US012386646B2

(12) **United States Patent**
Chen et al.

(10) **Patent No.: US 12,386,646 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **CLUSTER INFRASTRUCTURE WITH ON-DEMAND ACTIVATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 723 days.

(21) Appl. No.: **17/748,931**

(22) Filed: **May 19, 2022**

(65) **Prior Publication Data**

US 2023/0376335 A1 Nov. 23, 2023

(51) **Int. Cl.**

G06F 9/455	(2018.01)
G06F 9/4401	(2018.01)
G06F 9/48	(2006.01)
G06F 9/50	(2006.01)
G06F 11/14	(2006.01)

(52) **U.S. Cl.**
CPC ***G06F 9/45558*** (2013.01); ***G06F 9/4418*** (2013.01); ***G06F 9/485*** (2013.01); ***G06F 9/4881*** (2013.01); ***G06F 11/1469*** (2013.01); *G06F 2009/45575* (2013.01); *G06F 2009/45595* (2013.01); *G06F 9/4856* (2013.01); *G06F 9/5077* (2013.01); *G06F 2201/84* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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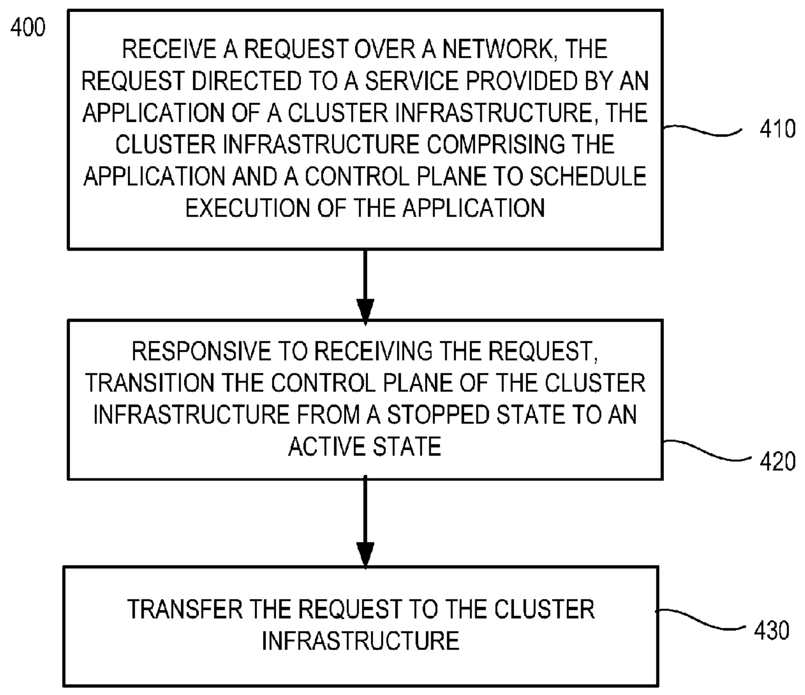
(57) **ABSTRACT**

A request is received over a network. The request is directed to a service provided by an application of a cluster infrastructure. The cluster infrastructure includes the application and a control plane to schedule execution of the application. Responsive to receiving the request, the control plane of the cluster infrastructure is transitioned from a stopped state to an active state. The request is transferred to the cluster infrastructure.

20 Claims, 9 Drawing Sheets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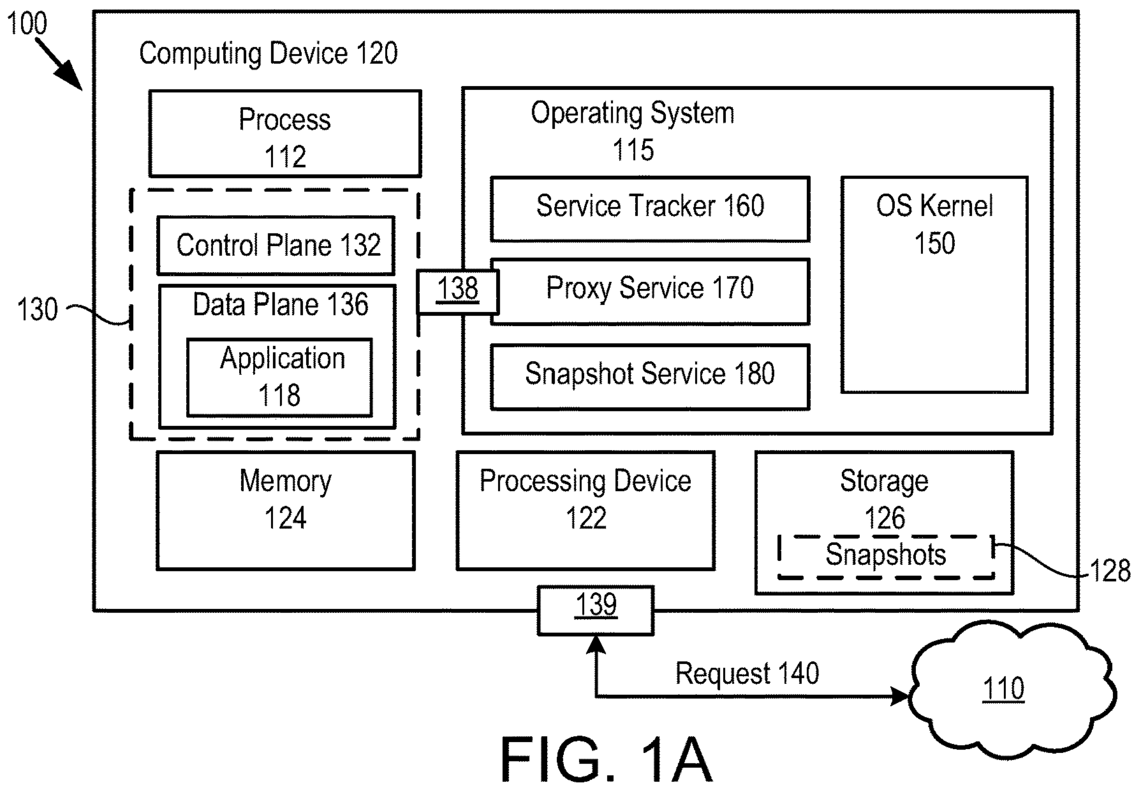
RECEIVE A REQUEST OVER A NETWORK, THE REQUEST DIRECTED TO A SERVICE PROVIDED BY AN APPLICATION OF A CLUSTER INFRASTRUCTURE, THE CLUSTER INFRASTRUCTURE COMPRISING THE APPLICATION AND A CONTROL PLANE TO SCHEDULE EXECUTION OF THE APPLICATION
410
RESPONSIVE TO RECEIVING THE REQUEST, TRANSITION THE CONTROL PLANE OF THE CLUSTER INFRASTRUCTURE FROM A STOPPED STATE TO AN ACTIVE STATE
420
TRANSFER THE REQUEST TO THE CLUSTER INFRASTRUCTURE
430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Computing Device 120
Process 112
Control Plane 132
Data Plane 136
Application 118
130
138
Operating System 115
Service Tracker 160
Proxy Service 170
Snapshot Service 180
OS Kernel 150
Memory 124
Processing Device 122
Storage 126
Snapshots
128
139
Request 140
110

FIG. 1A

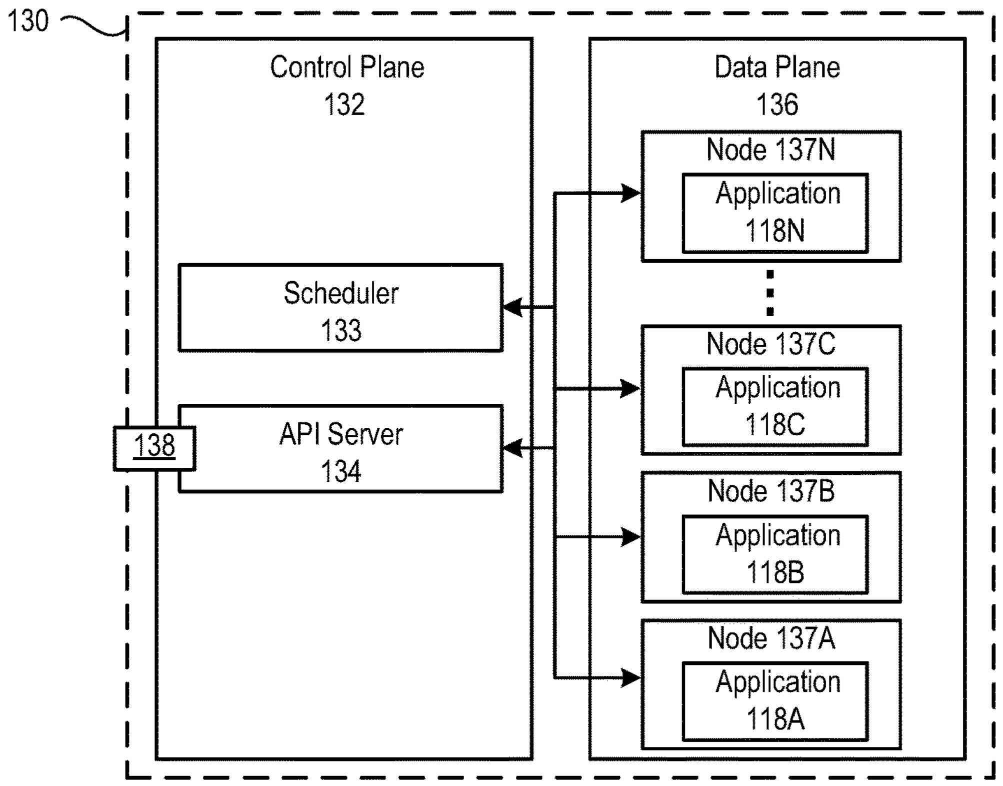
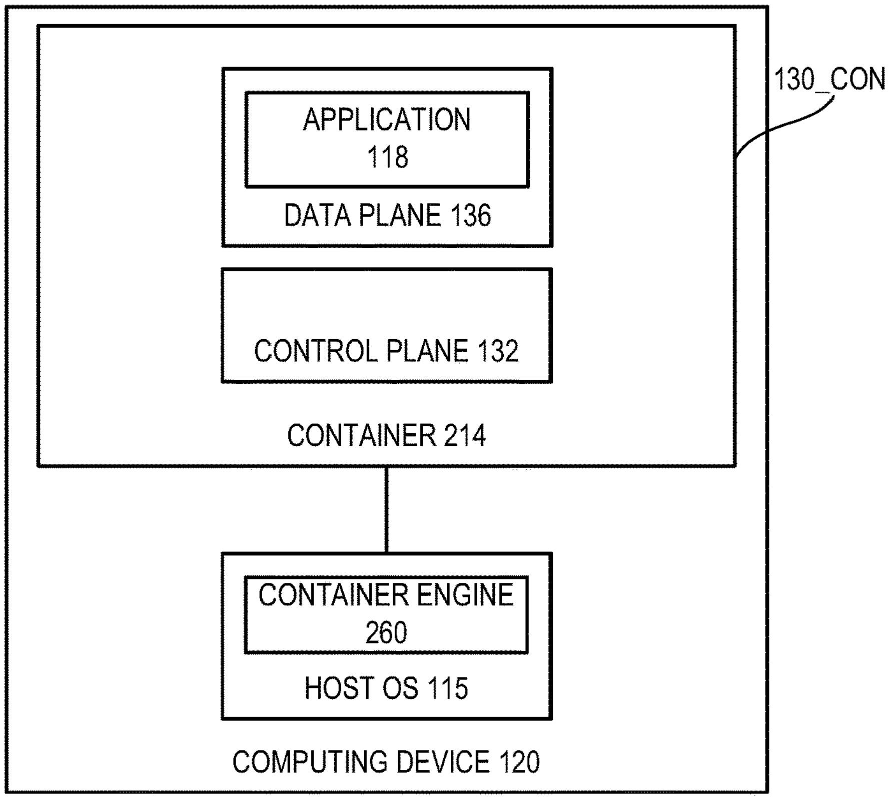

130
Control Plane 132
Scheduler 133
API Server 134
138
Data Plane 136
Node 137N
Application 118N
Node 137C
Application 118C
Node 137B
Application 118B
Node 137A
Application 118A

FIG. 1B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DATA PLANE 136
CONTROL PLANE 132
CONTAINER 214
130_CON
CONTAINER ENGINE 260
HOST OS 115
COMPUTING DEVICE 120

FIG. 2A

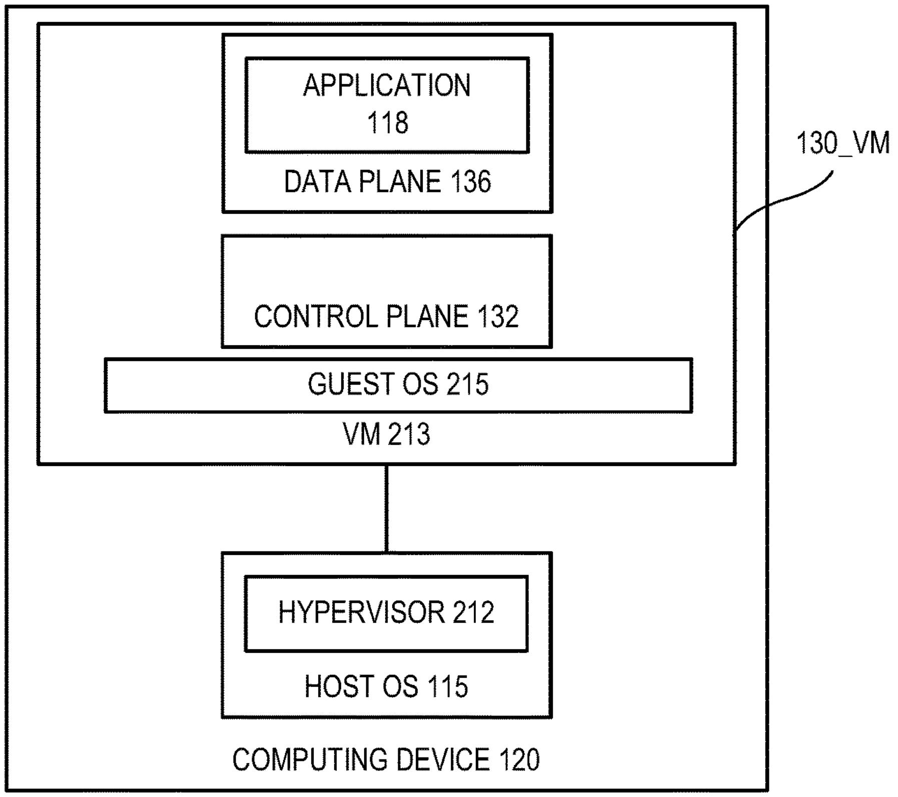
APPLICATION 118
DATA PLANE 136
CONTROL PLANE 132
GUEST OS 215
VM 213
130_VM
HYPERVISOR 212
HOST OS 115
COMPUTING DEVICE 120

FIG. 2B

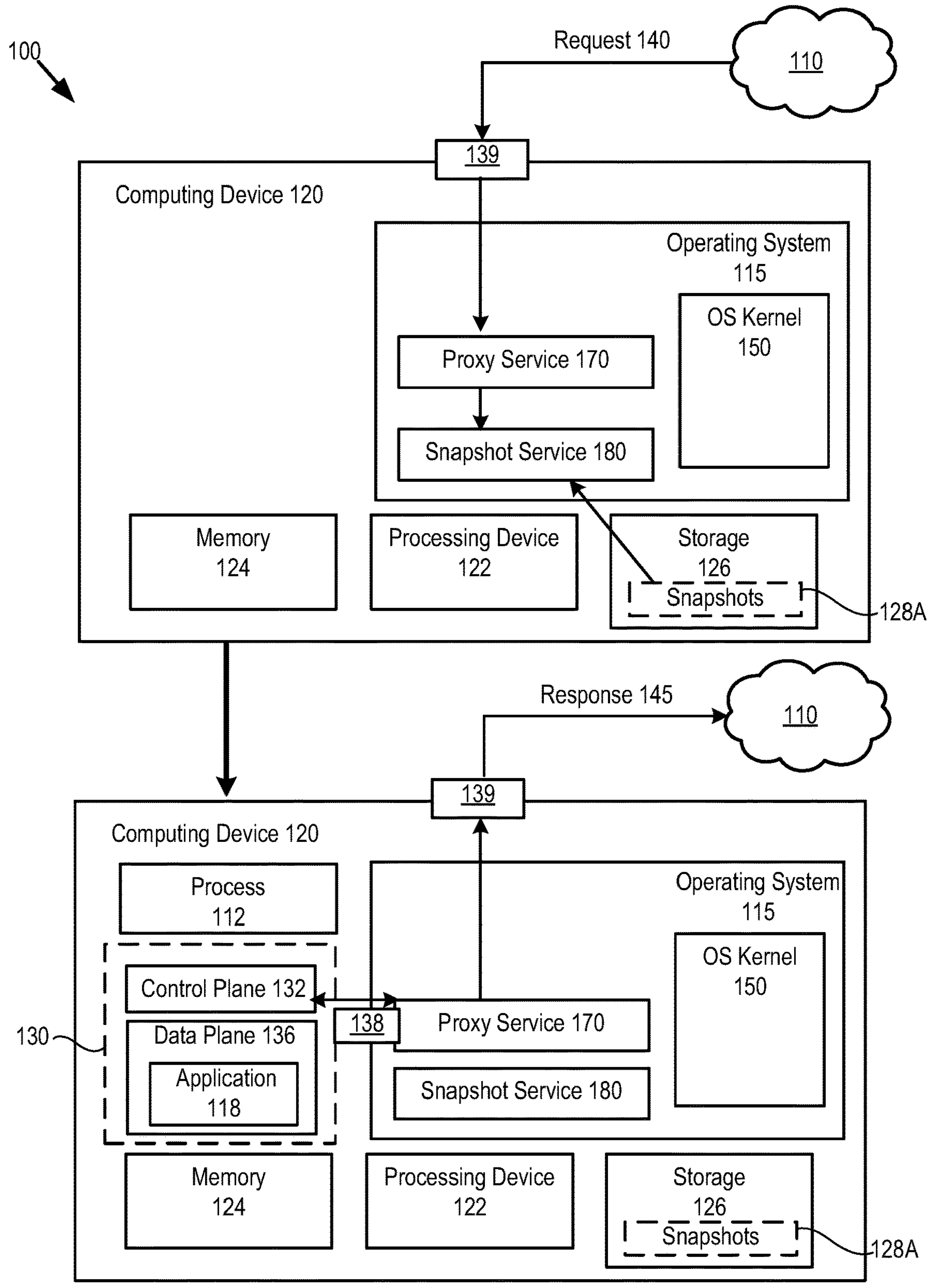
100
Request 140
110
139
Computing Device 120
Operating System 115
OS Kernel 150
Proxy Service 170
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128A
Response 145
110
139
Computing Device 120
Process 112
Operating System 115
Control Plane 132
Data Plane 136
Application 118
130
138
Proxy Service 170
OS Kernel 150
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128A

FIG. 3A

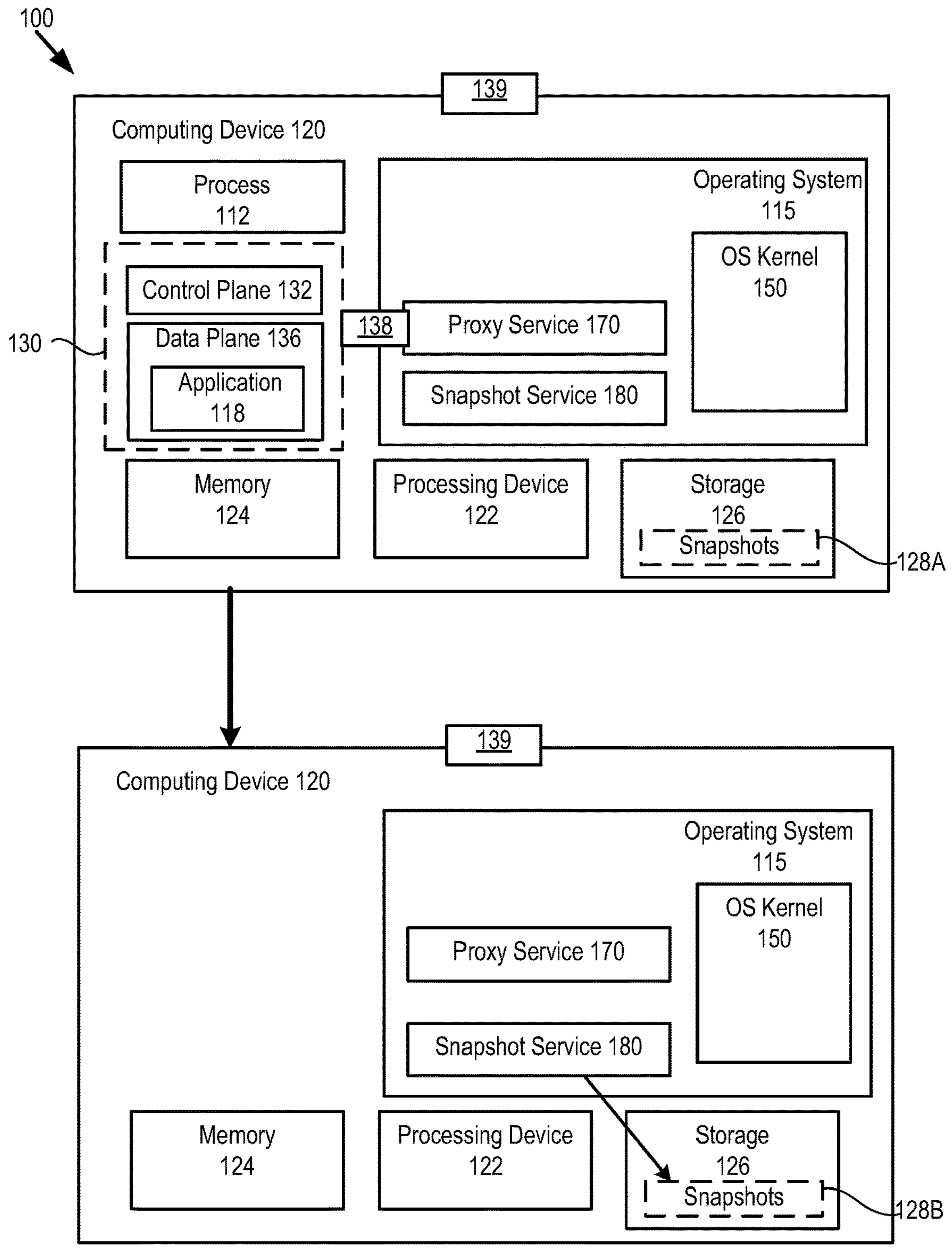
100
139
Computing Device 120
Process 112
130
Control Plane 132
Data Plane 136
Application 118
138
Operating System 115
OS Kernel 150
Proxy Service 170
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128A
139
Computing Device 120
Operating System 115
OS Kernel 150
Proxy Service 170
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128B

FIG. 3B

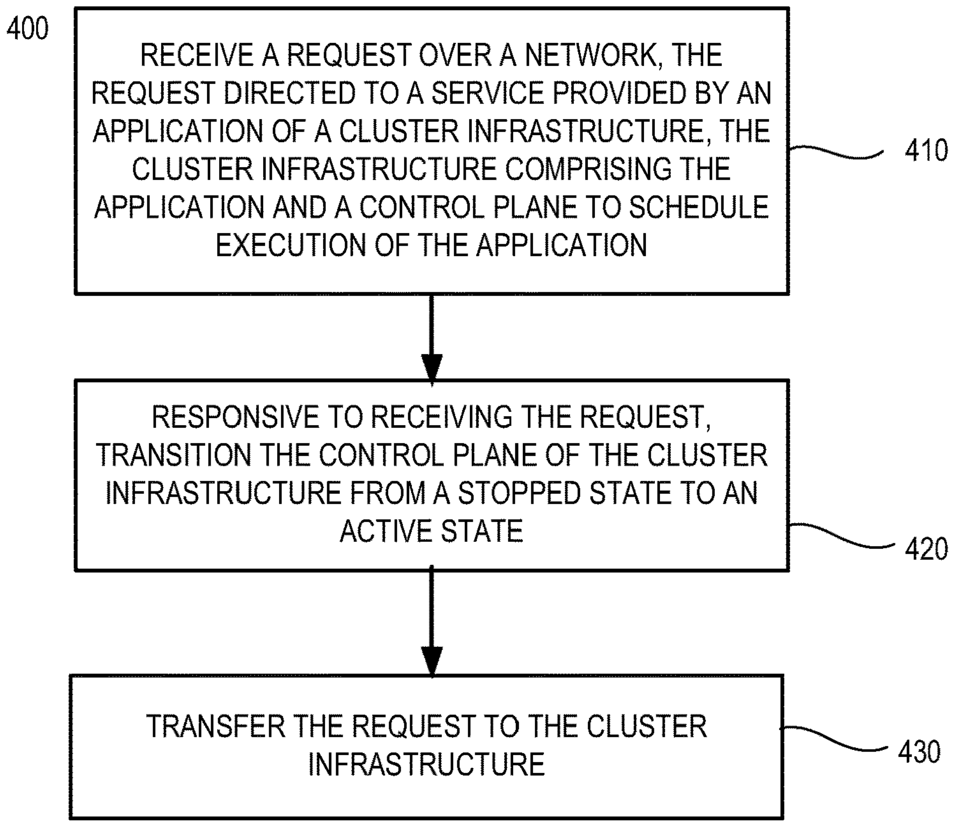
400
RECEIVE A REQUEST OVER A NETWORK, THE REQUEST DIRECTED TO A SERVICE PROVIDED BY AN APPLICATION OF A CLUSTER INFRASTRUCTURE, THE CLUSTER INFRASTRUCTURE COMPRISING THE APPLICATION AND A CONTROL PLANE TO SCHEDULE EXECUTION OF THE APPLICATION
410
RESPONSIVE TO RECEIVING THE REQUEST, TRANSITION THE CONTROL PLANE OF THE CLUSTER INFRASTRUCTURE FROM A STOPPED STATE TO AN ACTIVE STATE
420
TRANSFER THE REQUEST TO THE CLUSTER INFRASTRUCTURE
430

FIG. 4

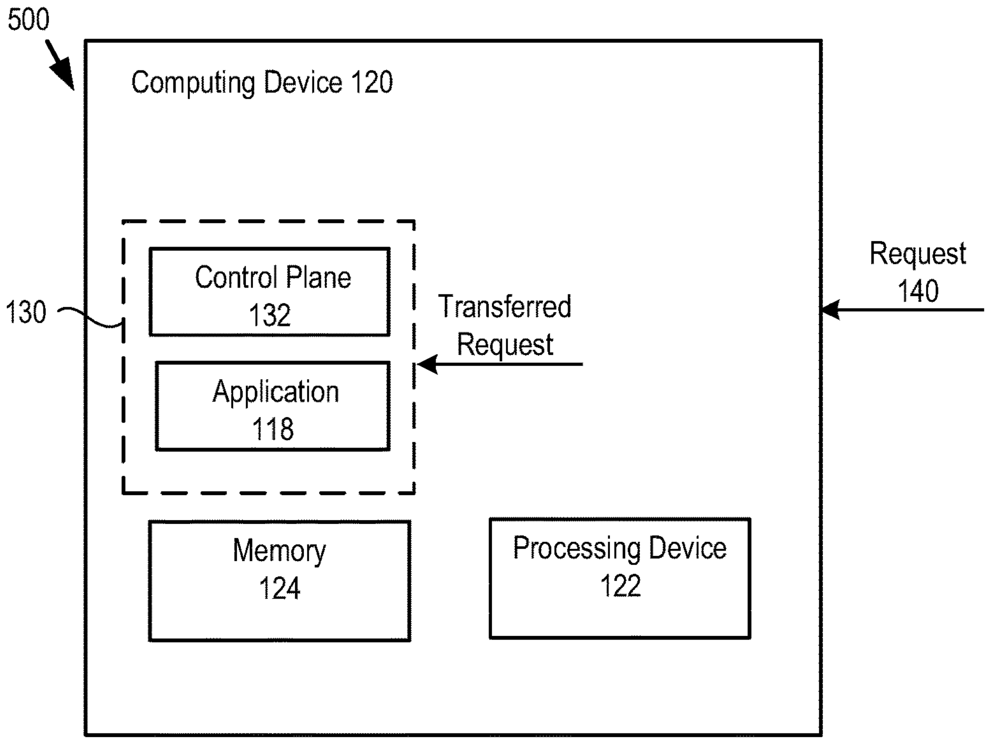
500
Computing Device 120
130
Control Plane 132
Application 118
Transferred Request
Request 140
Memory 124
Processing Device 122

FIG. 5

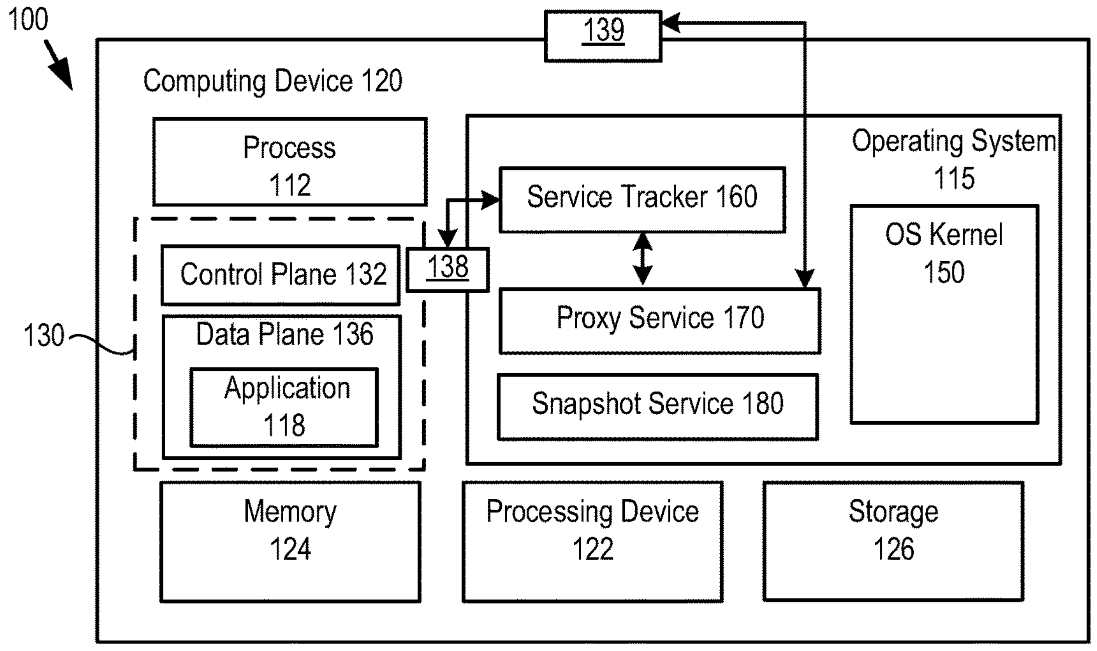
100
139
Computing Device 120
Process 112
Operating System 115
Service Tracker 160
Control Plane 132
138
Proxy Service 170
OS Kernel 150
130
Data Plane 136
Application 118
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126

FIG. 6

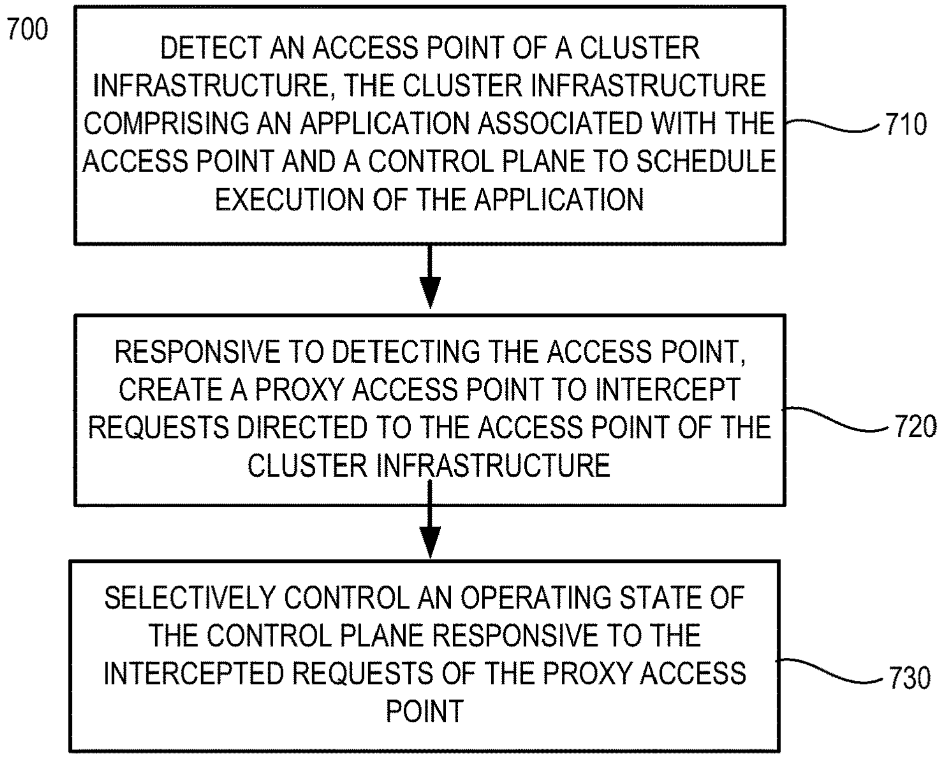
700
DETECT AN ACCESS POINT OF A CLUSTER INFRASTRUCTURE, THE CLUSTER INFRASTRUCTURE COMPRISING AN APPLICATION ASSOCIATED WITH THE ACCESS POINT AND A CONTROL PLANE TO SCHEDULE EXECUTION OF THE APPLICATION
710
RESPONSIVE TO DETECTING THE ACCESS POINT, CREATE A PROXY ACCESS POINT TO INTERCEPT REQUESTS DIRECTED TO THE ACCESS POINT OF THE CLUSTER INFRASTRUCTURE
720
SELECTIVELY CONTROL AN OPERATING STATE OF THE CONTROL PLANE RESPONSIVE TO THE INTERCEPTED REQUESTS OF THE PROXY ACCESS POINT
730

FIG. 7

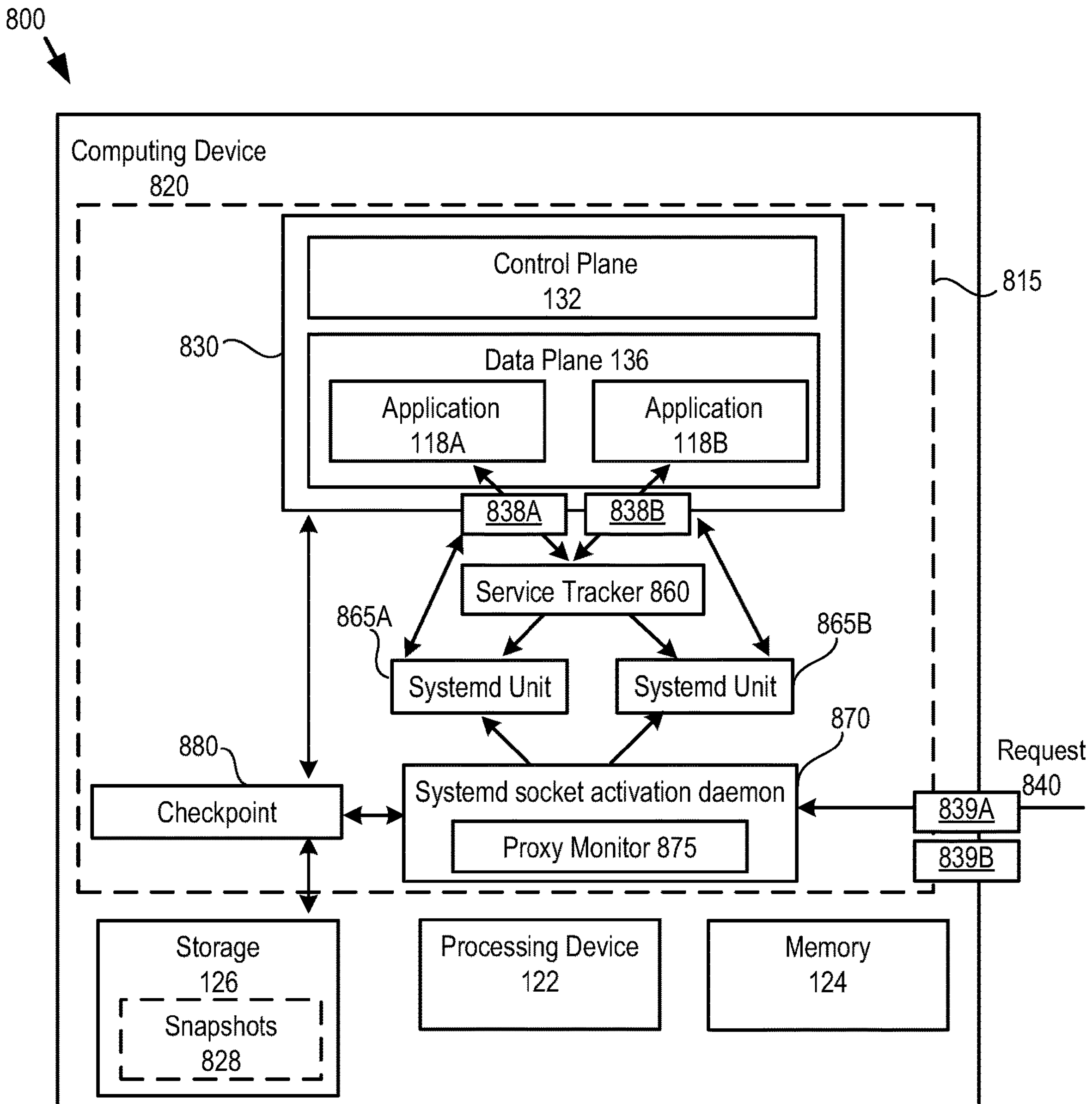
800
Computing Device 820
815
Control Plane 132
830
Data Plane 136
Application 118A
Application 118B
838A
838B
Service Tracker 860
865A
865B
Systemd Unit
Systemd Unit
870
880
Checkpoint
Systemd socket activation daemon
Proxy Monitor 875
Request 840
839A
839B
Storage 126
Snapshots 828
Processing Device 122
Memory 124

FIG. 8

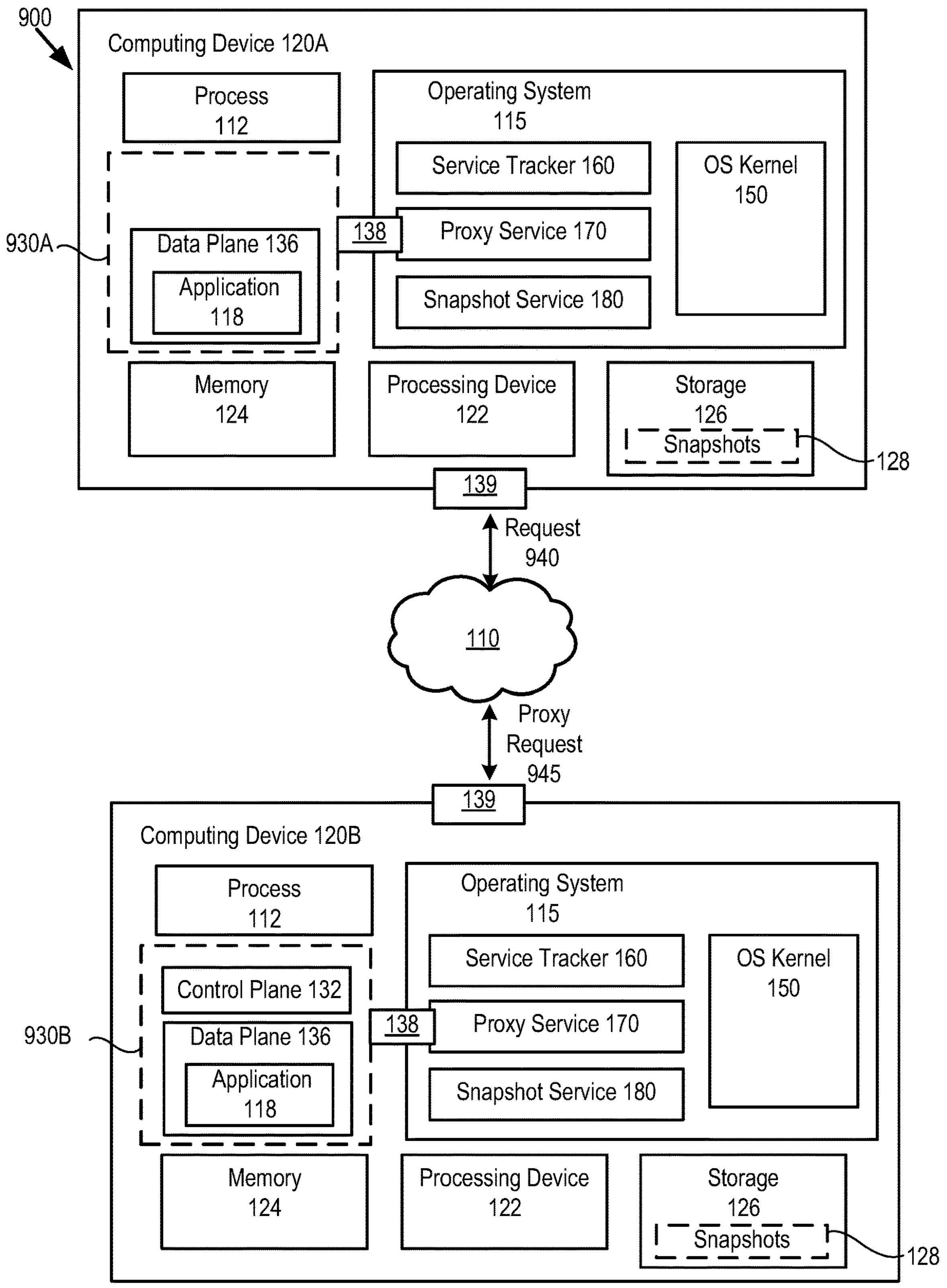
900
Computing Device 120A
Process 112
Operating System 115
Service Tracker 160
OS Kernel 150
930A
Data Plane 136
Application 118
138
Proxy Service 170
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128
139
Request 940
110
Proxy Request 945
139
Computing Device 120B
Process 112
Operating System 115
Service Tracker 160
OS Kernel 150
Control Plane 132
930B
Data Plane 136
Application 118
138
Proxy Service 170
Snapshot Service 180
Memory 124
Processing Device 122
Storage 126
Snapshots
128

FIG. 9

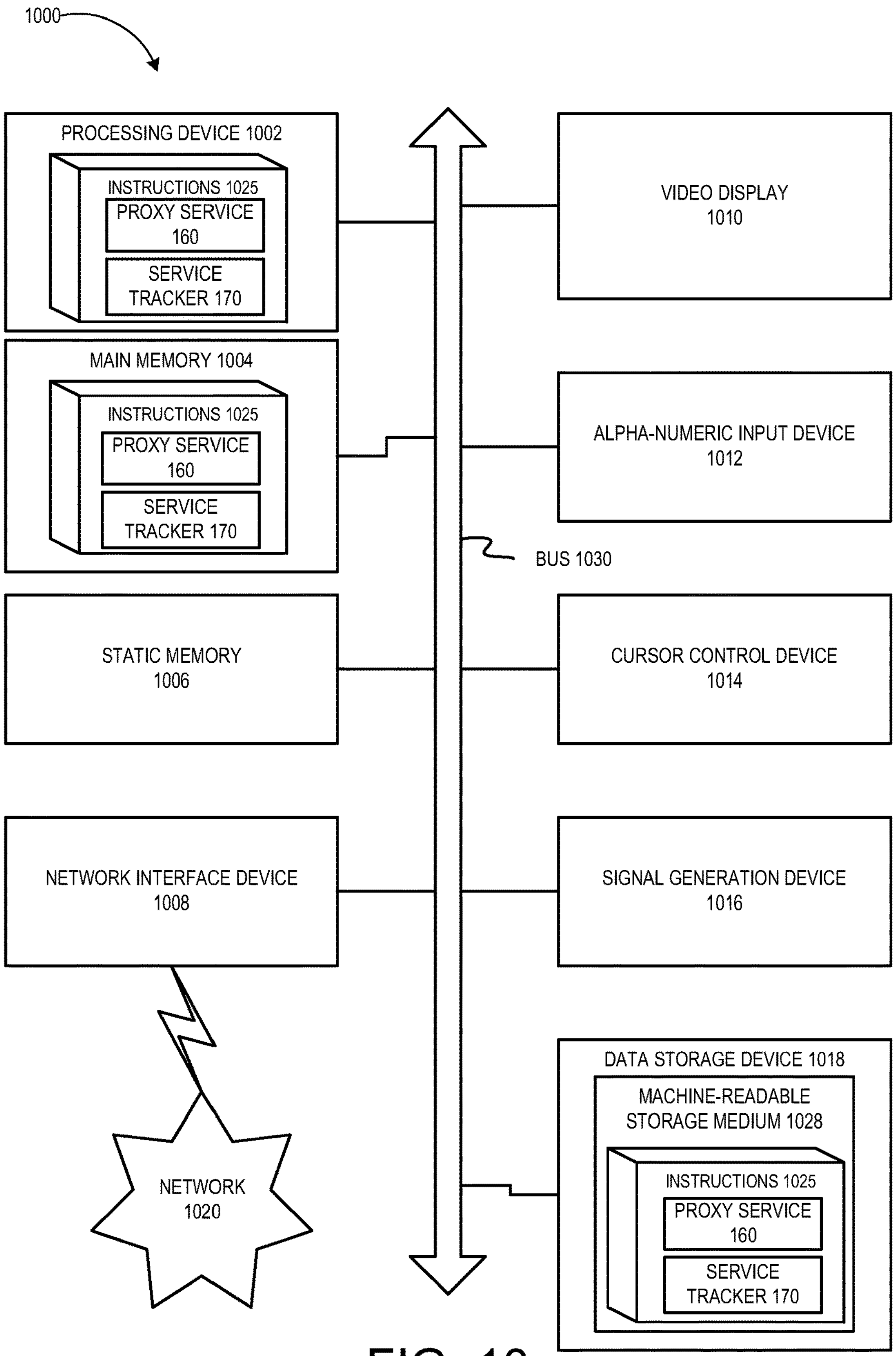
1000
PROCESSING DEVICE 1002
INSTRUCTIONS 1025
PROXY SERVICE 160
SERVICE TRACKER 170
MAIN MEMORY 1004
INSTRUCTIONS 1025
PROXY SERVICE 160
SERVICE TRACKER 170
STATIC MEMORY 1006
NETWORK INTERFACE DEVICE 1008
NETWORK 1020
VIDEO DISPLAY 1010
ALPHA-NUMERIC INPUT DEVICE 1012
BUS 1030
CURSOR CONTROL DEVICE 1014
SIGNAL GENERATION DEVICE 1016
DATA STORAGE DEVICE 1018
MACHINE-READABLE STORAGE MEDIUM 1028
INSTRUCTIONS 1025
PROXY SERVICE 160
SERVICE TRACKER 170

FIG. 10

CLUSTER INFRASTRUCTURE WITH ON-DEMAND ACTIVATION

TECHNICAL FIELD

Aspects of the present disclosure relate to computer cluster infrastructures, and more particularly, to the on-demand activation of clustering infrastructures.

BACKGROUND

Containers are components executing on an operating system that provide an environment for applications to run, while being isolated from any other components of a host machine, network, or data center etc. Multiple containers may execute on a single operating system kernel and share the resources of the hardware upon which the operating system is running.

A clustering infrastructure may schedule one or more containers for execution on one or more computing nodes (e.g., a computer server, virtual machine, or processing device). For example, load balancers or other types of scheduling operations may be used to distribute the one or more containers among the one or more computing nodes to execute services provided by the containers.

BRIEF DESCRIPTION OF THE DRAWINGS

The described embodiments and the advantages thereof may best be understood by reference to the following description taken in conjunction with the accompanying drawings. These drawings in no way limit any changes in form and detail that may be made to the described embodiments by one skilled in the art without departing from the scope of the described embodiments.

FIG. **1**A is a block diagram that illustrates an example system, according to some embodiments of the present disclosure.

FIG. **1**B is a block diagram that illustrates additional detail of a cluster infrastructure similar to that of FIG. **1**A, according to some embodiments of the present disclosure.

FIGS. **2**A and **2**B are block diagrams contrasting the use of a container executing as a cluster infrastructure within a computing device and an example virtual machine executing as a cluster infrastructure within a computing device, according to some embodiments of the present disclosure.

FIGS. **3**A and **3**B are schematic block diagrams illustrating examples of managing the transition of the cluster infrastructure, according to some embodiments of the present disclosure.

FIG. **4** is a flow diagram of a method for managing a cluster infrastructure, in accordance with some embodiments of the present disclosure.

FIG. **5** is a component diagram of an example of a device architecture, in accordance with embodiments of the disclosure.

FIG. **6** is a schematic block diagram illustrating an example operation of detecting an access point, according to some embodiments of the present disclosure.

FIG. **7** is a flow diagram of a method for dynamically detecting an access point, in accordance with some embodiments of the present disclosure.

FIG. **8** is a schematic block diagram illustrating an example embodiment of a computer system for managing a cluster infrastructure, according to some embodiments of the present disclosure.

FIG. **9** is a block diagram that illustrates an example system in which a cluster infrastructure incorporates a plurality of computing devices, according to some embodiments of the present disclosure.

FIG. **10** is a block diagram of an example computing device that may perform one or more of the operations described herein, according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

In computer systems supporting development and execution of application services, virtual machines and/or containers may be used. As an example, a virtual machine ("VM") may be a robust simulation of an actual physical computer system utilizing a hypervisor to allocate physical resources to the virtual machine. As another example, containers are active components executing on an operating system of a host system that provide an environment for applications to run, while being isolated from any other components of the host system. Multiple containers may execute on a single operating system kernel and share the resources of the hardware the operating system is running on.

Container-based virtualization systems may be lighter weight than systems using virtual machines with hypervisors. Containers may allow wide spread, parallel deployment of computing power for specific tasks. For example, a container may be instantiated to process a specific task and terminated after the task is complete. In large scale implementations, container orchestrators (e.g., Kubernetes®) may be used that manage the deployment and scheduling of large numbers of containers across multiple compute nodes. One example of a container orchestration platform is the Red Hat™ OpenShift™ platform built around Kubernetes.

Container orchestrators may employ cluster infrastructures. Cluster infrastructures may include a number of applications providing services (e.g., containers and/or VMs, also referred to as the data plane) and a control plane that manages the execution and/or distribution of the applications on one or more compute nodes. In a cluster infrastructure for containers, the compute nodes, which may include physical hosts, processors on a physical host, or virtual machines, may be configured as resources for execution of the containers. The container orchestrators may move the containers between and among the compute nodes as part of managing the execution of the containers. The control plane of the cluster infrastructure may perform the scheduling and/or load balancing of the containers, and their associated applications, among the compute nodes.

Cluster infrastructures, such as OpenShift clusters, may have portions which continue executing, regardless of whether they have active workloads. For example, the control plane of the cluster infrastructure may continue to execute on a processing device so as to remain available to handle traffic requests. The control plane may continue running even if the data plane (e.g., the applications providing the services) are no longer executing. This is neither cost efficient nor energy efficient. Although cluster hibernation in which the entire cluster is taken offline may help reduce this overhead, hibernated clusters may not be reactive to new traffic requests and thus may reduce the availability of the clusters and their associated services.

The present disclosure addresses the above-noted and other deficiencies by providing a demand-based activation for a cluster infrastructure that is capable of scaling the control plane of the cluster infrastructure to zero (e.g., by transitioning the cluster infrastructure to an off, inactive and/or non-executing, state). In some embodiments of the present disclosure, the cluster infrastructure itself may be provided as a container, such that it can be quickly check-pointed (e.g., saved and/or backed up) and restored. This approach may allow both the data plane and the control plane of the cluster infrastructure (e.g., a Kubernetes cluster) to scale to zero utilization when there are no requests for services running on the applications of the cluster infrastructure, thus improving cost and energy efficiency. Embodiments provided by the present disclosure may allow the cluster infrastructure to go to hibernation once there are no requests for services and the cluster infrastructure is no longer needed. However, when the services running on the cluster infrastructure are requested again, embodiments of the present disclosure can automatically (e.g., without manual intervention) re-activate the cluster infrastructure for these services. The embodiments of the present disclosure provide consistency of runtime states for services before and after hibernation (i.e. all the components in control and data planes) via snapshotting techniques. The embodiments of the present disclosure are beneficial for services that have occasional request arrivals. For example, embodiments of the present disclosure may be useful for free trial users that are building their business/personal web pages and do not have many visits. Other examples include edge computing use cases, where edge devices may respond to sporadic requests for batch data processing in manufacturing plant floors, clinics, restaurants, retail stores, etc. Embodiments of the present disclosure may reduce an amount of processing and/or power resources utilized by a cluster infrastructure while maintaining a consistent level of service and responsiveness to incoming requests

FIG. **1**A is a block diagram that illustrates an example system **100**, according to some embodiments of the present disclosure. FIG. **1**A and the other figures may use like reference numerals to identify like elements. A letter after a reference numeral, such as "**110**A," indicates that the text refers specifically to the element having that particular reference numeral. A reference numeral in the text without a following letter, such as "**110**," refers to any or all of the elements in the figures bearing that reference numeral.

As illustrated in FIG. **1**A, the system **100** includes a computing device **120**. The computing device **120** may include hardware such as processing device **122** (e.g., processors, central processing units (CPUs)), memory **124** (e.g., random access memory (RAM), storage devices **126** (e.g., hard-disk drive (HDD)), and solid-state drives (SSD), etc.), storage device **126**, and other hardware devices (e.g., sound card, video card, etc.). The storage device **126** of the computing device may comprise a persistent storage that is capable of storing data. A persistent storage may be a local storage unit or a remote storage unit. Persistent storage may be a magnetic storage unit, optical storage unit, solid state storage unit, electronic storage units (main memory), or similar storage unit. Persistent storage may also be a monolithic/single device or a distributed set of devices.

The computing device **120** may comprise any suitable type of computing device or machine that has a programmable processor including, for example, server computers, desktop computers, laptop computers, tablet computers, smartphones, set-top boxes, etc. In some examples, the computing device **120** may comprise a single machine or may include multiple interconnected machines (e.g., multiple servers configured in a cluster). The computing device **120** may each execute or include an operating system (OS) **115**, as discussed in more detail below. The operating system

115 of computing device **120** may manage the execution of other components (e.g., software, applications, etc.) and/or may manage access to the hardware (e.g., processors, memory, storage devices etc.) of the computing device **120**.

The computing device **120** may be coupled to (e.g., may be operatively coupled, communicatively coupled, may communicate data/messages with) network **110**. Network **110** may be a public network (e.g., the internet), a private network (e.g., a local area network (LAN) or wide area network (WAN)), or a combination thereof. In one embodiment, network **110** may include a wired or a wireless infrastructure, which may be provided by one or more wireless communications systems, such as a WIFI™ hotspot connected with the network **110** and/or a wireless carrier system that can be implemented using various data processing equipment, communication towers (e.g. cell towers), etc. The network **110** may carry communications (e.g., data, message, packets, frames, etc.) to and/or from computing device **120**.

The computing device **120** may execute an operating system **115**. Operating system **115** may be software to provide an interface between the computing hardware (e.g., processing device **122** and/or storage device **126**) and applications running on the operating system **115**. Operating system **115** may include an OS kernel **150** and a user space supporting the execution of one or more applications/processes **112**. Operating system kernel **150** may include several operating system functionalities, including but not limited to process management, hardware interfaces, access control and the like. The OS kernel **150** may execute with an elevated privilege and may manage the administration of the operating system **115**. Examples of operating systems **115** include WINDOWS™, LINUX™, ANDROID™, IOS™, and MACOS™.

As illustrated in FIG. **1**A, computing device **120** may run a cluster infrastructure **130**. For example, the cluster infrastructure **130** may be stored as computer instructions in memory **124**, and may be executed by processing device **122**. The cluster infrastructure **130** may include a control plane **132** and a data plane **136**. In some embodiments, the cluster infrastructure **130** may be isolated from other executing portions of the computing device **120**, in that it is not connected to other processes **112** of computing device **120**.

The data plane **136** of the cluster infrastructure **130** may include an application **118**. The application **118** may be a desktop application, a network application, a database application, or any other application that may execute within the data plane **136** of the cluster infrastructure **130**. The application **118** may provide a service to clients of the computing device **120**. For example, the application **118** may respond to incoming requests **140** to the computing device **120** (e.g., from network **110**).

The control plane **132** of the cluster infrastructure **130** may control the execution and/or scheduling of the data plane **136**. In some embodiments, requests for service (e.g., incoming request **140**) may initially be provided to the control plane **132** for scheduling on the data plane **136**. The control plane **132** may expose one or more access points, such as an application programming interface (API) of the application **118**.

FIG. **1**B is a block diagram that illustrates additional detail of a cluster infrastructure **130** similar to that of FIG. **1**A, according to some embodiments of the present disclosure. FIG. **1**B provides additional detail, for example, regarding the control plane **132** and the data plane **136** of the cluster infrastructure **130**.

Referring to FIG. **1**B, the data plane **136** may include a plurality of execution nodes **137**. As an example only, FIG. **1**B illustrates execution nodes **137**A, **137**B, **137**C through **137**N. The execution nodes **137** may be threads, processes, or processing devices, in some embodiments. The execution nodes **127** may be assigned one or more applications **118**. As previously described, the applications **118** may provide one or more services of the cluster infrastructure **130**. As an example only, FIG. **1**B illustrates applications **118**A, **118**B, **118**C through **118**N. As a non-limiting example, in a Kubernetes configuration, the node may correspond to a worker node, and the application **118** may correspond to a container. Applications **118**A to **118**N may be different instantiations of the same application **118** (e.g., providing a same service, but the embodiments of the present disclosure are not limited to such a configuration. In some embodiments, one or more of the applications **118**A to **118**N may be different (e.g., comprise a different executable and/or provide a different service) than other ones of the applications **118**A to **118**N.

The control plane **132** may include a scheduler **133** and an API server **134**. The scheduler **133** may schedule the applications **118** on the various nodes **137**. For example, in some embodiments, the scheduler **133** may perform a load balancing function for incoming requests **140** to the cluster infrastructure **130** (e.g., request **140** of FIG. **1**A). In response to receiving a request **140**, the scheduler **133** may determine which of the nodes **137** is available for execution of the request **140**, and forward the request to the determined node **137**.

The API server **134** may expose API functionality for the applications **118**. For example, the API server may listen for requests on an access point **138** (e.g., on a particular network port) and, after processing the requests, such as for security or validation, provide the request to the scheduler **133** for operation by the applications **118** of the various nodes **137**. In some embodiments, the incoming requests (e.g., request **140** of FIG. **1**A) or other communication may be directed directly to the applications **118** of the nodes **137**, bypassing the API server **134**.

Referring back to FIG. **1**A, in some embodiments, the cluster infrastructure **130** may be configured to execute on the computing device **120**, e.g., utilizing the processing device **122**. In some embodiments, the computing device **120** may provide a service tracker **160**. The service tracker **160** may be or include computer instructions and/or circuitry to monitor the cluster infrastructure **130**. In some embodiments, the service tracker **160** may monitor the cluster infrastructure **130** to detect access points **138** that the cluster infrastructure **130** provides as part of its execution of the application **118**. The access points **138** may include open ports that are exposed externally to the cluster infrastructure **130**. An example of an access point **138** includes a web server and/or associated uniform resource locator (URL), which may be provided (e.g., listening for connections) on a port that is opened (e.g., port **80**) on the computing device **120**. Such an access point **138** may listen for requests (e.g., request **140**) for access to the application **118**. The service tracker **160** may monitor the cluster infrastructure **130** for the creation of such access points **138** and intercept them. Information related to the access point **138** may be discovered by the service tracker **160** and provided to a proxy service **170**. Additional details of the operations of the service tracker **160** will be provided further herein.

The proxy service **170** may be configured to expose a proxy access point **139** that intercepts requests directed to access point **138** of the cluster infrastructure **130**. The proxy service **170** may be capable of receiving a request **140** on the proxy access point **139** even if the cluster infrastructure **130**, including a control plane **132** of the cluster infrastructure **130**, is not available. The proxy service **170** may be configured to transition the cluster infrastructure **130** from a stopped state to an executing state in response to receiving the request on the proxy access point **138**. Additional details of the operations of the proxy service **170** will be provided further herein.

The computing device **120** may also include a snapshot service **180**. The snapshot service **180** may be configured to take a snapshot **128** of the cluster infrastructure **130**. A snapshot **128** may be a data record of an operating state of the cluster infrastructure **130**. In some embodiments, the snapshot **128** may be stored in storage **126** of and/or connected to the computing device **120**. The snapshot **128** of the cluster infrastructure **130** may be used to transition the cluster infrastructure **130** from a stopped state to an executing state, and vice versa. For example, while the cluster infrastructure **130** is executing, the snapshot service **180** may take a snapshot **128** of the executing cluster infrastructure **130**. The snapshot **128** may capture a current state of the memory, data, and other electronic state of the cluster infrastructure **130**, which can be saved/written into storage **126**. To restore the cluster infrastructure **130** from the snapshot **128**, the snapshot **128** may be loaded into the computing device **120** (e.g., into memory **124**), including the state of the captured data, and may be transitioned to a running state. Once restored from the snapshot **128**, the cluster infrastructure **130** may begin executing at the same state as when the snapshot **128** was taken. Restoring from a snapshot **128** can be differentiated from beginning an execution of the cluster infrastructure **130** in that the snapshot **128** can omit operations to initialize the cluster infrastructure **130**, and a state of the cluster infrastructure **130** (e.g., of the applications **118**) may be maintained in a same state as when the snapshot **128** was taken. Thus, the cluster infrastructure **130** can be transitioned from a stopped state to a running state based on the snapshot **128**, without having to run through a full initialization.

The cluster infrastructure **130** may be implemented in a variety of ways. For example, in some embodiments, the cluster infrastructure may be implemented with the control plane **132** and the data plane **136** implemented as software containers (e.g., a container image). In some embodiments, the cluster infrastructure may be implemented with the control plane **132** and the data plane **136** implemented utilizing VMs. FIG. **2**A is a block diagram that illustrates an example in which a cluster infrastructure **130** is implemented as a container executing within a computing device, in accordance with some embodiments of the present disclosure. FIG. **2**B is a block diagram that illustrates an example in which a cluster infrastructure **130** is implemented as a virtual machine executing within a computing device, in accordance with some embodiments of the present disclosure. FIGS. **2**A and **2**B contrast the use of a virtual machine with the use of a container to form the cluster infrastructure **130** of FIGS. **1**A and **1**B.

Referring to FIG. **2**A, in an embodiment incorporating a container-based cluster infrastructure **130**_CON, a computing device **120** may include hardware (e.g., processing devices, memory, storage devices, other devices, etc.) and a host OS **115**. A container **214** may execute as part of the host OS **115** on the computing device **120**. In one embodiment, the container **214** may be an isolated set of resources allocated to executing an application **118** and may be process independent from other applications, software, and/or processes. The host OS **115** may use namespaces to isolate the resources of the container **214** from other applications (or containers) executing on the host OS **115**. Container **214** may not implement separate guest OS (as will be described with respect to guest OS **215** of the VM **213** illustrated in FIG. **2**B). The container **214** may share the kernel, libraries, and binaries of the host OS **115** with other containers **214** that are executing on the computing device **120**. Although FIG. **2**A illustrates one container **214**, the computing device **120** may include multiple containers **114** in other embodiments.

In some embodiments, a container engine **260** may allow different containers **214** to share the host OS **115** (e.g., the OS kernel, binaries, libraries, etc.) of the computing device **120**. For example, the container engine **260** may multiplex the binaries and/or libraries of the host OS **115** between multiple containers **214**. The container engine **260** may also facilitate interactions between the container **214** and the resources of the computing device **120**. For example, the container engine **260** may manage requests from container **214** to access a memory (e.g., a RAM) of the computing device **120**. In another example, the container engine **260** may manage requests from the container **214** to access certain libraries/binaries of the host OS **115**. In other embodiments, the container engine **260** may also be used to create, remove, and manage containers **214**. In one embodiment, the container engine **260** may be a component of the host operating system **115** (e.g., Red Hat® Enterprise Linux). In another embodiment, container engine **260** may run on top of a host operating system **115**, or may run directly on host hardware without the use of a host operating system **115**.

The container-based cluster infrastructure **130**_CON may be formed of the container **214** which includes the control plane **132** (including the control plane applications discussed herein with respect to FIG. **1**B) and the data plane **136**. In some embodiments, the application **118** of the data plane **136** may also be implemented as a container. That is to say that is some embodiments, the container **214** may include additional containers (e.g., application **118**) that are controlled and executed within the container **214**, though the embodiments of the present disclosure are not limited to such a configuration.

Referring to FIG. **2**B, in an embodiment incorporating a VM-based cluster infrastructure **130**_VM, a computing device **120** may include hardware (e.g., processing devices, memory, storage devices, other devices, etc.) and a host OS **115**. As discussed above, one type of a virtual environment may be a virtual machine (VM) **213** executing on a computing device **120**. In some embodiments, the VM **213** may be a software implementation of a machine (e.g., a software implementation of a computing device) that includes its own operating system (referred to as guest OS **215**), including its own kernel, and executes application programs, applications, software. VM **213** may be, for example, a hardware emulation, a full virtualization, a para-virtualization, and an operating system-level virtualization VM.

Computing device **120** may include a hypervisor **212**, which may also be known as a virtual machine monitor (VMM). In the example shown, hypervisor **212** may be a component of a host operating system **115**. In another example, hypervisor **212** may run on top of a host operating system **115**, or may run directly on host hardware without the use of a host operating system **115**. Hypervisor **212** may manage system resources, including access to physical processing devices (e.g., processors, CPUs, etc.), physical memory (e.g., RAM), storage device (e.g., HDDs, SSDs), and/or other devices (e.g., sound cards, video cards, etc.).

The hypervisor **212**, though typically implemented in software, may emulate and export a bare machine interface to higher level software in the form of virtual processors and guest memory. Higher level software may comprise a standard or real-time operating system (OS), may be a highly stripped down operating environment with limited operating system functionality, may not include traditional OS facilities, etc. Hypervisor **212** may present other software (i.e., "guest" software) the abstraction of one or more virtual machines (VMs) that provide the same or different abstractions to various guest software (e.g., guest operating system, guest applications).

VM **213** may form part of the VM-based cluster infrastructure **130**_VM that may execute guest software that uses an underlying emulation of the physical resources (e.g., virtual processors and guest memory). As illustrated in FIG. **2**B, VM **213** may execute the control plane **132** and the data plane **136** as part of the guest OS **215**. In some embodiments, the control plane **132** (including the control plane applications discussed herein with respect to FIG. **1**B), may execute as one or more processes as part of, or controlled by, guest OS **215**. For example, the applications of the control plane **132** may run within a user space provided by the guest OS **215**. The application **118** of the data plane **136** may also run within the user space provided by the guest OS **215**, but the embodiments of the present disclosure are not limited to such a configuration. In some embodiments, the application **118** of the data plane **136** may be implemented as a container. That is to say that the cluster infrastructure **130**_VM may be implemented as a virtual machine, but the applications **118** within the virtual machine may be implemented as a container (e.g., with a container engine provided by the guest OS **215**).

FIGS. **2**A and **2**B illustrate some of the differences between a container-based cluster infrastructure **130**_CON (FIG. **2**A) and a VM-based solution cluster infrastructure **130**_VM (FIG. **2**B). In a VM-based solution, an entire virtual system, including a OS kernel and operating system (e.g., guest OS **215**) are utilized to execute the data plane **136** (e.g., application **118**) and the control plane **132**. While this can allow for a wide range of support, it may increase the overhead to execute the application **118**. In contrast, in a container-based solution, the cluster infrastructure **130**_CON executes from a same host OS **115**, eliminating the need for a full guest OS installation.

Though FIGS. **2**A and **2**B illustrate configurations in which either a VM-based cluster infrastructure **130** or a container-based cluster infrastructure **130** are utilized, the following discussion will focus on container-based implementations for ease of discussion. It will be understood, however, that the embodiments of the present disclosure are not limited to container-based cluster infrastructures **130**.

As described herein, proxy service **170** may be used to proxy requests for the cluster infrastructure **130** and transition a cluster infrastructure **130** from a stopped state to an active and/or executing state. FIGS. **3**A and **3**B are schematic block diagrams illustrating examples of managing the transition of the cluster infrastructure **130**, according to some embodiments of the present disclosure. A description of elements of FIGS. **3**A and **3**B that have previously described has been omitted for brevity.

Referring to FIG. **3**A, system **100** may include computing device **120**, including memory **124**, processing device **122**, and storage **126**. The processing device **122** may execute an operating system **115**, including OS kernel **150**. The processing device **122** may also execute proxy service **170** and snapshot service **180**. For example, proxy service **170** and snapshot service **180** may be stored in memory **124**, which is accessed by the processing device **122** during execution.

Storage **126** may contain, for example, a snapshot **128**A of a cluster infrastructure **130**. The snapshot **128**A may contain data sufficient to restore the cluster infrastructure **130** to operation, with the data and execution point of the cluster infrastructure **130** set as of a time when the snapshot **128**A was taken. In some embodiments, the snapshot **128**A may be a backup taken of the cluster infrastructure **130** at a particular point in time. The snapshot **128**A may include a copy of the current data of the cluster infrastructure **130** and other memory contents.

The proxy service **170** may be configured to listen for requests to the cluster infrastructure **130**. For example, as discussed herein with respect to FIGS. **1**A and **1**B, the cluster infrastructure **130** may be configured to expose an access point **138**. The control plane **132** and/or data plane **136** of the cluster infrastructure **130** may be configured to listen on the access point **138** for requests **140** (e.g., over network **110**). Rather than exposing the access point **138** of the cluster infrastructure **130** externally to the computing device **120**, the proxy service **170** may instead expose a proxy access point **139** and intercept any incoming requests **140** directed to the access point **138** of the cluster infrastructure **130**. In the example of FIG. **3**A, the proxy service **170** may receive a request **140** despite the fact that the cluster infrastructure **130** is not yet running/operational.

Upon receiving the request **140** at the proxy access point **139**, the proxy service **170** may determine that the request **140** is intended for cluster infrastructure **130**. For example, the proxy service **170** may maintain a mapping between the proxy access point **139** and the cluster infrastructure **130**. The proxy service **170** may determine if the cluster infrastructure **130** is operational. If the cluster infrastructure **130** is operational, the proxy service **170** may pass the request **140** on to the access point **138** of the cluster infrastructure **130**.

If the cluster infrastructure **130** is not operational, as is the case in the example of FIG. **3**A, the proxy service **170** may direct a message to snapshot service **180**. The snapshot service **180** may determine if a snapshot **128**A is available (e.g., in storage **126**). If the snapshot **128**A is available, the snapshot service **180** may proceed with restoring the snapshot **128**A to an active running state. Restoring the snapshot **128**A of the cluster infrastructure **130** may involve loading the data of the snapshot **128**A from the storage **126** into memory **124** and configuring the processing device **122** according to the data of the snapshot **128**A. Restoring the snapshot **128**A may transition the cluster infrastructure **130** from a stopped state to an active and/or running state (e.g., executing on the processing device **122**), with a current state that is substantially identical to when the snapshot **128**A was taken.

Referring to the lower half of FIG. **3**A, once the cluster infrastructure **130** has transitioned to an active state, the proxy service **170** may pass the request **140** to the access point **138**. The cluster infrastructure **130** may be unaware that the request **140** is from the proxy service **170** rather than the network **110**, but the embodiments of the present disclosure are not limited to such a configuration.

Once the cluster infrastructure **130** has completed the request **140**, a response **145** may be passed back to the proxy service **170**. The proxy service **170** may provide the response **145** to the network **110** (e.g., to the initiating client device). Though FIG. **3**A illustrates that the response **145** passes through the proxy service **170**, embodiments of the present disclosure are not limited to such a configuration. In some embodiments, the cluster infrastructure **130** may provide the response **145** directly to the network **110** (e.g., via a network interface of the cluster infrastructure **130**).

In the example of FIG. **3**A, it is assumed that a snapshot **128**A of the cluster infrastructure **130** is available in storage **126**. In some embodiments, the snapshot **128**A may not be present and/or available. In such embodiments, the snapshot service **180** and/or the proxy service **170** may start the cluster infrastructure **130** from scratch (e.g., from an executable) rather than through the use of a snapshot **128**A. In such a scenario, the proxy service **170** may wait until the cluster infrastructure **130** is up and running before passing the request **140** to the cluster infrastructure **130**.

Though the proxy service **170** and the snapshot service **180** are illustrated as separate identities in FIG. **3**A, this is merely for purposes of explanation. In some embodiments, the proxy service **170** may perform the duties of the snapshot service (e.g., be responsible for saving and/or loading snapshots **128**).

FIG. **3**B illustrates an example in which the cluster infrastructure **130** may be transitioned from an active state to an inactive and/or stopped state. Referring to FIG. **3**B, the computing device **120** may determine that it would be beneficial to transition the cluster infrastructure **130** to an inactive state. For example, in some embodiments, the proxy service **170** may determine that a time duration since a request **140** has been received on proxy access point **139** has exceeded a defined duration, e.g., one hour. In some embodiments, the computer device **120** may determine that a defined time point has been reached (e.g., the cluster infrastructure **130** is stopped after 10 PM). As would be apparent to one of ordinary skill in the art, other criteria for stopping the cluster infrastructure **130** may be used without deviating from the scope of the present disclosure.

Once the decision has been made to transition the cluster infrastructure **130** to the inactive and/or stopped state, the snapshot service **180** may perform a backup of the cluster infrastructure **130** to create snapshot **128**B. The snapshot **128**B may capture a current state of the cluster infrastructure **130** such that the cluster infrastructure **130** may be restored in a substantially identical state to when the snapshot **128**B was taken. The snapshot **128**B of FIG. **3**B may be different from the snapshot **128**A of FIG. **3**A in that the snapshot **128**B reflects differences in the operating state of the cluster infrastructure **130** that have taken place since the snapshot **128**A was reactivated.

Referring to the lower half of FIG. **3**B, as part of taking the snapshot **128**B, the snapshot service **180** may store the snapshot **128**B in storage **126**. The snapshot **128**B may then be available for the next point in time in which the activation of the cluster infrastructure **130** is desired, such as the process illustrated with respect to FIG. **3**A.

The embodiments of the present disclosure provide a mechanism by which a cluster infrastructure **130** may be dynamically (e.g., without manual intervention) started in response to incoming traffic (e.g., request **140**). The dynamic nature of the embodiments described herein allow for the cluster infrastructure **130** to be transitioned to stopped/inactive when it would be beneficial to do so, such as when traffic to the cluster infrastructure **130** has ceased for a defined period of time. In such a way, cluster infrastructures **130** that receive sporadic traffic may be deactivated and/or stopped to save power, while still allowing the cluster infrastructure **130** to be restarted when traffic resumes.

In addition, embodiments of the present disclosure also stop the control plane **132** of the cluster infrastructure **130**, in contrast to solutions that only adjust operation of the data plane **136**. Thus, both the data and the control portions of the cluster infrastructure **130** may be stopped to save even more power. In some embodiments, the proxy service **170** may be demand-driven as well. For example, the proxy service **170** may only be activated in response to receiving traffic on the proxy access point **139**. Thus, the proxy service **170** may utilize a fraction of the power and/or processing resources that might be utilized by the control plane **132** of the control infrastructure **130**. Embodiments of the present disclosure therefore provide power savings and reduced operational overhead as compared to conventional systems.

FIG. **4** is a flow diagram of a method **400** for managing a cluster infrastructure, in accordance with some embodiments of the present disclosure. Method **400** may be performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, a processor, a processing device, a central processing unit (CPU), a system-on-chip (SoC), etc.), software (e.g., instructions running/executing on a processing device), firmware (e.g., microcode), or a combination thereof. In some embodiments, the method **400** may be performed by a computing device (e.g., computing device **120** illustrated in FIGS. **1**A to **3**B).

With reference to FIG. **4**, method **400** illustrates example functions used by various embodiments. Although specific function blocks ("blocks") are disclosed in method **400**, such blocks are examples. That is, embodiments are well suited to performing various other blocks or variations of the blocks recited in method **400**. It is appreciated that the blocks in method **400** may be performed in an order different than presented, and that not all of the blocks in method **400** may be performed.

Referring simultaneously to FIGS. **1**A to **3**B as well, the method **400** begins at block **410**, in which a request **140** is received over a network **110**, the request **140** directed to a service provided by an application **118** of a cluster infrastructure **130**, the cluster infrastructure **130** comprising the application **118** and a control plane **132** to schedule execution of the application **118**.

In some embodiments, the cluster infrastructure **130** includes a container image and/or a VM. In some embodiments, the cluster infrastructure **130** includes the container image, and the container image comprises the control plane **132** of the cluster infrastructure **130**.

At block **420**, responsive to receiving the request **140**, the control plane **132** of the cluster infrastructure **130** may be transitioned from a stopped state to an active state. In some embodiments, transitioning the control plane of the cluster infrastructure **130** from a stopped state to an active state comprises restoring the cluster infrastructure **130** from a data snapshot **128**.

In some embodiments, responsive to determining that a time duration since any request **140** has been received that is directed to the service provided by the application **118** has exceeded a defined duration, a data snapshot **128** of the cluster infrastructure **130** may be created, and the control plane **132** of the cluster infrastructure **130** may be transitioned from the active state to the stopped state.

At block **430**, the request **140** may be transferred to the cluster infrastructure **130**. In some embodiments, the cluster infrastructure **230** provides an access point **138** for accessing the service of the application **118**, receiving the request **140** over the network **110** includes receiving the request **140** at a proxy access point **139**, and transferring the request **140** to the cluster infrastructure **130** includes transferring the request **140** between the proxy access point **139** and the access point **138** provided by the cluster infrastructure **130**.

In some embodiments, method **400** may further include: detecting a creation of the access point **138** provided by the cluster infrastructure **130**; and, responsive to detecting the creation of the access point **138**, creating the proxy access point **139** that is associated with the access point **138** provided by the cluster infrastructure **130**. In some embodiments, detecting the creation of the access point **138** provided by the cluster infrastructure **130** includes monitoring a creation of the access point **138** and determining if the access point **138** is to be exposed to the network **110**.

FIG. **5** is a component diagram of an example of a device architecture **500**, in accordance with embodiments of the disclosure. The device architecture **500** includes computing device **120** having processing device **122** and memory **124**, as described herein with respect to FIGS. **1**A, **1**B, **2**A, **2**B, **3**A, and **3**B.

The computing device **120** may receive request **140** directed to an application **118** of a cluster infrastructure **130**. In response to receiving the request **140**, the clustering infrastructure **130** may be transitioned from an inactive and/or stopped state to an active and/or executing state, as described herein with respect to FIGS. **3**A and **3**B. Transitioning the clustering infrastructure **130** to an active state may include transitioning a control plane **132** of the cluster infrastructure **130** from an inactive and/or stopped state to an active and/or executing state, as described herein with respect to FIGS. **3**A and **3**B. Once the cluster infrastructure **130** is active, the request **140** may be transferred to the cluster infrastructure **130** for processing.

The device architecture **500** of FIG. **5** provides the ability to dynamically control the execution of a cluster infrastructure **130** in a way that does not substantially impact performance. The device architecture **500** also allows the control plane **132** to be deactivated, further saving power and compute operations. The device architecture **500** provides technological improvement to conventional devices in that it reduces an amount of power utilized to provide a cluster infrastructure **130** while maintaining the ability for the cluster infrastructure **130** to timely respond to requests **140**.

As described herein, service tracker **160** may monitor the cluster infrastructure **130** to detect access points **138** associated with services provided by the application **118** of the cluster infrastructure **130**. Based on this detection, the service tracker **160** may configure the proxy service **170**. FIG. **6** is a schematic block diagram illustrating an example operation of detecting access point **138** by service tracker **160**, according to some embodiments of the present disclosure. A description of elements of FIG. **6** that have previously described has been omitted for brevity.

Referring to FIG. **6**, system **100** may include computing device **120**, including memory **124**, processing device **122**, and storage **126**. The processing device **122** may execute an operating system **115**, including OS kernel **150**. The processing device **122** may also execute service tracker **160**, proxy service **170**, and/or snapshot service **180**. For example, the service tracker **160**, the proxy service **170**, and snapshot service **180** may include computer instructions that are stored in memory **124**, which is accessed by the processing device **122** during execution.

Service tracker **160** may be configured to monitor the execution of cluster infrastructure **130**. As part of the execution of the cluster infrastructure **130**, the cluster infrastructure **130** may establish access point **138**. As described herein, access point **138** may correspond to an endpoint for queries/requests directed to a service provided by application **118** of the cluster infrastructure **130**. The access point **138** may correspond, for example, to a network port that may receive requests (such as request **140** over network **110**, as illustrated in FIG. **1**A). In some embodiments, the access point **138** may be provided for an access interface of the application **118** (e.g., via the API server **134** of FIG. **1**B). Thus, the access point **138** may be utilized to access the application **118** via that application interface, and request a service be performed by the application **118**.

In some embodiments, the service tracker **160** may detect the access point **138**, such as by monitoring for requests and/or operations to set up the access point **138**. In some embodiments, the establishment of the access point **138** may utilize a request from the cluster infrastructure **130** to the operating system **115**, such as a request to establish an endpoint. In some embodiments, the service tracker **160** may intercept such requests to detect the establishment of the access point **138**.

Upon detecting the establishment of the access point **138**, the service tracker **160** may communicate with and/or configure the proxy service **170** to establish the proxy access point **139** that corresponds to the access point **138**. The service tracker **160** may provide sufficient information, for example, for the proxy service **170** to map a proxy access point **139** to the access point **138**, and begin intercepting requests directed to the access point **138**.

Embodiments of the present disclosure provide operations in which a proxy access point **139** may be dynamically created to correspond to, and intercept requests for, an access point **138** of the cluster infrastructure **130**. By monitoring requests for the access point **138** using the proxy access point **139**, the proxy service **170** may be made aware of communications directed to the cluster infrastructure **130** and may then make decisions about whether to, and when to, transition the cluster infrastructure **130** between an inactive/stopped state and a running state (e.g., as described herein with respect to FIGS. **3**A and **3**B).

Though the proxy service **170** and the service tracker **160** are illustrated as separate identities in FIG. **6**, this is merely for purposes of explanation. In some embodiments, the proxy service **170** may perform the duties of the service tracker **160** (e.g., be responsible for detecting access points **138** of the cluster infrastructure **130**).

FIG. **7** is a flow diagram of a method **700** for dynamically detecting an access point, in accordance with some embodiments of the present disclosure. Method **700** may be performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, a processor, a processing device, a central processing unit (CPU), a system-on-chip (SoC), etc.), software (e.g., instructions running/executing on a processing device), firmware (e.g., microcode), or a combination thereof. In some embodiments, the method **700** may be performed by a computing device (e.g., computing device **120** illustrated in FIGS. **1**A to **6**).

With reference to FIG. **7**, method **700** illustrates example functions used by various embodiments. Although specific function blocks ("blocks") are disclosed in method **700**, such blocks are examples. That is, embodiments are well suited to performing various other blocks or variations of the blocks recited in method **700**. It is appreciated that the blocks in method **700** may be performed in an order different than presented, and that not all of the blocks in method **700** may be performed.

Referring simultaneously to FIGS. **1**A to **6** as well, the method **700** begins at block **710**, in which an access point **138** of an application interface of a cluster infrastructure **130** is detected. The cluster infrastructure **130** may include an application **118** associated with the access point **138** and a control plane **132** to schedule execution of the application **118**. In some embodiments, the cluster infrastructure **130** comprises a container image, a VM, or both a container image and a VM (e.g., the VM includes containers). In some embodiments, the cluster infrastructure **130** comprises a container image, and the container image comprises the control plane **132** of the cluster infrastructure **130**. In some embodiments, the cluster infrastructure **130** further comprises a data plane **136**, and the application **118** is within the data plane **136**.

At block **720**, responsive to detecting the access point **138**, a proxy access point **139** may be created to intercept requests directed to the access point **138** of the cluster infrastructure **130**. In some embodiments, detecting the access point **138** of the cluster infrastructure **130** includes monitoring a creation of the access point **138** and determining if the access point **138** is to be exposed to a network **110** coupled to the system **100**. In some embodiments, determining if the access point is to be exposed to the network **110** coupled to the system **100** includes analyzing a type of a service provided by the application **118**.

At block **730**, an operating state of the control plane **132** may be selectively controlled responsive to the intercepted requests of the proxy access point **139**. In some embodiments, selectively controlling the operating state of the control plane **132** responsive to the intercepted requests of the proxy access point **139** includes transitioning the control plane **132** of the cluster infrastructure **130** from a stopped state to an active state. In some embodiments, selectively controlling the operating state of the control plane **132** responsive to the intercepted requests of the proxy access point **139** includes transitioning the control plane **132** of the cluster infrastructure **130** from an active state to a stopped state responsive to determining that a time duration since any intercepted requests have been received has exceeded a defined duration. In some embodiments, selectively controlling the operating state of the control plane **132** responsive to the intercepted requests of the proxy access point **139** includes restoring the cluster infrastructure **130** from a data snapshot **128** responsive to receiving the intercepted requests.

In some embodiments, selectively controlling the operating state of the control plane **132** responsive to the intercepted requests of the proxy access point **139** includes, in response to intercepting a request **140** directed to the access point **138** of the cluster infrastructure **130**, determining if the cluster infrastructure **130** is currently executing on the system, and, responsive to determining that the cluster infrastructure **130** is not currently executing on the system, initiating a restore of the cluster infrastructure **130** from a data snapshot **128** of the cluster infrastructure **130** in a storage device.

FIG. **8** is a schematic block diagram illustrating an example embodiment of a computer system **800** for managing a cluster infrastructure **830**, according to some embodiments of the present disclosure. A description of elements of FIG. **8** that have previously described has been omitted for brevity.

Referring to FIG. **8**, system **800** may include computing device **820**, including memory **124**, processing device **122**, and storage **126**. The processing device **122** may execute instruction code (e.g., as accessed from memory **124**), portions of which are illustrated in FIG. **8**. For example, the processing device **122** may execute an operating system **815**. In the non-limiting example of FIG. **8**, the operating system **815** may be a LINUX-based operating system **815**.

As illustrated in FIG. **8**, computing device **820** may run a cluster infrastructure **830**. For example, the cluster infrastructure **830** may be stored as computer instructions in memory **124**, and may be executed by processing device **122**. The cluster infrastructure **830** may include a control plane **132** and a data plane **136**. In some embodiments, the cluster infrastructure **830** may include a cluster based on Kubernetes/OpenShift that has been instantiated into a container image (e.g., similar to container **214** of FIG. **2**A). The containerized cluster infrastructure **830** may be executed by way of a container engine (see FIG. **2**A) executing within operating system **815**.

In the example of FIG. **8**, the containerized cluster infrastructure **830** may include two applications **118**A, **118**B within the data plane **136**. The two applications **118**A, **118**B may be the same applications or different applications (e.g., providing different services). Each of the applications **118**A, **118**B may provide a respective application interface. For example, first application **118**A may provide a first application interface via first access point **838**A, and second application **118**B may provide a second application interface via second access point **838**B. In some embodiments, the first and second access points **838**A, **838**B may be provided via a service (e.g., an API service, such as API server **134** of FIG. **1**B) of the control plane **132**. For example, the control plane **132** may establish the first and second access points **838**A, **838**B via requests to the operating system **815**. In some embodiments, the requests to create the first and second access points **838**A, **838**B may indicate that the first and second access points **838**A, **838**B are to be exposed externally to the computing device **820**. For example, the first and second access points **838**A, **838**B may be respectively associated with a first externally visible proxy access point **839**A and a second externally visible proxy access point **839**B of the computing device **820**. The first and second externally visible proxy access points **839**A, **839**B may be capable of receiving requests **840** (e.g., over a network to which the computing device **820** is connected, such as network **110** of FIG. **1**A).

Checkpoint service **880**, which may perform functions similar to snapshot service **180** described herein, may be configured to create, and restore, snapshots **828** of the containerized cluster infrastructure **830**. Since the cluster infrastructure **830** is provided as a container, which may support the capability of being backed up and restored, the checkpoint service can checkpoint and restore the cluster infrastructure atomically.

In some embodiments, a service tracker **860**, which may perform functions similar to service tracker **160** described herein, may monitor the containerized cluster infrastructure **830** and detect the creation of the first and second access points **838**A, **838**B that are externally visible. In some embodiments, externally visible refers to an access point that may be accessed by entities external to the computing device **820**. For example, in a Kubernetes/OpenShift environment, the service tracker **860** may detect that the first and second access points **838**A, **838**B are associated with a service having a type of “LoadBalancer” or “NodePort”. Upon detecting such a request for externally visible access points **838**A, **838**B, the service tracker **860** may create systemd service units **865**. The systemd service units **865** may be, for example, segments of computer instructions that are configured to handle communications with the applications **118**. Thus, the service tracker **860** may create a first systemd service unit **865**A associated with the first access point **838**A (and thus first application **118**A) and create a second systemd service unit **865**B associated with the second access point **838**B (and thus second application **118**B).

After creating the systemd service units **865**, externally visible proxy access points **839**A may be created. For example, a first proxy access point **839**A may be created to be associated with the first access point **838**A and a second proxy access point **839**B may be created to be associated with the second access point **838**B. The first and second proxy access points **839**A, **839**B may be configured to accept requests **840**, which may be directed to one or more of the first and second applications **118**A, **118**B. In some embodiments, the first and second proxy access points **839**A, **839**B are sockets exposed by a network interface of the operating system **815**.

The first and second proxy access points **839**A, **839**B may be associated with a systemd socket activation daemon **870**. The systemd socket activation daemon **870** may perform some of the functions described herein with respect to proxy service **170**. In some embodiments, the systemd socket activation daemon **870** may be a socket-activated network forwarder proxy. The systemd socket activation daemon **870** may be used to bi-directionally forward traffic between two sockets. An example of its operation is illustrated in FIG. **8**. When a request **840** is received at one of the externally-visible proxy access points **839**A, **839**B, such as first proxy access point **839**A, the systemd socket activation daemon **870** may be automatically activated in response to the request **840**. The systemd socket activation daemon **870** may execute the systemd service unit **865** associated with the first proxy access point **839**A, in this case first systemd service unit **865**A.

Since the first systemd service unit **865**A is associated with the containerized cluster infrastructure **830**, the systemd socket activation daemon **870** may determine if the containerized cluster infrastructure **830** is currently executing. If the containerized cluster infrastructure **830** is not running, then the systemd socket activation daemon **870** (or the first systemd service unit **865**A) may request that the checkpoint service **880** spin up (e.g., restore to execution from snapshot **828**) the containerized cluster infrastructure **830** based on the data snapshot **828**. Once the containerized cluster infrastructure **830** is executing, the first systemd service unit **865**A may bi-directionally forward traffic between the first access point **838**A and the first proxy access point **839**A. It will be understood that though the example discussion of FIG. **8** focused on the operation of the first proxy access point **839**A, the second proxy access point **839**B (as well as any other proxy access points) may work similarly. The use of the systemd socket activation daemon **870** may allow for the activation of the systemd service units **865** dynamically in response to the receipt of the request **840**. This may allow the computing device **120** to quickly transition the containerized cluster infrastructure **830** to a running state if it is stopped.

In some embodiments, a proxy monitor **875** may monitor the traffic received from the proxy access points **839**. Should the traffic from the proxy access points **839** fall below a particular level or cease for a defined duration, the proxy monitor **875** may direct the checkpoint service **880** to create a snapshot **828** of the currently executing containerized cluster infrastructure **830** and transition the containerized cluster infrastructure **830**, including the control plane **132**, to a stopped state. In some embodiments, the proxy monitor **875** may transition the containerized cluster infrastructure **830** when traffic from all of the proxy access points **839** associated with the cluster infrastructure have ceased for the defined duration.

In some embodiments, the proxy monitor **875** may be optional, and the systemd service units **865** may be used to signal that the containerized cluster infrastructure **830** should be stopped. For example, once the systemd service units **865** no longer serve any requests and stay idle for a defined period of time, they may signal the systemd socket activation daemon **870** to exit. When the systemd socket activation daemon **870** receives the exit signals from all the systemd service units **865** associated with the containerized cluster infrastructure **830**, the systemd socket activation daemon **870** may initiate a checkpoint (e.g., via the checkpoint service **880**) of the containerized cluster infrastructure **830**. The checkpoint may transition the containerized cluster infrastructure **830** to an inactive/stopped state (e.g., shuts the containerized cluster infrastructure **830** down).

In the Kubernetes/OpenShift example of FIG. **8**, both control and data planes **132**, **136** are fully containerized so that they can be activated, and deactivated, through a single entrypoint atomically. Containerized clusters may provide one way in which atomic and consistent snapshots (e.g., snapshots **828** provided by checkpoint service **880**) may be conveniently made. The use of the container allows the control plane **132** to be transition to a stopped/inactive state during period of no traffic, but quickly reactivated when traffic appears.

Instead of managing the cluster as in some conventional techniques, embodiments according to the present disclosure provide consistent service level availability. Services and their dependencies running on the clusters may be tracked and honored so that the integrity of the services are maintained once activated. This can be implemented, for example, by the service tracker **860** that monitors the services provisioned by the applications **118** of the cluster infrastructure **830** and creates systemd service units **865** for these services.

Unlike simple cluster start and stop mechanisms used in some related techniques, the embodiments of the present disclosure provide that the runtime states of containerized services are maintained between activations so that no data loss or corruption will occur, thus supporting production deployment. This can be implemented by taking a snapshot of the current runtime state (e.g., through a checkpoint service **880**, such as e.g. podman checkpoint) and restoring the containerized cluster infrastructure **830** as described herein.

Though embodiments described herein have focused on embodiments in which the cluster infrastructure **130** is implemented on a computing device **120**, embodiments of the present disclosure are not limited to such a configuration. FIG. **9** is a block diagram that illustrates an example system **900** in which a cluster infrastructure **930** incorporates a plurality of computing devices **120**, according to some embodiments of the present disclosure. A description of elements of FIG. **9** that have been previously described will be omitted for brevity.

Referring to FIG. **9**, a distributed computing system **900** may include a plurality of computing devices **120**, such as first computing device **120**A and second computing device **120**B. The first and second computing devices **120**A, **120**B may be connected via network **110**. The first and second computing devices **120**A, **120**B may communicate with one another, for example, to perform operations associated with a cluster infrastructure **930**.

In some embodiments, the cluster infrastructure **930** may contain a first portion **930**A executing on the first computing device **120**A and a second portion **930**B on the second computing device **120**B. The operations of the cluster infrastructure **930** may be distributed between the first and second portions **930**A, **930**B. For example, in some embodiments, the data plane **136** may exist in both the first and second portions **930**A, **930**B of the cluster infrastructure **930**.

In some embodiments, the control plane **132** may not be present in all portions of the cluster infrastructure **930**. For example, as illustrated in FIG. **9**, the control plane **132** may be present in the second portion **930**B of the cluster infrastructure **930**, but not in the first portion **930**A. In such a scenario, the control plane **132** may direct the operations of the data planes **136** of both the first and second portions **930**A, **930**B of the cluster infrastructure **930**.

FIG. **9** illustrates an example in which various portions of the cluster infrastructure **930** are present on different computing devices **120**, but may be dependent on one another. In such a scenario, it may beneficial to synchronize when the cluster infrastructure is transitioned to a stopped/inactive state (or resumed from a snapshot **128**) across each of the computing devices **120** participating in the cluster infrastructure.

In such a scenario, when a request **940** is received by a computing device (e.g., at proxy access point **139** of first computing device **120**A) a decision may be made as to whether the cluster infrastructure **930** is to be transitioned from a stopped/inactive state to a running state, as described herein. In this case, it may be beneficial to transition all of the portions **930**A, **930**B of the cluster infrastructure **930** within the computing system **900**. To do this, a proxy request **945** may be sent to the other computing devices **120** within the computing system **900**. For example, the proxy request **945** may be sent by the proxy service **170** (though the embodiments of the present disclosure are not limited thereto).

The proxy request **945** may instruct the other computing devices **120** (e.g., the proxy service **170** of the other computing devices **120**) to concurrently activate their respective portions of the cluster infrastructure **930**. In this way, the state of the cluster infrastructure **930** may be synchronized across multiple machines.

A somewhat similar approach may be taken when it is determined that the cluster infrastructure **930** is to be transitioned to an inactive and/or stopped state from a running state, as described herein. For example, a proxy request **945** may be transmitted between the computing devices **120** indicating that the cluster infrastructure **930** is to be transitioned to an inactive/stopped state. Each of the computing devices **120** may respectively create snapshots **128** of their respective portions of the cluster infrastructure **930** such that the transition of the cluster infrastructure **930** to the inactive/stopped state is synchronized across the computing devices **120** of the computer system **900**.

FIG. **10** is a block diagram of an example computing device **1000** that may perform one or more of the operations described herein, in accordance with some embodiments of the disclosure. Computing device **1000** may be connected to other computing devices in a LAN, an intranet, an extranet, and/or the Internet. The computing device may operate in the capacity of a server machine in client-server network environment or in the capacity of a client in a peer-to-peer network environment. The computing device may be provided by a personal computer (PC), a set-top box (STB), a server, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single computing device is illustrated, the term "computing device" shall also be taken to include any collection of computing devices that individually or jointly execute a set (or multiple sets) of instructions to perform the methods discussed herein.

The example computing device **1000** may include a processing device (e.g., a general purpose processor, a PLD, etc.) **1002**, a main memory **1004** (e.g., synchronous dynamic random access memory (DRAM), read-only memory (ROM)), a static memory **1006** (e.g., flash memory and a data storage device **1018**), which may communicate with each other via a bus **1030**.

Processing device **1002** may be provided by one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. In an illustrative example, processing device **1002** may include a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or a processor implementing other instruction sets or processors implementing a combination of instruction sets. Processing device **1002** may also include one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. The processing device **1002** may execute the operations described herein, in accordance with one or more aspects of the present disclosure, for performing the operations and steps discussed herein.

Computing device **1000** may further include a network interface device **1008** which may communicate with a network **1020**. The computing device **1000** also may include a video display unit **1010** (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)), an alphanumeric input device **1012** (e.g., a keyboard), a cursor control device **1014** (e.g., a mouse) and an acoustic signal generation device **1016** (e.g., a speaker). In one embodiment, video display unit **1010**, alphanumeric input device **1012**, and cursor control device **1014** may be combined into a single component or device (e.g., an LCD touch screen).

Data storage device **1018** may include a computer-readable storage medium **1028** on which may be stored one or more sets of instructions **1025** that may include instructions for a managing a cluster infrastructure, e.g., proxy service **170** and/or service tracker **160**, for carrying out the operations described herein, in accordance with one or more aspects of the present disclosure. Instructions **1025** may also reside, completely or at least partially, within main memory **1004** and/or within processing device **1002** during execution thereof by computing device **1000**, main memory **1004** and processing device **1002** also constituting computer-readable media. The instructions **1025** may further be transmitted or received over a network **1020** via network interface device **1008**.

While computer-readable storage medium **1028** is shown in an illustrative example to be a single medium, the term "computer-readable storage medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database and/or associated caches and servers) that store the one or more sets of instructions. The term "computer-readable storage medium" shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by the machine and that cause the machine to perform the methods described herein. The term "computer-readable storage medium" shall accordingly be taken to include, but not be limited to, solid-state memories, optical media and magnetic media.

Example 1 is a method comprising: receiving a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application; responsive to receiving the request, transitioning the control plane of the cluster infrastructure from a stopped state to an active state; and transferring the request to the cluster infrastructure.

Example 2 is the method of Example 1, wherein the cluster infrastructure comprises a container image or a virtual machine (VM).

Example 3 is the method of any of Examples 1-2, wherein the cluster infrastructure comprises a container image, and wherein the container image comprises the control plane of the cluster infrastructure.

Example 4 is the method of any of Examples 1-3, wherein transitioning the control plane of the cluster infrastructure from a stopped state to an active state comprises restoring the cluster infrastructure from a data snapshot.

Example 5 is the method of any of Examples 1-4, further comprising: responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, creating a data snapshot of the cluster infrastructure; and transitioning the control plane of the cluster infrastructure from the active state to the stopped state.

Example 6 is the method of any of Examples 1-5, wherein the cluster infrastructure provides an access point for accessing the service of the application, wherein receiving the request over the network comprises receiving the request at a proxy access point, and wherein transferring the request to the cluster infrastructure comprises transferring the request between the proxy access point and the access point provided by the cluster infrastructure.

Example 7 is the method of any of Examples 1-6, further comprising: detecting the creation of the access point provided by the cluster infrastructure; responsive to detecting the creation of the access point, creating the proxy access point that is associated with the access point provided by the cluster infrastructure.

Example 8 is the method of Example 7, wherein, detecting the creation of the access point provided by the cluster infrastructure comprises monitoring a creation of the access point and determining if the access point is to be exposed to the network.

Example 9 is the method of any of Examples 1-8, wherein the cluster infrastructure comprises a first portion on a first computing device and a second portion on a second computing device, and wherein transitioning the control plane of the cluster infrastructure from the stopped state to the active state comprises transitioning an operating state of the first portion and the second portion between the stopped state and the active state.

Example 10 is a system comprising: a memory; and a processing device operatively coupled to the memory, to: receive a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application; responsive to receiving the request, transition the control plane of the cluster infrastructure from a stopped state to an active state; and transfer the request to the cluster infrastructure.

Example 11 is the system of Example 10, wherein the cluster infrastructure comprises a container image or a virtual machine (VM).

Example 12 is the system of any of Examples 10-11, wherein the cluster infrastructure comprises a container image, and wherein the container image comprises the control plane of the cluster infrastructure.

Example 13 is the system of any of Examples 10-12, wherein, to transition the control plane of the cluster infrastructure from a stopped state to an active state, the processing device is to restore the cluster infrastructure from a data snapshot.

Example 14 is the system of any of Examples 10-13, wherein the processing device is further to: responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, create a data snapshot of the cluster infrastructure; and transition the control plane of the cluster infrastructure from the active state to the stopped state.

Example 15 is the system of any of Examples 10-14, wherein the cluster infrastructure provides an access point for accessing the service of the application, wherein, to receive the request over the network, the processing device is to receive the request at a proxy access point, and wherein, to transfer the request to the cluster infrastructure, the processing device is to transfer the request between the proxy access point and the access point provided by the cluster infrastructure.

Example 16 is the system of any of Examples 10-15, wherein the processing device is further to: detect a creation of the access point provided by the cluster infrastructure; and responsive to detecting the creation of the access point, create the proxy access point that is associated with the access point provided by the cluster infrastructure.

Example 17 is the system of Example 16, wherein, to detect the creation of the access point provided by the cluster infrastructure, the processing device is to monitor a creation of the access point and determine if the access point is to be exposed to the network.

Example 18 is the system of any of Examples 10-17, wherein the cluster infrastructure comprises a first portion on a first computing device and a second portion on a second computing device, and wherein, to transition the control plane of the cluster infrastructure from the stopped state to the active state, the processing device is to transition an operating state of the first portion and the second portion between the stopped state and the active state.

Example 19 is a non-transitory computer-readable storage medium including instructions that, when executed by a processing device, cause the processing device to: receive a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application; responsive to receiving the request, transition, by the processing device, the control plane of the cluster infrastructure from a stopped state to an active state; and transfer the request to the cluster infrastructure.

Example 20 is the non-transitory computer-readable storage medium of Example 19, wherein the cluster infrastructure comprises a container image, and wherein the container image comprises the control plane of the cluster infrastructure.

Example 21 is the non-transitory computer-readable storage medium of any of Examples 19-20, wherein, to transition the control plane of the cluster infrastructure from a stopped state to an active state, the processing device is to restore the cluster infrastructure from a data snapshot.

Example 22 is the non-transitory computer-readable storage medium of any of Examples 19-21, wherein the processing device is further to: responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, create a data snapshot of the cluster infrastructure; and transition the control plane of the cluster infrastructure from the active state to the stopped state.

Example 23 is the non-transitory computer-readable storage medium of any of Examples 19-22, wherein the cluster infrastructure provides an access point for accessing the service of the application, wherein, to receive the request over the network, the processing device is to receive the request at a proxy access point, and wherein, to transfer the request to the cluster infrastructure, the processing device is to transfer the request between the proxy access point and the access point provided by the cluster infrastructure.

Example 24 is the non-transitory computer-readable storage medium of any of Examples 19-23, wherein the processing device is further to: detect a creation of the access point provided by the cluster infrastructure; and responsive to detecting the creation of the access point, create the proxy access point that is associated with the access point provided by the cluster infrastructure.

Example 25 is the non-transitory computer-readable storage medium of any of Examples 19-24, wherein the cluster infrastructure comprises a container image or a virtual machine (VM).

Example 26 is the non-transitory computer-readable storage medium of Example 25, wherein, to detect the creation of the access point provided by the cluster infrastructure, the processing device is to monitor a creation of the access point and determine if the access point is to be exposed to the network.

Example 27 is the non-transitory computer-readable storage medium of any of Examples 19-26, wherein the cluster infrastructure comprises a first portion on a first computing device and a second portion on a second computing device, and wherein, to transition the control plane of the cluster infrastructure from the stopped state to the active state, the processing device is to transition an operating state of the first portion and the second portion between the stopped state and the active state.

Example 28 is a system comprising: a memory; and a processing device operatively coupled to the memory, to: detect an access point of a cluster infrastructure, the cluster infrastructure comprising an application associated with the access point and a control plane to schedule execution of the application; responsive to detecting the access point, create a proxy access point to intercept requests directed to the access point of the cluster infrastructure; and selectively control an operating state of the control plane responsive to the intercepted requests of the proxy access point.

Example 29 is the system of Example 28, wherein the cluster infrastructure comprises a container image or a virtual machine (VM).

Example 30 is the system of any of Examples 28-29, wherein the cluster infrastructure comprises a container image, and wherein the container image comprises the control plane of the cluster infrastructure.

Example 31 is the system of any of Examples 28-30, wherein to selectively control the operating state of the control plane responsive to the intercepted requests of the proxy access point, the processing device is to transition the control plane of the cluster infrastructure from a stopped state to an active state.

Example 32 is the system of any of Examples 28-31, wherein to selectively control an operating state of the control plane responsive to the intercepted requests of the proxy access point, the processing device is to transition the control plane of the cluster infrastructure from an active state to a stopped state responsive to determining that a time duration since any intercepted requests have been received has exceeded a defined duration.

Example 33 is the system of any of Examples 28-32, wherein to selectively control an operating state of the control plane responsive to the intercepted requests of the proxy access point, the processing device is to restore the cluster infrastructure from a data snapshot responsive to receiving the intercepted requests.

Example 34 is the system of any of Examples 28-33, wherein, to detect an access point of a cluster infrastructure, the processing device is to monitor a creation of the access point and determine if the access point is to be exposed to a network coupled to the system.

Example 35 is the system of Example 34, wherein to determine if the access point is to be exposed to a network coupled to the system, the processing device is to analyze a type of a service provided by the application.

Example 36 is the system of any of Examples 28-35, wherein the cluster infrastructure comprises a first portion on a first computing device and a second portion on a second computing device, and wherein to selectively control the operating state of the control plane responsive to the intercepted requests of the proxy access point, the processor is to selective transition an operating state of the first portion and the second portion between a stopped state and an active state.

Example 37 is the system of any of Examples 28-36, wherein the cluster infrastructure further comprises a data plane, and wherein the application is within the data plane.

Example 38 is the system of any of Examples 28-37, wherein the system further comprises a storage, and wherein, to selectively control the operating state of the control plane responsive to the intercepted requests of the proxy access point, the processing device is to: in response to intercepting a request directed to the access point of the cluster infrastructure, determine if the cluster infrastructure is currently executing on the system; and, responsive to determining that the cluster infrastructure is not currently executing on the system, initiate a restore of the cluster infrastructure from a data snapshot of the cluster infrastructure in the storage.

Example 39 is an apparatus comprising: means to receive a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application; means to transition, responsive to receiving the request, the control plane of the cluster infrastructure from a stopped state to an active state; and means to transfer the request to the cluster infrastructure.

Example 40 is the apparatus of Example 39, wherein the cluster infrastructure comprises a container image or a virtual machine (VM).

Example 41 is the apparatus of any of Examples 39-40, wherein the cluster infrastructure comprises a container image, and wherein the container image comprises the control plane of the cluster infrastructure.

Example 42 is the apparatus of any of Examples 39-41, wherein the means to transition the control plane of the cluster infrastructure from a stopped state to an active state comprises means to restore the cluster infrastructure from a data snapshot.

Example 43 is the apparatus of any of Examples 39-42, further comprising: means to create, responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, a data snapshot of the cluster infrastructure; and means to transition the control plane of the cluster infrastructure from the active state to the stopped state.

Example 44 is the apparatus of any of Examples 39-43, wherein the cluster infrastructure provides an access point for accessing the service of the application, wherein the means to receive the request over the network comprises means to receive the request at a proxy access point, and wherein the means to transfer the request to the cluster infrastructure comprises means to transfer the request between the proxy access point and the access point provided by the cluster infrastructure.

Example 45 is the apparatus of any of Examples 39-44, further comprising: means to detect a creation of the access point provided by the cluster infrastructure; and means to create, responsive to detecting the creation of the access point, the proxy access point that is associated with the access point provided by the cluster infrastructure.

Example 46 is the apparatus of Example 45, wherein the means to detect the creation of the access point provided by the cluster infrastructure comprises means to monitor a creation of the access point and determine if the access point is to be exposed to the network.

Example 46 is the apparatus of any of Examples 39-46, wherein the cluster infrastructure comprises a first portion on a first computing device and a second portion on a second computing device, and wherein the means to transition the control plane of the cluster infrastructure from the stopped state to the active state comprises means to transition an operating state of the first portion and the second portion between the stopped state and the active state.

Unless specifically stated otherwise, terms such as "receiving," "transitioning," "transferring," "restoring," "creating," "detecting," or the like, refer to actions and processes performed or implemented by computing devices that manipulates and transforms data represented as physical (electronic) quantities within the computing device's registers and memories into other data similarly represented as physical quantities within the computing device memories or registers or other such information storage, transmission or display devices. Also, the terms "first," "second," "third," "fourth," etc., as used herein are meant as labels to distinguish among different elements and may not necessarily have an ordinal meaning according to their numerical designation.

Examples described herein also relate to an apparatus for performing the operations described herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computing device selectively programmed by a computer program stored in the computing device. Such a computer program may be stored in a computer-readable non-transitory storage medium.

The methods and illustrative examples described herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used in accordance with the teachings described herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear as set forth in the description above.

The above description is intended to be illustrative, and not restrictive. Although the present disclosure has been described with references to specific illustrative examples, it will be recognized that the present disclosure is not limited to the examples described. The scope of the disclosure should be determined with reference to the following claims, along with the full scope of equivalents to which the claims are entitled.

As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “includes”, and/or “including”, when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. Therefore, the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the term “and/or” includes any and all combination of one or more of the associated listed items.

It should also be noted that in some alternative implementations, the functions/acts noted may occur out of the order noted in the figures. For example, two figures shown in succession may in fact be executed substantially concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

Although the method operations were described in a specific order, it should be understood that other operations may be performed in between described operations, described operations may be adjusted so that they occur at slightly different times or the described operations may be distributed in a system which allows the occurrence of the processing operations at various intervals associated with the processing.

Various units, circuits, or other components may be described or claimed as “configured to” or “configurable to” perform a task or tasks. In such contexts, the phrase “configured to” or “configurable to” is used to connote structure by indicating that the units/circuits/components include structure (e.g., circuitry) that performs the task or tasks during operation. As such, the unit/circuit/component can be said to be configured to perform the task, or configurable to perform the task, even when the specified unit/circuit/component is not currently operational (e.g., is not on). The units/circuits/components used with the “configured to” or “configurable to” language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a unit/circuit/component is “configured to” perform one or more tasks, or is “configurable to” perform one or more tasks, is expressly intended not to invoke 35 U.S.C. 112, sixth paragraph, for that unit/circuit/component. Additionally, “configured to” or “configurable to” can include generic structure (e.g., generic circuitry) that is manipulated by software and/or firmware (e.g., an FPGA or a general-purpose processor executing software) to operate in manner that is capable of performing the task(s) at issue. “Configured to” may also include adapting a manufacturing process (e.g., a semiconductor fabrication facility) to fabricate devices (e.g., integrated circuits) that are adapted to implement or perform one or more tasks. “Configurable to” is expressly intended not to apply to blank media, an unprogrammed processor or unprogrammed generic computer, or an unprogrammed programmable logic device, programmable gate array, or other unprogrammed device, unless accompanied by programmed media that confers the ability to the unprogrammed device to be configured to perform the disclosed function(s).

The foregoing description, for the purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the embodiments and its practical applications, to thereby enable others skilled in the art to best utilize the embodiments and various modifications as may be suited to the particular use contemplated. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

What is claimed is:

1. A method comprising:

receiving a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application;

responsive to receiving the request, transitioning, by a processing device, the control plane of the cluster infrastructure from a stopped state to an active state; and

transferring the request to the cluster infrastructure.

2. The method of claim **1**, wherein the cluster infrastructure comprises a container image, a virtual machine (VM), or both a container image and a VM.

3. The method of claim **2**, wherein the cluster infrastructure comprises the container image, and

wherein the container image comprises the control plane of the cluster infrastructure.

4. The method of claim **1**, wherein transitioning the control plane of the cluster infrastructure from a stopped state to an active state comprises restoring the cluster infrastructure from a data snapshot.

5. The method of claim **1**, further comprising:

responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, creating a data snapshot of the cluster infrastructure; and

transitioning the control plane of the cluster infrastructure from the active state to the stopped state.

6. The method of claim **1**, wherein the cluster infrastructure provides an access point for accessing the service of the application,

wherein receiving the request over the network comprises receiving the request at a proxy access point, and

wherein transferring the request to the cluster infrastructure comprises transferring the request between the proxy access point and the access point provided by the cluster infrastructure.

7. The method of claim **6**, further comprising:

detecting a creation of the access point provided by the cluster infrastructure; and

responsive to detecting the creation of the access point, creating the proxy access point that is associated with the access point provided by the cluster infrastructure.

8. A system comprising:

a memory; and

a processing device, operatively coupled to the memory, to:

receive a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application;

responsive to receiving the request, transition the control plane of the cluster infrastructure from a stopped state to an active state; and

transfer the request to the cluster infrastructure.

9. The system of claim **8**, wherein the cluster infrastructure comprises a container image, a virtual machine (VM), or both a container image and a VM.

10. The system of claim **9**, wherein the cluster infrastructure comprises the container image, and

wherein the container image comprises the control plane of the cluster infrastructure.

11. The system of claim **8**, wherein, to transition the control plane of the cluster infrastructure from a stopped state to an active state, the processing device is to restore the cluster infrastructure from a data snapshot.

12. The system of claim **8**, wherein the processing device is further to:

responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, create a data snapshot of the cluster infrastructure; and

transition the control plane of the cluster infrastructure from the active state to the stopped state.

13. The system of claim **8**, wherein the cluster infrastructure provides an access point for accessing the service of the application,

wherein, to receive the request over the network, the processing device is to receive the request at a proxy access point, and

wherein, to transfer the request to the cluster infrastructure, the processing device is to transfer the request between the proxy access point and the access point provided by the cluster infrastructure.

14. The system of claim **13**, wherein the processing device is further to:

detect a creation of the access point provided by the cluster infrastructure; and

responsive to detecting the creation of the access point, create the proxy access point that is associated with the access point provided by the cluster infrastructure.

15. A non-transitory computer-readable storage medium including instructions that, when executed by a processing device, cause the processing device to:

receive a request over a network, the request directed to a service provided by an application of a cluster infrastructure, the cluster infrastructure comprising the application and a control plane to schedule execution of the application;

responsive to receiving the request, transition, by the processing device, the control plane of the cluster infrastructure from a stopped state to an active state; and

transfer the request to the cluster infrastructure.

16. The non-transitory computer-readable storage medium of claim **15**, wherein the cluster infrastructure comprises a container image, and

wherein the container image comprises the control plane of the cluster infrastructure.

17. The non-transitory computer-readable storage medium of claim **15**, wherein, to transition the control plane of the cluster infrastructure from a stopped state to an active state, the processing device is to restore the cluster infrastructure from a data snapshot.

18. The non-transitory computer-readable storage medium of claim **15**, wherein the processing device is further to:

responsive to determining that a time duration since any request has been received that is directed to the service provided by the application has exceeded a defined duration, create a data snapshot of the cluster infrastructure; and

transition the control plane of the cluster infrastructure from the active state to the stopped state.

19. The non-transitory computer-readable storage medium of claim **15**, wherein the cluster infrastructure provides an access point for accessing the service of the application,

wherein, to receive the request over the network, the processing device is to receive the request at a proxy access point, and

wherein, to transfer the request to the cluster infrastructure, the processing device is to transfer the request between the proxy access point and the access point provided by the cluster infrastructure.

20. The non-transitory computer-readable storage medium of claim **19**, wherein the processing device is further to:

detect a creation of the access point provided by the cluster infrastructure; and

responsive to detecting the creation of the access point, create the proxy access point that is associated with the access point provided by the cluster infrastructure.

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