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DYNAMIC ASSIGNMENT OF NETWORK RESOURCES TO SLICES IN PODS

Abstract

An apparatus comprises a memory and a processor communicatively coupled to one another. The memory may comprise information on one or more network resources. The processor may be configured to determine that the one or more network resources are available for allocation to first resource pools and second resource pools in response to determining that the one or more network resources are unassigned, assign first network resources to the first resource pools, and assign second network resources to the second resource pools. Further, the processor may be configured to generate a first pod in the one or more containerized clusters comprising the first resource pools, generate a second pod comprising the second resource pools, assign a first slice group ID of one or more slice group IDs to the first pod and assign a second slice group ID of the one or more slice group IDs to the second pod.

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Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates generally to assigning network resources in a communication system, and more specifically to a system and method to dynamically assign network resources to slices in pods associated with a platform and infrastructure layer.

BACKGROUND

[0002] In some wireless communications systems, pods are deployed in a containerized environment. The pods are small deployable units of computing that are created and managed in the containerized environment. The pods may comprise one or more containers with shared storage and network resources. The shared storage and network resources may be co-located and co-scheduled. The network resources may be power resources, memory resources, and processing resources that are consumed in attempts to access services in a given wireless communication system. The network resources are wasted when the pods comprise more network resources than needed to access specific services in the given wireless communication system.

SUMMARY OF THE DISCLOSURE

Dynamic Assignment of Cells to Pods

[0003] In one or more embodiments, systems and methods disclosed herein dynamically assign cells to pod. In particular, the systems and methods may be configured to dynamically redistribute and/or reassign cells to pods. The systems and methods are configured to distribute, redistribute, assign, and/or reassign network resources corresponding to multiple cells into multiple pods. In some embodiments, the systems and methods analyze network resources available for different cells associated with a wireless communication system and assign these network resources to individual pods of equal or different size. The pods may be configured to be deployed in a containerized environment (e.g., Kubernetes environment). The pods may comprise network resources that are co-located and co-scheduled. The pods may be configured as redundancies of one another or as standalone portions of a wireless communication network. Herein, the systems and methods may be configured to dynamically assign the network resources during maintenance windows. Further, the systems and methods may be configured to dynamically assign the network resources outside of maintenance windows.

[0004] In one or more embodiments, the systems and methods described herein are integrated into a practical application of dynamically allocating cells to pods. In particular, the systems and methods may be configured to relocate and/or reassign network resources to specific pods during a maintenance window. The systems and methods may be configured to assign network resources of cells to pods of a same size. In this regard, a first number of cells in the first pod may be equal or different from a second number of cells in the second pod. In the systems and methods, while the first number of cells and the second number of cells may not be equal to one another, a first number of network resources comprising the first number of cells may be equal to a second number of network resources comprising the second number of cells. The network resources in the first pod and the network resources in the second pod may be shuffled between pods during maintenance window to utilize the network resources effectively and in symmetric manner. In other embodiments, the systems and methods are integrated into a practical application of relocating and/or reassigning network resources to specific pods outside the maintenance window. In this regard, the systems and methods may be configured to dynamically update the pods in by redistributing cells while the wireless communication system is online

[0005] In addition, the system and method described herein are integrated into a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods prevent or eliminate waste of network resources. In particular, the systems and methods reduce memory usage and increase processing speed by dynamically assigning the cells to be used by the pods configured to enable access to specific services in the wireless communication system. Further, the systems and methods described herein provide a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods comprise a machine learning algorithm that actively generates insights based on usage of the cells in the pods. In some embodiments, the machine learning algorithm may provide the dynamic access commands based on some or all the insights obtained from the usage of the cells. As the machine learning algorithm is trained to account for many of the situations and conditions changing in the usage of the cells, multiple dynamic access commands are generated to relieve stress conditions in future processing operations (e.g., reduce and/or alleviate traffic) in the wireless communication system. In other embodiments, the systems and methods may be configured to generate real-time instructions to reassign and/or reallocate cells within existing and/or new pods. In this regard, resources may be saved in the user equipment by identifying new relevant operations to perform. The device resources may be power resources, memory resources, and processing resources that the user equipment saves by proactively and automatically determining a new immediate reassignments and/or reallocations to perform.

[0006] In one or more embodiments, the systems and methods may be performed by an apparatus, such as a server, communicatively coupled to multiple network components in a core network, one or more base stations in a radio access network, and one or more user equipment. Further, the systems may comprise a wireless communication system, which comprises the apparatus. In addition, the systems and methods may be performed as part of a process performed by the apparatus communicatively coupled to the network components in the core network. As a non-limiting example, the apparatus may comprise a memory and a processor communicatively coupled to one another. The memory may comprise information on one or more network resources configured for allocation in one or more containerized clusters and one or more cell identifiers (IDs). Each cell ID may correspond to at least one cell configured to be associated with at least one pod in the one or more containerized clusters. The processor may be configured to determine whether the one or more network resources are unassigned, determine that the one or more network resources are available for allocation to the one or more cell IDs in response to determining that the one or more network resources are unassigned, divide the one or more network resources into first network resources and second network resources, assign the first network resources to first cell IDs, and assign the second network resources to second cell IDs. Further, the processor is configured to generate a first pod in the one or more containerized clusters comprising the first cell IDs and generate a second pod in the one or more containerized clusters comprising the second cell IDs.

Dynamic Assignment of Network Resources to Resource Pools in Pods

[0007] In one or more embodiments, systems and methods disclosed herein dynamically assign network resources to resource pools in pods. In particular, the systems and methods may be configured to dynamically assign network resources to resource pools in pods associated with a cloud radio access network (CRAN). The systems and methods are configured to dynamically redistribute and/or reassign network resources to resource pools. In some embodiments, the systems and methods leverage cell redistribution into generating resource pools for physical layer applications in the CRAN. The pods may be configured to be deployed in a containerized environment (e.g., Kubernetes environment). The pods may comprise network resources that are co-located and co-scheduled. The pods may be configured as redundancies of one another or as standalone portions of a wireless communication network. Herein, the pods may be created and/or resized to enable Layer 1 (L1) operations and Layer 2 (L2) operations. The systems and methods may be configured to maintain a pool of floating resources for each layer. In this regard, the systems and methods may be configured to create and maintain an L1 resource pool, an L2 resource pool, and a floating resource pool to enable L1 operations and L2 operations. During off-peak hours, the systems and methods may be configured to monitor utilization of the L1 resource pool, the L2 resource pool, and the floating resource pool and determining whether to resize the resource pools to optimize usage of the network resources.

[0008] In one or more embodiments, the systems and methods are incorporated into the practical applications of (1) resizing of the pods and (2) improving CRAN multi-pool uses. In particular, the systems and methods may be configured to relocate and/or reassign network resources to the resource pools during a maintenance window or outside a maintenance window. The systems and methods may be configured to assign network resources to resource pools in pods of a same size or different sizes. The pods may comprise different sizes configured to support enterprise use cases at each resource pool. In some embodiments, the systems and methods are integrated in the practical application of reserving computing capacity in the pods managing a set of cells and keep some computing capacity in a resource pool in a floating mode. The resource pools may be scaled vertically and/or horizontally to support higher capacity during enterprise operations, mission critical operations in an organization, strict SLA use cases, and the like. In other embodiments, the systems and methods may be incorporated in multi-tenancy operations supported on a same wireless communication system running analytics/multi-access edge computing (MEC) applications during off peak hours on the wireless communication network. In yet more embodiments, the systems and methods may be configured to perform energy savings at CRAN sites. Herein, the systems and methods incorporate the practical application of managing L1 operations and L2 operations by different sets of cells located in different pods. Further, The systems and methods are incorporated in the practical application of performing downlink (DL) operations and uplink (UL) operations (e.g., processing). The DL operations and the UL operations may be assigned to individual dedicated cores and/or across multiple cores. For CRAN configuration, the systems and methods may be configured to create separate resource pools to perform L1 operations and L2 operations for individual sets of cells spanning across bigger sets of cells/cell sites. During off peak hours, the systems and methods are configured to monitor utilization of the L1 resource pools and the L2 resource pools. The systems and methods may be configured to shrink and/or expand footprints to optimize network resource consumption. The systems and methods may be configured to scale the L1 resource pools and L2 resource pools vertically and/or horizontally to improve utilization during peak times. Further, the systems and methods may be configured to implement handover operations to move user equipment connectivity to other cells, as long as quality of service is not compromised, to reduce the footprint of computing required.

[0009] In addition, the system and method described herein are integrated into a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods prevent or eliminate waste of network resources. In particular, the systems and methods reduce memory usage and increase processing speed by dynamically assigning the network resources in resource pools configured to enable access to specific services in the wireless communication system. Further, the systems and methods described herein provide a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods comprise a machine learning algorithm that actively generates insights based on usage of the network resources in the pods. In some embodiments, the machine learning algorithm may provide the dynamic access commands based on some or all the insights obtained from the usage of the network resources in the resource pools. As the machine learning algorithm is trained to account for many of the situations and conditions changing in the usage of the network resources in the resource pools, multiple dynamic access commands are generated to relieve stress conditions in future processing operations (e.g., reduce and/or alleviate traffic) in the wireless communication system. In other embodiments, the systems and methods may be configured to generate real-time instructions to reassign and/or reallocate network resources within existing and/or new resource pools in existing and/or new pods. In this regard, resources may be saved in the user equipment by identifying new relevant operations to perform. The device resources may be power resources, memory resources, and processing resources that the user equipment saves by proactively and automatically determining a new immediate reassignments and/or reallocations to perform.

[0010] In one or more embodiments, the systems and methods may be performed by an apparatus, such as a server, communicatively coupled to multiple network components in a core network, one or more base stations in a radio access network, and one or more user equipment. Further, the systems may comprise a wireless communication system, which comprises the apparatus. In addition, the systems and methods may be performed as part of a process performed by the apparatus communicatively coupled to the network components in the core network. As a non-limiting example, the apparatus may comprise a memory and a processor communicatively coupled to one another. The memory may comprise information on one or more network resources configured for allocation in one or more containerized clusters. The processor may be configured to determine whether the one or more network resources are unassigned, determine that the one or more network resources are available for allocation to a first resource pool and a second resource pool in response to determining that the one or more network resources are unassigned, determine first network resources of the one or more network resources configured to enable first layer operations, and determine second network resources of the one or more network resources configured to enable second layer operations. Further, the processor may be configured to assign the first network resources to the first resource pool, assign the second network resources to the second resource pool, generate a first pod in the one or more containerized clusters comprising the first resource pool, and generate a second pod in the one or more containerized clusters comprising the second resource pool.

Dynamic Assignment of Network Resources to Slices in Pods

[0011] In one or more embodiments, systems and methods disclosed herein dynamically assign network resources to slices in pods. In particular, the systems and methods may be configured to dynamically assign network resources to slices in pods associated with a platform and infrastructure layer. The systems and methods are configured to dynamically redistribute and/or reassign network resources to network slices. In some embodiments, the systems and methods dynamically allocate network resources into network slices in accordance with one or more configuration parameters that may include: Service Level Agreement (SLA) considerations, general organization rules and policies, or emergency procedures. The slices may be configured as quick access to the network resources in individual pods. The network resources may be accessed without interfering with a rest of operations in a wireless communication network. Herein, the network resources may be accessed to experience higher priority and Quality of Service (QoS).

[0012] In one or more embodiments, the systems and methods are incorporated into the practical applications of (1) resizing of the pods and (2) improving slicing operations. In particular, the systems and methods may be configured to relocate and/or reassign network resources to the slices during a maintenance window or outside a maintenance window. The systems and methods may be configured to assign network resources to slices in pods of a same size or different sizes. The pods may comprise different sizes configured to support enterprise use cases at each slice. In some embodiments, the systems and methods are integrated in the practical application of reserving computing capacity in the pods managing a set of cells and keep some computing capacity in a slice in a floating mode. The slices may be scaled vertically and/or horizontally to support higher capacity during enterprise operations, mission critical operations in an organization, strict SLA use cases, and the like. In other embodiments, the systems and methods may be configured to perform multi-tenancy operations supported on a same wireless communication system running analytics/MEC applications during off peak hours on the wireless communication network. In yet other embodiments, the systems and methods are configured to enable access of network resources in slices at a platform and infrastructure layer. Herein, the network resources may be allocated to

slice infrastructure and platform resources for high priority services to provide better QoS.
[0013] In addition, the system and method described herein are integrated into a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods prevent or eliminate waste of network resources. In particular, the systems and methods reduce memory usage and increase processing speed by dynamically assigning the network resources in slices configured to enable access to specific services in the wireless communication system. Further, the systems and methods described herein provide a technical advantage of increasing processing speeds in a computer system, because processors associated with the systems and methods comprise a machine learning algorithm that actively generates insights based on usage of the network resources in the pods. In some embodiments, the machine learning algorithm may provide the dynamic access commands based on some or all the insights obtained from the usage of the network resources in the slices. As the machine learning algorithm is trained to account for many of the situations and conditions changing in the usage of the network resources in the slices, multiple dynamic access commands are generated to relieve stress conditions in future processing operations (e.g., reduce and/or alleviate traffic) in the wireless communication system. In other embodiments, the systems and methods may be configured to generate real-time instructions to reassign and/or reallocate network resources within existing and/or new slices in existing and/or new pods. In this regard, resources may be saved in the user equipment by identifying new relevant operations to perform. The device resources may be power resources, memory resources, and processing resources that the user equipment saves by proactively and automatically determining a new immediate reassignments and/or reallocations to perform.
[0014] In one or more embodiments, the systems and methods may be performed by an apparatus, such as a server, communicatively coupled to multiple network components in a core network, one or more base stations in a radio access network, and one or more user equipment. Further, the systems may comprise a wireless communication system, which comprises the apparatus. In addition, the systems and methods may be performed as part of a process performed by the apparatus communicatively coupled to the network components in the core network. As a non-limiting example, the apparatus may comprise a memory and a processor communicatively coupled to one another. The memory may comprise information on one or more network resources available for allocation in one or more containerized clusters and one or more slice group identifiers (IDs). Each slice group ID may correspond to at least one slice group configured to be associated with at least one pod in the one or more containerized clusters. The processor may be configured to determine whether the one or more network resources are unassigned, determine that the one or more network resources are available for allocation to first resource pools and second resource pools in response to determining that the one or more network resources are unassigned, assign first network resources to the first resource pools, and assign second network resources to the second resource pools. Further, the processor may be configured to generate a first pod in the one or more containerized clusters comprising the first resource pools, generate a second pod in the one or more containerized clusters comprising the second resource pools, assign a first slice group ID of the one or more slice group IDs to the first pod and assign a second slice group ID of the one or more slice group IDs to the second pod. The first slice group ID may be configured to access at least one slice of the first resource pools in the first pod. The second slice group ID may be configured to access at least one slice of the second resource pools in the second pod.
[0015] Certain embodiments of this disclosure may comprise some, all, or none of these advantages. These advantages and other features will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] For a more complete understanding of this disclosure, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

[0017] FIG. **1** illustrates an example communication system, in accordance with one or more embodiments;

[0018] FIGS. **2**A and **2**B illustrate examples of containerized clusters implemented in the communication system of FIG. **1**, in accordance with one or more embodiments;

[0019] FIG. **3** illustrates an example flowchart of a method to dynamically assign cells to pod, in accordance with one or more embodiments;

[0020] FIGS. **4**A and **4**B illustrate examples of containerized clusters implemented in the communication system of FIG. **1**, in accordance with one or more embodiments;

[0021] FIG. **5** illustrates an example flowchart of a method to dynamically assign network resources to resource pools in pods, in accordance with one or more embodiments;

[0022] FIG. **6** illustrate an example of a containerized cluster implemented in the communication system of FIG. **1**, in accordance with one or more embodiments; and

[0023] FIG. **7** illustrates an example flowchart of a method to dynamically assign network resources to slices in pods, in accordance with one or more embodiments.

DETAILED DESCRIPTION

[0024] In one or more embodiments, systems and methods described herein are configured to dynamically assign network resources in pods. In one or more embodiments, FIG. **1** illustrates a communication system **100** in which a server **102** generates one or more assignments **104** to access one or more services **106** in the communication system **100**. FIGS. **2**A and **2**B illustrate a containerized cluster **200***a* and a containerized cluster **200***b*, respectively. The containerized cluster **200***a* and the containerized cluster **200***b* are implemented by the communication system **100** of FIG. **1**. FIG. **3** illustrates a process **300** to dynamically generate assignments **104** to access the one or more services **106** as performed by the communication system **100** of FIG. **1**. FIGS. **4**A and **4**B illustrate a containerized cluster **400***a* and a containerized cluster **400***b*, respectively. The containerized cluster **400***a* and the containerized cluster **400***b* are implemented by the communication system **100** of FIG. **1**. FIG. **5** illustrates a process **500** to dynamically generate assignments **104** to access the one or more services **106** as performed by the communication system **100** of FIG. **1**. FIG. **6** illustrates a containerized cluster **600** implemented by the communication system **100** of FIG. **1**. FIG. **7** illustrates a process **700** to dynamically generate assignments **104** to access the one or more services **106** as performed by the communication system **100** of FIG. **1**.

[0025] Herein, the multiple references to containerized clusters are non-limiting examples of containerized service clusters configured as container orchestration platforms for scheduling and automating deployment, management, and scaling of containerized services (e.g., applications).

Communication System Overview

[0026] FIG. **1** illustrates a diagram of a communication system **100** (e.g., a wireless communication system) comprises a server **102** configured to dynamically create one or more assignments **104** to access the one or more services **106**, in accordance with one or more embodiments. The assignments **104** may be outputs configured to provide assignments of network resources **107** to one or more pods **108**. The network resources **107** may be power resources, memory resources, and/or processing resources that are consumed in the communication system **100** to communicate in one or more data networks **110**. In FIG. **1**, the server **102** is communicatively coupled to multiple devices in the communication system **100**. While FIG. **1** shows the server **102** connected directly to the one or more data networks **110**, the server **102** may be located inside a core network **112** as part of one or more network components **114***a*-**114***f* (collectively, network components **114**) in the core network **112**.

[0027] In one or more embodiments, the communication system **100** comprises the user equipment **116***a*-**116***g* (collectively, user equipment **116**), a radio access network (RAN) **118**, the core network **112**, the one or more data networks **110**, and the server **102**. In some embodiments, the communication system **100** may comprise a Fifth Generation (5G) mobile network or wireless communication system, utilizing high frequency bands (e.g., 24 Gigahertz (GHz), 39 GHz, and the like) or lower frequency bands such (e.g., frequency range FR1 Sub 6 GHz-less than 7.125 GHz). In this regard, the communication system **100** may comprise a large number of antennas. In some embodiments, the communication system may perform one or more communication operations associated with 5G New Radio (NR) protocols described in reference to the Third Generation Partnership Project (3GPP). As part of the 5G NR protocols, the communication system **100** may perform one or more millimeter (mm) wave technology operations to improve bandwidth or latency in wireless communications.

[0028] In some embodiments, the communication system **100** may be configured to partially or completely enable communications via one or more various radio access technologies (RATs), wireless communication technologies, or telecommunication standards, such as Global System for Mobiles (GSM) (e.g., Second Generation (2G) mobile networks), Universal Mobile Telecommunications System (UMTS) (e.g., Third Generation (3G) mobile networks), Long Term Evolution (LTE) of mobile networks, LTE-Advanced (LTE-A) mobile networks, 5G NR mobile networks, or Sixth Generation (6G) mobile networks.

Service-Based Architecture

[0029] The communication system **100** may comprise a service-based architecture (SBA). The SBA may be an organization scheme in the core network **112** that comprises authentication, security, session management, and aggregation of traffic from end devices (e.g., the user equipment **116**). In the SBA, the core network **112** may be representative of the 5G Core network and comprises multiple network components **114**. In the SBA, the network components **114** are hardware (e.g., electronic circuitry with communication ports, a processor, and a memory) configured to perform one or more specific network functions (NFs) **119**. Herein, the network components **114***a*-**114***f* may be configured to perform one or more NFs **119**. The NFs **119** maybe referenced using an NF-associated name. For example, a network component **114***a* configured to perform a network repository function (NRF) **119***a* may be referred to as an NRF (or a NRF network component). In another example, one of the network components **119***a*-**119***f* may comprise a version of the server **102** with a server processor **120** configured to perform one or more specific NFs **119**.

[0030] In some embodiments, individual network components **114** provide services or resources to other network components **114** performing different NFs **119**. In other embodiments, each NF is a service provider that allocates one or more resources in communications inside or outside the network components **114** to provide one or more services **106**. The services may be specific for each of the network components **114** and their respective NFs **119** instead of each of the network components **114** providing and consuming processing resources and memory resources to perform multiple NFs **119** in the core network **112**. In 5G NR mobile networks, the SBA is defined by 3GPP to comprise one or more network components **114** configured to perform specific NFs **119** to provide control plane operations and user plane operations. In the 5G NR, the control plane comprises any part of the communication system **100** that controls operations and routing associated with data packets and forwarding operations. Further, in the 5G NR, the user plane comprises any part of the communication system **100** that carries user traffic operations.

[0031] In one or more embodiments, the SBA may be configured to provide slices in accordance with specific application scenarios. A slice may be portions of a collection of NFs **119** that are combined into providing specific application resources. The application resources may be provided to one or more user equipment **116** simultaneously via web-based Application Programming

Interfaces (APIs). The APIs may enable flexible and agile deployment of innovative services. An API may be a set of instructions that, when executed by a processor, perform modular or cloud-native functions and procedures allowing creation of applications (e.g., the services **106**) that access features or data of an operating system, application, or other service in the communication system **100**.

Communication System Components

Server

[0032] The server **102** is generally any apparatus or device that is configured to process data, communicate with the data networks **110**, one or more network components **114** in the core network **112**, the RAN **118**, and the user equipment **116**. The server **102** may be configured to monitor, track data, control routing of signal, and control operations of certain electronic components in the communication system **100**, associated databases, associated systems, and the like, via one or more interfaces. The server **102** is generally configured to oversee operations of the server processing engine **122**. The operations of the server processing engine **122** are described further below. In some embodiments, the server **102** comprises the server processor **120**, one or more server Input (I)/Output (O) interfaces **124** configured to communicate one or more distributed unit (DU) assignments **126***a* and one or more radio unit (RU) assignments **126***b*, and a server memory **128** communicatively coupled to one another. The server **102** may be configured as shown, or in any other configuration. As described above, the server **102** may be located in one of the network components **114** located in the core network **112** and may be configured to perform one or more NFs **119** associated with communication operations of the core network **112**.

[0033] In one or more embodiments, the server processor **120**, the server I/O interfaces **124**, and the server memory **128** may be located at a same location or distributed over multiple remote locations separate from one another.

[0034] The server processor **120** may comprise one or more processors operably coupled to and in signal communication with the server I/O interfaces **124**, and the server memory **128**. The server processor **120** is any electronic circuitry, including, but not limited to, state machines, one or more central processing unit (CPU) chips, logic units, cores (e.g., a multi-core processor), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), or digital signal processors (DSPs). The server processor **120** may be a programmable logic device, a microcontroller, a microprocessor, or any suitable combination of the preceding. The one or more processors in the server processor **120** are configured to process data and may be implemented in hardware or software executed by hardware. For example, the server processor **120** may be an 8-bit, a 16-bit, a 32-bit, a 64-bit, or any other suitable architecture. The server processor **120** may comprise an arithmetic logic unit (ALU) to perform arithmetic and logic operations, processor registers that supply operands to the ALU, and store the results of ALU operations, and a control unit that fetches software instructions such as server instructions **130** from the server memory **128** and executes the server instructions **130** by directing the coordinated operations of the ALU, registers and other components via the server processing engine **122**. The server processor **120** may be configured to execute various instructions **130**. For example, the server processor **120** may be configured to execute the server instructions **130** to perform functions or perform operations disclosed herein, such as some or all of those described with respect to FIGS. **1-7**. In some embodiments, the functions described herein are implemented using logic units, FPGAs, ASICs, DSPs, or any other suitable hardware or electronic circuitry.

[0035] In the example of FIG. **1**, the server I/O interfaces **124** may comprise one or more displays configured to display a two-dimensional (2D) or three-dimensional (3D) representation of a service. Examples of the representations may comprise, but are not limited to, a graphical or simulated representation of an application, diagram, tables, or any other suitable type of data information or representation. In some embodiments, the one or more displays may be configured to present visual information to one or more users **129**. The one or more displays may be configured to present visual information to the one or more users **129** updated in real-time. The one or more displays may be a wearable optical display (e.g., glasses or a head-mounted display (HMD)) configured to reflect projected images and enable user to see through the one or more displays. For example, the one or more displays may comprise display units, one or more lenses, one or more semi-transparent mirrors embedded in an eye glass structure, a visor structure, or a helmet structure. Examples of display units comprise, but are not limited to, a cathode ray tube (CRT) display, a liquid crystal display (LCD), a liquid crystal on silicon (LCOS) display, a light emitting diode (LED) display, an organic LED (OLED) display, an active-matrix OLED (AMOLED) display, a projector display, or any other suitable type of display. In another embodiment, the one or more displays are a graphical display on the server **102**. For example, the graphical display may be a tablet display or a smartphone display configured to display the data representations.

[0036] In one or more embodiments, the server I/O interfaces **124** may be hardware configured to perform one or more communication operations. The server I/O interfaces **124** may comprise one or more antennas as part of a transceiver, a receiver, or a transmitter for communicating using one or more wireless communication protocols or technologies. In some embodiments, the server I/O interfaces **124** may be configured to communicate using, for example, NR or LTE using at least some shared radio components. In other embodiments, the server I/O interfaces **124** may be configured to communicate using single or shared radio frequency (RF) bands. The RF bands may be coupled to a single antenna, or may be coupled to multiple antennas (e.g., for a multiple-input multiple output (MIMO) configuration) to perform wireless communications.

[0037] The server I/O interfaces **124** may comprise one or more server network interfaces that may be any suitable hardware or software (e.g., executed by hardware) to facilitate any suitable type of communication in wireless or wired connections. These connections may comprise, but not be limited to, all or a portion of network connections coupled to additional network components **114** in the core network **112**, the RAN **118**, the user equipment **116**, the Internet, an Intranet, a private network, a public network, a peer-to-peer network, the public switched telephone network, a cellular network, a local area network (LAN), a metropolitan area network (MAN), a wide area network (WAN), and a satellite network. The server network interface **124** may be configured to support any suitable type of communication protocol.

[0038] The server I/O interfaces **124** may comprise one or more administrator interfaces that may be user interfaces configured to provide access and control to of the server **102** to one or more users **129** via the user equipment **116** or electronic devices. The one or more users **129** may access the server memory **128** upon confirming one or more access credentials to demonstrate that access or control to the server **102** may be modified. In some embodiments, the one or more administrator interfaces may be configured to provide hardware and software resources to the one or more users **129**. Examples of user devices comprise, but are not limited to, a laptop, a computer, a smartphone, a tablet, a smart device, an Internet-of-Things (IoT) device, a simulated reality device, an augmented reality device, or any other suitable type of device. The administrator interfaces may enable access to one or more graphical user interfaces (GUIs) via an image generator display (e.g., the one or more displays), a touchscreen, a touchpad, multiple keys, multiple buttons, a mouse, or any other suitable type of hardware that allow users **129** to view data or to provide inputs into the server **102**. The server **102** may be configured to allow users **129** to send requests to one or more network components **114** or network.

[0039] In some embodiments, the server I/O interfaces **124** may be configured to provide the one or more DU assignments **126*a*** and the one or more RU assignments **126*b*** to one or more electronic components in the communication system **100**. The DU assignments **126*a*** may be one or more assignments **104** of one or more network resources **107** generated for one or more DUs in the communication system **100**. The DUs may be hardware and software executed by hardware that is deployed on a cell site in communication with the server **102**. The DUs may be deployed close to the RUs on the cell site and provides support for lower layers of a protocol stack such as the radio link control (RLC), medium access control (MAC), and parts of the physical (PHY) layer. The RU assignments **126***b* may be one or more assignments **104** of one or more network resources **107** generated for one or more RUs in the communication system **100**. The RUs are radio hardware entities that convert radio signals sent to and from antennas into digital signals for transmission over a packet network. The RUs handle a digital front end (DFE) and a lower PHY layer.

[0040] The server memory **128** may be volatile or non-volatile and may comprise a read-only memory (ROM), random-access memory (RAM), ternary content-addressable memory (TCAM), dynamic random-access memory (DRAM), and static random-access memory (SRAM). The server memory **128** may be implemented using one or more disks, tape drives, solid-state drives, and/or the like. The server memory **128** is operable to store the server instructions **130**, one or more layer operations **132**, one or more directories **134** comprising access to tenant profiles **136** associated with the one or more services **106** and the one or more of the NFs **119**, an access control list **138**, one or more rules and policies **140**, one or more access commands **142**, the one or more assignments **104** comprising the one or more network resources **107** assigned to the one or more pods **108**, one or more system level agreements (SLAs) **144**, one or more cell identifiers (IDs) **146**, one or more slice group IDs **148**, one or more machine learning (ML) models **150**, one or more resource pools **152***a* and **152***b* (collectively, resource pools **152**), one or more tier lists **154** comprising one or more tiers **156***a*-**156***c* (collectively, tiers **156**), an ML algorithm **158**, and one or more artificial intelligence (AI) commands **160**. The cell IDs **146** may be an ID indicating at least one cell that is configured to be associated with at least one pod **108** in one or more container clusters **162***a* and **162***b* (collectively, container clusters **162**) associated with the core network **112**. In the server memory **128**, the server instructions **130** may comprise commands and controls for operating one or more specific NFs **119** in the core network **112** when executed by the server processing engine **122** of the server processor **120**.

[0041] Herein, the multiple references to container clusters **162** are non-limiting examples of containerized service clusters configured as container orchestration platforms for scheduling and automating deployment, management, and scaling of containerized services (e.g., applications).

[0042] In one or more embodiments, the access commands **142** are configured to establish one or more communication sessions between two or more network components **114** in the core network **112**. The access commands **142** may be configured to establish one or more communication sessions between one or more network components **114** in the core network **112** and one of the user equipment **116**. Each configuration command of the access commands **142** may establish a communication session between a first network component of the network components **114** comprising the server **102** and a second network component of the network components **114** based at least in part upon a first configuration command of the access commands **142**. The access commands **142** may be routing and configuration information for reinstating or reestablishing communication sessions when a change is detected in the operations of the core network **112**. For example, in response to losing a specific communication session established with the first access command, the server **102** may attempt to reinstate the specific communication session based at least in part upon a second access command. The access commands **142** may be dynamically or periodically updated from another of the network components **114** in the core network **112**. Herein, communication sessions refer to communication signals exchanged between the server **102** and additional network components **114** in the core network **112**. In some embodiments, the access commands **142** are provided to the server **102** from another of the network components **114** performing a specific NF. The access commands **142** may be configured to enable access of the one or more services **106**. The access commands **142** may be configured to enable access of one or more cell IDs **146** (referenced in FIGS. **2**A-**3**), the one or more resource pools **152** (referenced in FIGS. **4**A-**5**), and/or one or more slice group IDs **148** (referenced ion FIGS. **6** and **7**) in one or more container clusters **162**.

[0043] The directories **134** may be configured to store service-specific information, tenant-specific information, and/or user-specific information. The directories **134** may enable the server **102** to confirm tenant credentials to access one or more network components (e.g., one of the network components **114** configured to perform the NRF **119***a*, an authentication server function (AUSF) **119***b*, an access and management function (AMF) **119***c*, one or more cloud network functions (CNFs) **119***d*, a policy control function (PCF) **119***e*, a unified data repository (UDR) **119***f*, a session management function (SMF) **119***g*, one or more Service Communication Proxys (SCPs) **119***h*, or the like) in the core network **112**. The directories **134** may be configured to store the tenant profiles **136** and a reference to the one or more services **106**. The directories **134** may be configured to store provider-specific information and service-specific information. The provider-specific information may enable the server **102** to validate credentials associated with a specific provider (e.g., one of the NFs **119**) against corresponding user-specific information and service-specific information. In some embodiments, the tenant profiles **136** may comprise lists of electronic devices (e.g., the user equipment **116**) that are configured to receive resources allocated from the server **102**.
[0044] In one or more embodiments, the access commands **142** may be a communication or a message configured to indicate a request for access of an application (via an API) or a service **106**. In some embodiments, the access commands **142** may be a communication or a message configured to enable access to one or more entitlements in an application (via an API) or a service **106**. The entitlements may be configured to provide one or more connectivity allowances (e.g., access) between the server **102**, the user equipment **116**, the one or more base stations **168**, and the one or more of the network components **114**. The entitlements may be assigned to specific departments or tenants. The entitlements may be predefined or dynamically defined in accordance with the rules and policies **140**. The assignments **104** comprises allocation information and/or commands to modify usage of the network resources **107**. The assignments **104** may distribute or redistribute the network resources **107** to modify operations at a base station (e.g., a cell site) in the RAN **118**. The assignments **104** may comprise modifications (e.g., increase, reduction, and/or replacement) of the network resources **107** distributed to one or more of the pods **108**. The network resources **107** may comprise power resources associated with a power supply, processing resources associated with a processor, and/or memory resources associated with a memory. In one or more embodiments, the network resources **107** may be dynamically enabled at any given base station **168** to modify routing operations of communication sessions. The network resources **107** may be modified at the given base station **168** and/or user equipment **116** to prioritize assigning resources to maintain certain communication sessions. For example, the processing resources may be reassigned at a base station **168** from one communication session to another communication session. In some embodiments, the assignments **104** may be modified in response to detecting a change or modification caused for a specific type of resource. For example, the network resources **107** may be reassigned to prioritize communication sessions between emergency organizations in a predefined area. In this example, a first number of the network resources **107** assigned to a first communication session may be dynamically reduced by an amount while a second number of the network resources **107** may be dynamically increased by the same amount. The assignments **104** may be generated dynamically (e.g., on demand) or periodically.
[0045] In one or more embodiments, the pods **108** are deployable units of computing that are created and managed in the containerized environment. The pods **108** may be configured as redundancies of one another or as standalone portions of a wireless communication network. The pods **108** may comprise one or more containers (e.g., the container clusters **162**) with shared storage and network resources. The shared storage and network resources may be co-located and co-scheduled. The network resources **107** may be power resources, memory resources, and processing resources that are consumed in attempts to access the services **106** in a given communication system **100**.
[0046] In one or more embodiments, the cell IDs **146** may be configured to reference one or more

specific cells associated with any given service **106** for one or more given tenants. The slice group IDs **148** may be configured to reference one or more specific slice groups associated with any given service **106** for one or more given tenants. The resource pools **152** may be configured to provide the ability to define a level (e.g., amount) of service capacity that is available for these services **106** by geographical area and time slots. The resource pools **152** may be an aggregate collection of resources needed to perform a delivery service or provided service **106**. In some embodiments, the resource pools **152** may be predefined or dynamically defined by an organization providing access to the network resources **107**.

[0047] In one or more embodiments, the access control list **138** (also referred to as ACL) may comprise rules that may allow or deny access to one or more of the entitlements that allow user equipment **116** to access the services **106**. The rules and policies **140** may be security configuration commands or regulatory operations predefined by an organization or one or more users **129**. The rules and policies **140** may be dynamically defined by the one or more users **129**. The one or more rules and policies **140** may be one or more a policy as defined in the 3GPP standards. The SLAs **144** may be configured to define one or more levels of service **106** expected by a tenant, laying out the metrics by which a given service **106** is measured.

[0048] In one or more embodiments, the pods **108** may be created and/or resized to enable the layer operations **132**. The layer operations **132** may be configured to perform Layer 1 (L1) operations and/or Layer 2 (L2) operations. In some embodiments, the server **102** may be configured to maintain a pool of floating resources for each layer. In this regard, the server **102** may be configured to create and maintain an L1 resource pool **152**, an L2 resource pool **152**, and/or a floating resource pool **152** to enable L1 operations and L2 operations. In some embodiments, the server **102** may be configured to monitor utilization of the L1 resource pool **152**, the L2 resource pool **152**, and/or the floating resource pool **152** and determining whether to resize the resource pools **152** to optimize usage of the network resources **107**.

[0049] The tier lists **154** comprise one or more priority levels for one or more communication sessions established in the communication system **100**. In one or more embodiments, the server **102** may be configured to control, monitor, and regulate the communication sessions in accordance with one or more of the tier lists **154**. The tier lists **154** may be modified over time such that new tier lists **154** may be added or removed, as-needed dynamically or periodically. The tier lists **154** may be modified immediately upon a triggering event caused by an admin console access. The tier lists **154** may be modified periodically upon entering a triggering event during a maintenance window. In some embodiments, the server **102** may dynamically manage spectra for all three tiers **156** with first priority for user equipment **116** in a first tier **156**A, second priority for user equipment **116** in a second tier **156**B, and third for user equipment **116** in a third tier **156**C. In some embodiments, to use the spectrum, the server **102** may use the tenant profiles **136** to assign one or more resources (e.g., network resources **107**) and deploy corresponding access points. For example, one of the user equipment **116** may request use of spectrum channels via a connection request. In turn, the server **102** (e.g., acting as at least a part of an administrator) may receive connectivity data in the request indicating latitude, longitude, and height into a database (e.g., the server memory **128**). In some embodiments, the server **102** may determine whether the requested spectrum is available. The server **102** may then assign spectrum channels and grant authority to operate in the channels in accordance with a priority level (e.g., depending on the tiers **156**). In this regard, the server **102** may authorize allocation of appropriate transmission power levels and allocation of channel resources.

[0050] In one or more embodiments, the ML algorithm **158** may be executed by the server processor **120** to evaluate the usage in the network resources **107** in the pods **108**. Further, the ML algorithm **158** may be configured to interpret and transform information associated with the network resources **107** into structured data sets and subsequently stored as files or tables. The ML algorithm **158** may cleanse, normalize raw data, and derive intermediate data to generate uniform

data in terms of encoding, format, and data types. The ML algorithm **158** may be executed to run user queries and advanced analytical tools on the structured data. The ML algorithm **158** may be configured to generate the one or more AI commands **160** based on current usage of the resources **107** in the pods **108**, the resource pools **152**, and/or existing instructions **130**. In turn, the server processor **120** may be configured to generate the assignments **104** dynamically based on the outputs of the ML algorithm **158**. The AI commands **160** may be parameters that modify the allocation and/or assignment of the resources **107** in the assignments **104**. The AI commands **160** may be combined with the existing instructions **130** to create the dynamic instructions and/or configuration commands. In one or more embodiments, the dynamic instructions and/or configuration commands may be dynamically-generated updates for the existing instructions **130**.
[0051] In one or more embodiments, the ML algorithm **158** may be configured to generate one or more ML models **150** that preemptively modify the assignments **104** based at least in part upon the usage of the network resources **107** in the pods **108**. In some embodiments, the server **102** may be configured to generate a library of ML models **150** categorized in accordance with one or more categories and/or characteristics. The one or more categories and/or characteristics may comprise morphology, spectrum deployed, traffic utilization, services offered, broadband, voice, mission critical, strict SLAs, and the like. One or more of the ML models **150** may be con figured with attributes that are priority for each of the services **106**, air interface capacity per cell, and/or numbers of network resources **107** associated with a specific Quality of Service (QoS).
[0052] In one or more embodiments, the ML models **150** may be created and maintained based at least in part upon one or more different characteristics. For example, a nominal mapping of an assignment **104** of multiple network resources **107** for a couple of cell IDs **146** in a single pod **108** may be implemented in the communication system **100**. After a period of time, the ML algorithm **158** following an existing ML model **150** may be configured to generate one or more AI commands **160** that trigger changes in the allocation of the network resources **107**. The ML model **150** may be configured to account for urban morphology, urban density, rural morphology, rural density, and similar conditions. In this regard, the trigger may cause a new assignment **104** to be generated in which the network resources **107** are reallocated to better enable communication sessions and operations in the communication system **100**. The changes may comprise changes in spectrum availability, power consumption, and the like to optimize QoS while optimizing overall traffic conditions in the communication sessions.
[0053] In one or more embodiments, the assignments **104** cause additional pods **108** to be generated and/or previous pods **108** to be discarded and/or deactivated. The assignments **104** may cause different resource pools **152** to be modified. For example, the network resources **107** assigned for a college campus may be dynamically modified based on student attendance, campus events, weather changes, and the like. Further, the network resources **107** may be dynamically assigned, redistributed, and/or modified for different slices overlapping the resource pools **152**. In some embodiments, the network resources **107** may be dynamically assigned, redistributed, and/or modified for different slice groups comprising one or more individual slices overlapping the resource pools **152**. The network resources **107** may be dynamically assigned, redistributed, and/or modified to increase, reduce, and/or maintain uplink (UL) operations. For example, some of the pods **108** may be dynamically assigned network resources **107** configured to mostly implement UL operations. The network resources **107** may be dynamically assigned, redistributed, and/or modified to increase, reduce, and/or maintain downlink (DL) operations. For example, some of the pods **108** may be dynamically assigned network resources **107** configured to mostly implement DL operations.
[0054] Herein, the network resources **107** may be dynamically allocated to the pods **108** to include one or more of the aforementioned characteristics. For example, a given pod **108** may be generated to include certain number of network resources **107** for slices configured in resource pools **152** to perform L1 operations and DL operations. In the containerized environment, the pods **108** may be

assigned to specific cores and/or specific containerized clusters.

User Equipment

[0055] In one or more embodiments, each of the user equipment **116** may be any computing device configured to communicate with other devices, such as the server **102**, other network components **114** in the core network **112**, databases, and the like in the communication system **100**. Each of the user equipment **116** may be configured to perform specific functions described herein and interact with one or more network components **114** in the core network **112** via one or more base stations **168*a*-168*g*** (collectively, base stations **168**). Examples of user equipment **116** comprise, but are not limited to, a laptop, a computer, a smartphone, a tablet, a smart device, an IoT device, a simulated reality device, an augmented reality device, or any other suitable type of device.

[0056] In one or more embodiments, referring to the user equipment **116*a*** as a non-limiting example of the user equipment **116**, the user equipment **116*a*** may comprise a user equipment (UE) network interface **170**, a UE I/O interface **172**, a UE processor **174** executing operations via a UE processing engine **176**, and a UE memory **178** comprising one or more instructions **180** configured to be executed by the UE processor **174**. The UE network interface **170** may be any suitable hardware or software (e.g., executed by hardware) to facilitate any suitable type of communication in wireless or wired connections. These connections may comprise, but not be limited to, all or a portion of network connections coupled to additional network components **114** in the core network **112**, the RAN **118**, the Internet, an Intranet, a private network, a public network, a peer-to-peer network, the public switched telephone network, a cellular network, a local area network (LAN), a metropolitan area network (MAN), a wide area network (WAN), and a satellite network. The UE network interface **170** may be configured to support any suitable type of communication protocol.

[0057] The UE I/O interface **172** may be hardware configured to perform one or more communication operations. The UE I/O interface **172** may comprise one or more antennas as part of a transceiver, a receiver, or a transmitter for communicating using one or more wireless communication protocols or technologies. In some embodiments, the UE I/O interface **172** may be configured to communicate using, for example, 5G NR or LTE using at least some shared radio components. In other embodiments, the UE I/O interface **172** may be configured to communicate using single or shared RF bands. The RF bands may be coupled to a single antenna, or may be coupled to multiple antennas (e.g., for a MIMO configuration) to perform wireless communications. In some embodiments, the user equipment **116*a*** may comprise capabilities for voice communication, mobile broadband services (e.g., video streaming, navigation, and the like), or other types of applications. In this regard, the UE I/O interface **172** of the user equipment **116*a*** may communicate using machine-to-machine (M2M) communication, such as machine-type communication (MTC), or another type of M2M communication.

[0058] In some embodiments, the user equipment **116*a*** is communicatively coupled to one or more of the base stations **168** via one or more communication links **190*a*-190*g*** (e.g., collectively, communication links **190**). The user equipment **116*a*** may be a device with cellular communication capability such as a mobile phone, a hand-held device, a computer, a laptop, a tablet, a smart watch or other wearable device, or virtually any type of wireless device. In some applications, the user equipment **116** may be referred to as a UE, UE device, or terminal.

[0059] The UE processor **174** may comprise one or more processors operably coupled to and in signal communication with the UE network interface **170**, the UE I/O interface **172**, and the UE memory **178**. The UE processor **174** is any electronic circuitry, including, but not limited to, state machines, one or more CPU chips, logic units, cores (e.g., a multi-core processor), FPGAs, ASICs, or DSPs. The UE processor **174** may be a programmable logic device, a microcontroller, a microprocessor, or any suitable combination of the preceding. The one or more processors in the UE processor **174** are configured to process data and may be implemented in hardware or software executed by hardware. For example, the UE processor **174** may be an 8-bit, a 16-bit, a 32-bit, a 64-bit, or any other suitable architecture. The UE processor **174** comprises an ALU to perform arithmetic and logic operations, processor registers that supply operands to the ALU, and store the results of ALU operations, and a control unit that fetches software instructions such as UE instructions **180** from the UE memory **178** and executes the UE instructions **180** by directing the coordinated operations of the ALU, registers, and other components via a UE processing engine **176**. The UE processor **174** may be configured to execute various instructions. For example, the UE processor **174** may be configured to execute the UE instructions **180** to implement functions or perform operations disclosed herein, such as some or all of those described with respect to FIGS. **1-7**. In some embodiments, the functions described herein are implemented using logic units, FPGAs, ASICs, DSPs, or any other suitable hardware or electronic circuitry.

Radio Access Network

[0060] In one or more embodiments, the RAN **118** enables the user equipment **116** to access one or more services in the core network **112**. The one or more services may be a mobile telephone service, a Short Message Service (SMS) message service, a Multimedia Message Service (MMS) message service, an Internet access, cloud computing, or other types of data services. The RAN **118** may comprise the base stations **168** in signal communication with the user equipment **116** via the one or more communication links **190**. Each of the base stations **168** may service the user equipment **116*a*-116*g***. In some embodiments, while multiple base stations **168** are shown connected to multiple user equipment **116** via the communication links **190**, one or more additional base stations **168** may be connected to one or more additional user equipment **116** via one or more additional communication links **190**. For example, the base stations **168*a*-168*g*** may exchange connectivity signals with the user equipment **116*a*** via the communication link **190*a***. In another example, the base station **168*g*** may exchange connectivity signals with the user equipment **116*g*** via the communication link **190*g***. In yet another example, the base stations **168** may service some user equipment **116** located within a geographic area serviced by one of the base

[0061] In one or more embodiments, referring to the base station **168*a*** as a non-limiting example of the base station **168**, the base station **168*a*** may comprise a base station (BS) network interface **182**, a BS I/O interface **184**, a BS processor **186**, and a BS memory **188**. The BS network interface **182** may be any suitable hardware or software (e.g., executed by hardware) to facilitate any suitable type of communication in wireless or wired connections between the core network **112** and the user equipment **116**. These connections may comprise, but not be limited to, all or a portion of network connections coupled to additional network components **114** in the core network **112**, other base stations **168**, the user equipment **116**, the Internet, an Intranet, a private network, a public network, a peer-to-peer network, the public switched telephone network, a cellular network, a LAN, a MAN, a WAN, and a satellite network. The BS network interface **182** may be configured to support any suitable type of communication protocol.

[0062] The BS I/O interface **184** may be hardware configured to perform one or more communication operations. The BS I/O interface **184** may comprise one or more antennas as part of a transceiver, a receiver, or a transmitter for communicating using one or more wireless communication protocols or technologies. In some embodiments, the BS I/O interface **184** may be configured to communicate using, for example, 5G NR or LTE using at least some shared radio components. In other embodiments, the BS I/O interface **184** may be configured to communicate using single or shared RF bands. The RF bands may be coupled to a single antenna, or may be coupled to multiple antennas (e.g., for a MIMO configuration) to perform wireless communications. In some embodiments, the base station **168*a*** may allocate resources in accordance with one or more routing and configuration operations obtained from the core network **112**. In some embodiments, resources may be allocated to enable capabilities in the user equipment **116** for voice communication, mobile broadband services (e.g., video streaming, navigation, and the like), or other types of applications.

[0063] In some embodiments, the base station **168*a*** is communicatively coupled to one or more of the user equipment **116** via the one or more communication links **190**. In some applications, the base stations **168** may be referred to as a BS, evolved Node B (eNodeB or eNB), a next generation Node B, gNodeB, gNB, or terminal.

[0064] The BS processor **186** may comprise one or more processors operably coupled to and in signal communication with the BS network interface **182**, the BS I/O interface **184**, and the BS memory **188**. The BS processor **186** is any electronic circuitry, including, but not limited to, state machines, one or more CPU chips, logic units, cores (e.g., a multi-core processor), FPGAs, ASICs, or DSPs. The BS processor **186** may be a programmable logic device, a microcontroller, a microprocessor, or any suitable combination of the preceding. The one or more processors in the BS processor **186** are configured to process data and may be implemented in hardware or software executed by hardware. For example, the BS processor **186** may be an 8-bit, a 16-bit, a 32-bit, a 64-bit, or any other suitable architecture. The BS processor **186** comprises an ALU to perform arithmetic and logic operations, processor registers that supply operands to the ALU, and store the results of ALU operations, and a control unit that fetches software instructions (not shown) from the BS memory **188** and executes the software instructions by directing the coordinated operations of the ALU, registers, and other components via a processing engine (not shown) in the BS processor **186**. The BS processor **186** may be configured to execute various instructions. For example, the BS processor **186** may be configured to execute the software instructions to implement functions or perform operations disclosed herein, such as some or all of those described with respect to FIGS. **1-7**. In some embodiments, the functions described herein are implemented using logic units, FPGAs, ASICs, DSPs, or any other suitable hardware or electronic circuitry.

Core Network

[0065] The core network **112** may be a network configured to manage communication sessions for the user equipment **116**. In one or more embodiments, the core network **112** may establish connections between user equipment **116** and a particular data network **110** in accordance with one or more communication protocols. The core network **112** may be a multi-core network **112** configured to comprise multiple cores. In this regard, the multi-core network may comprise multiple NFs **119** in each core. In the example of FIG. **1**, the core network **112** comprises the network component **114***a* configured to perform the NRF **119***a*, the network component **114***b* configured to perform the AUSF **119***b*, the network component **114***c* configured to perform the AMF **119***c*, the network component **114***d* configured to perform the CNFs **119***d*, the network component **114***e* configured to perform the PCF **119***e* and the UDR **119***f*, and the network component **114***f* configured to perform the SMF **119***g* and the SCPs **119***h*. Herein, as a non-limiting example, while the NRF **119***a* is associated with the network component **114***a*, the core network **112** may comprise multiple network component **114** performing the NRF **119***a*. For example, a Unified Data Management (UDM) may be part of a core.

[0066] In some embodiments, the NRF **119***a* may comprise a service registration procedure that accesses the one or more databases to store or retrieve routing and configuration information associated with one or more network components **114** in the core network **112**. The NRF **119***a* may access the database to discover services offered by other networks or other network components **114** with service discovery procedures and service authorization procedures. The NRF **119***a* may maintain a list of available NFs operations available in the core network **112** and any network components **114** associated with performing a given NF **119**. The NRF **119***a* may also performs registration and discovery of service such that different NFs **119** may find each other via APIs. As an example, when the SMF **119***g* is registered to the NRF **119***a*, the SMF **119***g* is discoverable by the AMF **119***c* when the user equipment **116** attempts to access a given service type via the SMF **119***g*. In other embodiments, the NFs **119** may be connected via a communication bus to all other additional network elements in the core network **112**. In the SBA, the NRF **119***a* may enable access between the user equipment **116** and the services offered via the NFs **119**.

[0067] In one or more embodiments, the network components **114***d* performing the one or more CNFs **119***d* may be configured to operate multiple services associated with one or more services

106, while dynamically directing network traffic within the core network **112**. In some embodiments, the network component **114*f*** performing the SMF **119*g*** may be configured to manage one or more communication sessions established between network components **114** of the core network **112**, allocate and manage resource allocation routing for the user equipment **116**, user plane selection, QoS and configuration enforcements for the control plane, service registration, discovery, establishment, and the like. In other embodiments, the network component **114*c*** performing the AMF **119*c*** may be configured to manage mobility, registration, connections, and overall access for the other network components **114** in the core network **112**. The AMF **119*c*** may act as an entry point for connections between the user equipment **116** and a given service. In yet other embodiments, the network component **114*f*** performing the one or more SCPs **119*h*** may be configured to provide a point of entry for a cluster of NFs **119** in the core network **112** to the user equipment **116** once the user equipment **116** are discovered by the NRF **119*a***. This allows the SCPs **119*h*** to be delegated discovery points in the core network **112**. The network component **114*b*** performing the AUSF **119*b*** may be configured to share performing of some of the aforementioned operations with a Unified Data Management (UDM) (not shown). In this regard, the AUSF **119*b*** may be configured to perform authentication processes while the UDM manages user data for any other processes in the core network **112**. In other embodiments, the UDM may receive requests for subscriber data from the SMF **119*g***, the AMF **119*c***, and the AUSF **119*b*** before providing any services **106**. The AUSF **119*b*** may be implemented in one of the network components **114** configured to enable the AMF **119*c*** to authenticate the user equipment **116**. The network component **114*e*** performing the PCF **119*e*** may be configured to provide a policy control framework in which the rules and policies **140** are implemented in accordance with one or more application guidelines. In some embodiments, the PCF **119*e*** may apply policy decisions to services provided, accessing subscription information, and the like to control behavior associated with the core network **112**. The network component **114*f*** performing the UDR **119*f*** configured to operate as a centralized data repository for subscription data, subscriber policy data, session information, context information, and application states. In some embodiments, the UDR **119*f*** may be configured to provide API integrations with other NFs **119** to retrieve subscriber subscription and policy data. The UDR **119*f*** may notify other NFs **119** of changes in subscriber data, supports real-time or batch (e.g., bulk) data access provisioning and subscriber data provisioning, and manages service parameters and application data for advanced applications.

[0068] In some embodiments, the core network **112** enables the user equipment **116** to communicate with the server **102**, or another type of device, located in a particular data network **110** or in signal communication with a particular data network **110**. The core network **112** may implement a communication method that does not require the establishment of a specific communication protocol connection between the user equipment **116** and one or more of the data networks **110**. The core network **112** may include one or more types of network devices (not shown), which may perform different NFs **119**.

[0069] In some embodiments, the core network **112** may include a 5G NR or an LTE access network (e.g., an evolved packet core (EPC) network) among others. In this regards, the core network **112** may comprise one or more logical networks implemented via wireless connections or wired connections. Each logical network may comprise an end-to-end virtual network with dedicated power, storage, or computation resources. Each logical network may be configured to perform a specific application comprising individual policies, rules, or priorities. Further, each logical network may be associated with a particular QoS class, type of service, or particular user associated with one or more of the user equipment **116**. For example, a logical network may be a Mobile Private Network (MPN) configured for a particular organization. In this example, when the user equipment **116*a*** is configured and activated by a wireless network associated with the RAN **118**, the user equipment **116*a*** may be configured to connect to one or more particular network slices (i.e., logical networks) in the core network **112**. Any logical networks or slices that may be configured for the user equipment **116***a* may be configured using one of the network components **114** of FIG. **1** performing a Network Slice Selection Function (NSSF) that may store a subscription profile associated with the user equipment **116***a*, in a network component operating as a Unified Data Management (UDM). Further, when the user equipment **116***a* may request a connection to a particular logical network or slice, the user equipment **116***a* may send a request to the network component performing the AMF **119***c*. The AMF **119***c* may provide a list of allowed logical networks or slices to the user equipment **116***a*. The user equipment **116***a* may then request a Packet Data Unit (PDU) connection with one or more of the provided logical networks or slices.

Data Networks

[0070] In the example system **100** of FIG. **1**, the data networks **110** may facilitate communication within the communication system **100**. This disclosure contemplates that the data networks **110** may be any suitable network operable to facilitate communication between the server **102**, the core network **112**, the RAN **118**, and the user equipment **116**. The data networks **110** may include any interconnecting system capable of transmitting audio, video, signals, data, messages, or any combination of the preceding. The data networks **110** may include all or a portion of a LAN, a WAN, an overlay network, a software-defined network (SDN), a virtual private network (VPN), a packet data network (e.g., the Internet), a mobile telephone network (e.g., cellular networks, such as 4G or 5G), a Plain Old Telephone (POT) network, a wireless data network (e.g., WiFi, WiGig, WiMax, and the like), a Long Term Evolution (LTE) network, a Universal Mobile Telecommunications System (UMTS) network, a peer-to-peer (P2P) network, a Bluetooth network, a Near Field Communication network, a Zigbee network, or any other suitable network, operable to facilitate communication between the components of the communication system **100**. In other embodiments, the communication system **100** may not have all of these components or may comprise other elements instead of, or in addition to, those above.

Dynamic Assignment of Cells to Pods

[0071] FIGS. **2**A and **2**B illustrate examples of container clusters **162** in accordance with one or more embodiments. In the example of FIG. **2**A, a containerized cluster **200***a* is shown comprising a core **202** and a core **204** in a containerized environment. In the example of FIG. **2**B, a containerized cluster **200***b* is shown comprising a core **206** and a core **208** in a containerized environment. Each of the cores **202-208** comprises at least one pod **108** and at least one cell associated with a cell ID **146**. As described above, the cell ID **146** references the network resources **107** assigned to at least one cell for a given pod **108**. The pods **108** are examples of possible pods **108** comprising resources assigned during a maintenance window or outside a maintenance window. In this regard, FIG. **2**A shows pods **108** of equal sizes **214-216** while FIG. **2**B shows pods of different sizes **262-266**.

[0072] In one or more embodiments, the pods **108***a*-**108***f* are allocated in different order and/or different cores than those shown in FIGS. **2**A and **2**B. In one or more embodiments, the containerized cluster **200***a* and the containerized cluster **200***b* comprise dynamically assigned cell IDs **146***a*-**146***x* in the pods **108***a*-**108***f*. In particular, the containerized cluster **200***a* and the containerized cluster **200***b* may comprise cells that are dynamically redistributed and/or reassigned to the pods **108***a*-**108***f*. The server **102** may be configured to distribute, redistribute, assign, and/or reassign the network resources **107** corresponding to multiple cells into the multiple pods **108***a*-**108***f*. In some embodiments, the server **102** may be configured to analyze the network resources **107** available for different cells associated with the communication system **100** and assign these network resources **107** to individual pods **108** of equal or different size. The pods **108** may be configured to be deployed in a containerized environment (e.g., Kubernetes environment). The pods **108** may comprise network resources **107** that are co-located and co-scheduled. The pods may be configured as redundancies of one another or as standalone portions of the communication network. Herein, the server **102** may be configured to dynamically assign the network resources **107** during maintenance windows. Further, the server **102** may be configured to dynamically assign the network resources **107** outside of maintenance windows.

[0073] In FIG. **2**A, as a non-limiting representative example, the core **202** in the containerized cluster **200***a* comprises a pod **108***a* and a pod **108***b*. The pod **108***a* in the core **202** comprises a size **212** and cell IDs **146***a*-**146***d*. The pod **108***b* in the core **202** comprises a size **214** and cell IDs **146***e*-**146***h*. The pod **108***c* in the core **204** comprises a size **216** and cell IDs **146***i*-**146***l*. The sizes **216-216** are shown to be equal to one another. In this regard, each of the pods **108***a*-**108***c* comprise a same number of network resources **107**. In the example of FIG. **2**A, the server **102** may be configured to assign network resources **107** corresponding to cells in the pods **108***a*-**108***c*. In this regard, the server **102** is configured to assign the cells in accordance with the corresponding cell IDs **146***a*-**146***l*. The cell IDs **146***a*-**146***l* are representative of one or more cells. Herein, a number of the cell IDs **146***a*-**146***l* indicate a number of resources assigned to a specific pod **108**. The pod **108***a* is assigned the cell ID **146***a*, the cell ID **146***b*, the cell ID **146***c*, and the cell ID **146***d*. The pod **108***b* is assigned the cell ID **146***e*, the cell ID **146***f*, the cell ID **146***g*, and the cell ID **146***h*. The pod **108***c* is assigned the cell ID **146***i*, the cell ID **146***j*, the cell ID **146***k*, and the cell ID **146***l*.
[0074] In FIG. **2**B, as a non-limiting representative example, the core **206** in the containerized cluster **200***b* comprises a pod **108***d* and a pod **108***e*. The pod **108***d* in the core **202** comprises a size **262** and cell IDs **146***m*-**146***p*. The pod **108***d* in the core **202** comprises a size **264** and cell IDs **146***q*-**146***s*. The pod **108***f* in the core **208** comprises a size **266** and cell IDs **146***t*-**146***x*. The sizes **262-266** are shown to be different from one another. In this regard, each of the pods **108***d*-**108***f* comprise a same number of network resources **107**. In the example of FIG. **2**B, the server **102** may be configured to assign network resources **107** corresponding to cells in the pods **108***d*-**108***f*. In this regard, the server **102** is configured to assign the cells in accordance with the corresponding cell IDs **146***m*-**146***x*. The cell IDs **146***m*-**146***x* are representative of one or more cells. Herein, a number of the cell IDs **146***m*-**146***x* indicate a number of resources assigned to a specific pod **108**. The pod **108***d* is assigned the cell ID **146***m*, the cell ID **146***n*, the cell ID **1460**, and the cell ID **146***p*. The pod **108***e* is assigned the cell ID **146***q*, the cell ID **146***r*, and the cell ID **146***s*. The pod **108***f* is assigned the cell ID **146***t*, the cell ID **146***u*, the cell ID **146***v*, the cell ID **146***w*, and the cell ID **146***x*.
[0075] In one or more embodiments, the pods **108***a*-**108***c* may be created comprising the cell IDs **146***a*-**146***l* as part of a first assignment **104**. A second assignment **104** may shuffle the cell IDs **146***a*-**146***l* in accordance with a second assignment **104** into new pods **108**. The second assignment **104** may shuffle the cell IDs **146***a*-**146***l* in accordance with the second assignment **104** into the pods **108***a*-**108***c* while the communication system is online. In some embodiments, the first assignment **104** and/or the second assignment **104** may be implemented during a maintenance window. The maintenance window may be predefined or dynamically defined. In other embodiments, the first assignment **104** and/or the second assignment **104** may be implemented outside of a maintenance window.
Example Process to Dynamically Assign Cells to Pods
[0076] FIG. **3** illustrates an example flowchart of a process **300** to dynamically assign cells to pods **108**, in accordance with one or more embodiments. In one or more embodiments, the process **300** comprises operations **302-332**. Modifications, additions, or omissions may be made to the process **300**. The process **300** may include more, fewer, or other operations than those shown below. For example, operations may be performed in parallel or in any suitable order. While at times discussed as the server **102**, one or more of the user equipment **116**, components of any of thereof, or any suitable system or components of the communication system **100** may perform one or more operations of the process **300**. For example, one or more operations of the process **300** may be implemented, at least in part, in the form of server instructions **130** of FIG. **1**, stored on non-transitory computer readable media, tangible media, machine-readable media (e.g., server memory **128** of FIG. **1** operating as a non-transitory computer readable medium) that when run by one or more processors (e.g., the server processor **120** of FIG. **1**) may cause the one or more processors to perform operations described in operations **302-332** of the process **300**. The process **300** may be perform during a maintenance window or outside a maintenance window.

[0077] The process **300** starts at operation **302**, where the server **102** identifies one or more network resources **107**. The server **102** may obtain information on one or more network resources **107** configured for allocation in one or more container clusters **162**. At operation **304**, the server **102** is configured to determine whether any of the network resources **107** are unassigned. The server **102** may be configured to identify that the network resources **107** are assigned to multiple cell IDs **146**. In this case, the server **102** may be configured to unassign the network resources **107** from the cell IDs **146**. At this stage, the server **102** may be configured to combine the network resources **107** into a group of unassigned network resources. If the server **102** determines that any of the network resources **107** are not unassigned (i.e., NO), the process **300** proceeds to operation **312**. At operation **312**, the server **102** determines that there are no network resources **107** available for assignment. If the server **102** determines that any of the network resources **107** are unassigned (i.e., YES), the process **300** proceeds to operation **322**. At operation **322**, the server **102** determines that the one or more network resources **107** are available for allocation to one or more cell IDs **146**. In some embodiments, the server **102** may be configured to identify QoSs associated with one or more communication links.

[0078] The process **300** continues to operation **324**, where the server **102** is configured to divide the one or more network resources **107** into a first group of network resources **107** and a second group of network resources **107**. At operation **326**, the server **102** is configured to assign the first group of network resources **107** to a first group of cell IDs **146**. Herein, the network resources **107** may be divided based at least in part upon the QoSs identified. At operation **328**, the server **102** is configured to assign the second group of network resources **107** to a second group of cell IDs **146**.

[0079] In this case, the process **300** may conclude at operation **330** and operation **332**. At operation **330**, the server **102** is configured to generate a first pod **108** in one or more containerized clusters **162** comprising the first cell IDs **146**. In this case, the first pod **108** may be updated and/or generated as a new pod **108** to comprise the first cell IDs **146**. At operation **332**, the server **102** is configured to generate a second pod **108** in one or more containerized clusters **162** comprising the second cell IDs **146**. In this case, the second pod **108** may be updated and/or generated as a new pod **108** to comprise the second cell IDs **146**. If updated, the first pod **108** and the second pod **108** may be updated outside of a maintenance window. If updated, the first pod **108** and the second pod **108** may be updated during a maintenance window.

Dynamic Assignment of Network Resources to Resource Pools in Pods

[0080] FIGS. **4**A and **4**B illustrate examples of container clusters **162** in accordance with one or more embodiments. In the example of FIG. **4**A, a containerized cluster **400*a*** is shown comprising a core **402** and a core **404** in a containerized environment. In the example of FIG. **4**B, a containerized cluster **400*b*** is shown comprising a core **406** and a core **408** in a containerized environment. Each of the cores **402-408** comprises at least one pod **108** and at least one resource pool **152**. The pods **108*a*-108*d*** are examples of possible pods **108** comprising resources **107** assigned during a maintenance window or outside a maintenance window. In this regard, FIG. **4**A shows pods **108** of equal sizes **412** and **414**, while FIG. **4**B shows pods of different sizes **416** and **418**. The pods **108*a*-108*d*** comprise resource pools **152*a*-152*l*** comprising sizes **422-472**. Further, the cores **402-408** may be configured to perform specific DL operations or UL operations. The DL core **402** and the DL core **406** may be configured to perform DL operations. The UL core **404** and the UL core **408** may be configured to perform UL operations. In some embodiments, the pods **108** are allocated in different order and/or different cores than those shown in FIGS. **2**A and **2**B.

[0081] In some embodiments, the server **102** is configured to keep some computing capacity in at least one resource pool **152** in a floating mode. The resource pools **152*a*-152*l*** may be scaled vertically and/or horizontally to support higher capacity during enterprise operations, mission critical operations in an organization, strict SLA use cases, and the like. In other embodiments, the resource pools **152*a*-152*l*** may be configured to enable multi-tenancy operations in the communication system **100** running analytics/MEC applications during off peak hours on a wireless communication network. The server **102** methods may be configured to perform energy savings at CRAN sites.

[0082] In one or more embodiments, the pods **108***a*-**108***d* comprise examples of dynamically assigned network resources **107** to resource pools **152***a*-**152***l*. In particular, the examples in FIGS. **4**A and **4**B comprise resource pools **152***a*-**152***l* with dynamically assigned network resources **107** in the pods **108***a*-**108***d*. The pods **108***a*-**108***d* may be associated with a CRAN. The server **102** are configured to dynamically redistribute and/or reassign the network resources **107** to the resource pools **152***a*-**152***l*. In some embodiments, the server **102** may leverage cell redistribution into generating the resource pools **152***a*-**152***l* for physical layer applications in the CRAN. The pods **108***a*-**108***d* may be configured to be deployed in a containerized environment (e.g., Kubernetes environment). The pods **108***a*-**108***d* may comprise network resources **107** that are co-located and co-scheduled. The pods **108***a*-**108***d* may be configured as redundancies of one another or as standalone portions of a wireless communication network. Herein, the pods **108***a*-**108***d* may be created and/or resized to enable layer operations **132** comprising Layer 1 (L1) operations and Layer 2 (L2) operations. The server **102** may be configured to maintain a pool of floating resources for each layer. In this regard, the server **102** may be configured to create and maintain an L1 resource pool **152**, an L2 resource pool **152**, and a floating resource pool **152** configured to enable L1 operations and L2 operations. During off-peak hours, the server **102** may be configured to monitor utilization of the L1 resource pool **152**, the L2 resource pool **152**, and the floating resource pool **152** and determining whether to resize the resource pools **152** to optimize usage of the network resources **107**.

[0083] In the example of FIG. **4**A, as a non-limiting representative example, the DL core **402** in the containerized cluster **400***a* comprises the DL pod **108***a* and the UL pod **108***b*. The DL pod **108***a* in the core **402** comprises a size **412** and resource pools **152***a*-**152***c*. The resource pool **152***a* comprises a size **422**. The resource pool **152***b* comprises a size **424**. The resource pool **152***c* comprises a size **426**. In the containerized cluster **400***a*, as a non-limited example, the sizes **422**-**426** are shown to be equal to one another. The UL pod **108***b* in the core **404** comprises a size **414** and resource pools **152***a*-**152***c*. The resource pool **152***d* comprises a size **428**. The resource pool **152***e* comprises a size **430**. The resource pool **152***f* comprises a size **432**. In the containerized cluster **400***a*, as a non-limited example, the sizes **428**-**432** are shown to be equal to one another.

[0084] In the example of FIG. **4**B, as a non-limiting representative example, the DL core **406** in the containerized cluster **400***b* comprises the DL pod **108***c* and the UL pod **108***d*. The DL pod **108***c* in the core **406** comprises a size **416** and resource pools **152***g*-**152***i*. The resource pool **152***g* comprises a size **462**. The resource pool **152***h* comprises a size **464**. The resource pool **152***i* comprises a size **466**. In the containerized cluster **400***b*, the sizes **462**-**466** are shown to be different to one another as a non-limited example. The UL pod **108***d* in the core **408** comprises a size **418** and resource pools **152***j*-**152***l*. The resource pool **152***j* comprises a size **468**. The resource pool **152***k* comprises a size **470**. The resource pool **152***l* comprises a size **472**. In the containerized cluster **400***b*, as a non-limited example, the sizes **468**-**472** are shown to be different to one another.

Example Process to Dynamically Assign Network Resources to Resource Pools in Pods

[0085] FIG. **5** illustrates an example flowchart of a process **500** to dynamically assign network resources **107** to pods **108**, in accordance with one or more embodiments. In one or more embodiments, the process **500** comprises operations **502**-**534**. Modifications, additions, or omissions may be made to the process **500**. The process **500** may include more, fewer, or other operations than those shown below. For example, operations may be performed in parallel or in any suitable order. While at times discussed as the server **102**, one or more of the user equipment **116**, components of any of thereof, or any suitable system or components of the communication system **100** may perform one or more operations of the process **500**. For example, one or more operations of the process **500** may be implemented, at least in part, in the form of server instructions **130** of FIG. **1**, stored on non-transitory computer readable media, tangible media, machine-readable media (e.g., server memory **128** of FIG. **1** operating as a non-transitory computer readable medium) that when run by one or more processors (e.g., the server processor **120** of FIG. **1**) may cause the one or more processors to perform operations described in operations **502-534** of the process **500**. The process **500** may be perform during a maintenance window or outside a maintenance window.

[0086] The process **500** starts at operation **502**, where the server **102** identifies one or more network resources **107**. The server **102** may obtain information on one or more network resources **107** configured for allocation in one or more container clusters **162**. At operation **504**, the server **102** is configured to determine whether any of the network resources **107** are unassigned. The server **102** may be configured to identify that the network resources **107** are assigned to multiple resource pools **152**. In this case, the server **102** may be configured to unassign the network resources **107** from the resource pools **152**. If the server **102** determines that any of the network resources **107** are not unassigned (i.e., NO), the process **500** proceeds to operation **512**. At operation **512**, the server **102** determines that there are no network resources **107** available for assignment. If the server **102** determines that any of the network resources **107** are unassigned (i.e., YES), the process **500** proceeds to operation **522**. At operation **522**, the server **102** determines that the one or more network resources **107** are available for allocation to one or more resource pools **152**.

[0087] The process **500** continues to operation **524**, where the server **102** is configured to determine a first group of network resources **107** configured to enable first layer operations **132**. At operation **526**, the server **102** is configured to determine a second group of network resources **107** configured to enable second layer operations **132**. The first layer operations **132** and the second layer operations **132** may be same or different operations. The first layer operations **132** may comprise L1 operations, L2 operations, or a combination of L1 operations and L2 operations. The second layer operations **132** may comprise L1 operations, L2 operations, or a combination of L1 operations and L2 operations.

[0088] In this case, the process **300** may conclude at operations **528-534**. At operation **528**, the server **102** is configured to assign the first group of network resources **107** to a first resource pool **152***a*. At operation **530**, the server **102** is configured to assign the second group of network resources **107** to a second resource pool **152***b*. At operation **532**, the server **102** is configured to generate a first pod **108** in one or more containerized clusters **162** comprising the first resource pool **152***a*. In this case, the first pod **108** may be updated and/or generated as a new pod **108** to comprise the first resource pool **152***a*. At operation **534**, the server **102** is configured to generate a second pod **108** in one or more containerized clusters **162** comprising the second resource pool **152***b*. In this case, the second pod **108** may be updated and/or generated as a new pod **108** to comprise the second resource pool **152***b*.

Dynamic Assignment of Network Resources to Slices in Pods

[0089] FIG. **6** illustrates an example of a container clusters **162** in accordance with one or more embodiments. In the example of FIG. **6**, a containerized cluster **600** is shown comprising a core **602** and a core **604** in a containerized environment. Each of the cores **602** and **604** comprises at least one pod **108** and at least one resource pool **152**. The pods **108***a* and **108***b* are examples of possible pods **108** comprising resources assigned during a maintenance window or outside a maintenance window. The pods **108***a* and **108***b* may comprise same or different sizes. In some embodiments, the pods **108** are allocated in different order and/or different cores than those shown in FIG. **6**.

[0090] In FIG. **6**, as a non-limiting representative example, the cores **602** and **604** in the containerized cluster **600** comprise a pod **108***a* and a pod **108***b*, respectively. The pod **108***a* in the core **602** comprises slices **612-616** across the resource pool **152***a* and the resource pool **152***b*. The pod **108***b* in the core **604** comprises slices **618-622** across the resource pools **152***c* and the resource pools **152***d*.

[0091] In one or more embodiments, the pods **108***a* and **108***b* comprise slices **612-622** with dynamically assigned network resources **107**. In particular, the pods **108***a* and **108***b* comprise resource pools **152***a*-**152***d* associated with a platform and infrastructure layer. The server **102** may be configured to redistribute and/or reassign the network resources **107** to the network slices **612-622**. In some embodiments, the server **102** dynamically allocates the network resources **107** into the network slices **612-622** in accordance with one or more configuration parameters that may include: SLA considerations, general organization rules and policies, or emergency procedures. The slices **612-622** may be configured as quick access to the network resources **107** in the individual pods **108***a* and **108***b*. The network resources **107** may be accessed without interfering with a rest of operations in a wireless communication network. Herein, the network resources **107** may be accessed to experience communication with higher priority and QoS. As described above, the slices **612-622** may correspond to one or more slice group IDs **148**.

Example Process to Dynamically Assign Network Resources to Slices in Pods

[0092] FIG. **7** show an example flowchart of a process **700** to dynamically assign network resources **107** to pods **108**, in accordance with one or more embodiments. In one or more embodiments, the process **700** comprises operations **702-734**. Modifications, additions, or omissions may be made to the process **700**. The process **700** may include more, fewer, or other operations than those shown below. For example, operations may be performed in parallel or in any suitable order. While at times discussed as the server **102**, one or more of the user equipment **116**, components of any of thereof, or any suitable system or components of the communication system **100** may perform one or more operations of the process **700**. For example, one or more operations of the process **700** may be implemented, at least in part, in the form of server instructions **130** of FIG. **1**, stored on non-transitory computer readable media, tangible media, machine-readable media (e.g., server memory **128** of FIG. **1** operating as a non-transitory computer readable medium) that when run by one or more processors (e.g., the server processor **120** of FIG. **1**) may cause the one or more processors to perform operations described in operations **702-734** of the process **700**.

[0093] The process **700** starts at operation **702**, where the server **102** identifies one or more network resources **107**. The server **102** may obtain information on one or more network resources **107** configured for allocation in one or more container clusters **162**. At operation **704**, the server **102** is configured to determine whether any of the network resources **107** are unassigned. The server **102** may be configured to identify that the network resources **107** are assigned to multiple slice group IDs **148**. In this case, the server **102** may be configured to unassign the network resources **107** from the cell IDs **146**. At this stage, the server **102** may be configured to combine the network resources **107** into a group of unassigned network resources. If the server **102** determines that any of the network resources **107** are not unassigned (i.e., NO), the process **700** proceeds to operation **712**. At operation **712**, the server **102** determines that there are no network resources **107** available for assignment. If the server **102** determines that any of the network resources **107** are unassigned (i.e., YES), the process **700** proceeds to operation **722**. At operation **722**, the server **102** determines that the one or more network resources **107** are available for allocation to one or more resource pools **152**.

[0094] The process **700** continues to operation **724**, where the server **102** is configured to determine a first group of network resources **107** configured to enable first layer operations **132**. At operation **726**, the server **102** is configured to determine a second group of network resources **107** configured to enable second layer operations **132**. At operation **728**, the server **102** is configured to generate a first pod **108** in one or more containerized clusters **162** comprising the first resource pool **152***a*. At operation **730**, the server **102** is configured to generate a second pod **108** in one or more containerized clusters **162** comprising the second resource pool **152***b*.

[0095] In this case, the process **700** may conclude at operation **732** and operation **734**. At operation **732**, the server **102** is configured to assign a first slice group ID **148** configured to access at least one slice (one of slices **612-622**) of the first resource pool **152***a* to the first pod **108**. In this case, the first pod **108** may be updated and/or generated as a new pod **108** to comprise the first resource pool **152***a*. At operation **734**, the server **102** is configured to assign a second slice group ID **148** configured to access at least one slice (one of slices **612-622**) of the second resource pool **152***a* to the first pod **108**. In this case, the second pod **108** may be updated and/or generated as a new pod **108** to comprise the second resource pool **152***b*.

SCOPE OF THE DISCLOSURE

[0096] While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods might be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated with another system or certain features may be omitted, or not implemented.

[0097] In addition, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

[0098] To aid the Patent Office, and any readers of any patent issued on this application in interpreting the claims appended hereto, applicants note that they do not intend any of the appended claims to invoke 35 U.S.C. § 112(f) as it exists on the date of filing hereof unless the words "means for" or "step for" are explicitly used in the particular claim.

Claims

1. An apparatus, comprising: a memory, comprising: information on one or more network resources available for allocation in one or more containerized clusters; and one or more slice group identifiers (IDs), each slice group ID corresponding to at least one slice group configured to be associated with at least one pod in the one or more containerized clusters; and a processor communicatively coupled to the memory and configured to: determine whether the one or more network resources are unassigned; in response to determining that the one or more network resources are unassigned, determine that the one or more network resources are available for allocation to a first plurality of resource pools and a second plurality of resource pools; assign a first plurality of network resources to the first plurality of resource pools; assign a second plurality of network resources to the second plurality of resource pools; generate a first pod in the one or more containerized clusters comprising the first plurality of resource pools; generate a second pod in the one or more containerized clusters comprising the second plurality of resource pools; assign a first slice group ID of the one or more slice group IDs to the first pod, the first slice group ID being configured to access at least one slice of the first plurality of resource pools in the first pod; and assign a second slice group ID of the one or more slice group IDs to the second pod, the second slice group ID being configured to access at least one slice of the second plurality of resource pools in the second pod.

2. The apparatus of claim 1, wherein the processor is further configured to: identify the first plurality of network resources assigned to the first plurality of resource pools and the second plurality of network resources assigned to the second plurality of resource pools; unassign the first plurality of network resources from the first plurality of resource pools; unassign the second plurality of network resources from the second of plurality resource pools; combine the first plurality of network resources and the second plurality of network resources into a plurality of unassigned network resources; determine that the plurality of unassigned network resources are available for reallocation to the first plurality of resource pools and the second plurality of resource pools; determine a third plurality of network resources of the plurality of unassigned network resources configured to enable a third plurality of layer operations; determine a fourth plurality of network resources of the plurality of unassigned network resources configured to enable a fourth plurality of layer operations; assign the third plurality of network resources to the first plurality of resource pools; assign the fourth plurality of network resources to the second plurality of resource pools; update the first pod in the one or more containerized clusters to comprise the first plurality of resource pools comprising the third plurality of network resources; and update the second pod in the one or more containerized clusters to comprise the second plurality of resource pools comprising the fourth plurality of network resources.

3. The apparatus of claim 2, wherein: the first pod comprises a first size; the second pod comprises a second size; and the first size is different from the second size.

4. The apparatus of claim 3, wherein the first pod and the second pod are updated outside of a maintenance window.

5. The apparatus of claim 3, wherein the first pod and the second pod are updated during a maintenance window.

6. The apparatus of claim 1, wherein the processor is further configured to: in conjunction with determining the first slice group ID of the one or more slice group IDs configured to access at least one slice of the first plurality of resource pools in the first pod, generate a first slice, a second slice, and a third slice in the first pod.

7. The apparatus of claim 6, wherein: the first slice comprises a first size and is associated with a first system level agreement; the second slice comprises a second size and is associated with a second system level agreement, the second size being smaller than the first size; and the third slice comprises a third size and is associated with a third system level agreement, the third size being smaller than the second size.

8. A method, comprising: determining whether one or more network resources are unassigned, the one or more network resources being available for allocation in one or more containerized clusters; in response to determining that the one or more network resources are unassigned, determining that the one or more network resources are available for allocation to a first plurality of resource pools and a second plurality of resource pools; assigning a first plurality of network resources to the first plurality of resource pools; assigning a second plurality of network resources to the second plurality of resource pools; generating a first pod in the one or more containerized clusters comprising the first plurality of resource pools; generating a second pod in the one or more containerized clusters comprising the second plurality of resource pools; generating a first slice group identifiers (ID) of one or more slice group IDs configured to access at least one slice of the first plurality of resource pools in the first pod, each slice group ID of the one or more slice group IDs corresponding to at least one slice group configured to be associated with at least one pod in the one or more containerized clusters; and generating a second slice group ID of the one or more slice group IDs configured to access at least one slice of the second plurality of resource pools in the second pod.

9. The method of claim 8, further comprising: identifying the first plurality of network resources assigned to the first plurality of resource pools and the second plurality of network resources assigned to the second plurality of resource pools; unassigning the first plurality of network resources from the first plurality of resource pools; unassigning the second plurality of network resources from the second plurality of resource pools; combining the first plurality of network resources and the second plurality of network resources into a plurality of unassigned network resources; determining that the plurality of unassigned network resources are available for reallocation to the first plurality of resource pools and the second plurality of resource pools; determining a third plurality of network resources of the plurality of unassigned network resources configured to enable a third plurality of layer operations; determining a fourth plurality of network resources of the plurality of unassigned network resources configured to enable a fourth plurality of layer operations; assigning the third plurality of network resources to the first plurality of resource pools; assigning the fourth plurality of network resources to the second plurality of resource pools; updating the first pod in the one or more containerized clusters to comprise the first plurality of resource pools comprising the third plurality of network resources; and updating the second pod in the one or more containerized clusters to comprise the second plurality of resource pools comprising the fourth plurality of network resources.

10. The method of claim 9, wherein: the first pod comprises a first size; the second pod comprises a second size; and the first size is different from the second size.

11. The method of claim 9, wherein the first pod and the second pod are updated outside of a maintenance window.

12. The method of claim 9, wherein the first pod and the second pod are updated during a maintenance window.

13. The method of claim 8, further comprising: in conjunction with determining the first slice group ID of the one or more slice group IDs configured to access at least one slice of the first plurality of resource pools in the first pod, generating a first slice, a second slice, and a third slice in the first pod.

14. The method of claim 13, wherein: the first slice comprises a first size and is associated with a first system level agreement; the second slice comprises a second size and is associated with a second system level agreement, the second size being smaller than the first size; and the third slice comprises a third size and is associated with a third system level agreement, the third size being smaller than the second size.

15. A non-transitory computer-readable medium storing instructions that when executed by a processor cause the processor to: determine whether one or more network resources are unassigned, the one or more network resources being available for allocation in one or more containerized clusters; in response to determining that the one or more network resources are unassigned, determine that the one or more network resources are available for allocation to a first plurality of resource pools and a second plurality of resource pools; assign a first plurality of network resources to the first plurality of resource pools; assign a second plurality of network resources to the second plurality of resource pools; generate a first pod in the one or more containerized clusters comprising the first plurality of resource pools; generate a second pod in the one or more containerized clusters comprising the second plurality of resource pools; generate a first slice group identifiers (ID) of one or more slice group IDs configured to access at least one slice of the first plurality of resource pools in the first pod, each slice group ID of the one or more slice group IDs corresponding to at least one slice group configured to be associated with at least one pod in the one or more containerized clusters; and generate a second slice group ID of the one or more slice group IDs configured to access at least one slice of the second plurality of resource pools in the second pod.

16. The non-transitory computer-readable medium of claim 15, the processor being further caused to: identify the first plurality of network resources assigned to the first plurality of resource pools and the second plurality of network resources assigned to the second plurality of resource pools; unassign the first plurality of network resources from the first plurality of resource pools; unassign the second plurality of network resources from the second plurality of resource pools; combine the first plurality of network resources and the second plurality of network resources into a plurality of unassigned network resources; determine that the plurality of unassigned network resources are available for reallocation to the first plurality of resource pools and the second plurality of resource pools; determine a third plurality of network resources of the plurality of unassigned network resources configured to enable a third plurality of layer operations; determine a fourth plurality of network resources of the plurality of unassigned network resources configured to enable a fourth plurality of layer operations; assign the third plurality of network resources to the first plurality of resource pools; assign the fourth plurality of network resources to the second plurality of resource pools; update the first pod in the one or more containerized clusters to comprise the first plurality of resource pools comprising the third plurality of network resources; and update the second pod in the one or more containerized clusters to comprise the second plurality of resource pools comprising the fourth plurality of network resources.

17. The non-transitory computer-readable medium of claim 16, wherein: the first pod comprises a first size; the second pod comprises a second size; and the first size is different from the second size.

18. The non-transitory computer-readable medium of claim 16, wherein the first pod and the second pod are updated outside of a maintenance window.

19. The non-transitory computer-readable medium of claim 16, wherein the first pod and the second pod are updated during a maintenance window.

20. The non-transitory computer-readable medium of claim 15, the processor being further caused to: in conjunction with determining the first slice group ID of the one or more slice group IDs configured to access at least one slice of the first plurality of resource pools in the first pod, generate a first slice, a second slice, and a third slice in the first pod.