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(54) BACKUPS FOR CLOUD-BASED 5G NETWORKS

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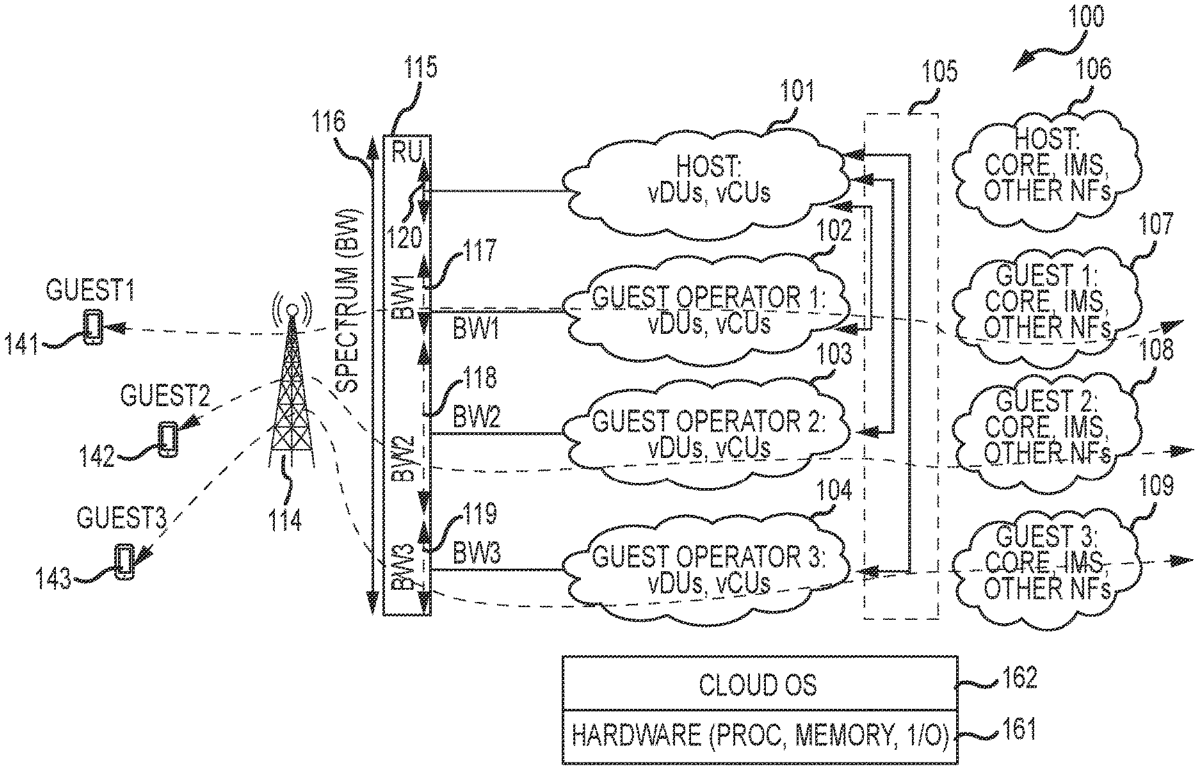
(57) ABSTRACT

Systems and methods for backing up a cloud-based network include a first instance of a computing resource running in a first region. A first backup service is running in the first region and configured to take a first backup of the first instance. The backup service uses a key management service of the first region to encrypt the first backup with a first cryptographic key to generate a first encrypted backup. The first encrypted backup is stored in a first backup vault of the first region. A second backup service runs in a second region and receives a copy of the first backup. A second key management service of the second region encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup. The second encrypted backup is stored in a second backup vault of the second region.


100
115
116
RU
101
105
106
HOST: vDUs, vCUs
HOST: CORE, IMS, OTHER NFs
SPECTRUM (BW)
120
117
102
107
BW1
BW1
GUEST OPERATOR 1: vDUs, vCUs
GUEST 1: CORE, IMS, OTHER NFs
GUEST1
141
GUEST2
142
GUEST3
143
114
118
BW2
BW2
103
108
GUEST OPERATOR 2: vDUs, vCUs
GUEST 2: CORE, IMS, OTHER NFs
119
BW3
BW3
104
109
GUEST OPERATOR 3: vDUs, vCUs
GUEST 3: CORE, IMS, OTHER NFs
CLOUD OS
162
HARDWARE (PROC, MEMORY, 1/O)
161

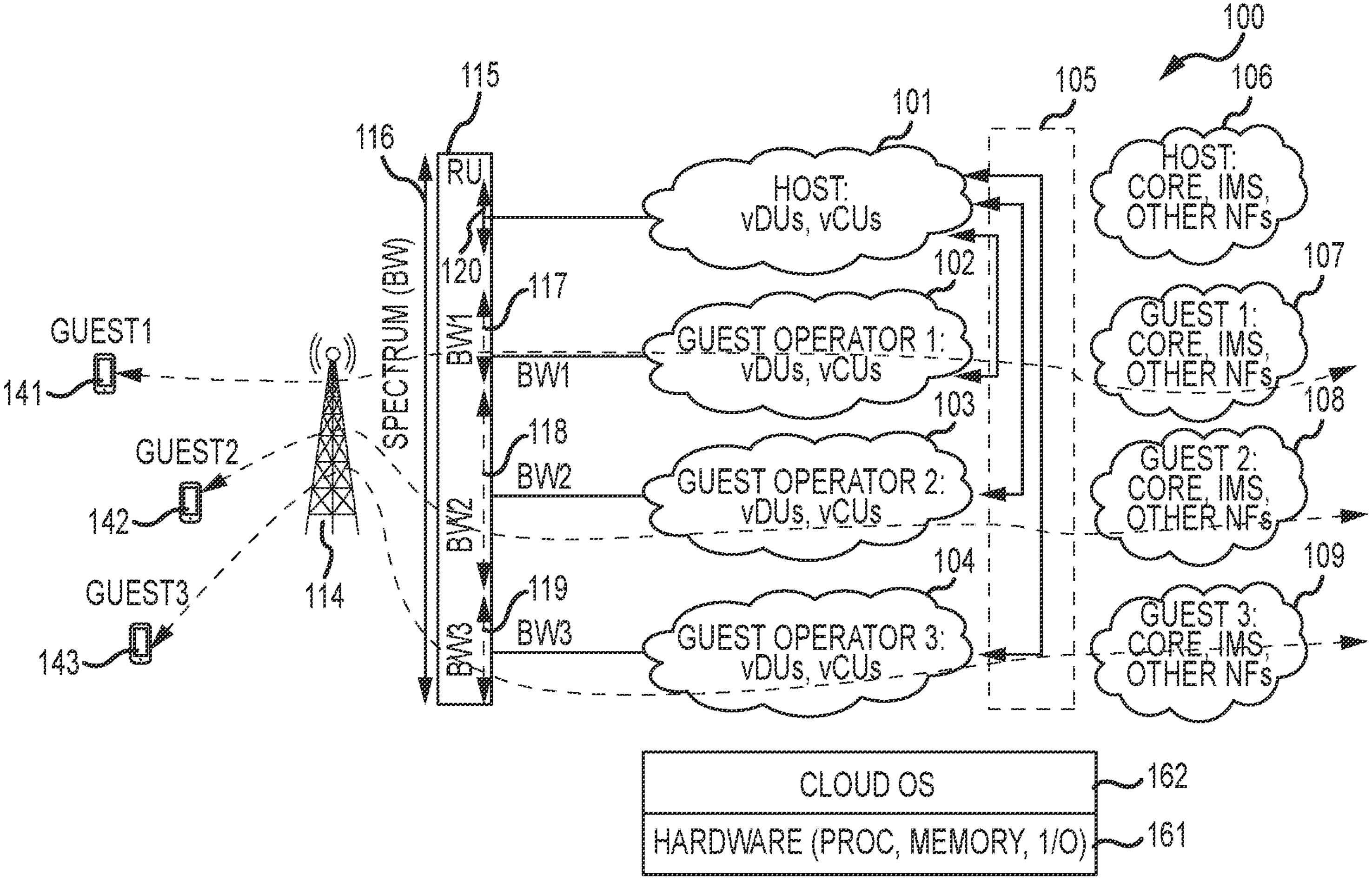

100
106
HOST:
CORE, IMS,
OTHER NFs
107
GUEST 1:
CORE, IMS,
OTHER NFs
108
GUEST 2:
CORE, IMS,
OTHER NFs
109
GUEST 3:
CORE, IMS,
OTHER NFs
105
101
HOST:
vDUs, vCUs
102
GUEST OPERATOR 1:
vDUs, vCUs
103
GUEST OPERATOR 2:
vDUs, vCUs
104
GUEST OPERATOR 3:
vDUs, vCUs
115
RU
120
BW1
BW2
BW3
117
BW1
118
BW2
119
BW3
116
SPECTRUM (BW)
114
GUEST1
141
GUEST2
142
GUEST3
143
CLOUD OS
162
HARDWARE (PROC, MEMORY, 1/O)
161

FIG.1

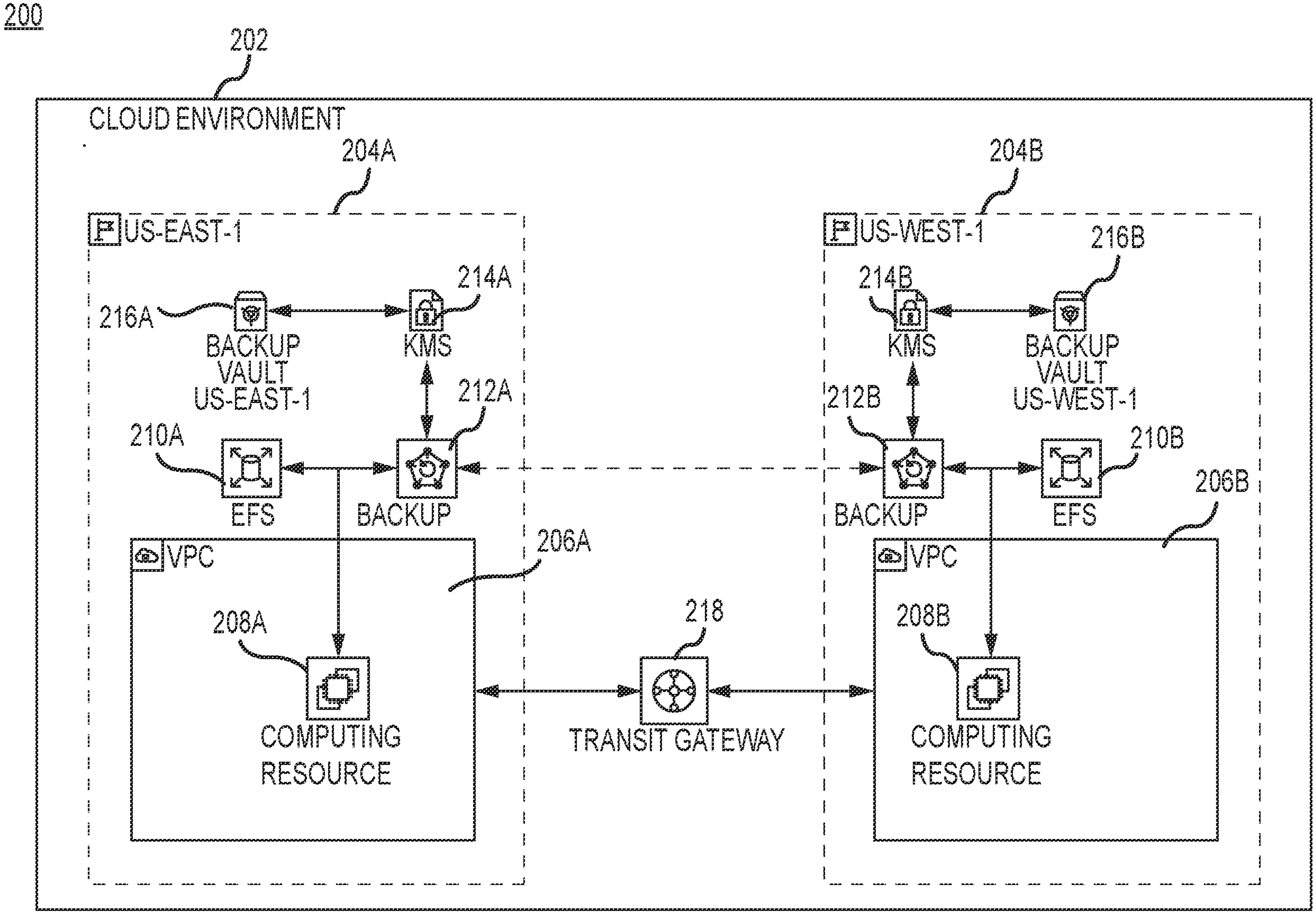

200
202
CLOUD ENVIRONMENT
204A
US-EAST-1
216A
BACKUP
VAULT
US-EAST-1
214A
KMS
212A
210A
EFS
BACKUP
206A
VPC
208A
COMPUTING
RESOURCE
218
TRANSIT GATEWAY
204B
US-WEST-1
216B
214B
KMS
BACKUP
VAULT
US-WEST-1
212B
210B
BACKUP
EFS
206B
VPC
208B
COMPUTING
RESOURCE

FIG.2

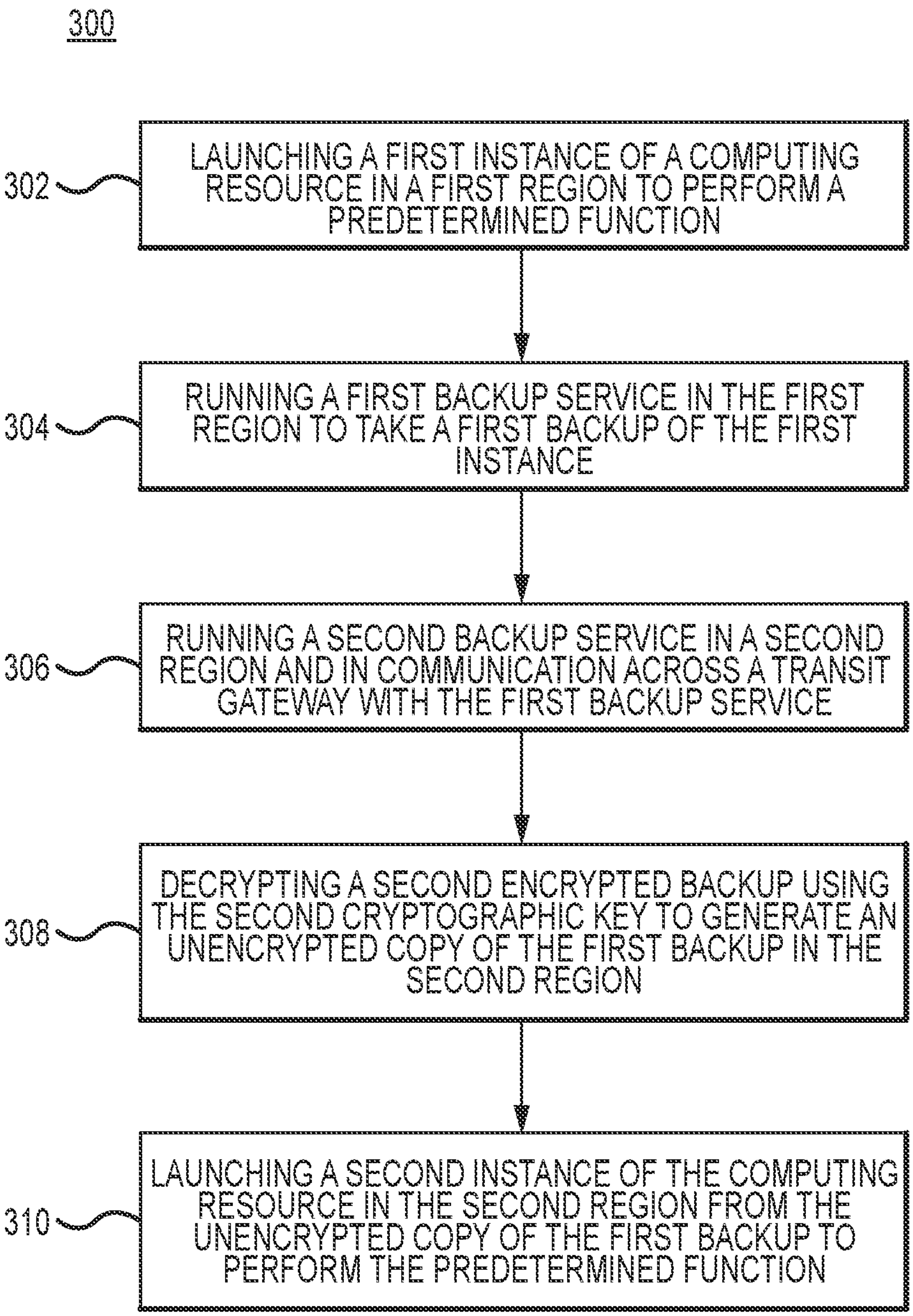

300
302
LAUNCHING A FIRST INSTANCE OF A COMPUTING RESOURCE IN A FIRST REGION TO PERFORM A PREDETERMINED FUNCTION
304
RUNNING A FIRST BACKUP SERVICE IN THE FIRST REGION TO TAKE A FIRST BACKUP OF THE FIRST INSTANCE
306
RUNNING A SECOND BACKUP SERVICE IN A SECOND REGION AND IN COMMUNICATION ACROSS A TRANSIT GATEWAY WITH THE FIRST BACKUP SERVICE
308
DECRYPTING A SECOND ENCRYPTED BACKUP USING THE SECOND CRYPTOGRAPHIC KEY TO GENERATE AN UNENCRYPTED COPY OF THE FIRST BACKUP IN THE SECOND REGION
310
LAUNCHING A SECOND INSTANCE OF THE COMPUTING RESOURCE IN THE SECOND REGION FROM THE UNENCRYPTED COPY OF THE FIRST BACKUP TO PERFORM THE PREDETERMINED FUNCTION

FIG.3

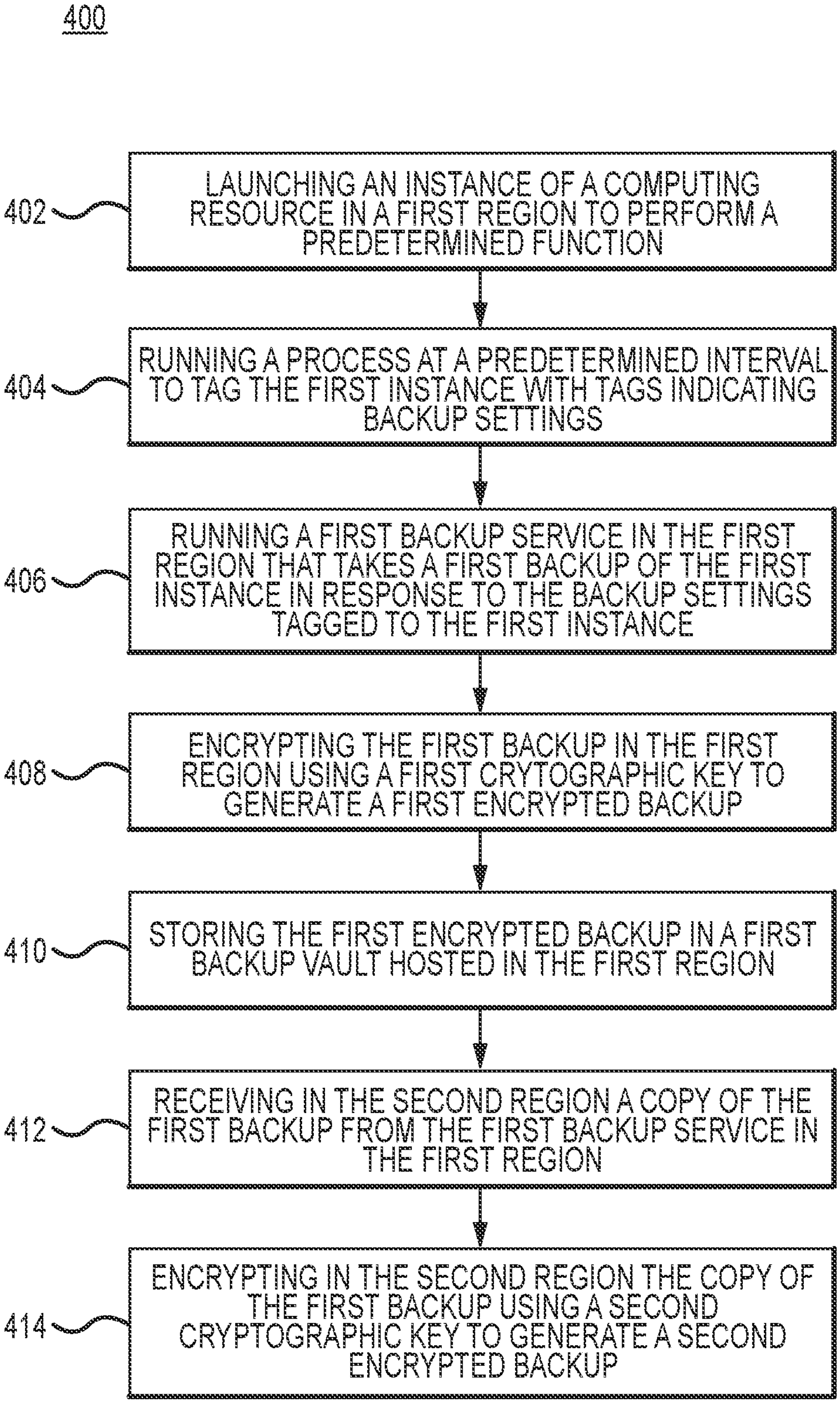

400
402
LAUNCHING AN INSTANCE OF A COMPUTING RESOURCE IN A FIRST REGION TO PERFORM A PREDETERMINED FUNCTION
404
RUNNING A PROCESS AT A PREDETERMINED INTERVAL TO TAG THE FIRST INSTANCE WITH TAGS INDICATING BACKUP SETTINGS
406
RUNNING A FIRST BACKUP SERVICE IN THE FIRST REGION THAT TAKES A FIRST BACKUP OF THE FIRST INSTANCE IN RESPONSE TO THE BACKUP SETTINGS TAGGED TO THE FIRST INSTANCE
408
ENCRYPTING THE FIRST BACKUP IN THE FIRST REGION USING A FIRST CRYTOGRAPHIC KEY TO GENERATE A FIRST ENCRYPTED BACKUP
410
STORING THE FIRST ENCRYPTED BACKUP IN A FIRST BACKUP VAULT HOSTED IN THE FIRST REGION
412
RECEIVING IN THE SECOND REGION A COPY OF THE FIRST BACKUP FROM THE FIRST BACKUP SERVICE IN THE FIRST REGION
414
ENCRYPTING IN THE SECOND REGION THE COPY OF THE FIRST BACKUP USING A SECOND CRYPTOGRAPHIC KEY TO GENERATE A SECOND ENCRYPTED BACKUP

FIG.4

BACKUPS FOR CLOUD-BASED 5G NETWORKS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/338,162 filed on May 4, 2022, and entitled "BACKUPS FOR CLOUD-BASED 5G NETWORKS," which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The following discussion generally relates to backup systems, and in particular to systems and methods for backing up virtualized components of cloud-based networks.

BACKGROUND

[0003] Computing systems fail, often resulting in data loss and downtime. System-level, application-level, or data-level backups are all examples of countermeasures that can be effective against such failures. However, backups have long been vulnerable to complete loss as the result of a disaster at the storage location of the backup.

[0004] As cloud-based systems become more prevalent, virtual systems are frequently commissioned and decommissioned during normal operation. These virtual assets may be spun up at different geographic locations using backups. In some systems, a copy of the backup must be transferred to a restoration location before successfully restoring a system or otherwise launching a virtual machine from the backup.

[0005] Restoring a computing asset from a backup can be time consuming, particularly when a transfer step is a prerequisite to restore or launch the asset at a different facility than the backup location. In addition to incurring a time cost, the transfer process consumes bandwidth that might otherwise be available for operations. A need exists for an expedient and cost-effective system for backing up and restoring cloud-based systems running at different geographic locations.

[0006] System backups are also vulnerable to data loss or modification if stored in cleartext, for example, or otherwise stored in unprotected or minimally protected storage configurations. Backing up and transferring backups to a different geographic location using some traditional methods may tend to expose backup files to malfeasance, whether intentional or not, because of insufficient security controls such as shared cryptographic keys. Accidental or intentional corruption or loss of backup files introduces a risk that a desired backup file may not be reliable when accessed, which can be problematic as systems are brought online from backups of unknown integrity.

SUMMARY

[0007] Various embodiments take secure backups in a cloud-based network for rapid redeployment. An embodiment of a backup system for a cloud-based data and telephone network includes a first instance of a computing resource running in a first region. A first backup service is running in the first region and configured to take a first backup of the first instance. The backup service uses a key management service of the first region to encrypt the first backup with a first cryptographic key to generate a first encrypted backup. The first encrypted backup is stored in a first backup vault of the first region. A second backup service is running in a second region and in communication across a transit gateway with the first backup service. The second backup service receives a copy of the first backup. A second key management service of the second region encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup. The second encrypted backup is stored in a second backup vault of the second region.

[0008] An embodiment of an automated process for taking backups in a cloud-based environment includes the step of launching a first instance of a computing resource in a first region to perform a predetermined function. A first backup service runs in the first region to take a first backup of the first instance. The first backup service uses a first key management service hosted in the first region to encrypt the first backup with a first cryptographic key and generate a first encrypted backup. The first encrypted backup is stored in a first backup vault hosted in the first region. The process includes running a second backup service in a second region and in communication across a transit gateway with the first backup service. The second backup service receives a copy of the first backup from the first backup service. The second backup service uses a second key management service hosted in the second region that encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup. The second encrypted backup is stored in a second backup vault hosted in the second region. The process further includes decrypting the second encrypted backup using the second cryptographic key to generate an unencrypted copy of the first backup. A second instance of the computing resource is launched in the second region from the unencrypted copy of the first backup to perform the predetermined function.

[0009] An automated process for taking backups in a cloud-based environment includes launching a first instance of a computing resource in a first region to perform a predetermined function, in accordance with various embodiments. A process is run at a predetermined interval to tag the first instance with tags indicating backup settings. A first backup service runs in the first region that takes a first backup of the first instance in response to the backup settings tagged to the first instance. A first key management service hosted in the first region encrypts the first backup using a first cryptographic key to generate a first encrypted backup. The process includes storing the first encrypted backup in a first backup vault hosted in the first region, running a second backup service in a second region, and receiving, by the second backup service in the second region, a copy of the first backup from the first backup service in the first region. The second backup service is in communication across a transit gateway with the first backup service. A second key management service hosted in the second region encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup. The second encrypted backup is stored in a second backup vault hosted in the second region.

[0010] In various embodiments, the second backup service decrypts the second encrypted backup using the second cryptographic key to generate the copy of the first backup. The second backup service creates a second instance running in the second region from the copy of the first backup. The first region comprises a first availability zone, and the second region comprises a second availability zone. The first region is geographically remote from the second region. A process runs at a predetermined interval to tag the first instance with backup settings. A process runs at a predetermined interval to associate tags with the first instance. The tags indicate backup settings. The backup settings indicated by the tags include a backup frequency and a retention period associated with the first instance. The first key management service is isolated from the second cryptographic key, and the second key management service is isolated from the first cryptographic key.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by referring to the detailed description and claims when considered in connection with the illustrations.

[0012] FIG. **1** illustrates an example of a cloud-based wireless network that includes virtualized network functions, in accordance with various embodiments.

[0013] FIG. **2** illustrates an example architecture for a secure backup system on a cloud-based network, in accordance with various embodiments.

[0014] FIG. **3** illustrates an example of a process for backing up and launching network functions on a cloud-based wireless network, in accordance with various embodiments.

[0015] FIG. **4** illustrates an example of a process for backing up network functions on a cloud-based wireless network in multiple regions, in accordance with various embodiments.

DETAILED DESCRIPTION

[0016] The following detailed description is intended to provide several examples that will illustrate the broader concepts that are set forth herein, but it is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0017] Systems, methods, and devices of the present disclosure enable expedient and cost-effective backup and restoration of cloud-based assets in a secure manner. The backup systems described herein can support a cloud-based data and telephone networks, though the backup systems described herein may be implemented in any cloud-based environment.

[0018] According to various embodiments, a distributed backup and restoration system operates in support of various cloud-based computing assets in a mobile network system. Backups are taken in one geographic region for cloud-based assets running in that region, and the backups are stored in a backup vault that is local to the region. Cryptographic keys are used to manage access backups in the vault. Backup files are replicated at a geographically remote location and stored in a separate backup vault integrated with a separate key management service. The system can use a transit gateway to transfer backup files at low cost without consuming operational bandwidth.

[0019] Using replicated backups in different geographic regions allows for real time (or near real-time, accounting for some delays inherent in processing, data communications and the like) restoration or commissioning of virtual assets in a 5G wireless network in a secure and efficient manner. The use of a distributed backup system also provides for rapid adaptation to dynamic cloud-based systems in a manner that makes very efficient use of available data processing resources, thereby conserving energy, data storage, and cost to the system operator.

[0020] Additionally, the use of different key management services running in different regions to store the copies of the same backup as described below promotes the use of different cryptographic keys to encrypt and store copies of the same backup. The duplicative copies stored using different encryption keys tend to protect the backups from tampering.

[0021] The backups can be used to support virtualized components of telephony networks. Traditionally, data and telephone networks relied upon proprietary designs based upon very specialized hardware and dedicated point-to-point data connections. More recently, industry standards such as the Open Radio Access Network ("Open RAN" or "0-RAN") standard have been developed to describe interactions between the network and various client devices. The O-RAN model follows a virtualized wireless architecture in which 5G base stations ("gNBs") are implemented using separate centralized units (CUs), distributed units (DUs) and radio units (RUs), along with various control planes that provide additional network functions (e.g., 5G Core, IMS, OSS/BSS/IT). Generally speaking, it is still necessary to implement the RUs with physical transmitters, antennas and other hardware located onsite within broadcast range of the end user's device.

[0022] Other components of the network, however, can be implemented using a more centralized architecture based upon cloud-based computing resources, such as those available from Amazon Web Services (AWS) or the like. This provides much better network management, scalability, reliability and redundancy, as well as other benefits. O-RAN CUs, DUs, control planes or other components of the network can now be implemented as software modules executed by distributed (e.g., "cloud") computing hardware. Other network functions such as access control, message routing, security, billing and the like can similarly be implemented using centralized cloud computing resources. Often, a CU, DU, control plane or other image is created in software for execution by one or more virtual computers operating in parallel within the cloud environment. Images may be created using backup systems described herein to support rapid scaling to increase or decrease the available computing capacity as needed.

[0023] The use of virtualized hardware provides numerous benefits in terms of rapid deployment and scalability, but it also presents certain technical challenges that have not been encountered in more traditional wireless networks. Unlike traditional wireless networks that scaled through the addition of physical routers, switches and other hardware, RAN networks can scale upwardly and downwardly very quickly as new cloud-based services are deployed or existing services are retired or redeployed. Additional network components can be very quickly deployed, for example, through the use of virtual components executing in a cloud environment that can be very quickly duplicated and spawned as needed to support increased demand. Similarly, virtual components can be de-commissioned very quickly with very little cost or effort when network capacity allows. The virtual components provide substantial efficiencies, especially when compared to prior networks based upon complex interconnections between geographically dispersed routers, servers and the like. One challenge that does arise, however, involves backing up and commissioning virtual components such a rapidly-evolving, dynamic network.

[0024] Referring now to FIG. **1**, an example cellular communication system **100** is shown having a backup and restoration system for virtualized network functions, in accordance with various embodiments. As used herein, the term network function may describe a functional building block within a network infrastructure. Network functions typically include well-defined external interfaces and a well-defined functional behavior. Network functions may be implemented in a cloud-based environment using virtualization tools such as, for example, virtual machines or containers. The systems described herein may thus spool up or retire network functions by launching a new instance or retiring an existing instance of the network function.

[0025] In various embodiments, cellular communication system **100** includes a host operator maintaining ownership of one or more radio units (RUs) **115** associated with a wireless network cell. The example of FIG. **1** depicts a host operator operating a "radio/spectrum as a service (R/SaaS)" that allocates bandwidth on its own radio units for use by one or more guest network operators, though the systems, methods, and devices described herein could be applied to any wireless network using virtualized network services. Examples of guest network operators may include internal brands of the host operator, system integrators, enterprises, external MVNOs, or converged operators. The host and the guest network operators may maintain desired network services to support user equipment (UE) **141**, **142**, **143**, and may use backup and restoration systems to support network functions instantiating network services.

[0026] In the example of FIG. **1**, each RU **115** communicates with UE **141**, **142**, **143** operating within a geographic area (e.g., a cell) using one or more antennas **114** (also referred to herein as towers) capable of transmitting and receiving messages within an assigned spectrum or bandwidth **116** of electromagnetic bandwidth. In various embodiments, guest networks **102**, **103**, **104** interact with a provisioning plane **105** to obtain desired spectrum (e.g., portions of bandwidth **117**, **118**, **119**, **120**, respectively) across one or more of the RUs **115** operated by the host **101**. Provisioning plane **105** allows guest network operators to obtain or change their assigned bandwidths on different RUs **115** on an on-demand and dynamic basis. Network services **107**, **108**, **109** may be maintained by guest operators and network services **106** may be maintained by host **101**. Network services are scaled up and down in response to network load, and backup and restoration of network services or other virtualized systems are taken and performed as described herein.

[0027] The Open RAN standard breaks communications into three main domains: the RU that handles radio frequency (RF) and lower physical layer functions of the radio protocol stack, including beamforming; the DU that handles higher physical access layer, media access (MAC) layer and radio link control (RLC) functions; and the CU that performs higher level functions, including quality of service (QoS) routing and the like. The CU also supports packet data convergence protocol (PDCP), service data adaptation protocol (SDAP) and radio resource controller (RRC) functions. The RU, DU and CU functions are described in more detail in the Open RAN standards, as updated from time to time, and may be modified as desired to implement the various functions and features described herein. In the example of FIG. **1**, host **101** maintains one or more DUs and CUs (i.e., network functions) as part of its own network. The DU communicates with one or more RUs **115**, as specified in the Open RAN standard.

[0028] The various network components shown in FIG. **1** are typically implemented using software or firmware instructions that are stored in a non-transitory data storage (e.g., a disk drive or solid-state memory) for execution by one or more processors. The various components shown in FIG. **1** can be implemented using cloud-based hardware **161** and an appropriate operating system **162** such as the AWS® platform, although other embodiments could use other cloud platforms or any type of conventional physical computing hardware **161**, as desired. In that regard, components of network **100** may be implemented using network functions, containers, virtual machines, or other virtualized implementations suitable for a cloud-based network. Backups and restorations of the virtualized systems and network functions are performed across multiple geographic regions and managed using multiple key vaults with different encryption keys.

[0029] As illustrated in the example of FIG. **1**, system **100** includes a host network **101** and one or more guest networks **102**, **103**, **104**. The host network **101** is typically operated by an organization that owns radio equipment and sufficient spectrum (potentially on different bands) to offer 5G capacity and coverage. Host network **101** provides 5G service to connected UEs, and it manages network services available to its own UEs or those of its guest operators. Host network **101** includes at least one DU and at least one CU, both of which will typically be spooled up as virtual network functions restored from backups taken and stored on the cloud-based network.

[0030] Guest networks **102**, **103**, **104** operated by guest operators can manage their own networks using allocated portions of the bandwidth **116** handled by one or more of the RUs **115** associated with the host **101**. The guest networks **102**, **103**, **104** communicate with one or more UEs **141-143** using allocated bandwidth **116** on the host's RU **115**. Guest networks **102**, **103**, **104** may include one or more virtual DUs and CUs, as well as other network services **106**, **107**, **108**, **109**, as desired. Generally, one or more guest operators will instantiate its own 5G virtualized network functions (e.g., CMS, vCUs, vDUs, etc.) using cloud-based resources, as noted above. However, various embodiments may operate outside of cloud-based environments. Host network **101** may also generate its own network services to manage software and services available to UE **141-143**.

[0031] Guest operators may lease or otherwise obtain any needed 5G access for its planned services, capacity and coverage based on an arrangement with the host provider. A guest provider may then operate and manages its own 5G network **102**, **103**, **104** independently of the host **101** and the other guests. A network operator can optimize its own network by implementing its own cloud-based network services, which may also be backed up and restored using the backup systems and techniques described herein.

[0032] Each RU **115** is typically associated with a different wireless cell that provides wireless data communications to user devices **141-143**. RUs **115** may be implemented with radios, filters, amplifiers and other telecommunications hardware to transmit digital data streams via one or more antennas **114**. Generally, RU hardware includes one or more processors, non-transitory data storage (e.g., a hard drive or solid state memory) and appropriate interfaces to perform the various functions described herein. RUs are physically located on-site with the transmitter/antenna **114**, as appropriate. Conventional 5G networks may make use of any number of wireless cells spread across any geographic area, each with its own on-site RU **115**.

[0033] RUs **115** support wireless communications with any number of user devices **141-143**. UE **141-143** are often mobile phones or other portable devices that can move between different cells associated with the different RUs **115**, although 5G networks are also widely expected to support home and office computing, industrial computing, robotics, Internet-of-Things (IoT) and many other devices. While the example illustrated in FIG. **1** shows one RU **115** for convenience, a practical implementation will typically have any number of virtualized RUs **115** that can each be individually configured to provide highly configurable geographic coverage for a host or guest network, if desired. Host **101** and guest operators **102**, **103**, **104** can automatically scale and manage using backup systems and methods described herein.

[0034] Referring now to FIG. **2**, an example system **200** is shown for backing up cloud-based computing assets. The various functions depicted in FIG. **2** may be performed by programmed logic (e.g., software or firmware) stored within non-transitory memory and executed by processors, as appropriate. Other embodiments may perform additional functions or may organize the different functions in an equivalent but alternate manner. Cloud-based environment **202** may be a dedicated environment for operating a data and telephone network.

[0035] In various embodiments, a process or service running inside or outside of dedicated cloud-based environment **202** assesses virtual computing assets (e.g., instances **206**) for backup settings as reflected by tags or other metadata associated with the virtual computing assets. Region **204**A may be located geographically remote from region **204**B, region **204**A may be logically separated from region **204**B, or region **204**A may be isolated from region **204**B in any other desirable manner. Functional elements of region **204**B with a reference numeral ending in B are similar to or the same as functional elements of region **204**A having the same reference numeral ending in A.

[0036] In the illustrated example of FIG. **2**, regions **204**A and **204**B are availability zones. As used herein, the term availability zone may describe discrete data centers. Availability zones may include redundant power, networking, and connectivity. Different availability zones may be located in different geographic regions. Using availability zones enable operation of production applications and databases in a highly available, fault tolerant, and scalable manner. Availability zones may be interconnected with high-bandwidth, low-latency networking, over fully redundant, dedicated fiber lines that are end-to-end encrypted.

[0037] In various embodiments, a process or service runs at predetermined intervals to tag instances **206** that lack backup configurations based on tags. The process or service may look for a specific tag and may tag instances **206** that lack the specific tag with backup settings. The process may also deploy tags or overwrite tags for instances **206** in response to user input or configuration changes. The tags associated with an instance **206** may indicate backup frequency, retention period, backup size restrictions, backup retention locations, backup replication locations, or other backup characteristics for the associated instance **206**. In an example embodiment, each instance **206** has a tag that corresponds to a backup schedule with a backup frequency and a retention period such as a tag reading "1-7," which indicates the tagged instance should be backed up daily and backups should be retained for 7 days. Other tagging schemes can also be used to identify backup characteristics associated with an instance **206**.

[0038] Instance **206**A runs on a computing resource **208**A. In the example depicted in FIG. **2**, computing resources **208**A and **208**B may be Elastic Compute Cloud (EC2) services available on AWS, though in other embodiments other cloud-computing resources may be used to host instances **206**. Each instance **206**A is in communication with a file system **210**A. File system **210**A may be, for example, an Elastic File System (EFS) available on AWS. File system **210**A may also be a New Technology File System (NTFS), FAT32 file system, a relational database, a structured data store, an unstructured data store, or any other suitable storage system. Instance **206**A and file system **210**A may also be in communication with a backup service **212**A.

[0039] The backup service depicted in the example of FIG. **2** may be, for example, an AWS backup service. Although the features depicted in the example of FIG. **2** may be implemented using AWS-based tools, system **200** can be implemented on any cloud-service provider. System **200** may also be implemented using tools hosted on Server-Space, Microsoft Azure, Google Cloud Platform, IBM Cloud Services, Kamatera, VMware, or any other cloud service provider, for example.

[0040] In various embodiment, a key management service **214**A (KMS) encrypts backups of instances **206**A running in its region **204**A. In the illustrated example, KMS **214**A and KMS **214**B can be key management services hosted by AWS. KMS **214**A stores the encrypted backups from its instances **206**A in vault **216**A. KMS **214**A also may also store encrypted backups from instances **206**B in vault **216**A.

[0041] Backups are replicated into other regions using a transit gateway **218** in various embodiments. For example, backups taken in region **204**A may be replicated to or otherwise stored in region **204**B. Transit gateway **218** may be a low-cost data transfer medium dedicated to operations of the hosting cloud-platform. For example, transit gateway **218** may be backbone data transit maintained and operated by a cloud-service provider such as AWS.

[0042] Backups stored in different regions may use different cryptographic keys in various embodiments. For example, a backup of instance **206**A stored in vault **216**A may be encrypted using a key stored in KMS **214**A, while a replicated copy of the same backup of instance **206**A stored in vault **216**B is encrypted using a different key stored in KMS **214**B. The use of different keys in different regions **204** may tend to improve security by restricting access according to least privilege principals. In response to different keys being used in different regions, an entity using the key from region **204**A for a particular backup cannot access the same backup in region **204**B using the same key from KMS **214**A. Backup service **212**A may be capable of taking backups and restoring instances **206** from backups.

Backup service **212** may also be configured to replicate backups into other regions **204** across transit gateway **218**.

[0043] By replicating backups into different regions **204**, backups stored in one region tend to be protected from catastrophic loss in other regions. For example, backups in region **204**A tend to be protected from disaster causing loss of data or computing devices in region **204**B. Replication also enables rapid deployment of virtualized assets in different regions. For example, a copy of the backup of instance **206**A from region **204**A may be stored in region **204**B so that a copy of instance **206**A may be commissioned as instance **206**B in region **204**B in real-time using the backup. In that regard, a copy of instance **206**A may be created in region **204**B without decrypting the backup in region **204**A and transferring the backup from region **204**A to region **204**B. Backups managed according to system **200** may enable instantiation according to the foregoing example without using bandwidth and time to accommodate an on-demand transfer of the backup to a different region prior to launching the duplicate instance.

[0044] Referring now to FIG. **3**, automated process **300** is shown for execution by system **200** to take backups in a cloud-based data and telephony network, in accordance with various embodiments. System **200** may launch a first instance **206**A of a computing resource in a first region **204**A to perform a predetermined network function (Block **302**). The predetermined network function may be a virtual DU, virtual CU, core function, IMS function, or other network function in data and telephony network **100**. The backup service **212**A runs to take a backup of the first instance **206**A (Block **304**). The backup service **212**A may use a key management service **214**A hosted in the first region **204**A to encrypt the first backup with a cryptographic key and generate an encrypted backup of instance **206**A. The encrypted backup is stored in backup vault **216**A hosted in the region **204**A.

[0045] In various embodiments, a second backup service **212**B runs in a second region **204**B and is in communication across a transit gateway **218** with the first backup service **212**A (Block **306**). The second backup service **212**B receives a copy of the backup of instance **206**A from the first backup service **212**A through transit gateway **218**. The second backup service **212**B uses a second key management service **214**B hosted in the second region **204**B that encrypts the copy of the backup of instance **206**A using a second cryptographic key to generate a second encrypted backup of instance **206**A. The second encrypted backup of instance **206**A is stored in a second backup vault **216**B hosted in the second region **204**B. The same backup of instance may thus be stored and encrypted in two different regions using two different encryption keys.

[0046] Various embodiments of process **300** decrypt the second encrypted backup using the second cryptographic key to generate an unencrypted copy of the backup of instance **206**A (Block **308**). The cryptographic key may implement the Advanced Encryption Standard (AES), public key encryption, OpenPGP, or any other encryption technique. The first key management service is isolated from the second cryptographic key, and the second key management service is isolated from the first cryptographic key.

[0047] A second instance **206**B of the computing resource is launched in the second region **204**B from the unencrypted copy of the backup of instance **206**A to perform the predetermined function (Block **310**). The second backup service **212**B decrypts the second encrypted backup using the second key management service **214**B hosted in the second region **204**B. The second key management service **214**B uses its own encryption keys, which typically differ from the encryption keys of the first key management service **214**A. The first region **204**A and second region **204**B may be different availability zones, geographic regions, cells, service areas, data centers, or any other suitable grouping. The first region **204**A is typically geographically remote from the second region **204**B to protect from disaster or other causes of catastrophic failure that are location dependent.

[0048] In various embodiments, a process runs at a predetermined interval to associate tags indicating backup settings with instances. The backup settings indicated by the tags typically include a backup frequency and a retention period associated with the tagged instance. Some embodiments may apply default retention period or frequency in response to the data missing from a tag.

[0049] Referring now to FIG. **4**, an automated process **400** is shown for securely taking and replicating backups using system **200**, in accordance with various embodiments. Process **400** includes launching a first instance **206**A of a computing resource in a first region **204**A to perform a predetermined function (Block **402**). A process is run at a predetermined interval to tag the first instance with tags indicating backup settings (Block **404**). A first backup service **212**A runs in the first region **204**A and takes a backup of the first instance **206**A in response to the backup settings tagged to the first instance (Block **406**). A first key management service is hosted in the first region **204**A, and it encrypts the first backup using a first cryptographic key to generate an encrypted backup of first instance **206**A (Block **408**).

[0050] In various embodiments, system **200** stores storing the first encrypted backup in a first backup vault hosted in the first region **204**A (Block **410**). A second backup service **212**B runs in a second region **204**B and is in communication across a transit gateway with the first backup service **212**A. The second backup service **212**B in the second region **204**B receives a copy of the first backup from the first backup service **212**A in the first region **204**A (Block **412**). A second key management service **214**B hosted in the second region **204**B encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup (Block **414**). The second encrypted backup in a second backup vault **216**B hosted in the second region **204**B.

[0051] Various embodiments of system **200** decrypt the second encrypted backup using the second cryptographic key to generate an unencrypted copy of the first backup at the second region **204**B. A second instance **206**B of the computing resource is launched in second region **204**B to perform the predetermined function. The second backup service **212**B decrypts the second encrypted backup using the second key management service hosted in the second region **204**B. The first region **204**A and second region **204**B are availability zones and are geographically remote from one another. The backup settings indicated by the tags include a backup frequency and a retention period associated with the first instance.

[0052] Systems, methods, and devices of the present disclosure tend to securely take and store backups from cloud-based instances of computing resources. The backups are stored at remote locations using different cryptographic keys as an additional layer of security. A compromised backup in one region thus would typically not compromise the backup in a different region. Storing backups in different regions also increases the speed of deploying computing resources in geographically disparate regions.

[0053] Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships or couplings between the various elements. It should be noted that many alternative or additional functional relationships or connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the inventions.

[0054] The scope of the invention is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "A, B, or C" is used herein, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C.

[0055] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112(f) unless the element is expressly recited using the phrase "means for." As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or device that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or device.

[0056] The term "exemplary" is used herein to represent one example, instance, or illustration that may have any number of alternates. Any implementation described herein as "exemplary" should not necessarily be construed as preferred or advantageous over other implementations. While several exemplary embodiments have been presented in the foregoing detailed description, it should be appreciated that a vast number of alternate but equivalent variations exist, and the examples presented herein are not intended to limit the scope, applicability, or configuration of the invention in any way. To the contrary, various changes may be made in the function and arrangement of the various features described herein without departing from the scope of the claims and their legal equivalents.

What is claimed is:

1. A backup system for a cloud-based data and telephone network, comprising:

a first instance of a computing resource running in a first region;

a first backup service running in the first region and configured to take a first backup of the first instance,

wherein the first backup service uses a key management service of the first region to encrypt the first backup with a first cryptographic key to generate a first encrypted backup,

wherein the first encrypted backup is stored in a first backup vault of the first region; and

a second backup service running in a second region and in communication across a transit gateway with the first backup service,

wherein the second backup service receives a copy of the first backup,

wherein the second backup service uses a second key management service of the second region to encrypt the copy of the first backup using a second cryptographic key to generate a second encrypted backup, and

wherein the second encrypted backup is stored in a second backup vault of the second region.

2. The backup system of claim **1**, wherein the second backup service decrypts the second encrypted backup using the second cryptographic key to generate the copy of the first backup.

3. The backup system of claim **2**, wherein the second backup service creates a second instance running in the second region from the copy of the first backup.

4. The backup system of claim **1**, wherein the first region comprises a first availability zone, and the second region comprises a second availability zone.

5. The backup system of claim **1**, wherein the first region is geographically remote from the second region.

6. The backup system of claim **1**, wherein a process runs at a predetermined interval to tag the first instance with backup settings.

7. An automated process for taking backups in a cloud-based environment, comprising:

launching a first instance of a computing resource in a first region to perform a predetermined function;

running a first backup service in the first region to take a first backup of the first instance,

wherein the first backup service uses a first key management service hosted in the first region to encrypt the first backup with a first cryptographic key and generate a first encrypted backup,

wherein the first encrypted backup is stored in a first backup vault hosted in the first region;

running a second backup service in a second region and in communication across a transit gateway with the first backup service,

wherein the second backup service receives a copy of the first backup from the first backup service,

wherein the second backup service uses a second key management service hosted in the second region that encrypts the copy of the first backup using a second cryptographic key to generate a second encrypted backup, and

wherein the second encrypted backup is stored in a second backup vault hosted in the second region;

decrypting the second encrypted backup using the second cryptographic key to generate an unencrypted copy of the first backup; and

launching a second instance of the computing resource in the second region from the unencrypted copy of the first backup to perform the predetermined function.

8. The automated process of claim **7**, wherein the second backup service decrypts the second encrypted backup using the second key management service hosted in the second region.

9. The automated process of claim **7**, wherein the first region comprises a first availability zone, and the second region comprises a second availability zone.

10. The automated process of claim **7**, wherein the first region is geographically remote from the second region.

11. The automated process of claim **7**, further comprising running a process at a predetermined interval to associate tags with the first instance, wherein the tags indicate backup settings.

12. The automated process of claim **11**, wherein the backup settings indicated by the tags include a backup frequency and a retention period associated with the first instance.

13. The automated process of claim **7**, wherein the first key management service is isolated from the second cryptographic key, and the second key management service is isolated from the first cryptographic key.

14. An automated process for taking backups in a cloud-based environment, comprising:

launching a first instance of a computing resource in a first region to perform a predetermined function;

running a process at a predetermined interval to tag the first instance with tags indicating backup settings;

running a first backup service in the first region that takes a first backup of the first instance in response to the backup settings tagged to the first instance,

encrypting, by a first key management service hosted in the first region, the first backup using a first cryptographic key to generate a first encrypted backup,

storing the first encrypted backup in a first backup vault hosted in the first region;

running a second backup service in a second region, the second backup service in communication across a transit gateway with the first backup service,

receiving, by the second backup service in the second region, a copy of the first backup from the first backup service in the first region,

encrypting, by a second key management service hosted in the second region, the copy of the first backup using a second cryptographic key to generate a second encrypted backup; and

storing the second encrypted backup in a second backup vault hosted in the second region.

15. The automated process of claim **14**, further comprising:

decrypting the second encrypted backup using the second cryptographic key to generate an unencrypted copy of the first backup; and

launching a second instance of the computing resource to perform the predetermined function in the second region from the unencrypted copy of the first backup.

16. The automated process of claim **15**, wherein the second backup service decrypts the second encrypted backup using the second key management service hosted in the second region.

17. The automated process of claim **14**, wherein the first region comprises a first availability zone, and the second region comprises a second availability zone.

18. The automated process of claim **14**, wherein the first region is geographically remote from the second region.

19. The automated process of claim **14**, wherein the backup settings indicated by the tags include a backup frequency and a retention period associated with the first instance.

20. The automated process of claim **14**, wherein the first key management service is isolated from the second cryptographic key, and the second key management service is isolated from the first cryptographic key.

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