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(54) **Title**: SYSTEM AND METHOD FOR A CONTROL PLANE REFERENCE MODEL FRAMEWORK
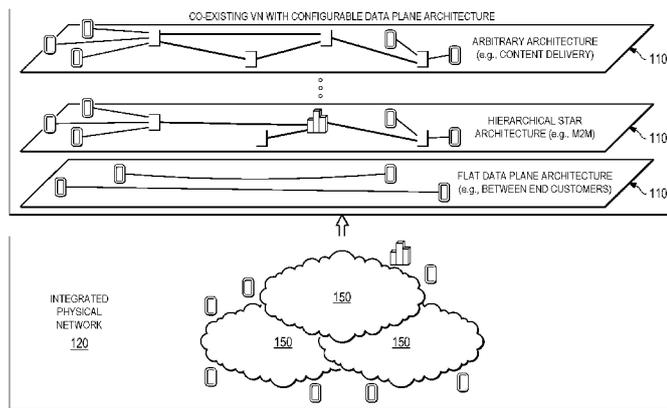
FIG. 1

(57) **Abstract**: Embodiments are provided for implementing control plane functionality to configure a data plane at a plurality of network nodes. A software defined topology (SDT) component is configured to determine a data plane logical topology indicating a plurality of selected nodes and a logical architecture connecting the selected nodes. The data plane logical topology enables traffic delivery for a service or virtual network for an end-customer or operator. A software defined networking (SDN) component is configured to interact with the SDT component and map the data plane logical topology to a physical network. The mapping includes allocating network nodes including the selected nodes and network resources which enable communications for the service or virtual network and meet QoS requirement. A software defined protocol (SDP) component is configured to interact with the SDN and define data plane protocol and process functionality for the network nodes.

System and Method for a Control Plane Reference Model Framework

[0001]   This application claims the benefit of U.S. Provisional Application No. 61/810,608 filed on April 10, 2013, entitled "System and Method for a Control Plane Reference Model Framework," and U.S. Non-provisional Application No. 14/245,830, filed on April 4, 2014, entitled "System and Method for a Control Plane Reference Model Framework," which are hereby incorporated herein by reference as if reproduced in their entireties.

TECHNICAL FIELD

[0002]   The present invention relates to the field of network communications, and, in particular embodiments, to a system and method for a control plane reference model framework.

BACKGROUND

[0003]   Software-defined networking (SDN) provides a mapping between logical topology requirements and physical infrastructure resources. Radio coordination is part of SDN for radio access networks (RANs). The SDN in RAN generally manages routing and traffic engineering (TE) to provide a forwarding path and required bandwidth or rate for traffic flow over each link over the path (multiple routes are also possible). The SDN in RAN also manages radio coordination to provide on-demand configuration of radio node specification, including the access link/backhaul link and the carrier. The on-demand configuration may include selecting built-in components with different specifications. The on-demand configuration can also include coordinating the mapping/allocation of the 5-tuple wireless resource (time/frequency/code/ power/spatial) to active flows. However, as radio nodes functionality and RAN or other integrated network in general evolve, managing the control plane, such as in term of SDN framework, becomes challenging. There is a need for an improved control plane reference model and architecture for such networks including radio nodes and other nodes.

SUMMARY OF THE INVENTION

[0004]   In accordance with an embodiment, a method by a network component for implementing control plane functionality to configure a data plane at a plurality of network nodes includes determining, using a software defined topology (SDT) component, a data plane logical topology indicating a plurality of selected nodes and a logical architecture connecting the selected nodes. The method further includes mapping, using a software defined networking (SDN) component, the data plane logical topology to a physical network, the mapping

comprising allocating network nodes including the selected nodes and network resources which enable information delivery and communication for a service or virtual network and meet quality of service (QoS) requirement. The method further includes defining, using a software defined protocol (SDP) component, a data plane protocol including data plane process functionality for the allocated network nodes.

[0005]   In accordance with another embodiment, a network component configured for implementing software defined topology (SDT) control plane functionality to configure a data plane at a plurality of network nodes includes at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to determine, using a software defined topology (SDT) component, a data plane logical topology indicating a plurality of selected nodes, a logical architecture connecting the selected nodes at the data plane, and attributes of connections between the selected nodes. The data plane logical topology is determined according to a logical topology provided by a customer and enabling information delivery and communication of a service or virtual network. The programming includes further instructions to send information about the data plane logical topology to a software defined networking (SDN) component configured for mapping the data plane logical topology to a physical network.

[0006]   In accordance with another embodiment, a network component configured for implementing software defined networking (SDN) control plane functionality to configure a data plane at a plurality of network nodes includes at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to receive, from a software defined topology (SDT) component, information about a data plane logical topology determined according to a logical topology provided by a customer for enabling information delivery and communication of a service or virtual network. The programming includes further instructions to map the data plane logical topology to a physical network, the mapping comprising allocating network nodes including selected nodes and network resources which enable information delivery and communication for the service or virtual network and meet quality of service (QoS) requirement. The programming includes further instructions to send information about the mapping to a software defined protocol (SDP) component configured for defining a data plane protocol for the network nodes.

[0007]   In accordance with another embodiment, a network component configured for implementing software defined protocol (SDP) control plane functionality to configure a data plane at a plurality of network nodes includes at least one processor and a non-transitory

computer readable storage medium storing programming for execution by the at least one processor. The programming include instructions to receive, from a software defined networking (SDN) component, information about a mapping between a data plane logical topology and a physical network, the mapping comprising allocating network nodes and network resources which enable information delivery and communication for a service or virtual network and meet quality of service (QoS) requirement. The programming includes further instructions to define a data plane protocol including data plane process functionality for the allocated network nodes in the physical network corresponding to the mapped data plane logical topology. The instructions to define the data plane protocol include instructions to configure radio operation parameters for a radio node from the network nodes.

[0008]   In accordance with another embodiment, a method for configuring a radio node at a data plane, the method comprising receiving, at the radio node, information indicating a set of data process functionality, workflow for handling and processing traffic, and corresponding parameters and status information as determined by a software defined protocol (SDP) control element. The received information enables communication and traffic delivery for a service or virtual network. The method further includes performing, by the radio node, an operation at the data plane according to the received information.

[0009]   In accordance with yet another embodiment, a radio node component configurable at a data plane by one or more control plane components includes, at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to receive information indicating a set of data process functionality, workflow for handling and processing traffic, and corresponding parameters and status information as determined by a software defined protocol (SDP) control element. The received information enables communication and information delivery for a service or virtual network. The programming includes further instructions to perform an operation of the radio node, at the data plane, according to the received information.

[0010]   The foregoing has outlined rather broadly the features of an embodiment of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of embodiments of the invention will be described hereinafter, which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those

skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]   For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

[0012]   Figure 1 illustrates a scenario of implementing multiple co-existing customized virtual networks at a control plane;

[0013]   Figure 2 illustrates an embodiment of a control plane architecture;

[0014]   Figure 3 illustrates an embodiment of control components within a domain controller;

[0015]   Figure 4 illustrates an embodiment working flow for handling content transmission between end-to-end customers;

[0016]   Figure 5 illustrates an embodiment working flow for handling machine-to-machine (M2M) communications;

[0017]   Figure 6 illustrates an embodiment working flow for handling content dissemination into a content delivery network (CDN);

[0018]   Figure 7 illustrates an embodiment working flow for handling content delivery to customers in a CDN;

[0019]   Figure 8 illustrates an embodiment of a configurable and multi-functional radio node;

[0020]   Figure 9 illustrates an embodiment of an interface between the control plane and radio node; and

[0021]   Figure 10 is a diagram of an exemplary processing system that can be used to implement various embodiments.

[0022]   Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated. The figures are drawn to clearly illustrate the relevant aspects of the embodiments and are not necessarily drawn to scale.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0023]   The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

[0024]   Current and future wireless networks or integrated wireless and non-wireless networks are expected to enable high flexibility, high efficiency, high openness and customization to customers (e.g., virtual network operators) and consumers. Currently, there is no systematic description of control plane functionality in wireless or integrated networks. Such networks also lack systematic description of control plane functionality workflow. Further, there is no definition of interface between the data plane (e.g., at a radio node level) and the different control plane components.

[0025]   To enable such high-functioning wireless or integrated (combined wireless and non-wireless) networks, embodiments are provided herein to present a framework for a control plane reference model for such types of networks. The embodiments include identifying key control functionality of the control plane, and providing a control plane architecture to enable the control functionality of multiple control components. Additionally, interface between the control components are provided. Various workflows among the control components are also provided for exemplary scenarios.

[0026]   To avoid the excessive complexity of Software-defined networking (SDN) and process complexity of network nodes in data plane, software defined topology (SDT) functionality is introduced to control plane to define service/application/virtual network (VN) specific data plane topology based on service logical topology before SDN. A service can be any network service provided by network resources, such as a data service, a voice service, a video service, other network based services, or combinations thereof. In order to provide a fully customized network, software defined data plane protocol (SDP) functionality is also introduced in control plane to define the service/application/VN specific data process. In control plane, in addition to a SDN functionality component, SDT and SDP components are also included. The embodiments also include identifying radio node functionality for improved or future wireless networks, and interface between the remote control plane and such radio nodes (e.g., at the data plane). This framework of reference model and interface design can be used in the systematic design, development of algorithms, and control mechanisms of future wireless or integrated network architecture.

[0027]   Figure 1 illustrates using multiple co-existing customized virtual networks 100 that can be implemented using the control plane functionality herein and further using integrated physical network resources 120. The integrated physical network resources may include multiple domains or sub-networks 150. The co-existing customized virtual networks 100 achieved using the control plane functionality can be configured according to various logical architectures, including for example an arbitrary architecture such as for content delivery, a hierarchical star architecture such as for machine-to-machine (M2M) communications, and a flat data plane architecture such as for between end customers.

[0028]   Figure 2 shows an embodiment of a control plane architecture 200 that enables a configurable data plane architecture, such as the configurable data plane architecture 100, and allows the functioning and operation of the various configured VNs 102 at the data plane. The control plane architecture 200 is a logical control architecture that has a hierarchical structure to handle multiple geographic domains 250, which may be networks, sub-networks, or other types of network domains. A plurality of domain controllers 220 assigned to the different domains 250 are each configured with three control elements, including a software defined topology (SDT) component, a software defined network (SDN) component, and a software defined protocol (SDP) component. These control components may be implemented using software, hardware, or both. The physical implementation of the control functionality of the components can be implemented by a network entity or location (e.g., the domain controllers 220 corresponds to a node or data center), or alternatively can be virtual cloud based (e.g., in a distributed manner across a network or virtual network referred which is referred to as a cloud). The SDT component provides on-demand, configurable and customized logical data plane architecture. The SDN component provides on-demand customized resource management to meet the requirement of the defined data plane architecture. The SDP component provides on-demand, configurable and customized data plane process protocol that may be both radio related and non-radio related. The size of the domain 250 for each individual domain controller 220 can be different and can be dynamically configured. Additionally, an inter-domain coordinator 210 can be used to coordinate inter-domain control functionality between the different domain controllers 220. Each domain controller 220 can communicate with the inter-domain coordinator 210 via a first interface (e.g., via API), referred to in Figure 2 as a domain control-to-orchestrator (C-O) interface. The domain controller 220 can communicate with another domain controller 220 via a second interface, referred to in Figure 2 as a domain control-to-domain control (C-C) interface. The domain controller 220 also communicates with its respective domain via a third interface,

referred to in Figure 2 as a domain control-to-physical network (C-P) interface (or control plane-to-data plane (C-D) interface.

[0029]   In an embodiment, the network nodes belong to a first layer, e.g., at the various domains 250, and are abstracted (or grouped) into virtual nodes at a second layer. Thus, the second layer comprises virtual nodes each being a group of multiple physical nodes at the first layer. The virtual nodes at the second layer are treated by the SDT/SDN/SDP components, e.g., in the domain controllers 220, as individual nodes having corresponding input and output parameters for control and configuration. As such, the network nodes at the first layer, which form the virtual nodes, can be transparent to the SDT/SDN/SDP components. Multiple abstraction levels may be used to group nodes into higher abstraction layer nodes. For example, the network nodes at the physical network layer may be grouped into virtual nodes at a first abstraction layer. The virtual nodes at the first abstraction layer may further be grouped into virtual nodes at a second abstraction layer, which may then be treated by the SDT/SDN/SDP components as individual nodes. This network layer abstraction simplifies handling and managing a large number of nodes in multiple networks or domains by the SDT/SDN/SDP components.

[0030]   Figure 3 shows an embodiment of control components 300 within a domain controller 310. The control components 300 include a SDT component 311, a SDN component 312, and a SDP element 313 with respective control functionalities, as described above. The control components of the domain controller 310 provide the control functionality to the corresponding domain 320. The integrated physical network 320 may include or the corresponding domain may be a wireless network including radio nodes. The domain controller 310 may be managed or operated by an operator to handle, on-demand, communication and information delivery for a service or a VN. To perform the control functionality of the control components 300, the domain controller 310 receives input via API (application programming interface) from an application/service/VN operator to obtain service requirement (e.g., service logical topology, quality of service, preferred cost). The domain controller 310 also receives input information from the integrated physical network 320, including network status analysis information, infrastructure abstraction information, mobility track information (e.g., for mobile users), and/or quality of service (QoS) analysis information. The control elements at the domain controller 310 processes such information to provide a customized data plane for handling communications and data forwarding for a service or VN, by resource management such as path/bandwidth or rate allocation to meet the requirement of the defined data plane, and the data plane process protocol for forwarding/processing of associated traffic. The decisions from the

control elements at the domain controller 310 are sent to the data plane (the network nodes) via the interface between control plane and data plane (I-CD). The interface between the applications/service/virtual network operator and control plane includes information, such as, service logical topology, application/traffic characteristics, end-customer mobility distribution, required service QoS, and/or other relevant information for enabling an applications/service/virtual network. The interface (I-Mob) between Mobility management/track and control plane includes information such as current location of end-customers, e.g., geographic location, location relative to network, and possible prediction of location. The interface (I-QoE) between control plane and Delivered QoE analysis includes QoE analysis information such as based on QoE information (e.g., rate, packet loss rate, black screen time). The interface (I-DC-QoE) between data plane and control plane includes the QoE information. The interface (I-abs) between control plane and infrastructure abstraction includes information such as effective spectra efficiency of mobile terminals. The interface (I-NS) between control pane and network status analysis includes information such as network load. The interface (I-DC-NS) between data plane and control plane includes information such as node load and packet drop rates. The interface (I-CD) includes information such as routing information, data process functionality, and work flow.

[0031]   Figure 4 shows an embodiment working flow 400 for handling content/information transmission between end-to-end customers. The working flow 400 is an exemplary scheme implemented by the control elements (SDT, SDN, and SDP), e.g., using the control plane architecture 200, to configure the virtual network for forwarding/processing/handling traffic between end-to-end customers. The SDT component determines the logical data plane topology architecture and source/destination locations based on factors, such as service/connectivity requirements, available network resource, QoS requirement, and/or other factors. As part of determining the logical topology for the data plane, the SDT component selects network elements or nodes and required service quality necessary to implement or enable the data plane (for a service or VN). For instance, the selected elements may be at least a source location/node and a destination location/node for handling content/information transmission between end-to-end customers/devices. The SDT also uses mobility tracking, network status, and quality of experience (QoE) information. The SDT provides the decision to the SDN component.

[0032]   The SDN component maps the logical topology (from the SDT component) to a physical network resource. This process includes allocating network resources (e.g., one or more paths or routes, bandwidth) to meet the required data plane architecture and QoS requirement. The SDN component operation may involve multiple-handshake and negotiation between the

control components and/or the inter-domain controllers. The SDN component operations may also use physical infrastructure abstraction information. According to the SDN component decision, the SDP component defines the data plane process functionality, e.g., as part of a data plane protocol, for each involved network node assigned by the SDN component, including radio nodes for wireless networks if considered. The control components interface with each other and negotiate for the best solution, for example to satisfy QoS with the minimum network resource used and/or maximize the operator/customer revenue. Additional on-going adaptation may also follow. For instance, the SDT component may need to reconfigure the logical data plane architecture to adapt to dynamic changes such as change in required end-to-end service/flow rate due to source rate adaptation to handle network congestion or receiver behavior at the nodes/end user's equipment, change in service/flow rate in some links on the forwarding path caused by compression due to link congestion, or change of source or destination location due to node/user mobility. The SDN needs to adapt to the modification of logical data plane topology to remap logical connectivity to physical network resource, and for reconfiguring (by the SDP component) the data plane protocol. In an embodiment, the SDT, SDN, and SDP iteratively or continuously implement their corresponding control functionality, thus adjusting dynamically to changes that may occur for a service or virtual network. This provides dynamic change to the data plane topology and necessary remapping into adjusted network resources according to the changes.

[0033]   Figure 5 shows an embodiment working flow 500 for handling machine-to-machine (M2M) communications. The working flow 500 is an exemplary scheme implemented by the control elements (SDT, SDN, and SDP), e.g., as in domain controller 310, to configure the data plane for forwarding and handling traffic for M2M communications, e.g., between machines such as sensors or meters absent of direct user involvement. The SDT component determines the logical data plane topology architecture, e.g., for a first VN, based on factors such as traffic characteristics and end-devices distribution, connectivity/QoS requirements, available network resource, and/or other factors. The SDT may also use mobility tracking, network status, and QoE information. The SDT provides the decision to the SDN component. The SDN component maps the logical topology (from the SDT component) to a physical network resource. This process includes allocating network resources (e.g., one or more paths or routes, bandwidth) to meet the required data plane architecture and QoS requirement. The SDN component operation may involve multiple-handshake and negotiation between the control components and/or the inter-domain controllers. The SDN component operations may also use physical infrastructure abstraction information. According to the SDN component decision, the SDP component defines the data plane process functionality, e.g., as part of a data plane protocol, for each involved

network node assigned by the SDN component, including radio nodes for wireless networks if considered. The control components interface with each other and negotiate for the best solution, for example to satisfy QoS with the minimum network resource used and/or maximize the operator/customer revenue. Additional on-going adaptation may also follow, such as logical topology changes (by the SDT component) due to traffic distribution (e.g., mobility) change and network status change, remapping (by the SDN component) the logical topology to physical network resource, and reconfiguring (by the SDP component) the data plane protocol.

[0034]   Figure 6 illustrates an embodiment working flow 600 for handling content dissemination into a CDN. The working flow 600 is an exemplary scheme implemented by the control elements (SDT, SDN, and SDP), e.g., as in domain controller 310, to configure the data plane for dissemination of content traffic for a CDN. The SDT component determines the logical data plane topology architecture, including determining the locations of content storages based on factors, such as content popularity level, and QoS information. The SDT may also use mobility tracking, network status, and QoE information. The SDT provides the decision to the SDN component. The SDN component maps the logical topology to a physical network resource, e.g., including allocating network resources (e.g., one or more paths or routes, bandwidth) to meet the required data plane architecture and QoS requirement. The SDN component operation may involve multiple-handshake and negotiation between the control components and/or the domain controllers. The SDN component operations may also use physical infrastructure abstraction information. According to the SDN component decision, the SDP component defines the data plane process functionality, e.g., as part of a data plane protocol, for each involved network node, e.g., including radio nodes, assigned by the SDN component. The control components interface with each other and negotiate for the best solution, for example to satisfy QoS with the minimum network resource used and/or maximize the operator/customer revenue. Additional on-going adaptation may also follow, such as according to content popularity change, consumer distribution change, and network status changes. Such changes can trigger reconfiguration by the SDT component. Adaptation to data plane architecture may also trigger remapping between the logical topology and physical network resource (by the SDN component), and reconfiguration of the data plane protocol (by the SDP component).

[0035]   Figure 7 illustrates an embodiment working flow 700 for handling content delivery to customers in a CDN. The working flow 700 is an exemplary scheme implemented by the control elements (SDT, SDN, and SDP), e.g., as in domain controller 310, to configure the data plane for dissemination of CDN content delivery to users (e.g., consumers of content). The SDT component determines the logical data plane topology architecture, including, determining the

locations of content sources, and intended user (or content consumer) for delivery based on factors, including content delivery/request and QoS information. The SDT may also use mobility tracking, network status, and QoE information. The SDT provides the decision to the SDN component. The SDN component maps the logical topology to a physical network resource, e.g., including allocating network resources (e.g., one or more paths or routes, bandwidth) to meet the required data plane architecture and QoS requirement. The SDN component operation may involve multiple-handshake and negotiation between the control components and/or the domain controllers. The SDN component operations may also use physical infrastructure abstraction information. According to the SDN component decision, the SDP component defines the data plane process functionality, e.g., as part of a data plane protocol, for each involved network node, e.g., including radio nodes, assigned by the SDN component. The control components interface with each other and negotiate for the best solution, for example to satisfy QoS with the minimum network resource used and/or maximize the operator/customer revenue. Additional on-going adaptation may also follow, such as according to consumer location change (user mobility) and customer changes. Such changes can trigger reconfiguration by the SDT component. Adaptation to data plane architecture may also trigger remapping between the logical topology and physical network resource (by the SDN component), and reconfiguration of the data plane protocol (by the SDP component).

[0036]   Figure 8 illustrates an embodiment of a configurable and multi-functional radio node 800. The radio node 800 is one node or component of a wireless or integrated network that can be configured, e.g., at the data plane level, with suitable radio node functionality using the control plane architecture described above, for instance by the SDP component. The radio node 800 is equipped with single or multiple configurable or built-in radio transmitter(s)/receiver(s). A transmitter/receiver of the radio node 800 can be customized to support both access link and backhaul link communications, with configurable carrier band, antenna steer, antenna (steering, beam-width, and/or other antenna features). The radio node 800 can also be equipped with suitable storage capability. The radio node may also perform a switch function, to operate as a receiver connection for a selected transmitter, e.g., based on instructions from the control plane. The configurable radio node 800 can include one or more multiple wireless/fabric backhaul functions with configurable band RF. The configurable radio node 800 can also include narrow beam backhaul functionality, e.g., at a higher RF band, a routing functionality, one or more configurable access link functions, in-band or out-of-band sensor functionality, or combinations thereof. Multiple types of multi-functional radio nodes 800 may be configured depending on the functionality implemented.

[0037]   Figure 9 illustrates an embodiment of an interface 900 between the control plane and a radio node/network node with configurable functionality at the data plane, such as the radio node 800. The control plane can be centralized and remote with respect to the radio node, for instance at a domain controller component, as in domain controller 310, or may be virtual cloud based. The depth of centralized radio control and coordination may be configurable. For instance, fast adaptation required control (e.g., link adaptation, fast error recovery) may be locally controlled at the radio node. Slow adaptation required control (e.g., power control, spatial control, carrier coordination) may be remote (centralized) controlled at the control plane. The interface 900 may include a SDP-to-data plane logical interface that configures, for the radio node, the set of data process functionality, workflow for handling /processing traffic and corresponding parameters and status. The interface 900 may include a SDN-to-data plane logical interface that configures the forwarding rule and radio operation parameters for the radio node. The interface 900 may also include a SDT-to-data plane logical interface that configures the content storage and traffic rate and compression rule and traffic filtering, for the radio node.

[0038]   Figure 10 is a block diagram of an exemplary processing system 1000 that can be used to implement various embodiments. Specific devices may utilize all of the components shown, or only a subset of the components and levels of integration may vary from device to device. Furthermore, a device may contain multiple instances of a component, such as multiple processing units, processors, memories, transmitters, receivers, etc. The processing system 1000 may comprise a processing unit 1001 equipped with one or more input/output devices, such as a network interfaces, storage interfaces, and the like. The processing unit 1001 may include a central processing unit (CPU) 1010, a memory 1020, a mass storage device 1030, and an I/O interface 1060 connected to a bus. The bus may be one or more of any type of several bus architectures including a memory bus or memory controller, a peripheral bus or the like.

[0039]   The CPU 1010 may comprise any type of electronic data processor. The memory 1020 may comprise any type of system memory such as static random access memory (SRAM), dynamic random access memory (DRAM), synchronous DRAM (SDRAM), read-only memory (ROM), a combination thereof, or the like. In an embodiment, the memory 1020 may include ROM for use at boot-up, and DRAM for program and data storage for use while executing programs. In embodiments, the memory 1020 is non-transitory. The mass storage device 1030 may comprise any type of storage device configured to store data, programs, and other information and to make the data, programs, and other information accessible via the bus. The mass storage device 1030 may comprise, for example, one or more of a solid state drive, hard disk drive, a magnetic disk drive, an optical disk drive, or the like.

[0040]   The processing unit 1001 also includes one or more network interfaces 1050, which may comprise wired links, such as an Ethernet cable or the like, and/or wireless links to access nodes or one or more networks 1080. The network interface 1050 allows the processing unit 1001 to communicate with remote units via the networks 1080. For example, the network interface 1050 may provide wireless communication via one or more transmitters/transmit antennas and one or more receivers/receive antennas. In an embodiment, the processing unit 1001 is coupled to a local-area network or a wide-area network for data processing and communications with remote devices, such as other processing units, the Internet, remote storage facilities, or the like.

[0041]   While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods might be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

[0042]   In addition, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

WHAT IS CLAIMED IS:

1.   A method by a network component for implementing control plane functionality to
configure a data plane at a plurality of network nodes, the method comprising:

determining, using a software defined topology (SDT) component, a data plane logical
topology indicating a plurality of selected nodes and a logical architecture connecting the
selected nodes;

mapping, using a software defined networking (SDN) component, the data plane logical
topology to a physical network, the mapping comprising allocating network nodes of a service or
virtual network, wherein the allocated network nodes include the selected nodes and network
resources, and wherein the network resources enable information exchange of the service or
virtual network, and meet quality of service (QoS) requirement; and

defining, using a software defined protocol (SDP) component, a data plane protocol
including data plane process functionality for the allocated network nodes.

2.   The method of claim 1, wherein determining the data plane logical topology includes
configuring at least one of traffic filtering, traffic aggregation, traffic convergence, and load
balancing functionality for the selected nodes, wherein mapping the data plane logical topology
to the physical network includes configuring data forwarding rules for the network nodes, and
wherein defining the data plane protocol includes configuring a set of data process functionality,
workflow for handling and processing traffic, and corresponding parameters and status
information for the network nodes.

3.   The method of claim 1 further comprising configuring radio operation parameters of a
radio node from the network nodes.

4.   The method of claim 1 further comprising exchanging information between each of the
SDN component, the SDT component, and the SDP component to negotiate and cooperate for
configuring data plane for the network nodes.

5.   The method of claim 1, wherein the data plane logical topology is determined and
mapped to the physical network according to at least one of mobility tracking, network status,
quality of experience (QoE) information, and network node capability.

6.   The method of claim 1, wherein the data plane logical topology is determined and
mapped to the physical network for handling traffic transmission between end-to-end customers

according to at least one of service requirement, connectivity requirement, available network resource, and the QoS requirement.

7.   The method of claim 1, wherein the data plane logical topology is determined and mapped to the physical network for handling machine-to-machine (M2M) communications according to at least one of traffic characteristics, end-devices distribution, connectivity requirement, available network resource, and the QoS requirement.

8.   The method of claim 1, wherein the data plane logical topology is determined and mapped to the physical network for handling content dissemination into a network according to at least one of content storage based factors content popularity, and the QoS requirement, and wherein determining the data plane logical topology includes determining destinations for content cache in the network.

9.   The method of claim 1, wherein the data plane logical topology is determined and mapped to the physical network for handling content delivery to customers in a content delivery network (CDN) according to at least one of destination of content, requesting mobile or terminal, and the QoS requirement, and wherein determining the data plane logical topology includes determining sources for content delivery.

10.   The method of claim 1, wherein allocating network resources to meet the data plane logical topology and the QoS requirement includes allocating, for the network nodes, a path or multiple paths and corresponding bandwidth in the physical network.

11.   The method of claim 1, wherein the selected node of the data plane logical topology indicates a source location and a destination location of the service or virtual network, and further indicates a logical architecture to connect the selected nodes at data plane and attributes of connections of the selected nodes, the data plane attributes including at least one of rate and delay attributes.

12.   The method of claim 1, wherein physical network is divided into a plurality of control domains, and wherein the SDT component, the SDN component, and the SDP component are assigned to a first domain from the plurality of control domains in the physical network.

13.   The method of claim 12 further comprising exchanging information with a second SDN component, a second SDT component, or a second SDP component, the second SDP component being assigned to a second domain from the plurality of control domains to cooperate for configuring data plane for the network nodes in the first domain or the second domain.

14.   The method of claim 1, wherein the network nodes correspond to a first layer and are abstracted into virtual nodes at a second layer, and wherein the data plane logical topology is determined, using the SDT, for the virtual nodes at the second layer.

15.   The method of claim 1 further comprising:

receiving, at a control plane via a first interface, network status analysis information including network load from a network status analysis component;

receiving, at the control plane via a second interface, infrastructure abstraction information including effective spectra efficiency of mobile terminals from an infrastructure abstraction component;

receiving, at the control plane via a third interface, mobility management and tracking information including current geographic locations, locations relative to network, or predictions of locations of end-customers from a mobility management and tracking component;

receiving, at the control plane via a fourth interface, quality of experience (QoE) analysis information from a QoE analysis component; and

providing, via a fifth interface at the control plane, control functionality decisions including routing information, data process functionality, and work flow to a service or virtual network.

16.   The method of claim 15, wherein the network status analysis information is determined by the network status analysis component according to network status information including node load or packet drop rates obtained from the data plane via a first interface between the control plane and the data plane, and wherein the QoE analysis information is determined by the QoE analysis component according to rate, packet loss rate, or black screen time experience information obtained from the data plane via a second interface between the control plane and the data plane.

17.   The method of claim 1 further comprising repeating steps for determining the data plane logical topology using the SDT, mapping the data plane logical topology to the physical network using the SDN, and defining the data plane protocol using the SDP data plane process

functionality for the allocated network nodes, wherein repeating the steps adjusts dynamically to changes related to the service or virtual network.

18.   The method of claim 1, wherein the data plane logical topology is determined according to a logical topology provided by a customer and enabling information exchange of the service or virtual network.

19.   The method of claim 18, wherein the customer is an end-customer, a service operator, or a virtual network operator.

20.   A network component configured for implementing software defined topology (SDT) control plane functionality to configure a data plane at a plurality of network nodes, the network component comprising:

at least one processor; and

a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

determine, using a software defined topology (SDT) component, a data plane logical topology indicating a plurality of selected nodes, a logical architecture connecting the selected nodes at the data plane, and attributes of connections between the selected nodes, wherein the data plane logical topology is determined according to a logical topology provided by a customer and enabling information exchange of a service or virtual network; and

send information about the data plane logical topology to a software defined networking (SDN) component configured for mapping the data plane logical topology to a physical network.

21.   The network component of claim 20, wherein the network nodes include a radio node at the data plane configurable by the network component, and wherein the instructions to determine the data plane logical topology includes instructions to configure radio operation parameters for the radio node.

22.   A network component configured for implementing software defined networking (SDN) control plane functionality to configure a data plane at a plurality of network nodes, the network component comprising:

at least one processor; and

a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

receive, from a software defined topology (SDT) component, information about a data plane logical topology determined according to a logical topology provided by a customer for enabling information exchange of a service or virtual network;

map the data plane logical topology to a physical network, the mapping comprising allocating network nodes including selected nodes and network resources, wherein the network resources enable information exchange of the service or virtual network and meet quality of service (QoS) requirement; and

send information about the mapping to a software defined protocol (SDP) component configured for defining a data plane protocol for the network nodes.

23.   The network component of claim 22, wherein allocating network resources enabling information exchange of the service or virtual network and meeting QoS requirement includes allocating, for the network nodes, a path or multiple paths and corresponding bandwidth in the physical network.

24.   The network component of claim 22, wherein instructions to map the data plane logical topology include instructions to configure data forwarding rules for the network nodes.

25.   The network component of claim 22, wherein the network nodes include a radio node at the data plane configurable by the network component, and wherein instructions to map the data plane logical topology include instructions to configure radio operation parameters for the radio node.

26.   A network component configured for implementing software defined protocol (SDP) control plane functionality to configure a data plane at a plurality of network nodes, the network component comprising:

at least one processor; and

a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

receive, from a software defined networking (SDN) component, information about a mapping between a data plane logical topology and a physical network, the mapping comprising allocating network nodes and network resources, wherein the network resources enable information exchange of the service or virtual network and meet quality of service (QoS) requirement; and

define a data plane protocol including data plane process functionality for the allocated network nodes in the physical network corresponding to the mapped data plane logical topology, wherein instructions to define the data plane protocol include instructions to configure radio operation parameters for a radio node from the network nodes.

27.   The network component of claim 26, wherein instructions to define the data plane protocol include instructions to configure a set of data process functionality, workflow for handling and processing traffic, and corresponding parameters and status information for the network nodes.

28.   A method for configuring a radio node at a data plane, the method comprising:

receiving, at the radio node, information indicating a set of data process functionality, workflow for handling and processing traffic, and corresponding parameters and status information as determined by a software defined protocol (SDP) control element, the received information enabling information exchange of a service or virtual network; and

performing, by the radio node, an operation at the data plane according to the received information.

29.   The method of claim 28 further comprising:

receiving, at the radio node, additional information to configure at least one of traffic filtering, traffic aggregation, traffic convergence, and load balancing functionality, and radio operation parameters as determined by a software defined topology (SDT) control element, wherein the additional information are received directly from the SDT control element or via the SDP control element; and

performing, by the radio node, the operation at the data plane according to the additional information.

30.   The method of claim 28 further comprising:

receiving, at the radio node, additional information to configure data forwarding rules as determined by a software defined networking (SDN) control element; and

performing, by the radio node, the operation at the data plane according to the additional information.

31.   A radio node component configurable at a data plane by one or more control plane components, the radio node comprising:

at least one processor; and

a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

receive information indicating a set of data process functionality, workflow for handling and processing traffic, and corresponding parameters and status information as determined by a software defined protocol (SDP) control element, the received information enabling information exchange of a service or virtual network; and

perform an operation of the radio node, at the data plane, according to the received information.

32.   The radio node of claim 31, wherein the programming includes further instructions to:

receive additional information to configure at least one of traffic filtering, traffic aggregation, traffic convergence, and load balancing functionality, and radio operation parameters as determined by a software defined topology (SDT) control element, wherein the instructions are received directly from the SDT control element or via the SDP control element; and

perform the operation of the radio node, at the data plane, according to the additional information.

33.   The radio node of claim 31, wherein the programming includes further instructions to:

receive, at the radio node, additional information to configure data forwarding rules as determined by a software defined networking (SDN) control element; and

perform the operation of the radio node, at the data plane, according to the additional information.

34.   The radio node of claim 31, wherein the programming includes further instructions to:

receive additional information to configure at least one of a wireless backhaul functionality, a radio frequency (RF) band for the wireless backhaul functionality, a narrow beam backhaul link, a RF band for the narrow beam backhaul link, a routing functionality, an access link functionality, and a sensor functionality; and

perform an operation of the radio node, at the data plane, according to the additional information.

FIG. 1

C-P INTERFACE:
CONTROL TO PHYSICAL
NETWORK INTERFACE

C-C INTERFACE:
DOMAIN CONTROL TO
DOMAIN CONTROL
INTERFACE

C-O INTERFACE
DOMAIN CONTROL
TO ORCHESTRATOR

210

DOMAIN
CONTROLLER

210

INTER-DOMAIN
COORDINATOR

API

220

DOMAIN
CONTROLLER

250

250

250

200

220

DOMAIN
CONTROLLER

C-C
INTERFACE

C-P
INTERFACE
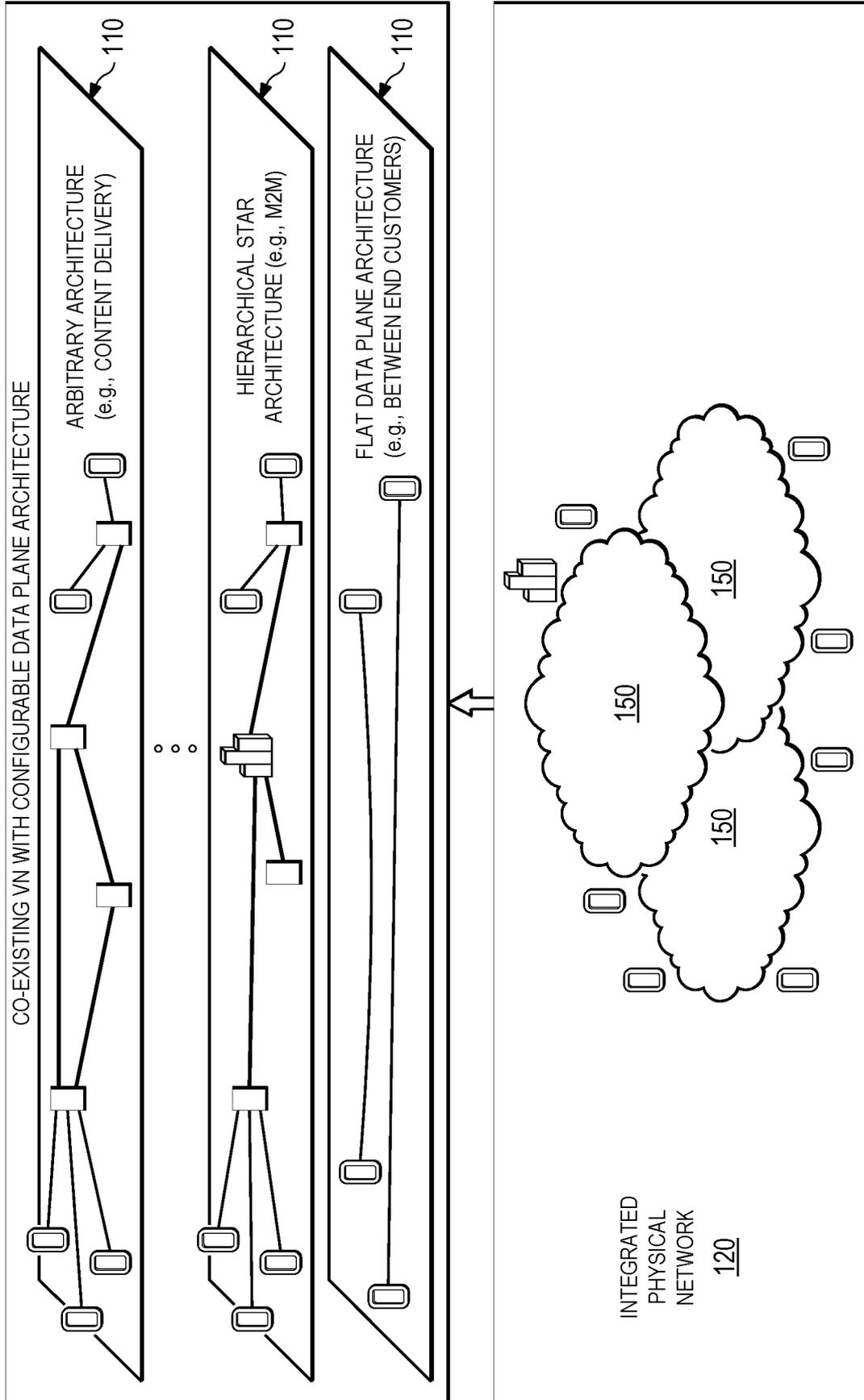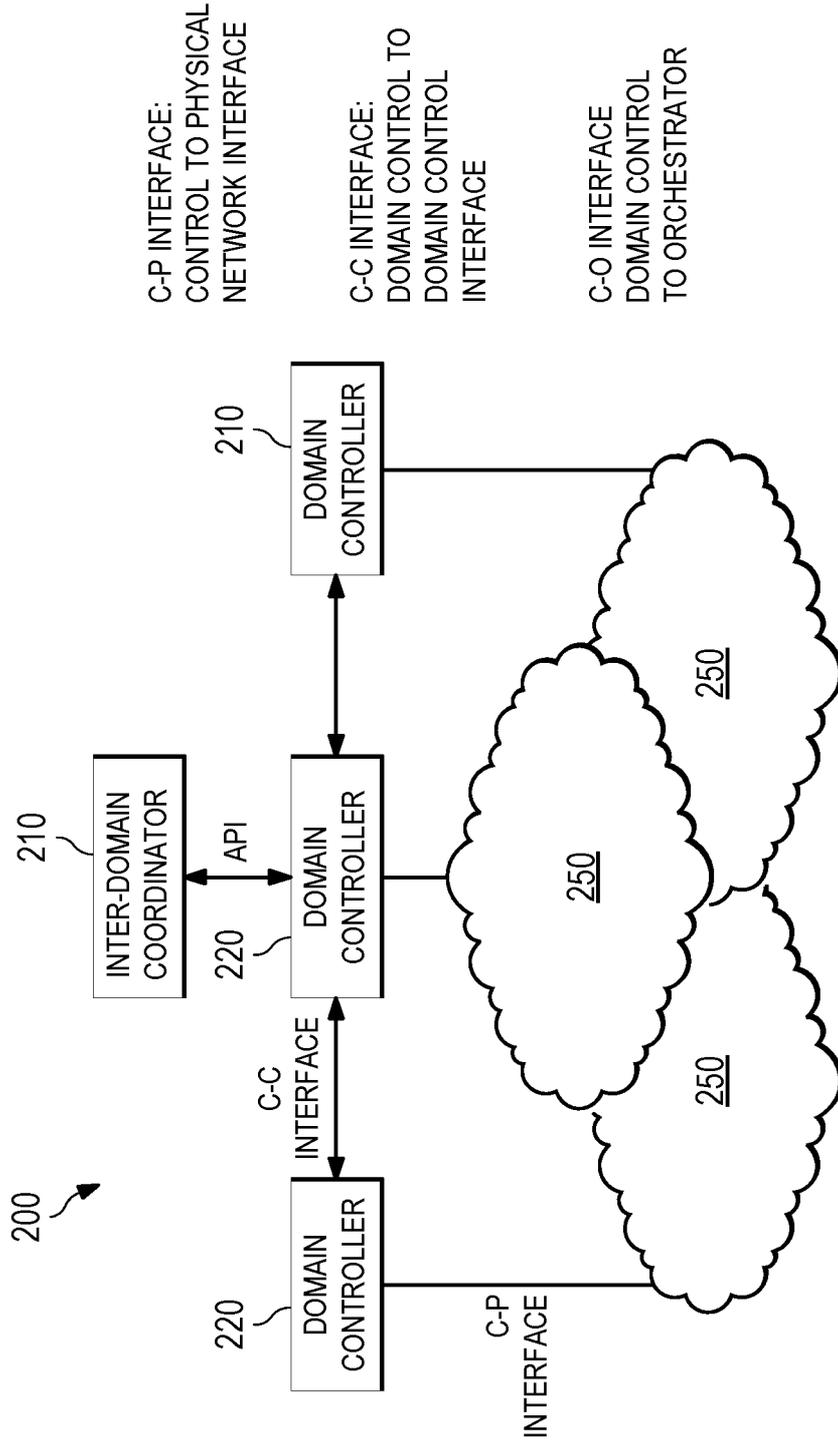
FIG. 2
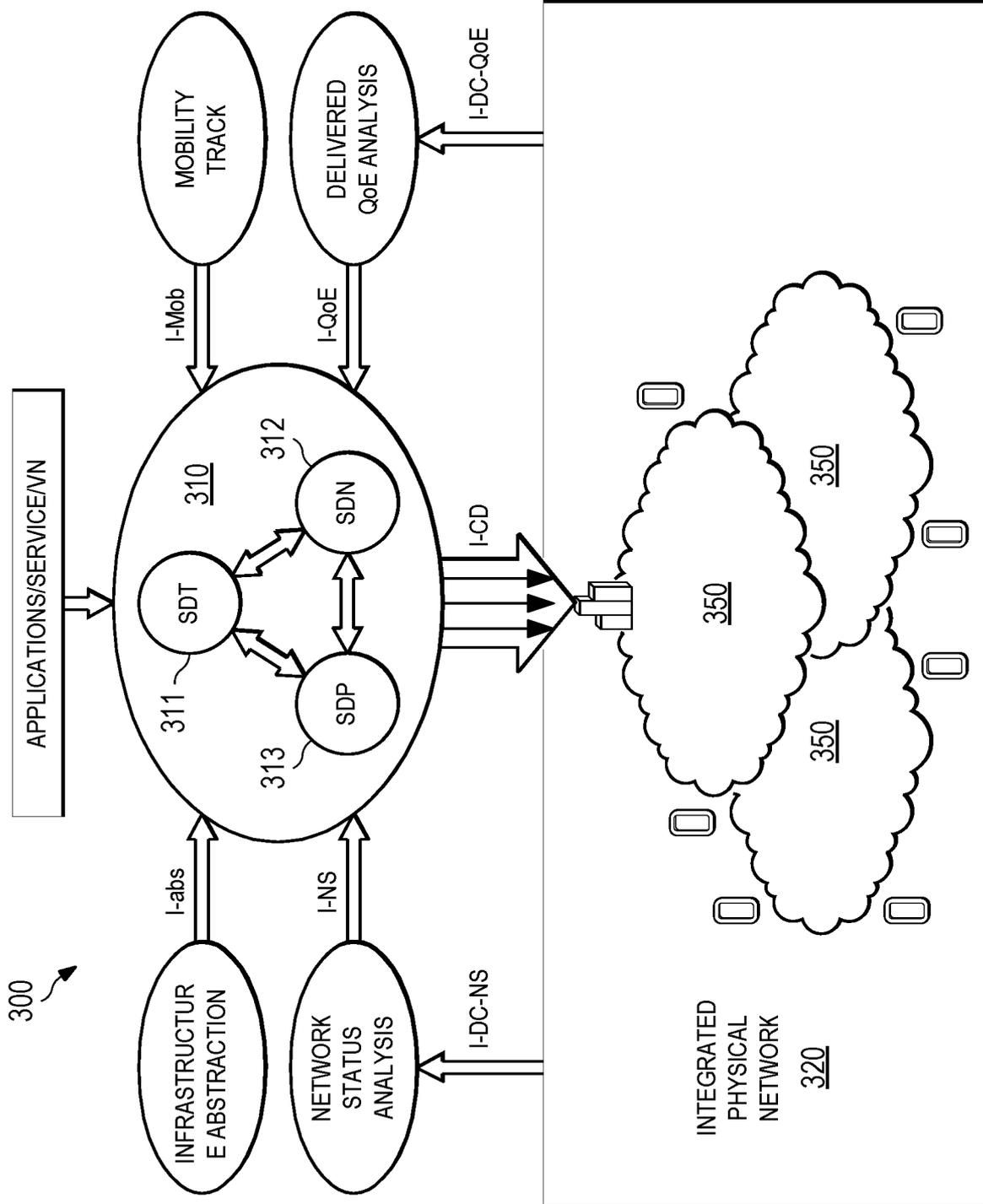
FIG. 3
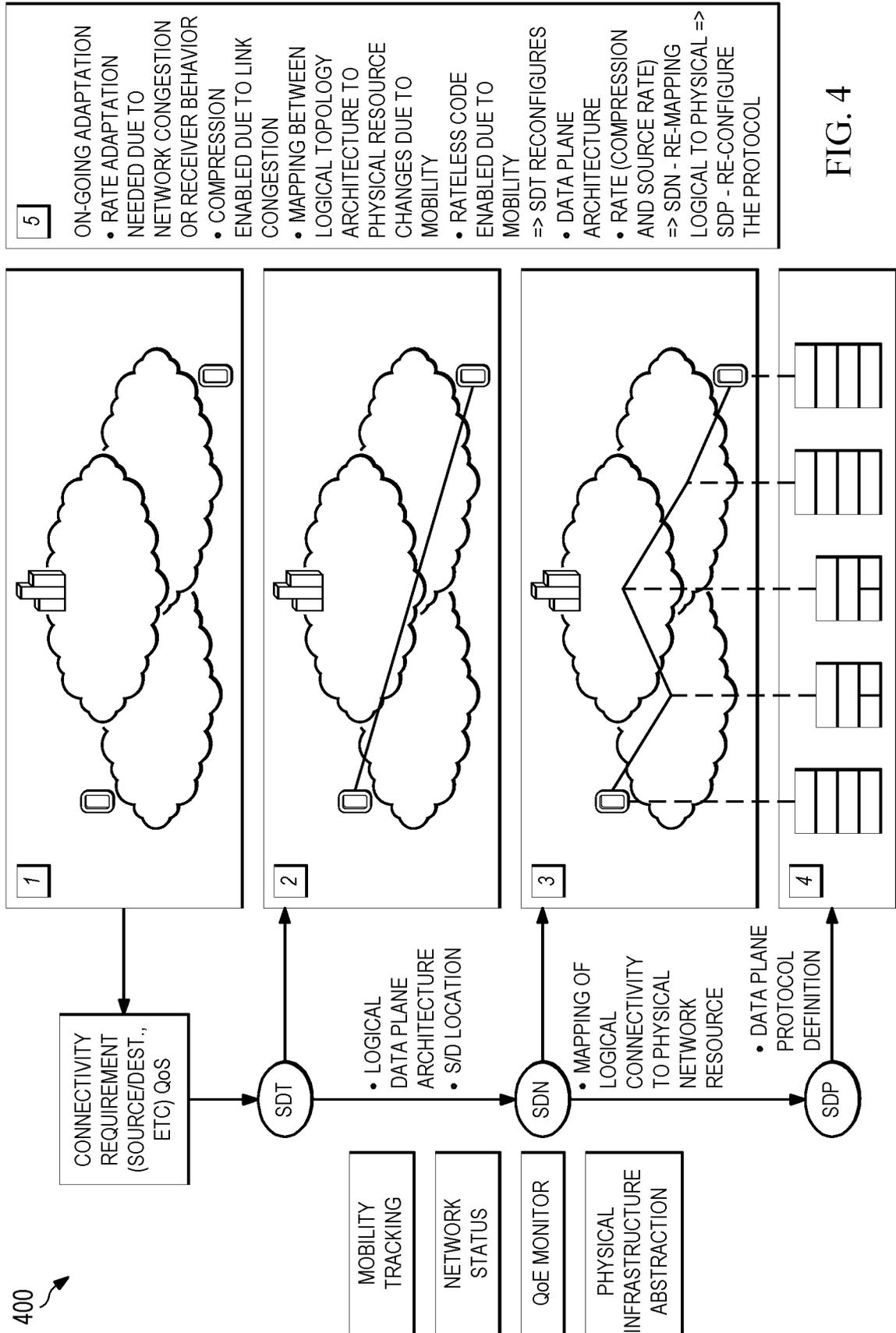
FIG. 4
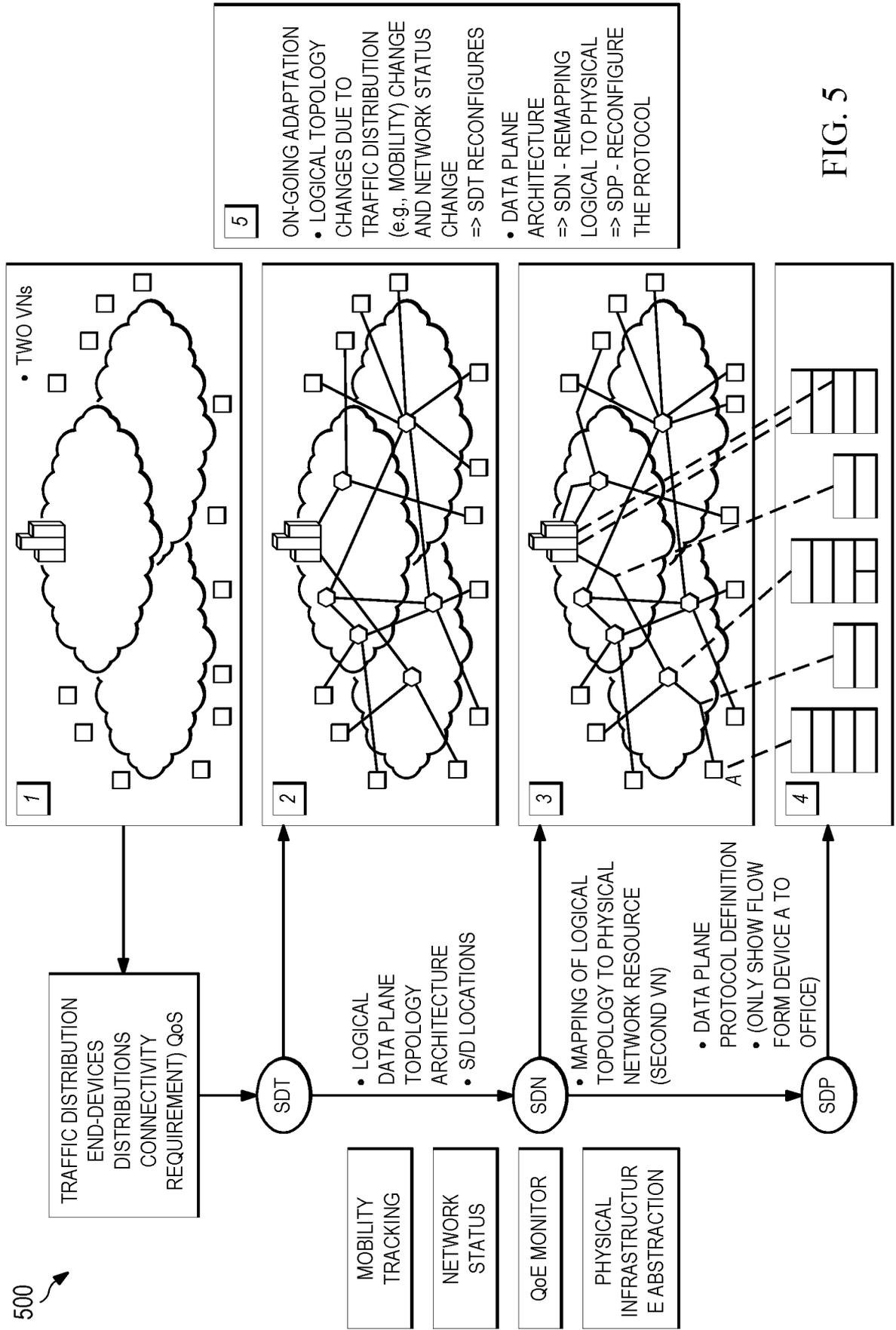
FIG. 5
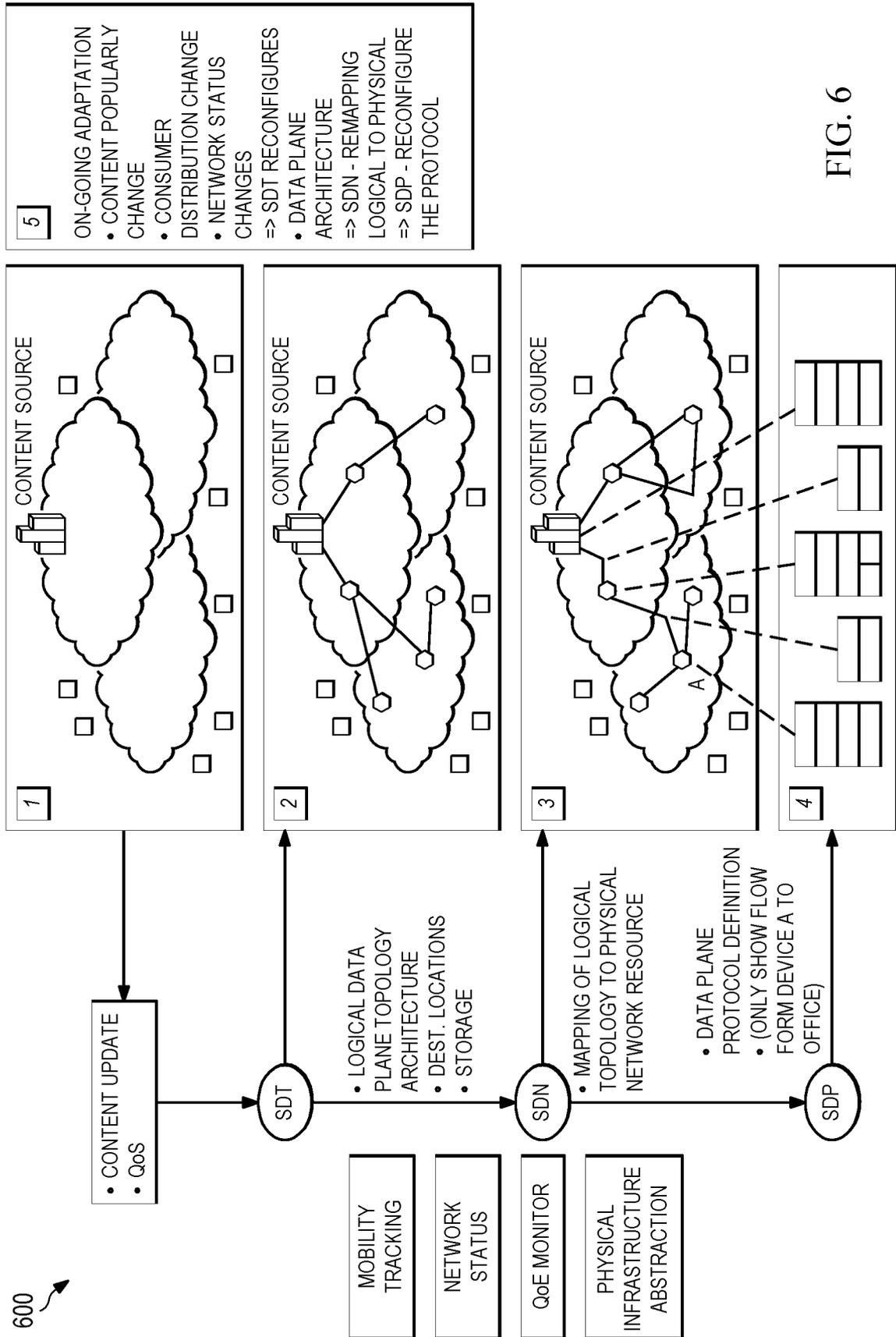
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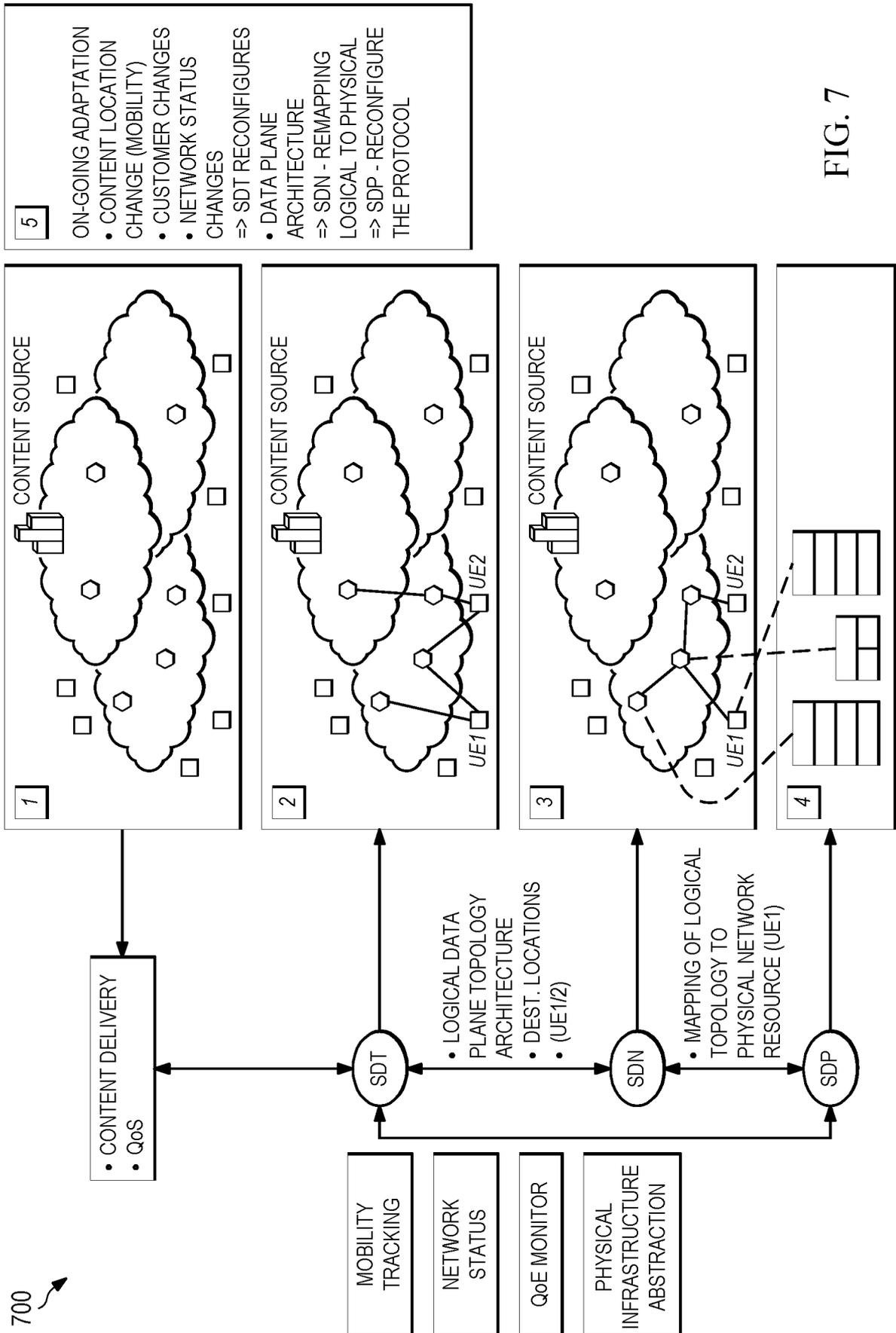
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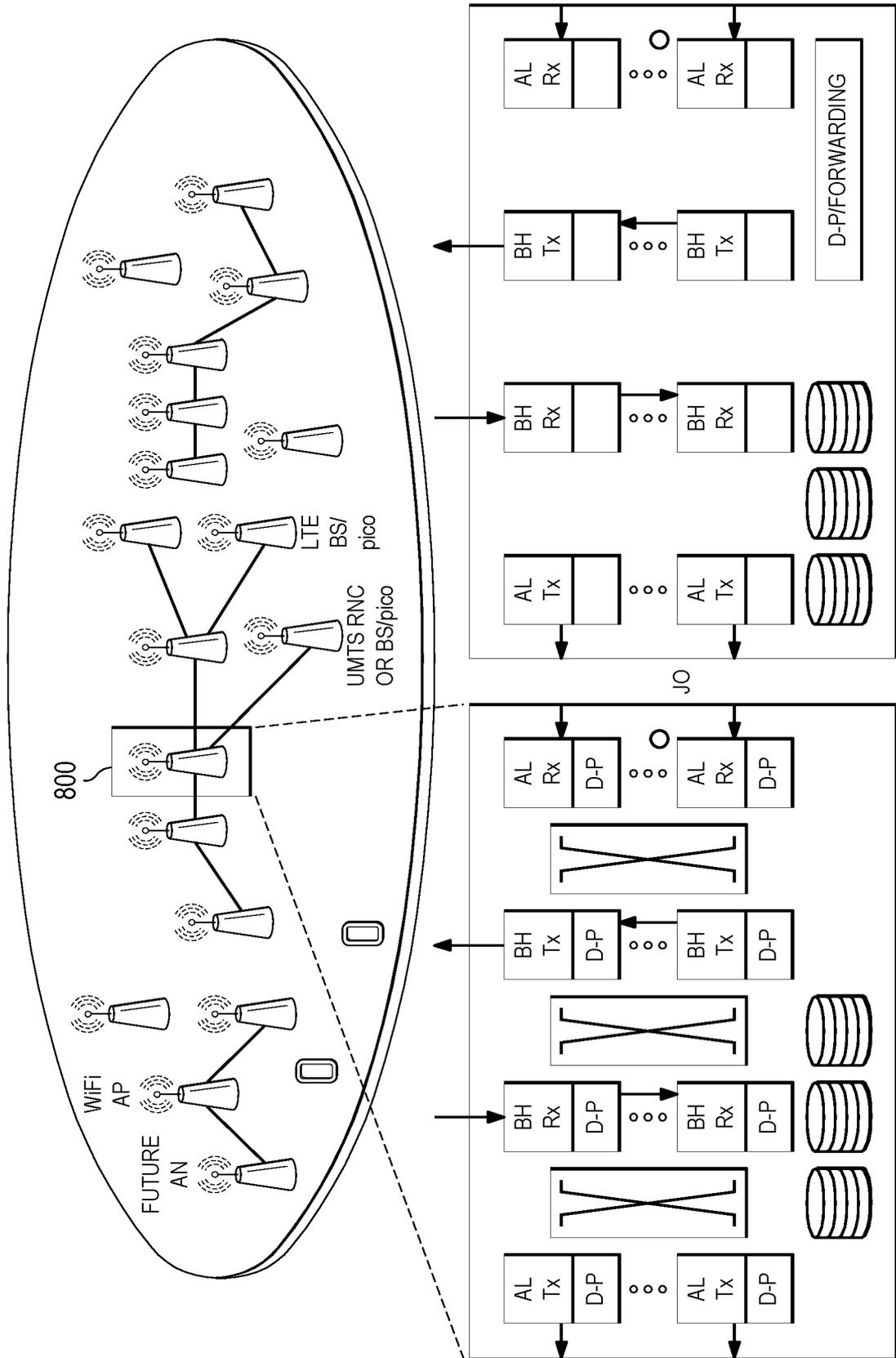
FIG. 8
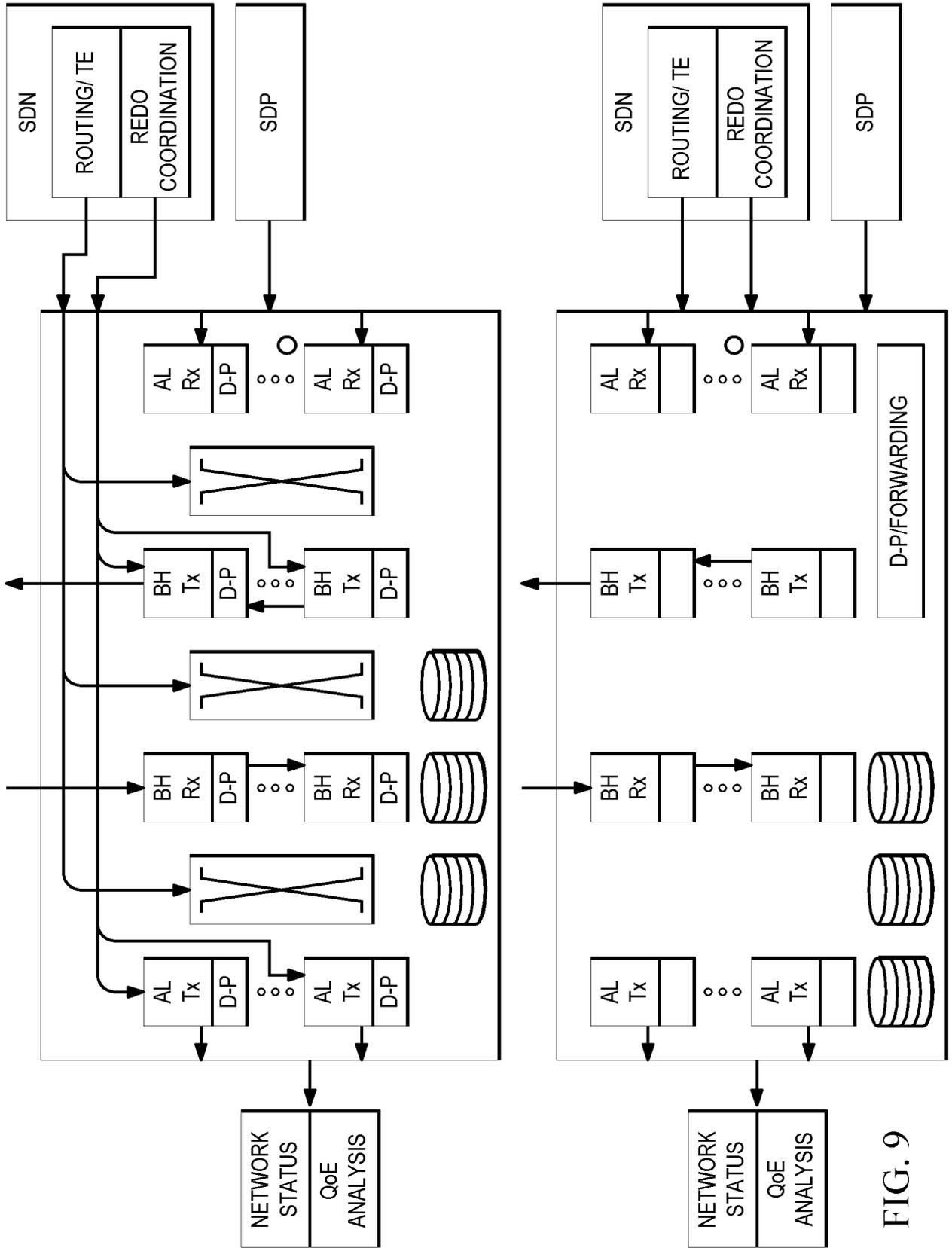
FIG. 9
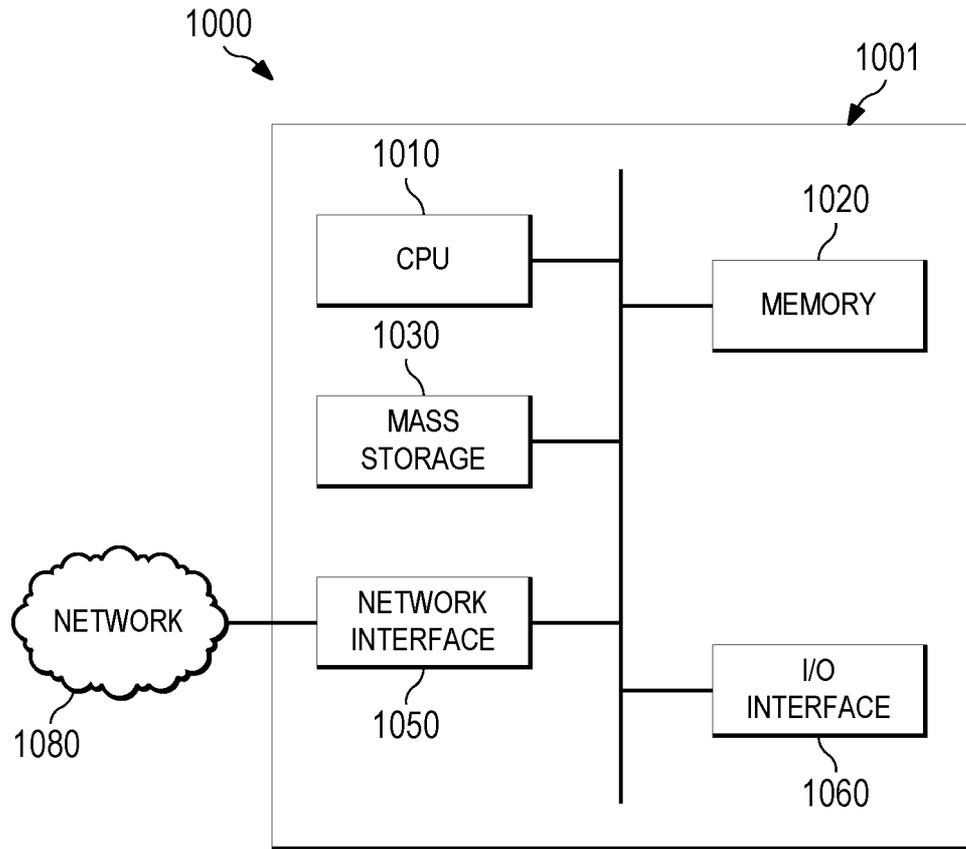
FIG. 10

	International application No.
	PCT/CN2014/075035

A. CLASSIFICATION OF SUBJECT MATTER

H04L 12/24(2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L; G06F; H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS;DWPI:node, message+, logical, defined, virtual, map+, define+, physical, configu+, plane, SDN, parameter+, software, receiv+, information, topology, status, network+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102075402 A (HUAWEI TECHNOLOGIES CO., LTD.ET AL.) 25 May 2011 (2011-05-25) the whole document	1-34
A	CN 101499851 A (ZTE COMMUNICATION CO., LTD. ET AL.) 05 August 2009 (2009-08-05) the whole document	1-34
A	US 2011131252 A1 (KOREA ELECTRONICS TELECOMM) 02 June 2011 (2011-06-02) the whole document	1-34
A	US 8346816 B2 (KOREA ELECTRONICS TELECOMMET AL.) 01 January 2013 (2013-01-01) the whole document	1-34

☐ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

*	Special categories of cited documents:		
"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 June 2014	**25 August 2014**

Name and mailing address of the ISA/	Authorized officer
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Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62412015**

Form PCT/ISA/210 (second sheet) (July 2009)

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				KR	20110059295	A	02 June 2011
				US	8346816	B2	01 January 2013
US	8346816	B2	01 January 2013	JP	2011113571	A	09 June 2011
				US	2011131252	A1	02 June 2011
				KR	20110059295	A	02 June 2011