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Banerjee et al.

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(54) **UTILIZING NETWORK ANALYTICS FOR SERVICE PROVISIONING**

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(51) **Int. Cl.**
H04L 67/1008 (2022.01)
H04L 43/0882 (2022.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 67/1008*** (2013.01); ***H04L 43/0882*** (2013.01); ***H04L 43/16*** (2013.01); ***H04L 67/51*** (2022.05)

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

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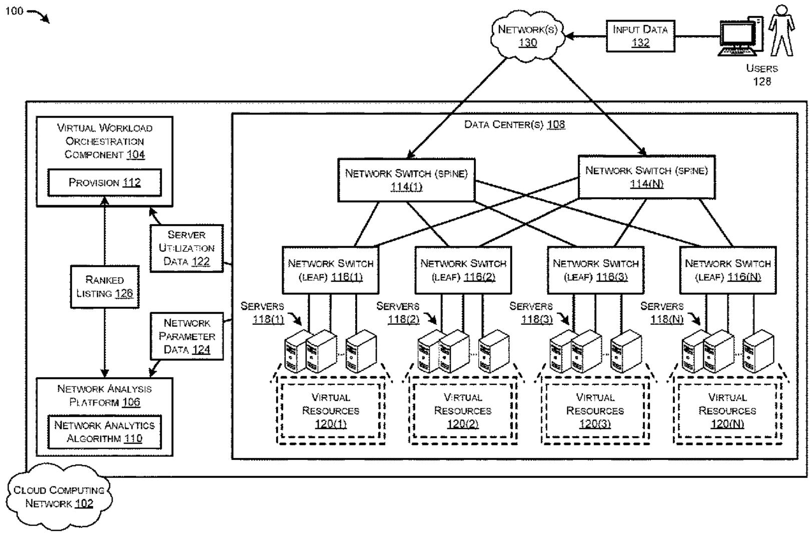
Primary Examiner — Backhean Tiv
(74) *Attorney, Agent, or Firm* — Lee & Hayes, P.C.

(57) **ABSTRACT**

This disclosure describes techniques for collecting network parameter data for network switches and/or physical servers and provisioning virtual resources of a service on physical servers based on network resource availability. The network parameter data may include network resource availability data, diagnostic constraint data, traffic flow data, etc. The techniques include determining network switches that have an availability of network resources to support a virtual resource on a connected physical server. A scheduler may deploy virtual machines to particular servers based on the network parameter data in lieu of, or in addition to, the server utilization data of the physical servers (e.g., CPU usage, memory usage, etc.). In this way, a virtual resource may be deployed to a physical server that has an availability of the server resources, but also is connected to a network switch with the availability of network resources to support the virtual resource.

20 Claims, 7 Drawing Sheets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Users 128
Data Center(s) 108
Virtual Workload Orchestration Component 104
Provision 112
Server Utilization Data 122
Ranked Listing 126
Network Parameter Data 124
Network Analysis Platform 106
Network Analytics Algorithm 110
Network Switch (spine) 114(1)
Network Switch (spine) 114(N)
Network Switch (leaf) 116(1)
Network Switch (leaf) 116(2)
Network Switch (leaf) 116(3)
Network Switch (leaf) 116(N)
Servers 118(1)
Servers 118(2)
Servers 118(3)
Servers 118(N)
Virtual Resources 120(1)
Virtual Resources 120(2)
Virtual Resources 120(3)
Virtual Resources 120(N)
Cloud Computing Network 102

(51) **Int. Cl.**

H04L 43/16	(2022.01)
H04L 67/51	(2022.01)

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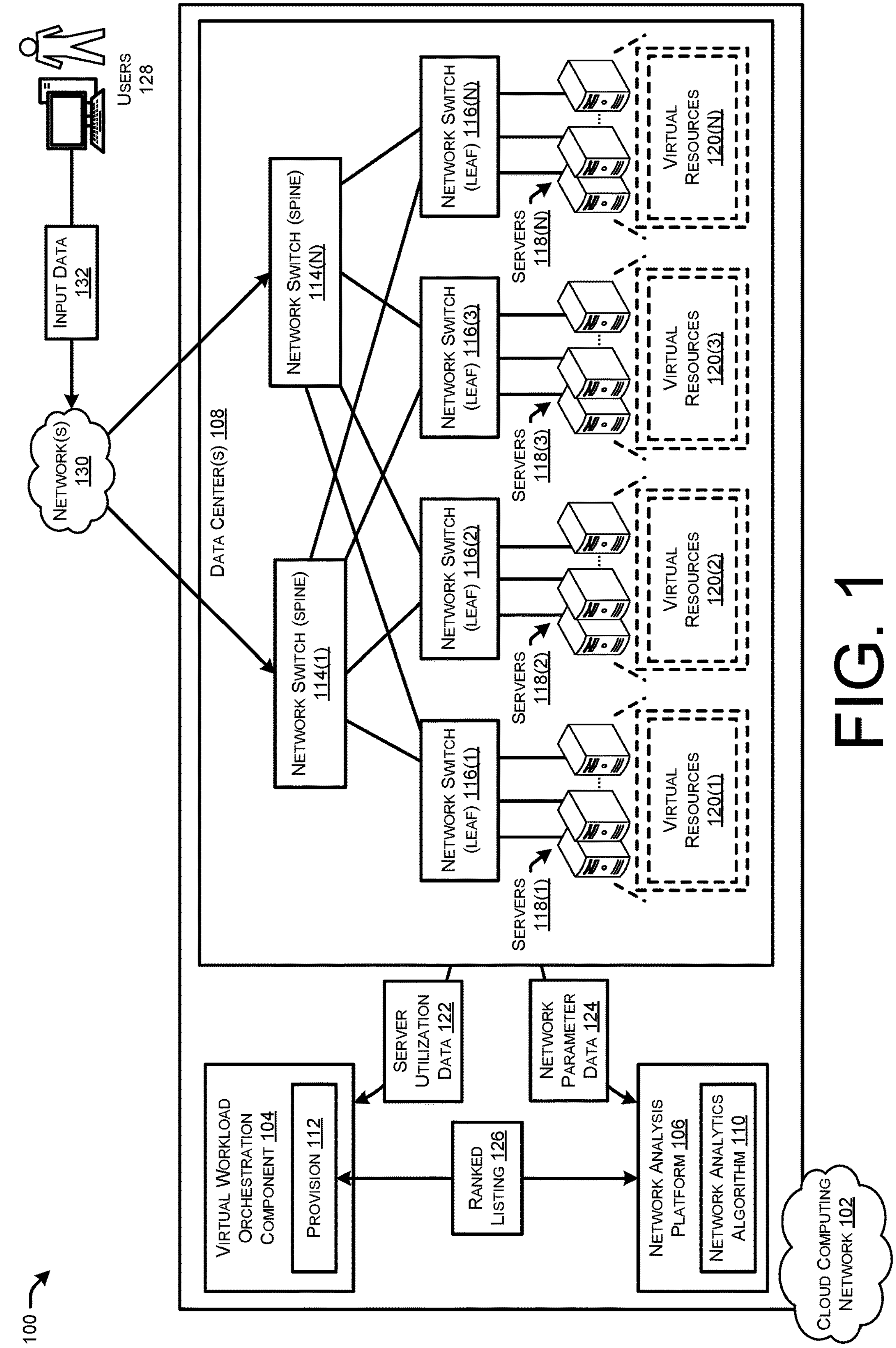
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Network(s) 130
Cloud Computing Network 102
Data Center(s) 108
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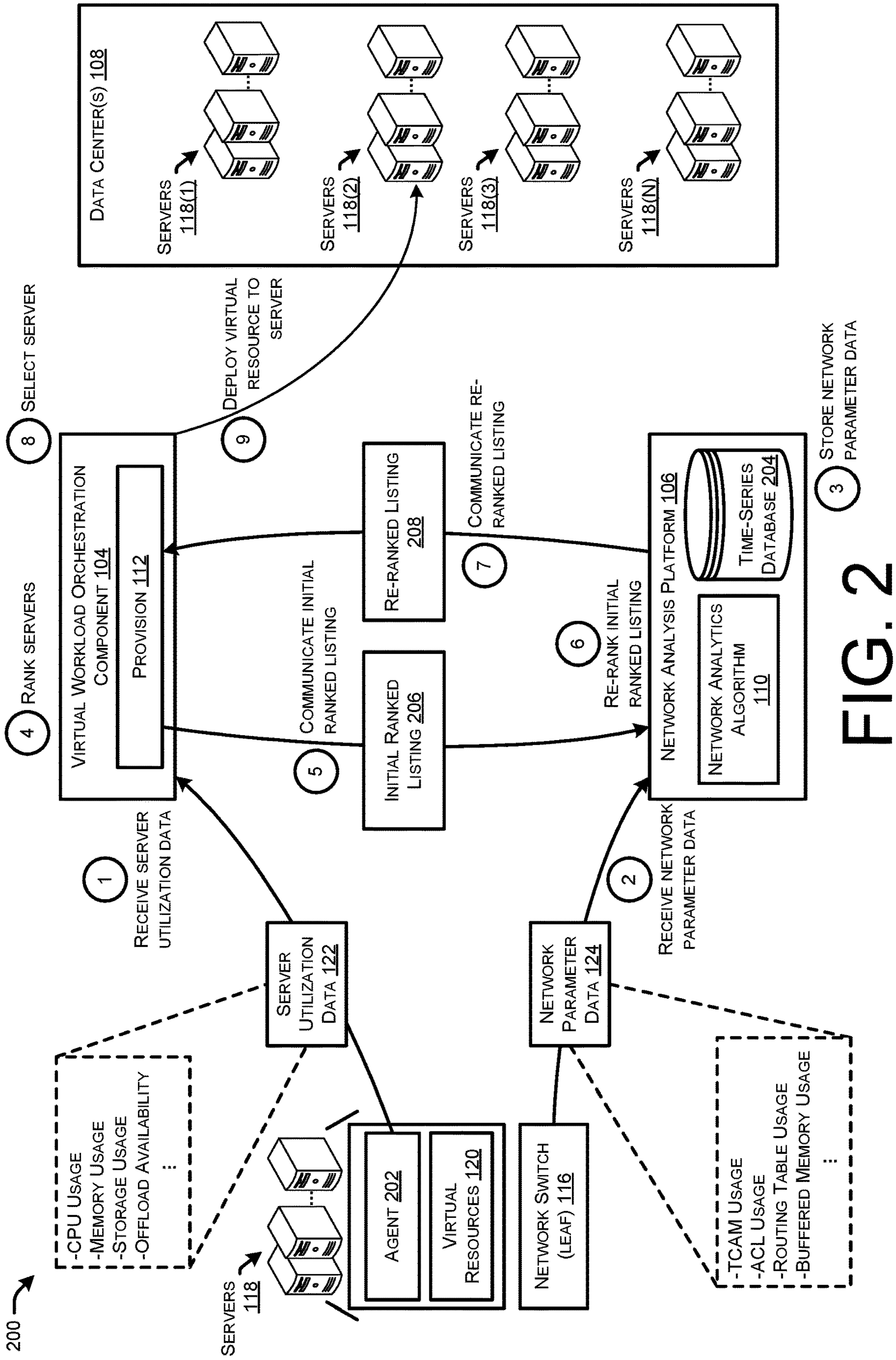
Network Switch (spine) 114(N)
Network Switch (leaf) 116(1)
Network Switch (leaf) 116(2)
Network Switch 116(3) (leaf)
Network Switch (leaf) 116(N)
Servers 118(1)
Servers 118(2)
Servers 118(3)
Servers 118(N)
Virtual Resources 120(1)
Virtual Resources 120(2)
Virtual Resources 120(3)
Virtual Resources 120(N)
Server Utilization Data 122
Network Parameter Data 124
Ranked Listing 126
Virtual Workload Orchestration Component 104
Provision 112
Network Analysis Platform 106
Network Analytics Algorithm 110

FIG. 1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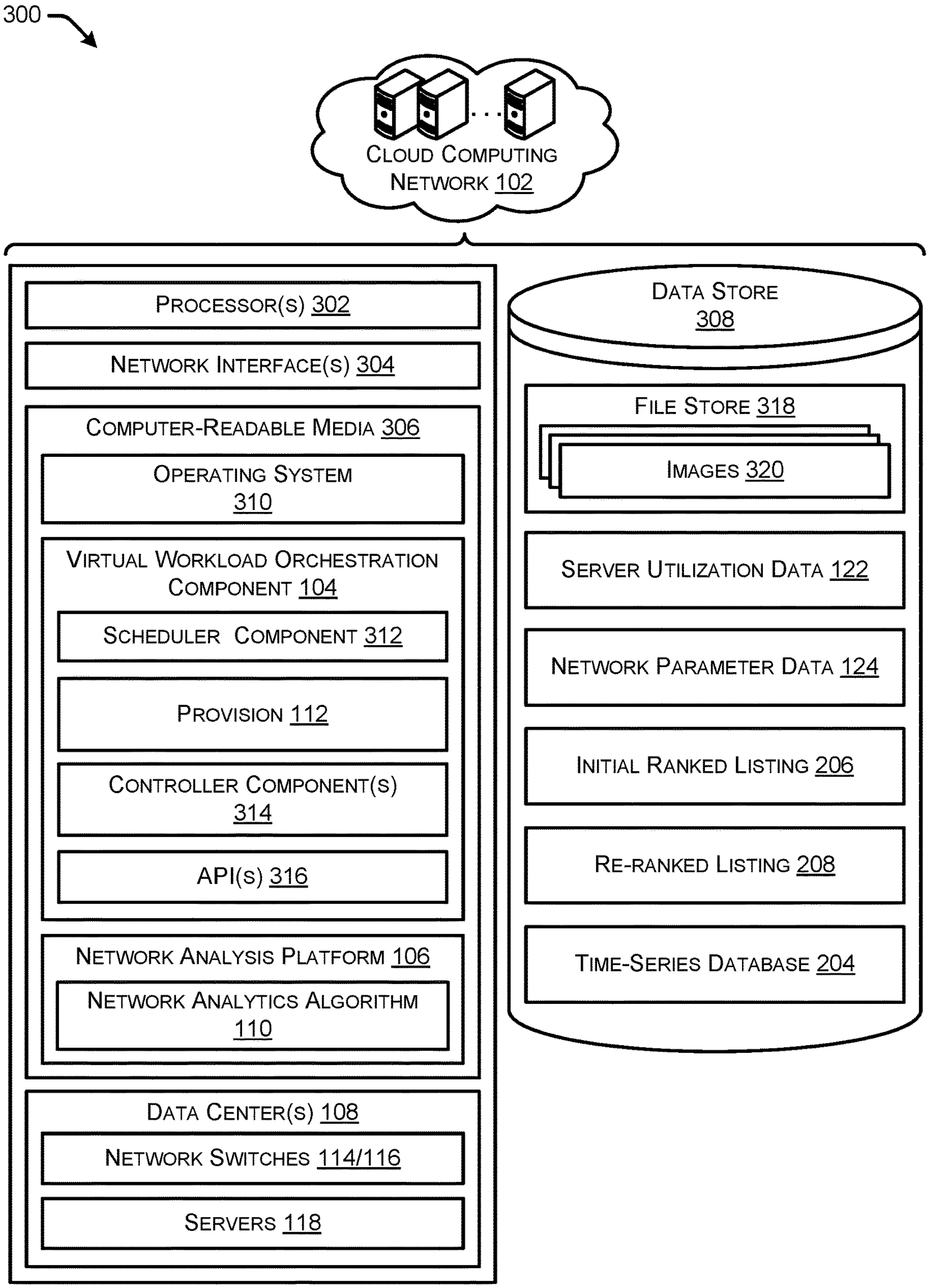
Servers 118
Agent 202
Virtual Resources 120
Network Switch (Leaf) 116
-CPU Usage
-Memory Usage
-Storage Usage
-Offload Availability
⋮
Server Utilization Data 122
Network Parameter Data 124
-TCAM Usage
-ACL Usage
-Routing Table Usage
-Buffered Memory Usage
⋮
1 Receive server utilization data
2 Receive network parameter data
Virtual Workload Orchestration Component 104
Provision 112
4 Rank servers
5 Communicate initial ranked listing
Initial Ranked Listing 206
Network Analysis Platform 106
Network Analytics Algorithm 110
Time-Series Database 204
3 Store network parameter data
6 Re-rank initial ranked listing
Re-Ranked Listing 208
7 Communicate re-ranked listing
8 Select server
9 Deploy virtual resource to server
Data Center(s) 108
Servers 118(1)
Servers 118(2)
Servers 118(3)
Servers 118(N)

FIG. 2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Network Interface(s) 304
Computer-Readable Media 306
Operating System 310
Virtual Workload Orchestration Component 104
Scheduler Component 312
Provision 112
Controller Component(s) 314
API(s) 316
Network Analysis Platform 106
Network Analytics Algorithm 110
Data Center(s) 108
Network Switches 114/116
Servers 118
Data Store 308
File Store 318
Images 320
Server Utilization Data 122
Network Parameter Data 124
Initial Ranked Listing 206
Re-ranked Listing 208
Time-Series Database 204

FIG. 3

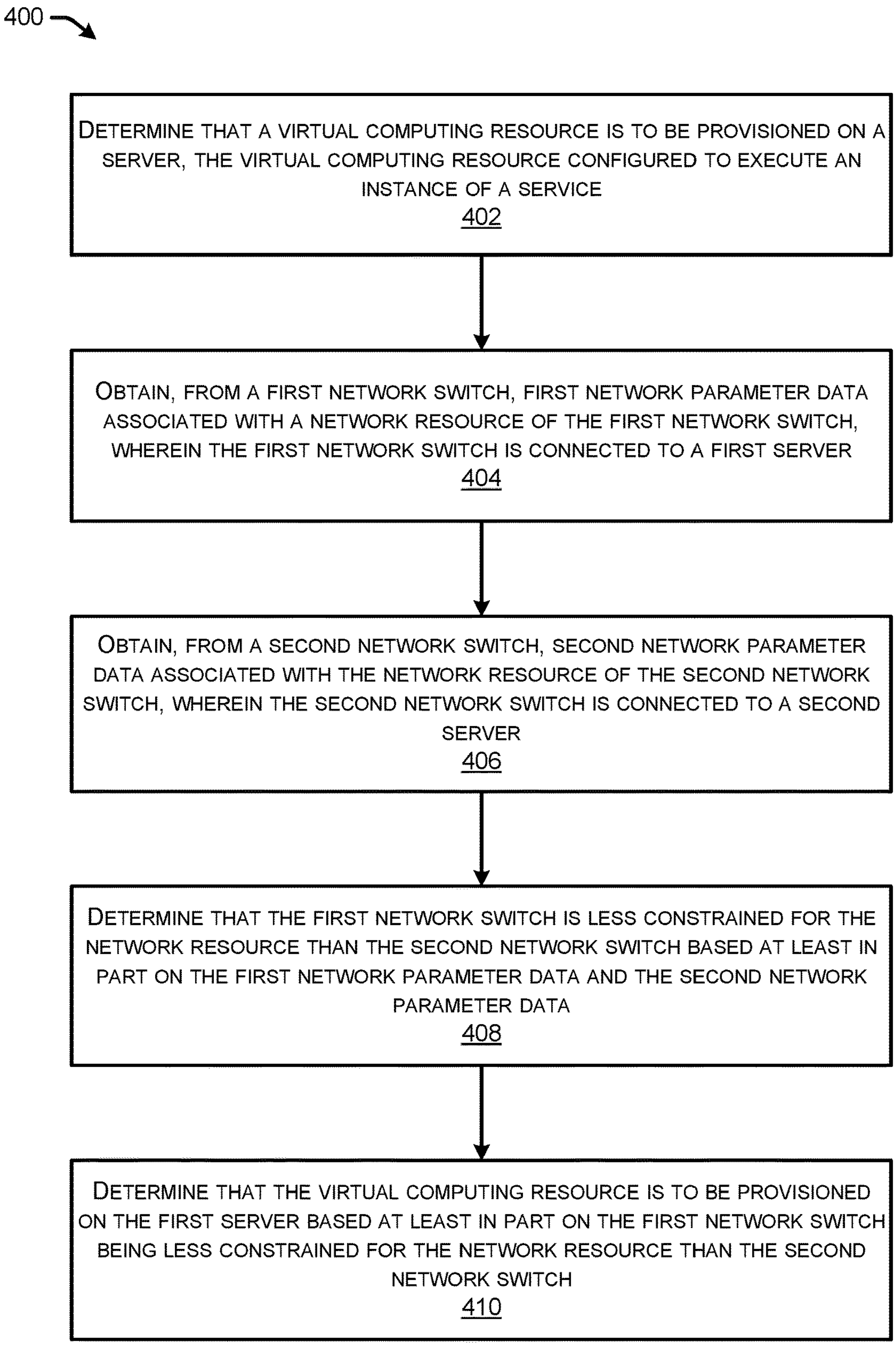

400
DETERMINE THAT A VIRTUAL COMPUTING RESOURCE IS TO BE PROVISIONED ON A SERVER, THE VIRTUAL COMPUTING RESOURCE CONFIGURED TO EXECUTE AN INSTANCE OF A SERVICE
402
OBTAIN, FROM A FIRST NETWORK SWITCH, FIRST NETWORK PARAMETER DATA ASSOCIATED WITH A NETWORK RESOURCE OF THE FIRST NETWORK SWITCH, WHEREIN THE FIRST NETWORK SWITCH IS CONNECTED TO A FIRST SERVER
404
OBTAIN, FROM A SECOND NETWORK SWITCH, SECOND NETWORK PARAMETER DATA ASSOCIATED WITH THE NETWORK RESOURCE OF THE SECOND NETWORK SWITCH, WHEREIN THE SECOND NETWORK SWITCH IS CONNECTED TO A SECOND SERVER
406
DETERMINE THAT THE FIRST NETWORK SWITCH IS LESS CONSTRAINED FOR THE NETWORK RESOURCE THAN THE SECOND NETWORK SWITCH BASED AT LEAST IN PART ON THE FIRST NETWORK PARAMETER DATA AND THE SECOND NETWORK PARAMETER DATA
408
DETERMINE THAT THE VIRTUAL COMPUTING RESOURCE IS TO BE PROVISIONED ON THE FIRST SERVER BASED AT LEAST IN PART ON THE FIRST NETWORK SWITCH BEING LESS CONSTRAINED FOR THE NETWORK RESOURCE THAN THE SECOND NETWORK SWITCH
410

FIG. 4

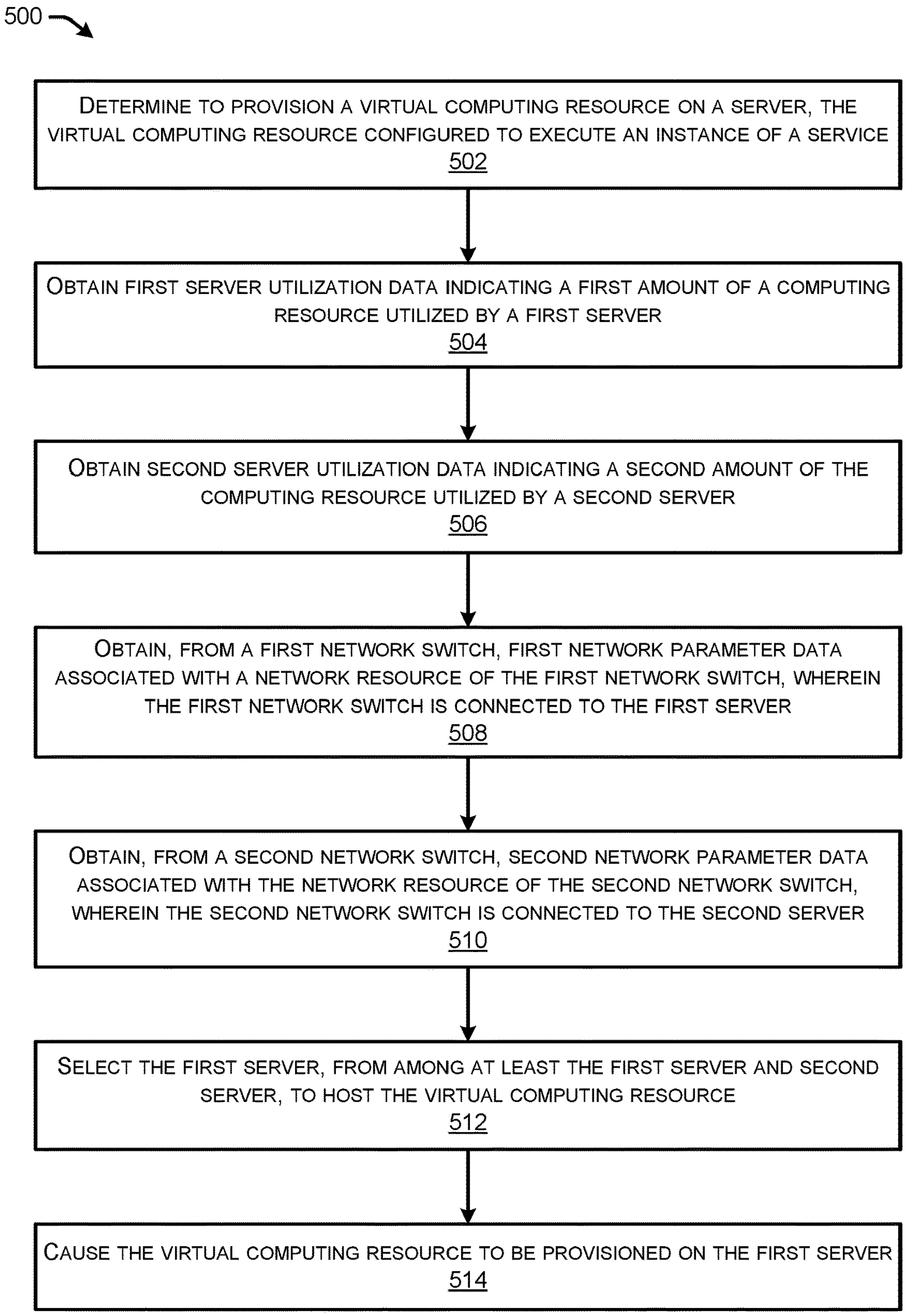
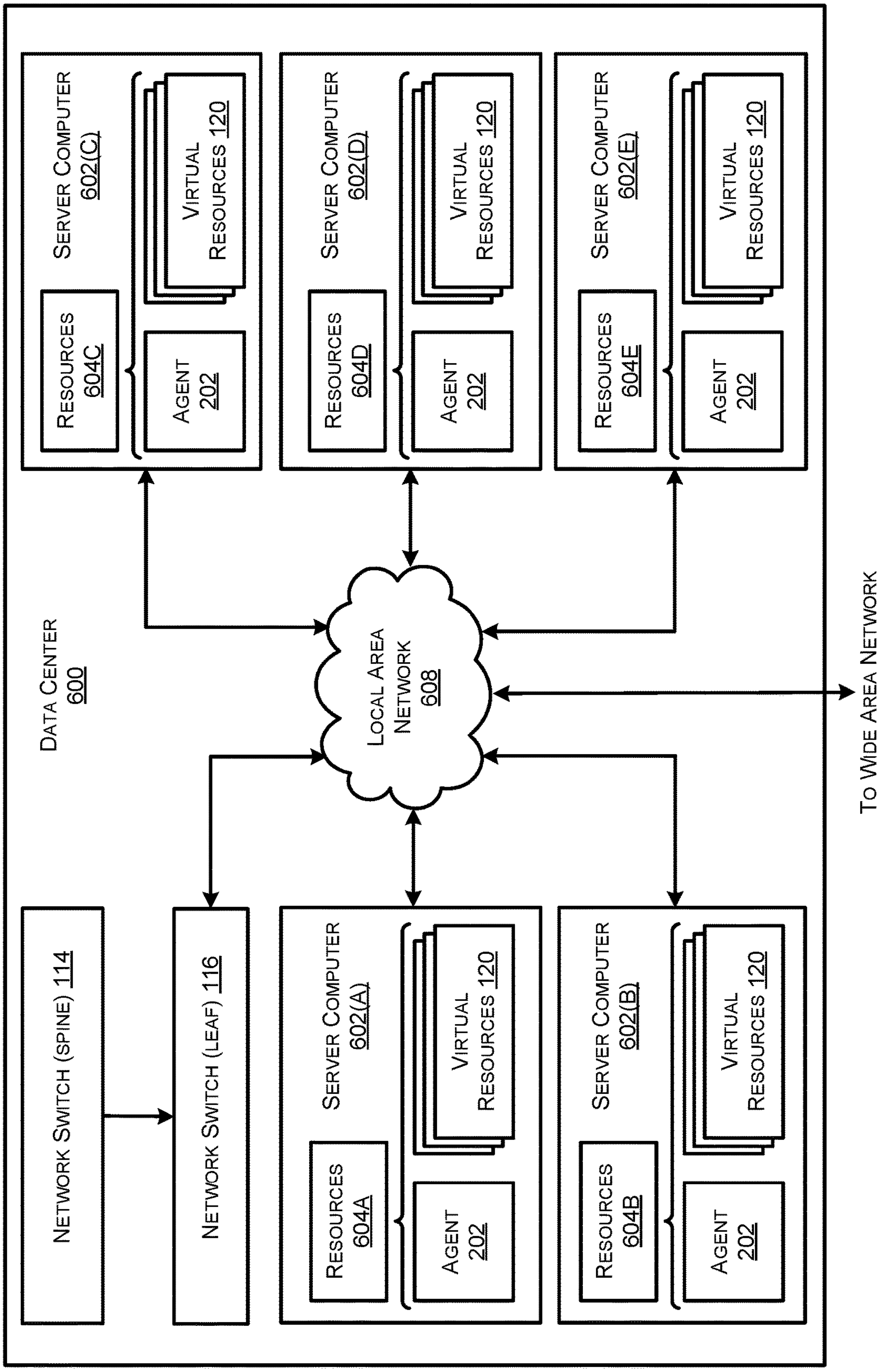

500
DETERMINE TO PROVISION A VIRTUAL COMPUTING RESOURCE ON A SERVER, THE VIRTUAL COMPUTING RESOURCE CONFIGURED TO EXECUTE AN INSTANCE OF A SERVICE
502
OBTAIN FIRST SERVER UTILIZATION DATA INDICATING A FIRST AMOUNT OF A COMPUTING RESOURCE UTILIZED BY A FIRST SERVER
504
OBTAIN SECOND SERVER UTILIZATION DATA INDICATING A SECOND AMOUNT OF THE COMPUTING RESOURCE UTILIZED BY A SECOND SERVER
506
OBTAIN, FROM A FIRST NETWORK SWITCH, FIRST NETWORK PARAMETER DATA ASSOCIATED WITH A NETWORK RESOURCE OF THE FIRST NETWORK SWITCH, WHEREIN THE FIRST NETWORK SWITCH IS CONNECTED TO THE FIRST SERVER
508
OBTAIN, FROM A SECOND NETWORK SWITCH, SECOND NETWORK PARAMETER DATA ASSOCIATED WITH THE NETWORK RESOURCE OF THE SECOND NETWORK SWITCH, WHEREIN THE SECOND NETWORK SWITCH IS CONNECTED TO THE SECOND SERVER
510
SELECT THE FIRST SERVER, FROM AMONG AT LEAST THE FIRST SERVER AND SECOND SERVER, TO HOST THE VIRTUAL COMPUTING RESOURCE
512
CAUSE THE VIRTUAL COMPUTING RESOURCE TO BE PROVISIONED ON THE FIRST SERVER
514

FIG. 5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Network Switch (Spine) 114
Network Switch (Leaf) 116
Server Computer 602(A)
Resources 604A
Agent 202
Virtual Resources 120
Server Computer 602(B)
Resources 604B
Agent 202
Virtual Resources 120
Local Area Network 608
Server Computer 602(C)
Resources 604C
Agent 202
Virtual Resources 120
Server Computer 602(D)
Resources 604D
Agent 202
Virtual Resources 120
Server Computer 602(E)
Resources 604E
Agent 202
Virtual Resources 120
To Wide Area Network

FIG. 6

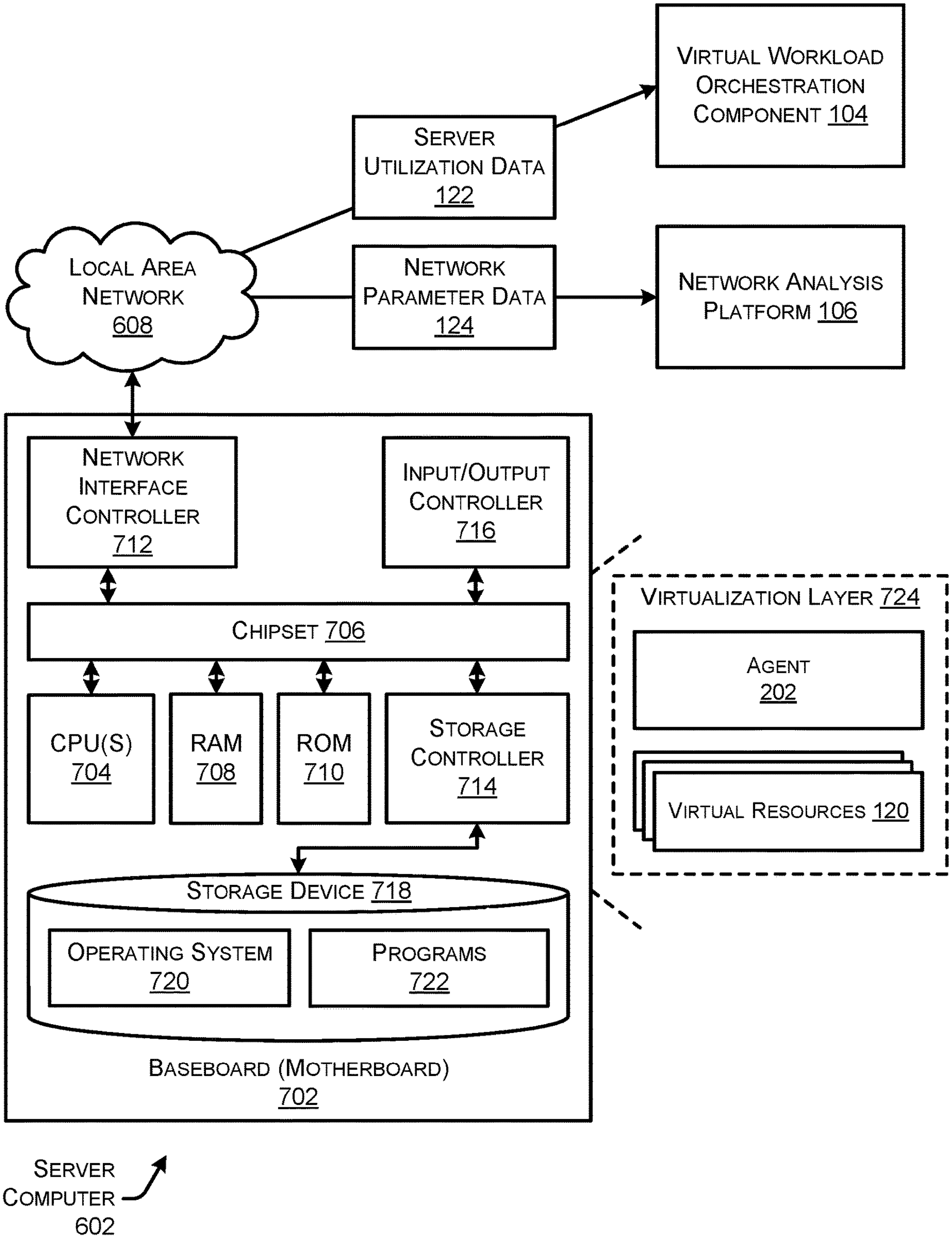
Virtual Workload Orchestration Component 104
Server Utilization Data 122
Local Area Network 608
Network Parameter Data 124
Network Analysis Platform 106
Network Interface Controller 712
Input/Output Controller 716
Chipset 706
Virtualization Layer 724
Agent 202
CPU(S) 704
RAM 708
ROM 710
Storage Controller 714
Virtual Resources 120
Storage Device 718
Operating System 720
Programs 722
Baseboard (Motherboard) 702
Server Computer 602

FIG. 7

UTILIZING NETWORK ANALYTICS FOR SERVICE PROVISIONING

CROSS-REFERENCE TO RELATED APPLICATION

This patent application is a continuation of and claims priority to U.S. patent application Ser. No. 16/565,048, filed Sep. 9, 2019, which is fully incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates generally to orchestrating the provisioning of instances of services across physical servers at locations that improve performance of the services.

BACKGROUND

Cloud computing provides users with access to computing resources to fulfill users' computing resource needs. In some examples, service providers can manage and provide cloud computing resources to users to fulfill their needs without the users having to invest in and maintain their own computing infrastructure. Cloud computing often involves the use of networks of data centers which house servers, routers, and other devices that provide computing resources to users such as compute resources, networking resources, storage resources, database resources, application resources, and so forth. Users may be allocated portions of the computing resources using virtualization technology that remain available for peak demands of the users. The virtualized portions, or virtualized networks, of computing resources may be scaled up (or down) according to the computing needs of a given user without the need to maintain excess computing capacity. For example, an online retailer can scale a virtualized network of computing resources to meet increased demand during the holiday shopping season without having to maintain the underlying physical computing infrastructure used to provide the retailer's online presence.

To support a service (or application) using cloud computing, various types of schedulers are utilized to automate deployment, scaling, and operations of the virtual computing resources (or "virtual resources") across physical servers in a cloud computing network. To effectively orchestrate the virtual resources, the schedulers may track what virtual resources have been placed on what physical servers in order to determine where to spin up or place new virtual resources. Additionally, the physical servers may run one or more software agents (or minions) locally that collect server utilization data for the physical server and provide the utilization data to the schedulers. Such server utilization data may be collected for server parameters such as central processing unit (CPU) usage, memory consumption, offload availability, solid-state drive (SSD) availability, and other server parameters. Schedulers may collect and utilize this server utilization data to determine how to orchestrate the placement of virtual resources.

For example, a scheduler may determine that a virtual resource is scheduled to be spun up, and further determine the resource utilization requirements for that virtual resource. The scheduler may then identify a physical server that has availability of server resources (e.g., CPU availability, memory availability, storage availability, etc.) to adequately support the virtual resource. The virtual resource may then be deployed to the physical server that has availability to support the virtual resource. Thus, while schedulers may provision services intelligently in some respects, the provisioning of services may still suffer from inefficiencies.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is set forth below with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items. The systems depicted in the accompanying figures are not to scale and components within the figures may be depicted not to scale with each other.

FIG. **1** illustrates a system-architecture diagram of an example environment in which a network analysis platform receives network parameter data for network switches and servers, and determines a server on which to deploy a virtual resource using the network parameter data.

FIG. **2** illustrates a component diagram of an example flow for a virtual workload orchestration component and a network analysis platform to deploy a virtual resource on a server based on server utilization data and network parameter data.

FIG. **3** illustrates a component diagram illustrating example components of a cloud computing network.

FIG. **4** illustrates a flow diagram of an example method for components of a cloud computing network to deploy a virtual resource on a server based at least in part on network parameter data.

FIG. **5** illustrates a flow diagram of an example method for components of a cloud computing network to deploy a virtual resource on a server based on server utilization data and network parameter data.

FIG. **6** illustrates a computing system diagram illustrating a configuration for a data center that can be utilized to implement aspects of the technologies disclosed herein.

FIG. **7** is a computer architecture diagram showing an illustrative computer hardware architecture for implementing a server device that can be utilized to implement aspects of the various technologies presented herein.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

This disclosure describes a method of utilizing network analytics for cloud computing networks to provision instances of services across physical servers at locations with availability of network resources to support the network requirements of the services. The method includes determining that a virtual computing resource is to be provisioned on a server in the cloud computing network. Further, the method includes obtaining network parameter data for a first network switch connected to a first server, and a second network switch connected to a second server. The network parameter data may be associated with a network resource of the first network switch and second network switch. Additionally, the method includes determining that the first network switch is less constrained for the network resource than the second network switch. The method further includes determining that the virtual computing resource is to be provisioned on the first server based at least in part on the first network switch being less constrained for the network resource than the second network switch.

Additionally, the techniques described herein may be performed by a system and/or device having non-transitory computer-readable media storing computer-executable instructions that, when executed by one or more processors, performs the method described above.

Example Embodiments

The usefulness of server virtualization, from virtual machines to containers to storage, has resulted in a rapid increase in cloud computing and data centers. Using virtualization technologies, a single physical server can host multiple applications, operating systems, and/or data storage instances using server virtualization (e.g., a software layer called a hypervisor). In this way, multiple applications or processes may execute on a single physical server to drive up overall hardware utilization of that physical server. Various virtualization technologies are utilized by cloud computing systems. Often, cloud computing systems may utilize multiple virtual machines running workloads on individual physical servers. Additionally, or alternatively, cloud computing systems may utilize application clustering (or software clustering) where multiple physical servers are turned into a cluster of physical servers, or a group of servers, that act like a single system. Each of the servers in the physical cluster collectively run or support a same application or service, referred to herein as a clustered application. For example, virtual machines (VMs) and/or containers may run individual instances of a service or application to provide a distributed clustered service or application. A distributed clustered application that runs on a cluster of physical servers provide various advantages, such as increased availability, increased scalability, and failover protections.

Thus, a cloud computing network can support one or more services (also referred to herein as "applications") for one or more users. The services may each be allocated exclusive use of physical servers in the cloud computing network (or "single tenant"), or share use of physical servers with instances of other services (or "multi-tenant"). In any architecture, and using any type of virtual resource, the number of virtual instances of a service provisioned in the cloud computing network may scale to meet increased demand of the service. To orchestrate the provisioning of services, schedulers are utilized to automate deployment, scaling, and operations of the virtual resources of the service deployed across physical servers of the cloud computing network.

As noted above, schedulers collect and analyze server utilization data for server parameters of the various physical servers, such as central processing unit (CPU) usage, memory consumption, offload availability, solid-state drive (SSD) availability, and other server parameters. The schedulers may utilize this server utilization data to determine how to orchestrate the placement of virtual resources. For example, a scheduler may determine that a virtual resource is scheduled to be spun up, and further determine the resource utilization requirements for that virtual resource. The scheduler may then identify a physical server that has availability of server resources (e.g., CPU availability, memory availability, storage availability, etc.) to adequately support the virtual resource. The virtual resource may then be deployed to the physical server that has availability to support the virtual resource. In this way, schedulers may deploy virtual resources on servers that have availability across various hardware-based server parameters (e.g., CPU, memory, storage, etc.).

While schedulers and virtualization techniques efficiently drive up the utilization of underlying resources of servers (e.g., CPU, memory, storage/disk, etc.), the volume of east-west traffic in data centers may increase due to the communication between the increasing number virtual resources on the physical servers. The increased traffic on networks in data centers may result in various inefficiencies in network resource utilization, which may in turn result in undesirable issues that negatively impact network performance, such as packet drops, latency, and so forth. Although various data center architectures are utilized to help compensate for the negative impacts on network performance (e.g., leaf-spine architectures), various issues exist in communication networks due to the communication traffic between virtual resources provisioned in data centers of cloud computing networks.

This disclosure describes techniques for collecting network parameter data for network switches and/or physical servers connected to the network switches, and provisioning virtual resources of a service on physical servers based on the network switches and/or physical servers having an availability of network resources to support the virtual resources. The network parameter data may include indications of availability of network resources of the network switches. Further, the network parameter data may include indications of diagnostic constraints for network resources of the network switches (and any violations thereof), flow data indicating amounts of traffic between the network switches and the physical servers, and so forth. The techniques described herein include determining network switches (and/or connected physical servers) that have an availability of network resources to support the deployment of a virtual resource on a physical server. In some examples, a scheduler may determine to deploy virtual machines to particular physical servers using the network parameter data in lieu of, or in addition to, the use of the server utilization data of the physical servers. In this way, a virtual resource may be deployed to a physical server that has not only the availability of not only the hardware resources to support the virtual resource, but also has the availability (or is connected to a network switch with the availability) of network resources to support the virtual resource.

Generally, physical servers in a cloud computing network may execute software agents (or minions) that collect server utilization data for the individual servers indicating instantaneous, as well as average, usage for hardware resources of the physical servers. For instance, the server utilization data for the physical servers may include instantaneous and/or average values of CPU usage, memory usage, disk usage, and the like. Further, software agents may, in some examples, determine what portions of the overall usage values are attributable to the different virtual resources on the physical servers. The server utilization data may then be relayed back to a scheduler that is configured to analyze the server utilization data and determine which physical servers have hardware resource availability to support a virtual resource that is to be provisioned.

According to the techniques described herein, the cloud computing network may further include or be associated with a network analysis platform that is configured to collect and analyze various network parameter data indicating usage and availability of network resources for devices in the cloud computing network (e.g., servers, switches, routers, etc.). For example, the network analysis platform may communicate with network switches to collect the network parameter data. The network switches may be, in some examples, leaf switches such as top-of-rack (TOR) switches that are connected to a group of physical servers (e.g., 32 servers, 48 servers, etc.). The network switches may be configured to maintain various types of network parameter data that indicates availability of network resources used to support virtual resources deployed on the servers connected to the network switches.

The network switches may provide the network analysis platform with network parameter data indicating network resource data for the network switches. For instance, the network resource data may include indications (e.g., instantaneous values, average values, etc.) of network resources associated with the network switches, such as an availability of ternary content addressable memory (TCAM) on the network switches, entries in access control lists (ACLs) on the network switches, routing table entries in routing tables on the network switches, buffered memory on the network switches, etc. The network analysis platform may receive the network resource data from the network switches and store the network resource data for further analysis, such as in a time-series database.

The network switches may additionally, or alternatively provide the network analysis platform with other network parameter data including network diagnostic data indicating diagnostic constraints for network resources of the network switches (and/or any violations thereof), flow data indicating amounts of traffic between the network switches and the physical servers, and so forth. For instance, the network diagnostic data may indicate various network diagnostic constraints, and indications of violations of those constraints, such as indications of (i) a number of times memory constraint thresholds of the network switches were exceeded, (ii) a number of times interface error thresholds of the network switches were exceeded, (iii) a number of times buffer drop thresholds of the network switches were exceeded, (iv) a number of times quality of service (QoS) thresholds of the network switches were exceeded, etc.

Further, the network parameter data may include the flow data indicating amounts of traffic between the network switches and the physical servers. The flow data may indicate various information regarding how much traffic is flowing between switches and servers, such as maximum amounts of data that can flow on the links between the network switches and the server (e.g., 20 Gbps, 10 Gbps, etc.), instantaneous amounts of data flowing on the links, average amounts of data flowing on the links, peak values and low values for data amounts flowing on the links, and so forth. The network analysis platform may receive and store this flow data locally for further use in determining where to deploy virtual resources.

Thus, the network analysis platform may receive various network parameter data as described above, including one or more of network resource data, network diagnostic data, and/or network flow data. The network analysis platform may utilize the network parameter data to determine on which servers to deploy virtual resources. In some examples, the network analysis platform may rank the physical servers based on the network parameter data collected from their respective network switches and select the physical server with the highest ranking. The highest ranked physical server may generally correspond to the physical server that is associated with a network switch with the best availability across network resources that are utilized to support the virtual resource to be deployed.

In some examples, the network analysis platform may work in conjunction with a scheduler (or be included in a scheduler) to select physical servers on which to deploy virtual resources based on the server utilization data as well as the network parameter data. For example, the scheduler may determine, using the server utilization data, an initial ranked list of physical servers based on their availability to support a virtual resource with respect to availability of hardware resources of the server (e.g., CPU, memory, storage, etc.). The network analysis platform may receive this initial ranked list and re-order the rankings of the physical servers based on the network parameter data. For example, a particular server may be ranked highest on the list by the scheduler due to the availability of server resources, but the associated network switch may have low availability (e.g., near or at max capacity) for network resources to support a virtual resource. Accordingly, the network analysis platform may move the physical server down the ranked list, and may similarly move other physical servers up the ranked list, to generate a final ranked list of physical servers. In this way, the final ranked list of physical servers will indicate the servers that are most optimized, or have the most availability, with respect to server resources as well as network resources. The scheduler may then utilize the final ranked list of servers to select a physical server on which to deploy a virtual resource. In some examples, the scheduler may obtain the final ranked list of servers from the network analysis platform via an API call. For instance, the scheduler may call an API that requests the network analysis platform generate the final ranked list of servers and return the final ranked list. In some instances, the network analysis platform may determine the final ranked list of servers based on receiving the API request from the scheduler, and in other examples, the network analysis platform may continue to maintain the final ranked list of servers and have the final ranked list available to the scheduler via the API (or multiple APIs).

As described herein, a virtual resource can generally include any type of resources implemented by virtualization techniques, such as containers, virtual machines, virtual storage, and so forth. Further, although the techniques described as being implemented in data centers and/or a cloud computing network, the techniques are generally applicable for any network of devices managed by any entity where virtual resources are provisioned. In some instances, the techniques may be performed by a schedulers or orchestrator, and in other examples, various components may be used in a system to perform the techniques described herein. The devices and components by which the techniques are performed herein are a matter of implementation, and the techniques described are not limited to any specific architecture or implementation.

The techniques described herein provide various improvements and efficiencies with respect to provisioning services over networks of devices using virtual resources. For instance, the techniques described herein may reduce the amount of dropped data, latency, and other issues experienced in networks due to lack of network resources. By deploying virtual resources to locations (e.g., servers) that have availability of network resources, or are connected to network switches with availability of network resources, the network communications performed by these servers and virtual resources may be improved.

Certain implementations and embodiments of the disclosure will now be described more fully below with reference to the accompanying figures, in which various aspects are shown. However, the various aspects may be implemented in many different forms and should not be construed as limited to the implementations set forth herein. The disclosure encompasses variations of the embodiments, as described herein. Like numbers refer to like elements throughout.

FIG. **1** illustrates a system-architecture diagram of an example environment **100** including a cloud computing network **102** that includes a virtual workload orchestration component **104** and a network analysis platform **106**.

In some examples, computing resources of a cloud computing network **102** may be utilized by the virtual workload orchestration component **104** to instantiate, support, run, and/or execute virtual resources (e.g., virtual machines, containers, etc.). The cloud computing network **102** may comprise one or more data centers **108** that include various networking devices, such as spine network switches **114(1)**-**114**(N), leaf network switches **116(1)**, and servers **118(1)**-**118**(N) where N is any integer greater than "1." In some examples, the data centers **108** may be located across geographic areas, and the cloud computing network **102** may be a distributed network through which users (often customers) may interact via user devices to manage or otherwise interact with service provided by the cloud computing network **102**.

The cloud computing network **102** may provide on-demand availability of computing system resources, such as data storage, computing power (e.g., CPU, GPU, etc.), networking, databases, etc., without direct active management by users. In some examples, the cloud computing network **102** may be managed and maintained by a service provider such that users do not have to invest in and maintain the computing infrastructure for their computing resource needs. Generally, a user may be provided access to, or allocated use of, a portion of the computing resources in the cloud computing network **102**. The cloud computing network **102** may scale, such as by spinning up resources or spinning down resources, based on demand for the individual users. The portions of the cloud computing network **102** may be allocated using hardware virtualization such that portions of the cloud computing network **102** can be configured and managed by the user (e.g., security configuration, load balancing configuration, etc.). However, the cloud computing network **102** need not be managed by a service provider, and can be managed by any entity, including the user themselves that run the applications or services.

In some examples, a user, admin, customer, or other entity may request that one or more servers **118** in the cloud computing network **102** be grouped into a cluster where each server **118** is a cluster node. Generally, a cluster may refer to a group of servers **118** working together in a system or network to provide users with, among other benefits, higher availability of applications or services. Each node in the physical cluster may run or execute one or more virtual resources **120**(**1**)-**120**(N), such as application containers, virtual machines, etc., that run an application, service, process, or the like. By running virtual resources **120** on different servers **118** or nodes, the cluster of servers **118** can reduce downtime and outages by allowing another server **118** to take over in the event of an outage. For instance, if one of these servers **118** experiences a service outage, the workload on that server **118** may be redistributed to another server **118** before any downtime is experienced by the client. In this way, the physical cluster may support applications and services with a higher level of availability, reliability, and scalability than a single server **118** offers.

Each server **118** (or node) may support one or more virtual resources **120**. The virtual resources may each encapsulate the files, dependencies, libraries, etc., of an application or service to run on an operating system of a server **118**. In some examples, a single physical server **118** may run multiple virtual resources **120** on the same operating system at the same time. In this way, the server **118** may run multiple virtual resources **120** that each run independent instances of the same application. However, in some instances the physical servers **118** may run one or more virtual machines where each virtual machine runs an independent instance of the application, service, or other process. The virtual resources **120** can generally run or support any service, application, clustered environment, and so forth.

The data centers **108** are illustrated as utilizing a leaf-spine architecture where each spine network switch **114** is connected to every leaf network switch **116** in the network fabric. Thus, no matter which leaf network switch **116** a server **118** is connected to, the server **118** crosses the same number of devices every time it connects to another server **118** (unless the other server **118** is on the same leaf **116**). In some examples, the leaf-spine architecture may minimize latency and bottlenecks because each payload only travels one spine network switch **114** and another leaf network switch **116** to reach an endpoint. The spine switches **114** may have high port density and comprise the core of the architecture. The leaf-spine topology may be layer **2** or layer **3** depending on whether the links between the leaf and spine layer will be switched or routed. Although the data centers **108** are illustrated **108** as a leaf-spine architecture, any architecture known in the art may be utilized equally to implement the techniques described herein.

The techniques described herein include collecting various data, such as server utilization data **122** and network parameters data **124**, and determine on which servers **118** to deploy virtual resources **120**. The virtual workload orchestration component **104** may be an orchestration platform for virtual resources **120** that manages the provisioning of services or applications in a computing environment. The virtual workload orchestration component **104** may perform or manage tasks such as virtual resources **120** deployment, scaling, configuration, versioning, rolling updates, etc. The virtual workload orchestration component **104** may include or be a scheduler that manages services by deploying the virtual resources **120** to the servers **118**. Generally, the scheduler attempts to match virtual resources **120** to suitable sets of resources on servers **118** according to server resource availability.

The virtual workload orchestration component **104** may collect various server utilization data **122** from the servers **118** in the data centers **108**. The server utilization data **122** may indicate availability/usage of hardware resources of the servers. For instance, the server utilization data **122** may indicate central processing unit (CPU) usage, memory consumption, offload availability, solid-state drive (SSD) availability, and other server parameters. The server utilization data **122** may indicate this data as one or more of instantaneous values, average values over a collecting period, instantaneous/average percentages of usage versus maximum resources, and/or any other indication of server resource usage.

The virtual workload orchestration component **104** may utilize this server utilization data **122** to determine how to orchestrate the placement of virtual resources **118**. For example, a scheduler may determine that a virtual resource **118** is scheduled to be spun up for a service (or migrated), and further determine the resource utilization requirements for that virtual resource **118**. For instance, the virtual workload orchestration component **104** may store fingerprints that indicate average server utilization for the virtual resources **118** of difference services. The scheduler may then identify a server **118** that has availability of server resources (e.g., CPU availability, memory availability, storage availability, etc.) to adequately support the virtual resource **120**. The virtual resource **120** may then be deployed to the physical server **118** that has availability to support the virtual resource **120**. In this way, schedulers of the virtual workload orchestration component **104** may deploy virtual resources **120** on servers **118** that have availability across various hardware-based server parameters (e.g., CPU, memory, storage, etc.).

As noted above, the virtual workload orchestration component **104** may only contemplate server utilization data **122** in order to efficiently drive up the utilization of underlying resources of the servers **118** (e.g., CPU, memory, storage/disk, etc.). However, this may result in the volume of east-west traffic in data centers **108** increasing due to the communication between the increasing number virtual resources **120** on the servers **118**. The increased traffic on networks in data centers **108** may result in various inefficiencies in network resource utilization, which may in turn result in undesirable issues that negatively impact network performance, such as packet drops, latency, and so forth.

Accordingly, the cloud computing network **102** may further include a network analysis platform **106** configured to collect network parameter data **124** for the network switches **114**/**116** and/or servers **118** connected to the network switches **114**. Generally, the network parameter data **124** may include data indicating availability or usage of any type of network resources needed to support a virtual resource **120**. In some examples, the network switches **116** may provide the network parameter data **124** to the network analysis platform **106**. For example, the network switches **116** may periodically, continuously, upon receiving a request, etc., provide the network analysis platform **106** with the network parameter data **124**. The network parameter data **124** may include network resource data indicating availability of network resources for the switches **116** and/or servers **18**, diagnostic constraint data indicating violations of diagnostic thresholds set for network resources of the switches **116** and/or servers **118**, and/or flow data indicating amounts and spikes of network traffic between the switches **114**/**116** and/or servers **118**.

The network resource data **124** may include indications (e.g., instantaneous values, average values, etc.) of network resources associated with the network switches **114**, such as an availability or usage of ternary content addressable memory (TCAM) on the network switches **114**, entries in access control lists (ACLs) on the network switches **114**, routing table entries in routing tables on the network switches **114**, buffered memory on the network switches **114**, etc. The network analysis platform **106** may receive the network resource data **124** from the network switches **114** and store the network resource data **124** for further analysis, such as in a time-series database.

The network switches **114** may additionally, or alternatively provide the network analysis platform **106** with other network parameter data **124** including network diagnostic data indicating diagnostic constraints for network resources of the network switches **114** (and/or any violations thereof). For instance, the network diagnostic data may indicate various network diagnostic constraints, and indications of violations of those constraints, such as indications of a number of times memory constraint thresholds of the network switches **114** were exceeded, a number of times interface error thresholds of the network switches **114** were exceeded, a number of times buffer drop thresholds of the network switches **114** were exceeded, a number of times QoS thresholds of the network switches **114** were exceeded, etc.

Further, the network parameter data **124** may include the flow data indicating amounts of traffic between the network switches **116** and the servers **118**. The flow data may indicate various information regarding how much traffic is flowing between switches **116** and servers, such as maximum amounts of data that can flow on the links between the network switches **116** and the servers **118** (e.g., 20 Gbps, 10 Gbps, etc.), instantaneous amounts of data flowing on the links, average amounts of data flowing on the links, peak values and low values for data amounts flowing on the links, and so forth. The network analysis platform **106** may receive and store this flow data locally for further use in determining where to deploy virtual resources **120**.

In some examples, the network analysis platform **106** and the virtual workload orchestration component **104** may deploy a virtual resource **120** to a server **118** based on the network parameter data **124** without considering the server utilization data **122**. However, in some examples a virtual resource **120** may be deployed based on both the sever utilization data **122** and the network parameter data **124**. In such examples, the network analysis platform **106** may work in conjunction with the virtual workload orchestration component **104** (e.g., a scheduler) to select servers **118** on which to deploy virtual resources **120** based on the server utilization data **122** as well as the network parameter data **124**. For example, the virtual workload orchestration component **104** may determine, using the server utilization data **122**, an initial ranked listing **126** of servers **118** based on their availability to support a virtual resource **120** with respect to availability of hardware resources of the server **118** (e.g., CPU, memory, storage, etc.). The network analysis platform **106** may receive this initial ranked list **126** and re-order the rankings of the servers **118** based on the network parameter data **124**. For instance, the virtual workload orchestration component **104** may include a provision **112** that allows the network analysis platform **106** to modify the ranked listing **126** determined by the virtual workload orchestration component **104**.

As an example, a particular server **118** may be ranked highest on the listing **126** by the virtual workload orchestration component **104** due to the availability of server resources on that server **118** (e.g., CPU, memory, etc.), but the associated network switch **116** may have low availability (e.g., near or at max capacity) for network resources to support a virtual resource **120**. Accordingly, the network analysis platform **106** may move the server **118** down the ranked list **126**, and may similarly move other servers **118** up the ranked list **126**, to generate a final ranked list **126** of servers **126**. In this way, the final ranked listing **126** of servers **118** will indicate the servers **118** that are most optimized, or have the most availability, with respect to server resources as well as network resources. The virtual workload orchestration component **104** may then utilize the final ranked listing **126** of servers **118** to select a server **118** on which to deploy a virtual resource **120**.

The network analysis platform **106** may include a network analysis algorithm **110** that determines how to rank the servers **118** based on the network parameter data **124**, and/or how to modify the ranked listing **126** based on the network parameter **124**. The network analysis algorithm **110** may analyze the various network parameter data **124** and assign weights or coefficients to the various network parameter data **124**. For instance, the network analysis algorithm **110** may analyze the network resources, diagnostic constraints, and flow data and assign coefficients to each of those categories. For example, the network analysis algorithm **110** may analyze the network constraints and determine a weighting value based on availability of the network resources for a network switch **116** (e.g., 0.9 weighting factor indicates availability and 0.2 indicates low availability). Similarly, the network analysis algorithm **110** may assign a weighting value to the diagnostic constraints of the network switch **116** and assign a weighting value based on how many times a threshold of the diagnostic constraint has been violated (e.g., assign 0.9 based on a low number of interface errors, assign a 0.2 based on a high number of memory usage that exceeds a diagnostic memory threshold, etc.). Further, the network analysis algorithm **110** may assign weighting values based on the amount of flow data and/or spikes in the flow data with respect to the maximum amount of data that can flow through the link. For instance, the network analysis algorithm **110** may assign a weighting value of 0.8 to a server **118** that has a link to a network switch **116** that permits 20 Gbps and is utilizing 4 Gbps. Conversely, the network analysis algorithm **110** may assign a weighting value of 0.2 to a server **118** that has a link to a network switch **116** that permits 20 Gbps and is utilizing 16 Gbps.

The network analysis platform **106** may then compute an overall weighting score for each server **118** based on the weighting scores determined for the network resources, diagnostic constraints, and flow data. The network analysis platform **106** may utilize the overall weighting score to determine the rankings for the servers **118**, and/or to re-rank the ranked listing **126** of servers **118** received from the virtual workload orchestration component **104**. In some examples, the network analysis platform **106** may maintain the re-ranked listing **126** of servers **118** (e.g., periodically, continuously, etc.). In this way, the network analysis platform **106** may have the re-ranked listing **126** of servers readily available for the virtual workload orchestration component **104** by maintaining the re-ranked listing **126**. However, in some examples the network analysis platform **106** may re-rank the listing **126** responsive to receiving a request (e.g., API) depending on the configuration implemented by the cloud computing network **102**.

After determining the ranking of servers **118**, the virtual workload orchestration component **104** may deploy a virtual resource **120** based on the ranked listing **126**. The virtual workload orchestration component **104** may determine the ranked listing **126** based on the network parameter data **124**, or based on the server utilization data **122** in conjunction with the network parameter data **124**. The virtual workload orchestration component **104** may then deploy the virtual resource **120** to the top ranked server **118** in the ranked listing **126**, or one of the top ranked servers **118** in the ranked listing **126**.

Generally, the number of virtual resources **120** may scale based on a number of users **128** interacting with the clustered application. The users **128** may comprise one or more of individual users, groups of users, organizations, businesses, or other entities that interact with the cloud computing network **102** via respective user devices. The user devices may be any type of computing device capable of connecting to the cloud computing network **102** via a suitable data communications network **130** such as, but not limited to, a laptop or desktop computer, a tablet computing device, a server computer, a television, or a mobile telephone. Administrative users employed by the operator of the cloud computing network **102**, such as administrators managing the operation of the cloud computing network **102**, might also connect with, manage, and utilize resources provided by the service provider network **102** in a similar fashion.

The users **128** may provide input data **132** via the network (s) **130** to interact with the service that is supported by the virtual resources **120** running on the servers **118**. For example, the users **128** may submit requests to process data, retrieve data, store data, and so forth such that virtual resources **120** are spun up or spun down to process the requests based on demand.

In some examples, the network analysis platform **106** may be included in the virtual workload orchestration component such that the techniques described herein may be performed by a single system, entity, device, component, etc. However, the techniques are equally applicable using any number of devices, components, services, processes, etc., based on the infrastructure determined to implement the provisioning of services using virtual resources **120** running in data centers **108** and on servers **118**.

FIG. **2** illustrates a component diagram **200** of an example flow for a virtual workload orchestration component **104** and a network analysis platform **106** to deploy a virtual resource **120** on a server **118** based on server utilization data **132** and network parameter data **124**.

In some examples, the servers **118** may each run one or more software agents **202** (or minions) that collect various data described herein. For instance, the agent **202** may monitor and collect usage data included in the server utilization data **122** indicating the hardware resources of the servers **118** being utilized by the virtual resources **120**. The agent **202** may further be configured to provide the server utilization data **122** to the virtual workload orchestration component **104**.

At “1,” the agent **202** may provide the server utilization data **122** to the virtual workload orchestration component **104**. The server utilization data **122** may include indications (e.g., values, percentages, etc.) of CPU usage, memory usage, storage usage, offload availability, etc.

At “2,” the network switch **116** may provide network parameter data **124** to the network analysis platform **106**. The network parameter data **124** may include TCAM usage, ACL usage, routing table usage, buffered memory usage, etc. The steps “1” and “2” may occur contemptuously, continually, and/or at different times.

At “3,” the network analysis platform **106** may store the network parameter data **124** in a time-series database **204** that indicates usage over time for each server **118**. In this way, historical network usage data may be stored in the time-series database **204** to determine how the servers **118** act overtime to support the virtual resources **120**.

At “4,” the virtual workload orchestration component **104** may rank the servers using the server utilization data **122**. For instance, the virtual workload orchestration component **104** may rank the servers **118** based on the server utilization data **122** according to various techniques, such as by weighting one or more the dimensions of server usage based on availability of the server resources.

At “5,” the virtual workload orchestration component **104** may provide an initial ranked listing **206** of the servers **118** to the network analysis platform **106**, such as by the provision **112** (e.g., API call). At “6,” the network analysis platform **106** may re-rank the initial ranked listing of servers **118** based at least in part on the network parameter data **124** according to the techniques described herein. At “7,” the network analysis platform **106** may communicate the re-ranked listing **208** of the servers **118** to the virtual workload orchestration component **104**. At “8,” the virtual workload orchestration component **104** may select a server **118** on which to provision the virtual workload **120** based at least in part on the re-ranked listing **208**. At "9," the virtual workload orchestration component **104** may cause the virtual resource **120** to be deployed to the server **118** selected based at least in part on the re-ranked listing **208**.

FIG. **3** illustrates a component diagram **300** that depicts example components of a cloud computing network **102**. As illustrated, the cloud computing network **102** may include one or more hardware processors **302** (processors) configured to execute one or more stored instructions. The processor(s) **302** may comprise one or more cores. Further, the cloud computing network **102** may include one or more network interfaces **304** configured to provide communications between the cloud computing network **102** and other devices, such as the user device(s), and communications between devices in the cloud computing network **102** (e.g., servers **118**, network switches **114**/**116**, load balancers, routers, etc.). The network interfaces **304** may include devices configured to couple to personal area networks (PANs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the network interfaces **304** may include devices compatible with Ethernet, Wi-Fi™, and so forth.

The cloud computing network **102** may include computer-readable media **306** that stores one or more operating systems **310**. The operating system(s) **310** may generally support basic functions of the devices in the cloud computing network **102**, such as scheduling tasks on the devices, executing applications on the devices, controlling peripheral devices, and so forth. The computer-readable media **306** may further store the virtual workload orchestration component **104** that is configured to, when executed by the processor(s) **302**, perform at least the functions described herein. In addition to the provision **112**, the virtual workload orchestration component **104** may further store a scheduler component **312**, one or more controller components **314**, and one or more APIs **316**.

The controller components **314** may execute routine tasks to ensure the desired state of the virtual resources **120** match the observed state. For instance, the controller components **314** may determine that the correct number of virtual resources **120** are running for their respective cluster or group. The controller components **314** may identify the state of the servers **118** and respond when a server **118** goes down. The APIs **316** may generally serve as a foundation for a declarative configuration scheme for the virtual workload orchestration component **104**.

The computer-readable media **306** may further store the instructions of the network analysis platform **106** configured to, when executed by the processor(s) **302**, perform the techniques described herein. For instance, the network analytics algorithm **110** may execute to perform the techniques for determining which server **118** is most optimized to support a virtual resource **120** based on network parameter data **124** associated with network switches **114** and/or the servers **118** themselves.

The cloud computing network **102** may further include the data centers **108** described above, which include the network switches **114**/**66**, servers **118**, and/or other devices (e.g., load balancers, routers, etc.).

The cloud computing network **102** may include a data store **308** that is stored on a device of the cloud computing network **102**, or across multiple devices of the cloud computing network **102**. The data store may include a file store **318** that includes one or more images **320** that may comprise static files that include executable code to run an isolated process, such as an application container image, virtual machine image, database instance image, storage image, etc. The images **320** may comprise system libraries, system tools, and other platform settings a software program needs to run on a virtualized platform.

The data store **308** may further store the server utilization data **122**, network parameter data **122**, initial ranked listing **206**, re-ranked listing **208**, and the time-series database **204** as described herein.

FIGS. **4** and **5** illustrate flow diagrams of example methods **400** and that illustrate aspects of the functions performed at least partly by the cloud computing network **102** as described in FIGS. **1**-**3**. The logical operations described herein with respect to FIGS. **4** and **5** may be implemented (1) as a sequence of computer-implemented acts or program modules running on a computing system and/or (2) as interconnected machine logic circuits or circuit modules within the computing system.

The implementation of the various components described herein is a matter of choice dependent on the performance and other requirements of the computing system. Accordingly, the logical operations described herein are referred to variously as operations, structural devices, acts, or modules. These operations, structural devices, acts, and modules can be implemented in software, in firmware, in special purpose digital logic, and any combination thereof. It should also be appreciated that more or fewer operations might be performed than shown in the FIGS. **4** and **5** and described herein. These operations can also be performed in parallel, or in a different order than those described herein. Some or all of these operations can also be performed by components other than those specifically identified. Although the techniques described in this disclosure is with reference to specific components, in other examples, the techniques may be implemented by less components, more components, different components, or any configuration of components.

FIG. **4** illustrates a flow diagram of an example method **400** for components of a cloud computing network **102** to deploy a virtual resource **120** on a server **118** based at least in part on network parameter data **124**. In some examples, the method **400** may be performed by a system comprising one or more processors **302** and one or more non-transitory computer-readable media **306** storing computer-executable instructions that, when executed by the one or more processors **302**, cause the one or more processors **302** to perform the method **400**.

At **402**, the cloud computing network **102** may determine that a virtual computing resource **120** is to be provisioned on a server **118** where the virtual computing resource **120** is configured to execute an instance of a service (e.g., application). For instance, a virtual workload orchestration component **104** may receive a request, or determine based on demand, to spin up a virtual computing resource **120** of a server.

At **404**, the cloud computing network **102** may obtain, from a first network switch **116**(**1**), first network parameter data **124** associated with a network resource of the first network switch **116**(**1**). The first network switch **116**(**1**) may be connected to at least a first server **118**(**1**).

At **406**, the cloud computing network **102** may obtain, from a second network switch **116**(**2**), second network parameter data **124** that may be associated with the network resource of the second network switch **116**(**2**). The second network switch may be connected to a second server **118**(**2**).

The first network parameter data **124** and the second network parameter data **124** may comprise at least one of first indications of availability of content addressable memory (CAM) on the first network switch **116**(**1**) and the second network switch **116**(**2**), second indications of availability of entries in access control lists (ACLs) on the first network switch **116**(**1**) and the second network switch **116**(**2**), third indications of availability of routing table entries in routing tables on the first network switch **116**(**1**) and the second network switch **116**(**2**), or fourth indications of availability of buffered memory on the first network switch **116**(**1**) and the second network switch **116**(**2**).

The first network parameter data **124** and the second network parameter data **124** may comprise at least one of first indications of a number of times memory constraint thresholds of the first network switch **116**(**1**) and the second network switch **116**(**2**) were exceeded, second indications of a number of times interface error thresholds of the first network switch **116**(**1**) and the second network switch **116**(**2**) were exceeded, third indications of a number of times buffer drop thresholds of the first network switch **116**(**1**) and the second network switch **116**(**2**) were exceeded, or fourth indications of a number of times quality of service (QoS) thresholds of the first network switch **116**(**1**) and the second network switch **116**(**2**) were exceeded.

At **408**, the cloud computing network **102** may determine that the first network switch **116**(**1**) is less constrained for the network resource than the second network switch **116**(**2**) based at least in part on the first network parameter data **124** and the second network parameter data **124** (e.g., higher availability of TCAM, ACL list entries, routing table entries, less diagnostic constraint thresholds exceeded, less flow rate compared to maximum flow rate, etc.).

At **410**, the cloud computing network **102** may determine that the virtual computing resource **120** is to be provisioned on the first server **118**(**1**) based at least in part on the first network switch **116**(**1**) being less constrained for the network resource than the second network switch **116**(**2**).

In some examples, the method **400** further includes receiving a health status metric associated with the network resource or another network resource of the first network switch **116**(**1**). The health status metric may indicate how health the first network switch **116**(**1**) is with respect to network resources, such as availability of network resources, number of times diagnostic constraint thresholds have been violated, amount of traffic over links compared to maximum allowed traffic over the link, etc. Further, the method **400** may include determine that the health status metric is below a threshold, and based at least in part on the health status metric being below the threshold, move the virtual computing resource **120** from the first server **118**(**1**) to the second server **118**(**2**) or a third server **118**(**3**).

FIG. **5** illustrates a flow diagram of an example method **500** for components of a cloud computing network **102** to deploy a virtual resource **120** on a server **118** based on server utilization data **122** and network parameter data **124**. In some examples, the method **500** may be performed entirely by a scheduler (e.g., virtual workload orchestration component **104**), or by a combination of components, services, platforms, processes, etc. (e.g., network analysis platform **106**, virtual workload orchestration component **104**, etc.).

At **502**, the cloud computing network **102** may determine to provision a virtual computing resource **120** on a server **118**, where the virtual computing resource **120** is configured to execute an instance of a service.

At **504**, the cloud computing network **102** may obtain first server utilization data **124** indicating a first amount of a computing resource utilized by a first server **118**(**1**). At **506**, the cloud computing network **102** may obtain second server utilization data **124** indicating a second amount of the computing resource utilized by a second server **118**(**2**).

At **508**, the cloud computing network **102** may obtain, from a first network switch **116**(**1**), first network parameter data **124** associated with a network resource of the first network switch **116**(**1**) where the first network switch **116**(**1**) is connected to the first server; **118**(**1**).

At **510**, the cloud computing network **102** may obtain, from a second network switch **116**(**2**), second network parameter data **124** associated with the network resource of the second network switch **116**(**2**) where the second network switch **116**(**2**) is connected to the second server **118**(**2**).

At **512**, the cloud computing network **102** may select the first server **118**(**1**), from among at least the first server **118**(**1**) and second server **118**(**2**), to host the virtual computing resource **120** based at least in part on the first server utilization data **122**, the second server utilization data **122**, the first network parameter data **124**, and the second network parameter data **124**. At **514**, the cloud computing network **102** may cause the virtual computing resource to be provisioned on the first server.

FIG. **6** is a computing system diagram illustrating a configuration for a data center **600** that can be utilized to implement aspects of the technologies disclosed herein. The example data center **600** shown in FIG. **6** includes several server computers **602**A-**602**E (which might be referred to herein singularly as "a server computer **602**" or in the plural as "the server computers **602**") for providing computing resources. In some examples, the resources and/or server computers **602** may include, or correspond to, the servers **118** described herein.

The server computers **602** can be standard tower, rack-mount, or blade server computers configured appropriately for providing the computing resources described herein. As mentioned above, the computing resources provided by the cloud computing network **102** can be data processing resources such as VM instances or hardware computing systems, database clusters, computing clusters, storage clusters, data storage resources, database resources, networking resources, and others. Some of the servers **602** can also be configured to execute a resource manager capable of instantiating and/or managing the computing resources. In the case of VM instances, for example, the resource manager can be a hypervisor or another type of program configured to enable the execution of multiple VM instances on a single server computer **602**. Server computers **602** in the data center **600** can also be configured to provide network services and other types of services.

In the example data center **600** shown in FIG. **6**, an appropriate LAN **608** is also utilized to interconnect the server computers **602**A-**602**E. It should be appreciated that the configuration and network topology described herein has been greatly simplified and that many more computing systems, software components, networks, and networking devices can be utilized to interconnect the various computing systems disclosed herein and to provide the functionality described above. Appropriate load balancing devices or other types of network infrastructure components can also be utilized for balancing a load between data centers **600**, between each of the server computers **602**A-**602**E in each data center **600**, and, potentially, between computing resources in each of the server computers **602**. It should be appreciated that the configuration of the data center **600** described with reference to FIG. **6** is merely illustrative and that other implementations can be utilized.

As illustrated in FIG. **6**, the server computers **602** may each execute one or more virtual resources **120** that support a service or application provisioned across a set or cluster of servers **602**. The virtual resources **120** on each server computer **602** may support a single application or service, or multiple applications or services (for one or more users).

In some instances, the cloud computing network **102** may provide computing resources, like application containers, VM instances, and storage, on a permanent or an as-needed basis. Among other types of functionality, the computing resources provided by the cloud computing network **102** may be utilized to implement the various services described above. The computing resources provided by the cloud computing network **102** can include various types of computing resources, such as data processing resources like application containers and VM instances, data storage resources, networking resources, data communication resources, network services, and the like.

Each type of computing resource provided by the cloud computing network **102** can be general-purpose or can be available in a number of specific configurations. For example, data processing resources can be available as physical computers or VM instances in a number of different configurations. The VM instances can be configured to execute applications, including web servers, application servers, media servers, database servers, some or all of the network services described above, and/or other types of programs. Data storage resources can include file storage devices, block storage devices, and the like. The cloud computing network **102** can also be configured to provide other types of computing resources not mentioned specifically herein.

The computing resources provided by the cloud computing network **102** may be enabled in one embodiment by one or more data centers **600** (which might be referred to herein singularly as "a data center **600**" or in the plural as "the data centers **600**"). The data centers **600** are facilities utilized to house and operate computer systems and associated components. The data centers **600** typically include redundant and backup power, communications, cooling, and security systems. The data centers **600** can also be located in geographically disparate locations. One illustrative embodiment for a data center **600** that can be utilized to implement the technologies disclosed herein will be described below with regard to FIG. **6**.

As illustrated, the data center **600** may include one or more spine network switches **114** connected to one or more leaf network switches **116**. The leaf network switch **116** may be connected to the server computers **602** that support the virtual resources **120**.

FIG. **7** shows an example computer architecture for a server computer **602** capable of executing program components for implementing the functionality described above. The computer architecture shown in FIG. **7** illustrates a conventional server computer, workstation, desktop computer, laptop, tablet, network appliance, e-reader, smartphone, or other computing device, and can be utilized to execute any of the software components presented herein. The server computer **602** may, in some examples, correspond to a physical server **118** described herein.

The computer **602** includes a baseboard **702**, or "motherboard," which is a printed circuit board to which a multitude of components or devices can be connected by way of a system bus or other electrical communication paths. In one illustrative configuration, one or more central processing units ("CPUs") **704** operate in conjunction with a chipset **706**. The CPUs **704** can be standard programmable processors that perform arithmetic and logical operations necessary for the operation of the computer **602**.

The CPUs **704** perform operations by transitioning from one discrete, physical state to the next through the manipulation of switching elements that differentiate between and change these states. Switching elements generally include electronic circuits that maintain one of two binary states, such as flip-flops, and electronic circuits that provide an output state based on the logical combination of the states of one or more other switching elements, such as logic gates. These basic switching elements can be combined to create more complex logic circuits, including registers, adders-subtractors, arithmetic logic units, floating-point units, and the like.

The chipset **706** provides an interface between the CPUs **704** and the remainder of the components and devices on the baseboard **702**. The chipset **706** can provide an interface to a RAM **708**, used as the main memory in the computer **602**. The chipset **706** can further provide an interface to a computer-readable storage medium such as a read-only memory ("ROM") **710** or non-volatile RAM ("NVRAM") for storing basic routines that help to startup the computer **602** and to transfer information between the various components and devices. The ROM **710** or NVRAM can also store other software components necessary for the operation of the computer **602** in accordance with the configurations described herein.

The computer **602** can operate in a networked environment using logical connections to remote computing devices and computer systems through a network, such as the network **608**. The chipset **706** can include functionality for providing network connectivity through a NIC **712**, such as a gigabit Ethernet adapter. The NIC **712** is capable of connecting the computer **602** to other computing devices over the network **608** (or **130**). It should be appreciated that multiple NICs **712** can be present in the computer **602**, connecting the computer to other types of networks and remote computer systems.

The computer **602** can be connected to a storage device **718** that provides non-volatile storage for the computer. The storage device **718** can store an operating system **720**, programs **722**, and data, which have been described in greater detail herein. The storage device **718** can be connected to the computer **602** through a storage controller **714** connected to the chipset **706**. The storage device **718** can consist of one or more physical storage units. The storage controller **714** can interface with the physical storage units through a serial attached SCSI ("SAS") interface, a serial advanced technology attachment ("SATA") interface, a fiber channel ("FC") interface, or other type of interface for physically connecting and transferring data between computers and physical storage units.

The computer **602** can store data on the storage device **718** by transforming the physical state of the physical storage units to reflect the information being stored. The specific transformation of physical state can depend on various factors, in different embodiments of this description. Examples of such factors can include, but are not limited to, the technology used to implement the physical storage units, whether the storage device **718** is characterized as primary or secondary storage, and the like.

For example, the computer **602** can store information to the storage device **718** by issuing instructions through the storage controller **714** to alter the magnetic characteristics of a particular location within a magnetic disk drive unit, the reflective or refractive characteristics of a particular location in an optical storage unit, or the electrical characteristics of a particular capacitor, transistor, or other discrete component in a solid-state storage unit. Other transformations of physical media are possible without departing from the scope and spirit of the present description, with the foregoing examples provided only to facilitate this description. The computer **602** can further read information from the storage device **718** by detecting the physical states or characteristics of one or more particular locations within the physical storage units.

In addition to the mass storage device **718** described above, the computer **602** can have access to other computer-readable storage media to store and retrieve information, such as program modules, data structures, or other data. It should be appreciated by those skilled in the art that computer-readable storage media is any available media that provides for the non-transitory storage of data and that can be accessed by the computer **602**. In some examples, the operations performed by the cloud computing network **102**, and or any components included therein, may be supported by one or more devices similar to computer **602**. Stated otherwise, some or all of the operations performed by the cloud computing network **102**, and or any components included therein, may be performed by one or more computer devices **602** operating in a cloud-based arrangement.

By way of example, and not limitation, computer-readable storage media can include volatile and non-volatile, removable and non-removable media implemented in any method or technology. Computer-readable storage media includes, but is not limited to, RAM, ROM, erasable programmable ROM ("EPROM"), electrically-erasable programmable ROM ("EEPROM"), flash memory or other solid-state memory technology, compact disc ROM ("CD-ROM"), digital versatile disk ("DVD"), high definition DVD ("HD-DVD"), BLU-RAY, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store the desired information in a non-transitory fashion.

As mentioned briefly above, the storage device **718** can store an operating system **720** utilized to control the operation of the computer **602**. According to one embodiment, the operating system comprises the LINUX operating system. According to another embodiment, the operating system comprises the WINDOWS® SERVER operating system from MICROSOFT Corporation of Redmond, Washington According to further embodiments, the operating system can comprise the UNIX operating system or one of its variants. It should be appreciated that other operating systems can also be utilized. The storage device **718** can store other system or application programs and data utilized by the computer **602**.

In one embodiment, the storage device **718** or other computer-readable storage media is encoded with computer-executable instructions which, when loaded into the computer **602**, transform the computer from a general-purpose computing system into a special-purpose computer capable of implementing the embodiments described herein. These computer-executable instructions transform the computer **602** by specifying how the CPUs **704** transition between states, as described above. According to one embodiment, the computer **602** has access to computer-readable storage media storing computer-executable instructions which, when executed by the computer **602**, perform the various processes described above with regard to FIGS. **1-6**. The computer **602** can also include computer-readable storage media having instructions stored thereupon for performing any of the other computer-implemented operations described herein.

The computer **602** can also include one or more input/output controllers **716** for receiving and processing input from a number of input devices, such as a keyboard, a mouse, a touchpad, a touch screen, an electronic stylus, or other type of input device. Similarly, an input/output controller **716** can provide output to a display, such as a computer monitor, a flat-panel display, a digital projector, a printer, or other type of output device. It will be appreciated that the computer **602** might not include all of the components shown in FIG. **7**, can include other components that are not explicitly shown in FIG. **7**, or might utilize an architecture completely different than that shown in FIG. **7**.

The server computer **602** may support a virtualization layer **724**, such as one or more virtual resources **120** executing on the server computer **602**. In some examples, the virtualization layer **724** may be supported by a hypervisor that provides one or more virtual machines running on the server computer **602** to perform functions described herein. The virtualization layer **724** may generally support a virtual resource that performs at least portions of the techniques described herein. The agent **202** may collect various data and provide it to components. For instance, the agent **202** may collect server utilization data **122** and provide it to the virtual workload orchestration component **104**, and collect network parameter data **124** and provide it to the network analysis platform **106**.

While the invention is described with respect to the specific examples, it is to be understood that the scope of the invention is not limited to these specific examples. Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

Although the application describes embodiments having specific structural features and/or methodological acts, it is to be understood that the claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are merely illustrative some embodiments that fall within the scope of the claims of the application.

What is claimed is:

1. A method comprising:

receiving a list of servers associated with an orchestration system that are capable of hosting an application workload, the list determined based at least in part on server utilization data associated with the servers;

obtaining first network parameter data collected from a first network switch that is connected to a first server included in the list of servers, the first network parameter data indicating utilization of a first network resource on the first network switch;

determining, based at least in part on the first network parameter data, that the first network switch is less constrained for the first network resource than a second network switch is constrained for a second network resource on the second network switch, the second network switch connected to a second server included in the list of servers, wherein the first network resource and the second network resource are a same network resource type; and

based at least in part on the first network switch being less constrained for the first network resource than the second network switch is for the second network resource, provisioning the application workload on the first server.

2. The method of claim **1**, wherein the first network parameter data indicates utilization of multiple network resource types of the first network switch, the method further comprising:

calculating, based at least in part on the first network parameter data, a first utilization weighting value representing the utilization of the multiple network resource types of the first network switch;

calculating, based at least in part on second network parameter data associated with the second network switch, a second utilization weighting value representing the utilization of the multiple network resource types of the second network switch; and

provisioning the application workload on the first server based at least in part on the first utilization weighting value being greater than the second utilization weighting value.

3. The method of claim **1**, wherein provisioning the application workload on the first server comprises provisioning the application workload on the first server without assessing whether the first server is more or less constrained for a computing resource than other servers included in the list of servers.

4. The method of claim **1**, further comprising obtaining second network parameter data associated with the second network switch, the second network parameter data indicating utilization of the second network resource of the second network switch, wherein determining that the first network switch is less constrained for the first network resource than the second network switch is for the second network resource is further based at least in part on the second network parameter data.

5. The method of claim **1**, wherein the list of servers is a ranked list of servers received from the orchestration system, the servers ranked based on an availability of a computing resource for hosting the application workload.

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

calculating resource utilization weighting values associated with each network switch that is connected to a respective server included in the list of servers;

determining a new ranked list of servers based at least in part on the resource utilization weighting values; and

selecting the first server from the new ranked list of servers for hosting the application workload.

7. The method of claim **1**, wherein the network resource type of the first network resource and the second network resource comprises at least one of:

a ternary content addressable memory (TCAM);

an access control list (ACL);

a routing table;

a buffered memory; or

a flow rate.

8. The method of claim **1**, further comprising determining, based at least in part on the list of servers, respective network switches that are connected to respective servers included in the list of servers, the respective network switches including at least the first network switch and the second network switch, wherein obtaining the first network parameter data associated with the first network switch is based at least in part on determining that the first network switch is connected to the first server.

9. A system comprising:

one or more processors; and

one or more non-transitory computer-readable media storing instructions that, when executed, cause the one or more processors to perform operations comprising:

receiving a list of servers associated with an orchestration system that are capable of hosting an application workload, the list determined based at least in part on server utilization data associated with the servers;

obtaining first network parameter data collected from a first network switch that is connected to a first server included in the list of servers, the first network parameter data indicating utilization of a first network resource on the first network switch;

determining, based at least in part on the first network parameter data, that the first network switch is less constrained for the first network resource than a second network switch is constrained for a second network resource on the second network switch, the second network switch connected to a second server included in the list of servers, wherein the first network resource and the second network resource are a same network resource type; and

based at least in part on the first network switch being less constrained for the first network resource than the second network switch is for the second network resource, provisioning the application workload on the first server.

10. The system of claim **9**, wherein the first network parameter data indicates utilization of multiple network resource types of the first network switch, the operations further comprising:

calculating, based at least in part on the first network parameter data, a first utilization weighting value representing the utilization of the multiple network resource types of the first network switch;

calculating, based at least in part on second network parameter data associated with the second network switch, a second utilization weighting value representing the utilization of the multiple network resource types of the second network switch; and

provisioning the application workload on the first server based at least in part on the first utilization weighting value being greater than the second utilization weighting value.

11. The system of claim **9**, wherein provisioning the application workload on the first server comprises provisioning the application workload on the first server without assessing whether the first server is more or less constrained for a computing resource than other servers included in the list of servers.

12. The system of claim **9**, the operations further comprising obtaining second network parameter data associated with the second network switch, the second network parameter data indicating utilization of the second network resource of the second network switch, wherein determining that the first network switch is less constrained for the first network resource than the second network switch is for the second network resource is further based at least in part on the second network parameter data.

13. The system of claim **9**, wherein the list of servers is a ranked list of servers received from the orchestration system, the servers ranked based on an availability of a computing resource for hosting the application workload, the operations further comprising:

calculating, based at least in part on first network parameter data, resource utilization weighting values associated with each network switch that is connected to a respective server included in the list of servers;

determining a new ranked list of servers based at least in part on the resource utilization weighting values; and selecting the first server from the new ranked list of servers for hosting the application workload.

14. The system of claim **9**, wherein the network resource type of the first network resource and the second network resource comprises at least one of:

a ternary content addressable memory (TCAM);

an access control list (ACL);

a routing table;

a buffered memory; or

a flow rate.

15. The system of claim **9**, the operations further comprising determining, based at least in part on the list of servers, respective network switches that are connected to respective servers included in the list of servers, the respective network switches including at least the first network switch and the second network switch, wherein obtaining the first network parameter data associated with the first network switch is based at least in part on determining that the first network switch is connected to the first server.

16. One or more non-transitory computer-readable media storing instructions that, when executed, cause one or more processors to perform operations comprising:

receiving a list of servers associated with an orchestration system that are capable of hosting an application workload, the list determined based at least in part on server utilization data associated with the servers;

obtaining first network parameter data collected from a first network switch that is connected to a first server included in the list of servers, the first network parameter data indicating utilization of a first network resource on the first network switch;

determining, based at least in part on the first network parameter data, that the first network switch is less constrained for the first network resource than a second network switch is constrained for a second network resource on the second network switch, the second network switch connected to a second server included in the list of servers, wherein the first network resource and the second network resource are a same network resource type; and

based at least in part on the first network switch being less constrained for the first network resource than the second network switch is for the second network resource, provisioning the application workload on the first server.

17. The one or more non-transitory computer-readable media of claim **16**, wherein the first network parameter data indicates utilization of multiple network resource types of the first network switch, the operations further comprising:

calculating, based at least in part on the first network parameter data, a first utilization weighting value representing the utilization of the multiple network resource types of the first network switch;

calculating, based at least in part on second network parameter data associated with the second network switch, a second utilization weighting value representing the utilization of the multiple network resource types of the second network switch; and

provisioning the application workload on the first server based at least in part on the first utilization weighting value being greater than the second utilization weighting value.

18. The one or more non-transitory computer-readable media of claim **16**, wherein provisioning the application workload on the first server comprises provisioning the application workload on the first server without assessing whether the first server is more or less constrained for a computing resource than other servers included in the list of servers.

19. The one or more non-transitory computer-readable media of claim **16**, the operations further comprising obtaining second network parameter data associated with the second network switch, the second network parameter data indicating utilization of the second network resource of the second network switch, wherein determining that the first network switch is less constrained for the first network resource than the second network switch is for the second network resource is further based at least in part on the second network parameter data.

20. The one or more non-transitory computer-readable media of claim **16**, wherein the first network resource comprises at least one of:

a ternary content addressable memory (TCAM) located on the first network switch;

an access control list (ACL) located on the first network switch;

a routing table located on the first network switch;

a buffered memory of the first network switch; or

a flow rate across the first network switch.

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