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(54) **CLOUD CONTENT SCANNING USING LOCALLY DEPLOYED CONTAINERIZED SCANNERS**

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(73) Assignee: **Proofpoint, Inc.**, Sunnyvale, CA (US)

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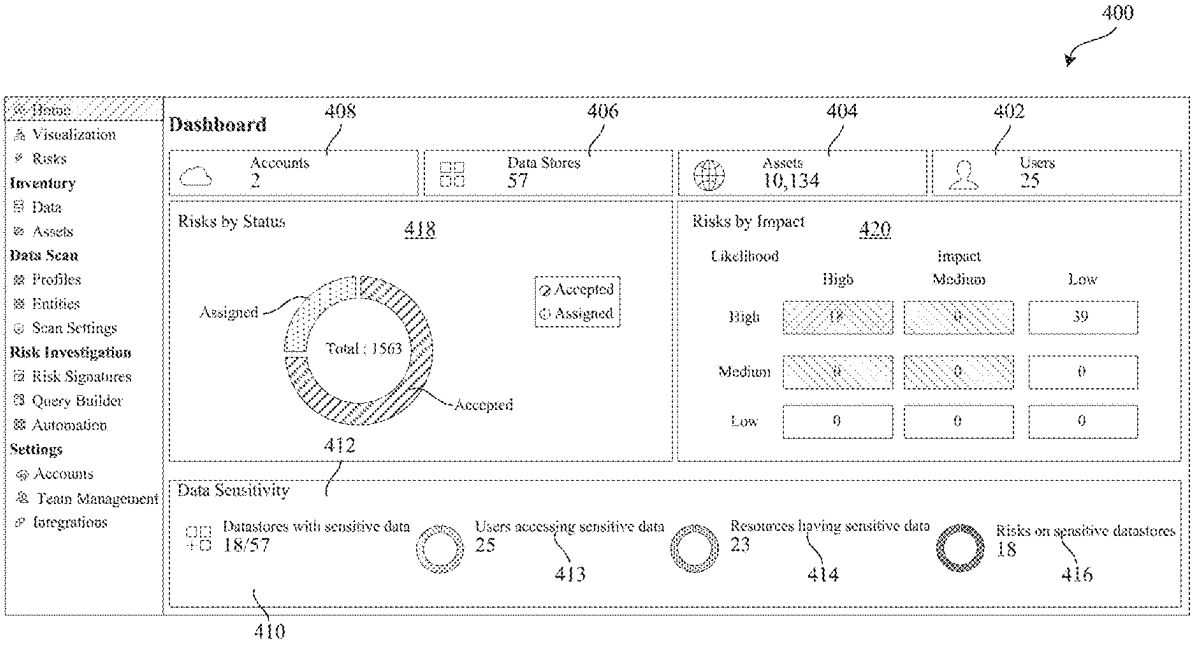
(57) **ABSTRACT**

The technology disclosed herein relates to streamlined analysis of security posture of a cloud environment. In particular, the technology relates to computer-implemented method of content scanning that includes obtaining access to a cloud environment account for content scanning of storage resources, queuing objects in the cloud environment account, partitioning the objects into a number of object chunks, and initializing a number of serverless, containerized scanners based on the number of object chunks. Each serverless, containerized scanner, of the number of serverless, containerized scanners, is deployed locally on the cloud environment account and scans a corresponding object chunk to detect a plurality of different data patterns. The number of object chunks is at least one hundred times the number of serverless, containerized scanners.



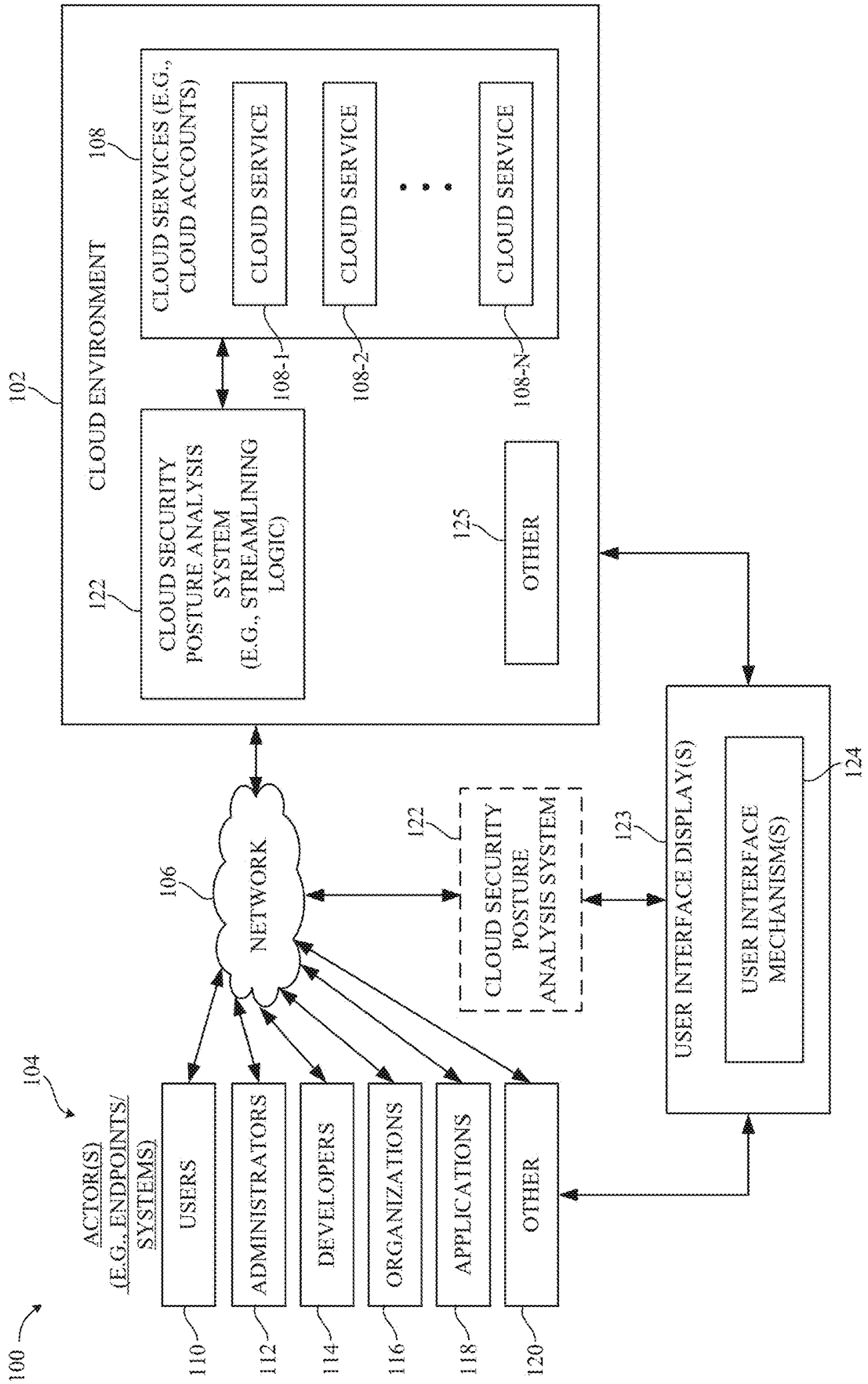

100
102
CLOUD ENVIRONMENT
108
CLOUD SERVICES (E.G., CLOUD ACCOUNTS)
CLOUD SERVICE
CLOUD SERVICE
CLOUD SERVICE
108-1
108-2
108-N
122
CLOUD SECURITY POSTURE ANALYSIS SYSTEM (E.G., STREAMLINING LOGIC)
125
OTHER
106
NETWORK
122
CLOUD SECURITY POSTURE ANALYSIS SYSTEM
123
USER INTERFACE DISPLAY(S)
USER INTERFACE MECHANISM(S)
124
104
ACTOR(S) (E.G., ENDPOINTS/ SYSTEMS)
USERS
ADMINISTRATORS
DEVELOPERS
ORGANIZATIONS
APPLICATIONS
OTHER
110
112
114
116
118
120

FIG. 1

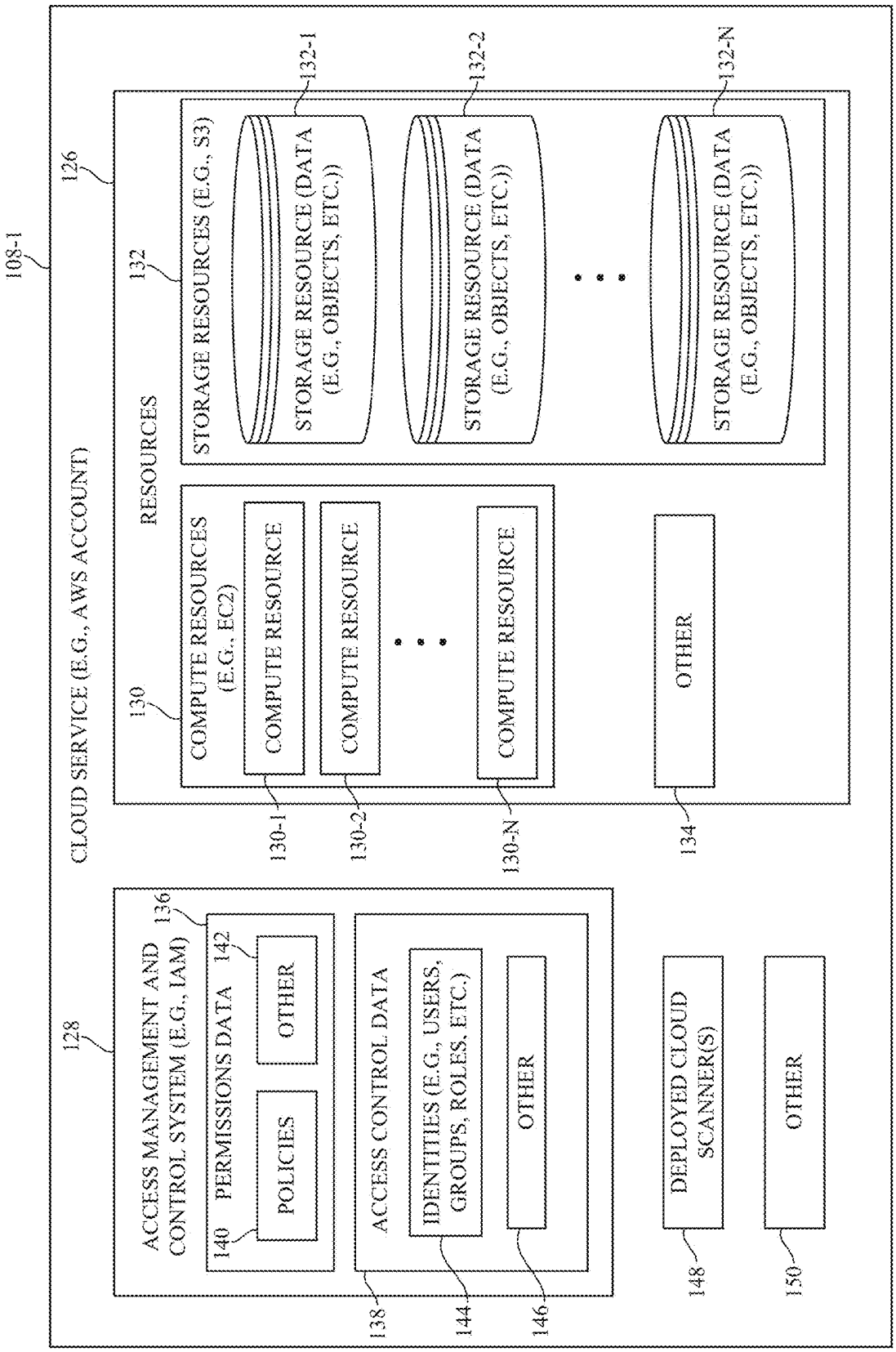

108-1
CLOUD SERVICE (E.G., AWS ACCOUNT)
126
RESOURCES
132
STORAGE RESOURCES (E.G., S3)
132-1
STORAGE RESOURCE (DATA (E.G., OBJECTS, ETC.))
132-2
STORAGE RESOURCE (DATA (E.G., OBJECTS, ETC.))
132-N
STORAGE RESOURCE (DATA (E.G., OBJECTS, ETC.))
130
COMPUTE RESOURCES (E.G., EC2)
COMPUTE RESOURCE
COMPUTE RESOURCE
COMPUTE RESOURCE
130-1
130-2
130-N
OTHER
134
128
ACCESS MANAGEMENT AND CONTROL SYSTEM (E.G., IAM)
136
PERMISSIONS DATA
142
OTHER
140
POLICIES
ACCESS CONTROL DATA
IDENTITIES (E.G., USERS, GROUPS, ROLES, ETC.)
OTHER
138
144
146
DEPLOYED CLOUD SCANNER(S)
148
OTHER
150

FIG. 2

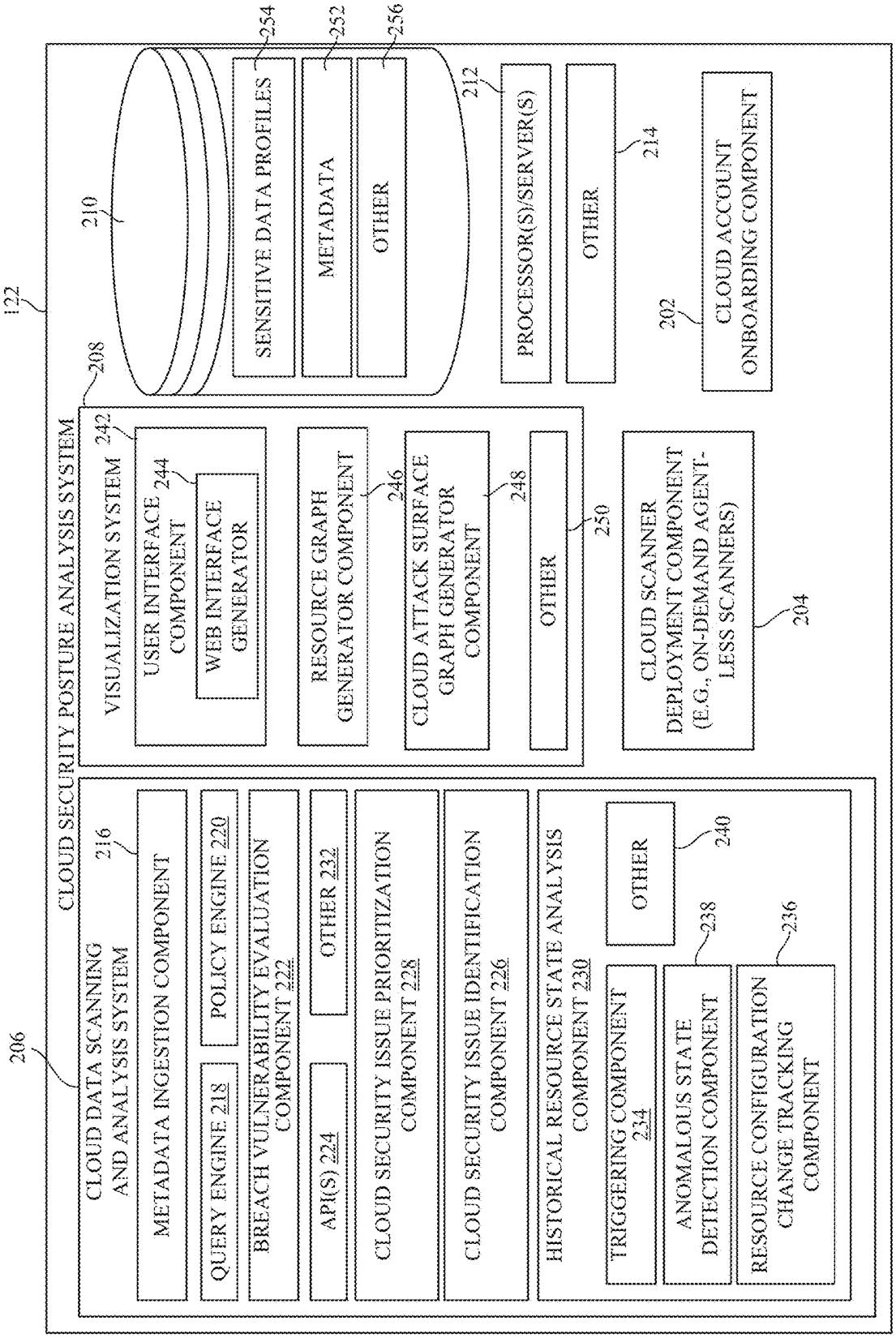

122
CLOUD SECURITY POSTURE ANALYSIS SYSTEM
206
CLOUD DATA SCANNING AND ANALYSIS SYSTEM
216
METADATA INGESTION COMPONENT
QUERY ENGINE 218
POLICY ENGINE 220
BREACH VULNERABILITY EVALUATION COMPONENT 222
API(S) 224
OTHER 232
CLOUD SECURITY ISSUE PRIORITIZATION COMPONENT 228
CLOUD SECURITY ISSUE IDENTIFICATION COMPONENT 226
HISTORICAL RESOURCE STATE ANALYSIS COMPONENT 230
TRIGGERING COMPONENT 234
ANOMALOUS STATE DETECTION COMPONENT
238
RESOURCE CONFIGURATION CHANGE TRACKING COMPONENT
236
OTHER
240
208
VISUALIZATION SYSTEM
242
USER INTERFACE COMPONENT
244
WEB INTERFACE GENERATOR
RESOURCE GRAPH GENERATOR COMPONENT
246
CLOUD ATTACK SURFACE GRAPH GENERATOR COMPONENT
248
OTHER
250
CLOUD SCANNER DEPLOYMENT COMPONENT (E.G., ON-DEMAND AGENT-LESS SCANNERS)
204
210
SENSITIVE DATA PROFILES
254
METADATA
252
OTHER
256
212
PROCESSOR(S)/SERVER(S)
OTHER
214
202
CLOUD ACCOUNT ONBOARDING COMPONENT

FIG. 3

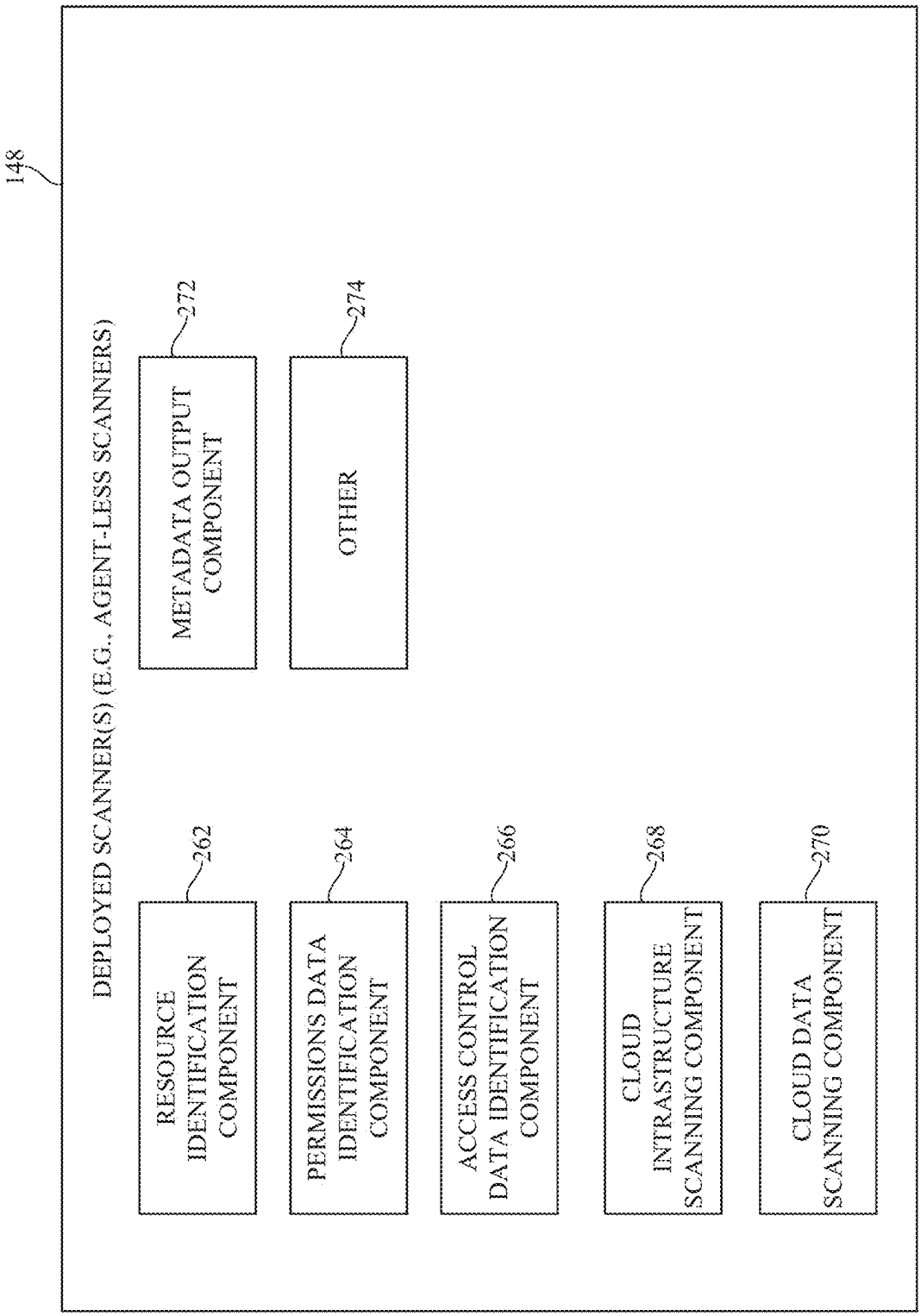

148
DEPLOYED SCANNER(S) (E.G., AGENT-LESS SCANNERS)
RESOURCE IDENTIFICATION COMPONENT
262
PERMISSIONS DATA IDENTIFICATION COMPONENT
264
ACCESS CONTROL DATA IDENTIFICATION COMPONENT
266
CLOUD INTRASTRUCTURE SCANNING COMPONENT
268
CLOUD DATA SCANNING COMPONENT
270
METADATA OUTPUT COMPONENT
272
OTHER
274

FIG. 4

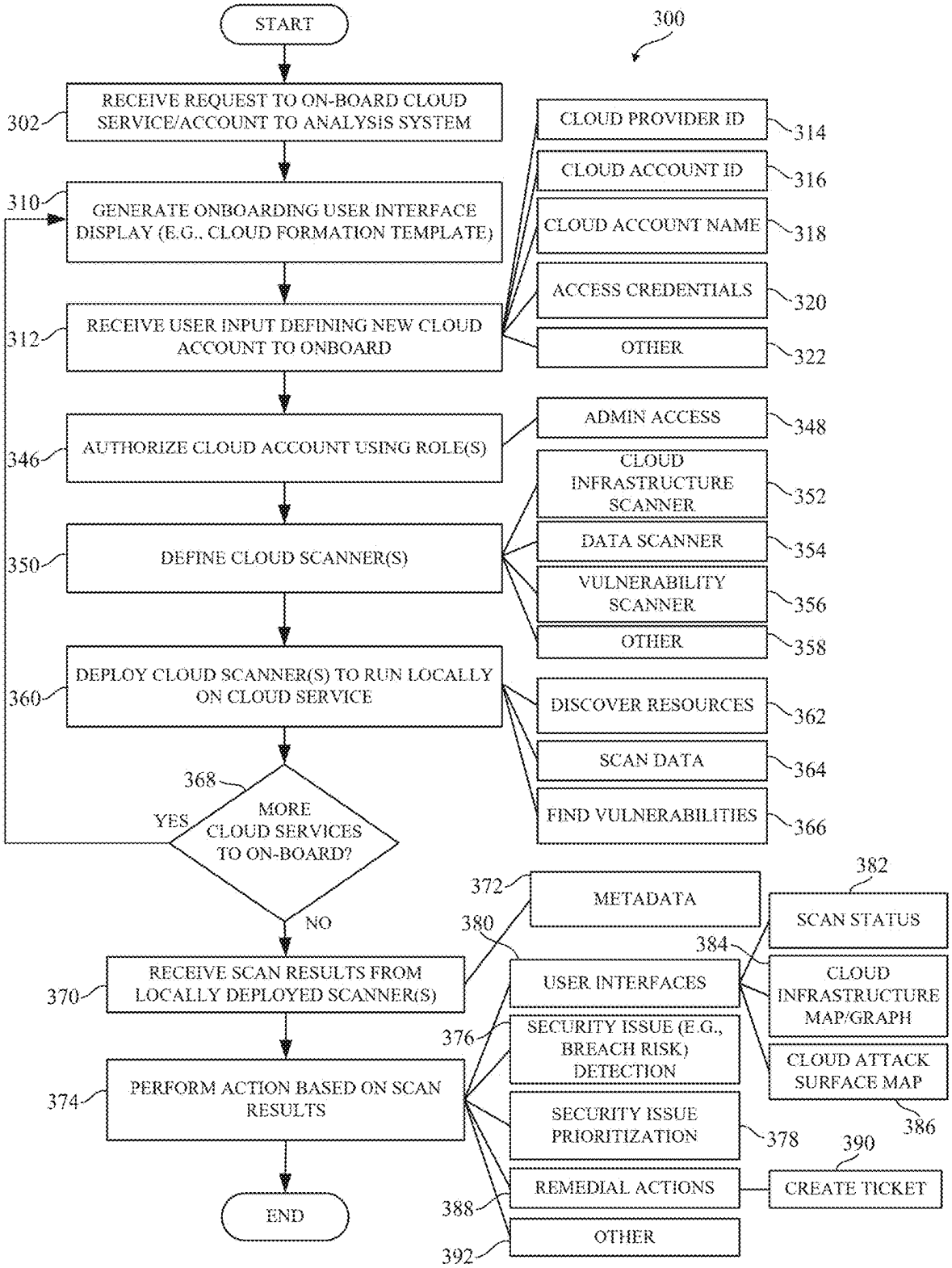

300
START
302
RECEIVE REQUEST TO ON-BOARD CLOUD SERVICE/ACCOUNT TO ANALYSIS SYSTEM
310
GENERATE ONBOARDING USER INTERFACE DISPLAY (E.G., CLOUD FORMATION TEMPLATE)
312
RECEIVE USER INPUT DEFINING NEW CLOUD ACCOUNT TO ONBOARD
CLOUD PROVIDER ID
314
CLOUD ACCOUNT ID
316
CLOUD ACCOUNT NAME
318
ACCESS CREDENTIALS
320
OTHER
322
346
AUTHORIZE CLOUD ACCOUNT USING ROLE(S)
ADMIN ACCESS
348
350
DEFINE CLOUD SCANNER(S)
CLOUD INFRASTRUCTURE SCANNER
352
DATA SCANNER
354
VULNERABILITY SCANNER
356
OTHER
358
360
DEPLOY CLOUD SCANNER(S) TO RUN LOCALLY ON CLOUD SERVICE
DISCOVER RESOURCES
362
SCAN DATA
364
FIND VULNERABILITIES
366
368
MORE CLOUD SERVICES TO ON-BOARD?
YES
NO
370
RECEIVE SCAN RESULTS FROM LOCALLY DEPLOYED SCANNER(S)
372
METADATA
380
USER INTERFACES
382
SCAN STATUS
384
CLOUD INFRASTRUCTURE MAP/GRAPH
CLOUD ATTACK SURFACE MAP
386
374
PERFORM ACTION BASED ON SCAN RESULTS
376
SECURITY ISSUE (E.G., BREACH RISK) DETECTION
SECURITY ISSUE PRIORITIZATION
378
REMEDIAL ACTIONS
388
390
CREATE TICKET
OTHER
392
END

FIG. 5

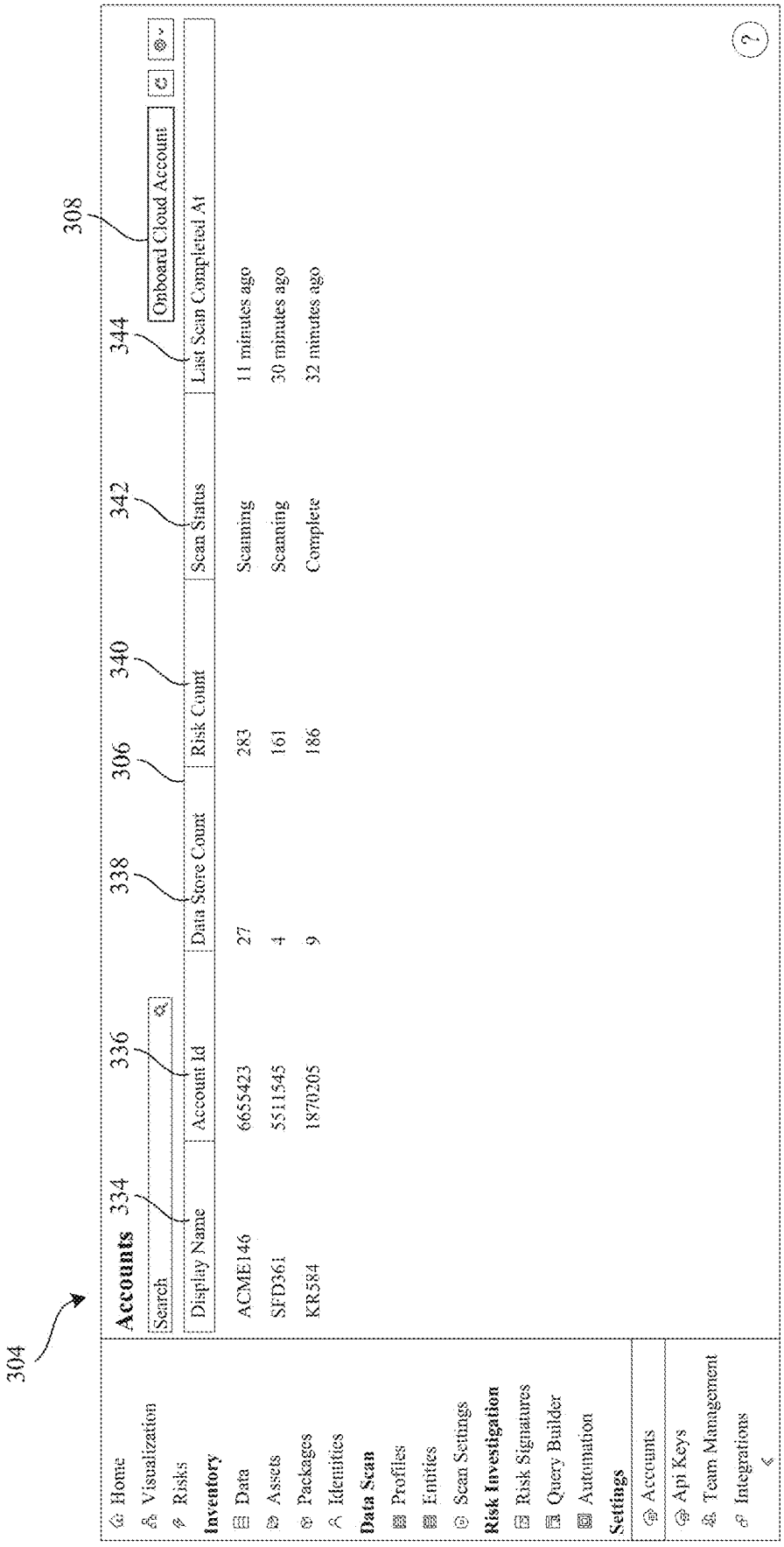

304
Home
Visualization
Risks
Inventory
Data
Assets
Packages
Identities
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automation
Settings
Accounts
Api Keys
Team Management
Integrations
Accounts
334
336
338
306
340
342
344
308
Search
Onboard Cloud Account
Display Name
Account Id
Data Store Count
Risk Count
Scan Status
Last Scan Completed At
ACME146 6655423 27 283 Scanning 11 minutes ago
SFD361 5511545 4 161 Scanning 30 minutes ago
KR584 1870205 9 186 Complete 32 minutes ago

FIG. 6

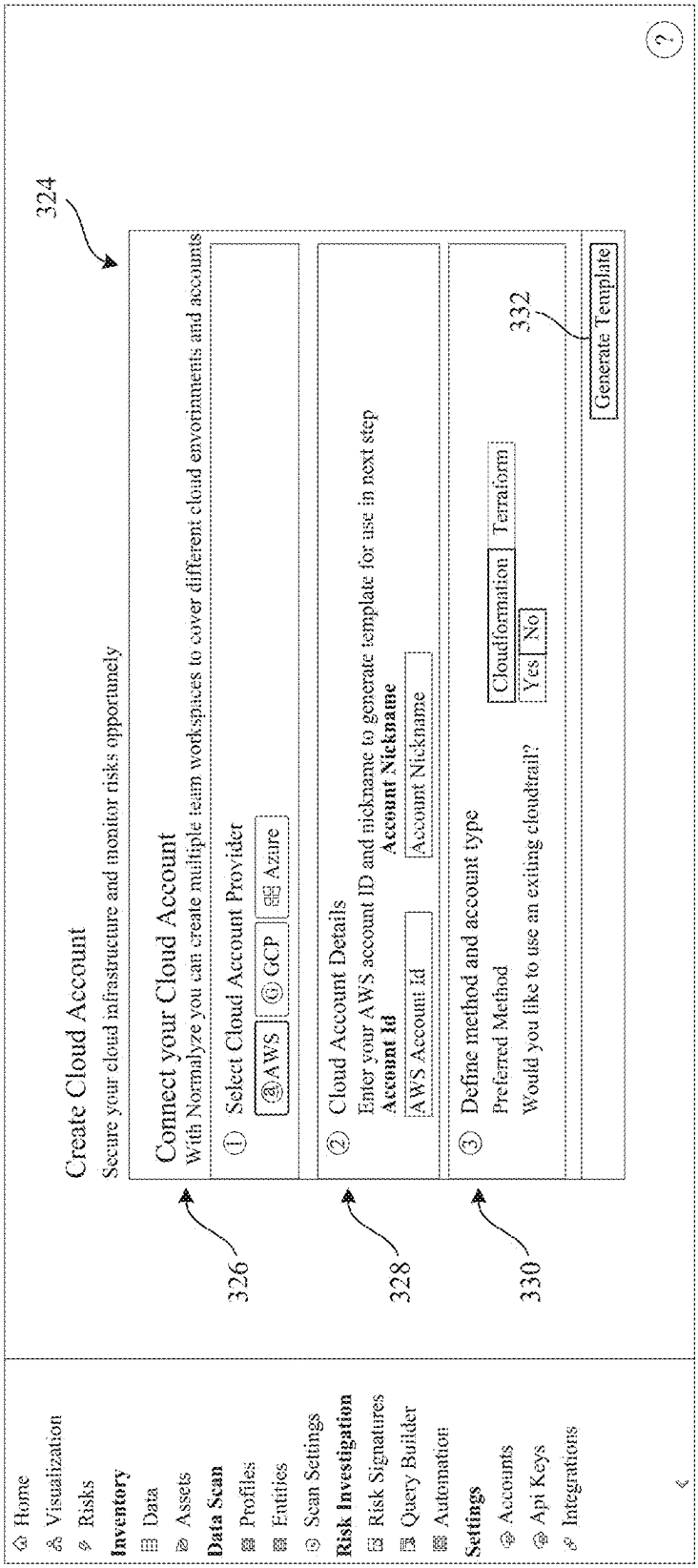

Home
Visualization
Risks
Inventory
Data
Assets
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automation
Settings
Accounts
Api Keys
Integrations
Create Cloud Account
Secure your cloud infrastructure and monitor risks opportunely
324
Connect your Cloud Account
With Normalyze you can create multiple team workspaces to cover different cloud environments and accounts
① Select Cloud Account Provider
AWS
GCP
Azure
326
② Cloud Account Details
Enter your AWS account ID and nickname to generate template for use in next step
Account Id
Account Nickname
AWS Account Id
Account Nickname
328
③ Define method and account type
Preferred Method
Cloudformation
Terraform
Would you like to use an exiting cloudtrail?
Yes
No
330
332
Generate Template
?

FIG. 7

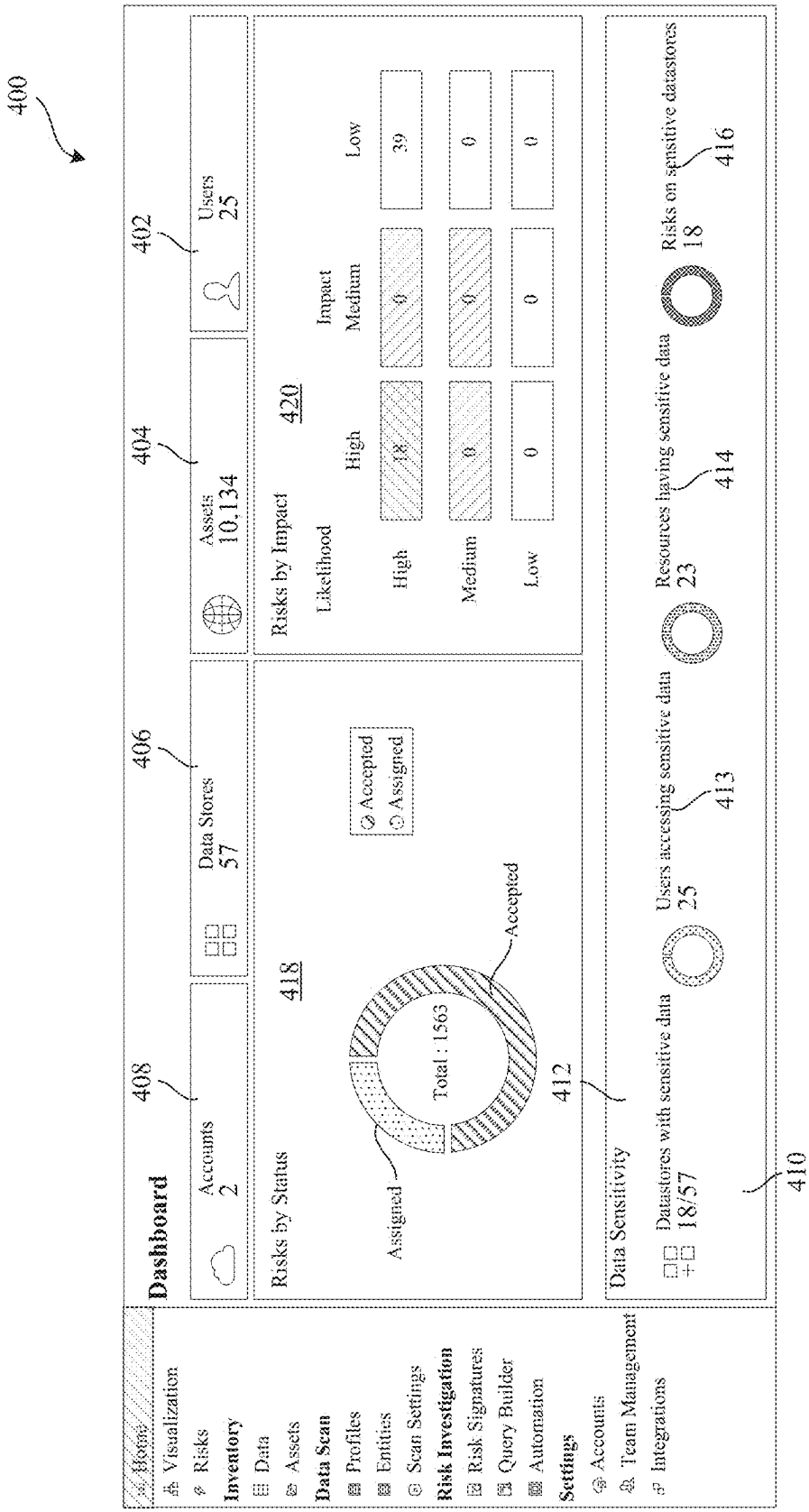

400
Home
Visualization
Risks
Inventory
Data
Assets
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automation
Settings
Accounts
Team Management
Integrations
Dashboard
408
Accounts
2
406
Data Stores
57
404
Assets
10,134
402
Users
25
Risks by Status
418
Assigned
Accepted
Total : 1563
Accepted
Assigned
412
Risks by Impact
420
Likelihood
Impact
High
Medium
Low
High
Medium
Low
18
0
39
0
0
0
0
0
Data Sensitivity
Datastores with sensitive data
18/57
Users accessing sensitive data
25
413
Resources having sensitive data
23
414
Risks on sensitive datastores
18
416
410

FIG. 8

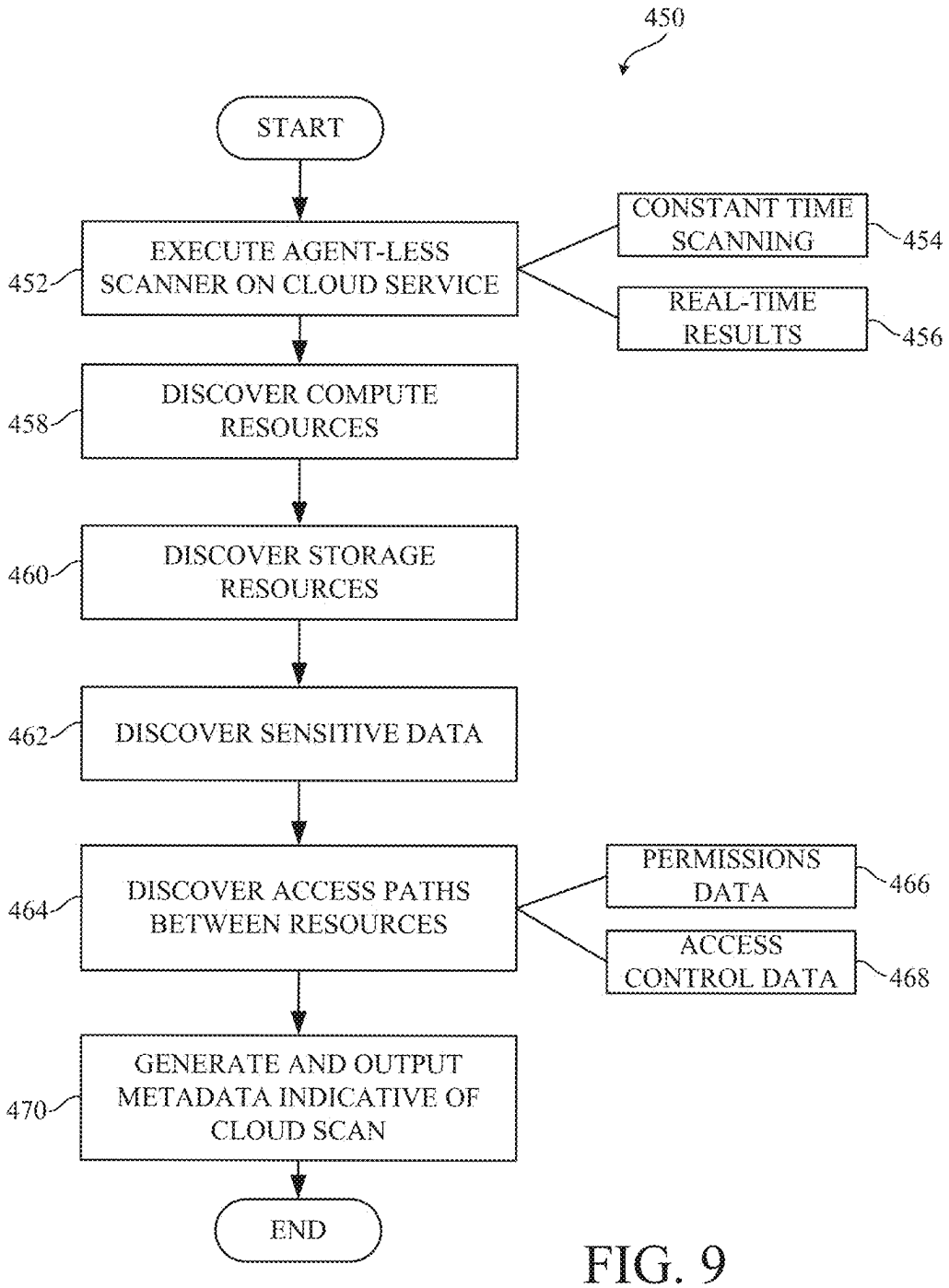

450
START
EXECUTE AGENT-LESS SCANNER ON CLOUD SERVICE
452
CONSTANT TIME SCANNING
454
REAL-TIME RESULTS
456
DISCOVER COMPUTE RESOURCES
458
DISCOVER STORAGE RESOURCES
460
DISCOVER SENSITIVE DATA
462
DISCOVER ACCESS PATHS BETWEEN RESOURCES
464
PERMISSIONS DATA
466
ACCESS CONTROL DATA
468
GENERATE AND OUTPUT METADATA INDICATIVE OF CLOUD SCAN
470
END

FIG. 9

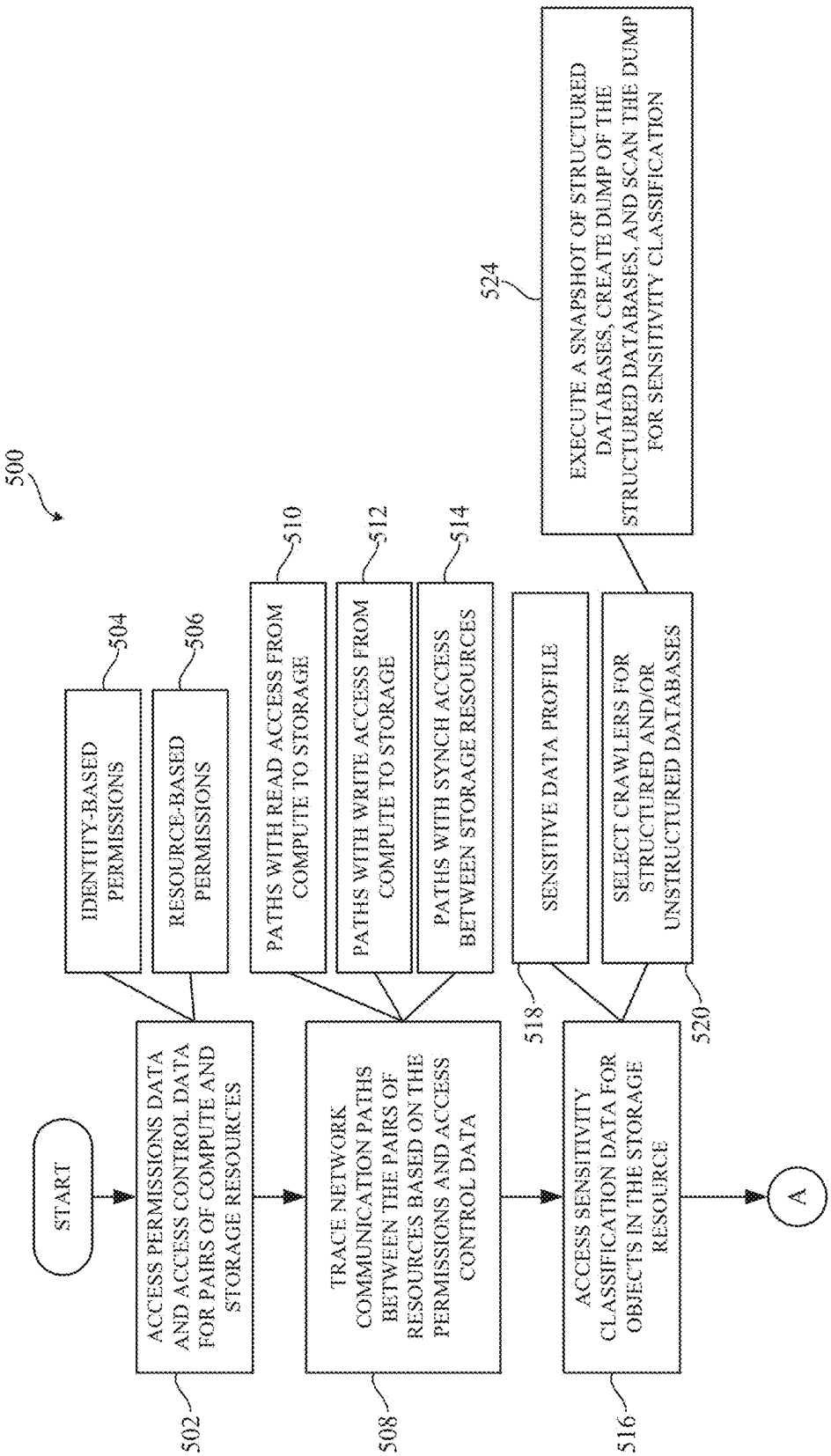

500
START
ACCESS PERMISSIONS DATA AND ACCESS CONTROL DATA FOR PAIRS OF COMPUTE AND STORAGE RESOURCES
502
IDENTITY-BASED PERMISSIONS
504
RESOURCE-BASED PERMISSIONS
506
TRACE NETWORK COMMUNICATION PATHS BETWEEN THE PAIRS OF RESOURCES BASED ON THE PERMISSIONS AND ACCESS CONTROL DATA
508
PATHS WITH READ ACCESS FROM COMPUTE TO STORAGE
510
PATHS WITH WRITE ACCESS FROM COMPUTE TO STORAGE
512
PATHS WITH SYNCH ACCESS BETWEEN STORAGE RESOURCES
514
ACCESS SENSITIVITY CLASSIFICATION DATA FOR OBJECTS IN THE STORAGE RESOURCE
516
SENSITIVE DATA PROFILE
518
SELECT CRAWLERS FOR STRUCTURED AND/OR UNSTRUCTURED DATABASES
520
EXECUTE A SNAPSHOT OF STRUCTURED DATABASES, CREATE DUMP OF THE STRUCTURED DATABASES, AND SCAN THE DUMP FOR SENSITIVITY CLASSIFICATION
524
A

FIG. 10-1

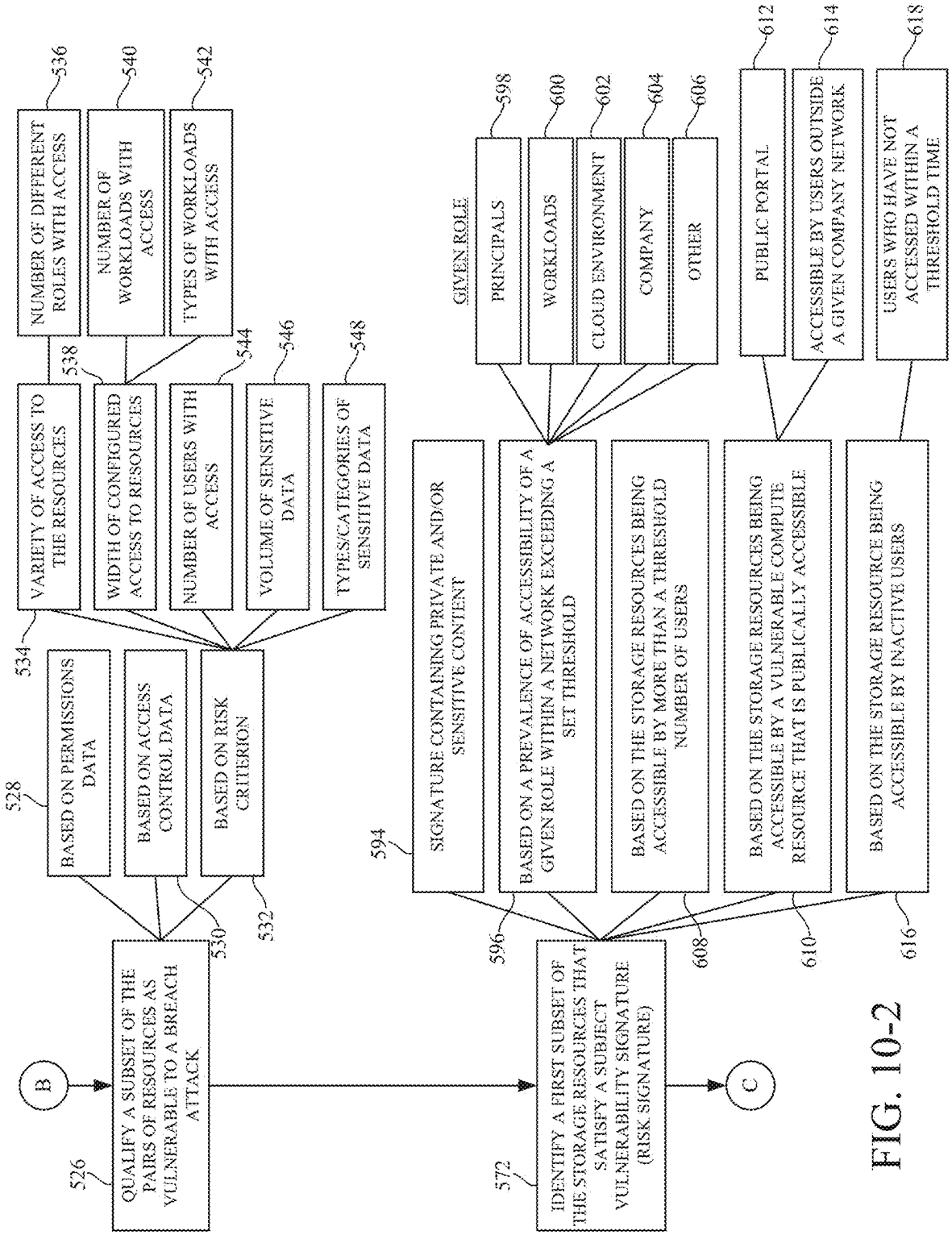

B
526
QUALIFY A SUBSET OF THE PAIRS OF RESOURCES AS VULNERABLE TO A BREACH ATTACK
528
BASED ON PERMISSIONS DATA
530
BASED ON ACCESS CONTROL DATA
532
BASED ON RISK CRITERION
534
VARIETY OF ACCESS TO THE RESOURCES
536
NUMBER OF DIFFERENT ROLES WITH ACCESS
538
WIDTH OF CONFIGURED ACCESS TO RESOURCES
540
NUMBER OF WORKLOADS WITH ACCESS
542
TYPES OF WORKLOADS WITH ACCESS
544
NUMBER OF USERS WITH ACCESS
546
VOLUME OF SENSITIVE DATA
548
TYPES/CATEGORIES OF SENSITIVE DATA
572
IDENTIFY A FIRST SUBSET OF THE STORAGE RESOURCES THAT SATISFY A SUBJECT VULNERABILITY SIGNATURE (RISK SIGNATURE)
594
SIGNATURE CONTAINING PRIVATE AND/OR SENSITIVE CONTENT
596
BASED ON A PREVALENCE OF ACCESSIBILITY OF A GIVEN ROLE WITHIN A NETWORK EXCEEDING A SET THRESHOLD
GIVEN ROLE
598
PRINCIPALS
600
WORKLOADS
602
CLOUD ENVIRONMENT
604
COMPANY
606
OTHER
608
BASED ON THE STORAGE RESOURCES BEING ACCESSIBLE BY MORE THAN A THRESHOLD NUMBER OF USERS
610
BASED ON THE STORAGE RESOURCES BEING ACCESSIBLE BY A VULNERABLE COMPUTE RESOURCE THAT IS PUBLICALLY ACCESSIBLE
612
PUBLIC PORTAL
614
ACCESSIBLE BY USERS OUTSIDE A GIVEN COMPANY NETWORK
616
BASED ON THE STORAGE RESOURCE BEING ACCESSIBLE BY INACTIVE USERS
618
USERS WHO HAVE NOT ACCESSED WITHIN A THRESHOLD TIME
C

FIG. 10-2

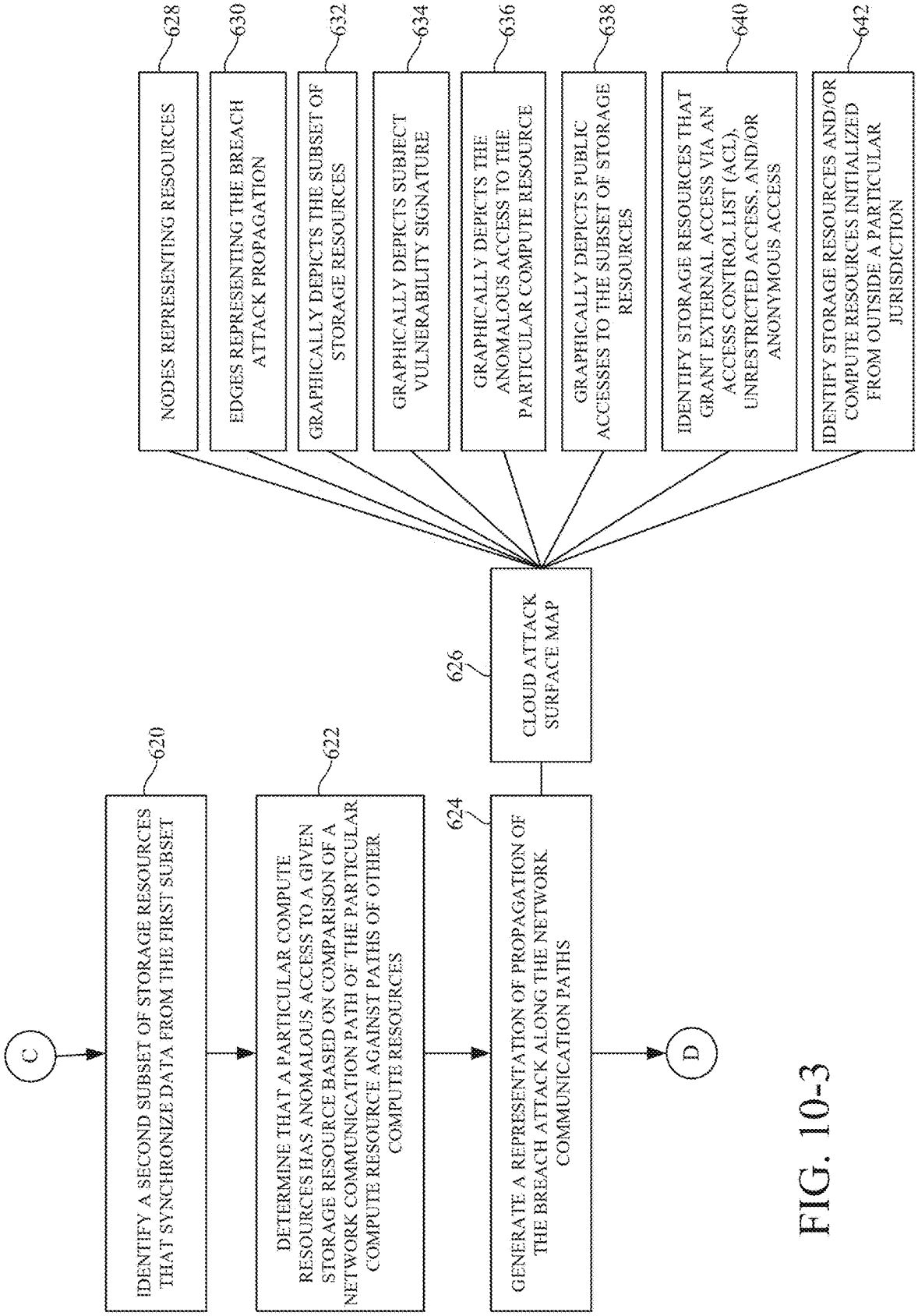

C
620
IDENTIFY A SECOND SUBSET OF STORAGE RESOURCES THAT SYNCHRONIZE DATA FROM THE FIRST SUBSET
622
DETERMINE THAT A PARTICULAR COMPUTE RESOURCES HAS ANOMALOUS ACCESS TO A GIVEN STORAGE RESOURCE BASED ON COMPARISON OF A NETWORK COMMUNICATION PATH OF THE PARTICULAR COMPUTE RESOURCE AGAINST PATHS OF OTHER COMPUTE RESOURCES
624
GENERATE A REPRESENTATION OF PROPAGATION OF THE BREACH ATTACK ALONG THE NETWORK COMMUNICATION PATHS
D
626
CLOUD ATTACK SURFACE MAP
628
NODES REPRESENTING RESOURCES
630
EDGES REPRESENTING THE BREACH ATTACK PROPAGATION
632
GRAPHICALLY DEPICTS THE SUBSET OF STORAGE RESOURCES
634
GRAPHICALLY DEPICTS SUBJECT VULNERABILITY SIGNATURE
636
GRAPHICALLY DEPICTS THE ANOMALOUS ACCESS TO THE PARTICULAR COMPUTE RESOURCE
638
GRAPHICALLY DEPICTS PUBLIC ACCESSES TO THE SUBSET OF STORAGE RESOURCES
640
IDENTIFY STORAGE RESOURCES THAT GRANT EXTERNAL ACCESS VIA AN ACCESS CONTROL LIST (ACL), UNRESTRICTED ACCESS, AND/OR ANONYMOUS ACCESS
642
IDENTIFY STORAGE RESOURCES AND/OR COMPUTE RESOURCES INITIALIZED FROM OUTSIDE A PARTICULAR JURISDICTION

FIG. 10-3

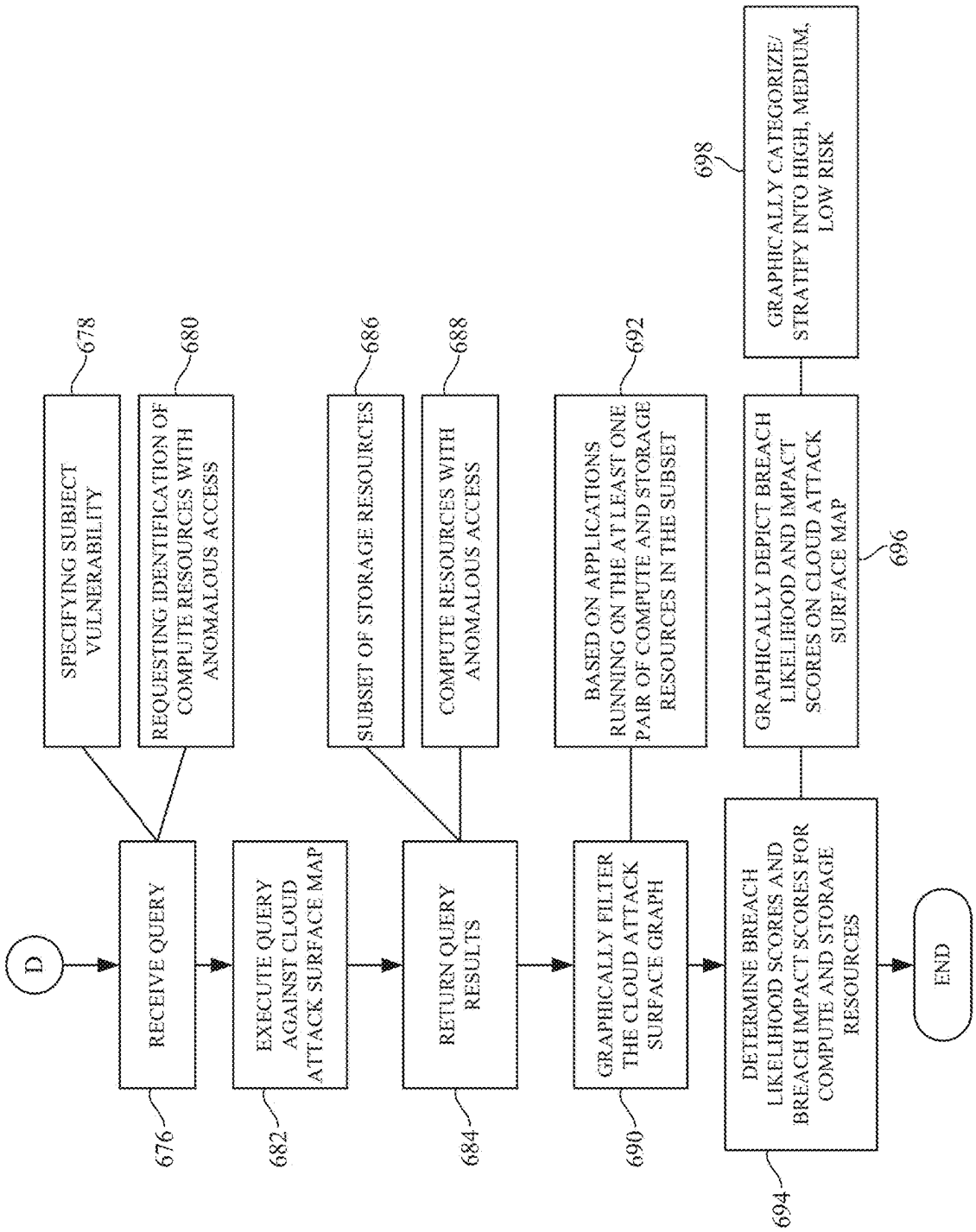

D
RECEIVE QUERY
676
SPECIFYING SUBJECT VULNERABILITY
678
REQUESTING IDENTIFICATION OF COMPUTE RESOURCES WITH ANOMALOUS ACCESS
680
EXECUTE QUERY AGAINST CLOUD ATTACK SURFACE MAP
682
RETURN QUERY RESULTS
684
SUBSET OF STORAGE RESOURCES
686
COMPUTE RESOURCES WITH ANOMALOUS ACCESS
688
GRAPHICALLY FILTER THE CLOUD ATTACK SURFACE GRAPH
690
BASED ON APPLICATIONS RUNNING ON THE AT LEAST ONE PAIR OF COMPUTE AND STORAGE RESOURCES IN THE SUBSET
692
DETERMINE BREACH LIKELIHOOD SCORES AND BREACH IMPACT SCORES FOR COMPUTE AND STORAGE RESOURCES
694
GRAPHICALLY DEPICT BREACH LIKELIHOOD AND IMPACT SCORES ON CLOUD ATTACK SURFACE MAP
696
GRAPHICALLY CATEGORIZE/ STRATIFY INTO HIGH, MEDIUM, LOW RISK
698
END

FIG. 10-4

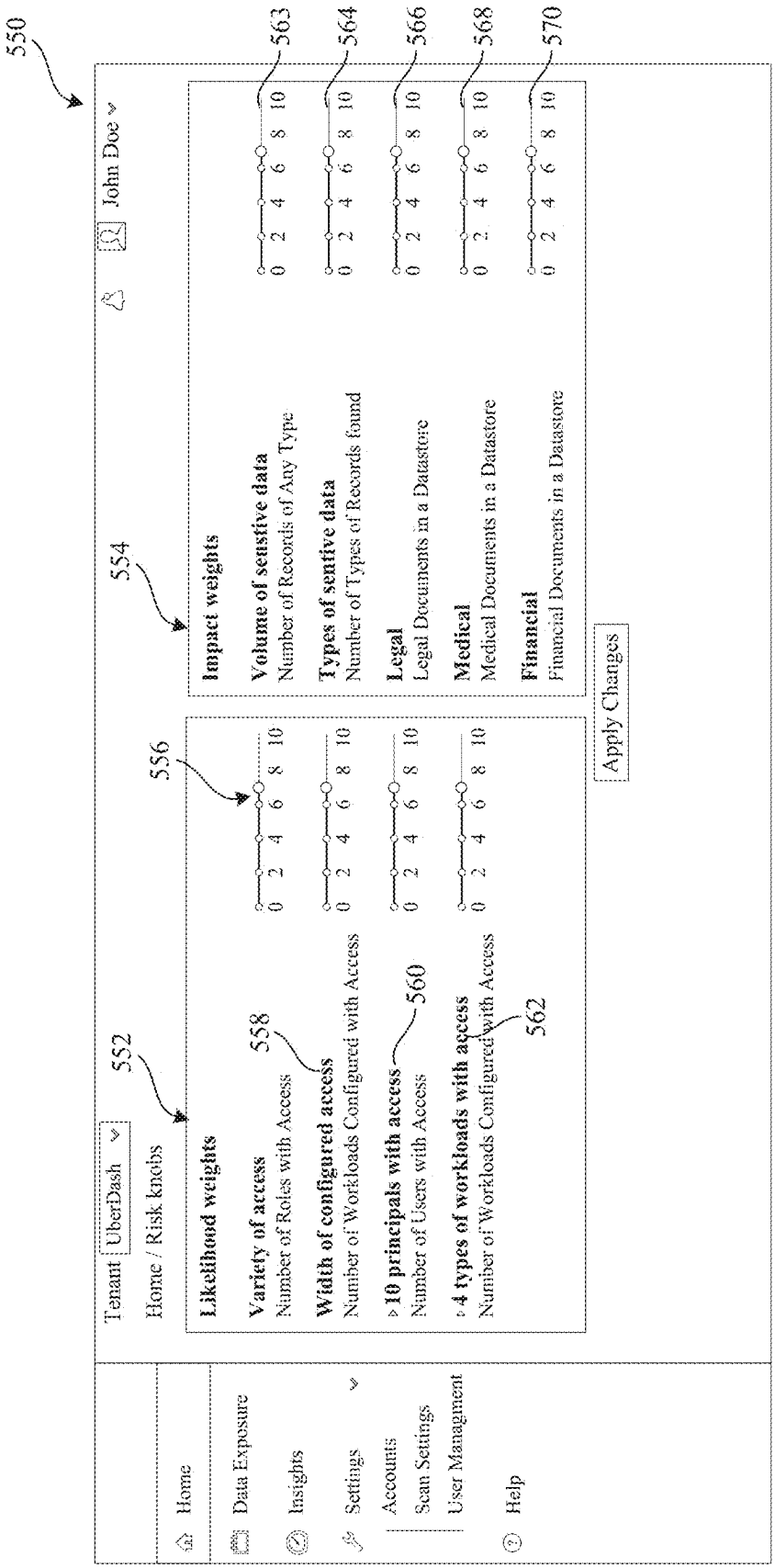

550
Home
Data Exposure
Insights
Settings
Accounts
Scan Settings
User Managment
Help
Tenant UberDash
552
Home / Risk knobs
John Doe
554
Likelihood weights
Variety of access
Number of Roles with Access
558
Width of configured access
Number of Workloads Configured with Access
>10 principals with access
Number of Users with Access
560
>4 types of workloads with access
Number of Workloads Configured with Access
562
556
0 2 4 6 8 10
Impact weights
Volume of sensitive data
Number of Records of Any Type
563
Types of sentive data
Number of Types of Records found
564
Legal
Legal Documents in a Datastore
566
Medical
Medical Documents in a Datastore
568
Financial
Financial Documents in a Datastore
570
Apply Changes

FIG. 11

576

574

- Home
- Visualization
- Risks

**Inventory**

- Data
- Assets

**Data Scan**

- Profiles
- Entities
- Scan Settings

**Risk Investigation**

- Risk Signatures
- Query Builder
- Automation

**Settings**

- Accounts
- Api Keys
- Team Management
- Integrations

**Risk Signatures** 578 580 582 584 586 588 590 592

Search

| Name | Signature Id | Description | Result Header | Resource | Tags | Likelihood Factor | Impact Factor |
|---|---|---|---|---|---|---|---|
| s3_bucket_mfa_deletion_not_enabled | 3017 | S3 Bucket's MFA delete is disabled | account_id account_name bucket_id +6 | bucket_arn | aws s3 configuration_check | 7 | |
| s3_bucket_not_enable_transfer_acceleration | 3022 | S3 Bucket's transfer acceleration is disabled | account_id account_name bucket_id +6 | bucket_arn | aws s3 | 3 | |
| s3_bucket_granting_write_access_to_all_authenticated_users | 3026 | S3 Bucket's grants WRITE (Upload/Delete) access to all authenti... | account_id account_name bucket_id +6 | bucket_arn | aws s3 iam | 10 | |
| s3_bucket_server_side_encryption_not_enabled | 3013 | S3 Bucket's default encryption is not enabled | account_id account_name bucket_id +6 | bucket_arn | aws s3 GDPR | 7 | |
| s3_bucket_name_not_dns_compilant | 3012 | S3 Bucket's name is not DNS complaint | account_id account_name bucket_id +6 | bucket_arn | aws s3 | 3 | |
| s3_bucket_not_enable_object_lock | 3021 | S3 Bucket's object lock is not enabled | account_id account_name bucket_id +6 | bucket_arn | aws s3 | 3 | |
| iam_password_policy_with_minimal_length_less_than_14_having_access_to_sensitive_data | 2534 | IAM User's password policy does not require minimal length o... | account_id account_name bucket_id +8 | bucket_arn | aws iam | 10 | 10 |

1-30 of 230 items < 1 2 3 4 5 ... 8 > 30 / page

FIG. 12

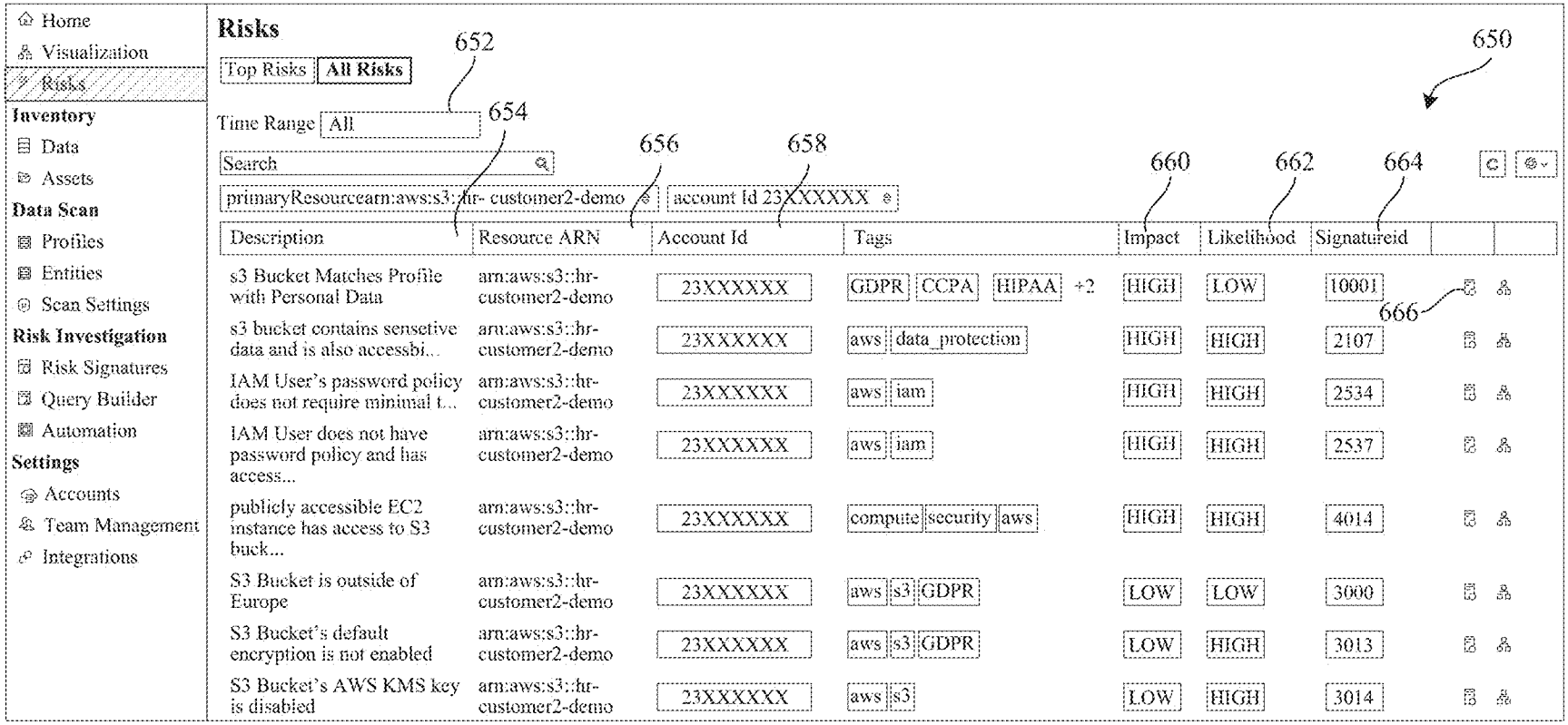

Home
Visualization
Risks
Inventory
Data
Assets
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automation
Settings
Accounts
Team Management
Integrations
Risks
Top Risks
All Risks
Time Range
All
Search
primaryResourcearn:aws:s3::hr- customer2-demo
account Id 23XXXXXX
Description
Resource ARN
Account Id
Tags
Impact
Likelihood
Signatureid
s3 Bucket Matches Profile with Personal Data
arn:aws:s3::hr-customer2-demo
23XXXXXX
GDPR
CCPA
HIPAA
+2
HIGH
LOW
10001
s3 bucket contains sensetive data and is also accessbi...
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
data_protection
HIGH
HIGH
2107
IAM User's password policy does not require minimal t...
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
iam
HIGH
HIGH
2534
IAM User does not have password policy and has access...
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
iam
HIGH
HIGH
2537
publicly accessible EC2 instance has access to S3 buck...
arn:aws:s3::hr-customer2-demo
23XXXXXX
compute
security
aws
HIGH
HIGH
4014
S3 Bucket is outside of Europe
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
s3
GDPR
LOW
LOW
3000
S3 Bucket's default encryption is not enabled
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
s3
GDPR
LOW
HIGH
3013
S3 Bucket's AWS KMS key is disabled
arn:aws:s3::hr-customer2-demo
23XXXXXX
aws
s3
LOW
HIGH
3014
650
652
654
656
658
660
662
664
666

FIG. 13

650

668

670

672

Home
Visualization
Risks
**Inventory**
Data
Assets
**Data Scan**
Profiles
Entities
Scan Settings
**Risk Investigation**
Risk Signatures
Query Builder
Automation
**Settings**
Accounts
Team Management
Integrations

## Risks

Top Risks | **All Risks**

Time Range: All

Search

primaryResourcearn:aws:s3::hr- customer2-demo | account Id 23XXXXXX

| Description | Resource ARN | Account Id |
|---|---|---|
| s3 Bucket Matches Profile with Personal Data | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| s3 bucket contains sensetive data and is also accessbi... | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| IAM User's password policy does not require minimal t... | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| IAM User does not have password policy and has access... | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| Ipublicly accessible EC2 instance has access to S3 buck... | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| S3 Bucket is outside of Europe | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| S3 Bucket's default encryption is not enabled | arn:aws:s3::hr-customer2-demo | 23XXXXXX |
| S3 Bucket's AWS KMS key is disabled | arn:aws:s3::hr-customer2-demo | 23XXXXXX |

## Risks Overview

First Seen: a month ago

Impact/Likelihood: HIGH | HIGH

**Details** | Actions | JSON

**Risk Description** Publicly accessible EC2 Instance has access to S3 bucket containing sensitive data.

**Query** MATCH (a:AWSAccount).[:RESOURCE]->[i:EC2 Instance(exposed_internet:true)]-[:HAS_ROLE]-> (r:AWSRole).[:CAN_READ | CAN_WRITE]-> (s:S3 Bucket0.[:CONTAINS]->(t:SCANResult) WHERE a.id=(ACCOUNT_ID) RETURN

**Results**

| Key | Value |
|---|---|
| Impact | |
| Bucket_Id | hr-customer2-demo |
| riskScore | |
| account_Id | 23XXXXXX |
| bucket_arn | arn:aws:s3::hr-customer2-demo |
| Likelihood | |
| bucket_name | hr-customer2-demo |
| instance_Id | i.09acxxxxxxxxxxxx |
| account_name | default |
| instance_arn | arn:aws:ec2:us-east-2:23XXXXXX:instance/ i.09acxxxxxxxxxxxx |

FIG. 14

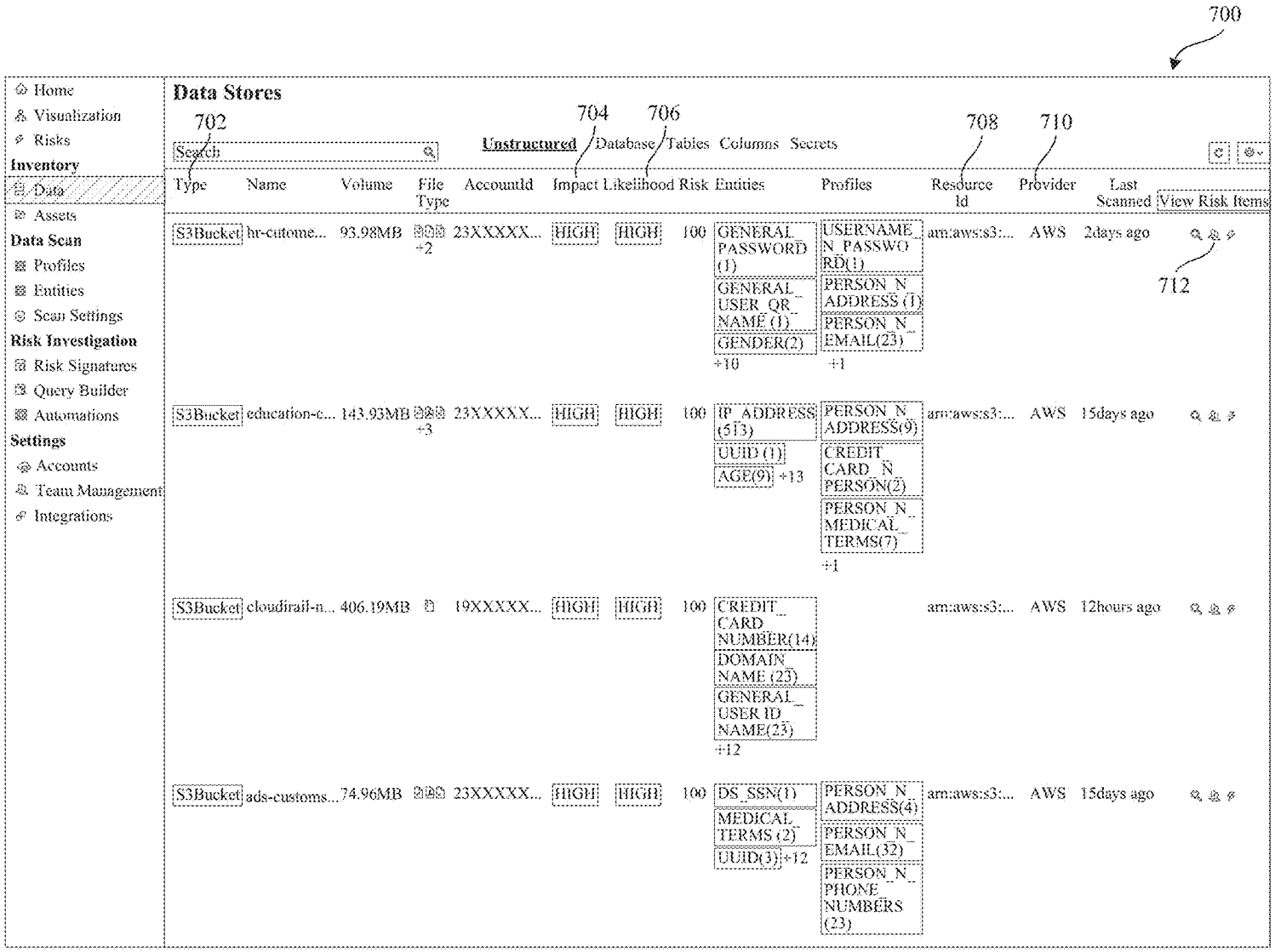

700
Home
Visualization
Risks
Inventory
Data
Assets
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automations
Settings
Accounts
Team Management
Integrations
Data Stores
702
704
706
708
710
712
Search
Unstructured
Database
Tables
Columns
Secrets
Type
Name
Volume
File Type
AccountId
Impact
Likelihood
Risk
Entities
Profiles
Resource Id
Provider
Last Scanned
View Risk Items
S3Bucket
hr-cutome...
93.98MB
+2
23XXXXX...
HIGH
HIGH
100
GENERAL_PASSWORD (1)
GENERAL_USER_QR_NAME (1)
GENDER(2)
+10
USERNAME_N_PASSWORD(1)
PERSON_N_ADDRESS (1)
PERSON_N_EMAIL(23)
+1
arn:aws:s3:...
AWS
2days ago
S3Bucket
education-c...
143.93MB
+3
23XXXXX...
HIGH
HIGH
100
IP_ADDRESS (513)
UUID (1)
AGE(9)
+13
PERSON_N_ADDRESS(9)
CREDIT_CARD_N_PERSON(2)
PERSON_N_MEDICAL_TERMS(7)
+1
arn:aws:s3:...
AWS
15days ago
S3Bucket
cloudtrail-n...
406.19MB
19XXXXX...
HIGH
HIGH
100
CREDIT_CARD_NUMBER(14)
DOMAIN_NAME (23)
GENERAL_USER ID_NAME(23)
+12
arn:aws:s3:...
AWS
12hours ago
S3Bucket
ads-customs...
74.96MB
23XXXXX...
HIGH
HIGH
100
DS_SSN(1)
MEDICAL_TERMS (2)
UUID(3)
+12
PERSON_N_ADDRESS(4)
PERSON_N_EMAIL(32)
PERSON_N_PHONE_NUMBERS (23)
arn:aws:s3:...
AWS
15days ago

FIG. 15

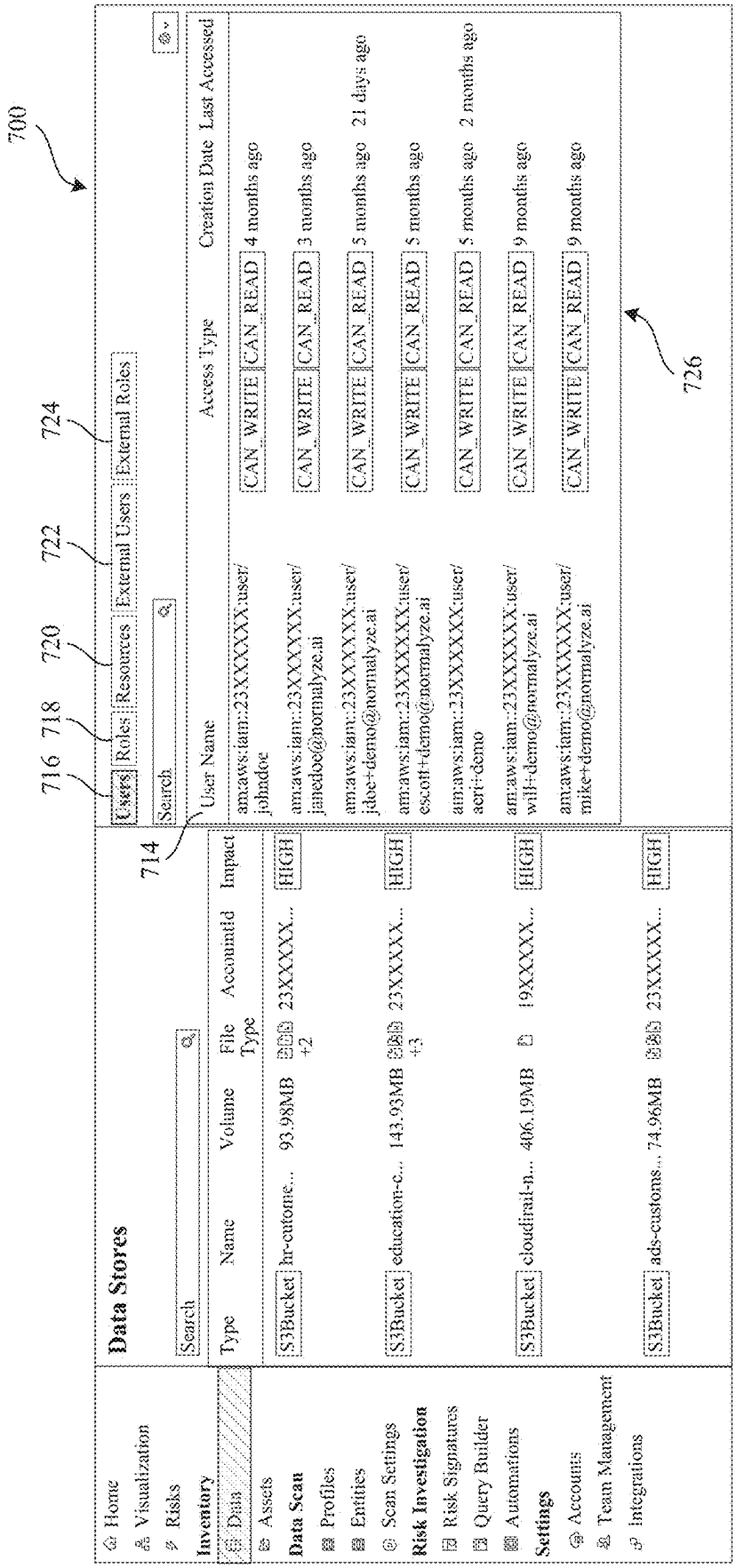

700
716
718
720
722
724
714
726
Home
Visualization
Risks
Inventory
Data
Assets
Data Scan
Profiles
Entities
Scan Settings
Risk Investigation
Risk Signatures
Query Builder
Automations
Settings
Accounts
Team Management
Integrations
Data Stores
Search
Type
Name
Volume
File Type
AccountId
Impact
S3Bucket
hr-cutome...
93.98MB
+2
23XXXXX...
HIGH
education-c...
143.93MB
+3
23XXXXX...
HIGH
cloudirait-n...
406.19MB
19XXXXX...
HIGH
ads-customs...
74.96MB
23XXXXX...
HIGH
Users
Roles
Resources
External Users
External Roles
Search
User Name
Access Type
Creation Date
Last Accessed
am:aws:iam::23XXXXXX:user/johndoe
CAN_WRITE
CAN_READ
4 months ago
am:aws:iam::23XXXXXX:user/janedoe@normalyze.ai
CAN_WRITE
CAN_READ
3 months ago
am:aws:iam::23XXXXXX:user/jdoe+demo@normalyze.ai
CAN_WRITE
CAN_READ
5 months ago
21 days ago
am:aws:iam::23XXXXXX:user/escott+demo@normalyze.ai
CAN_WRITE
CAN_READ
5 months ago
am:aws:iam::23XXXXXX:user/aeri+demo
CAN_WRITE
CAN_READ
5 months ago
2 months ago
am:aws:iam::23XXXXXX:user/will+demo@normalyze.ai
CAN_WRITE
CAN_READ
9 months ago
am:aws:iam::23XXXXXX:user/mike+demo@normalyze.ai
CAN_WRITE
CAN_READ
9 months ago

FIG. 16

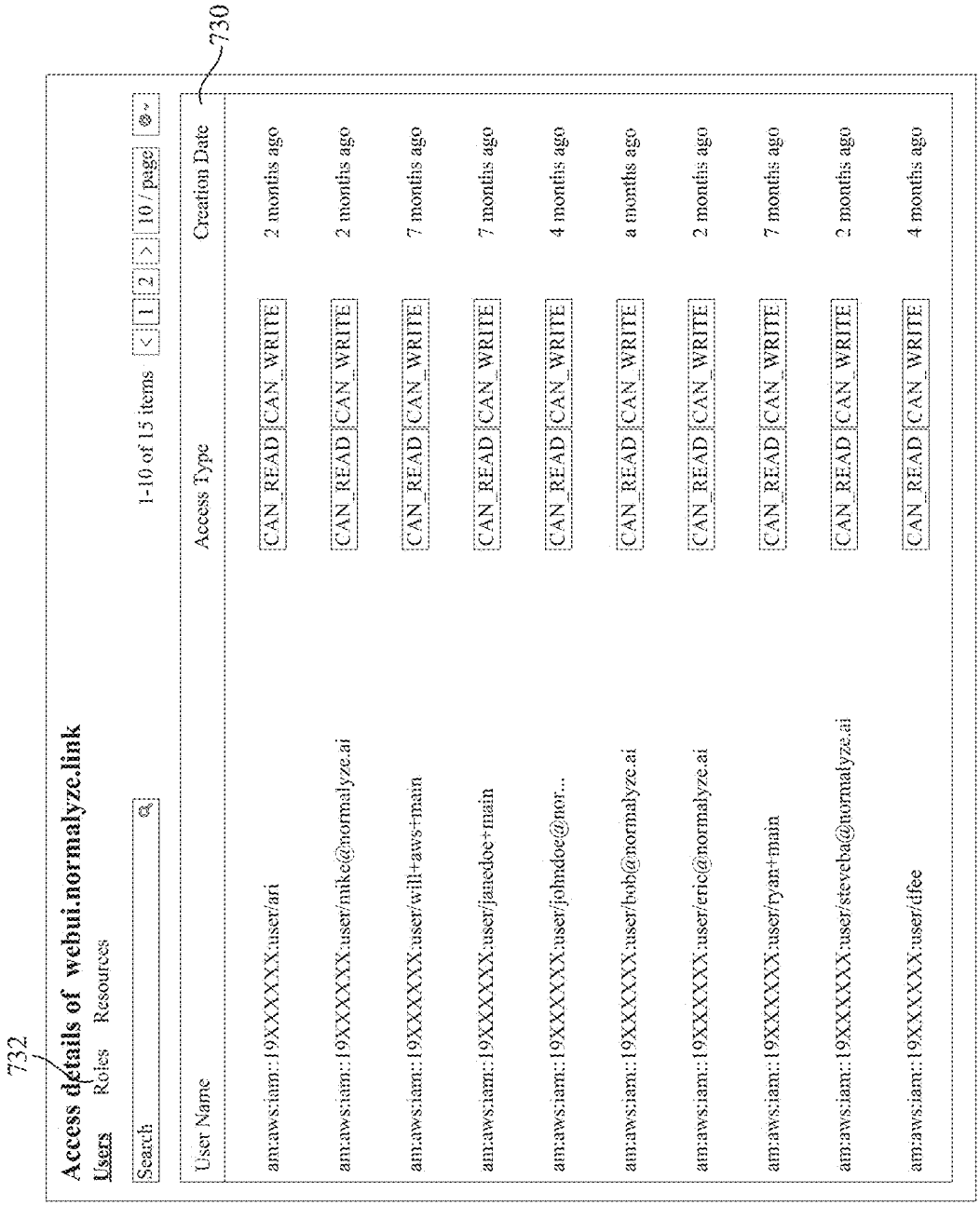

732
730
Access details of webui.normalyze.link
Users
Roles
Resources
Search
1-10 of 15 items
< 1 2 > 10 / page
User Name
Access Type
Creation Date
arn:aws:iam::19XXXXXX:user/ari
CAN_READ CAN_WRITE
2 months ago
arn:aws:iam::19XXXXXX:user/mike@normalyze.ai
CAN_READ CAN_WRITE
2 months ago
arn:aws:iam::19XXXXXX:user/will+aws+main
CAN_READ CAN_WRITE
7 months ago
arn:aws:iam::19XXXXXX:user/janedoe+main
CAN_READ CAN_WRITE
7 months ago
arn:aws:iam::19XXXXXX:user/johndoe@nor...
CAN_READ CAN_WRITE
4 months ago
arn:aws:iam::19XXXXXX:user/bob@normalyze.ai
CAN_READ CAN_WRITE
a months ago
arn:aws:iam::19XXXXXX:user/eric@normalyze.ai
CAN_READ CAN_WRITE
2 months ago
arn:aws:iam::19XXXXXX:user/ryan+main
CAN_READ CAN_WRITE
7 months ago
arn:aws:iam::19XXXXXX:user/steveba@normalyze.ai
CAN_READ CAN_WRITE
2 months ago
arn:aws:iam::19XXXXXX:user/dfee
CAN_READ CAN_WRITE
4 months ago

FIG. 17

734

**Access details of webui.normalyze.link**

Users **Roles** Resources

Search

1-10 of 11 items < 1 2 > 10 / page

| Role Name | Access Type | Creation Date |
|---|---|---|
| am:aws:iam::45XXXXX:role/platform-45XXXXX-_ | CAN_READ | 6 days ago |
| am:aws:iam::45XXXXX:rty_role | CAN_READ CAN_WRITE | 5 months ago |
| am:aws:iam::45XXXXX:role/deploy-compute_access-sm | CAN_READ CAN_WRITE | 3 months ago |
| am:aws:iam::45XXXXX:role/normalyze-45XXXXX | CAN_READ | a months ago |
| am:aws:iam::45XXXXX:role/EnableDeployAcce... | CAN_READ CAN_WRITE | 3 months ago |
| am:aws:iam::45XXXXX:role/test_scan | CAN_READ CAN_WRITE | 7 months ago |
| am:aws:iam::45XXXXX:role/OrganizationAccountAccess... | CAN_READ CAN_WRITE | 7 months ago |
| am:aws:iam::45XXXXX:role/analyzerplatform-051_ | CAN_READ | a day ago |
| am:aws:iam::45XXXXX:role/cloud_scanner | CAN_READ CAN_WRITE | 7 months ago |
| am:aws:iam::45XXXXX:roler/AWSCloudFormationStackSe... | CAN_READ | a months ago |

FIG. 18

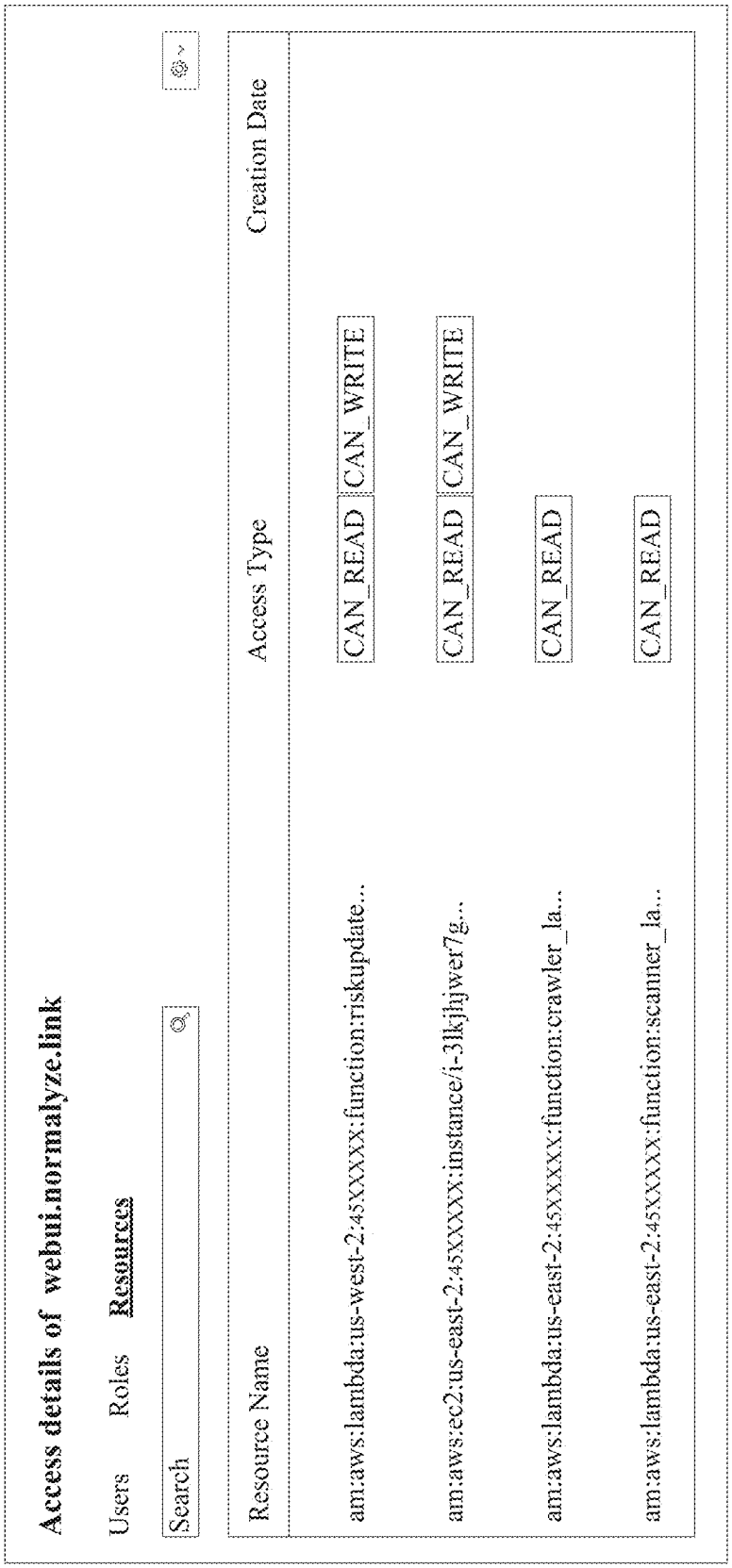

Access details of webui.normalyze.link
Users
Roles
Resources
Search
Resource Name
Access Type
Creation Date
am:aws:lambda:us-west-2:45XXXXX:function:riskupdate...
CAN_READ
CAN_WRITE
am:aws:ec2:us-east-2:45XXXXX:instance/i-3lkjhjwer7g...
CAN_READ
CAN_WRITE
am:aws:lambda:us-east-2:45XXXXX:function:crawler_la...
CAN_READ
am:aws:lambda:us-east-2:45XXXXX:function:scanner_la...
CAN_READ

FIG. 19

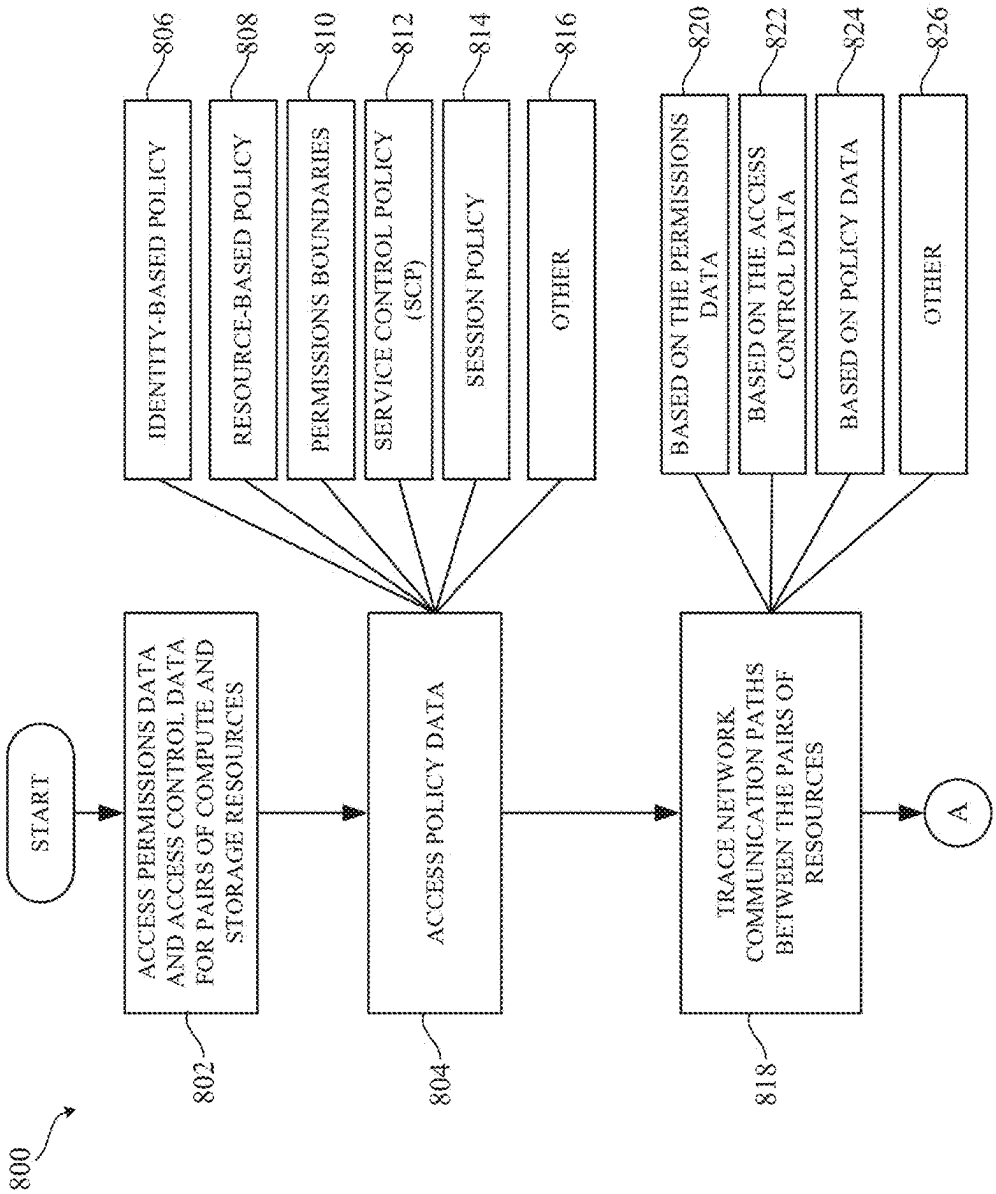

800
START
ACCESS PERMISSIONS DATA AND ACCESS CONTROL DATA FOR PAIRS OF COMPUTE AND STORAGE RESOURCES
802
ACCESS POLICY DATA
804
IDENTITY-BASED POLICY
806
RESOURCE-BASED POLICY
808
PERMISSIONS BOUNDARIES
810
SERVICE CONTROL POLICY (SCP)
812
SESSION POLICY
814
OTHER
816
TRACE NETWORK COMMUNICATION PATHS BETWEEN THE PAIRS OF RESOURCES
818
BASED ON THE PERMISSIONS DATA
820
BASED ON THE ACCESS CONTROL DATA
822
BASED ON POLICY DATA
824
OTHER
826
A

FIG. 20-1

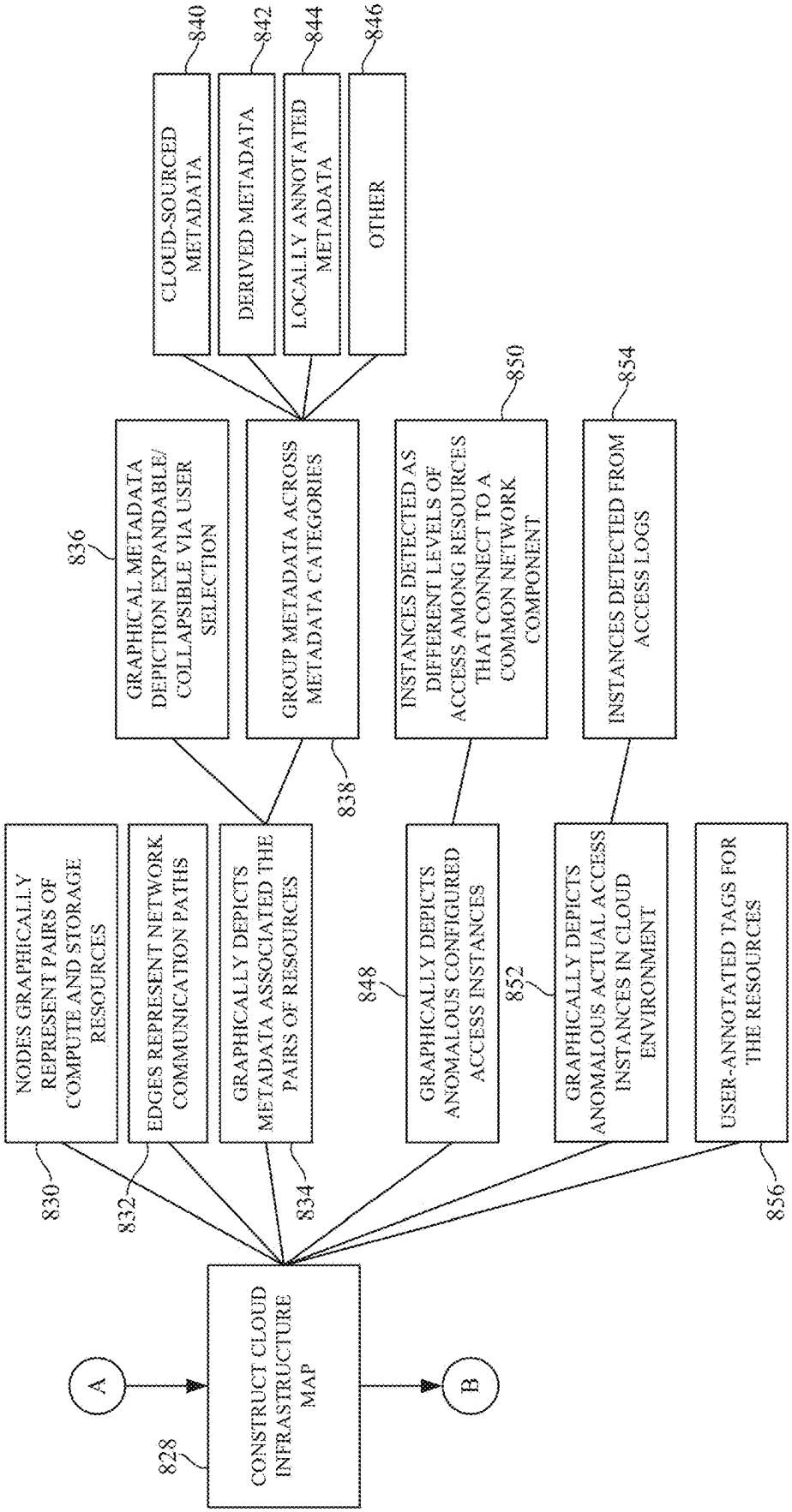

A
CONSTRUCT CLOUD INFRASTRUCTURE MAP
828
B
NODES GRAPHICALLY REPRESENT PAIRS OF COMPUTE AND STORAGE RESOURCES
830
EDGES REPRESENT NETWORK COMMUNICATION PATHS
832
GRAPHICALLY DEPICTS METADATA ASSOCIATED THE PAIRS OF RESOURCES
834
GRAPHICAL METADATA DEPICTION EXPANDABLE/ COLLAPSIBLE VIA USER SELECTION
836
GROUP METADATA ACROSS METADATA CATEGORIES
838
CLOUD-SOURCED METADATA
840
DERIVED METADATA
842
LOCALLY ANNOTATED METADATA
844
OTHER
846
GRAPHICALLY DEPICTS ANOMALOUS CONFIGURED ACCESS INSTANCES
848
INSTANCES DETECTED AS DIFFERENT LEVELS OF ACCESS AMONG RESOURCES THAT CONNECT TO A COMMON NETWORK COMPONENT
850
GRAPHICALLY DEPICTS ANOMALOUS ACTUAL ACCESS INSTANCES IN CLOUD ENVIRONMENT
852
INSTANCES DETECTED FROM ACCESS LOGS
854
USER-ANNOTATED TAGS FOR THE RESOURCES
856

FIG. 20-2

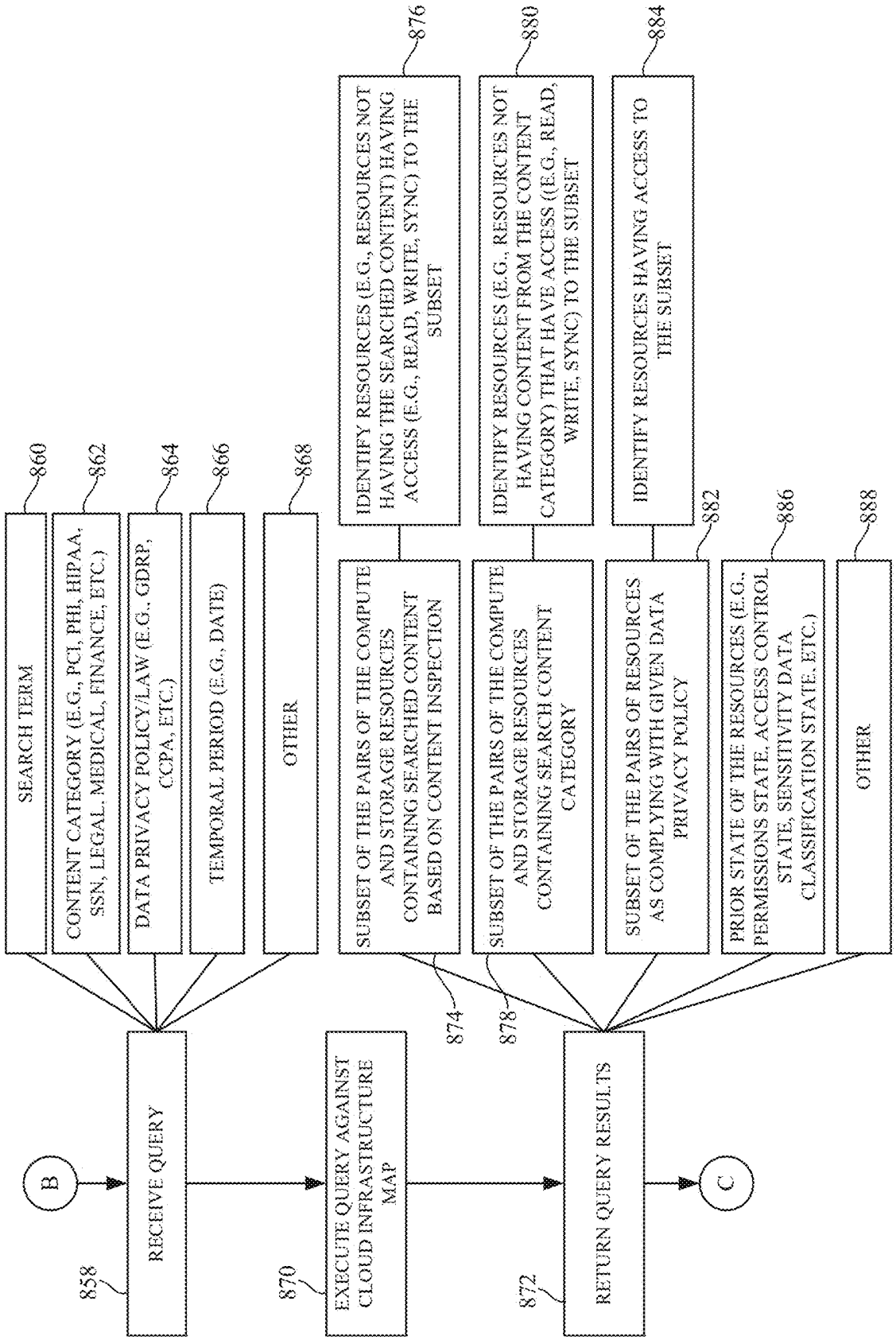

B
858
RECEIVE QUERY
860
SEARCH TERM
862
CONTENT CATEGORY (E.G., PCI, PHI, HIPAA, SSN, LEGAL, MEDICAL, FINANCE, ETC.)
864
DATA PRIVACY POLICY/LAW (E.G., GDRP, CCPA, ETC.)
866
TEMPORAL PERIOD (E.G., DATE)
868
OTHER
870
EXECUTE QUERY AGAINST CLOUD INFRASTRUCTURE MAP
872
RETURN QUERY RESULTS
874
SUBSET OF THE PAIRS OF THE COMPUTE AND STORAGE RESOURCES CONTAINING SEARCHED CONTENT BASED ON CONTENT INSPECTION
876
IDENTIFY RESOURCES (E.G., RESOURCES NOT HAVING THE SEARCHED CONTENT) HAVING ACCESS (E.G., READ, WRITE, SYNC) TO THE SUBSET
878
SUBSET OF THE PAIRS OF THE COMPUTE AND STORAGE RESOURCES CONTAINING SEARCH CONTENT CATEGORY
880
IDENTIFY RESOURCES (E.G., RESOURCES NOT HAVING CONTENT FROM THE CONTENT CATEGORY) THAT HAVE ACCESS ((E.G., READ, WRITE, SYNC) TO THE SUBSET
882
SUBSET OF THE PAIRS OF RESOURCES AS COMPLYING WITH GIVEN DATA PRIVACY POLICY
884
IDENTIFY RESOURCES HAVING ACCESS TO THE SUBSET
886
PRIOR STATE OF THE RESOURCES (E.G., PERMISSIONS STATE, ACCESS CONTROL STATE, SENSITIVITY DATA CLASSIFICATION STATE, ETC.)
888
OTHER
C

FIG. 20-3

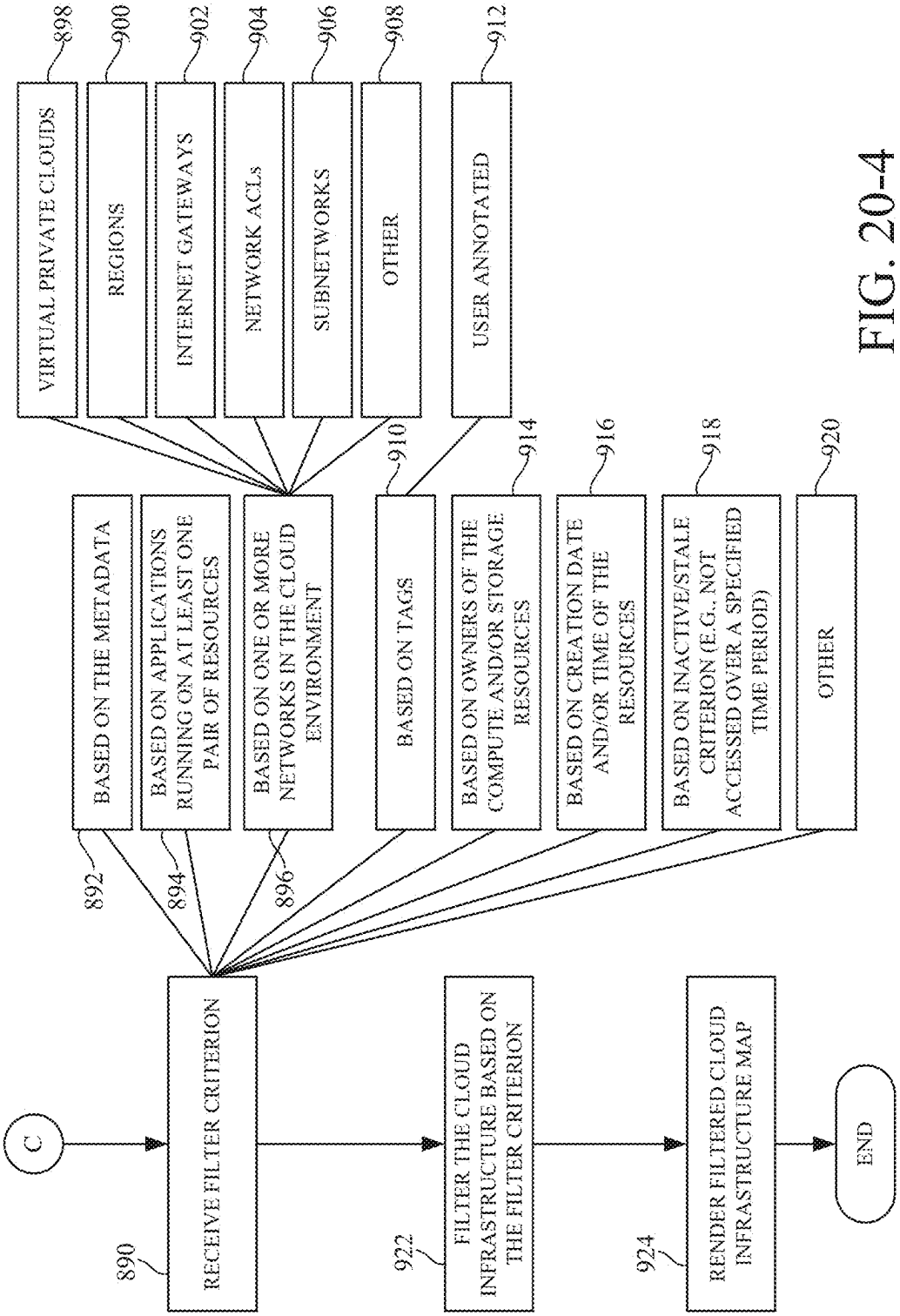

C
890
RECEIVE FILTER CRITERION
892
BASED ON THE METADATA
894
BASED ON APPLICATIONS RUNNING ON AT LEAST ONE PAIR OF RESOURCES
896
BASED ON ONE OR MORE NETWORKS IN THE CLOUD ENVIRONMENT
898
VIRTUAL PRIVATE CLOUDS
900
REGIONS
902
INTERNET GATEWAYS
904
NETWORK ACLs
906
SUBNETWORKS
908
OTHER
910
BASED ON TAGS
912
USER ANNOTATED
914
BASED ON OWNERS OF THE COMPUTE AND/OR STORAGE RESOURCES
916
BASED ON CREATION DATE AND/OR TIME OF THE RESOURCES
918
BASED ON INACTIVE/STALE CRITERION (E.G., NOT ACCESSED OVER A SPECIFIED TIME PERIOD)
920
OTHER
922
FILTER THE CLOUD INFRASTRUCTURE BASED ON THE FILTER CRITERION
924
RENDER FILTERED CLOUD INFRASTRUCTURE MAP
END

FIG. 20-4

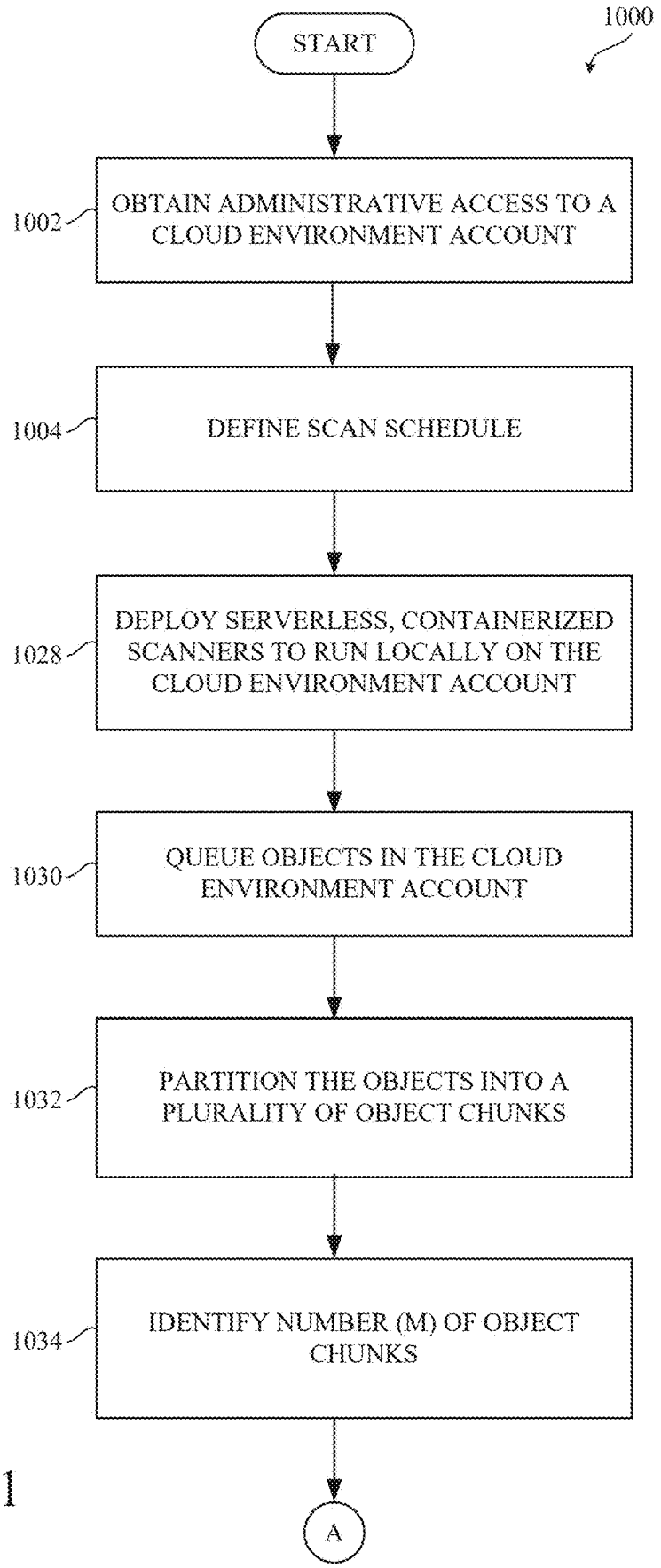

1000
START
1002
OBTAIN ADMINISTRATIVE ACCESS TO A CLOUD ENVIRONMENT ACCOUNT
1004
DEFINE SCAN SCHEDULE
1028
DEPLOY SERVERLESS, CONTAINERIZED SCANNERS TO RUN LOCALLY ON THE CLOUD ENVIRONMENT ACCOUNT
1030
QUEUE OBJECTS IN THE CLOUD ENVIRONMENT ACCOUNT
1032
PARTITION THE OBJECTS INTO A PLURALITY OF OBJECT CHUNKS
1034
IDENTIFY NUMBER (M) OF OBJECT CHUNKS
A

FIG. 21-1

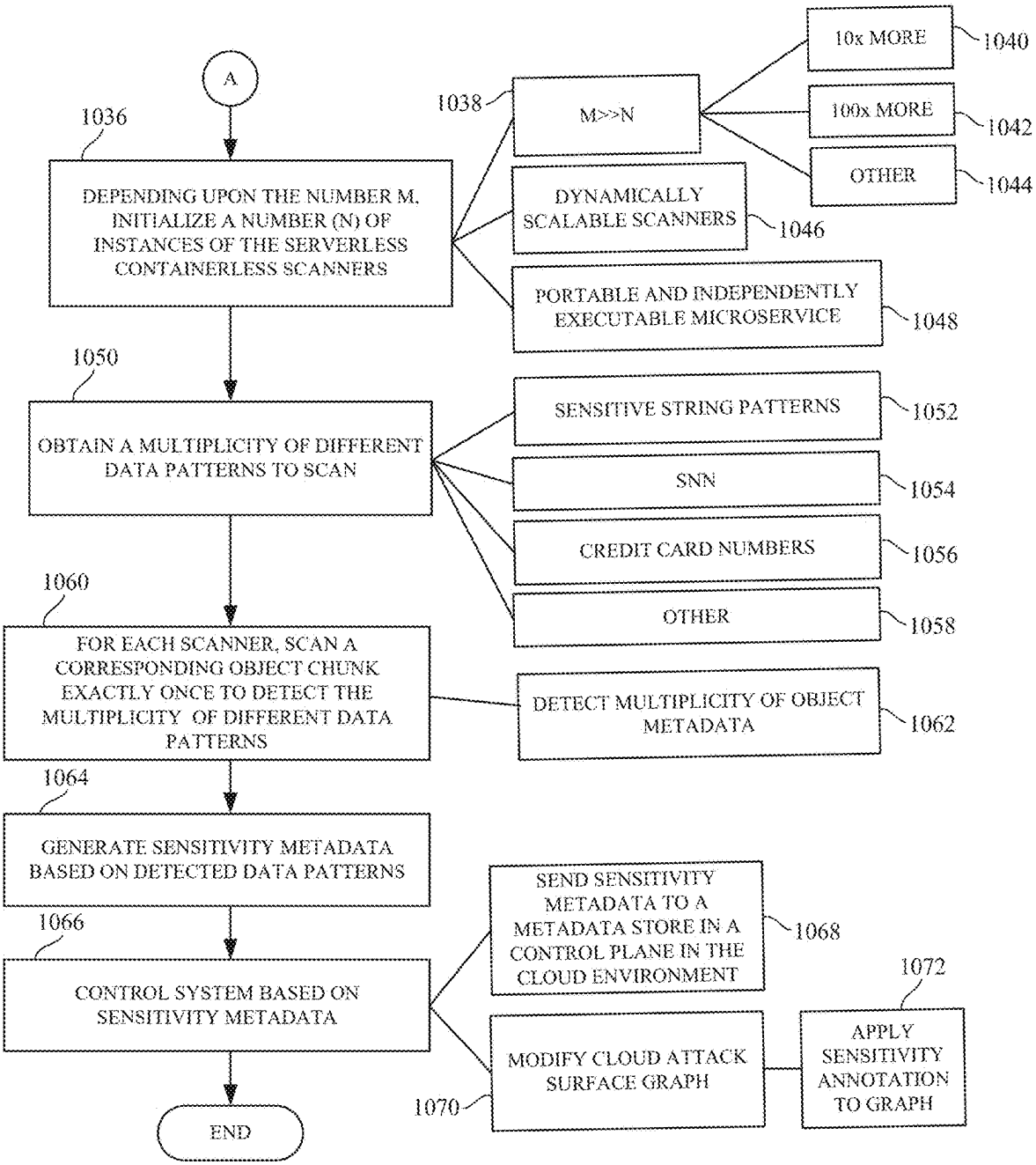

A
1036
DEPENDING UPON THE NUMBER M, INITIALIZE A NUMBER (N) OF INSTANCES OF THE SERVERLESS CONTAINERLESS SCANNERS
1038
M>>N
10x MORE
1040
100x MORE
1042
OTHER
1044
DYNAMICALLY SCALABLE SCANNERS
1046
PORTABLE AND INDEPENDENTLY EXECUTABLE MICROSERVICE
1048
1050
OBTAIN A MULTIPLICITY OF DIFFERENT DATA PATTERNS TO SCAN
SENSITIVE STRING PATTERNS
1052
SNN
1054
CREDIT CARD NUMBERS
1056
OTHER
1058
1060
FOR EACH SCANNER, SCAN A CORRESPONDING OBJECT CHUNK EXACTLY ONCE TO DETECT THE MULTIPLICITY OF DIFFERENT DATA PATTERNS
DETECT MULTIPLICITY OF OBJECT METADATA
1062
1064
GENERATE SENSITIVITY METADATA BASED ON DETECTED DATA PATTERNS
1066
CONTROL SYSTEM BASED ON SENSITIVITY METADATA
SEND SENSITIVITY METADATA TO A METADATA STORE IN A CONTROL PLANE IN THE CLOUD ENVIRONMENT
1068
1072
MODIFY CLOUD ATTACK SURFACE GRAPH
APPLY SENSITIVITY ANNOTATION TO GRAPH
1070
END

FIG. 21-2

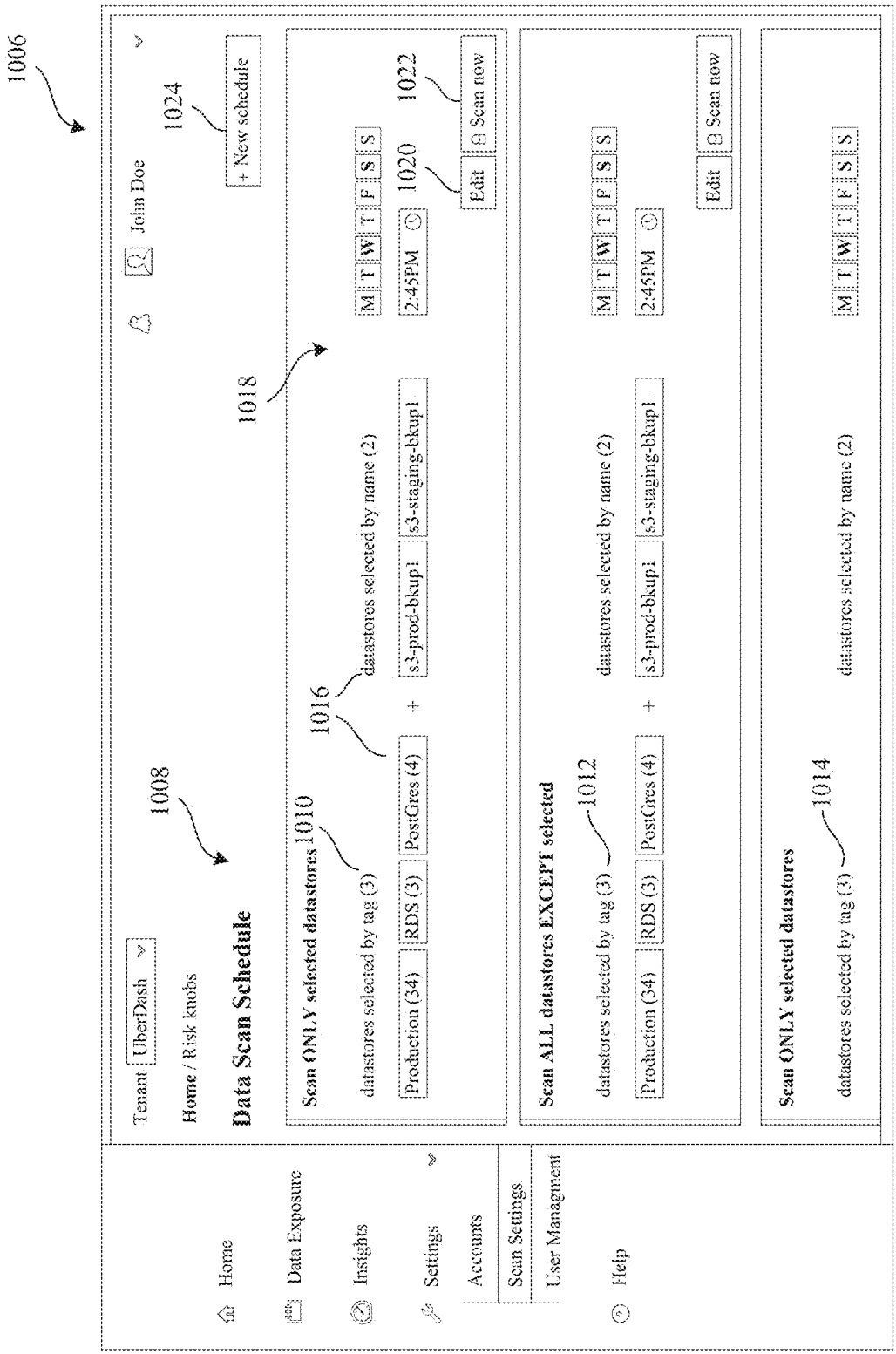

1006
Tenant
UberDash
Home / Risk knobs
Data Scan Schedule
1008
John Doe
1024
+ New schedule
1018
Scan ONLY selected datastores
1010
datastores selected by tag (3)
Production (34)
RDS (3)
PostGres (4)
1016
+
datastores selected by name (2)
s3-prod-bkup1
s3-staging-bkup1
M T W T F S S
2:45PM
1020
Edit
Scan now
1022
Scan ALL datastores EXCEPT selected
1012
datastores selected by tag (3)
Production (34)
RDS (3)
PostGres (4)
+
datastores selected by name (2)
s3-prod-bkup1
s3-staging-bkup1
M T W T F S S
2:45PM
Edit
Scan now
Scan ONLY selected datastores
1014
datastores selected by tag (3)
datastores selected by name (2)
M T W T F S S
Home
Data Exposure
Insights
Settings
Accounts
Scan Settings
User Managment
Help

FIG. 22

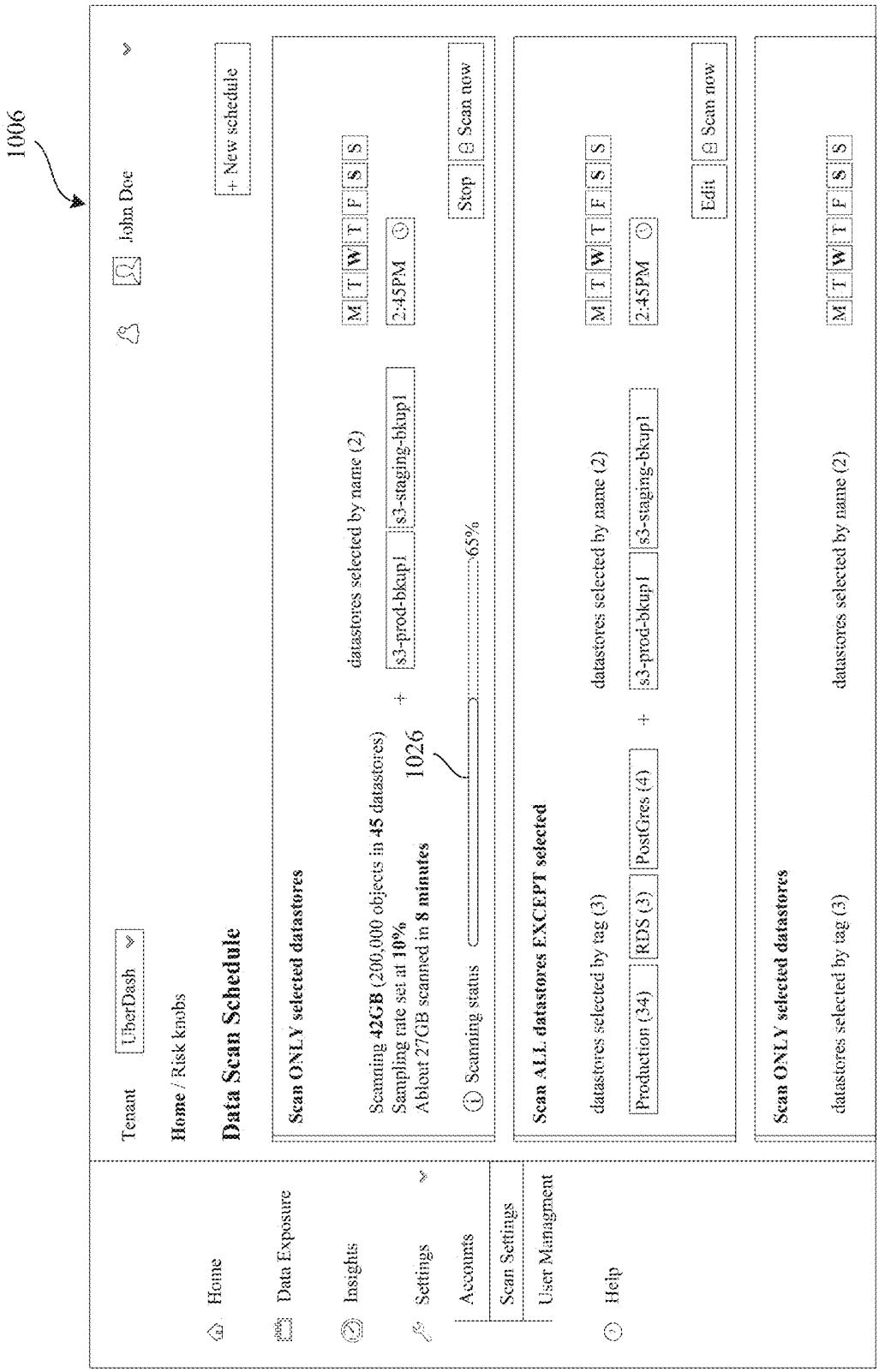

1006
Tenant
UberDash
John Doe
Home / Risk knobs
Data Scan Schedule
+ New schedule
Home
Data Exposure
Insights
Settings
Accounts
Scan Settings
User Managment
Help
Scan ONLY selected datastores
Scanning 42GB (200,000 objects in 45 datastores)
Sampling rate set at 10%
Ablout 27GB scanned in 8 minutes
1026
Scanning status
65%
datastores selected by name (2)
s3-prod-bkup1
s3-staging-bkup1
M T W T F S S
2:45PM
Stop
Scan now
Scan ALL datastores EXCEPT selected
datastores selected by tag (3)
Production (34)
RDS (3)
PostGres (4)
datastores selected by name (2)
s3-prod-bkup1
s3-staging-bkup1
M T W T F S S
2:45PM
Edit
Scan now
Scan ONLY selected datastores
datastores selected by tag (3)
datastores selected by name (2)
M T W T F S S

FIG. 23

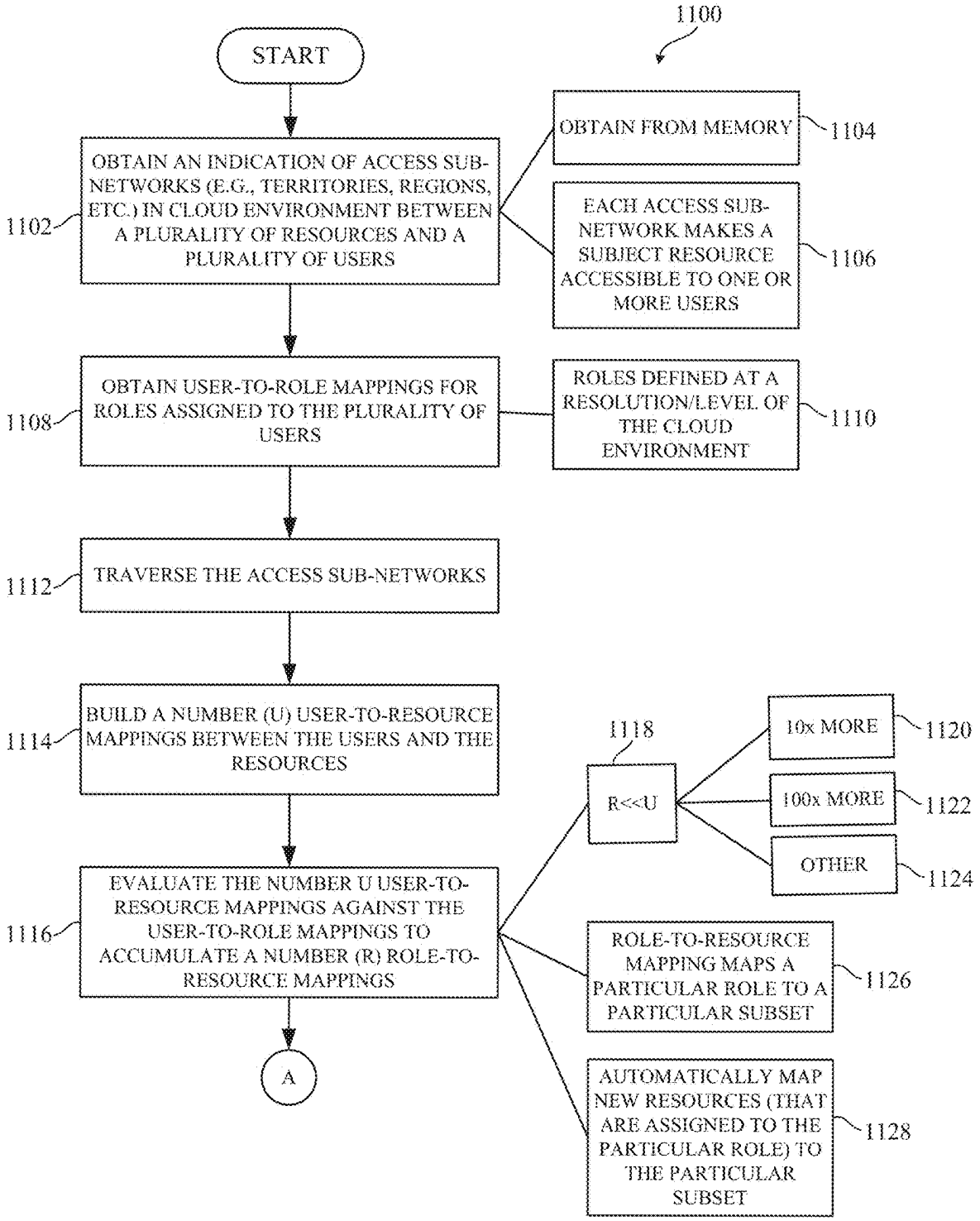

1100
START
OBTAIN AN INDICATION OF ACCESS SUB-NETWORKS (E.G., TERRITORIES, REGIONS, ETC.) IN CLOUD ENVIRONMENT BETWEEN A PLURALITY OF RESOURCES AND A PLURALITY OF USERS
1102
OBTAIN FROM MEMORY
1104
EACH ACCESS SUB-NETWORK MAKES A SUBJECT RESOURCE ACCESSIBLE TO ONE OR MORE USERS
1106
OBTAIN USER-TO-ROLE MAPPINGS FOR ROLES ASSIGNED TO THE PLURALITY OF USERS
1108
ROLES DEFINED AT A RESOLUTION/LEVEL OF THE CLOUD ENVIRONMENT
1110
TRAVERSE THE ACCESS SUB-NETWORKS
1112
BUILD A NUMBER (U) USER-TO-RESOURCE MAPPINGS BETWEEN THE USERS AND THE RESOURCES
1114
EVALUATE THE NUMBER U USER-TO-RESOURCE MAPPINGS AGAINST THE USER-TO-ROLE MAPPINGS TO ACCUMULATE A NUMBER (R) ROLE-TO-RESOURCE MAPPINGS
1116
A
1118
R<<U
10x MORE
1120
100x MORE
1122
OTHER
1124
ROLE-TO-RESOURCE MAPPING MAPS A PARTICULAR ROLE TO A PARTICULAR SUBSET
1126
AUTOMATICALLY MAP NEW RESOURCES (THAT ARE ASSIGNED TO THE PARTICULAR ROLE) TO THE PARTICULAR SUBSET
1128

FIG. 24-1

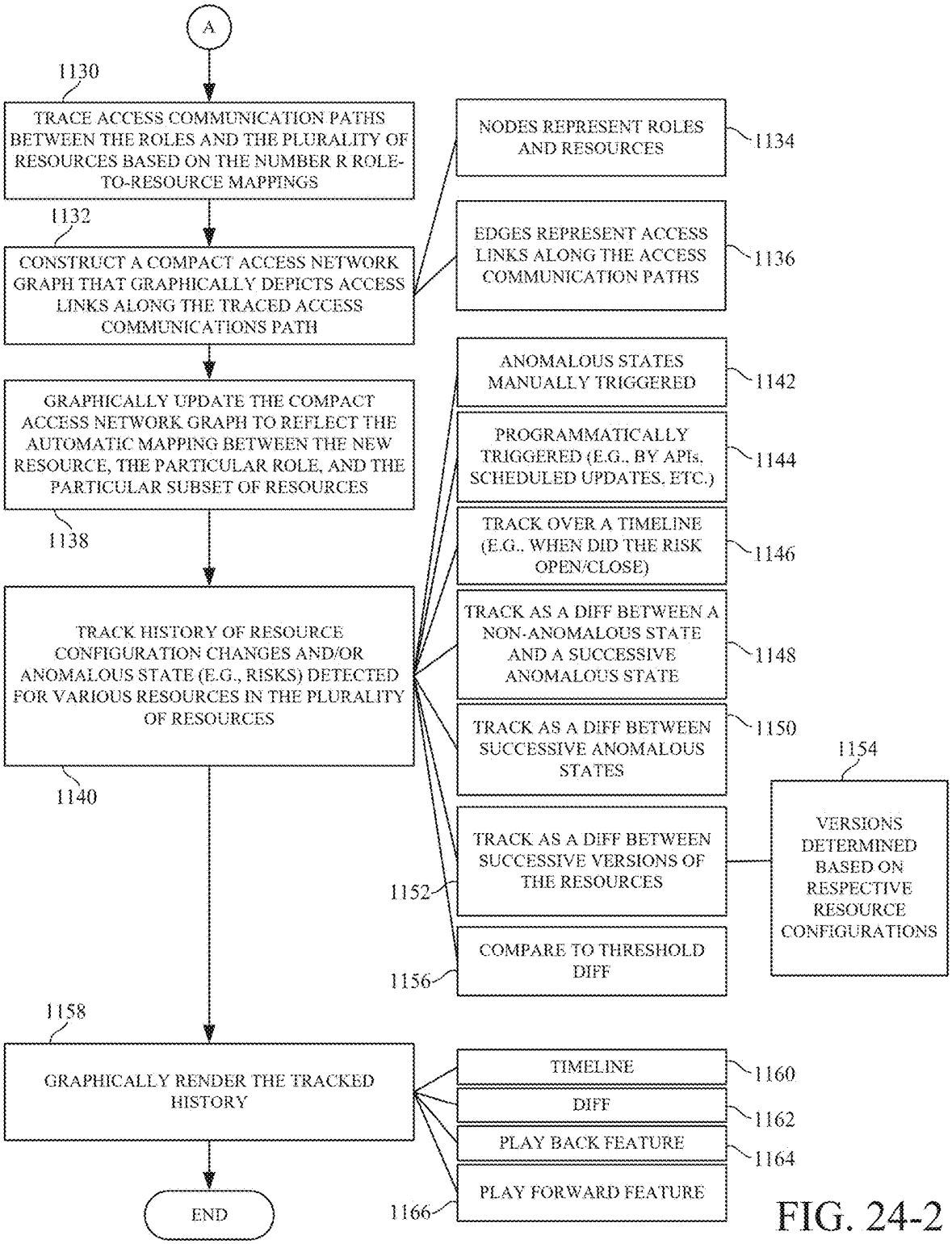

A
1130
TRACE ACCESS COMMUNICATION PATHS BETWEEN THE ROLES AND THE PLURALITY OF RESOURCES BASED ON THE NUMBER R ROLE-TO-RESOURCE MAPPINGS
1132
CONSTRUCT A COMPACT ACCESS NETWORK GRAPH THAT GRAPHICALLY DEPICTS ACCESS LINKS ALONG THE TRACED ACCESS COMMUNICATIONS PATH
NODES REPRESENT ROLES AND RESOURCES
1134
EDGES REPRESENT ACCESS LINKS ALONG THE ACCESS COMMUNICATION PATHS
1136
GRAPHICALLY UPDATE THE COMPACT ACCESS NETWORK GRAPH TO REFLECT THE AUTOMATIC MAPPING BETWEEN THE NEW RESOURCE, THE PARTICULAR ROLE, AND THE PARTICULAR SUBSET OF RESOURCES
1138
TRACK HISTORY OF RESOURCE CONFIGURATION CHANGES AND/OR ANOMALOUS STATE (E.G., RISKS) DETECTED FOR VARIOUS RESOURCES IN THE PLURALITY OF RESOURCES
1140
ANOMALOUS STATES MANUALLY TRIGGERED
1142
PROGRAMMATICALLY TRIGGERED (E.G., BY APIs, SCHEDULED UPDATES, ETC.)
1144
TRACK OVER A TIMELINE (E.G., WHEN DID THE RISK OPEN/CLOSE)
1146
TRACK AS A DIFF BETWEEN A NON-ANOMALOUS STATE AND A SUCCESSIVE ANOMALOUS STATE
1148
TRACK AS A DIFF BETWEEN SUCCESSIVE ANOMALOUS STATES
1150
TRACK AS A DIFF BETWEEN SUCCESSIVE VERSIONS OF THE RESOURCES
1152
1154
VERSIONS DETERMINED BASED ON RESPECTIVE RESOURCE CONFIGURATIONS
COMPARE TO THRESHOLD DIFF
1156
1158
GRAPHICALLY RENDER THE TRACKED HISTORY
TIMELINE
1160
DIFF
1162
PLAY BACK FEATURE
1164
PLAY FORWARD FEATURE
1166
END

FIG. 24-2

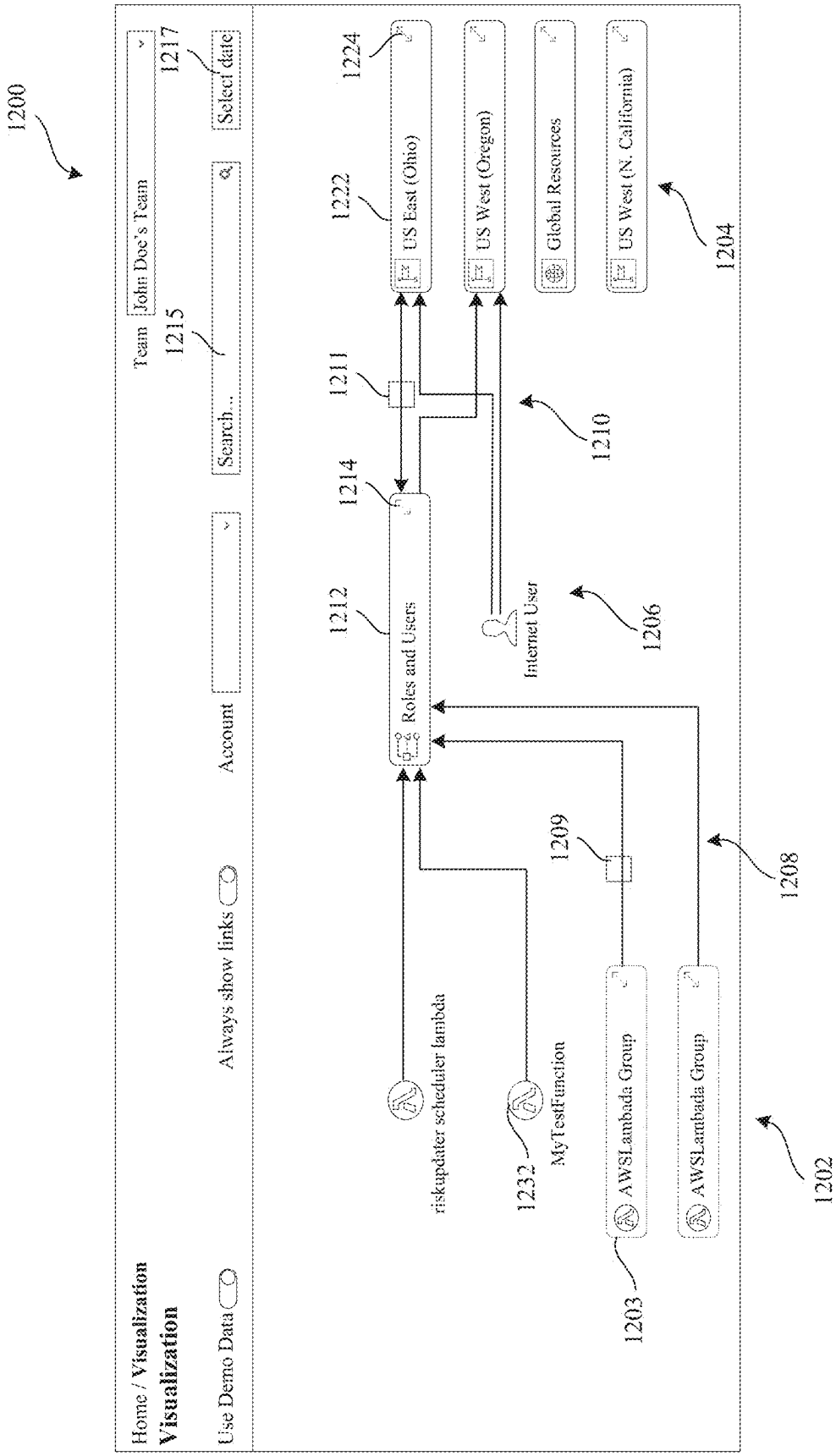

1200
Home / Visualization
Visualization
Use Demo Data
Always show links
Account
Team
John Doe's Team
1217
Select date
1215
Search...
1224
US East (Ohio)
1222
US West (Oregon)
Global Resources
US West (N. California)
1204
1211
1210
1214
1212
Roles and Users
Internet User
1206
1209
1208
riskupdater scheduler lambda
1232
MyTestFunction
AWSLambada Group
AWSLambada Group
1203
1202

FIG. 25

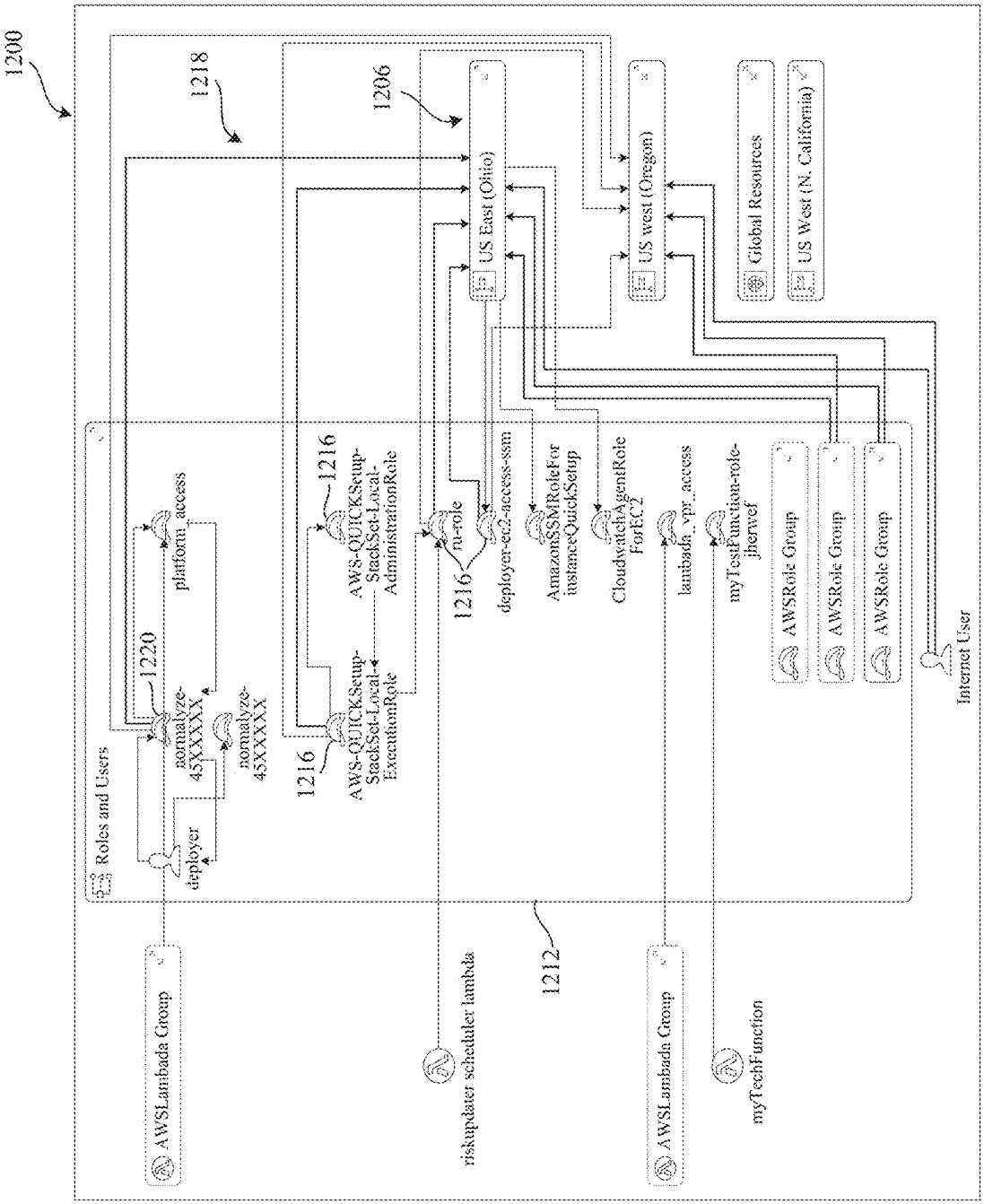

1200
1218
1206
US East (Ohio)
US west (Oregon)
Global Resources
US West (N. California)
Roles and Users
platform_access
1220
normalyze-45XXXXX
normalyze-45XXXXX
deployer
1216
AWS-QUICKSetup-StackSet-Local-AdministrationRole
AWS-QUICKSetup-StackSet-Local-ExecutionRole
1216
ru-role
deployer-ec2-access-ssm
AmazonSSMRoleFor instanceQuickSetup
CloudwatchAgentRole ForEC2
lambda_vpc_access
myTestFunction-role-jherwef
AWSRole Group
AWSRole Group
AWSRole Group
Internet User
AWSLambada Group
riskupdater scheduler lambda
1212
AWSLambada Group
myTechFunction

FIG. 26

**Properties of AWSRole - normalyze-45XXXXX**


```
▽ {
        arn : "arn:aws:iam::45XXXXX:roe/normalyze-45XXXXX"
        cratedate : "2021-08-17 05:26:02+00:00"
        firstseen : "1629956945933"
        id : 11930
        lastupdated : 1630153466
        name : "normalyze-45XXXXX:"
        path : "/"
        releid : "FRE89JML52WS"
    }
```


FIG. 27

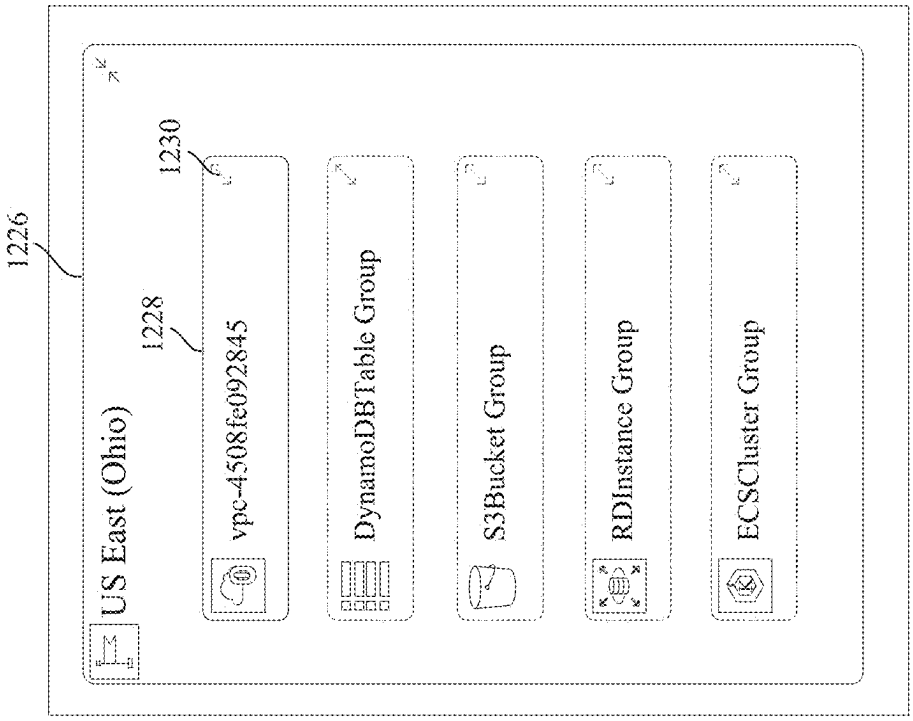

1226
US East (Ohio)
1228
vpc-4508fe092845
1230
DynamoDBTable Group
S3Bucket Group
RDInstance Group
ECSCluster Group

FIG. 28

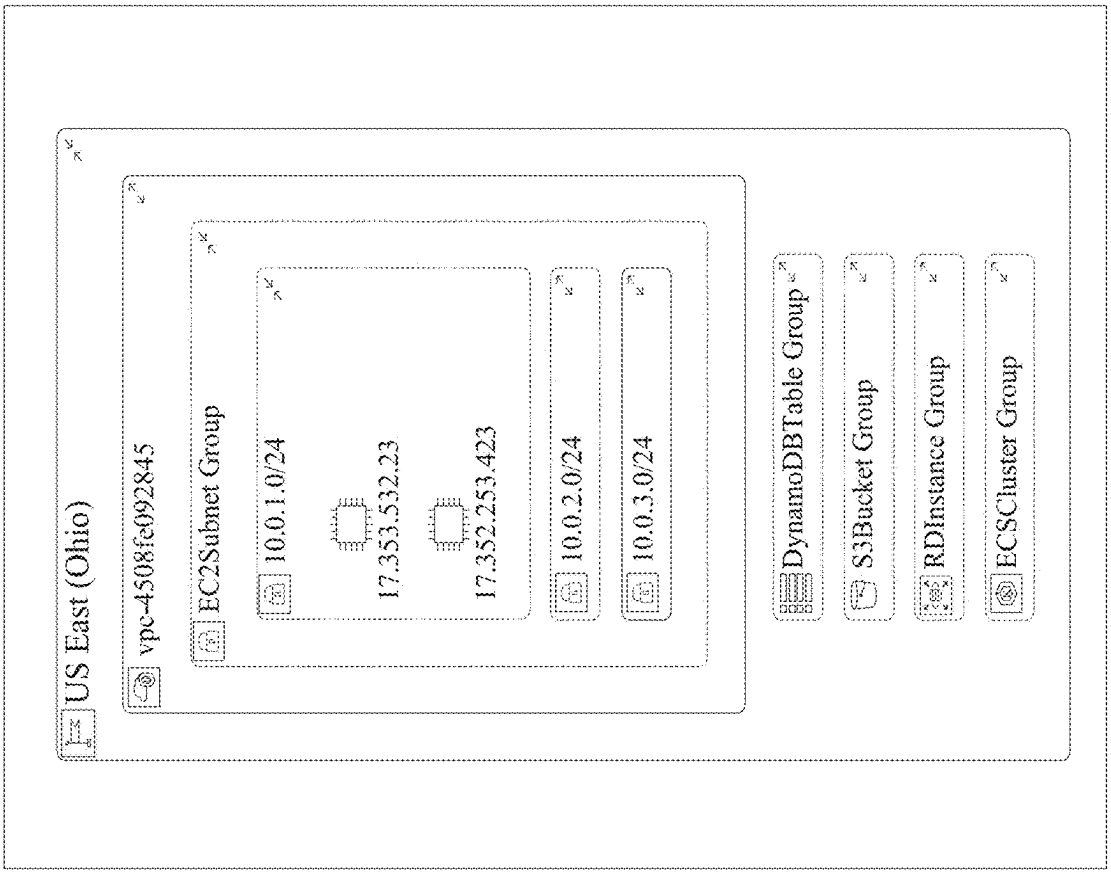

US East (Ohio)
vpc-4508fc092845
EC2Subnet Group
10.0.1.0/24
17.353.532.23
17.352.253.423
10.0.2.0/24
10.0.3.0/24
DynamoDBTable Group
S3Bucket Group
RDInstance Group
ECSCluster Group

FIG. 29

**Properties of AWSLambda - myTestFunction**


```
▽{
    arn : "arn:aws:lambda:us-east-2:19XXXXXXX:function:myTestFunction"
    description : ""
    firstseen : "1629956945933"
    id : "arn+aws:lambada:us:east-2:19XXXXXXX:function:myTestFunction"
    lastupdated : 1630153466
    memory : 128
    modifieddate : " 2021-08-06T17:03:58.496+0000"
    name : "myTestFunction"
    runtime : "python3.7"
    timeout : 303
}
```


FIG. 30

1250

Home / **Resources**

**Resources**

Team John Doe

1266

**Resources** Changes

1268 1260

Search

1252 1254 1256 1258

1-10 of 218 items < 1 2 3 4 5 ... 22 >

| arm | Account Id | Resource Type | Name | Region | Details |
|---|---|---|---|---|---|
| arm:aws:ecr:us:west-2:543098234985:repository/data-scan-c23c34 | 543098234985 | ECRRepository | data-scan-c23c34 | us-west-2 | Details |
| arm:aws:ecr:us:east-2:543098234985:repository/metdata-crawl53 | 543098234985 | ECRRepository | metdata-crawl53 | us-east-2 | Details |
| arm:aws:ecr:us:west-2:543098234985:repository/cand-retr | 543098234985 | ECRRepository | cand-retr | us-west-2 | Details |
| arm:aws:ecr:us:east-2:543098234985:repository/data-scanner-c23c34 | 543098234985 | ECRRepository | data-scanner-c23c34 | us-east-2 | Details |
| arm:aws:ecr:us:west-2:543098234985:repository/data-scanner-c23c34 | 543098234985 | ECRRepository | data-scanner-c23c34 | us-west-2 | Details |
| arm:aws:ecr:us:east-1:543098234985:repository/data-scanner-c23c34 | 543098234985 | ECRRepository | data-scanner-c23c34 | us-east-1 | Details |
| arm:aws:ecr:us:east-1:543098234985:repository/metadata-crawl-c4 | 543098234985 | ECRRepository | metadata-crawl-c4 | us-east-1 | Details |
| arm:aws:ecr:us:west-2:543098234985:repository/metadata-crawl-f3 | 543098234985 | ECRRepository | metadata-crawl-f3 | us-west-2 | Details |
| arm:aws:ecr:us:east-1:543098234985:repository/data-scan-c324f | 543098234985 | ECRRepository | data-scan-c324f | us-east-1 | Details |

1262

FIG. 31

**data-scanner-b468d429-e5f1-44e1-b64f-2b2fe4661804**

1264


```
{
    createAt : "2021-09-10 02:17:12+00:00"
    encryptionConfiguration : {
        encryptionType : "AES256"
    }
    imageScanningConfiguration : {
        scanOnPush : false
    }
    imageTagMutability : "MUTABLE"
    original : {
        TeamId : 6
        accountId : "8972435844"
        arn :
        "arm:aws:ecr:us-west-2:8972435844:repository/data-scan-bd9-ef1
        234ikj93
        hash : "03ljkf90324244"
        id : 3428
        name : "data-scanfe4661804"
        region : "us-west-2"
        resourceType : "ECRRepository"
    }
    registryId : "8972435844
    repositoryArn :
    "arm:aws:ecr:us-west-2:8972435844:repository/data-scan-4-e5f1-44ei
    -f35f3g34jj"
    repositoryName : "data-scan046d2-e1-4i-6f-2bfe64"
    repositoryUrl :
    "8972435844.dkr.ecr.us-west-2.amazonaws.com/8972435844"

}
```


FIG. 32

Home / **Resources**

Team John Doe

## Resources

**Resources** Changes

| arm | Account Id | Resource Type | Name | Region | Details |
|---|---|---|---|---|---|
| arm:aws:iam::543098234985:user/kap+demo@platform.a1 | 543098234985 | AWSUser | kap+demo@platform.a1 | aws+global | Details |
| arm:aws:s3:::accounting-customer2-demo | 543098234985 | S3Bucket | accounting-customer2-demo | us-east-2 | Details |
| arm:aws:s3:::ads-customer2-demo | 543098234985 | S3Bucket | ads-customer2-demo | us-east-2 | Details |
| arm:aws:iam::543098234985:user/erik+demo@platform.ai | 543098234985 | AWSUser | erik+demo@platform.ai | aws+global | Details |
| arm:aws:s3:::ads-customer-challenging-bucket | 543098234985 | S3Bucket | customer-challenging-bucket | us-east-2 | Details |
| arm:aws:s3:::control-customer2-demo | 543098234985 | S3Bucket | control-customer2-demo | us-east-2 | Details |
| arm:aws:iam::543098234985:role/aws-service-role/support.amazonaws | 543098234985 | AWSRole | AWServiceRoleForSupport | aws+global | Details |
| arm:aws:s3:::education-customer2-demo | 543098234985 | S3Bucket | education-customer2-demo | us-east-2 | Details |
| arm:aws:iam::543098234985:role/aws-service-role/cloudtrail.amazon | 543098234985 | ECRRepository | AWServiceRoleForCloudTr... | aws+global | Details |
| arm:aws:iam::543098234985:user/ravsa+demo@platform.ai | 543098234985 | AWSUser | ravsa+demo@platform.ai | aws+global | Details |

FIG. 33

1270

Home / **Resources**

Team John Doe

## Resources

**Resources** Changes

Search

resourceType: AWSRole ×  arn:aws:iam:258972395875:role/config-service-main ×

| arn | Account Id | Resource Type | Name | Region | Details |
|---|---|---|---|---|---|
| arn:aws:iam:258972395875:role/config-service-main | 258972395875 | AWSRole | config-service-main | aws+global | Details |

1272

## History


```
{
        "Arn" : "arn:aws:iam:258972395875:role/config-service-main",
        "AssumeRolePolicyDocument" : {
                "Statement": [
                        "{\n      \"Sid \": \"sts:AssumeRolw\",\n \"Effect\": \"allow\",\n \"Principal\": {\n\"Service\": \"ecs-tasks.amazonaws.com\"\n }\n}"
                ],
                "Version": "2012-10-17"
        },
        "CreateDate" : "2021-03-02 10:39:08+00:00",
        "MaxSessionDuration" : 3600,
        "Path" : "/",
        "RoleId" : "IFLERFIL7896FERE",
        "RoleName" : "config-service-main"
}
```


FIG. 34

**config-service-main**

```
▽ {
    "Arn" : "arn:aws:iam:258972395875:role/config-service-main",
  ▽ "AssumeRolePolicyDocument" : {
      ▽ "Statement": [
1274        ▽ 0 :{
                Action : "sts:AssumeRole"
1276            Effect : "Allow"
              ▽ Principal : {
                  Service : "ecs-tasks.amazonaws.com"
                }
                Sid : ""
              }
          }
          Version : "2012-10-17"
    }
    CreateDate : "021-03-02 10:39:08+00:00"
    MaxSessionDuration : 3600
    Path : "/"
    RoleId : "IFLERFIL7896FERE"
    RoleName : "config-service-main"
    ▷ Original : { . . . }
}
```

FIG. 35

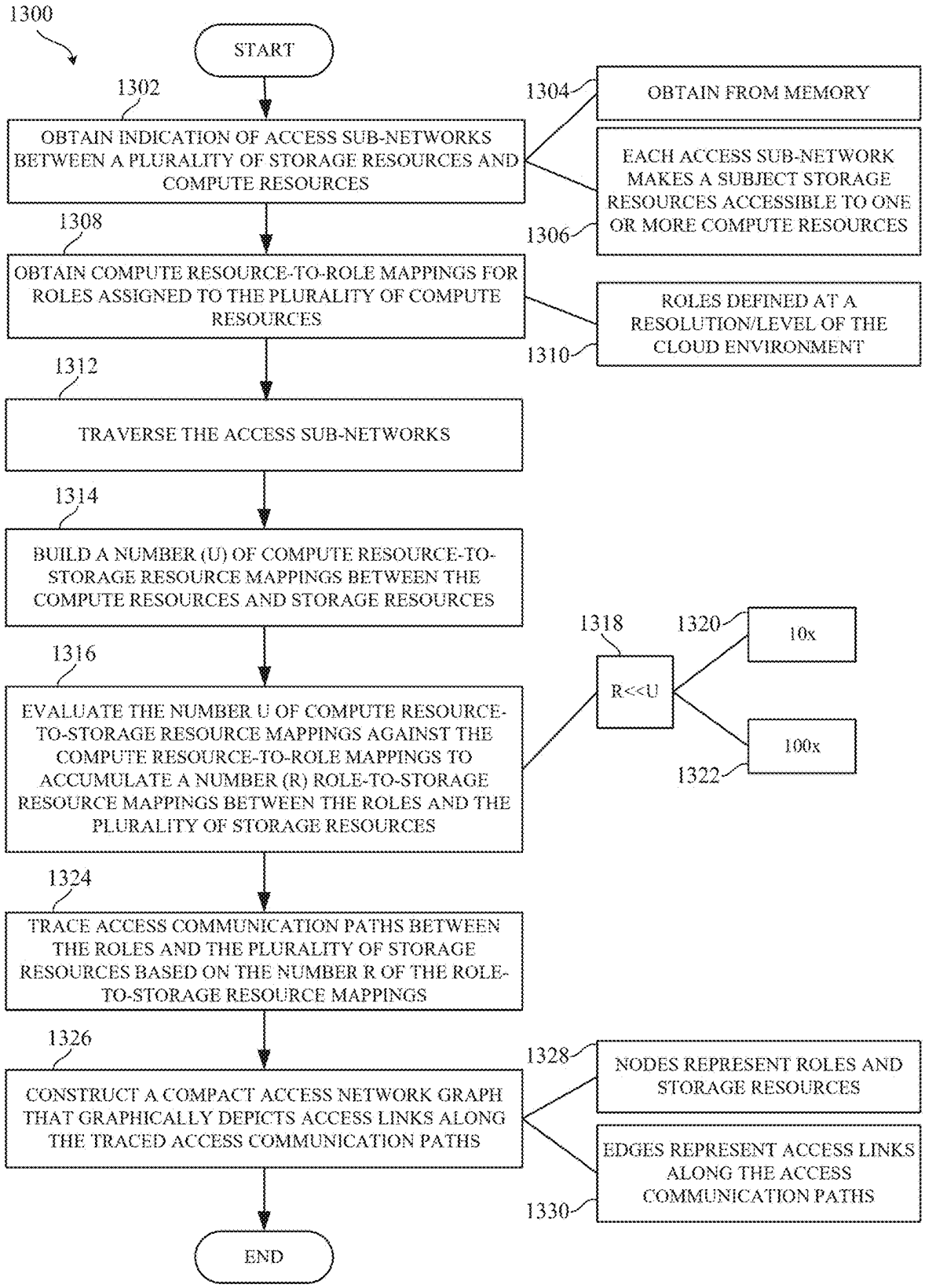

1300
START
1302
OBTAIN INDICATION OF ACCESS SUB-NETWORKS BETWEEN A PLURALITY OF STORAGE RESOURCES AND COMPUTE RESOURCES
1304
OBTAIN FROM MEMORY
EACH ACCESS SUB-NETWORK MAKES A SUBJECT STORAGE RESOURCES ACCESSIBLE TO ONE OR MORE COMPUTE RESOURCES
1306
1308
OBTAIN COMPUTE RESOURCE-TO-ROLE MAPPINGS FOR ROLES ASSIGNED TO THE PLURALITY OF COMPUTE RESOURCES
ROLES DEFINED AT A RESOLUTION/LEVEL OF THE CLOUD ENVIRONMENT
1310
1312
TRAVERSE THE ACCESS SUB-NETWORKS
1314
BUILD A NUMBER (U) OF COMPUTE RESOURCE-TO-STORAGE RESOURCE MAPPINGS BETWEEN THE COMPUTE RESOURCES AND STORAGE RESOURCES
1318
1320
10x
1316
R<<U
EVALUATE THE NUMBER U OF COMPUTE RESOURCE-TO-STORAGE RESOURCE MAPPINGS AGAINST THE COMPUTE RESOURCE-TO-ROLE MAPPINGS TO ACCUMULATE A NUMBER (R) ROLE-TO-STORAGE RESOURCE MAPPINGS BETWEEN THE ROLES AND THE PLURALITY OF STORAGE RESOURCES
100x
1322
1324
TRACE ACCESS COMMUNICATION PATHS BETWEEN THE ROLES AND THE PLURALITY OF STORAGE RESOURCES BASED ON THE NUMBER R OF THE ROLE-TO-STORAGE RESOURCE MAPPINGS
1326
1328
NODES REPRESENT ROLES AND STORAGE RESOURCES
CONSTRUCT A COMPACT ACCESS NETWORK GRAPH THAT GRAPHICALLY DEPICTS ACCESS LINKS ALONG THE TRACED ACCESS COMMUNICATION PATHS
EDGES REPRESENT ACCESS LINKS ALONG THE ACCESS COMMUNICATION PATHS
1330
END

FIG. 36

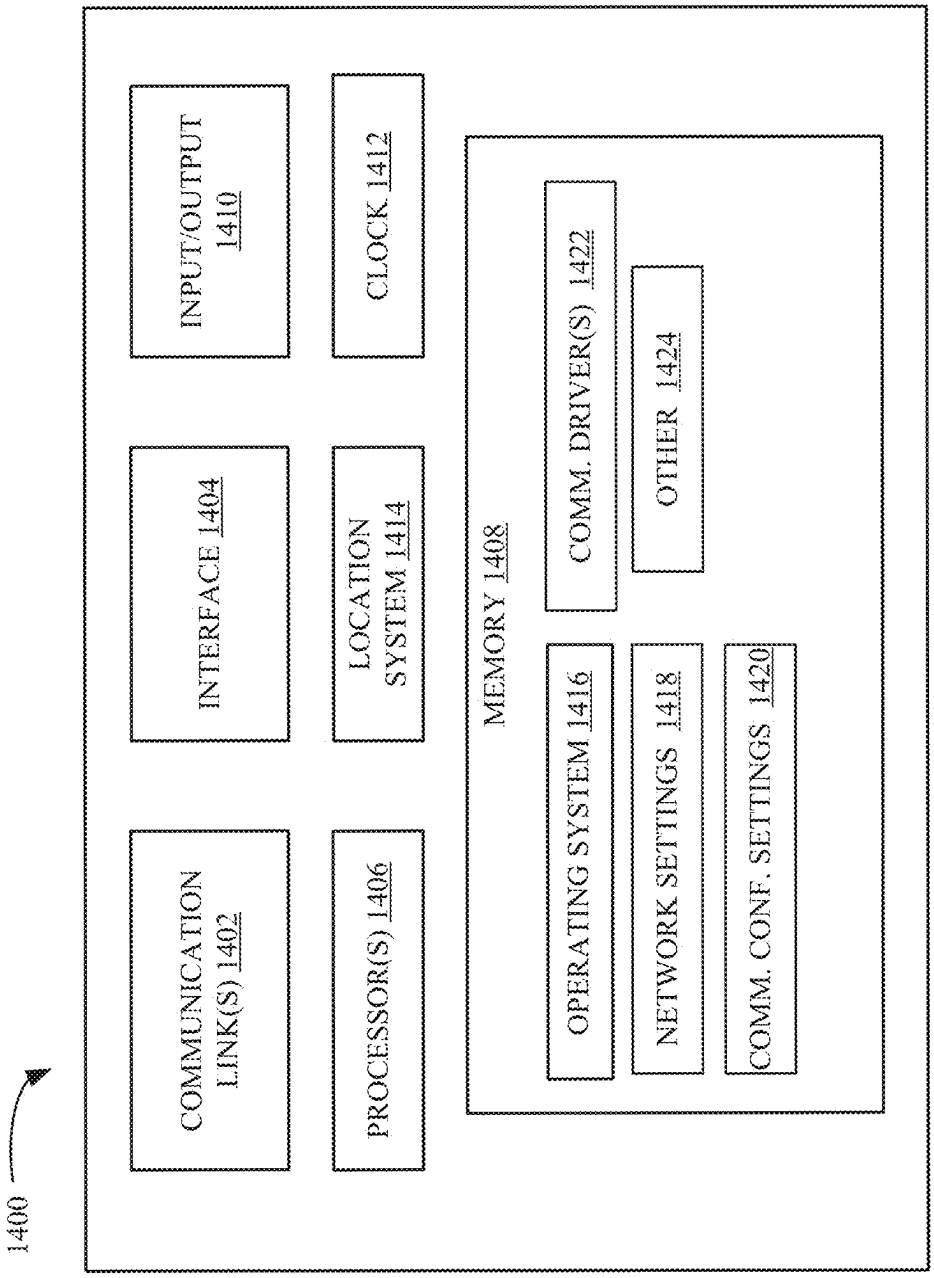

1400
COMMUNICATION LINK(S) 1402
INTERFACE 1404
INPUT/OUTPUT 1410
PROCESSOR(S) 1406
LOCATION SYSTEM 1414
CLOCK 1412
MEMORY 1408
OPERATING SYSTEM 1416
NETWORK SETTINGS 1418
COMM. CONF. SETTINGS 1420
COMM. DRIVER(S) 1422
OTHER 1424

FIG. 37

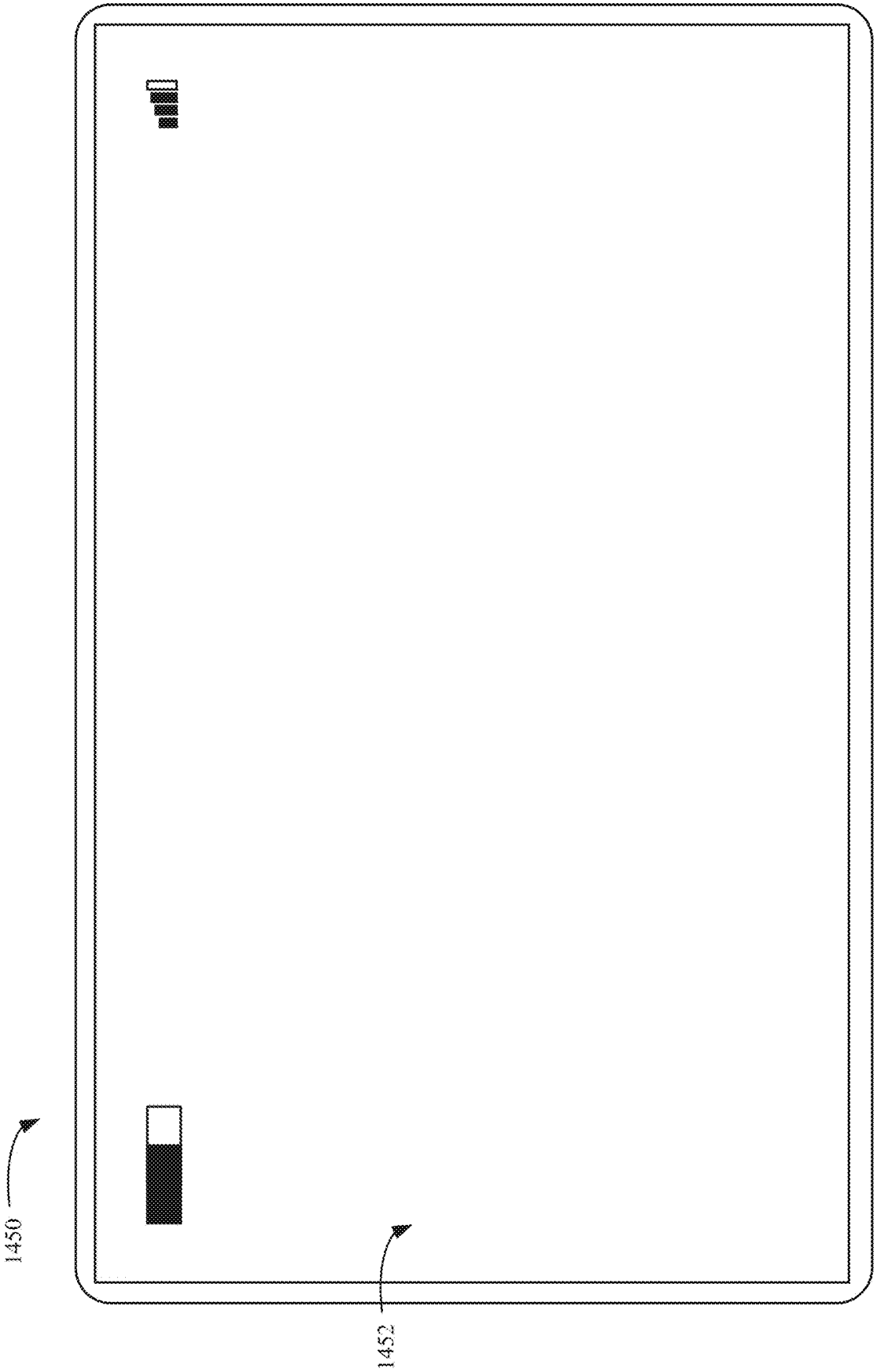



FIG. 38

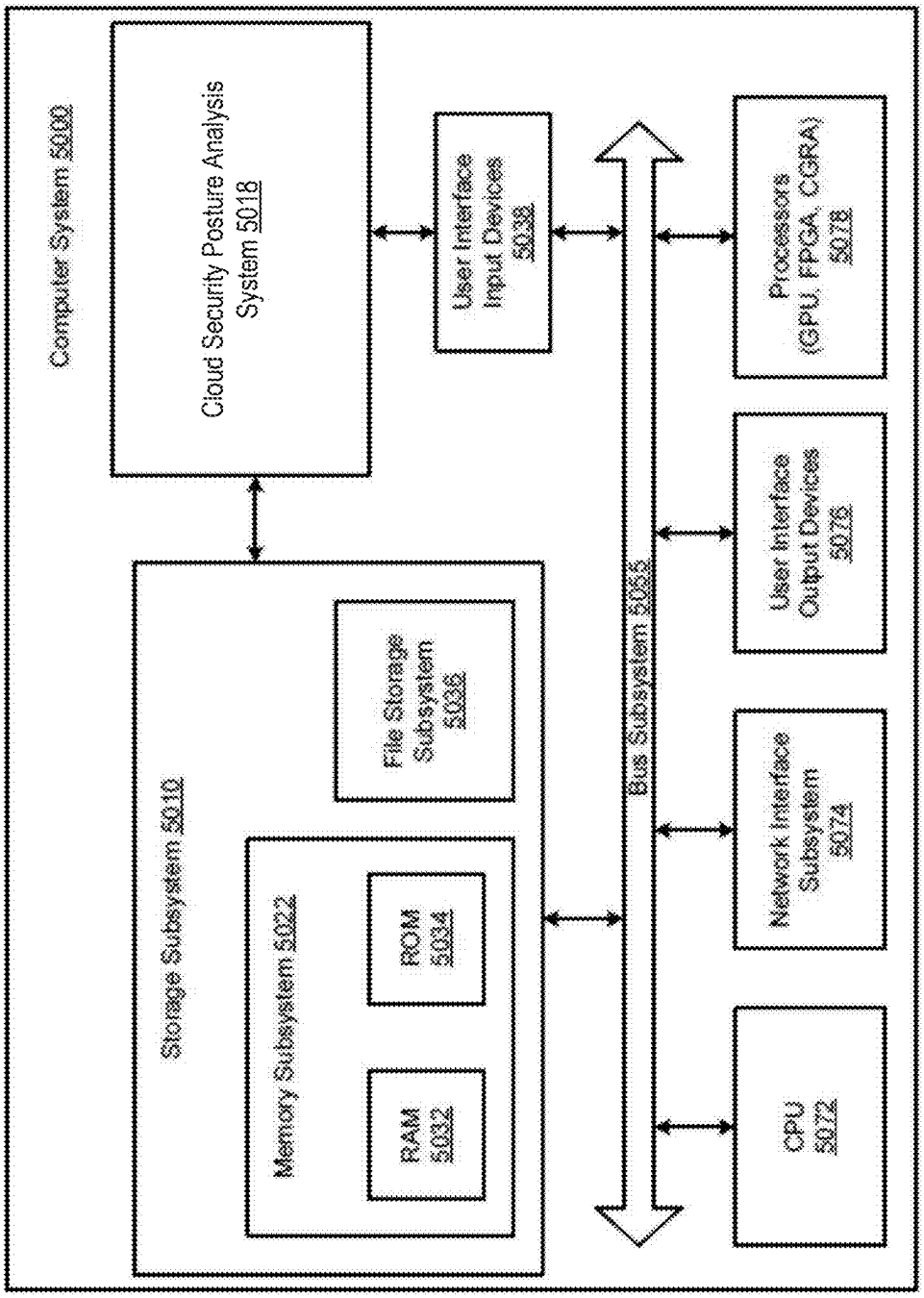

Computer System 5000
Cloud Security Posture Analysis System 5018
Storage Subsystem 5010
Memory Subsystem 5022
RAM 5032
ROM 5034
File Storage Subsystem 5036
User Interface Input Devices 5038
Bus Subsystem 5055
Processors (GPU, FPGA, CGRA) 5078
User Interface Output Devices 5076
Network Interface Subsystem 5074
CPU 5072

FIG. 39

# CLOUD CONTENT SCANNING USING LOCALLY DEPLOYED CONTAINERIZED SCANNERS

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** The present application is a continuation of and claims priority to U.S. patent application Ser. No. 18/444,928, filed Feb. 19, 2024, which is a continuation of and claims priority to U.S. patent application Ser. No. 18/090,195, filed Dec. 28, 2022, which is a continuation of and claims priority to U.S. patent application Ser. No. 17/858,903, filed Jul. 6, 2022, now U.S. Pat. No. 11,575,696, which is based on and claims the benefit of U.S. provisional patent application Ser. Nos. 63/246,303, filed Sep. 20, 2021, 63/246,310, filed Sep. 21, 2021, 63/246,313, filed Sep. 21, 2021, and 63/246,315, filed Sep. 21, 2021; the contents of these applications are hereby incorporated by reference in their entirety.

## FIELD OF THE TECHNOLOGY DISCLOSED

**[0002]** The technology disclosed generally relates to cloud environments. More specifically, but not by limitation, the present disclosure relates to improved systems and methods of cloud security posture management (CSPM), cloud infrastructure entitlement management (CIEM), cloud-native application protection platform (CNAPP), and/or cloud-native configuration management database (CMDB).

## BACKGROUND

**[0003]** The subject matter discussed in this section should not be assumed to be prior art merely as a result of its mention in this section. Similarly, a problem mentioned in this section or associated with the subject matter provided as background should not be assumed to have been previously recognized in the prior art. The subject matter in this section merely represents different approaches, which in and of themselves can also correspond to implementations of the claimed technology.

**[0004]** Cloud computing provides on-demand availability of computer resources, such as data storage and compute resources, often without direct active management by users. Thus, a cloud environment can provide computation, software, data access, and storage services that do not require end-user knowledge of the physical location or configuration of the system that delivers the services. In various examples, remote servers can deliver the services over a wide area network, such as the Internet, using appropriate protocols, and those services can be accessed through a web browser or any other computing component.

**[0005]** Examples of cloud storage services include Amazon Web Services™ (AWS), Google Cloud Platform™ (GCP), and Microsoft Azure™, to name a few. Such cloud storage services provide on-demand network access to a shared pool of configurable resources. These resources can include networks, servers, storage, applications, services, etc. The end-users of such cloud services often include organizations that have a need to store sensitive and/or confidential data, such as personal information, financial information, medical information. Such information can be accessed by any of a number of users through permissions and access control data assigned or otherwise defined through administrator accounts.

**[0006]** The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

## SUMMARY

**[0007]** The technology disclosed herein relates to streamlined analysis of security posture of a cloud environment. In particular, the technology relates to computer-implemented method of content scanning that includes obtaining access to a cloud environment account for content scanning of storage resources, queuing objects in the cloud environment account, partitioning the objects into a number of object chunks, and initializing a number of serverless, containerized scanners based on the number of object chunks. Each serverless, containerized scanner, of the number of serverless, containerized scanners, is deployed locally on the cloud environment account and scans a corresponding object chunk to detect a plurality of different data patterns. The number of object chunks is at least one hundred times the number of serverless, containerized scanners.

**[0008]** This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The claimed subject matter is not limited to implementations that solve any or all disadvantages noted in the background.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** In the drawings, like reference characters generally refer to like parts throughout the different views. Also, the drawings are not necessarily to scale, with an emphasis instead generally being placed upon illustrating the principles of the technology disclosed. In the following description, various implementations of the technology disclosed are described with reference to the following drawings, in which:

**[0010]** FIG. **1** is a block diagram illustrating one example of a cloud architecture.

**[0011]** FIG. **2** is a block diagram illustrating one example of a cloud service.

**[0012]** FIG. **3** is a block diagram illustrating one example of a cloud security posture analysis system.

**[0013]** FIG. **4** is a block diagram illustrating one example of a deployed scanner.

**[0014]** FIG. **5** is a flow diagram showing an example operation of on-boarding a cloud account and deploying one or more scanners.

**[0015]** FIG. **6** illustrates one example of a user interface display representing on-boarded cloud accounts.

**[0016]** FIG. **7** illustrates one example of an on-boarding user interface display.

**[0017]** FIG. **8** illustrates one example of a user interface display having a dashboard representing on-boarded cloud service accounts.

**[0018]** FIG. **9** is a flow diagram illustrating one example of cloud infrastructure scanning performed by a cloud scanner deployed in a cloud service.

**[0019]** FIGS. **10-1**, **10-2**, **10-3**, and **10-4** (collectively referred to as FIG. **10**) provide a flow diagram illustrating an example operation for streamlined analysis of security posture.

**[0020]** FIG. **11** illustrates one example of a user interface display that facilitates user definition of a risk criterion.

**[0021]** FIG. **12** illustrates one example of a user interface display that displays a set of risk signatures.

**[0022]** FIG. **13** illustrates one example of a user interface display that graphically depicts vulnerability risks.

**[0023]** FIG. **14** illustrates one example of a details display pane.

**[0024]** FIG. **15** illustrates one example of a user interface display that graphically depicts breach likelihood and impact scores.

**[0025]** FIG. **16** illustrates one example of a user interface display having a details pane that displays details for a given resource.

**[0026]** FIG. **17** illustrates one example of a display pane showing user access details for a particular data store.

**[0027]** FIG. **18** illustrates one example of a display pane showing role access details for a particular data store.

**[0028]** FIG. **19** illustrates one example of a display pane showing resource access details for a particular data store.

**[0029]** FIGS. **20-1**, **20-2**, **20-3**, and **20-4** (collectively referred to as FIG. **20**) provide a flow diagram illustrating one example of infrastructure analysis and query execution.

**[0030]** FIGS. **21-1** and **21-2** (collectively referred to as FIG. **21**) provide a flow diagram illustrating one example of cloud data scanning in a cloud service.

**[0031]** FIGS. **22** and **23** illustrated example user interface displays for defining a scan schedule.

**[0032]** FIGS. **24-1** and **24-2** (collectively referred to as FIG. **24**) provide a flow diagram illustrating one example of depicting access links along communication paths between roles and resources.

**[0033]** FIGS. **25-30** illustrates examples of user interface displays having visualizations of access communication paths.

**[0034]** FIG. **31** shows one example of a user interface display to visualize resources identified based on data scanning performed on a cloud service.

**[0035]** FIGS. **32-35** show example user interface displays representing a particular resource.

**[0036]** FIG. **36** provide a flow diagram for streamlined analysis of access sub-networks in a cloud environment.

**[0037]** FIG. **37** is a simplified block diagram of one example of a client device.

**[0038]** FIG. **38** illustrates an example of a handheld or mobile device.

**[0039]** FIG. **39** shows an example computer system.

## DETAILED DESCRIPTION

**[0040]** The following discussion is presented to enable any person skilled in the art to make and use the technology disclosed, and is provided in the context of a particular application and its requirements. Various modifications to the disclosed implementations will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other implementations and applications without departing from the spirit and scope of the technology disclosed. Thus, the technology disclosed is not intended to be limited to the implementations shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

**[0041]** As noted above, cloud computing environments are used by organizations or other end-users to store a wide variety of different types of information in many contexts and for many uses. This data can often include sensitive and/or confidential information, and can be the target for malicious activity such as acts of fraud, privacy breaches, data theft, etc. These risks can arise from individuals that are both inside the organization as well as outside the organization.

**[0042]** Cloud environments often include security infrastructure to enforce access control, data loss prevention, or other processes to secure data from potential vulnerabilities. However, even with such security infrastructures, it can be difficult for an organization to understand the data posture and breadth of access to the data stored in the cloud in the organization's cloud account. In other words, it can be difficult to identify which users have access to which data, and which data may be exposed to malicious or otherwise unauthorized users, both inside or outside the organization.

**[0043]** The present system is directed to a cloud security posture analysis system configured to analyze and take action on the security posture of a cloud account. The system discovers sensitive data among the cloud storage resources and discovers access patterns to the sensitive data. The results are used to identify security vulnerabilities to understand the data security posture, detect and remediate the security vulnerabilities, and to prevent future breaches to sensitive data. The system provides real-time visibility and control on the control data infrastructure by discovering resources, sensitive data, and access paths, and tracking resource configuration, deep context and trust relationships in real-time as a graph or other visualization. It is noted that the technology disclosed herein can depict all graph embodiments in equivalent and analogous tabular formats or other visualization formats based on the data and logic disclosed herein.

**[0044]** The system can further score breach paths based on sensitivity, volume, and/or permissions to show an attack surface and perform constant time scanning, by deploying scanners locally within the cloud account. Thus, the scanners execute in the cloud service itself, with metadata being returned indicative of the analysis. Thus, in one example, an organization's cloud data does not leave the organization's cloud account. Rather, the data can be scanned in place and metadata sent for analysis by the cloud security posture analysis system, which further enhances data security.

**[0045]** FIG. **1** is a block diagram illustrating one example of a cloud architecture **100** in which a cloud environment **102** is accessed by one or more actors **104** through a network **106**, such as the Internet or other wide area network. Cloud environment **102** includes one or more cloud services **108-1**, **108-2**, **108**-N, collectively referred to as cloud services **108**. As noted above, cloud services **108** can include cloud storage services such as, but not limited to, AWS, GCP, Microsoft Azure, to name a few.

**[0046]** Further, cloud services **108-1**, **108-2**, **108**-N can include the same type of cloud service, or can be different types of cloud services, and can be accessed by any of a number of different actors **104**. For example, as illustrated in FIG. **1**, actors **104** include users **110**, administrators **112**,

developers **114**, organizations **116**, and/or applications **118**. Of course, other actors **120** can access cloud environment **102** as well.

**[0047]** Architecture **100** includes a cloud security posture analysis system **122** configured to access cloud services **108** to identify and analyze cloud security posture data. Examples of system **122** are discussed in further detail below. Briefly, however, system **122** is configured to access cloud services **108** and identify connected resources, entities, actors, etc. within those cloud services, and to identify risks and violations against access to sensitive information. As shown in FIG. **1**, system **122** can reside within cloud environment **102** or outside cloud environment **102**, as represented by the dashed box in FIG. **1**. Of course, system **122** can be distributed across multiple items inside and/or outside cloud environment **102**.

**[0048]** Users **110**, administrators **112**, developers **114**, or any other actors **104**, can interact with cloud environment **102** through user interface displays **123** having user interface mechanisms **124**. For example, a user can interact with user interface displays **123** provided on a user device (such as a mobile device, a laptop computer, a desktop computer, etc.) either directly or over network **106**. Cloud environment **102** can include other items **125** as well.

**[0049]** FIG. **2** is a block diagram illustrating one example of cloud service **108-1**. For the sake of the present discussion, but not by limitation, cloud service **108-1** will be discussed in the context of an account within AWS. Of course, other types of cloud services and providers are within the scope of the present disclosure.

**[0050]** Cloud service **108-1** includes a plurality of resources **126** and an access management and control system **128** configured to manage and control access to resources **126** by actors **104**. Resources **126** include compute resources **130**, storage resources **132**, and can include other resources **134**. Compute resources **130** include a plurality of individual compute resources **130-1**, **130-2**, **130**-N, which can be the same and/or different types of compute resources. In the present example, compute resources **130** can include elastic compute resources, such as elastic compute cloud (AWS EC2) resources, AWS Lambda, etc.

**[0051]** An elastic compute cloud (EC2) is a cloud computing service designed to provide virtual machines called instances, where users can select an instance with a desired amount of computing resources, such as the number and type of CPUs, memory and local storage. An EC2 resource allows users to create and run compute instances on AWS, and can use familiar operating systems like Linus, Windows, etc. Users can select an instance type based on the memory and computing requirements needed for the application or software to be run on the instance.

**[0052]** AWS Lambda is an event-based service that delivers short-term compute capabilities and is designed to run code without the need to deploy, use or manage virtual machine instances. An example implementation is used by an organization to address specific triggers or events, such as database updates, storage changes or custom events generated from other applications. Such a compute resource can include a server-less, event-driven compute service that allows a user to run code for many different types of applications or backend services without provisioning or managing servers.

**[0053]** Storage resources **132** are accessible through compute resources **130**, and can include a plurality of storage resources **132-1**, **132-2**, **132**-N, which can be the same and/or different types of storage resources. A storage resource **132** can be defined based on object storage. For example, AWS Simple Storage Service (S3) provides highly-scalable cloud object storage with a simple web service interface. An S3 object can contain both data and metadata, and objects can reside in containers called buckets. Each bucket can be identified by a unique user-specified key or file name. A bucket can be a simple flat folder without a file system hierarchy. A bucket can be viewed as a container (e.g., folder) for objects (e.g., files) stored in the S3 storage resource.

**[0054]** Compute resources **130** can access or otherwise interact with storage resources **132** through network communication paths based on permissions data **136** and/or access control data **138**. System **128** illustratively includes identity and access management (IAM) functionality that controls access to cloud service **108-1** using entities (e.g., IAM entities) provided by the cloud computing platform.

**[0055]** Permissions data **136** includes policies **140** and can include other permissions data **142**. Access control data **138** includes identities **144** and can include other access control data **146** as well. Examples of identities **144** include, but are not limited to, users, groups, roles, etc. In AWS, for example, an IAM user is an entity that is created in the AWS service and represents a person or service who uses the IAM user to interact with the cloud service. An IAM user provides the ability to sign into the AWS management console for interactive tasks and to make programmatic requests to AWS services using the API, and includes a name, password, and access keys to be used with the API. Permissions can be granted to the IAM user to make the IAM user a member of a user group with attached permission policies. An IAM user group is a collection of IAM users with specified permissions. Use of IAM groups can make management of permissions easier for those users. An IAM role in AWS is an IAM identity that has specific permissions, and has some similarities to an IAM user in that the IAM role is an AWS identity with permission policies that determine what the identity can and cannot do in AWS. However, instead of being uniquely associated with one person, a role is intended to be assumable by anyone who needs it. Roles can be used to delegate access to users, applications, and/or services that don't normally have access to the AWS resources. Roles can be used by IAM users in a same AWS account and/or in different AWS accounts than the role. Also, roles can be used by computer resources **130**, such as EC2 resources. A service role is a role assumed by a service to perform actions in an account on behalf of a user. Service roles include permissions required for the service to access the resources needed by the service. Service roles can vary from service to service. A service role for an EC2 instance, for example, is a special type of service role that an application running on an EC2 instance can assume to perform actions.

**[0056]** Policies **140** can include identity-based policies that are attached to IAM identities can grant permissions to the identity. Policies **140** can also include resource-based policies that are attached to resources **126**. Examples include S3 bucket policies and IAM role trust policies. An example trust policy includes a JSON policy document that defines the principles that are trusted to assume a role. In AWS, a policy is an object that, when associated with an identity or resource, defines permissions of the identity or resource. AWS evaluates these policies when an IAM principal user or

a role) makes a request. Permissions in the policy determine whether the request is allowed or denied. Policies are often stored as JSON documents that are attached to the IAM identities (user, groups of users, role).

**[0057]** A permissions boundary is a managed policy for an IAM identity that defines the maximum permissions that the identity-based policies can grant to an entity, but does not grant the permissions. Further, access control lists (ACLs) control which principles in other accounts can access the resource to which the ACL is attached. ACLs can be similar to resource-based policies. In some implementations of the technology disclosed, the terms "roles" and "policies" are used interchangeably.

**[0058]** Cloud service **108-1** includes one or more deployed cloud scanners **148**, and can include other items **150** as well. Cloud scanner **148** run locally on the cloud-based services and the server systems, and can utilize elastic compute resources, such as, but not limited to, AWS Lambda resources. Cloud scanner **148** is configured to access and scan the cloud service **108-1** on which the scanner is deployed. Examples are discussed in further detail below. Briefly, however, a scanner accesses the data stored in storage resources **132**, permissions data **136**, and access control data **138** to identify particular data patterns (such as, but not limited to, sensitive string patterns) and traverse or trace network communication paths between pairs of compute resources **130** and storage resources **132**. The results of the scanner can be utilized to identify subject vulnerabilities, such as resources vulnerable to a breach attack, and to construct a cloud attack surface graph or other data structure that depicts propagation of a breach attack along the network communication paths.

**[0059]** Given a graph of connected resources, such as compute resources **130**, storage resources **132**, etc., entities (e.g., accounts, roles, policies, etc.), and actors (e.g., users, administrators, etc.), risks and violations against access to sensitive information is identified. A directional graph can be built to capture nodes that represent the resources and labels that are assigned for search and retrieval purposes. For example, a label can mark the node as a database or S3 resource, actors as users, administrators, developers, etc. Relationships between the nodes are created using information available from the cloud infrastructure configuration. For example, using the configuration information, system **122** can determine that a resource belongs to a given account and create a relationship between the policy attached to a resource and/or identify the roles that can be taken up by a user.

**[0060]** FIG. **3** is a block diagram illustrating one example of cloud security posture analysis system **122**. As noted above, system **122** can be deployed in cloud environment **102** and/or access cloud environment **102** through network **106** shown in FIG. **1**.

**[0061]** System **122** includes a cloud account onboarding component **202**, a cloud scanner deployment component **204**, a cloud data scanning and analysis system **206**, a visualization system **208**, and a data store **210**. System **122** can also include one or more processors or servers **212**, and can include other items **214** as well.

**[0062]** Cloud account onboarding component **202** is configured to onboard cloud services **108** for analysis by system **122**. After onboarding, cloud scanner deployment component **204** is configured to deploy a cloud scanner (e.g., deployed cloud scanner(s) **148** shown in FIG. **2**) to the cloud service. In one example, the deployed scanners are on-demand agent-less scanners configured to perform agent-less scanning within the cloud service. One example of an agent-less scanner does not require agents to be installed on each specific device or machine. The scanners operate on the resources **126** and access management and control system **128** directly within the cloud service, and generate metadata that is returned to system **122**. Thus, in one example, the actual cloud service data is not required to leave the cloud service for analysis. Cloud data scanning and analysis system **206** includes a metadata ingestion component **216** configured to receive the metadata generated by the deployed cloud scanner(s) **148**. System **206** also includes a query engine **218**, a policy engine **220**, a breach vulnerability evaluation component **222**, one or more application programming interfaces (APIs) **224**, a cloud security issue identification component **226**, a cloud security issue prioritization component **228**, historical resource state analysis component **230**, and can include other items **232** as well.

**[0063]** Query engine **218** is configured to execute queries against the received metadata and generated cloud security issue data. Policy engine **220** can execute security policies against the cloud data and breach vulnerability evaluation component **222** is configured to evaluate potential breach vulnerabilities in the cloud service. APIs **224** are exposed to users, such as administrators, to interact with system **122** to access the cloud security posture data.

**[0064]** Component **226** is configured to identify cloud security issues and component **228** can prioritize the identified cloud security issues based on any of a number of criteria.

**[0065]** Historical resource state analysis component **230** is configured to analyze a history of states of resources **126**. Component **230** includes a triggering component **234** configured to detect a trigger that to perform historical resource state analysis. Triggering component **234** is configured to identify an event that triggers component **230** to analyze the state of resources **126**. The event can be, for example, a user input to selectively trigger the analysis, or a detected event such as the occurrence of a time period, an update to a resource, etc. Accordingly, historical resource state can be tracked automatically and/or in response to user input.

**[0066]** Component **230** includes a resource configuration change tracking component **236** configured to track changes in the configuration of resources **126**. Component **230** also includes an anomalous state detection component **238**, and can include other items **240** as well. Component **238** is configured to detect the occurrence of anomalous states in resources **126**. A resource anomaly can be identified where a given resource has an unexpected state, such as a difference from other similar resources identified in the cloud service.

**[0067]** Visualization system **208** is configured to generate visualizations of the cloud security posture from system **206**. Illustratively, system **208** includes a user interface component **242** configured to generate a user interface for a user, such as an administrator. In the illustrated example, component **242** includes a web interface generator **244** configured to generate web interfaces that can be displayed in a web browser on a client device.

**[0068]** Visualization system **208** also includes a resource graph generator component **246**, a cloud attack surface graph generator component **248**, and can include other items **250** as well. Resource graph generator component **246** is

configured to generate a graph or other representation of the relationships between resources **126**. For example, component **246** can generate a cloud infrastructure map that graphically depicts pairs of compute resources and storage resources as nodes and network communication paths as edges between the nodes.

**[0069]** Cloud attack surface graph generator component **248** is configured to generate a surface graph or other representation of vulnerabilities of resources to a breach attack. In one example, the representation of vulnerabilities can include a cloud attack surface map that graphically depicts propagation of a breach attack along network communication paths as edges between nodes that represent the corresponding resources.

**[0070]** Data store **210** stores the metadata **252** obtained by metadata ingestion component **216**, sensitive data profiles **254**, and can store other items **256** as well. Examples of sensitive data profiles are discussed in further detail below. Briefly, however, sensitive data profiles **254** can identify data patterns that are categorized as sensitive or meeting some predefined pattern of interest. Pattern matching can be performed based on the target data profiles. For example, pattern matching can be performed to identify social security numbers, credit card numbers, other personal data, medical information, to name a few. In one example, artificial intelligence (AI) is utilized to perform named entity recognition (e.g., natural language processing modules can identify sensitive data, in various languages, representing names, company names, locations, etc.).

**[0071]** FIG. **4** is a block diagram illustrating one example of a deployed scanner **148**. Scanner **148** includes a resource identification component **262**, a permissions data identification component **264**, an access control data identification component **266**, a cloud infrastructure scanning component **268**, a cloud data scanning component **270**, a metadata output component **272**, and can include other items **274** as well.

**[0072]** Resource identification component **262** is configured to identify the resources **126** within cloud service **108-1** (and/or other cloud services **108**) and to generate corresponding metadata that identifies these resources. Permissions data identification component **264** identifies the permissions data **136** and access control data identification component **266** identifies access control data **138**. Cloud infrastructure scanning component **268** scans the infrastructure of cloud service **108** to identify the relationships between resources **130** and **132** and cloud data scanning component **270** scans the actual data stored in storage resources **132**. The generated metadata is output by component **272** to cloud security posture analysis system **122**.

**[0073]** FIG. **5** is a flow diagram **300** showing an example operation of system **122** in on-boarding a cloud account and deploying one or more scanners. At block **302**, a request to on-board a cloud service to cloud security posture analysis system **122** is receives. For example, an administrator can submit a request to on-board cloud service **108-1**.

**[0074]** FIG. **6** illustrates one example of a user interface display **304** provided for an administrator. Display **304** includes a display pane **306** including a number of display elements representing cloud accounts that have been on-boarded to system **122**. Display **304** includes a user interface control **308** that can be actuated to submit an on-boarding request at block **302**.

**[0075]** Referring again to FIG. **5**, at block **310**, an on-boarding user interface display is generated. At block **312**, user input is received that defines a new cloud account to be on-boarded. The user input can define a cloud provider identification **314**, a cloud account identification **316**, a cloud account name **318**, access credentials to the cloud account **320**, and can include other input **322** defining the cloud account to be on-boarded.

**[0076]** FIG. **7** illustrates one example of an on-boarding user interface display **324** that is displayed in response to user actuation of control **308**.

**[0077]** Display **324** includes a user interface mechanism **326** configured to receive input to select or otherwise define a particular cloud account provider. In the illustrated example, mechanism **326** includes a plurality of selectable controls representing different cloud providers including, but not limited to, AWS, GCP, Azure.

**[0078]** Display **324** includes a user input mechanism **328** configured to receive input defining a cloud account identifier, and an account nickname. User input mechanisms **330** allow the user to define other parameters for the on-boarding. A user input mechanism **332** is actuated to generate a cloud formation template, or other template, to be used in the on-boarding process based on the selected cloud account provider.

**[0079]** Once the cloud account is connected to system **122**, display **304** in FIG. **6** can be updated to show the details of the cloud account as well as the scan status. In FIG. **6**, each entry includes a display name **334**, an account ID **336**, a data store count **338**, and a risk count **340**.

**[0080]** Data store count **338** includes an indication of the number of data stores in the cloud account and the risk count **340** includes an indication of a number if identified security risks. A field **342** indicates the last scan status, such as whether the last scan has completed or whether the scanner is currently in progress or currently scanning. A field **344** indicates the time at which the last scan was completed.

**[0081]** Referring again to FIG. **5**, at block **346**, the cloud account is authorized using roles. For example, administrator access (block **348**) can be defined for the cloud scanner using IAM roles. One or more cloud scanners are defined at block **350** and can include, but are not limited to, cloud infrastructure scanners **352**, cloud data scanners **354**, vulnerability scanners **356**, or other scanners **358**.

**[0082]** At block **360**, the cloud scanners are deployed to run locally on the cloud service, such as illustrated in FIG. **2**. The cloud scanners discover resources at block **362**, scan data in the resources at block **364**, and can find vulnerabilities at block **366**. As discussed in further detail below, a vulnerability can identified based on finding a predefined risk signature in the cloud service resources. The risk signatures can be queried upon, and define expected behavior within the cloud service and locate anomalies based on this data.

**[0083]** At block **368**, if more cloud services are to be on-boarded, operation returns to block **310**. At block **370**, the scan results from the deployed scanners are received. As noted above, the scan results include metadata (block **372**) generated by the scanners running locally on the cloud service.

**[0084]** At block **374**, one or more actions are performed based on the scan results. At block **376**, the action includes security issue detection. For example, a breach risk on a particular resource (such as a storage resource storing sen-

sitive data) is identified. At block **378**, security issue prioritization can be performed to prioritize the detected security issues. Examples of security issue detection and prioritization are discussed in further detail below. Briefly, security issues can be detected by executing a query against the scan results using vulnerability or risk signatures. The risk signatures identify criterion such as accessibility of the resources, access and/or permissions between resources, and data types in accessed data stores. Further, each risk signature can be scored and prioritized based impact. For example, a risk signature can include weights indicative of likelihood of occurrence of a breach and impact if the breach occurs.

**[0085]** The action can further include providing user interfaces at block **380** that indicate the scan status (block **382**), a cloud infrastructure representation (such as a map or graph) (block **384**), and/or a cloud attack surface representation (map or graph) (block **386**). The cloud attack surface representation can visualize vulnerabilities based on the low.

**[0086]** Remedial actions can be taken at block **388**, such as creating a ticket (block **390**) for a developer or other user to address the security issues. Of course, other actions can be taken at block **392**. For instance, the system can make adjustments to cloud account settings/configurations to address/remedy the security issues.

**[0087]** FIG. **8** illustrates one example of a user interface display **400**, that can be displayed at block **376**. Display **400** provides a dashboard for a user which provides an overview of on-boarded cloud service accounts. The dashboard identifies a number of users **402**, a number of assets **404**, a number of data stores **406**, and a number of accounts **408**. A data sensitivity pane **410** includes a display element **412** that identifies a number of the data stores that include sensitive data, a display element **413** that identifies a number of users with access to the sensitive data, a display element **414** that identifies a number of resources having sensitive data, and a display element **416** that identifies a number of risks on the data stores having sensitive data. Further, graphs or charts can be generated to identify those risks based on factors such as status (display element **418**) or impact (display element **420**).

**[0088]** Display element **420** illustratively categorizes the risks based on impact as well as the likelihood of occurrence of those risks. Risk categorization is discussed in further detail below. Briefly, however, display element **420** stratifies one or more of breach likelihood scores or breach impact scores categories representing different levels of severity, such as high, medium, and low severity levels. In one example, display element **420** is color coded based on the degree of impact of the risk (e.g., high impact is highlighted in red, medium impact is highlighted in yellow, and low impact is highlighted in green).

**[0089]** FIG. **9** is a flow diagram **450** illustrating one example of cloud infrastructure scanning performed by cloud scanner **148** deployed in cloud service **108-1**. At block **452**, an agent-less scanner is executed on the cloud service. The scanner can perform constant time scanning at block **454**.

**[0090]** An example constant time scanner runs an algorithm in which the running time does not depend, or has little dependence on, the size of the input. The scanner obtains a stream of bytes and looks for a multiplicity of patterns (one hundred patterns, two hundred patterns, three hundred patterns, etc.) in one pass through the stream of bytes, with the same or substantially similar performance.

**[0091]** Further, the scanner can return real-time results at block **456**. Accordingly, cloud security posture analysis **122** receives updates to the security posture data as changes are made to the cloud services.

**[0092]** At block **458**, the scanner discovers the compute resources **130** and, at block **460**, the storage resources **132**. Sensitive data can be discovered at block **462**. The agent-less scanner does not require a proxy or agent running in the cloud service, and can utilize server-less containers and resources to scan the documents and detect sensitive data. The data can be accessed using APIs associated with the scanners. The sensitive data can be identified using pattern matching, such as by querying the data using predefined risk signatures.

**[0093]** At block **464**, access paths between the resources are discovered based on permissions data **136** (block **466**), and/or access control data **138** (block **468**). A rule processing engine, such as using JSON metadata, can be utilized to analyze the roles and policies, and can build access relationships between the nodes representing the resources. The policies can be decoded to get access type (allow, deny, etc.) and the policy can be placed in a node to link from a source to target node and create the access relationship. At block **470**, metadata indicative of the scanning results is generated and outputted by metadata output component **272**.

**[0094]** FIGS. **10-1**, **10-2**, **10-3**, and **10-4** (collectively referred to as FIG. **10**) provide a flow diagram **500** illustrating an example operation for streamlined analysis of security posture. For sake of illustration, but not by limitation, FIG. **10** will be discussed in the context of cloud security posture analysis system **122** illustrated in FIG. **3**. Security posture can be analyzed by system **206** using metadata **252** to return from the cloud service scanners.

**[0095]** At block **502**, permissions data and access control data are accessed for pairs of compute and storage resources. The permissions and access control data can include identity-based permissions at block **504**, resource-based permissions at block **506**, or other permissions as well.

**[0096]** At block **508**, network communication paths between the pairs of resources are traced based on the permissions and access control data. For example, the permissions and access control data can identify which paths have read access from a compute resource from a particular compute resource to a particular storage resource, as represented at block **510**. Similarly, paths with write access from compute to storage resources can be identified at block **512**, paths with synchronization access between storage resources can be identified at block **514**. Of course, other types of paths can be identified as well.

**[0097]** For sake of example, but not by limitation, a directional graph is constructed to captures all resources as nodes, with labels assigned to the nodes for search and retrieval. In the AWS example, labels can mark a node as a database or S3 resource. Similarly, labels can represent actors as normal users, admins, developers, etc. Then, known relationships are identified between the nodes, for example using the information available from the cloud infrastructure configuration (e.g., defining a resource belongs to a given account). Similarly, a relationship can be created between the policy attached to a resource, and/or the roles that can be taken up by a user. In addition to storing static information, a rule processing engine (e.g., using

JavaScript Object Notation (JSON) metadata) to analyze the roles and policies and build the "access" relationship between the nodes. The analysis can be used to decode the policy to get the access type (e.g., allow, deny, etc.), and the placement of the policy in a node can be used to link from the source node to target node and create the access relationship (e.g., allow, deny, etc.). Similarly, role definitions can be analyzed to find the access type. The graph can therefore include various types of nodes, updated to reflect direct relationships.

**[0098]** An iterative process can be performed to find transitive relationships between resources (e.g., resource access for a given entity/actors/resources). In one example, for each access relationship from a first node N1 to a second node N2, the process identify all incoming access relationships of N1. Then, the access types targeting node N1 are analyzed and updated. Using the relationships identified to access N1, the relationships to N2 are updated, and a new set of access relationships are identified to N2 through N1. The process continues to proceed to identify all such relationships with the goal of creating relationships to all nodes that have sensitive data.

**[0099]** In one example, block **508** identifies "access types" which include normalized forms of access permissions. For example, an access type "can read" can be defined to include a plurality of different read objects within AWS (e.g., defined in terms of allowable APIs). Similarly, the AWS permissions "PutObject" and "PutObjectAcl" are transformed to a normalized access type "can write" within system **122**.

**[0100]** At block **516**, sensitivity classification data is accessed for objects in the storage resources. The sensitivity classification data can include sensitive data profiles at block **518**.

**[0101]** At block **520**, crawlers can be selected for structured and/or unstructured databases. Crawling the databases can include executing a snapshot of structured databases, creating a dump of structured databases, and scanning the dump for sensitivity classification, as represented at block **524**.

**[0102]** At block **526**, a subset of the pairs of resources are qualified as vulnerable to a breach attack. The qualification can be based on the permissions data at block **528**, the access control data at block **530**, and/or risk criterion at block **532**. The risk criterion can include any of a wide variety of different types of criteria. For example, a risk criterion can indicate a variety of access to the resources at block **534**. One example includes a number of different roles with access to the resource, as represented at block **536**.

**[0103]** Also, a risk criterion can indicate a width of configured access to the resources, at block **538**. For example, the width of configured can include a number of workloads with access to the resources (block **540**) and/or a type of workload with access to the resources (block **542**).

**[0104]** A risk criterion can also indicate a number of users with access to the resources at block **544**, a volume of sensitive data in the resources at block **546**, and/or types of categories of sensitive data at block **548**. Of course, other types of risk criterion can be utilized as well.

**[0105]** In one example, the risk criterion can be defined based on user input. FIG. **11** illustrates one example of a user interface display **550** that facilitates user definition of risk criterion. Display **550** includes a set of user input mechanisms that allows a user to define likelihood weights, represented at numeral **552**, and impact weights, represented at **554**.

**[0106]** For sake of illustration, a first user input mechanism **556** allows a user to set a weight that influences a likelihood score for variations in the variety of access to the resources (e.g., block **534**). Similarly, controls **558**, **560**, and **562** allow a user to set weights that influence likelihood scores for a width of configured access, a number of principles or users with access, and the type of workloads with access, represented by reference numerals **558**, **560**, and **562**, respectively.

**[0107]** Similarly, controls **563**, **564**, **566**, **568**, and **570**, allow a user to set weights on impact scores for risk criterion associated with a volume of sensitive data, a type of sensitive data, and categories of sensitive data (i.e., legal data, medical data, financial data), respectively.

**[0108]** Referring again to FIG. **10**, at block **572**, a first subset of the storage resources that satisfy a subject vulnerability signature are identified. A subject vulnerability signature illustratively includes a risk signature indicative of a risk of vulnerability or breach.

**[0109]** FIG. **12** illustrates an example user interface display **574** that can be accessed from display **304** illustrated in FIG. **6**, and displays a set of risk signatures. The risk signatures can be predefined and/or user-defined. For example, display **574** can include user input mechanisms that allow a user to add, delete, or modify a set of risk signatures **576**. As noted above, each risk signature defines a set of criteria that the resources and data in cloud service **108-1** can be queries upon to identify indications of vulnerabilities in the cloud service. The risk signatures in FIG. **12** include a name field **578**, a unique risk signature ID field **580**, and a description identified in a description field **582**. A result header field **584** identifies types of data that will be provided in the results when the risk signature is matched. A resource field **586** identifies the type of resource, and a tags field **588** identifies tags that label or otherwise identify the risk signature. Additionally, a likelihood factor field **590** indicates a likelihood factor that is assigned to the risk signature and an impact factor signature **592** indicates an impact factor assigned to the risk signature. The likelihood factor indicates a likelihood assigned to occurrence of the risk signature and the impact factor assigns an impact to the cloud service assigned to the occurrence of the risk signature. For sake of illustration, a likelihood factor of ten (out of a scale of ten) indicates that the vulnerability is likely to occur if the risk signature is identified in the cloud posture data, whereas a likelihood factor of one indicates a low likelihood. Similarly, an impact factor of ten (out of a scale of ten) indicates that the vulnerability is considered to have a high impact, whereas an impact factor of one indicates the vulnerability is considered to have a low impact on the cloud service.

**[0110]** A risk signature can be defined based upon any of a wide variety of criteria. For example, a risk signature can identify one or more configurations or settings of compute resources **130**. Examples include, but are not limited to, a configuration that indicates whether the compute resource provides accessibility to a particular type of data, such as confidential data, medical data, financial data, personal data, or any other type of private and/or sensitive content. In another example, a risk signature indicates that a compute resource is publicly accessible, includes a public Internet

protocol (IP) address, or has IP forwarding enabled. In another example, a risk signature indicates that a compute resource has monitoring disabled, has no IAM role assigned to the compute resource, has backup disabled, data encryption disabled, and/or a low or short backup retention policy. Also, a risk signature can identify password policies set for the compute resource. For instance, a risk signature can indicate a lack of minimum password policies, such as no minimum password length, no requirement of symbols, lowercase letters, uppercase letters, numbers, or password reuse policy. Also, a risk criterion can indicate a location of the compute resource, such as whether the compute resource is located outside of a particular region.

**[0111]** Risk signatures can also indicate configurations and/or settings of storage resources **132**. For example, the configurations and settings can indicate authentication or permissions enforced by the storage resource, such as whether authentication is required for read, write, delete, synchronization, or any other operation. Also, the risk signature can indicate whether multi-factor authentication is disabled for the storage resource, as well as a breadth of permissions grants (e.g., whether all authenticated users are granted permissions within the storage resource). Also, a risk signature can indicate whether encryption is enabled by default, a password policy enforced by the storage resource, whether the storage resource is anonymously accessible, publicly accessible, has a key management service disabled, has logging disabled, life cycle management disabled, whether the storage resource is utilized for website hosting, has geo-restriction disabled, or has backup functionality disabled. Also, the risk signature can indicate a type of data stored by the storage resource, such as the examples discussed above.

**[0112]** Referring again to FIG. **10**, the first subset of storage resources identified at block **572**, are based on determining that the storage resources satisfy a risk signature of containing private and/or sensitive content, as represented at block **594**. In another example, the subject vulnerability signature is based on a prevalence of accessibility of a given role within a network exceeding a set threshold, as represented at block **596**. For instance, the given role can include principles (block **598**), workloads (block **600**), a cloud environment (block **602**), a company (block **604**), or other roles (block **606**).

**[0113]** Also, the subject vulnerability signature can indicate that the storage resources are accessible by more than a threshold number of users, as represented at block **608**. Also, the subject vulnerability signature can indicate that the storage resources are accessible by a vulnerable compute resource that is publicly accessible, as represented at block **610**. This determination can be based on identifying that the compute resource is accessible through a public portal, at block **612** and/or is accessible by users outside a given company network at block **614**.

**[0114]** As represented at block **616**, the subject vulnerability signature can indicate that the storage resources are accessible by inactive users. For example, inactive users can include users who have not accessed the resources within a threshold time, at block **618**.

**[0115]** At block **620**, a second subset of storage resources are identified that synchronization data from the first subset. At block **622**, a particular compute resource is determined to have anomalous access to a given storage resource. The identification of anomalous access can be based on a comparison of a network communication path of the particular compute resource against paths of other compute resources. For example, the paths of other compute resources can be used to identify an expected communication path for the particular compute resource and/or expected permission for the particular resource. Then, if a difference above a threshold is identified, the particular compute resource is identified as anomalous.

**[0116]** At block **624**, a representation of the propagation of the breach attack along the network communication paths is generated. In one example, the representation includes a cloud attack surface map, as represented at block **626**. An example cloud attack surface map includes nodes representing the resources (block **628**) and edges representing the breach attack propagation (block **630**). The map graphically depicts the subset of storage resources (block **632**) and the subject vulnerability signature (block **634**). Also, the map can graphically depict the anomalous access to the particular compute resource (block **636**). For example, public accesses to the subset of storage resources can be graphically depicted at block **638** and storage resources that grant external access and/or resources that are initialized from outside a particular jurisdiction can be identified at blocks **640** and **642**, respectively.

**[0117]** FIG. **13** illustrates one example of a user interface display **650** that graphically depicts vulnerability risks, in tabular form. In one example, display **650** renders the data discussed with respect to the cloud attack surface at block **626** of FIG. **10** in a table.

**[0118]** Display **650** includes a user input mechanism **652** to specify a time range for visualizing the risk, and includes a description **654**, a resource identifier **656**, and an account identifier **658** for the cloud service account. The display can also indicate the impact **660** and likelihood **662** of the vulnerability risk, as well as signature identifier **664** that identifies the particular risk signature that was matched. Display **650** also includes a details control **666** that is actuatable to display details of the identified risk. One example of a details display pane **668** is illustrated in FIG. **14**. Display pane **668** shows a description of the risk at display element **670** and an indication **672** of the query utilized to match the risk signature.

**[0119]** Referring again to FIG. **10**, at block **676**, a query is received for execution against the results of the metadata analysis. For example, a query can specify a subject vulnerability at block **678** and/or the query can request identification of resources with anomalous access at block **680**.

**[0120]** At block **682**, the query is executed against the cloud attack surface map. For example, the cloud attack surface map can be filtered to identify results that match the query. The query results (e.g., the filtered map) is returned at block **684**. The filtered results can include identifying a subset of storage resources that match the query (block **686**) and/or resources having anomalous access at block **688**.

**[0121]** The cloud attack surface graph is graphically filtered based on the results at block **690**. For example, the graph can be filtered based on applications running on the pairs of resources in the identified subset (block **692**). Breach likelihood scores and breach impact scores are determined for the resources at block **694**, and the scores can be depicted on the cloud attack surface map at block **696**. In one example, the scores are graphically categorized or stratified at block **698** into high, medium, or low risk. One example is discussed above with respect to FIG. **8**.

**[0122]** FIG. **15** illustrates one example of a user interface display **700** configured to graphically depict breach likelihood and impact scores. Display **700** identifies data stores in storage resources **132** that are identified as meeting a subject vulnerability. Each entry shown in display **700** identifies a type **702** of the resource, an impact score **704**, a likelihood score **706**, a resource identifier **708** that identifies the resource, and a cloud service identifier **710** that identifies the particular cloud resource. Based on actuation of a risk item view generator mechanism **712**, display **700** shows details for the given resource in a details pane **714**, as shown in FIG. **16**. Display pane **714** can show users **716** that have access to the resource, roles **718** that have access to the resource, other resources **720** that have access to the resource, as well as external users **722** or external roles **724**. Display pane **714** also shows the access type **726**.

**[0123]** FIG. **17** illustrates one example of a display pane **730** showing access details for a particular data store, along with a list of users who have access to that data store, and the access type for those users. Upon actuation of a roles actuator **732**, the display shows a list of roles that have access to the data store, as shown in FIG. **18**. Upon actuation of a resources actuator **734**, the display shows a list of resources that have access to the data store, as shown in FIG. **19**.

**[0124]** FIGS. **20-1**, **20-2**, **20-3**, and **20-4** (collectively referred to as FIG. **20**) provide a flow diagram **800** illustrating one example of infrastructure analysis and query execution. At block **802**, permissions data and access control data for pairs of compute and storage resources is accessed. Policy data is accessed at block **804**. For example, the policy data can include identity-based policies (block **806**), resource-based policies (block **808**), permissions boundaries (block **810**), service control policies (SCP) (block **812**), session policies (block **814**) as well as other policies (block **816**).

**[0125]** At block **818**, network communication paths are traced between the pairs of resources. Tracing the network communication path can be based on the permissions data at block **820**, the access control data at block **822**, the policy data at block **824**, and/or other data at block **826**.

**[0126]** At block **828**, a cloud infrastructure map is constructed. An example of a cloud infrastructure map includes nodes that graphically represent pairs of compute and storage resources (block **830**), and edges that represent network communication paths between the resources (block **832**). At block **834**, the map graphically depicts metadata associated with the pairs of resources. For example, a graphical metadata depiction is expandable or collapsible via user selection, as represented at block **836**. The metadata can be grouped across metadata categories at block **838**, such as based on cloud-sourced metadata at block **840**, derived metadata at block **842**, locally annotated metadata at block **844**, or based on other metadata categories at block **846**.

**[0127]** The cloud infrastructure map can also graphically depict anomalous configured access instances at block **848**. For example, block **848** can detect different levels of access among resources that connect to a common network component, as represented at block **850**. At block **852**, the map graphically depicts anomalous actual access instances in the cloud environment. For instance, the instances can be detected from access logs at block **854**. User annotated tags for the resources can be depicted in the map at block **856** as well.

**[0128]** At block **858**, a query is received. The query can include a search term **860**, a content category (block **862**), a data privacy policy (block **864**), a temporal period (block **866**), and can include other items **868** as well.

**[0129]** The query is executed at block **870** and query results are returned at block **872**. For example, the query results can identify a subset of the pairs of resources that contain the searched content at block **874**. At block **876**, resources are identified that do not have the search content, but have access to the subset. At block **878**, the query results can identify a subset of the pairs of resources that contain a searched content category. For example, at block **880**, resources are identified that do not have the content from the content category, but that have access to the subset of resources that have the searched content category.

**[0130]** At block **882**, the query results can identify a subset of resources as complying with a given data privacy policy, specified in the query. Additionally, the results can identify resources that have access to the identified subset, at block **884**. At block **886**, a prior state of the resources is identified. Of course, the query results can identify other data **888** as well.

**[0131]** At block **890**, a filter criterion is received. The filter criterion can be based on the metadata (block **892**), based on applications running on at least one pair of resources (block **894**), and/or based on one or more networks in the cloud environment (block **896**). The networks can include virtual private clouds (VPCs) **898**, regions **900**, Internet gateways **902**, network access control lists **904**, sub networks **906**, or other networks **908**.

**[0132]** The filter criterion can also be based on tags at block **910**, such as users annotated tags represented at block **912**. The filter criterion can also be based on owners of the resources (block **914**), a creation date and/or time of the resources (block **916**), an inactive/stale criterion (block **918**), or other filter criterion (block **920**). At block **922**, the cloud infrastructure map is filtered based on the filter criterion and a filtered cloud infrastructure map is rendered at block **924**.

**[0133]** FIGS. **21-1** and **21-2** (collectively referred to as FIG. **21**) provide a flow diagram **1000** illustrating one example of cloud data scanning in a cloud service. At block **1002**, administrative access to the cloud account is obtained. A scan schedule for scanning the cloud account is defined at block **1004**.

**[0134]** FIGS. **22** and **23** illustrates example user interface displays for defining a scan schedule at block **1004**. As shown in FIG. **22**, a user interface display **1006** includes a list **1008** of currently defined scan schedules **1010**, **1012**, **1014**, etc. Each scan schedule is defined by a set of criteria **1016** for identifying which data stores are to be scanned, along with temporal criteria **1018** that define when the scan is to run. The scan schedule can be edited using an edit actuator **1020**. Further, the data scan can be executed manually, through a control **1022**. New schedules can be defined using a new schedule control **1024**. FIG. **23** illustrates user interface display **1006** when a given one of the data scans has been initiated and includes a scan status indicator **1026**.

**[0135]** Referring again to FIG. **21**, block **1028** represents deployment and execution of a scanner locally on the cloud account. In one example, the data is access using APIs, and text is extracted using a text extraction method. Once the text is obtained, natural language processing (NLP) modules identify sensitive data in different languages. For instance,

the scanner includes a file system crawler for each data store that is configured to identify pattern and context-based entities and/or machine learning-based entities, such as named entity recognition (names, company names, locations). Further, data loss prevention (DLP) engines can identify social security numbers, credit card numbers, etc. That is, the engine can identify which nodes content particular types of sensitive data.

**[0136]** A scanner is triggered and recognizers for sensitive entity detection are loaded, along with profiles for analysis. Text is extracted and entity detection is performed. In one example, the scanning is performed locally on the cloud service so that the organization's data does not leave the organization's cloud account, which can increase privacy and conformance with data policies. The scanners can be encapsulated as containers, that are deployed in the cloud environment using elastic compute instances, such as EC2 resources, Lambda resources, etc.

**[0137]** At block **1030**, objects in the cloud environment are queued and, at block **1032**, the objects are partitioned into a plurality of object chunks. At block **1034**, a number (M) of object chunks are identified. At block **1036**, depending upon the number M, a number (N) of instances of the server-less container-less scanners are initialized. In one example, the number M is significantly larger than the number N (block **1038**). For example, the number M can be ten times more (block **1040**) than the number N, one hundred times more (block **1042**) than the number N, etc. Of course, other numbers of object chunks and instances of the scanners can be utilized, as represented at block **1044**.

**[0138]** The scanners are dynamically scalable (block **1046**), and each scanner can be portable and independently executable as a microservice (block **1048**).

**[0139]** At block **1050**, a multiplicity of different data patterns to scan are obtained. For example, the data patterns can include sensitive string patterns (block **1052**), social security numbers (block **1054**), credit card numbers (block **1056**), or other data patterns (block **1058**).

**[0140]** For each scanner, a corresponding object chunk is scanned exactly once to detect the multiplicity of different data patterns, as represented at block **1060**. Accordingly, each scanner can identify a number of different data patterns, through a given pass through the object chunk. This single pass scanning increases efficiency by decreasing scanning latency. In one example, a multiplicity of object metadata can be detected at block **1062**.

**[0141]** Sensitivity metadata is generated at block **1064** based on the detected data patterns. The system is controlled based on the sensitivity metadata at block **1066**. For example, the sensitivity metadata is sent to a metadata store in a control plane in the cloud environment at block **1068**. Alternatively, or in addition, the cloud attack surface graph is modified at block **1070**. For example, sensitivity annotation is applied to the graph at block **1072**.

**[0142]** FIGS. **24-1** and **24-2** (collectively referred to as FIG. **24**) provide a flow diagram **1100** illustrating one example of depicting access links along communication paths between roles and resources. At block **1102**, an indication of access sub-networks (e.g., territories, regions, etc.) in a cloud environment between a plurality of resources and a plurality of users is obtained. For example, the indication can be obtained from memory at block **1104**. In one example, the access sub-networks are identified as subnetworks that make a subject resource accessible to one or more users, as represented at block **1106**.

**[0143]** At block **1108**, user-to-role mappings for roles assigned to the plurality of users is obtained. For example, access management and control system **128** is used to identify roles defined at a particular resolution or level of the cloud environment, as represented at block **1110**.

**[0144]** The access sub-networks are traversed at block **1112** and a number (U) of user-to-resource mappings between the users and the resources are built based on traversing the sub-networks, as represented at block **1114**.

**[0145]** At block **1116**, the number U of user-to-resource mappings is evaluated against the user-to-role mappings to accumulate a number (R) of role-to-resource mapping. In one example, the number U is significantly larger than the number R, as represented at block **1118**. For example, the number U can be ten times more (block **1120**) or one hundred times more (block **1122**) than the number R. Of course, other numbers of mappings can be utilized as well, as represented at block **1124**.

**[0146]** In one example, at block **1126** a role-to-resource mapping maps a particular role to a particular subset of resources. Also, new resources that are assigned to the particular role are automatically mapped to the particular subset, as represented at block **1128**.

**[0147]** At block **1130**, access communication paths between the roles and the plurality of resources are traced based on the number R of role-to-resource mapping.

**[0148]** At block **1132**, a compact access network graph is constructed that graphically depicts access links along the traced access communication path. For example, the graph can include nodes that represent roles and resources (block **1134**), and edges that represent access links along the access communication paths (block **1136**). At block **1138**, the compact access network graph can be graphically updated to reflect the new resource assigned at block **1128**.

**[0149]** At block **1140**, a history of resource configuration changes and/or anomalous state (e.g., risks) detected for various resources is tracked. For example, this tracking can be manually triggered at block **1142**, or programmatically triggered at block **1154**. Further, the history can be tracked over a timeline, such as to indicate when a particular risk opened and/or closed, as represented at block **1146**.

**[0150]** At block **1148**, a difference between a non-anomalous state and a successive anomalous state is tracked. The tracking can also include tracking a difference between successive anomalous states at block **1150** and/or a difference between successive versions of the resources at block **1152**. For example, the versions can be determined based on respective resource configurations of the successive versions, at block **1144**. The tracked difference can be compared to a threshold difference at block **1156**, to determine whether to track the instance of the resource configuration and/or state change.

**[0151]** At block **1158**, the tracked history can be graphically rendered, such as on a timeline at block **1160**. The tracked difference can be graphically rendered at block **1162**. Further, the tracked history can be provided with a playback feature **1164** or a play forward feature **1166**, which allow a user to navigate through the tracked history.

**[0152]** FIG. **25** illustrates a user interface display **1200** that includes a visualization of access communication paths. The visualization in FIG. **25** can be rendered as a cloud infrastructure graph (e.g., map) that shows relationships

between compute and storage resources and/or mappings between users, roles, and resources, based on the permissions data and the access control data. Further, the visualization can be augmented using sensitivity classification data to represent propagation of breach attack along communication paths. For example, the visualization in FIG. **25** can be configured to render the subset(s) of resources identified in FIG. **10**. That is, display **1200** can include the cloud attack surface map at block **626**.

**[0153]** As shown in FIG. **25**, nodes **1202** represent compute resources and nodes **1204** represent storage resources. Illustratively, the storage resources include data stores or buckets within a particular cloud service. Nodes **1206** represent roles and/or users. The links (e.g., access paths) or edges **1208** between nodes **1202** and **1206** represent that compute resources that can access the particular roles represented by nodes **1206**. The edges or links **1210** represent the storage resources that can be accessed by the particular roles or users represented by nodes **1206**.

**[0154]** Based on these relationships between compute and storage relationships, display elements can be rendered along, or otherwise visually associated with, the edges **1208** and/or **1210**, to identify and graphically depict the propagation of breach attack. For instance, vulnerability display elements can be rendered in association with edges **1208** and/or **1210** to identify that a subject vulnerability signature (e.g., one or more risk signatures shown in FIG. **12**) has been identified in the data, based on querying the permissions and access control data using the subject vulnerability signature. For example, display element **1209** represents a risk signature between nodes **1203** and **1212** and display element **1211** represents (such as by including a description, icon, label, etc.) a risk signature between nodes **1212** and **1222**. Each display element **1209**, **1211** can represent (such as by including a description, icon, label, etc.) corresponding likelihood and impact scores, can be actuatable to render details of the subject vulnerability, such as in a display pane on display **1200**. The details can include which risk signature has been matched, which sensitive data is at risk, etc.

**[0155]** The graph can be interactive at a plurality of different resolutions or levels. For example, a user can interact with the graph to zoom into a specific subset, e.g., based on cloud vendor concepts of proximity (regions, virtual private clouds (VPCs), subnets, etc.). Node **1212** includes an expand actuator **1214** that is actuatable to expand the display to show additional details of the roles, role groups, and/or users represented by node **1212**.

**[0156]** When zooming into one region, such as when using the actuators discussed below, other regions can be zoomed out. This can be particularly advantageous when handling large diagrams. Further, the graph includes one or more filter mechanisms configured to filter the graph data by logical properties, such as names, values of various fields, IP addresses, etc. For example, a free form search box **1215** is configured to receive search terms and filter out all resources (e.g., by removing display of those resources) except those resources matching the search terms. In one example, the search terms include a subject vulnerability signature (e.g., containing private and sensitive content, public accessibility, accessibility by a particular user and/or role, particular applications running on the resources, access types, etc.).

**[0157]** An input mechanism **1217** is configured to receive a temporal filter or search criterion. For example, a filter criterion is entered by a user to represent at least one of a creation time or date of computer resources and storage resources. Further, a query can be entered specifying at least one temporal period, wherein the cloud infrastructure map is updated to graphically return at least one prior state (e.g., a permissions state, an access control state, and/or a sensitivity data classification state) of compute resources and storage resources based on the temporal period.

**[0158]** A checkbox (not shown in FIG. **25**, and which can be global to the diagram) provides the ability to toggle whether or not direct neighbors of the matching resources are also displayed, even if those neighbors themselves don't match the search terms. This allows users to search for specific resources and immediately visualize all entities that have access to the searched resources. To illustrate, assume a search for personally identifiable information (PII) matches a set of S3 buckets. In this case, the graph renders resources that have access to that PII. Further, the graph can show associated data and metadata (e.g., properties extracted from cloud APIs, properties derived such as presence of sensitive data, access paths, etc.). This data and metadata can be shown on a panel to the left or right of the diagram (such as shown in FIGS. **27-30**). Further, user can actuate user interface controls to collapse/expand this panel. In one example, the panel remains collapsed or expanded until changed, even across different searches and login sessions. Additionally, the display can groups properties in related categories (e.g., summary, all metadata retrieved from the cloud, all metadata derived, local annotations, etc.), and the diagram can be filtered (such as by using the free form search bar mentioned above) by metadata such as tags, applications running on them, identified owners, time since created, etc.). The state of the resources can be shown as of a user defined date or time. A calendar component can allow users to select a particular date to visualize historical state data as of that particular date.

**[0159]** In one example, a user interface control allows user to define critical data (e.g., crown jewel data), such as through a filter mechanism (e.g., search box **1215**). The display then visually highlights that critical data along with all entities with access (defined by a filter such as CAN_READ/CAN_WRITE/CAN_SYNC etc) to the critical data. Anomalous configured access (different levels of access among similar resources can be visually highlighted in the display. For example, if there are four EC2 instances in a worker group connected to the same load balancer, all of the EC2 instances are expected to have the same type of access. However, if one of the EC2 instances has different access, the EC2 instance is identified as anomalous and visually highlighted to the user. Similarly, the display can visually highlight anomalous actual access. That is, instead of inspecting configured access, the system looks at actual access determined using, for example, access logs (e.g., cloudtrail logs, S3 access logs, etc.).

**[0160]** Further, the display can be configured to allow the user to add tags to one or more selected resources in the diagram. For instance, when users visualize cloud assets in context, the user can add additional tags that let the user write policies, perform filtering etc. that further aid in visualization and understanding. The user interface allows the user to choose one or more resources and add tags (keys and values in AWS Tags, for example) to selected resources.

**[0161]** FIG. **26** shows display **1200** after actuation of actuator **1214**. As shown in FIG. **26**, node **1212** has been expanded to show particular roles or role groups **1216** and

the relationships between those roles and role groups (as represented by links **1218**), to the nodes **1206**. Role groups **1216** is represented by an actuatable display element, that is actuatable to display additional details associated with the corresponding role. For example, display element **1220** is actuatable to display details of the corresponding role, as shown in FIG. **27**.

**[0162]** Referring again to FIG. **25**, the nodes **1204** representing the storage resources are also actuatable to show additional details. For example, node **1222** includes an actuator **1224** that is actuatable to display the view shown in FIG. **28**. FIG. **28** includes a representation **1226** of the constituents of the storage resource represented by node **1222**. One or more of the elements are further actuatable to show additional details of the constituent. For example, node display element **1228** includes an actuator **1230** to show, in the example display of FIG. **29**, details of the virtual private cloud represented by node display element **1228**.

**[0163]** Referring again to FIG. **25**, node **1232** is actuatable to show details of the corresponding compute resource. An example display for compute resource details is shown in FIG. **30**.

**[0164]** FIG. **31** shows one example of a user interface display **1250** that visualizes resources identified based on the data scanning performed on cloud service **108-1**. Display **1250** includes a list of display elements **1252**, each representing a particular resource. Each entry includes an account ID **1254**, a resource type **1256**, a name **1258**, and a region **1260**. A details actuator **1262** can be actuated to show additional details of the corresponding resource. For example, FIG. **32** shows a display **1264**, that is displayed in response to actuation of actuator **1262**.

**[0165]** Referring again to FIG. **31**, display **1250** includes navigation actuators **1266**, that are actuatable to navigate through different portions of the list. FIG. **33** illustrates a second page displayed in response to actuation of control **1268**.

**[0166]** FIG. **34** shows an example of a user interface display **1270** displaying details of a particular resource, and includes a details actuator **1272**. Actuation of actuator **1272** displays the interface shown in FIG. **35**. As shown in FIG. **35**, the resource (illustratively "config-service-main") is an AWS role having an access type identified at display element **1274**. The access type typically depends on the resource. In the present case, a principle **1276** identifies the entities that have the given role, and the access type identifies that the identified entities can assume the given role relative to the resource. This definition connects the roles to the resources.

**[0167]** FIG. **36** illustrates a flow diagram **1300** for streamlined analysis of access sub-networks, such as regions or territories, in a cloud environment. At block **1302**, an indication of access sub-networks between a plurality of storage resources and compute resources is obtained. For example, the indication can be obtained from memory at block **1304**. In one example, each access sub-network makes a subject storage resource accessible to one or more compute resources, as represented at block **1306**.

**[0168]** At block **1308**, compute resources-to-role mappings for roles assigned to the plurality of compute resources is obtained. Each mapping, in one example, maps a particular resource to a particular role defined in the cloud environment. The roles can be defined at a resolution or level of the cloud environment, as represented at block **1310**.

**[0169]** At block **1312**, the access sub-networks are traversed to build, at block **1314**, a number (U) of compute resources-to-storage resource mappings between the compute resources and storage resources. Each mapping, in one example, maps a particular compute resource to a particular storage resource.

**[0170]** At block **1316**, the number U of compute resources-to-storage resource mappings is evaluated against the compute resource-to-role mappings to accumulate a number (R) role-to-storage resource mappings between the roles and the plurality of storage resources. Each mapping, in the number R, maps a particular role to a particular storage resource and indicates which storage resource that particular role can access. In one example, the number U is significantly larger than the number R, as represented at block **1318**. For example, the number U can be greater than approximately ten times the number R, as represented at block **1320**. In another example, the number U is greater than approximately one hundred times the number R, as represented at block **1322**. These, of course, are for sake of example only.

**[0171]** At block **1324**, the access communication paths are traced between the roles and the plurality of storage resources based on the number R of the role-to-storage resource mappings.

**[0172]** At block **1326**, a compact access network graph is constructed that graphically depicts access links along the traced access communication paths. Examples of a network graph are discussed above. Briefly, in one example, nodes in the graph represent roles and storage resources (block **1328**), and edges represent access links along the access communication paths (block **1330**).

**[0173]** It can thus be seen that the present disclosure describes technology for security posture analysis of a cloud account. In some described examples, the technology can discover sensitive data among the cloud storage resources and as well as access patterns to the sensitive data, using local scanners that reduce or eliminate need to send the cloud data outside the cloud environment. This improves data security. Further, the technology facilitates the discover of security vulnerabilities to understand the data security posture, detect, and remediate the security vulnerabilities, and to prevent future breaches to sensitive data. The system provides real-time visibility and control on the control data infrastructure by discovering resources, sensitive data, and access paths, and tracking resource configuration, deep context, and trust relationships in real-time as a graph or other visualization.

**[0174]** One or more implementations of the technology disclosed or elements thereof can be implemented in the form of a computer product, including a non-transitory computer readable storage medium with computer usable program code for performing the method steps indicated. Furthermore, one or more implementations and clauses of the technology disclosed or elements thereof can be implemented in the form of an apparatus including a memory and at least one processor that is coupled to the memory and operative to perform exemplary method steps. Yet further, in another aspect, one or more implementations and clauses of the technology disclosed or elements thereof can be implemented in the form of means for carrying out one or more of the method steps described herein; the means can include (i) hardware module(s), (ii) software module(s) executing on one or more hardware processors, or (iii) a combination of

hardware and software modules; any of (i)-(iii) implement the specific techniques set forth herein, and the software modules are stored in a computer readable storage medium (or multiple such media).

**[0175]** Examples discussed herein include processor(s) and/or server(s). For sake of illustration, but not by limitation, the processors and/or servers include computer processors with associated memory and timing circuitry, and are functional parts of the corresponding systems or devices, and facilitate the functionality of the other components or items in those systems.

**[0176]** Also, user interface displays have been discussed. Examples of user interface displays can take a wide variety of forms with different user actuatable input mechanisms. For instance, a user input mechanism can include icons, links, menus, text boxes, check boxes, etc., and can be actuated in a wide variety of different ways. Examples of input devices for actuating the input mechanisms include, but are not limited to, hardware devices (e.g., point and click devices, hardware buttons, switches, a joystick or keyboard, thumb switches or thumb pads, etc.) and virtual devices (e.g., virtual keyboards or other virtual actuators). For instance, a user actuatable input mechanism can be actuated using a touch gesture on a touch sensitive screen. In another example, a user actuatable input mechanism can be actuated using a speech command.

**[0177]** The present figures show a number of blocks with corresponding functionality described herein. It is noted that fewer blocks can be used, such that functionality is performed by fewer components. Also, more blocks can be used with the functionality distributed among more components. Further, the data stores discussed herein can be broken into multiple data stores. All of the data stores can be local to the systems accessing the data stores, all of the data stores can be remote, or some data stores can be local while others can be remote.

**[0178]** The above discussion has described a variety of different systems, components, logic, and interactions. One or more of these systems, components, logic and/or interactions can be implemented by hardware, such as processors, memory, or other processing components. Some particular examples include, but are not limited to, artificial intelligence components, such as neural networks, that perform the functions associated with those systems, components, logic, and/or interactions. In addition, the systems, components, logic and/or interactions can be implemented by software that is loaded into a memory and is executed by a processor, server, or other computing component, as described below. The systems, components, logic and/or interactions can also be implemented by different combinations of hardware, software, firmware, etc., some examples of which are described below. These are some examples of different structures that can be used to implement any or all of the systems, components, logic, and/or interactions described above.

**[0179]** The elements of the described figures, or portions of the elements, can be disposed on a wide variety of different devices. Some of those devices include servers, desktop computers, laptop computers, tablet computers, or other mobile devices, such as palm top computers, cell phones, smart phones, multimedia players, personal digital assistants, etc.

**[0180]** FIG. **37** is a simplified block diagram of one example of a client device **1400**, such as a handheld or mobile device, in which the present system (or parts of the present system) can be deployed. FIG. **38** illustrates an example of a handheld or mobile device.

**[0181]** One or more communication links **1402** allows device **1400** to communicate with other computing devices, and can provide a channel for receiving information automatically, such as by scanning. An example includes communication protocols, such as wireless services used to provide cellular access to a network, as well as protocols that provide local wireless connections to networks.

**[0182]** Applications or other data can be received on an external (e.g., removable) storage device or memory that is connected to an interface **1404**. Interface **1404** and communication links **1402** communicate with one or more processors **1406** (which can include processors or servers described with respect to the figures) along a communication bus (not shown in FIG. **14**), that can also be connected to memory **1408** and input/output (I/O) components **1410**, as well as clock **1412** and a location system **1414**.

**[0183]** Components **1410** facilitate input and output operations for device **1400**, and can include input components such as microphones, touch screens, buttons, touch sensors, optical sensors, proximity sensors, orientation sensors, accelerometers. Components **1410** can include output components such as a display device, a speaker, and or a printer port.

**[0184]** Clock **1412** includes, in one example, a real time clock component that outputs a time and date, and can provide timing functions for processor **1406**. Location system **1414** outputs a current geographic location of device **1400** and can includes a global positioning system (GPS) receiver, a LORAN system, a dead reckoning system, a cellular triangulation system, or other positioning system. Memory **1408** stores an operating system **1416**, network applications and corresponding configuration settings **1418**, communication configuration settings **1420**, communication drivers **1422**, and can include other items **1424**. Examples of memory **1408** include types of tangible volatile and non-volatile computer-readable memory devices. Memory **1408** can also include computer storage media that stores computer readable instructions that, when executed by processor **1406**, cause the processor to perform computer-implemented steps or functions according to the instructions. Processor **1406** can be activated by other components to facilitate functionality of those components as well.

**[0185]** FIG. **38** illustrates one example of a tablet computer **1450** having a display screen **1452**, such as a touch screen or a stylus or pen-enabled interface. Screen **1452** can also provide a virtual keyboard and/or can be attached to a keyboard or other user input device through a mechanism, such as a wired or wireless link. Alternatively, or in addition, computer **1450** can receive voice inputs.

**[0186]** FIG. **39** shows an example computer system **5000** that can be used to implement the technology disclosed. Computer system **5000** includes at least one central processing unit (CPU) **5072** that communicates with a number of peripheral devices via bus subsystem **5055**. These peripheral devices can include a storage subsystem **5010** including, for example, memory devices and a file storage subsystem **5036**, user interface input devices **5038**, user interface output devices **5076**, and a network interface subsystem **5074**. The input and output devices allow user interaction with computer system **5000**. Network interface subsystem

**5074** provides an interface to outside networks, including an interface to corresponding interface devices in other computer systems.

**[0187]** In one implementation, cloud security posture analysis system **5018** is communicably linked to the storage subsystem **5010** and the user interface input devices **5038**.

**[0188]** User interface input devices **5038** can include a keyboard; pointing devices such as a mouse, trackball, touchpad, or graphics tablet; a scanner; a touch screen incorporated into the display; audio input devices such as voice recognition systems and microphones; and other types of input devices. In general, use of the term "input device" is intended to include all possible types of devices and ways to input information into computer system **5000**.

**[0189]** User interface output devices **5076** can include a display subsystem, a printer, a fax machine, or non-visual displays such as audio output devices. The display subsystem can include an LED display, a cathode ray tube (CRT), a flat-panel device such as a liquid crystal display (LCD), a projection device, or some other mechanism for creating a visible image. The display subsystem can also provide a non-visual display such as audio output devices. In general, use of the term "output device" is intended to include all possible types of devices and ways to output information from computer system **5000** to the user or to another machine or computer system.

**[0190]** Storage subsystem **5010** stores programming and data constructs that provide the functionality of some or all of the modules and methods described herein. These software modules are generally executed by processors **5078**.

**[0191]** Processors **5078** can be graphics processing units (GPUs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and/or coarse-grained reconfigurable architectures (CGRAs). Processors **5078** can be hosted by a deep learning cloud platform such as Google Cloud Platform™, Xilinx™, and Cirrascale™. Examples of processors **5078** include Google's Tensor Processing Unit (TPU)™, rackmount solutions like GX4 Rackmount Series™, GX50 Rackmount Series™, NVIDIA DGX-1™, Microsoft' Stratix V FPGA™, Graphcore's Intelligent Processor Unit (IPU)™, Qualcomm's Zeroth Platform™ with Snapdragon processors™, NVIDIA's Volta™, NVIDIA's DRIVE PX™, NVIDIA's JETSON TX1/TX2 MODULE™, Intel's Nirvana™, Movidius VPU™, Fujitsu DPI™, ARM's DynamicIQ™, IBM TrueNorth™, Lambda GPU Server with Testa V100s™, and others.

**[0192]** Memory subsystem **5022** used in the storage subsystem **5010** can include a number of memories including a main random access memory (RAM) **5032** for storage of instructions and data during program execution and a read only memory (ROM) **5034** in which fixed instructions are stored. A file storage subsystem **5036** can provide persistent storage for program and data files, and can include a hard disk drive, a floppy disk drive along with associated removable media, a CD-ROM drive, an optical drive, or removable media cartridges. The modules implementing the functionality of certain implementations can be stored by file storage subsystem **5036** in the storage subsystem **5010**, or in other machines accessible by the processor.

**[0193]** Bus subsystem **5055** provides a mechanism for letting the various components and subsystems of computer system **5000** communicate with each other as intended. Although bus subsystem **5055** is shown schematically as a single bus, alternative implementations of the bus subsystem can use multiple busses.

**[0194]** Computer system **5000** itself can be of varying types including a personal computer, a portable computer, a workstation, a computer terminal, a network computer, a television, a mainframe, a server farm, a widely-distributed set of loosely networked computers, or any other data processing system or user device. Due to the ever-changing nature of computers and networks, the description of computer system **5000** depicted in FIG. **50** is intended only as a specific example for purposes of illustrating the preferred implementations of the present invention. Many other configurations of computer system **5000** are possible having more or less components than the computer system depicted in FIG. **50**.

**[0195]** It should also be noted that the different examples described herein can be combined in different ways. That is, parts of one or more examples can be combined with parts of one or more other examples. All of this is contemplated herein.

**[0196]** The technology disclosed can be practiced as a system, method, or article of manufacture. One or more features of an implementation can be combined with the base implementation. Implementations that are not mutually exclusive are taught to be combinable.

**[0197]** One or more features of an implementation can be combined with other implementations. This disclosure periodically reminds the user of these options. Omission from some implementations of recitations that repeat these options should not be taken as limiting the combinations taught in the preceding sections—these recitations are hereby incorporated forward by reference into each of the following implementations.

**[0198]** Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed is:

**1**. A computer-implemented method of content scanning, the computer-implemented method comprising:

obtaining access to a cloud environment account for content scanning of storage resources;

queuing objects in the cloud environment account;

partitioning the objects into a number of object chunks; and

initializing a number of serverless, containerized scanners based on the number of object chunks, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, is deployed locally on the cloud environment account and scans a corresponding object chunk to detect a plurality of different data patterns, and wherein the number of object chunks is at least one hundred times the number of serverless, containerized scanners.

**2**. The computer-implemented method of claim **1**, wherein the number of object chunks is at least one thousand times the number of serverless, containerized scanners.

**3**. The computer-implemented method of claim **1**, wherein the number of serverless, containerized scanners is dynamically scalable.

**4**. The computer-implemented method of claim **1**, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, comprises a portable and independently executable microservice.

**5**. The computer-implemented method of claim **1**, wherein the different data patterns comprise different sensitive data patterns.

**6**. The computer-implemented method of claim **5**, wherein the different sensitive data patterns comprise a plurality of sensitive string patterns.

**7**. The computer-implemented method of claim **6**, and further comprising:

generating, by the serverless, containerized scanners, sensitivity metadata based on detection of at least some sensitive data patterns in the plurality of sensitivity string patterns.

**8**. The computer-implemented method of claim **7**, and further comprising:

sending, by the serverless, containerized scanners, the sensitivity metadata to a metadata store in a control plane in the cloud environment account.

**9**. The computer-implemented method of claim **8**, and further comprising:

applying sensitivity annotations to a cloud data attack surface graph based on the sensitivity metadata.

**10**. The computer-implemented method of claim **8**, and further comprising:

applying sensitivity annotations to a cloud infrastructure graph based on the sensitivity metadata.

**11**. The computer-implemented method of claim **1**, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, scans a corresponding object chunk exactly once to detect a multiplicity of object metadata.

**12**. A computing system comprising:

at least one processor; and

memory storing instructions executable by the at least one processor, wherein the instructions, when executed, cause the computing system to:

obtain access to a cloud environment account for content scanning of storage resources;

queue objects in the cloud environment account;

partition the objects into a number of object chunks; and

initialize a number of serverless, containerized scanners based on the number of object chunks, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, is deployed locally on the cloud environment account and scans a corresponding object chunk to detect a plurality of different data patterns, and wherein the number of object chunks is at least one hundred times the number of serverless, containerized scanners.

**13**. The computing system of claim **12**, wherein the number of serverless, containerized scanners is dynamically scalable.

**14**. The computing system of claim **12**, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, comprises a portable and independently executable microservice.

**15**. The computing system of claim **12**, wherein the plurality of different data patterns comprise a plurality of different sensitive data patterns, and the serverless, containerized scanners are configured to generate sensitivity metadata based on detection of at least some sensitive data patterns in the plurality of different sensitivity data patterns.

**16**. The computing system of claim **15**, wherein the serverless, containerized scanners are configured to send the sensitivity metadata to a metadata store in a control plane in the cloud environment account.

**17**. A computer-readable media having computer-readable instructions stored thereon, wherein the computer-readable instructions, when executed by a computer, cause the computer to:

obtain access to a cloud environment account for content scanning of storage resources;

queue objects in the cloud environment account;

partition the objects into a number of object chunks; and

initialize a number of serverless, containerized scanners based on the number of object chunks, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, is deployed locally on the cloud environment account and scans a corresponding object chunk to detect a plurality of different data patterns, and wherein the number of object chunks is at least one hundred times the number of serverless, containerized scanners.

**18**. The computer-readable media of claim **17**, wherein the number of serverless, containerized scanners is dynamically scalable.

**19**. The computer-readable media of claim **17**, wherein each serverless, containerized scanner, of the number of serverless, containerized scanners, comprises a portable and independently executable microservice.

**20**. The computer-readable media of claim **17**, wherein the plurality of different data patterns comprises a plurality of different sensitive data patterns, and the serverless, containerized scanners are configured to generate sensitivity metadata based on detection of at least some sensitive data patterns in the plurality of different sensitivity data patterns.

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