one or more search heads for the reduce phase **1752**. During the reduce phase **1752**, the search heads process the events through commands in the search query **1766** and aggregate the events to produce the final search results **1768**.

A search head, such as the search head **1762** illustrated in FIG. **17**, is a component of the search system **1760** that manages searches. The search head **1762**, which may also be referred to herein as a search management component, can be implemented using program code that can be executed on a computing device. The program code for the search head **1762** can be stored on a non-transitory computer-readable medium and from this medium can be loaded or copied to the memory of a computing device. One or more hardware processors of the computing device can read the program code from the memory and execute the program code in order to implement the operations of the search head **1762**.

Upon receiving the search query **1766**, the search head **1762** directs the query **1766** to one or more search peers, such as the search peer **1764** illustrated in FIG. **17**. "Search peer" is an alternate name for "indexer" and a search peer may be largely similar to the indexer described previously. The search peer **1764** may be referred to as a "peer node" when the search peer **1764** is part of an indexer cluster. The search peer **1764**, which may also be referred to as a search execution component, can be implemented using program code that can be executed on a computing device. In some implementations, one set of program code implements both the search head **1762** and the search peer **1764** such that the search head **1762** and the search peer **1764** form one component. In some implementations, the search head **1762** is an independent piece of code that performs searching and no indexing functionality. In these implementations, the search head **1762** may be referred to as a dedicated search head.

The search head **1762** may consider multiple criteria when determining whether to send the query **1766** to the particular search peer **1764**. For example, the search system **1760** may be configured to include multiple search peers that each have duplicative copies of at least some of the event data. In this example, the sending the search query **1766** to more than one search peer allows the search system **1760** to distribute the search workload across different hardware resources. As another example, search system **1760** may include different search peers for different purposes (e.g., one has an index storing a first type of data or from a first data source while a second has an index storing a second type of data or from a second data source). In this example, the search query **1766** may specify which indexes to search, and the search head **1762** will send the query **1766** to the search peers that have those indexes.

To identify events **1778** to send back to the search head **1762**, the search peer **1764** performs a map process **1770** to obtain event data **1774** from the index **1738** that is maintained by the search peer **1764**. During a first phase of the map process **1770**, the search peer **1764** identifies buckets that have events that are described by the time indicator in the search query **1766**. As noted above, a bucket contains events whose timestamps fall within a particular range of time. For each bucket **1744** whose events can be described by the time indicator, during a second phase of the map process **1770**, the search peer **1764** performs a keyword search **1772** using search terms specified in the search query **1766**. The search terms can be one or more of keywords, phrases, fields, Boolean expressions, and/or comparison expressions that in combination describe events being searched for. When segmentation is enabled at index time, the search peer **1764** performs the keyword search **1772** on the bucket's index file **1746**. As noted previously, the index file **1746** includes a lexicon of the searchable terms in the events stored in the bucket's raw data **1748** file. The keyword search **1772** searches the lexicon for searchable terms that correspond to one or more of the search terms in the query **1766**. As also noted above, the lexicon incudes, for each searchable term, a reference to each location in the raw data **1748** file where the searchable term can be found. Thus, when the keyword search identifies a searchable term in the index file **1746** that matches query **1766**, the search peer

1764 can use the location references to extract from the raw data 1748 file the event data 1774 for each event that include the searchable term.

In cases where segmentation was disabled at index time, the search peer 1764 performs the keyword search 1772 directly on the raw data 1748 file. To search the raw data 1748, the search peer 1764 may identify searchable segments in events in a similar manner as when the data was indexed. Thus, depending on how the search peer 1764 is configured, the search peer 1764 may look at event fields and/or parts of event fields to determine whether an event matches the query 1766. Any matching events can be added to the event data 1774 read from the raw data 1748 file. The search peer 1764 can further be configured to enable segmentation at search time, so that searching of the index 1738 causes the search peer 1764 to build a lexicon in the index file 1746.

The event data 1774 obtained from the raw data 1748 file includes the full text of each event found by the keyword search 1772. During a third phase of the map process 1770, the search peer 1764 performs event processing 1776 on the event data 1774, with the steps performed being determined by the configuration of the search peer 1764 and/or commands in the search query 1766. For example, the search peer 1764 can be configured to perform field discovery and field extraction. Field discovery is a process by which the search peer 1764 identifies and extracts key-value pairs from the events in the event data 1774. The search peer 1764 can, for example, be configured to automatically extract the first 100 fields (or another number of fields) in the event data 1774 that can be identified as key-value pairs. As another example, the search peer 1764 can extract any fields explicitly mentioned in the search query 1766. The search peer 1764 can, alternatively or additionally, be configured with particular field extractions to perform.

Other examples of steps that can be performed during event processing 1776 include: field aliasing (assigning an alternate name to a field); addition of fields from lookups (adding fields from an external source to events based on existing field values in the events); associating event types with events; source type renaming (changing the name of the source type associated with particular events); and tagging (adding one or more strings of text, or a "tags" to particular events), among other examples.

The search peer 1764 sends processed events 1778 to the search head 1762, which performs a reduce process 1780. The reduce process 1780 potentially receives events from multiple search peers and performs various results processing 1782 steps on the events. The results processing 1782 steps can include, for example, aggregating the events from different search peers into a single set of events, deduplicating and aggregating fields discovered by different search peers, counting the number of events found, and sorting the events by timestamp (e.g., newest first or oldest first), among other examples. Results processing 1782 can further include applying commands from the search query 1766 to the events. The query 1766 can include, for example, commands for evaluating and/or manipulating fields (e.g., to generate new fields from existing fields or parse fields that have more than one value). As another example, the query 1766 can include commands for calculating statistics over the events, such as counts of the occurrences of fields, or sums, averages, ranges, and so on, of field values. As another example, the query 1766 can include commands for generating statistical values for purposes of generating charts of graphs of the events.

Through results processing 1782, the reduce process 1780 produces the events found by processing the search query 1766, as well as some information about the events, which the search head 1762 outputs to the search and reporting app 1716 as search results 1768. The search and reporting app 1716 can generate visual interfaces for viewing the search results 1768. The search and reporting app 1716 can, for example, output visual interfaces for the network access application 1706 running on a computing device 1704 to generate.

The visual interfaces can include various visualizations of the search results 1768, such as tables, line or area charts, Choropleth maps, or single values. The search and reporting app 1716 can organize the visualizations into a dashboard, where the dashboard includes a panel for each visualization. A dashboard can thus include, for example, a panel listing the raw event data for the events in the search results 1768, a panel listing fields extracted at index time and/or found through field discovery along with statistics for those fields, and/or a timeline chart indicating how many events occurred at specific points in time (as indicated by the timestamps associated with each event). In various implementations, the search and reporting app 1716 can provide one or more default dashboards. Alternatively or additionally, the search and reporting app 1716 can include functionality that enables a user to configure custom dashboards.

The search and reporting app 1716 can also enable further investigation into the events in the search results 1768. The process of further investigation may be referred to as drill-down. For example, a visualization in a dashboard can include interactive elements, which, when selected, provide options for finding out more about the data being displayed by the interactive elements. To find out more, an interactive element can, for example, generate a new search that includes some of the data being displayed by the interactive element, and thus may be more focused than the initial search query 1766. As another example, an interactive element can launch a different dashboard whose panels include more detailed information about the data that is displayed by the interactive element. Other examples of actions that can be performed by interactive elements in a dashboard include opening a link, playing an audio or video file, or launching another application, among other examples.

FIG. 18 is a block diagram that illustrates a computer system 1800 utilized in implementing the above-described techniques, according to an example. Computer system 1800 may be, for example, a desktop computing device, laptop computing device, tablet, smartphone, server appliance, computing mainframe, multimedia device, handheld device, networking apparatus, or any other suitable device.

Computer system 1800 includes one or more buses 1802 or other communication mechanism for communicating information, and one or more hardware processors 1804 coupled with buses 1802 for processing information. Hardware processors 1804 may be, for example, general purpose microprocessors. Buses 1802 may include various internal and/or external components, including, without limitation, internal processor or memory busses, a Serial ATA bus, a PCI Express bus, a Universal Serial Bus, a HyperTransport bus, an Infiniband bus, and/or any other suitable wired or wireless communication channel.

Computer system 1800 also includes a main memory 1806, such as a random access memory (RAM) or other dynamic or volatile storage device, coupled to bus 1802 for storing information and instructions to be executed by processor 1804. Main memory 1806 also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **1804**. Such instructions, when stored in non-transitory storage media accessible to processor **1804**, render computer system **1800** a special-purpose machine that is customized to perform the operations specified in the instructions.

Computer system **1800** further includes one or more read only memories (ROM) **1808** or other static storage devices coupled to bus **1802** for storing static information and instructions for processor **1804**. One or more storage devices **1810**, such as a solid-state drive (SSD), magnetic disk, optical disk, or other suitable non-volatile storage device, is provided and coupled to bus **1802** for storing information and instructions.

Computer system **1800** may be coupled via bus **1802** to one or more displays **1812** for presenting information to a computer user. For instance, computer system **1800** may be connected via a High-Definition Multimedia Interface (HDMI) cable or other suitable cabling to a Liquid Crystal Display (LCD) monitor, and/or via a wireless connection such as peer-to-peer Wi-Fi Direct connection to a Light-Emitting Diode (LED) television. Other examples of suitable types of displays **1812** may include, without limitation, plasma display devices, projectors, cathode ray tube (CRT) monitors, electronic paper, virtual reality headsets, braille terminal, and/or any other suitable device for outputting information to a computer user. In an example, any suitable type of output device, such as, for instance, an audio speaker or printer, may be utilized instead of a display **1812**.

One or more input devices **1814** are coupled to bus **1802** for communicating information and command selections to processor **1804**. One example of an input device **1814** is a keyboard, including alphanumeric and other keys. Another type of user input device **1814** is cursor control **1816**, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor **1804** and for controlling cursor movement on display **1812**. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allows the device to specify positions in a plane. Yet other examples of suitable input devices **1814** include a touch-screen panel affixed to a display **1812**, cameras, microphones, accelerometers, motion detectors, and/or other sensors. In an example, a network-based input device **1814** may be utilized. In such an example, user input and/or other information or commands may be relayed via routers and/or switches on a Local Area Network (LAN) or other suitable shared network, or via a peer-to-peer network, from the input device **1814** to a network link **1820** on the computer system **1800**.

A computer system **1800** may implement techniques described herein using customized hard-wired logic, one or more ASICs or FPGAs, firmware and/or program logic which in combination with the computer system causes or programs computer system **1800** to be a special-purpose machine. According to one example, the techniques herein are performed by computer system **1800** in response to processor **1804** executing one or more sequences of one or more instructions contained in main memory **1806**. Such instructions may be read into main memory **1806** from another storage medium, such as storage device **1810**. Execution of the sequences of instructions contained in main memory **1806** causes processor **1804** to perform the process steps described herein. In other examples, hard-wired circuitry may be used in place of or in combination with software instructions.

The term "storage media" as used herein refers to any non-transitory media that store data and/or instructions that cause a machine to operate in a specific fashion. Such storage media may comprise non-volatile media and/or volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device **1810**. Volatile media includes dynamic memory, such as main memory **1806**. Common forms of storage media include, for example, a floppy disk, a flexible disk, hard disk, solid state drive, magnetic tape, or any other magnetic data storage medium, a CD-ROM, any other optical data storage medium, any physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EPROM, NVRAM, any other memory chip or cartridge.

Storage media is distinct from but may be used in conjunction with transmission media. Transmission media participates in transferring information between storage media. For example, transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise bus **1802**. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infra-red data communications.

Various forms of media may be involved in carrying one or more sequences of one or more instructions to processor **1804** for execution. For example, the instructions may initially be carried on a magnetic disk or a solid state drive of a remote computer. The remote computer can load the instructions into its dynamic memory and use a modem to send the instructions over a network, such as a cable network or cellular network, as modulate signals. A modem local to computer system **1800** can receive the data on the network and demodulate the signal to decode the transmitted instructions. Appropriate circuitry can then place the data on bus **1802**. Bus **1802** carries the data to main memory **1806**, from which processor **1804** retrieves and executes the instructions. The instructions received by main memory **1806** may optionally be stored on storage device **1810** either before or after execution by processor **1804**.

A computer system **1800** may also include, in an example, one or more communication interfaces **1818** coupled to bus **1802**. A communication interface **1818** provides a data communication coupling, typically two-way, to a network link **1820** that is connected to a local network **1822**. For example, a communication interface **1818** may be an integrated services digital network (ISDN) card, cable modem, satellite modem, or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, the one or more communication interfaces **1818** may include a local area network (LAN) card to provide a data communication connection to a compatible LAN. As yet another example, the one or more communication interfaces **1818** may include a wireless network interface controller, such as a 802.11-based controller, Bluetooth controller, Long Term Evolution (LTE) modem, and/or other types of wireless interfaces. In any such implementation, communication interface **1818** sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information.

Network link **1820** typically provides data communication through one or more networks to other data devices. For example, network link **1820** may provide a connection through local network **1822** to a host computer **1824** or to data equipment operated by a Service Provider **1826**. Service Provider **1826**, which may for example be an Internet Service Provider (ISP), in turn provides data communication services through a wide area network, such as the worldwide packet data communication network now commonly referred to as the "internet" **1828**. Local network **1822** and Internet **1828** both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link **1820** and through communication interface **1818**, which carry the digital data to and from computer system **1800**, are example forms of transmission media.

In an example, computer system **1800** can send messages and receive data, including program code and/or other types of instructions, through the network(s), network link **1820**, and communication interface **1818**. In the Internet example, a server **1830** might transmit a requested code for an application program through Internet **1828**, ISP **1826**, local network **1822** and communication interface **1818**. The received code may be executed by processor **1804** as it is received, and/or stored in storage device **1810**, or other non-volatile storage for later execution. As another example, information received via a network link **1820** may be interpreted and/or processed by a software component of the computer system **1800**, such as a web browser, application, or server, which in turn issues instructions based thereon to a processor **1804**, possibly via an operating system and/or other intermediate layers of software components.

In some examples, some or all the systems described herein may be or comprise server computer systems, including one or more computer systems **1800** that collectively implement various components of the system as a set of server-side processes. The server computer systems may include web server, application server, database server, and/or other conventional server components that certain above-described components utilize to provide the described functionality. The server computer systems may receive network-based communications comprising input data from any of a variety of sources, including without limitation user-operated client computing devices such as desktop computers, tablets, or smartphones, remote sensing devices, and/or other server computer systems.

Various examples and possible implementations have been described above, which recite certain features and/or functions. Although these examples and implementations have been described in language specific to structural features and/or functions, it is understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or functions described above. Rather, the specific features and functions described above are disclosed as examples of implementing the claims, and other equivalent features and acts are intended to be within the scope of the claims. Further, any or all of the features and functions described above can be combined with each other, except to the extent it may be otherwise stated above or to the extent that any such embodiments may be incompatible by virtue of their function or structure, as will be apparent to persons of ordinary skill in the art. Unless contrary to physical possibility, it is envisioned that (i) the methods/steps described herein may be performed in any sequence and/or in any combination, and (ii) the components of respective embodiments may be combined in any manner.

Processing of the various components of systems illustrated herein can be distributed across multiple machines, networks, and other computing resources. Two or more components of a system can be combined into fewer components. Various components of the illustrated systems can be implemented in one or more virtual machines or an isolated execution environment, rather than in dedicated computer hardware systems and/or computing devices. Likewise, the data repositories shown can represent physical and/or logical data storage, including, e.g., storage area networks or other distributed storage systems. Moreover, in some embodiments the connections between the components shown represent possible paths of data flow, rather than actual connections between hardware. While some examples of possible connections are shown, any of the subset of the components shown can communicate with any other subset of components in various implementations.

Examples have been described with reference to flow chart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products. Each block of the flow chart illustrations and/or block diagrams, and combinations of blocks in the flow chart illustrations and/or block diagrams, may be implemented by computer program instructions. Such instructions may be provided to a processor of a general purpose computer, special purpose computer, specially-equipped computer (e.g., comprising a high-performance database server, a graphics subsystem, etc.) or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor(s) of the computer or other programmable data processing apparatus, create means for implementing the acts specified in the flow chart and/or block diagram block or blocks. These computer program instructions may also be stored in a non-transitory computer-readable memory that can direct a computer or other programmable data processing apparatus to operate in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means which implement the acts specified in the flow chart and/or block diagram block or blocks. The computer program instructions may also be loaded to a computing device or other programmable data processing apparatus to cause operations to be performed on the computing device or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computing device or other programmable apparatus provide steps for implementing the acts specified in the flow chart and/or block diagram block or blocks.

In some embodiments, certain operations, acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all are necessary for the practice of the algorithms). In certain embodiments, operations, acts, functions, or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially.

What is claimed is:

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

displaying, by an extension to an integrated development environment (IDE), information about an app integrated with an information technology (IT) and security operations application, wherein the IT and security operations application is hosted by computing resources accessible to the extension over one or more computer networks, and wherein the app includes executable code and configuration information;

receiving, by the extension to the IDE, a first request to execute an action implemented by the app, wherein execution of the action involves the app communicating with a service or computing device;

causing display, in the IDE, of an interface element associated with the IDE and used to obtain an input value associated the action, wherein the first request to execute the action includes the input value;

sending, to the IT and security operations application, a second request to execute the action;

obtaining, from the IT and security operations application, results data related to execution of the action by the IT and security operations application; and

causing display, in the IDE, of the results data related to execution of the action by the IT and security operations application.

2. The method of claim 1, wherein the information about the app displayed by the extension includes at least one of: an identifier of the action implemented by the app, an identifier of a configuration associated with a service or computing device used by the app to access the service or computing device, or identifiers of one or more files stored by the IT and security operations application in association with the app.

3. The method of claim 1, wherein implementation of the app is based on two or more files accessible to the IDE, and wherein the method further comprises:

receiving a request to deploy the app to the IT and security operations application;

generating, by the extension to the IDE, a deployment package for the app based on the two or more files; and

sending the deployment package to the IT and security operations application via the one or more computer networks.

4. The method of claim 1, further comprising:

receiving, via the interface element of the IDE, the input value associated with the action, wherein the first request to execute the action includes the input value;

receiving, by the extension to the IDE, a request to save the input value for subsequent executions of the action;

receiving a third request to execute the action implemented by the app, wherein the second request identifies the input value saved for subsequent executions of the action; and

sending, to the IT and security operations application, a fourth request to execute the action, wherein the fourth request to execute the action includes the input value saved for subsequent executions of the action.

5. The method of claim 1, further comprising:

receiving, by the IDE, input modifying the executable code or configuration information of the app to obtain an updated version of the app, wherein the updated version of the app includes an updated action implemented by the app;

receiving a request to deploy the updated version of the app to the IT and security operations application;

sending, to the IT and security operations application, a deployment package including the updated version of the app;

receiving a third request to execute the updated action; and

sending, to the IT and security operations application, a fourth request to execute the updated action.

6. The method of claim 1, further comprising causing display of source code associated with the app in a source code editor of the IDE, wherein the source code is displayed in a same interface as the information about the app integrated with the IT and security operations application.

7. The method of claim 1, further comprising:

receiving input selecting a file associated with the app, wherein the file is stored at a storage location accessible to the IT and security operations application;

downloading, by the extension to the IDE, the file associated with the app; and

causing display of contents of the file associated with the app in a source code editor of the IDE.

8. The method of claim 1, wherein the information about the app is displayed in an app explorer panel of the IDE, and wherein the method further comprises:

receiving, by the extension to the IDE, input selecting the app in the app explorer panel;

responsive to the input selecting the app, obtaining, from the IT and security operations application, information describing contents of the app, wherein the contents of the app includes at least one of: one or more assets configured for the app, one or more actions implemented by the app, or one or more files; and

displaying the information describing contents of the app in the app explorer panel.

9. The method of claim 1, further comprising causing display of the interface element associated with the IDE and used to obtain the input value associated the action, wherein the extension to the IDE causes display of one or more suggested input values based on metadata associated with the app, and wherein the request to execute the action includes the input value.

10. The method of claim 1, wherein the executable code and configuration information enables the IT and security operations application to interface with a service or device that is external to the IT and security operations application.

11. The method of claim 1, further comprising:

causing display of a configuration file associated with the app in an editor interface of the IDE;

receiving input to modify a portion of the configuration file, wherein the configuration file includes a plurality of key-value pairs, and wherein the configuration file is associated with a schema defining valid keys for the configuration file; and

causing display of one or more suggested keys for the configuration file based on the schema.

12. The method of claim 1, further comprising:

receiving, via an app wizard interface, input corresponding to configurations for a new template app for the IT and security operations application; and

generating, based on the input, one or more files corresponding to the new template app.

13. The method of claim 1, further comprising displaying information about one or more playbooks configured at the IT and security operations application, wherein a playbook, upon execution, automates a series of two or more actions in an IT environment.

14. The method of claim 1, further comprising:

receiving, via the extension to the IDE, a fourth request to execute a playbook, wherein a playbook, upon execution, automates a series of two or more actions in an IT environment;

sending, to the IT and security operations application, a fifth request to execute the playbook;

obtaining, from the IT and security operations application, results data related to execution of the playbook by the IT and security operations application; and

causing display, in the IDE, of the results data related to execution of the playbook by the IT and security operations application.

15. A computing device, comprising:

a processor; and

a non-transitory computer-readable medium having stored thereon instructions that, when executed by the processor, cause the processor to perform operations including:

displaying, by an extension to an integrated development environment (IDE), information about an app integrated with an information technology (IT) and security operations application, wherein the IT and security operations application is hosted by computing resources accessible to the extension over one or more computer networks, and wherein the app includes executable code and configuration information;

receiving, by the extension to the IDE, a first request to execute an action implemented by the app, wherein execution of the action involves the app communicating with a service or computing device;

causing display, in the IDE, of an interface element associated with the IDE and used to obtain an input value associated the action, wherein the first request to execute the action includes the input value;

sending, to the IT and security operations application, a second request to execute the action;

obtaining, from the IT and security operations application, results data related to execution of the action by the IT and security operations application; and

causing display, in the IDE, of the results data related to execution of the action by the IT and security operations application.

**16**. The computing device of claim **15**, wherein the information about the app displayed by the extension includes at least one of: an identifier of the action implemented by the app, an identifier of a configuration associated with a service or computing device used by the app to access the service or computing device, or identifiers of one or more files stored by the IT and security operations application in association with the app.

**17**. The computing device of claim **15**, wherein implementation of the app is based on two or more files accessible to the IDE, and wherein the instructions, when executed by the processor, further cause the processor to perform operations including:

receiving a request to deploy the app to the IT and security operations application;

generating, by the extension to the IDE, a deployment package for the app based on the two or more files; and

sending the deployment package to the IT and security operations application via the one or more computer networks.

**18**. A non-transitory computer-readable medium having stored thereon instructions that, when executed by one or more processors, cause the one or more processor to perform operations including:

displaying, by an extension to an integrated development environment (IDE), information about an app integrated with an information technology (IT) and security operations application, wherein the IT and security operations application is hosted by computing resources accessible to the extension over one or more computer networks, and wherein the app includes executable code and configuration information;

receiving, by the extension to the IDE, a first request to execute an action implemented by the app, wherein execution of the action involves the app communicating with a service or computing device;

causing display, in the IDE, of an interface element associated with the IDE and used to obtain an input value associated the action, wherein the first request to execute the action includes the input value;

sending, to the IT and security operations application, a second request to execute the action;

obtaining, from the IT and security operations application, results data related to execution of the action by the IT and security operations application; and

causing display, in the IDE, of the results data related to execution of the action by the IT and security operations application.

**19**. The computer-readable medium of claim **18**, wherein the information about the app displayed by the extension includes at least one of: an identifier of the action implemented by the app, an identifier of a configuration associated with a service or computing device used by the app to access the service or computing device, or identifiers of one or more files stored by the IT and security operations application in association with the app.

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