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Zufall

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(54) **5G PRB BLANKING SYSTEM WITH 5G PHONE TO PREVENT INTERFERENCE WITH SATELLITE SIGNAL TRANSMISSION**

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H04B 7/185 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H04W 72/541*** (2023.01); ***H04B 7/1851*** (2013.01); ***H04B 7/1853*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04W 72/0446*** (2013.01); ***H04W 72/1268*** (2013.01); *H04W 84/06* (2013.01)

(58) **Field of Classification Search**

CPC .. H04B 5/0073; H04B 7/1851; H04B 7/1853; H04L 5/0007; H04W 16/14; H04W 72/0446; H04W 72/1268; H04W 72/54; H04W 72/541; H04W 84/06; H04W 88/085

See application file for complete search history.

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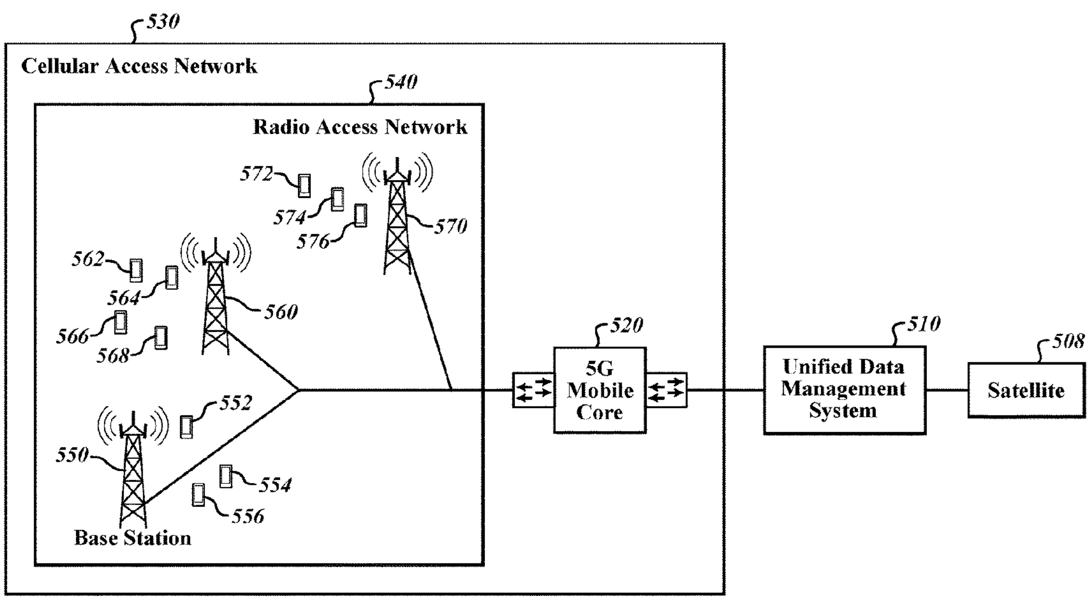
(57) **ABSTRACT**

Embodiments are directed towards systems and methods for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission. One such method includes: configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device; receiving a request to use a specified frequency at a specified time to communicate with the satellite; enabling the base station to stop download transmissions on specified frequency tones at the specified time; creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and facilitating upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

20 Claims, 7 Drawing Sheets



(51) **Int. Cl.**

H04L 5/00	(2006.01)
H04W 72/0446	(2023.01)
H04W 72/1268	(2023.01)
H04W 84/06	(2009.01)

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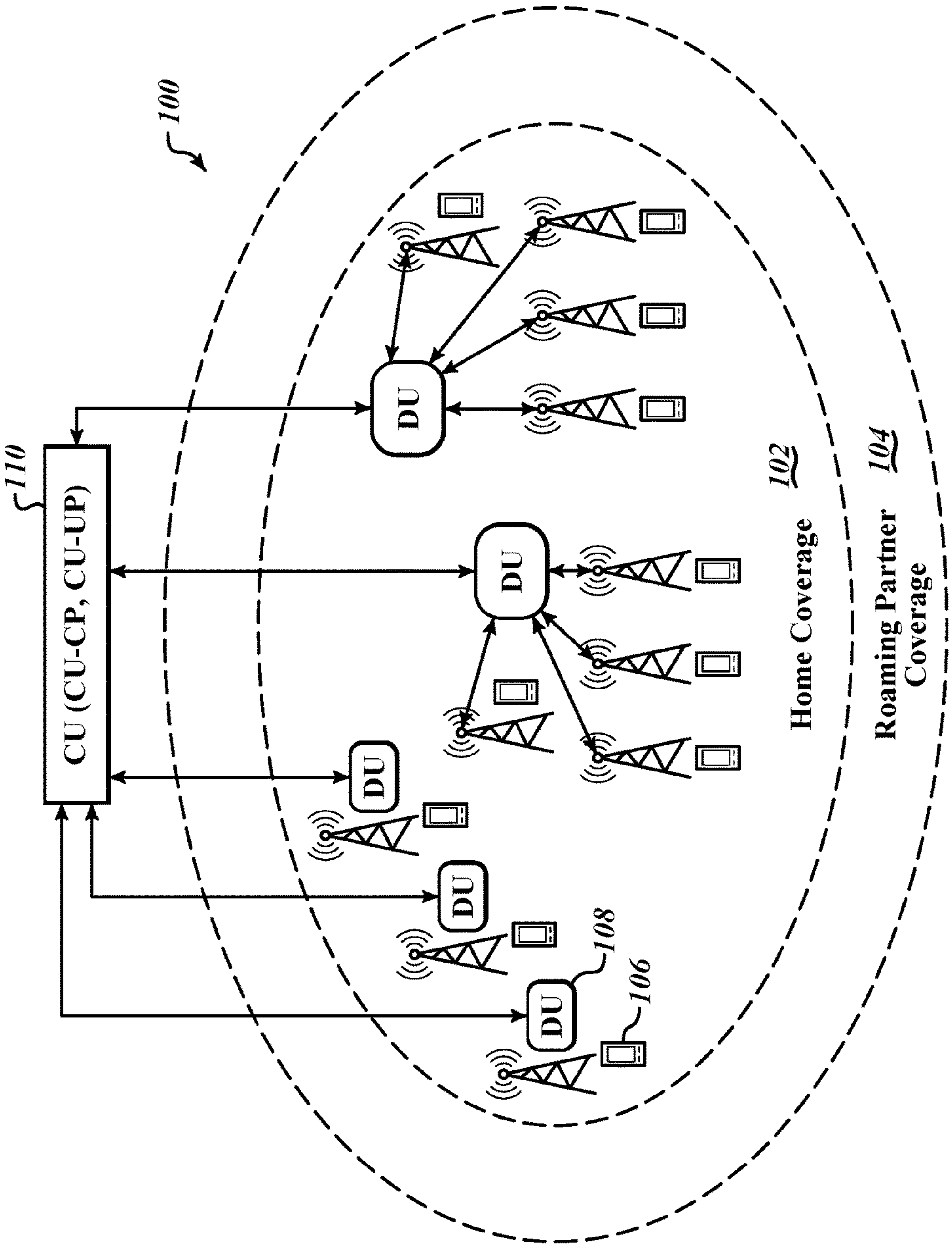
100
110
CU (CU-CP, CU-UP)
DU
DU
DU
DU
DU
108
106
Home Coverage
102
Roaming Partner Coverage
104

FIG.1

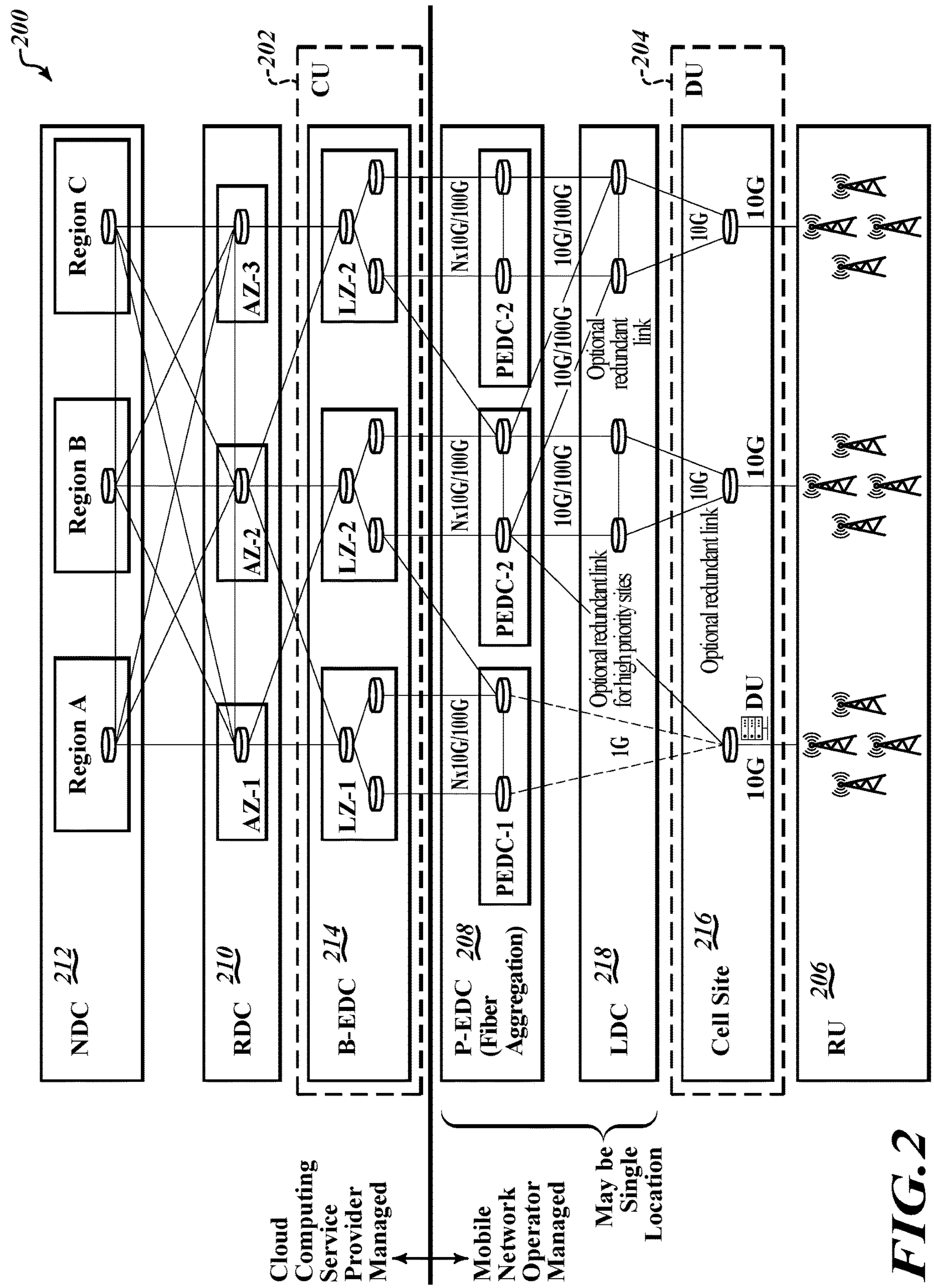
200
202
CU
204
DU
NDC 212
Region A
Region B
Region C
RDC 210
AZ-1
AZ-2
AZ-3
B-EDC 214
LZ-1
LZ-2
LZ-2
P-EDC 208 (Fiber Aggregation)
PEDC-1
PEDC-2
PEDC-2
Nx10G/100G
10G/100G
LDC 218
1G
Optional redundant link for high priority sites
Optional redundant link
Cell Site 216
10G
DU
RU 206
Cloud Computing Service Provider Managed
Mobile Network Operator Managed
May be Single Location

FIG.2

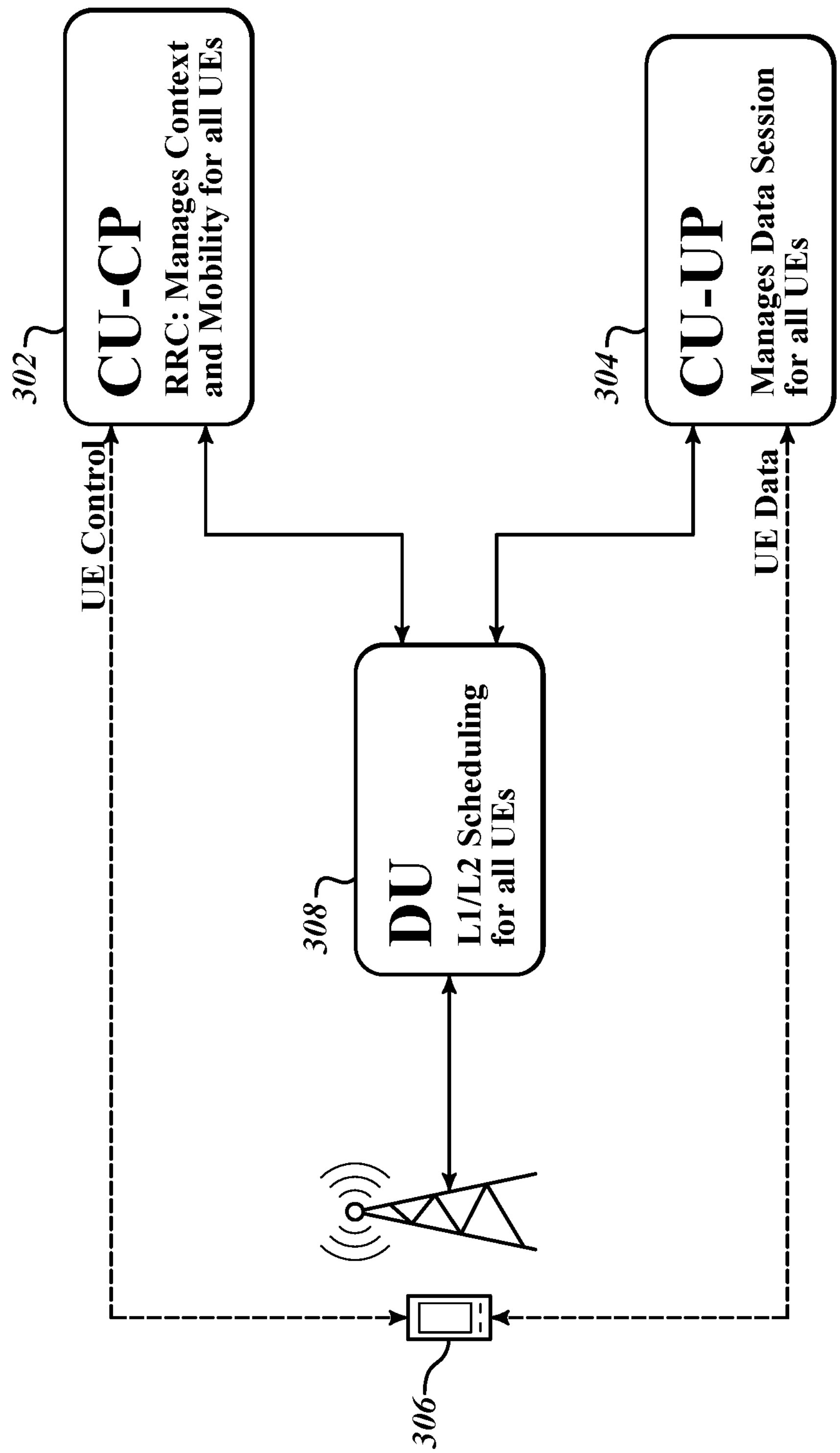
302
CU-CP
RRC: Manages Context and Mobility for all UEs
304
CU-UP
Manages Data Session for all UEs
UE Control
UE Data
308
DU
L1/L2 Scheduling for all UEs
306

FIG.3

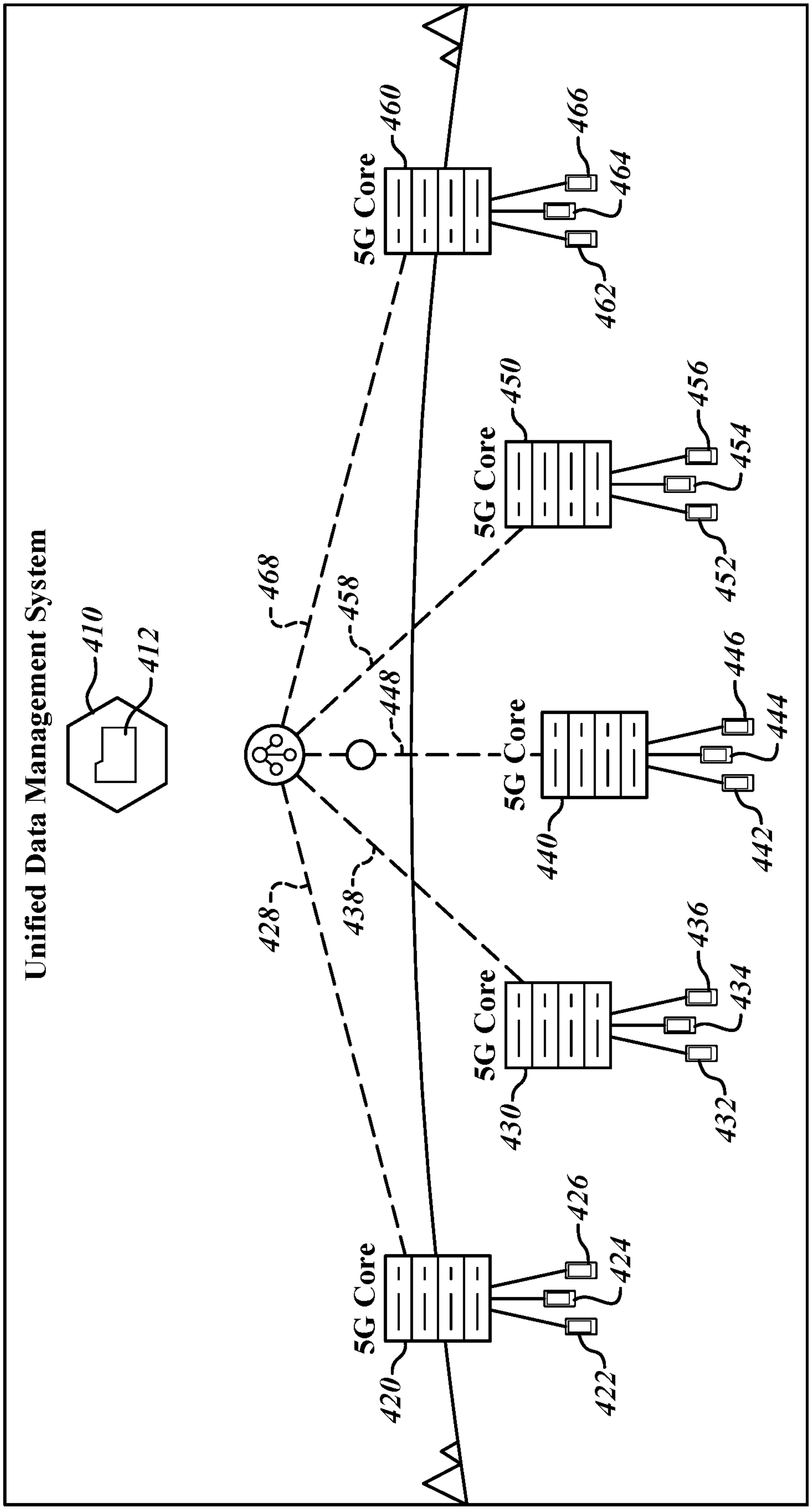
Unified Data Management System
410
412
468
458
448
438
428
5G Core
460
462
464
466
5G Core
450
452
454
456
5G Core
440
442
444
446
5G Core
430
432
434
436
5G Core
420
422
424
426

FIG.4

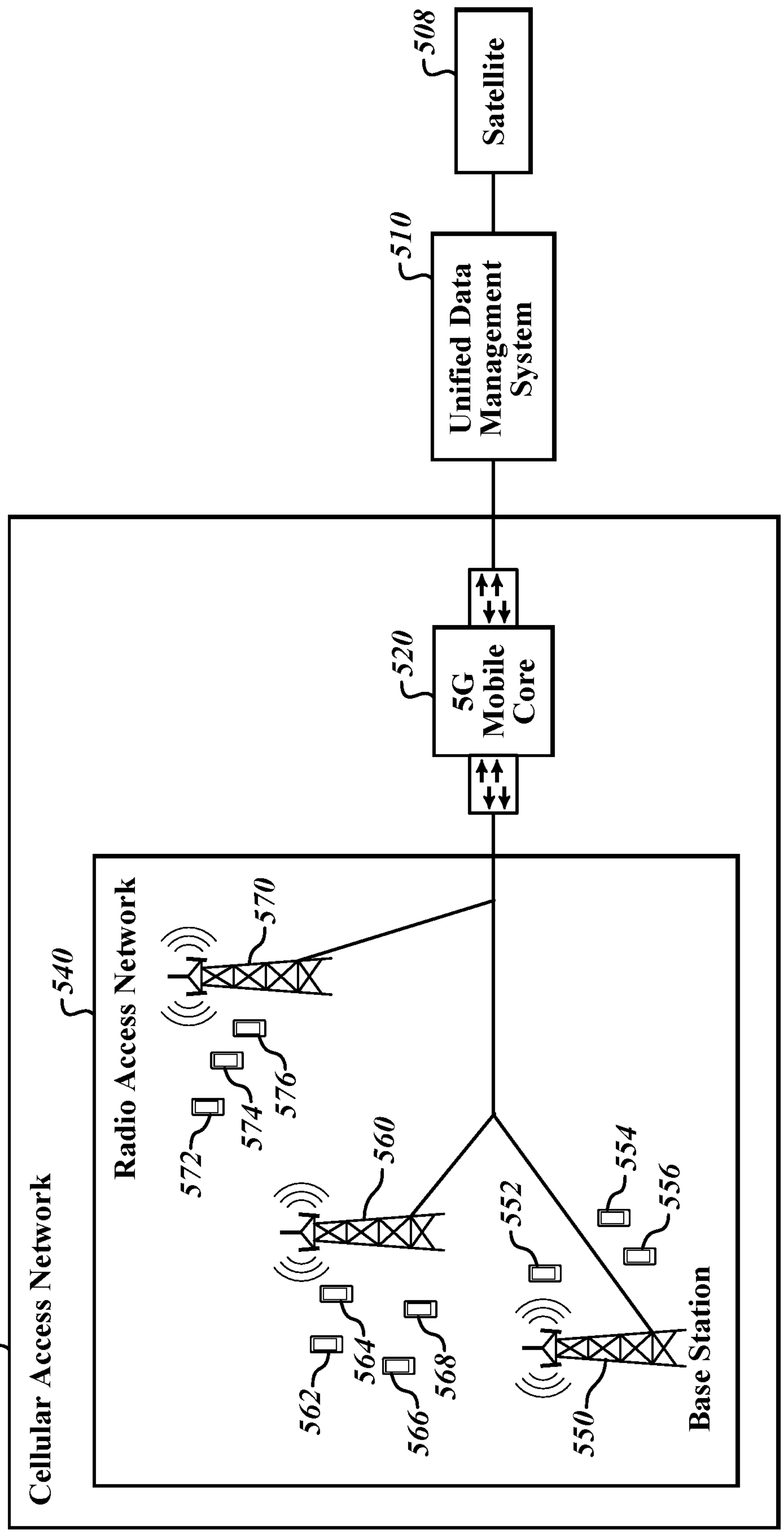
508
Satellite
510
Unified Data Management System
520
5G Mobile Core
530
Cellular Access Network
540
Radio Access Network
570
576
574
572
560
552
554
556
564
568
562
566
550
Base Station

FIG.5

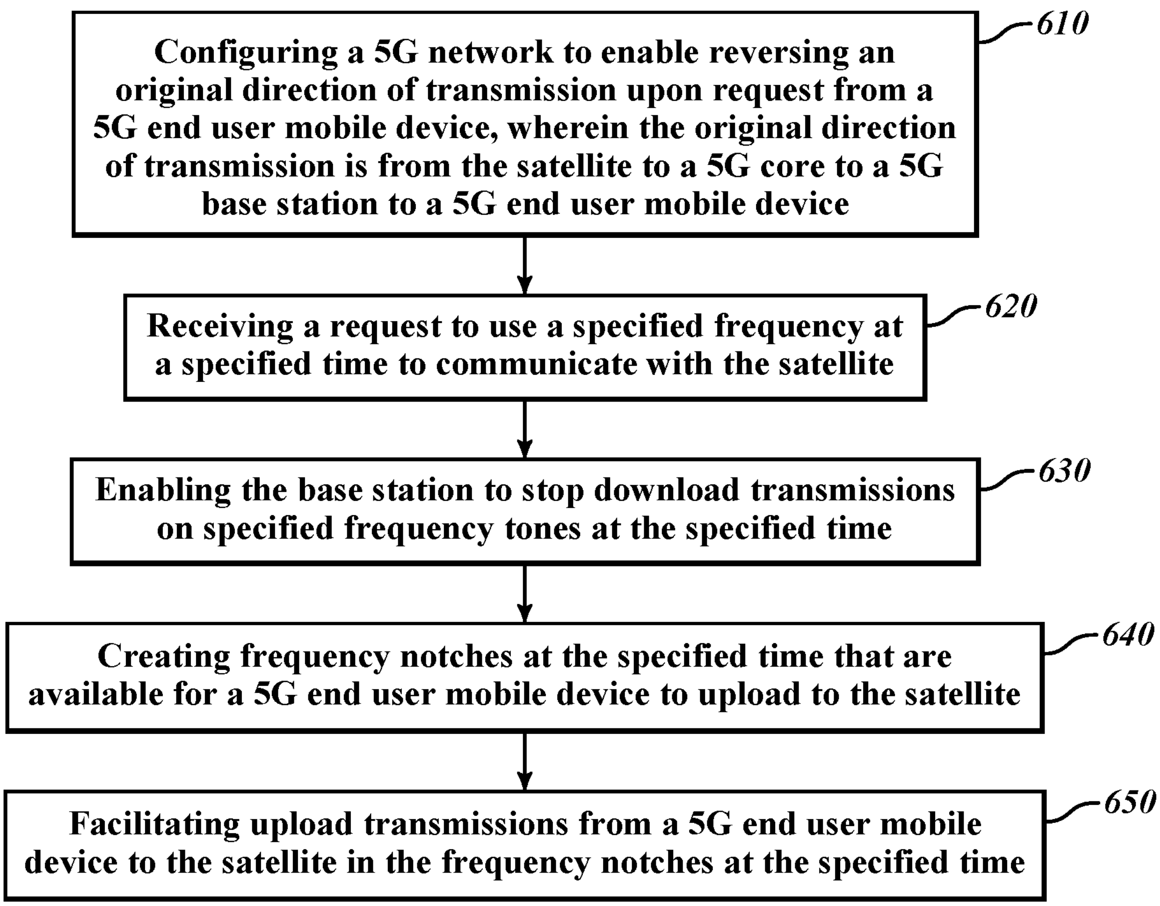
Configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from the satellite to a 5G core to a 5G base station to a 5G end user mobile device
610
Receiving a request to use a specified frequency at a specified time to communicate with the satellite
620
Enabling the base station to stop download transmissions on specified frequency tones at the specified time
630
Creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite
640
Facilitating upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time
650

FIG.6

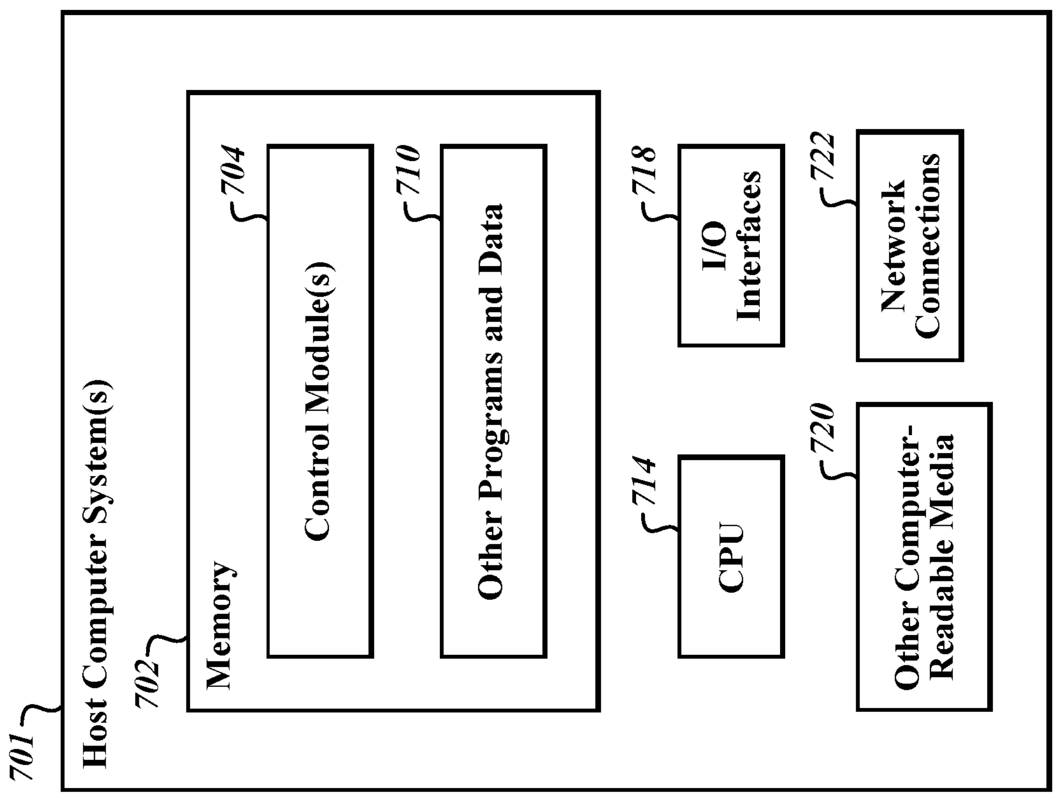
701
Host Computer System(s)
702
Memory
704
Control Module(s)
710
Other Programs and Data
714
CPU
718
I/O Interfaces
720
Other Computer-Readable Media
722
Network Connections

FIG. 7

5G PRB BLANKING SYSTEM WITH 5G PHONE TO PREVENT INTERFERENCE WITH SATELLITE SIGNAL TRANSMISSION

BACKGROUND

As the use of smart phones and Internet of Things (IoT) devices has increased, so too has the desire for more reliable, fast, and continuous transmission of content. In an effort to improve the content transmission, networks continue to improve with faster speeds and increased bandwidth. The advent and implementation of Fifth Generation (5G) wireless technology has resulted in faster speeds and increased bandwidth. Thus, minimizing interruptions in the supporting networking infrastructure is important to providing a resilient and stable network with the desired end-to-end performance. It is with respect to these and other considerations that the embodiments described herein have been made.

In some types of 5G network architecture, multiple 5G Cores are connected to a central database that manages subscriber information. During operation of the 5G network, there may be occasions when a 5G end user mobile device wants to transmit information to the satellite. This can be problematic because typically the satellite is transmitting information downward to the 5G network components. Thus, attempts by a 5G end user mobile device would typically result in interference. Such interference would be problematic for both the downward transmissions and the upward transmissions. However, an actual solution to this problem that has yet to be produced. The present disclosure addresses this and other issues.

BRIEF SUMMARY

The present disclosure relates generally to telecommunication networks, more particularly, to a 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission.

5G provides a broad range of wireless services delivered to the end user across multiple access platforms and multilayer networks. 5G is a dynamic, coherent and flexible framework of multiple advanced technologies supporting a variety of applications. 5G utilizes an intelligent architecture, with Radio Access Networks (RANs) not constrained by base station proximity or complex infrastructure. 5G enables a disaggregated, flexible, and virtual RAN with interfaces creating additional data access points.

5G network functions may be completely software-based and designed as cloud-native, meaning that they're agnostic to the underlying cloud infrastructure, allowing higher deployment agility and flexibility.

With the advent of 5G, industry experts defined how the 5G Core (5GC) network should evolve to support the needs of 5G New Radio (NR) and the advanced use cases enabled by it. The 3rd Generation Partnership Project (3GPP) develops protocols and standards for telecommunication technologies including RAN, core transport networks and service capabilities. 3GPP has provided complete system specifications for 5G network architecture which is much more service oriented than previous generations.

Multi-Access Edge Computing (MEC) is an important element of 5G architecture. MEC is an evolution in Telecommunications that brings the applications from centralized data centers to the network edge, and therefore closer to the end users and their devices. This essentially creates a shortcut in content delivery between the user and host, and the long network path that once separated them.

This MEC technology is not exclusive to 5G but is certainly important to its efficiency. Characteristics of the MEC include the low latency, high bandwidth and real time access to RAN information that distinguishes 5G architecture from its predecessors. This convergence of the RAN and core networks enables operators to leverage new approaches to network testing and validation. 5G networks based on the 3GPP 5G specifications provide an environment for MEC deployment. The 5G specifications define the enablers for edge computing, allowing MEC and 5G to collaboratively route traffic. In addition to the latency and bandwidth benefits of the MEC architecture, the distribution of computing power better enables the high volume of connected devices inherent to 5G deployment and the rise of IoT.

The 3rd Generation Partnership Project (3GPP) develops protocols for mobile telecommunications and has developed a standard for 5G. The 5G architecture is based on what is called a Service-Based Architecture (SBA), which leverages IT development principles and a cloud-native design approach. In this architecture, each network function (NF) offers one or more services to other NFs via Application Programming Interfaces (API). Network function virtualization (NFV) decouples software from hardware by replacing various network functions such as firewalls, load balancers and routers with virtualized instances running as software. This eliminates the need to invest in many expensive hardware elements and can also accelerate installation times, thereby providing revenue generating services to the customer faster.

NFV enables the 5G infrastructure by virtualizing appliances within the 5G network. This includes the network slicing technology that enables multiple virtual networks to run simultaneously. NFV may address other 5G challenges through virtualized computing, storage, and network resources that are customized based on the applications and customer segments. The concept of NFV extends to the RAN through, for example, network disaggregation promoted by alliances such as O-RAN. This enables flexibility, provides open interfaces and open-source development, ultimately to ease the deployment of new features and technology with scale. The O-RAN ALLIANCE objective is to allow multi-vendor deployment with off-the shelf hardware for the purposes of easier and faster inter-operability. Network disaggregation also allows components of the network to be virtualized, providing a means to scale and improve user experience as capacity grows. The benefits of virtualizing components of the RAN provide a means to be more cost effective from a hardware and software viewpoint especially for IoT applications where the number of devices is in the millions.

The 5G New Radio (5G NR) RAN comprises a set of radio base stations (each known as Next Generation Node B (gNB)) connected to the 5G Core (5GC) and to each other. The gNB incorporates three main functional modules: the Centralized Unit (CU), the distributed Unit (DU), and the Radio Unit (RU), which can be deployed in multiple combinations. The primary interface is referred to as the F1 interface between DU and CU and are interoperable across vendors. The CU may be further disaggregated into the CU user plane (CU-UP) and CU control plane (CU-CP), both of which connect to the DU over F1-U and F1-C interfaces respectively. This 5G RAN architecture is described in 3GPP TS 38.401 V16.8.0 (2021-12). Each network function (NF) is formed by a combination of small pieces of software code called microservices.

Briefly stated, one or more methods for 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission are disclosed. Some such methods include: providing, by a mobile network operator, a distributed unit (DU) of a fifth-generation New Radio (5G NR) cellular telecommunication network radio access network (RAN) that is served by a particular 5G NR cellular site base station, wherein the DU: is associated with a primary 5G NR Next Generation Node B (gNB) identified by a primary identifier (ID); and is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G NR primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID; configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from the satellite to a 5G Core to a 5G base station to a 5G end user mobile device; receiving a request to use a specified frequency at a specified time to communicate with the satellite; enabling the base station to stop download transmissions on specified frequency tones at the specified time; creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and facilitating upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

In some embodiments of the methods for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, the method further includes connecting an individual 5G end user mobile device to an associated 5G Core using an IMSI (International Mobile Subscriber Identifier) number. In another aspect of some embodiments, the system further includes providing a Unified Data Management system that includes a Distributed Subscriber Database and connects to a plurality of 5G Cores, wherein each 5G Core in turn connects to the primary gNB, and wherein the primary gNB in turn connects to a plurality of individual 5G end user mobile devices. In still another aspect of some embodiments, the receiving of the request to use the specified frequency at the specified time to communicate with the satellite is made by a 5G Core, a 5G base station, or a 5G end user mobile device. In yet another aspect of some embodiments, the system further includes requesting a base station in the primary gNB to reverse a direction of transmission. Also, in one or more aspects of some embodiments, the system further includes providing dynamic 5G PRB blanking reconfiguration of frequency notches. Furthermore, in some embodiments, the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

In other embodiments, one or more systems for 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission are disclosed. The system includes: a memory that stores computer executable instructions; and a processor that executes the computer executable instructions to: provide, by a mobile network operator, a distributed unit (DU) of a fifth-generation New Radio (5G NR) cellular telecommunication network radio access network (RAN) that is served by a particular 5G NR cellular site base station, wherein the DU: is associated with a primary 5G NR Next Generation Node B (gNB) identified by a primary identifier (ID); and is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G NR primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID; configure a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from the satellite to a 5G Core to a 5G base station to a 5G end user mobile device; receive a request to use a specified frequency at a specified time to communicate with the satellite; enable the base station to stop download transmissions on specified frequency tones at the specified time; create frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and facilitate upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

In some embodiments of the system for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, the system further includes connecting an individual 5G end user mobile device to an associated 5G Core using an IMSI (International Mobile Subscriber Identifier) number. In another aspect of some embodiments, the system further includes providing a Unified Data Management system that includes a Distributed Subscriber Database and connects to a plurality of 5G Cores, wherein each 5G Core in turn connects to the primary gNB, and wherein the primary gNB in turn connects to a plurality of individual 5G end user mobile devices. In still another aspect of some embodiments, the receiving of the request to use the specified frequency at the specified time to communicate with the satellite is made by a 5G Core, a 5G base station, or a 5G end user mobile device. In yet another aspect of some embodiments, the processor that executes the computer-executable instructions further causes the processor to: request a base station in the primary gNB to reverse a direction of transmission. Also, in one or more aspects of some embodiments, the system includes dynamic 5G PRB blanking reconfiguration of frequency notches. Furthermore, in some embodiments, the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

Additionally, in other embodiments, one or more non-transitory computer-readable storage mediums are disclosed. The one or more non-transitory computer-readable storage mediums have computer-executable instructions stored thereon that, when executed by a processor, cause the processor to: provide, by a mobile network operator, a distributed unit (DU) of a fifth-generation New Radio (5G NR) cellular telecommunication network radio access network (RAN) that is served by a particular 5G NR cellular site base station, wherein the DU: is associated with a primary 5G NR Next Generation Node B (gNB) identified by a primary identifier (ID); and is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G NR primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID; configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from the satellite to a 5G Core to a 5G base station to a 5G end user mobile device; requesting to use a specified frequency at a specified time to communicate with the satellite; enabling the base station to stop download transmissions on specified frequency tones at the specified time; creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and facilitating upload transmissions from a 5G end user mobile device to the satellite in the specified notches at the specified time.

In some embodiments, the computer-executable instructions, when executed by a processor, further cause the processor to: connect an individual 5G end user mobile device to an associated 5G Core using an IMSI (International Mobile Subscriber Identifier) number. In another aspect of some embodiments, the computer-executable instructions, when executed by a processor, further cause the processor to: provide a Unified Data Management system that includes a Distributed Subscriber Database and connects to a plurality of 5G Cores, wherein each 5G Core in turn connects to the primary gNB, and wherein the primary gNB in turn connects to a plurality of individual 5G end user mobile devices. In still another aspect of some embodiments, the computer-executable instructions, when executed by a processor, further cause the processor to: request a base station in the primary gNB to reverse a direction of transmission. In yet another aspect of some embodiments, the system further includes dynamic 5G PRB blanking reconfiguration of frequency notches. Furthermore, in some embodiments, the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Non-limiting and non-exhaustive embodiments are described with reference to the following drawings. In the drawings, like reference numerals refer to like parts throughout the various figures unless otherwise specified.

For a better understanding of the present invention, reference will be made to the following Detailed Description, which is to be read in association with the accompanying drawings:

FIG. **1** illustrates a context diagram of an environment in which a system for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission may be implemented in accordance with embodiments described herein.

FIG. **2** illustrates a diagram of an example system architecture overview of a system in which the environment of FIG. **1** may be implemented in accordance with embodiments described herein.

FIG. **3** illustrates a diagram showing connectivity between certain telecommunication network components during cellular telecommunication.

FIG. **4** illustrates a system that includes a central distributed subscriber database, a plurality of connected 5G Cores, and a plurality of mobile end user devices connected to each 5G Core.

FIG. **5** illustrates a system that includes a satellite, Unified Data Management system, one or more connected 5G Cores, a plurality of base stations, and a plurality of mobile end user devices.

FIG. **6** is a logic diagram showing number sequencing data flow between certain telecommunication network components during 5G PRB blanking.

FIG. **7** shows a system diagram that describes an example implementation of a computing system(s) for implementing embodiments described herein.

DETAILED DESCRIPTION

The following description, along with the accompanying drawings, sets forth certain specific details in order to provide a thorough understanding of various disclosed embodiments. However, one skilled in the relevant art will recognize that the disclosed embodiments may be practiced in various combinations, without one or more of these specific details, or with other methods, components, devices, materials, etc. In other instances, well-known structures or components that are associated with the environment of the present disclosure, including but not limited to the communication systems and networks, have not been shown or described in order to avoid unnecessarily obscuring descriptions of the embodiments. Additionally, the various embodiments may be methods, systems, media, or devices. Accordingly, the various embodiments may be entirely hardware embodiments, entirely software embodiments, or embodiments combining software and hardware aspects.

Throughout the specification, claims, and drawings, the following terms take the meaning explicitly associated herein, unless the context clearly dictates otherwise. The term "herein" refers to the specification, claims, and drawings associated with the current application. The phrases "in one embodiment," "in another embodiment," "in various embodiments," "in some embodiments," "in other embodiments," and other variations thereof refer to one or more features, structures, functions, limitations, or characteristics of the present disclosure, and are not limited to the same or different embodiments unless the context clearly dictates otherwise. As used herein, the term "or" is an inclusive "or" operator, and is equivalent to the phrases "A or B, or both" or "A or B or C, or any combination thereof," and lists with additional elements are similarly treated. The term "based on" is not exclusive and allows for being based on additional features, functions, aspects, or limitations not described, unless the context clearly dictates otherwise. In addition, throughout the specification, the meaning of "a," "an," and "the" include singular and plural references.

FIG. **1** illustrates a context diagram of an environment for a 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission may be implemented in accordance with embodiments described herein.

A given area **100** will mostly be covered by two or more mobile network operators' wireless networks. Generally, mobile network operators have some roaming agreements that allow users to roam from home network to partner network under certain conditions, shown in FIG. **1** as home coverage area **102** and roaming partner coverage area **104**. Operators may configure the mobile user's device, referred to herein as user equipment (UE), such as UE **106**, with priority and a timer to stay on the home network coverage area **102** versus the roaming partner network coverage area **104**. If a UE (e.g., UE **106**) cannot find the home network coverage area **102**, the UE will scan for a roaming network after a timer expiration (6 minutes, for example). This could have significant impact on customer experience in case of a catastrophic failure in the network. As shown in FIG. **1**, a 5G RAN is split into DUs (e.g., DU **108**) that manage scheduling of all the users and a CU that manages the mobility and radio resource control (RRC) state for all the UEs. The RRC is a layer within the 5G NR protocol stack. It exists only in the control plane, in the UE and in the gNB. The behavior and functions of RRC are governed by the current state of RRC. In 5G NR, RRC has three distinct states: RRC_IDLE, RRC_CONNECTED and RRC_INACTIVE.

FIG. 2 illustrates a diagram of an example system architecture overview of a system **200** in which the environment of FIG. **1** may be implemented in accordance with embodiments described herein.

As shown in FIG. **2**, the radio unit (RU) **206** converts radio signals sent to and from the antenna into a digital signal for transmission over packet networks. It handles the digital front end (DFE) and the lower physical (PHY) layer, as well as the digital beamforming functionality.

The DU **204** may sit close to the RU **206** and runs the radio link control (RLC), the Medium Access Control (MAC) sublayer of the 5G NR protocol stack, and parts of the PHY layer. The MAC sublayer interfaces to the RLC sublayer from above and to the PHY layer from below. The MAC sublayer maps information between logical and transport channels. Logical channels are about the type of information carried whereas transport channels are about how such information is carried. This logical node includes a subset of the gNB functions, depending on the functional split option, and its operation is controlled by the CU **202**.

The CU **202** is the centralized unit that runs the RRC and Packet Data Convergence Protocol (PDCP) layers. A gNB may comprise a CU and one DU connected to the CU via Fs-C and Fs-U interfaces for control plane (CP) and user plane (UP), respectively. A CU with multiple DUs will support multiple gNBs. The split architecture enables a 5G network to utilize different distribution of protocol stacks between CU **202** and DU **204** depending on mid-haul availability and network design. The CU **202** is a logical node that includes the gNB functions like transfer of user data, mobility control, RAN sharing, positioning, session management, etc., with the exception of functions that may be allocated exclusively to the DU **204**. The CU **202** controls the operation of several DUs **204** over the mid-haul interface.

As mentioned above, 5G network functionality is split into two functional units: the DU **204**, responsible for real time 5G layer 1 (L1) and 5G layer 2 (L2) scheduling functions, and the CU **202** responsible for non-real time, higher L2 and 5G layer 3 (L3). As shown in FIG. **2**, the DU's server and relevant software may be hosted on a cell site **216** itself or can be hosted in an edge cloud (local data center (LDC) **218** or central office) depending on transport availability and fronthaul interface. The CU's server and relevant software may be hosted in a regional cloud data center or, as shown in FIG. **2**, in a breakout edge data center (B-EDC) **214**. As shown in FIG. **2**, the DU **204** may be provisioned to communicate via a pass-through edge data center (P-EDC) **208**. The P-EDC **208** may provide a direct circuit fiber connection from the DU directly to the primary cloud availability zone (e.g., B-EDC **214**) hosting the CU **202**. In some embodiments, the LDC **218** and P-EDC **208** may be co-located or in a single location. The CU **202** may be connected to a regional cloud data center (RDC) **210**, which in turn may be connected to a national cloud data center (NDC) **212**. In the example embodiment, the P-EDC **208**, the LDC **218**, the cell site **216** and the RU **206** may all be managed by the mobile network operator and the B-EDC **214**, the RDC **210** and the NDC **212** may all be managed by a cloud computing service provider. According to various embodiments, the actual split between DU and RU may be different depending on the specific use-case and implementation.

FIG. **3** is a diagram showing connectivity between certain telecommunication network components during cellular telecommunication in accordance with embodiments described herein.

The central unit control plane (CU-CP), for example of CU **110** of FIG. **1** or CU **202** of FIG. **2**, primarily manages control processing of DUs, such as DU **308**, and UEs, such as UE **302**. The CU-CP **302** hosts RRC and the control-plane part of the PDCP protocol. CU-CP **302** manages the mobility and radio resource control (RRC) state for all the UEs. The RRC is a layer within the 5G NR protocol stack and manages context and mobility for all UEs. The behavior and functions of RRC are governed by the current state of RRC. In 5G NR, RRC has three distinct states: RRC_IDLE, RRC_CONNECTED and RRC_INACTIVE. The CU-CP **302** terminates the E1 interface connected with the central unit user plane (CU-UP) **304** and the F1-C interface connected with the DU **308**. The DU **308** maintains a constant heartbeat with CU **302**. The CU-UP **304** manages the data sessions for all UEs **306** and hosts the user plane part of the PDCP protocol. The CU-UP **304** terminates the E1 interface connected with the CU-CP and the F1-U interface connected with the DU **308**.

A virtual private cloud is a configurable pool of shared resources allocated within a public cloud environment. The VPC provides isolation between one VPC user and all other users of the same cloud, for example, by allocation of a private IP subnet and a virtual communication construct (e.g., a VLAN or a set of encrypted communication channels) per user. In some embodiments, this 5G network leverages the distributed nature of 5G cloud-native network functions and cloud flexibility, which optimizes the placement of 5G network functions for optimal performance based on latency, throughput and processing requirements.

In some embodiments, the network architecture utilizes a logical hierarchical architecture consisting of National Data Centers (NDCs), Regional Data Centers (RDCs) and Breakout Edge Data Centers (BEDCs), to accommodate the distributed nature of 5G functions and the varying requirements for service layer integration. In one or more embodiments, BEDCs are deployed in Local Zones hosting 5G NFs that have strict latency budgets. They may also be connected with Passthrough Edge Data Centers (PEDC), which serve as an aggregation point for all Local Data Centers (LDCs) and cell sites in a particular market. BEDCs also provide internet peering for 5G data service.

In one or more embodiments, an O-RAN network may be implemented that includes an RU (Radio Unit), which is deployed on towers and a DU (Distributed Unit), which controls the RU. These units interface with the Centralized Unit (CU), which is hosted in the BEDC at the Local Zone. These combined pieces provide a full RAN solution that handles all radio level control and subscriber data traffic.

In some embodiments, the User Plane Function (Data Network Name (DNN)) is collocated in the BEDC, which anchors user data sessions and routes to the internet. In another aspect, the BEDCs leverage local internet access available in Local Zones, which allows for a better user experience while optimizing network traffic utilization.

In one of more embodiments, the Regional Data Centers (RDCs) are hosted in the Region across multiple availability zones. The RDCs host 5G subscribers' signaling processes such as authentication and session management as well as voice for 5G subscribers. These workloads can operate with relatively high latencies, which allows for a centralized deployment throughout a region, resulting in cost efficiency and resiliency. For high availability, multiple RDCs are deployed in a region, each in a separate Availability Zone (AZ) to ensure application resiliency and high availability.

In another aspect of some embodiments, an AZ is one or more discrete data centers with redundant power, networking, and connectivity in a Region. In some embodiments, AZs in a Region are interconnected with high-bandwidth and low-latency networking over a fully redundant, dedicated metro fiber, which provides high-throughput, low-latency networking between AZs.

Cloud Native Functions (CNFs) deployed in the RDC utilize a high speed backbone to failover between AZs for application resiliency. CNFs like AMF and SMF, which are deployed in RDC, continue to be accessible from the BEDC in the Local Zone in case of an AZ failure. They serve as the backup CNF in the neighboring AZ and would take over and service the requests from the BEDC.

In this embodiment of the 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, dedicated VPCs are implemented for each Data Center type (e.g., local data center, breakout edge data center, regional data center, national data center, and the like). In some such embodiments, the national data center VPC stretches across multiple Availability Zones (AZs). In another aspect of some embodiments, two or more AZs are implemented per region of the cloud computing service provider.

Some embodiments of the 5G Core network functions require support for advanced routing capabilities inside VPC and across VPCs (e.g., UPF, SMF and ePDG). These functions rely on routing protocols such as BGP for route exchange and fast failover (both stateful and stateless). To support these requirements, virtual routers are deployed on EC2 to provide connectivity within and across VPCs, as well as back to the on-prem network.

FIG. **4** illustrates a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission that includes a Unified Data Management System **410**, central distributed subscriber database **412**, a plurality of connected 5G Cores **420**, **430**, **440**, **450**, and **460**, and a plurality of mobile end user devices **422**, **424**, **426**, **432**, **434**, **436**, **442**, **444**, **446**, **452**, **454**, **456**, **462**, **464**, and **466**. The central distributed subscriber database **412** is contained in the Unified Data Management System **410**. The plurality of connected 5G Cores **420**, **430**, **440**, **450**, and **460** are each connected to the central distributed subscriber database **412** by connection lines **428**, **438**, **448**, **458**, and **468**. The connection lines **428**, **438**, **448**, **458**, and **468** transmit voice and data information as well as control information, between the central distributed subscriber database **412** and the plurality of connected 5G Cores **420**, **430**, **440**, **450**, and **460**. Additionally, the plurality of mobile end user devices **422**, **424**, **426**, **432**, **434**, **436**, **442**, **444**, **446**, **452**, **454**, **456**, **462**, **464**, and **466** are each connected to their respective 5G Cores **420**, **430**, **440**, **450**, and **460**. In some embodiments this is a direct connection, while in other embodiments, there are additional telephony components (e.g., base stations, antennas, receivers, and the like) that bridge the connection between the plurality of mobile end user devices **422**, **424**, **426**, **432**, **434**, **436**, **442**, **444**, **446**, **452**, **454**, **456**, **462**, **464**, and **466** that are each connected to their respective 5G Cores **420**, **430**, **440**, **450**, and **460**.

Referring now to FIG. **5**, some embodiments of a 5G network architecture include a satellite **508**, a Unified Data Management System **510**, one or more 5G Cores **520**, a Cellular Access Network **530**, a 5G Radio Access Network **540**, a plurality of Base Stations **550**, **560**, **570**, and a plurality of 5G End User Mobile Devices **552**, **554**, **556**, **562**, **564**, **566**, **568**, **572** **574**, and **576**. As described above (and shown in FIG. **1**), the 5G RAN is split into DUs (e.g., DU **108**) that manage scheduling of all the users, and a CU that manages the mobility and radio resource control (RRC) state for all the UEs. Referring again to FIG. **5**, the 5G RAN **540** corresponds to a distributed collection of Base Stations **550**, **560**, **570**. As noted above, in 5G architecture the distributed collection of Base Stations **550**, **560**, **570** may be referred to as gNB.

The 5G Core **520** (which is sometimes referred to as a Next Generation Core) includes several functionalities that serves several purposes. Such functionalities include connectivity for data and voice services, ensuring uninterrupted service for users of the 5G end user mobile devices **552**, **554**, **556**, **562**, **564**, **566**, **568**, **572**, **574**, and **576**, and billing services. As shown in FIG. **5**, the 5G Core **520** is part of the architecture of the 5G cellular access network **530**. The 5G Core **520** provides an access bridge between the 5G RAN **540** and the Unified Data Management System **510**, which in turn is in communication with the satellite **508**. In some embodiments of the 5G PRB blanking system, each 5G Core **520** services a specific geographically area, such as a city or portion of a metropolitan area. While not shown in FIG. **5**, the associated 5G RAN **540** could service dozens or hundreds of Base Stations **550**, **560**, **570**.

In one or more embodiments, a 5G PRB blanking system with 5G end user mobile devices is disclosed. Such system and methods prevent interference with satellite signal transmission due to the 5G PRB blanking system. Typically, the satellite **508** sends a transmission to the Unified Data Management System **510**, which in turn forwards information to the one or more 5G Cores **520**, which again in turn forwards information to the plurality of Base Stations **550**, **560**, **570**, and finally to an 5G end user mobile device. In some embodiments, the 5G PRB blanking system configures a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device.

In another aspect of the 5G PRB blanking system, the system receives a request to use a specified frequency at a specified time to communicate with the satellite **508**. The 5G PRB blanking system also enables the Base Stations **550**, **560**, **570** to stop downloading transmissions on specified frequency tones at the specified time. Next, in response to the request, the 5G PRB blanking system creates frequency notches at the specified time that are available for a 5G end user mobile device **552** to upload to the satellite **508**. Additionally, the 5G PRB blanking system facilitates upload transmissions from a 5G end user mobile device **552** to the satellite **508** in the frequency notches at the specified time.

In some embodiments of the 5G PRB blanking system, the receiving of the request to use the specified frequency at the specified time to communicate with the satellite **508** is made by a 5G Core **520**, a 5G base station **550**, or a 5G end user mobile device **552**. In another aspect of some embodiments, the 5G PRB blanking system requests a Base Stations **550**, **560**, or **570** in the primary gNB to reverse a direction of transmission.

In other embodiments of the 5G PRB blanking system, the system provides dynamic 5G PRB blanking reconfiguration of frequency notches. Furthermore, in some embodiments of the 5G PRB blanking system, the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device **552** to upload to the satellite **508**. In some embodiments, min-slots may be used to improve scheduling and reduce latency. For example, the gNB may schedule mini-slot-based transmissions in the Uplink Pilot Time Slot (UpPTS) region of a subframe.

A functionality in 5G New Radio (NR) is a feature known as bandwidth parts (BWPs). A Bandwidth Part (BWP) is a contiguous set of physical resource blocks (PRBs) on a given carrier. These resource blocks are selected from a contiguous subset of the common resource blocks. Typically, in a 5G environment, the entire available bandwidth is very large so the band may be broken up into parts for use by certain devices. For this reason, Bandwidth Parts may sometime be referred to as RAN slicing. Bandwidth Parts enable more flexibility in how resources are assigned in a given carrier. Specifically, multiple, different signal types may be sent in a given bandwidth. Most 5G Base Stations **550**, **560**, or **570** can utilize the wider bandwidths that are available in 5G. However, most 5G end user mobile device **552** are not be able to use the larger available bandwidths supported by the 5G Base Stations **550**, **560**, or **570**. Bandwidth Parts enable multiplexing of different signals and signal types for better utilization of the spectrum and improved power utilization by the 5G end user mobile devices **552**, **554**, **556**, **562**, **564**, **566**, **568**, **572**, **574**, and **576**, as well as the optimizing of frequency notch scheduling for dynamic 5G PRB blanking.

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation format that may be implemented for 5G New Radio in some embodiments. OFDM is an efficient modulation format used in modern wireless communication systems including 5G. OFDM combines the benefits of Quadrature Amplitude Modulation (QAM) and Frequency Division Multiplexing (FDM) to produce a high-data-rate communication system. By employing the OFDM modulation format, bandlimited orthogonal signals can be combined while avoiding interchannel interference. Notably, OFDM is enabled by the use of the Inverse Fast Fourier Transform (IFFT) to efficiently create the time domain waveform from the array of modulated subcarriers. Therefore, in some embodiments of the 5G PRB blanking, OFDM may be implemented to help prevent uplink signals of a 5G end user mobile device (or other uplink transmitting component) from interfering with downlink signals from a satellite **508** (or other downlink transmitting component).

FIG. **6** is a logic diagram showing a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission. As shown in FIG. **6**, at operation **610**, a 5G network is configured to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from the satellite to a 5G core to a 5G base station to a 5G end user mobile device. At operation **620**, a request is received to use a specified frequency at a specified time to communicate with the satellite. At operation **630**, the base station is enabled to stop download transmissions on specified frequency tones at the specified time. At operation **640**, frequency notches are created at the specified time that are available for a 5G end user mobile device to upload to the satellite. At operation **650**, upload transmissions are facilitated from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

In some embodiments of a 5G PRB blanking system to prevent interference with satellite signal transmission, each individual mobile end user device **422**, **424**, **426**, **432**, **434**, **436**, **442**, **444**, **446**, **452**, **454**, **456**, **462**, **464**, and **466** is associated with its associated 5G Core **420**, **430**, **440**, **450**, and **460** using an IMSI (International Mobile Subscriber Identifier) number. An IMSI is a unique number associated with Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) network mobile phone users. As such, the IMSI is a unique number that identifies a mobile end user that is a subscriber to the carrier network.

In another aspect of some embodiments of the system, a mobile subscriber of each individual mobile end user device is identified by its SIM (Subscriber Identity Module) card. A SIM card is a smart card inside a mobile phone that includes an identification number that is unique to the owner of the mobile end user device. The SIM card may store personal data and prevent operation if it is removed. The SIM card may also include an authentication key that is used to authenticate the owner of the mobile end user device. Additionally, the SIM card includes a processor, memory, and security circuits.

FIG. **7** shows a system diagram that describes an example implementation of a computing system(s) for implementing embodiments described herein. The functionality described herein for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, can be implemented either on dedicated hardware, as a software instance running on dedicated hardware, or as a virtualized function instantiated on an appropriate platform, e.g., a cloud infrastructure. In some embodiments, such functionality may be completely software-based and designed as cloud-native, meaning that they're agnostic to the underlying cloud infrastructure, allowing higher deployment agility and flexibility.

In particular, shown is example host computer system(s) **701**. For example, such computer system(s) **701** may represent those in various data centers and cell sites shown and/or described herein that host the functions, components, microservices and other aspects described herein to implement a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission. In some embodiments, one or more special-purpose computing systems may be used to implement the functionality described herein. Accordingly, various embodiments described herein may be implemented in software, hardware, firmware, or in some combination thereof. Host computer system(s) **701** may include memory **702**, one or more central processing units (CPUs) **714**, I/O interfaces **718**, other computer-readable media **720**, and network connections **722**.

Memory **702** may include one or more various types of non-volatile and/or volatile storage technologies. Examples of memory **702** may include, but are not limited to, flash memory, hard disk drives, optical drives, solid-state drives, various types of random-access memory (RAM), various types of read-only memory (ROM), other computer-readable storage media (also referred to as processor-readable storage media), or the like, or any combination thereof. Memory **702** may be utilized to store information, including computer-readable instructions that are utilized by CPU **714** to perform actions, including those of embodiments described herein.

Memory **702** may have stored thereon control module(s) **704**. The control module(s) **704** may be configured to implement and/or perform some or all of the functions of the systems, components and modules described herein for a 5G PRB blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission. Memory **702** may also store other programs and data **710**, which may include rules, databases, application programming interfaces (APIs), software platforms, cloud computing service software, network management software, network orchestrator software, network functions (NF), AI or ML programs or models to perform the functionality described herein, user interfaces, operating systems, other network management functions, other NFs, etc.

Network connections **722** are configured to communicate with other computing devices to facilitate the functionality described herein. In various embodiments, the network connections **722** include transmitters and receivers (not illustrated), cellular telecommunication network equipment and interfaces, and/or other computer network equipment and interfaces to send and receive data as described herein, such as to send and receive instructions, commands and data to implement the processes described herein. I/O interfaces **718** may include a video interface, other data input or output interfaces, or the like. Other computer-readable media **720** may include other types of stationary or removable computer-readable media, such as removable flash drives, external hard drives, or the like.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

The invention claimed is:

1. A method for 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, the method comprising:

- providing, by a mobile network operator, a distributed unit (DU) of a fifth-generation (5G) cellular telecommunication network radio access network (RAN) that is served by a particular 5G cellular site base station, wherein the DU:
  - is associated with a primary 5G Node B (gNB) identified by a primary identifier (ID), wherein the primary gNB are a distributed collection of base stations; and
  - is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID;
- configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from a satellite to a 5G Core to a 5G base station to a 5G end user mobile device;
- receiving a request to use a specified frequency at a specified time to communicate with the satellite;
- enabling the base station to stop download transmissions on specified frequency tones at the specified time;
- creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and
- facilitating upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

2. The method of claim **1** further comprising: scheduling mini-slot-based uplink transmissions from a 5G end user mobile device in an Uplink Pilot Time Slot region of a subframe.

3. The method of claim **1**, further comprising: using Orthogonal Frequency Division Multiplexing (OFDM) to mitigate interference between uplink signals of the 5G end user mobile device and downlink signals from the satellite.

4. The method of claim **1**, wherein the receiving of the request to use the specified frequency at the specified time to communicate with the satellite is made by a 5G Core, a 5G base station, or a 5G end user mobile device.

5. The method of claim **1**, further comprising: requesting a base station in the primary gNB to reverse a direction of transmission.

6. The method of claim **1**, further comprising: providing dynamic 5G PRB blanking reconfiguration of frequency notches.

7. The method of claim **1**, wherein the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

8. A system for 5G Physical Resource Block (PRB) blanking system with 5G end user mobile devices to prevent interference with satellite signal transmission, the system comprising:

- a memory that stores computer executable instructions; and
- a processor that executes the computer-executable instructions and causes the processor to:
  - provide, by a mobile network operator, a distributed unit (DU) of a fifth-generation (5G) cellular telecommunication network radio access network (RAN) that is served by a particular 5G cellular site base station, wherein the DU:
    - is associated with a primary 5G Node B (gNB) identified by a primary identifier (ID); and
    - is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID;
  - configure a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from a satellite to a 5G Core to a 5G base station to a 5G end user mobile device;
  - receive a request to use a specified frequency at a specified time to communicate with the satellite;
  - enable the base station to stop download transmissions on specified frequency tones at the specified time;
  - create frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and
  - facilitate upload transmissions from a 5G end user mobile device to the satellite in the frequency notches at the specified time.

9. The system of claim **8**, wherein mini-slot-based uplink transmissions are scheduled from a 5G end user mobile device in an Uplink Pilot Time Slot region of a subframe.

10. The system of claim **8**, wherein Orthogonal Frequency Division Multiplexing (OFDM) is used to mitigate interference between uplink signals of the 5G end user mobile device and downlink signals from the satellite.

11. The system of claim **8**, wherein the receiving of the request to use the specified frequency at the specified time to communicate with the satellite is made by a 5G Core, a 5G base station, or a 5G end user mobile device.

12. The system of claim **8**, wherein the processor that executes the computer-executable instructions further causes the processor to: request a base station in the primary gNB to reverse a direction of transmission.

13. The system of claim **8**, wherein the system includes dynamic 5G PRB blanking reconfiguration of frequency notches.

14. The system of claim **8**, wherein the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

15. A non-transitory computer-readable storage medium having computer-executable instructions stored thereon that, when executed by a processor, cause the processor to:

provide, by a mobile network operator, a distributed unit (DU) of a fifth-generation New Radio (5G) cellular telecommunication network radio access network (RAN) that is served by a particular 5G cellular site base station, wherein the DU:

is associated with a primary 5G Node B (gNB) identified by a primary identifier (ID); and

is in operable communication with a corresponding primary central unit control plane (CU-CP) of a 5G primary centralized unit (CU) that is hosted on a cloud-native virtualized compute instance in a primary cloud availability zone and is also associated with the primary gNB identified by the primary ID;

configuring a 5G network to enable reversing an original direction of transmission upon request from a 5G end user mobile device, wherein the original direction of transmission is from a satellite to a 5G Core to a 5G base station to a 5G end user mobile device;

requesting to use a specified frequency at a specified time to communicate with the satellite;

enabling the base station to stop download transmissions on specified frequency tones at the specified time;

creating frequency notches at the specified time that are available for a 5G end user mobile device to upload to the satellite; and

facilitating upload transmissions from a 5G end user mobile device to the satellite in the specified notches at the specified time.

16. The non-transitory computer-readable storage medium of claim **15**, wherein the computer-executable instructions, when executed by a processor, further cause the processor to: schedule mini-slot-based uplink transmissions from a 5G end user mobile device in an Uplink Pilot Time Slot region of a subframe.

17. The non-transitory computer-readable storage medium of claim **15**, wherein the computer-executable instructions, when executed by a processor, further cause the processor to: use Orthogonal Frequency Division Multiplexing (OFDM) to mitigate interference between uplink signals of the 5G end user mobile device and downlink signals from the satellite.

18. The non-transitory computer-readable storage medium of claim **15**, wherein the computer-executable instructions, when executed by a processor, further cause the processor to: request a base station in the primary gNB to reverse a direction of transmission.

19. The non-transitory computer-readable storage medium of claim **15**, wherein the system includes dynamic 5G Physical Resource Block (PRB) blanking reconfiguration of frequency notches.

20. The non-transitory computer-readable storage medium of claim **15**, wherein the primary gNB configures Bandwidth Parts to optimize the 5G network for the frequency notches used for the 5G end user mobile device to upload to the satellite.

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