



US 20230337057A1

(19) **United States**

(12) **Patent Application Publication**
ARMENTA et al.

(10) **Pub. No.: US 2023/0337057 A1**

(43) **Pub. Date: Oct. 19, 2023**

(54) **CONTAINERIZED APPLICATION TECHNOLOGIES FOR CELLULAR NETWORKS AND RAN WORKLOADS**

Publication Classification

(51) **Int. Cl.**
H04W 28/086 (2006.01)
H04W 28/08 (2006.01)
(52) **U.S. Cl.**
CPC ... *H04W 28/0861* (2023.05); *H04W 28/0858* (2020.05)

(71) Applicant: **DISH WIRELESS L.L.C.**, Englewood, CO (US)

(72) Inventors: **Julio ARMENTA**, Englewood, CO (US); **Ash KHAMAS**, Englewood, CO (US)

(73) Assignee: **DISH WIRELESS L.L.C.**, Englewood, CO (US)

(21) Appl. No.: **18/134,707**

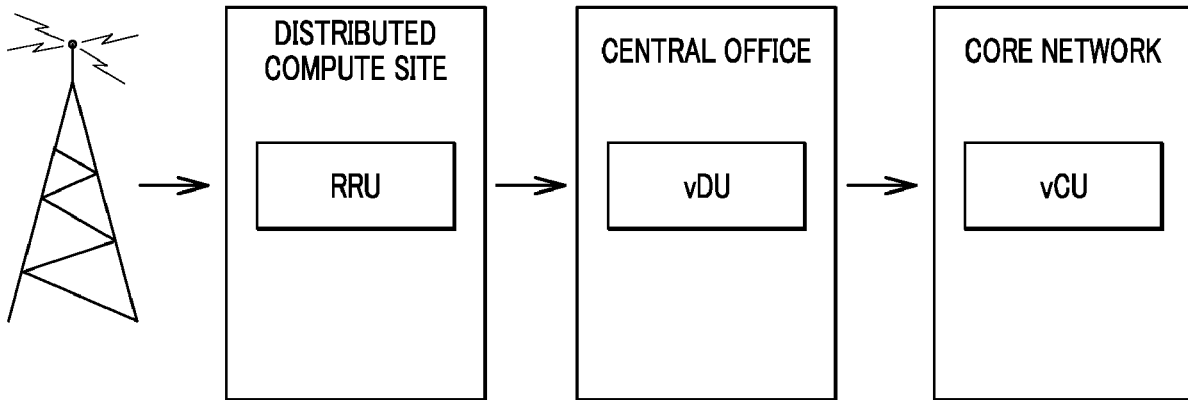
(22) Filed: **Apr. 14, 2023**

Related U.S. Application Data

(60) Provisional application No. 63/331,314, filed on Apr. 15, 2022.

(57) **ABSTRACT**

A 5G cellular network system is disclosed that includes a plurality of servers, each of the plurality of servers comprising a processor, memory, an operating system; a distributed unit (DU) and a worker. The DU is installed in the memory and comprising computer instructions, that when executed by the processor, processes and controls communications with at least one tower to handle communications between cellular devices. The worker is configured to communicate over a wide area network to a central unit (CU) in a core network for processing the communications to/from the DU and the at least one tower.



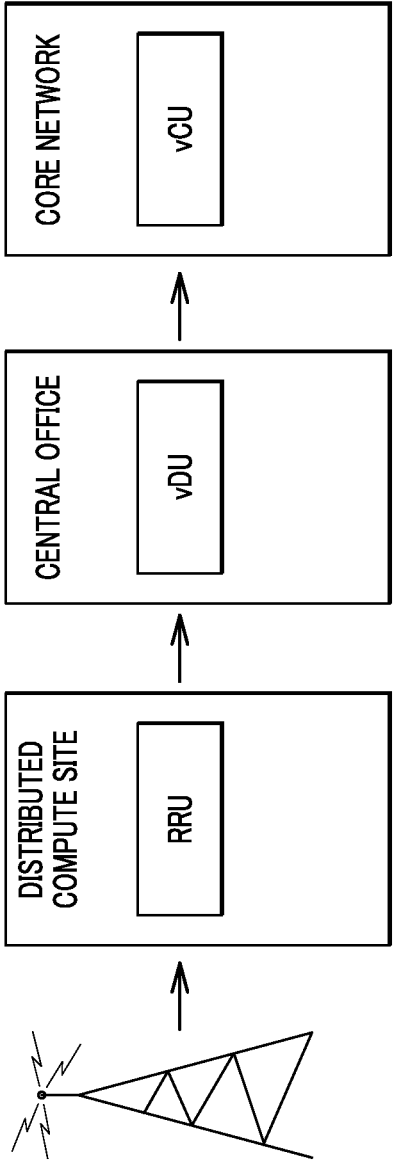


FIG. 1

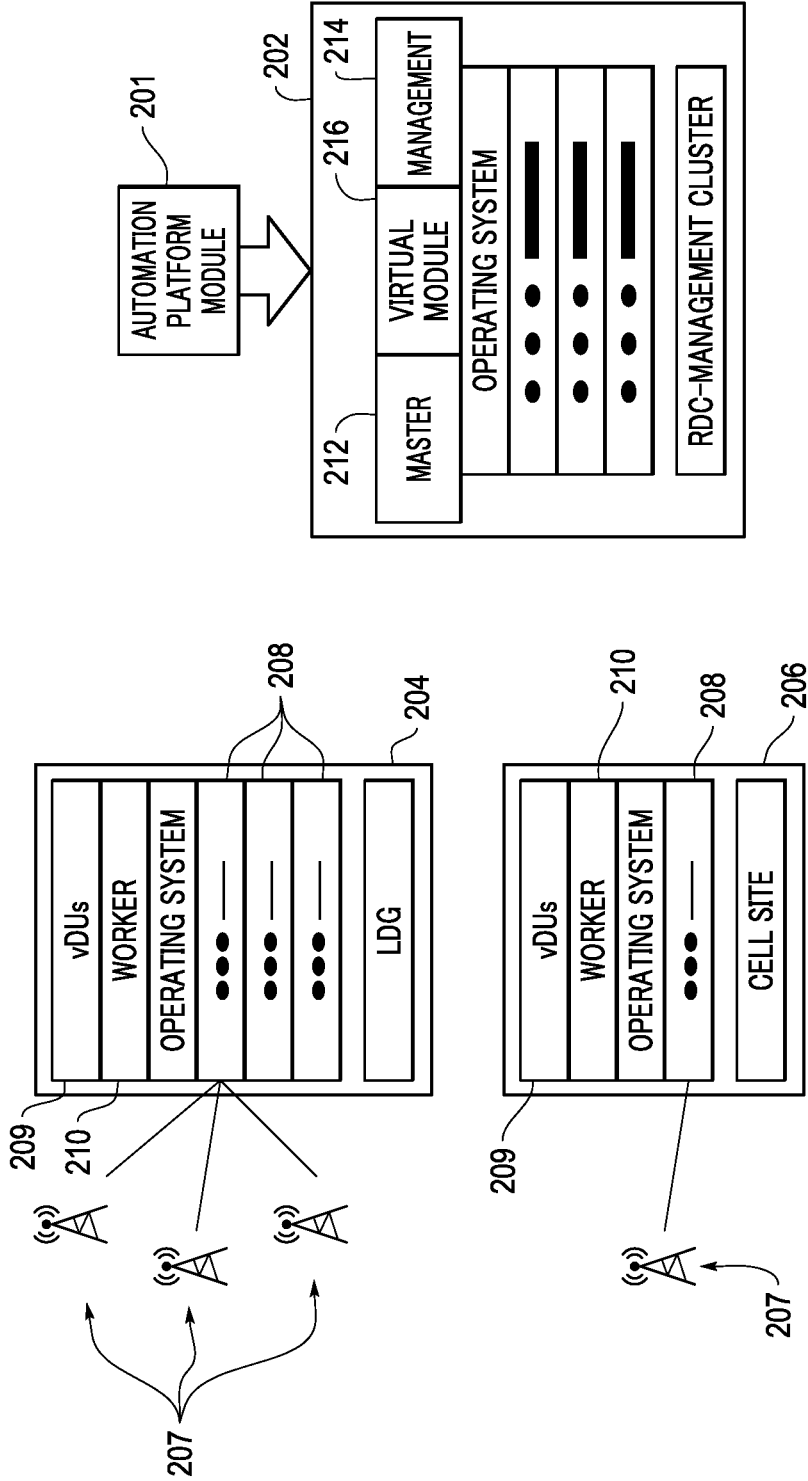


FIG. 2

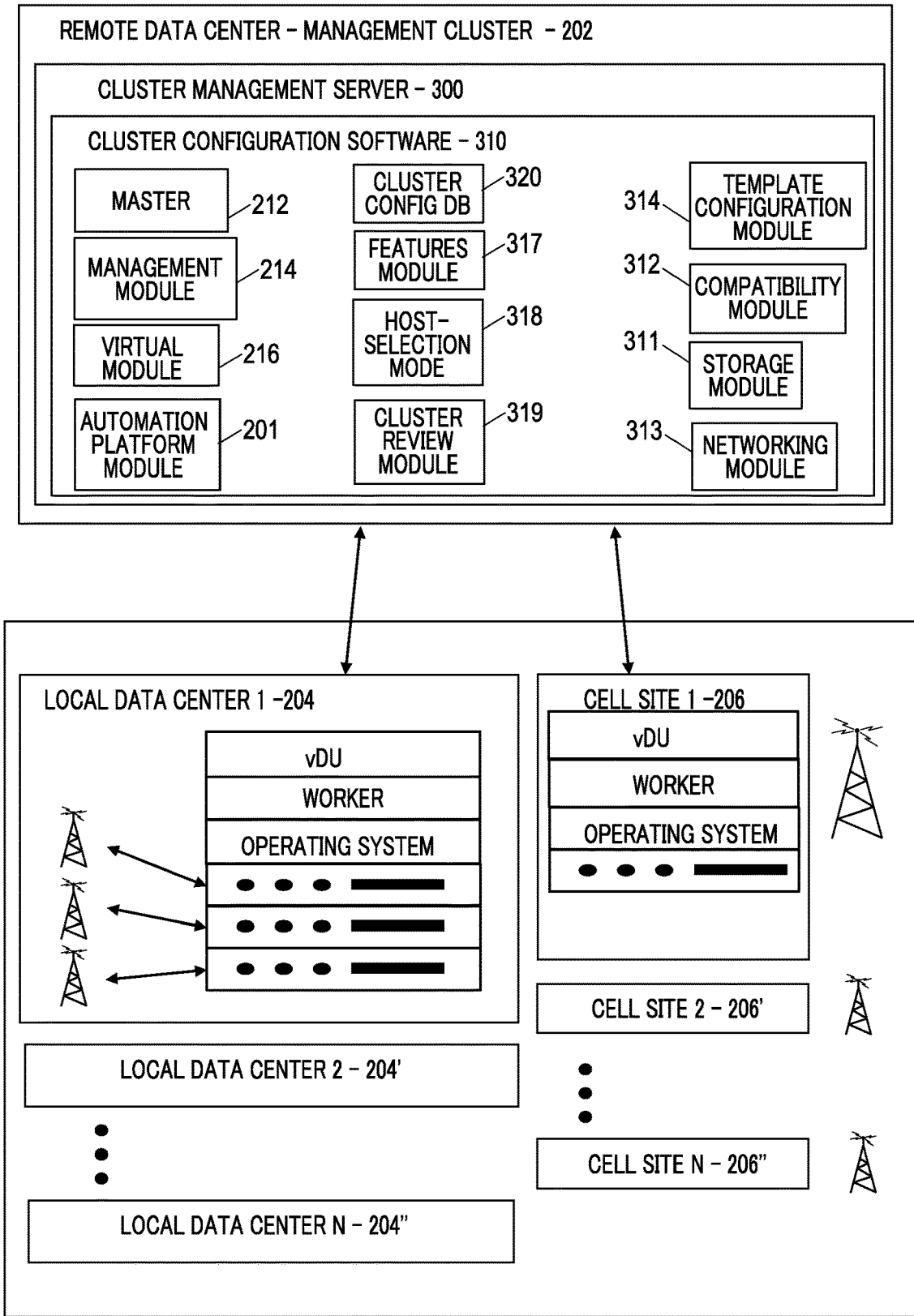


FIG. 3

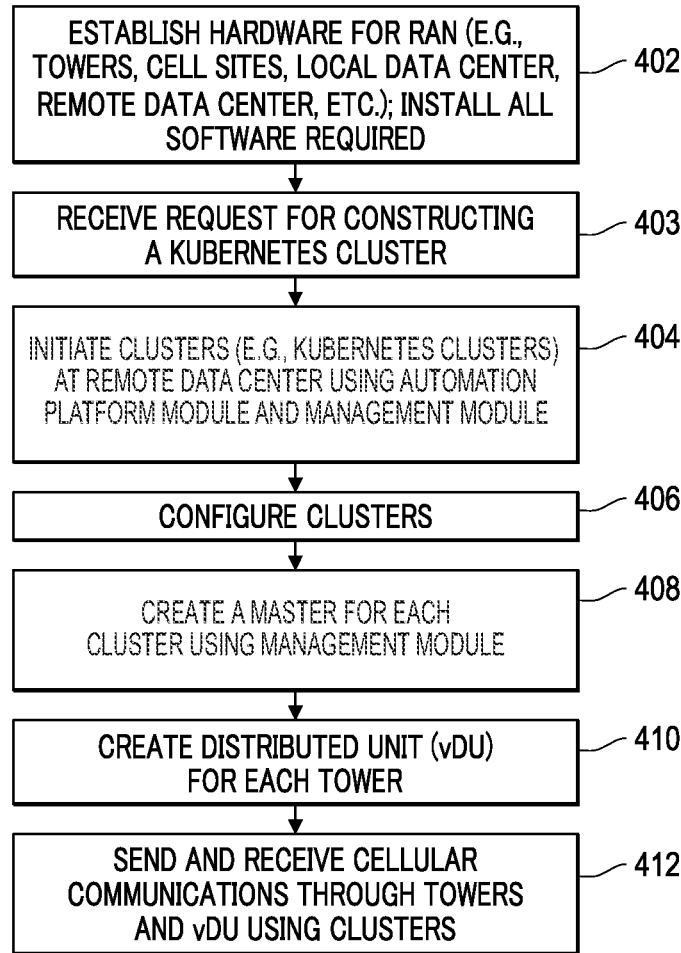


FIG. 4

CONTAINERIZED APPLICATION TECHNOLOGIES FOR CELLULAR NETWORKS AND RAN WORKLOADS

BACKGROUND

[0001] Demand for mobile bandwidth continues to grow as customers access new services and applications. To remain competitive, telecommunications companies must cost-effectively expand their network while also improving user experience.

[0002] Radio access networks (RANs) are an expensive element in mobile networks. They often require specialized hardware that can be difficult to upgrade and scale. As a result, RANs often become a source of performance problems that affect customer experience.

[0003] Current cellular infrastructure configurations do not allow for workload distributions, increased speeds and interconnectivity, and reduced capital and operational costs.

SUMMARY

[0004] Various embodiments provide solutions to provide systems and methods for running kubernetes clusters along with a RAN to coordinate workloads in a cellular network, such as a 5G cellular network.

[0005] According to an embodiment, disclosed is a system (e.g., RAN) including a plurality of clusters, wherein each cluster is configured to operate respective cell sites, wherein each cell site comprises: at least one tower configured to send and receive cellular communications to and from cellular phones; and a distributed unit (DU) configured to process and control communications to/from the cellular phones through the at least one tower; a core network connected with the plurality of clusters over a wide area network via a master module, the core network comprising: a central unit (CU) deployed remote from each of the plurality of clusters, wherein the master module manages messages from each DU via the plurality of clusters.

[0006] According to another embodiment, disclosed is a method for operating a radio access network (“RAN”) system comprising operating, via a plurality of clusters, respective cell sites, wherein each cell site comprises: at least one tower configured to send and receive cellular communications to and from cellular phones; and a distributed unit (DU) configured to process and control communications to/from the cellular phones through the at least one tower; transmitting, by a first DU, data received from an originating mobile phone to a core network connected with the plurality of clusters over a wide area network via a master module, the core network comprising: a central unit (CU) deployed remote from each of the plurality of clusters, wherein the master module manages messages from each DU via the plurality of clusters.

[0007] According to another embodiment, disclosed is a 5G cellular network system comprising: a plurality of servers, each of the plurality of servers comprising a processor, memory, an operating system; a distributed unit (DU) and a worker. The DU is installed in the memory and comprising computer instructions, that when executed by the processor, processes and controls communications with at least one tower to handle communications between cellular devices. The worker is configured to communicate over a wide area

network to a central unit (CU) in a core network for processing the communications to/from the DU and the at least one tower.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Aspects of the present invention is further described in the detailed description which follows in reference to the noted plurality of drawings by way of non-limiting examples of embodiments of the present invention in which like reference numerals represent similar parts throughout the several views of the drawings and wherein:

[0009] FIG. 1 illustrates a high level block diagram showing a 5G cellular network using vDUs and a vCU.

[0010] FIG. 2 illustrates a high level block diagram showing 5G cellular network with clusters.

[0011] FIG. 3 illustrates a block diagram of the system of FIG. 2 but further illustrating details of cluster configuration software, according to various embodiments.

[0012] FIG. 4 illustrates a method of establishing cellular communications using clusters.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] As mentioned above, various embodiments provide running containerized applications, such as kubernetes clusters, along with a radio access network (“RAN”) to coordinate workloads in a cellular network, such as a 5G cellular network.

[0014] Broadly speaking, embodiments of the present invention provide methods, apparatuses and computer implemented systems for configuring a 5G cellular network using servers at cell sites, cellular towers and containerized applications (e.g., kubernetes clusters) that stretch from a public network to a private network.

[0015] Establishing a Cellular Network Using Containerized Applications

[0016] First, the configuration using containerized application is discussed below. The containerized application can be any containerized application but is described herein as kubernetes clusters for ease of illustration, but it should be understood that the present invention should not be limited to kubernetes clusters and any containerized applications could instead be employed. In other words, the below description uses kubernetes clusters and exemplary embodiments but the present invention should not be limited to kubernetes clusters.

[0017] A kubernetes cluster may be part of a set of nodes that run containerized applications. Containerizing applications is an operating system-level virtualization method used to deploy and run distributed applications without launching an entire virtual machine (VM) for each application.

[0018] A cluster configuration software is available at a cluster configuration server. This guides a user, such as system administrator, through a series of software modules for configuring hosts of a cluster by defining features and matching hosts with requirements of features so as to enable usage of the features in the cluster. The software automatically mines available hosts, matches host with features requirements, and selects the hosts based on host-feature compatibility. The selected hosts are configured with appropriate cluster settings defined in a configuration template to be part of the cluster. The resulting cluster configuration provides an optimal cluster of hosts that are all compatible

with one another and allows usage of various features. Additional benefits can be realized based on the following detailed description.

[0019] The present application uses such containerized applications (e.g., kubernetes clusters) to deploy a RAN so that the virtual distributed unit (“vDU”) (also referred to herein as the “DU”) of the RAN is located at one cluster and the virtual central unit (“vCU”) (also referred to herein as the “CU”) is located at a remote location from the vDU, according to some embodiments. This configuration allows for a more stable and flexible configuration for the RAN.

[0020] With the above overview in mind, the following description sets forth numerous exemplary details in order to provide an understanding of at least some embodiments of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some or all of these details described herein and thus, should not be limited. Operations may be done in different orders, and may or may not include some of the processes described herein. Several exemplary embodiments of the invention will now be described in detail with reference to the accompanying drawings.

[0021] FIG. 1 illustrates a system that delivers full RAN functionality using network functions virtualization (NFV) infrastructure. In the embodiment shown in FIG. 1, the RAN includes a tower, radio unit (RU), a DU, a CU, and an element management system (EMS) (not shown). This approach decouples baseband functions from the underlying hardware and creates a software fabric. Within the solution architecture, virtualized baseband units (vBBU) process and dynamically allocate resources to remote radio units (RRUs) based on the current network needs. Baseband functions are split between CU and the DUs that can be deployed in aggregation centers or in central offices (or data centers) using a distributed architecture, such as using kubernetes clusters as discussed herein.

[0022] The virtualized CUs and DUs run as virtual network functions (VNFs) within the NFV infrastructure. The entire software stack that is needed is provided for NFV, including open source software. This software stack and distributed architecture increases interoperability, reliability, performance, manageability, and security across the NFV environment.

[0023] RAN standards may have deterministic, low-latency, and low-jitter signal processing, in some embodiments. These may be achieved using containerized applications (e.g., kubernetes clusters) to control respective DUs, RUs and towers. Moreover, the RAN may support different network topologies, allowing the system to choose the location and connectivity of all network components. Thus, the system allowing various DUs on containerized applications (e.g., kubernetes clusters) allows the network to pool resources across multiple cell sites, scale capacity based on conditions, and ease support and maintenance requirements.

[0024] FIG. 2 illustrates an exemplary system used in constructing clusters that allows a network to control cell sites, in one embodiment of the invention. The system includes a cluster configuration server that can be used by a cell site to provide various containers for processing of various functions. Each of the cell sites are accessed via at least one cellular tower (and RRU) by the client devices, which may be any computing device which has cellular capabilities, such as a mobile phone, computer or other computing device.

[0025] As shown, the system includes an automation platform (AP) module 201, a remote data center (RDC) 202, one or more local data centers (LDC), and one or more cell sites 206.

[0026] The cell sites 206 provide cellular service to the client devices through the use of a vDU 209, server 208, and a tower 207. The server 208 at a cell site 206 controls the vDU 209 located at the cell site 206, which in turn controls communications from the tower 207. Each DU 209 is software to control the communications with the towers 207, RRUs, and CU so that communications from client devices (not shown) can communicate from one tower 207 through the kubernetes clusters to another cellular tower 207. In other words, the voice and data from a cellular mobile client device connects to the towers 207 and then goes through the DU 209 to transmit such voice and data to another DU 209 to output such voice and data to another tower 207 using workers 210 networked via a core network/CU.

[0027] The server(s) 208 on each individual cell site 206 or LDC 204 may not have enough computing power to run a control plane that supports the functions in the mobile telecommunications system to establish and maintain the user plane. As such, the control plane may be run in a location that is remote from the cell sites 206, such as the RDC 202.

[0028] The RDC 202 is the management cluster which manages the LDC 204 and a plurality of cell sites 206. As mentioned above, the control plane may be deployed in the RDC 202. The control plane maintains the logic and workloads in the cell sites 206 from the RDC 202 while each of the containerized applications (e.g., kubernetes containers) is deployed at the cell sites 206. The control plane also monitors the workloads that are running properly and efficiently in the cell sites 206 and fixes any workload failures. If the control plane determines that a workload fails at the cell site 206, for example, the control plane redeploys the workload on the cell site 206.

[0029] The RDC 202 may include a master 212 (e.g., kubernetes master), a management module 214 and a virtual (or virtualization) module 216. The master module 212 monitors and controls the workers 210 (also referred to herein as kubernetes workers) and the applications running thereon, such as the DUs 209. If a DU 209 fails, the master module 212 recognizes this, and will redeploy the DU 209 automatically. In this regard, the clusters system has intelligence to maintain the configuration, architecture and stability of the applications running. Accordingly, the clusters system may be considered to be “self-healing”.

[0030] The management module 214 along with the Automation Platform 201 creates the clusters in the LDCs 204 and cell sites 206.

[0031] For each of the servers 209 in the LDC 204 and the cell sites 206, an operating system is loaded in order to run the workers 210. For example, such software could be ESKi and Photon OS. The DUs are also software, as mentioned above, that runs on the workers 210. In this regard, the software layers are the operating system, the workers 210, and then the DUs 209 as illustrated in FIG. 2.

[0032] The automation platform module 201 includes a GUI that allows a user to initiate clusters. The automation platform module 201 communicates with the management module 214 so that the management module 214 may create the clusters and a master module 212 for each cluster.

[0033] Prior to creating each of the clusters, the virtualization center **216** module creates a virtual machine (VM) so that the clusters can be created. VMs and containers are parts of the containerized applications (e.g., kubernetes clusters) infrastructure of data centers and cell sites. VMs are emulations of particular computer systems that operate based on the functions and computer architecture of real or hypothetical computers. A VM is equipped with a full server hardware stack that has been virtualized. Thus, a VM includes virtualized network adapters, virtualized storage, a virtualized CPU, and a virtualized BIOS. Since VMs include a full hardware stack, each VM may include a complete operating system (OS) to function, and VM instantiation thus may need booting a full OS.

[0034] In addition to VMs, which provide abstraction at the physical hardware level (e.g., by virtualizing the entire server hardware stack), containers are created on top of the VMs. Containers provide abstraction at the OS level. In most container systems, the user space is also abstracted. Application presentation systems create a segmented user space for each instance of an application. Applications may be used, for example, to deploy an office suite to dozens or thousands of remote workers. In doing so, these applications create sandboxed user spaces on a server for each connected user. While each user shares the same operating system instance including kernel, network connection, and base file system, each instance of the office suite has a separate user space.

[0035] In any event, once the VMs and containers are created, the master modules **212** then create a DU **209** for each VM, as will be described later herein.

[0036] FIG. 2 also shows an LDC **204**. In some embodiments, the LDC **204** is a data center that can support multiple servers and multiple towers for cellular communications. The LDC **204** is similar to the cell sites **206** except that each LDC **204** has multiple servers **208** corresponding to multiple towers **207** whereby each cell site **206** may only have a single server. Each server in the LDC **204** (as compared with the server in each cell site **206**) may support multiple towers. The server **208** in the LDC **204** may be different from the server **208** in the cell site **206** because the servers **208** in the LDC **204** are larger in memory and processing power (number of cores, etc.) relative to the servers **208** in the individual cell sites **206**. In this regard, each server **208** in the LDC **204** may run multiple DUs (e.g., 2 DUs), where each of these DUs independently operates a cell tower **207**. Thus, multiple towers **207** can be operated through the LDCs **204** using multiple DUs using the clusters. The LDCs **204** may be placed in bigger metropolitan areas whereas individual cell sites **206** may be placed at smaller population areas.

[0037] FIG. 3 illustrates a block diagram of the system of FIG. 2 but further illustrating details of cluster configuration software, according to various embodiments.

[0038] As illustrated, a cluster management server **300** is configured to run the cluster configuration software **310**. The cluster configuration software **310** runs using computing resources of the cluster management server **300**. The cluster management server **300** is configured to access a cluster configuration database **320**. In one embodiment, the cluster configuration database **320** includes a host list with data related to a plurality of hosts **330** including information associated with hosts, such as host capabilities. For instance, the host data may include list of hosts **330** accessed and

managed by the cluster management server **300**, and for each host **330**, a list of resources defining the respective host's capabilities. Alternately, the host data may include a list of every host in the entire virtual environment and the corresponding resources or may include only the hosts that are currently part of an existing cluster and the corresponding resources. In an alternate embodiment, the host list is maintained on a server that manages the entire virtual environment and is made available to the cluster management server **300**.

[0039] In addition to the data related to hosts **330**, the cluster configuration database **320** includes features list with data related to one or more features including a list of features and information associated with each of the features. The information related to the features include license information corresponding to each feature for which rights have been obtained for the hosts, and a list of requirements associated with each feature. The list of features may include, for example and without limitations, live migration, high availability, fault tolerance, distributed resource scheduling, etc. The list of requirements associated with each feature may include, for example, host name, networking and storage requirements. Information associated with features and hosts are obtained during installation procedure of respective components prior to receiving a request for forming a cluster.

[0040] Each host is associated with a local storage and is configured to support the corresponding containers running on the host. Thus, the host data may also include details of containers that are configured to be accessed and managed by each of the hosts **330**. The cluster management server **300** is also configured to access one or more shared storage and one or more shared network.

[0041] The cluster configuration software **310** includes one or more modules to identify hosts and features and manage host-feature compatibility during cluster configuration. The configuration software **310** includes a compatibility module **312** that retrieves a host list and a features list from the configuration database **320** when a request for cluster construction is received from the client. The compatibility module **312** checks for host-feature compatibility by executing a compatibility analysis which matches the feature requirements in the features list with the hosts capabilities from the host list and determines if sufficient compatibility exists for the hosts in the host list with the advanced features in the features list to enable a cluster to be configured that can utilize the advanced features. Some of the compatibilities that may be matched include hardware, software and licenses.

[0042] It should be noted that the aforementioned list of compatibilities are exemplary and should not be construed to be limiting. For instance, for a particular advanced feature, such as fault tolerance, the compatibility module checks whether the hosts provide a compatible processor family, host operating system, hardware virtualization enabled in the BIOS, and so forth, and whether appropriate licenses have been obtained for operation of the same. Additionally, the compatibility module **312** checks to determine if networking and storage requirements for each host in the cluster configuration database **320** are compatible for the selected features or whether the networking and storage requirements may be configured to make them compatible for the selected features. In one embodiment, the compatibility module checks for basic network requirements. This

might entail verifying each host's connection speed and the subnet to determine if each of the hosts has the desired speed connection and access to the right subnet to take advantage of the selected features. The networking and storage requirements are captured in the configuration database 320 during installation of networking and storage devices and are used for checking compatibility.

[0043] The compatibility module 312 identifies a set of hosts accessible to the management server 300 that either matches the requirements of the features or provides the best match and constructs a configuration template that defines the cluster configuration settings or profile that each host needs to conform in the configuration database 320. The configuration analysis provides a ranking for each of the identified hosts for the cluster. The analysis also presents a plurality of suggested adjustments to particular hosts so as to make the particular hosts more compatible with the requirements. The compatibility module 312 selects hosts that best match the features for the cluster. The cluster management server 300 uses the configuration settings in the configuration template to configure each of the hosts for the cluster. The configured cluster allows usage of the advanced features during operation and includes hosts that are most compatible with each other and with the selected advanced features.

[0044] In addition to the compatibility module 312, the configuration software 310 may include additional modules to aid in the management of the cluster including managing configuration settings within the configuration template, addition/deletion/customization of hosts and to fine-tune an already configured host so as to allow additional advanced features to be used in the cluster. Each of the modules is configured to interact with each other to exchange information during cluster construction. For instance, a template configuration module 314 may be used to construct a configuration template to which each host in a cluster may conform based on specific feature requirements for forming the cluster. The configuration template is forwarded to the compatibility module which uses the template during configuration of the hosts for the cluster. The host configuration template defines cluster settings and includes information related to network settings, storage settings and hardware configuration profile, such as processor type, number of network interface cards (NICs), etc. The cluster settings are determined by the feature requirements and are obtained from the Features list within the configuration database 320.

[0045] A configuration display module may be used to return information associated with the cluster configuration to the client for rendering and to provide options for a user to confirm, change or customize any of the presented cluster configuration information. In one embodiment, the cluster configuration information within the configuration template may be grouped in sections. Each section can be accessed to obtain further information regarding cluster configuration contained therein.

[0046] A features module 317 may be used for mining features for cluster construction. The features module 317 is configured to provide an interface to enable addition, deletion, and/or customization of one or more features for the cluster. The changes to the features are updated to the features list in the configuration database 320. A host-selection module 318 may be used for mining hosts for cluster configuration. The host-selection module 318 is configured to provide an interface to enable addition, deletion, and/or customization of one or more hosts. The host-

selection module 318 is further configured to compare all the available hosts against the feature requirements, rank the hosts based on the level of matching and return the ranked list along with suggested adjustments to a cluster review module 319 for onward transmission to the client for rendering.

[0047] The cluster review module 319 may be used to present the user with a proposed configuration returned by the host-selection module 318 for approval or modification. The configuration can be fine-tuned through modifications in appropriate modules during guided configuration set-up which are captured and updated to the host list in either the configuration database 320 or the server. The suggested adjustments may include guided tutorial for particular hosts or particular features. In one embodiment, the ranked list is used in the selection of the most suitable hosts for cluster configuration. For instance, highly ranked hosts or hosts with specific features or hosts that can support specific applications may be selected for cluster configuration. In other embodiments, the hosts are chosen without any consideration for their respective ranks. Hosts can be added or deleted from the current cluster. In one embodiment, after addition or deletion, the hosts are dynamically re-ranked to obtain a new ranked list. The cluster review module 312 provides a tool to analyze various combinations of hosts before selecting the best hosts for the cluster.

[0048] A storage module 311 enables selection of storage requirements for the cluster based on the host connectivity and provides an interface for setting up the storage requirements. Shared storage may be needed in order to take advantage of the advanced features. As a result, one should determine what storage is shared by all hosts in the cluster and use only those storages in the cluster in order to take advantage of the advanced features. The selection options for storage include all the shared storage available to every host in the cluster. The storage interface provides default storage settings based on the host configuration template stored in the configuration database 320 which is, in turn, based on compatibility with prior settings of hosts, networks and advanced features and enables editing of a portion of the default storage settings to take advantage of the advanced features. In one embodiment, if a certain storage is available to only a selected number of hosts in the cluster, the storage module 311 will provide necessary user alerts in a user interface with tutorials on how to go about fixing the storage requirement for the configuration in order to take advantage of the advanced features. The storage module performs edits to the default storage settings based on suggested adjustments. Any updates to the storage settings including a list of selected storage devices available to all hosts of the cluster are stored in the configuration database 320 as primary storage for the cluster during cluster configuration.

[0049] A networking module 313 enables selection of network settings that is best suited for the features and provides an interface for setting up the network settings for the cluster. The networking module provides default network settings, including preconfigured virtual switches encompassing several networks, based on the host configuration template stored in the cluster configuration database, enables selecting/editing the default network settings to enter specific network settings that can be applied/transmitted to all hosts, and provides suggested adjustments with guided tutorials for each network options so a user can make informed decisions on the optimal network settings for the

cluster to enable usage of the advanced features. The various features and options matching the cluster configuration requirements or selected during network setting configuration are stored in the configuration database and applied to the hosts so that the respective advanced features can be used in the cluster.

[0050] FIG. 3 also illustrates cell sites 206, 206', 206" that are configured to be clients of each cluster. Each cell site 206, 206', 206" is shown as includes a cellular tower 207 and a connection to each distributed unit (DU), similar to FIG. 2. Each DU is labeled as a virtualized distributed unit (vDU) 209, similar to FIG. 2, and each DU runs as virtual network functions (VNFs) within the an open source network functions virtualization (NFV) infrastructure.

[0051] With the above overview of the various components of a system used in the cluster configuration, specific details of how each component is used in establishing and communicating through a cellular network using kubernetes clusters, as shown in FIG. 4.

[0052] First, all of the hardware for establishing a cellular network (e.g., a RAN, which includes towers, RRUs, DUs, CU, etc.) and a cluster (e.g., servers, kubernetes workers, etc.) are provided, as described in block 402. The LDC 204, RDC 202, and cell sites 206, 206', 206" are created and networked together via a network.

[0053] In blocks 403-408, the process of constructing a cluster using plurality of hosts will now be described.

[0054] The process begins at block 403 with a request for constructing a cluster from a plurality of hosts which support one or more containers. The request is received at the automation platform module 201 from a client. The process of receiving a request for configuring a cluster then triggers initiating the clusters at the RDC 202 using the automation platform module 201, as illustrated in block 404.

[0055] In block 406, the clusters are configured and this process will now be described with reference to FIGS. 2-3.

[0056] The automation platform module 201 is started by a system administrator or by any other user interested in setting up a cluster. The automation platform module 201 then invokes the cluster configuration software on the cluster management server, such as a virtual module server, running cluster configuration software.

[0057] The invoking of the cluster configuration software triggers the cluster configuration workflow process at the cluster management server by initiating a compatibility module 312. Upon receiving the request for constructing a cluster, the compatibility module 312 queries a configuration database available to the management server and retrieves a host list of hosts that are accessible and managed by the management server and a features list of features for forming the cluster. The host list contains all hosts managed by the management server and a list of capabilities of each host. The list of capabilities of each host is obtained during installation of each host. The features list contains all licensed features that have at least a minimum number of host licenses for each licensed feature, a list of requirements, such as host, networking and storage requirements. The features list includes, but is not limited to, live migration, high availability, fault tolerance, distributed resource scheduling. Information in the features list and host list are obtained from an initial installation procedure before cluster configuration and through dynamic updates based on hosts

and features added, updated or deleted over time and based on number of licenses available and number of licenses in use.

[0058] The compatibility module 312 then checks for the host-feature compatibility by executing a compatibility analysis for each of the hosts. The compatibility analysis compares the capabilities of the hosts in the host list with the features requirements in the features list. Some of the host capability data checked during host-feature compatibility analysis include host operating system and version, host hardware configuration, Basic Input/Output System (BIOS) Feature list and whether power management is enabled in the BIOS, host computer processor family (for example, Intel, AMD, and so forth), number of processors per host, number of cores available per processor, speed of execution per processor, amount of internal RAM per host, shared storage available to the host, type of shared storage, number of paths to shared storage, number of hosts sharing the shared storage, amount of shared storage per host, type of storage adapter, amount of local storage per host, number and speed of network interface devices (NICs) per host. The above list of host capability data verified during compatibility analysis is exemplary and should not be construed as limiting.

[0059] Some of the features related data checked during compatibility analysis include determining number of licenses to operate an advanced feature, such as live migration/distributed resource scheduling, number and name of hosts with one or more Gigabit (GB) Network Interface Card/Controller (NIC), list of hosts on same subnet, list of hosts that share same storage, list of hosts in the same processor family, and list of hosts compatible with Enhanced live migration (e.g., VMware Enhanced VMotion) compatibility. The above list of feature related compatibility data is exemplary and should not be construed as limiting.

[0060] Based on the host-feature compatibility analysis, the compatibility module determines if there is sufficient host-feature compatibility for hosts included on the host list with the features included on the features list to enable a cluster to be constructed that can enable the features. Thus, for instance, for a particular feature, such as fault tolerance, the compatibility module checks whether the hosts provide hardware, software and license compatibility by determining if the hosts are from a compatible processor family, the hosts operating system, BIOS features enabled, and so forth, and whether there are sufficient licenses for operation of features for each host. The compatibility module also checks to determine whether networking and storage resources in the cluster configuration database for each host is compatible with the feature requirements. Based on the compatibility analysis, the compatibility module 312 generates a ranking of each of the hosts such that the highest ranked hosts are more compatible with the requirements for enabling the features. Using the ranking, the compatibility module 312 assembles a proposed cluster of hosts for cluster construction. In one embodiment, the assembling of hosts for the proposed cluster construction is based on one or more pre-defined rules. The pre-defined rules can be based on the hosts capabilities, feature requirements or both the hosts capabilities and feature requirements. For example, one of the pre-defined rules could be to identify and select all hosts that are compatible with the requirements of the selected features. Another pre-defined rule could be to select a given feature and choosing the largest number of hosts determined

by the number of licenses for the given feature based on the compatibility analysis. Yet another rule could be to select features and choosing all hosts whose capabilities satisfy the requirements of the selected features. Another rule could be to obtain compatibility criteria from a user and selecting all features and hosts that meet those criteria. Thus, based on the pre-defined rule, the largest number of hosts that are compatible with the features are selected for forming the cluster.

[0061] Based on the compatibility analysis, a host configuration template is constructed to include the configuration information from the proposed cluster configuration of the hosts. A list of configuration settings is defined from the host configuration template associated with the proposed cluster configuration of the hosts. Each of the hosts that are compatible will have to conform to this list of cluster configuration settings. The cluster configuration settings may be created by the compatibility module **312** or a template configuration module **314** that is distinct from the compatibility module. The configuration settings include network settings, such as number of NICs, bandwidth for each NIC, etc., storage settings and hardware configuration profile, such as processor type, etc. Along with the configuration settings, the compatibility module presents a plurality of suggested adjustments to particular hosts to enable the particular hosts to become compatible with the requirements. The suggested adjustment may include guided tutorials providing information about the incompatible hosts, and steps to be taken for making the hosts compatible as part of customizing the cluster. The cluster configuration settings from the configuration template are returned for rendering on a user interface associated with the client.

[0062] In one embodiment, the user interface is provided as a page. The page is divided into a plurality of sections or page elements with each section providing additional details or tools for confirming or customizing the current cluster.

[0063] The configuration settings from a configuration template are then rendered at the user interface on the client in response to the request for cluster configuration. If the rendered configuration settings are acceptable, the information in the configuration template is committed into the configuration database for the cluster and used by the management server for configuring the hosts for the cluster. The selected hosts are compatible with the features and with each other. Configuration of hosts may include transmitting storage and network settings from the host configuration template to each of the hosts in the cluster, which is then applied to the hosts. The application of the configuration settings including network settings to the hosts may be done through a software module available at the hosts, in one embodiment of the invention. In one embodiment, a final report providing an overview of the hosts and the cluster configuration features may be generated and rendered at the client after applying the settings from the configuration template. The cluster configuration workflow concludes after successful cluster construction with the hosts.

[0064] The cluster creation process further includes creating master modules **212** for each of the clusters being created, as provided in block **408**. This is because each master module controls and monitors performance of the respective cluster. Also, in block **410**, the DUs are also installed over the workers so that the DUs can communicate with the CU in the core network. In this regard, the DUs are

installed to communicate with a tower and a respective RRU to transmit communication received therewith to the CU and vice versa.

[0065] Once the clusters are created, communication between the clusters in the data centers occurs through the towers and DUs using the clusters, as provided in block **412**. In this regard, communication is facilitated and monitored using the master modules **212**. The clusters include containers running on the clusters and the DUs are running in the containers. In this regard, when voice and data that is received through a tower is received through the RRU and DU, they are then communicated through the containerized application (e.g., kubernetes cluster) network and then routed to a corresponding location it is addressed to. In this regard, the containerized application (e.g., kubernetes cluster) network is used as a network to communicate data between the DUs and the CU and vice versa. This network may be configured as a mesh network to easily distribute data quickly as well as having easily configured containerized applications that can be customized and updated on the fly.

[0066] Accordingly, a 5G network can be established using containerized applications (e.g., kubernetes) clusters which is more stable and managed more effectively than previous systems. Workloads of clusters can be managed by the master modules so that any processing that is high on one server can be distributed to other servers over the kubernetes clusters. This is performed using the master module which is continuously and automatically monitoring the workloads and health of all of the DUs.

[0067] Although specific embodiments were described herein, the scope of the invention is not limited to those specific embodiments. The scope of the invention is defined by the following claims and any equivalents therein.

[0068] As will be appreciated by one skilled in the art, aspects of the present disclosure may be embodied as a system, a method or a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0069] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a non-transitory computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the non-transitory computer readable storage medium would include the following: a portable computer diskette, a hard disk, a radio access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a non-transitory computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0070] Aspects of the present disclosure are described above with reference to flowchart illustrations and block diagrams of methods, apparatuses (systems) and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart

illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0071] The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0072] The flowcharts and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present disclosure. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function (s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems which perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

What is claimed is:

1. A radio access network (“RAN”) system comprising:
 - a plurality of clusters created using containerized applications, wherein kubernetes cluster is configured to operate respective cell sites, wherein each cell site comprises:
 - at least one tower configured to send and receive cellular communications to and from cellular phones; and
 - a distributed unit (DU) configured to process and control communications to/from the cellular phones through the at least one tower;
 - a core network connected with the plurality of clusters over a wide area network via a master module, the core network comprising:
 - a central unit (CU) deployed remote from each of the plurality of clusters, wherein the master module manages messages from each DU via the plurality of clusters.
2. The RAN system of claim 1, wherein each of the plurality of clusters includes a server that has installed thereon the following:

an operating system;

a worker configured to communicate with the master module located at the core network; and
the DU.

3. The RAN system of claim 2, wherein the DU communicates messages between cellular phones and the at least one tower, and wherein the worker communicates data from the DU to the CU over the wide area network.

4. The RAN system of claim 2, wherein the server further comprises an additional DU for each additional tower so that there is one DU for each corresponding tower communicatively connected to the server.

5. The RAN system of claim 1, wherein the master module creates each of the plurality of clusters.

6. The RAN system of claim 1, wherein each DU is associated with a respective tower of the at least one tower so that only one DU is assigned to one tower.

7. The RAN system of claim 1, wherein the RAN system makes up a 5G network for cellular phones to communicate with each other.

8. The RAN system of claim 1, wherein the core network further comprises the master module and wherein the core network communicates over the Internet to each of the clusters.

9. The RAN system of claim 1, wherein the DU comprises computer instructions configured to receive data messages sent from an originating mobile phone through a remote radio unit of a corresponding tower so that data in the data messages can be transmitted from the DU to the CU for processing, wherein the CU comprises computer instruction configured to relay second data to a second DU for delivery of the data messages to an end mobile phone through a second corresponding tower.

10. A method for operating a radio access network (“RAN”) system comprising:

operating, via a plurality of clusters, respective cell sites, wherein each cell site comprises:

at least one tower configured to send and receive cellular communications to and from cellular phones; and

a distributed unit (DU) configured to process and control communications to/from the cellular phones through the at least one tower;

transmitting, by a first DU, data received from an originating mobile phone to a core network connected with the plurality of clusters over a wide area network via a master module, the core network comprising:

a central unit (CU) deployed remote from each of the plurality of clusters, wherein the master module manages messages from each DU via the plurality of clusters.

11. The method of claim 10, further comprising:

receiving, by a first tower, from the originating mobile phone a first data message addressed to an end mobile phone;

processing, by the CU, the first data message including determining which DU to send the first data message to;

transmitting, by the CU to a second DU over the wide area network, data for sending the first data message to the end mobile phone; and

transmitting, by the second DU to a second tower, the first data message so that the second tower can transmit the first data message to the end mobile phone.

12. The method of claim 10, wherein each of the plurality of clusters includes a server that has installed thereon the following:

- an operating system;
- a worker configured to communicate with the master module located at the core network; and
- the DU.

13. The method of claim 12, wherein the DU communicates messages between cellular phones and the at least one tower, and wherein the worker communicates data from the DU to the CU over the wide area network.

14. The method of claim 10, wherein the server further comprises an additional DU for each additional tower so that there is one DU for each corresponding tower communicatively connected to the server.

15. The method of claim 10, wherein the master module creates each of the plurality of clusters.

16. The RAN system of claim 1, wherein the RAN system makes up a 5G network for cellular phones to communicate with each other.

17. A 5G cellular network system comprising:
- a plurality of servers, each of the plurality of servers comprising:
 - a processor;
 - memory;
 - an operating system;

- a distributed unit (DU) installed in the memory and comprising computer instructions, that when executed by the processor, processes and controls communications with at least one tower to handle communications between cellular devices; and
- a worker installed in the memory, wherein the worker is configured to communicate over a wide area network to a central unit (CU) in a core network for processing the communications to/from the DU and the at least one tower.

18. The 5G cellular network system of claim 1, wherein the CU comprises a master module (1) creates each of the plurality of clusters and (2) manages messages from each DU via the plurality of clusters.

19. The RAN system of claim 1, wherein the wide area network is the Internet.

20. The RAN system of claim 1, wherein the DU comprises computer instructions configured to receive data messages sent from an originating mobile phone through a remote radio unit of a corresponding tower so that data in the data messages can be transmitted from the DU to the CU for processing, wherein the CU comprises computer instruction configured to relay second data to a second DU for delivery of the data messages to an end mobile phone through a second corresponding tower.

* * * * *