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Balmakhtar et al.

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(54) **SYNCHRONIZED WIRELESS NETWORK SLICING**

(71) Applicant: **T-MOBILE INNOVATIONS LLC**, Overland Park, KS (US)

(72) Inventors: **Marouane Balmakhtar**, Fairfax, VA (US); **Lyle Walter Paczkowski**, Mission Hills, KS (US)

(73) Assignee: **T-MOBILE INNOVATIONS LLC**, Overland Park, KS (US)

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H04L 41/40	(2022.01)
H04L 41/5041	(2022.01)
H04W 12/06	(2021.01)

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CPC ***H04L 41/5041*** (2013.01); ***H04L 5/0053*** (2013.01); ***H04L 41/40*** (2022.05); ***H04W 12/06*** (2013.01)

(58) **Field of Classification Search**

CPC ... H04L 41/5041; H04L 5/0053; H04L 41/40; H04W 12/06

See application file for complete search history.

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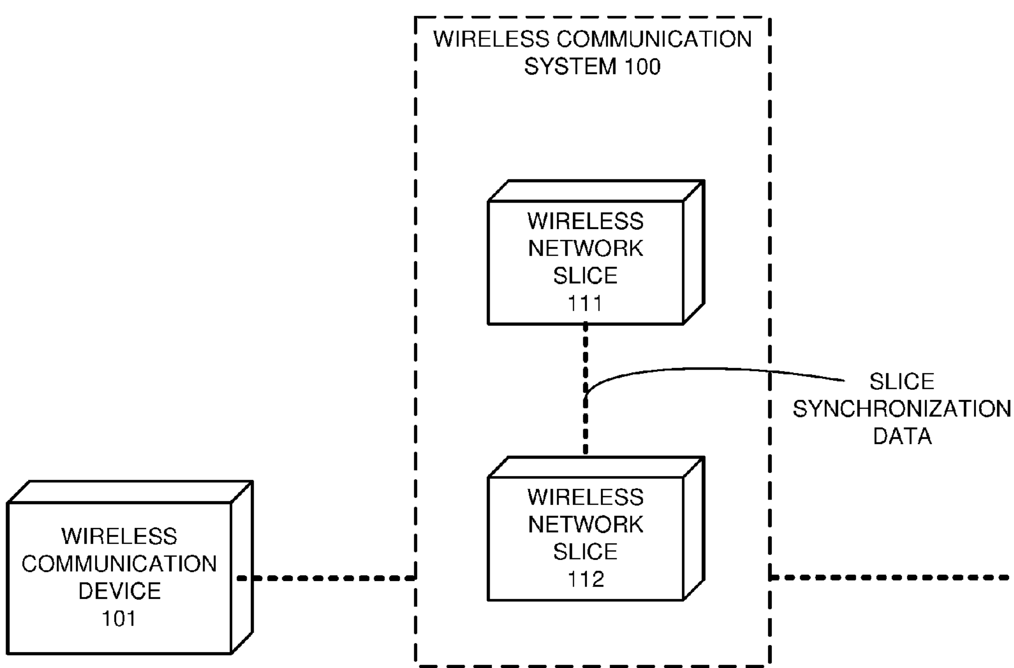
Primary Examiner — John B Walsh

(57) **ABSTRACT**

A first wireless network slice executes a first slice input and generates a first slice output. The first slice transfers the first slice output to a second wireless network slice. The second slice receives and authorizes the first slice output and transfers a first acknowledgement to the first slice. The first slice receives the first acknowledgement and responsively uses the first slice output to deliver a data communication service. The second slice executes a second slice input and generates a second slice output. The second slice transfers the second slice output to the first slice. The first slice receives and authorizes the second slice output and transfers a second acknowledgement to the second slice. The second slice receives the second acknowledgement and responsively uses the second slice output to deliver the data communication service.

20 Claims, 11 Drawing Sheets



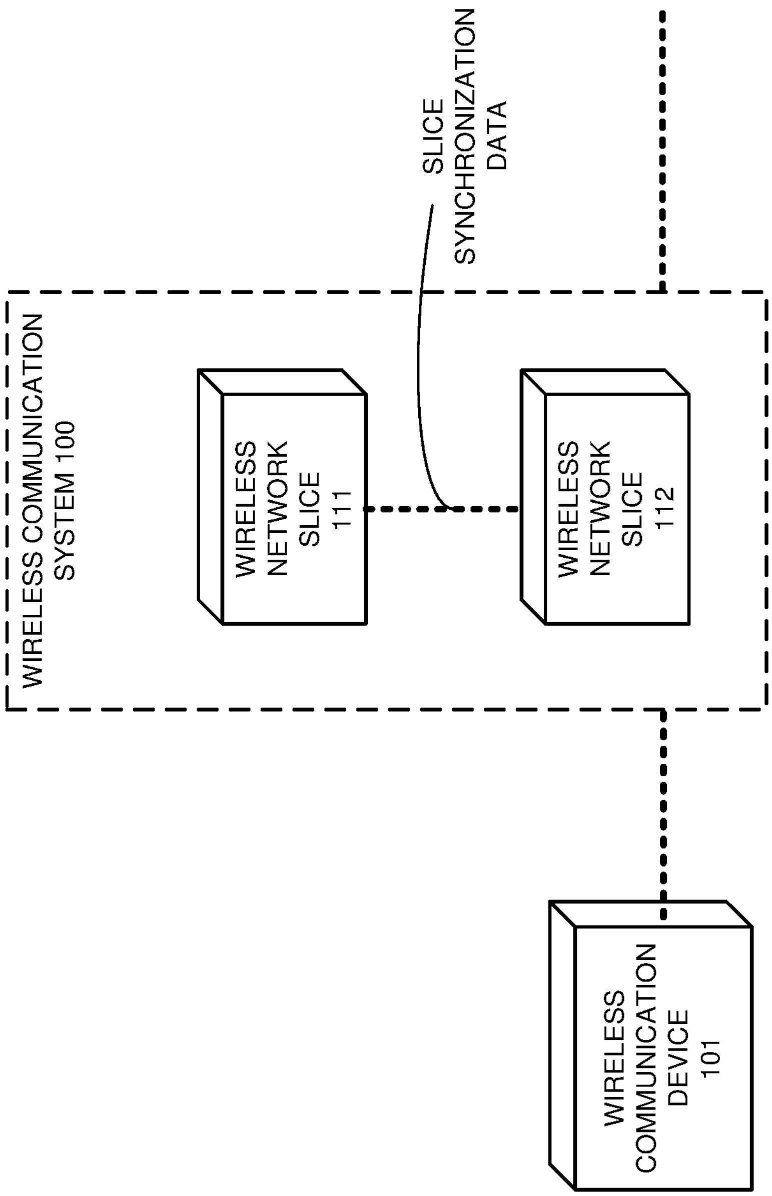
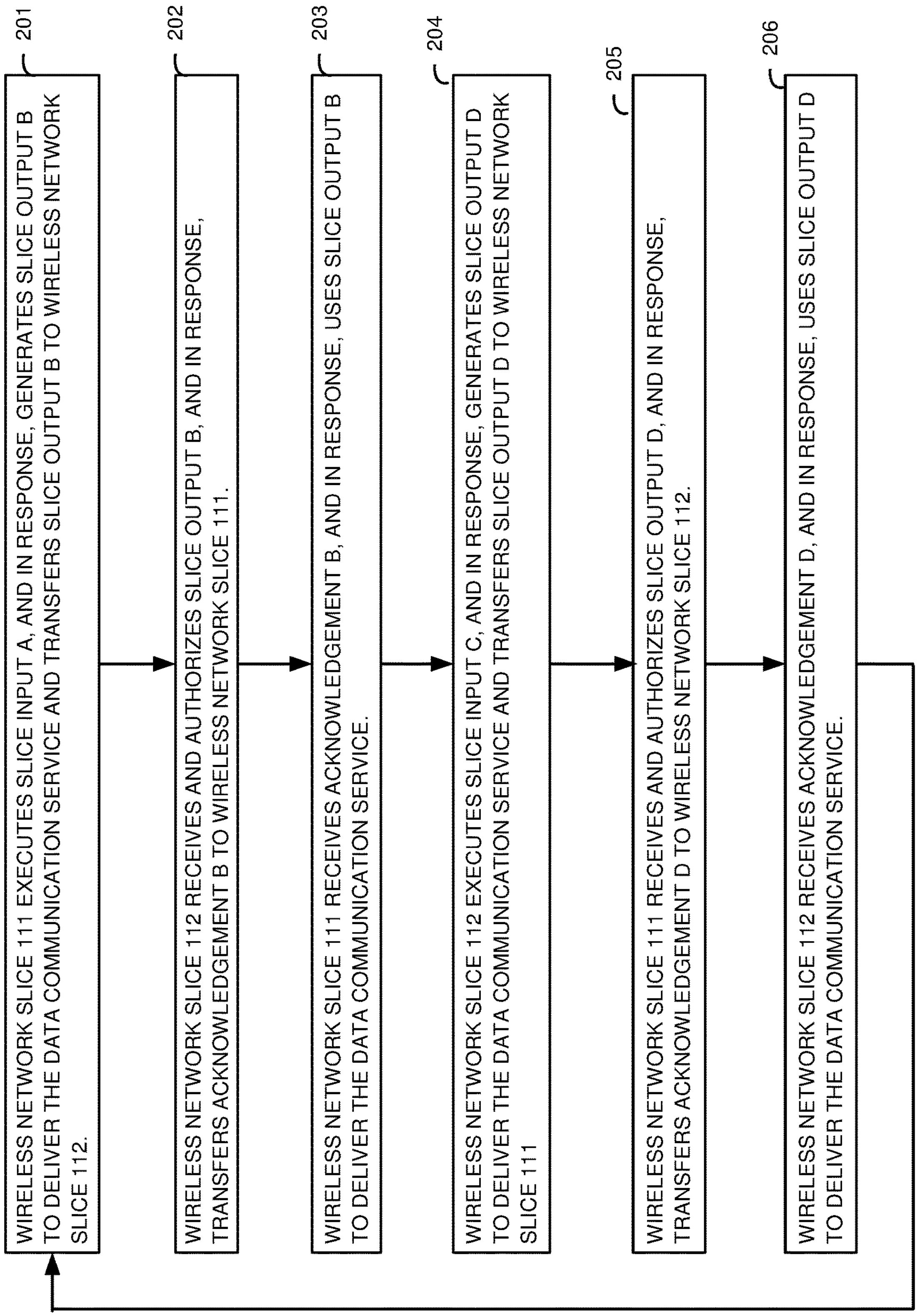

WIRELESS COMMUNICATION SYSTEM 100
WIRELESS NETWORK SLICE 111
WIRELESS NETWORK SLICE 112
SLICE SYNCHRONIZATION DATA
WIRELESS COMMUNICATION DEVICE 101

FIGURE 1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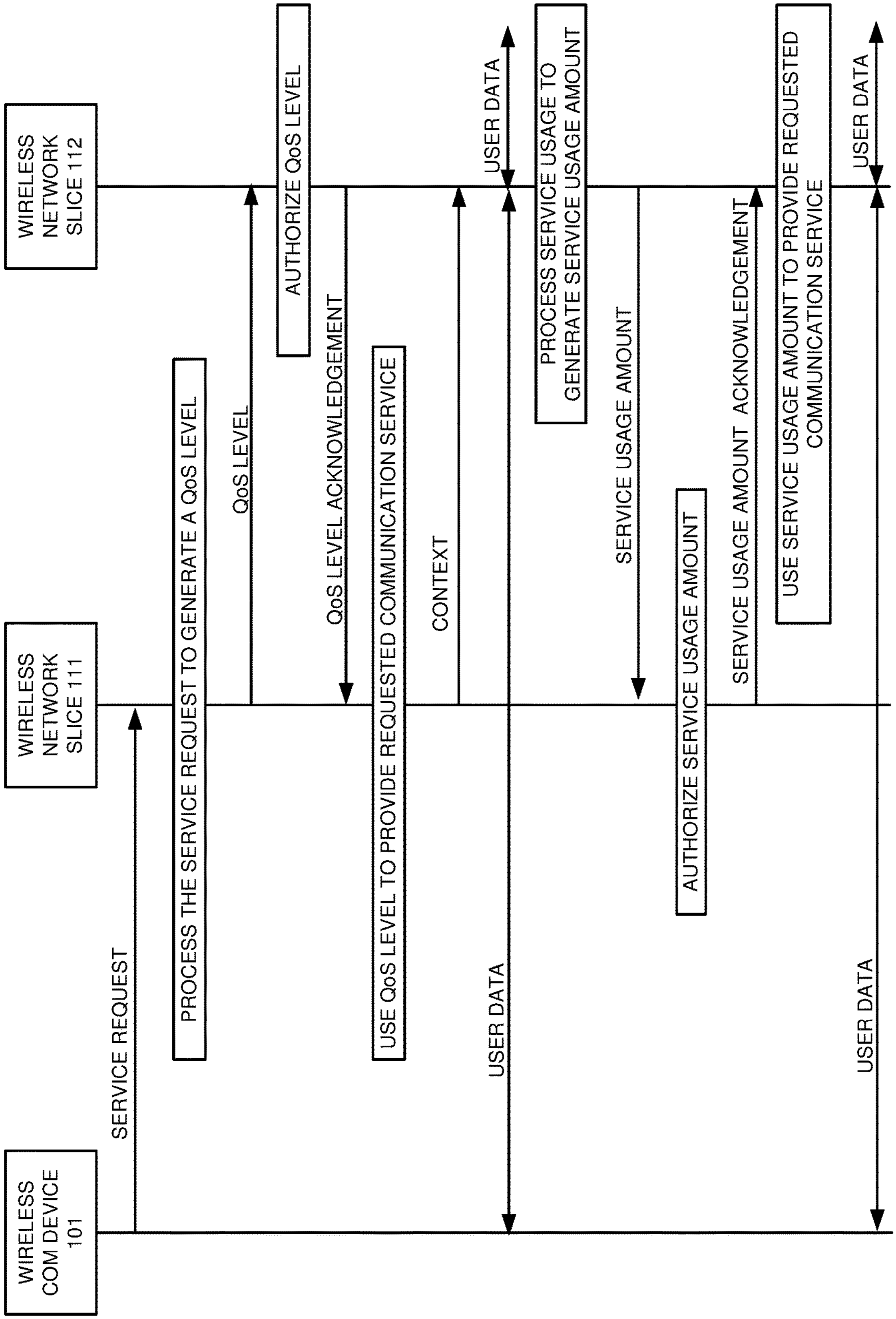
WIRELESS NETWORK SLICE 111 EXECUTES SLICE INPUT A, AND IN RESPONSE, GENERATES SLICE OUTPUT B TO DELIVER THE DATA COMMUNICATION SERVICE AND TRANSFERS SLICE OUTPUT B TO WIRELESS NETWORK SLICE 112.
202
WIRELESS NETWORK SLICE 112 RECEIVES AND AUTHORIZES SLICE OUTPUT B, AND IN RESPONSE, TRANSFERS ACKNOWLEDGEMENT B TO WIRELESS NETWORK SLICE 111.
203
WIRELESS NETWORK SLICE 111 RECEIVES ACKNOWLEDGEMENT B, AND IN RESPONSE, USES SLICE OUTPUT B TO DELIVER THE DATA COMMUNICATION SERVICE.
204
WIRELESS NETWORK SLICE 112 EXECUTES SLICE INPUT C, AND IN RESPONSE, GENERATES SLICE OUTPUT D TO DELIVER THE DATA COMMUNICATION SERVICE AND TRANSFERS SLICE OUTPUT D TO WIRELESS NETWORK SLICE 111
205
WIRELESS NETWORK SLICE 111 RECEIVES AND AUTHORIZES SLICE OUTPUT D, AND IN RESPONSE, TRANSFERS ACKNOWLEDGEMENT D TO WIRELESS NETWORK SLICE 112.
206
WIRELESS NETWORK SLICE 112 RECEIVES ACKNOWLEDGEMENT D, AND IN RESPONSE, USES SLICE OUTPUT D TO DELIVER THE DATA COMMUNICATION SERVICE.

FIGURE 2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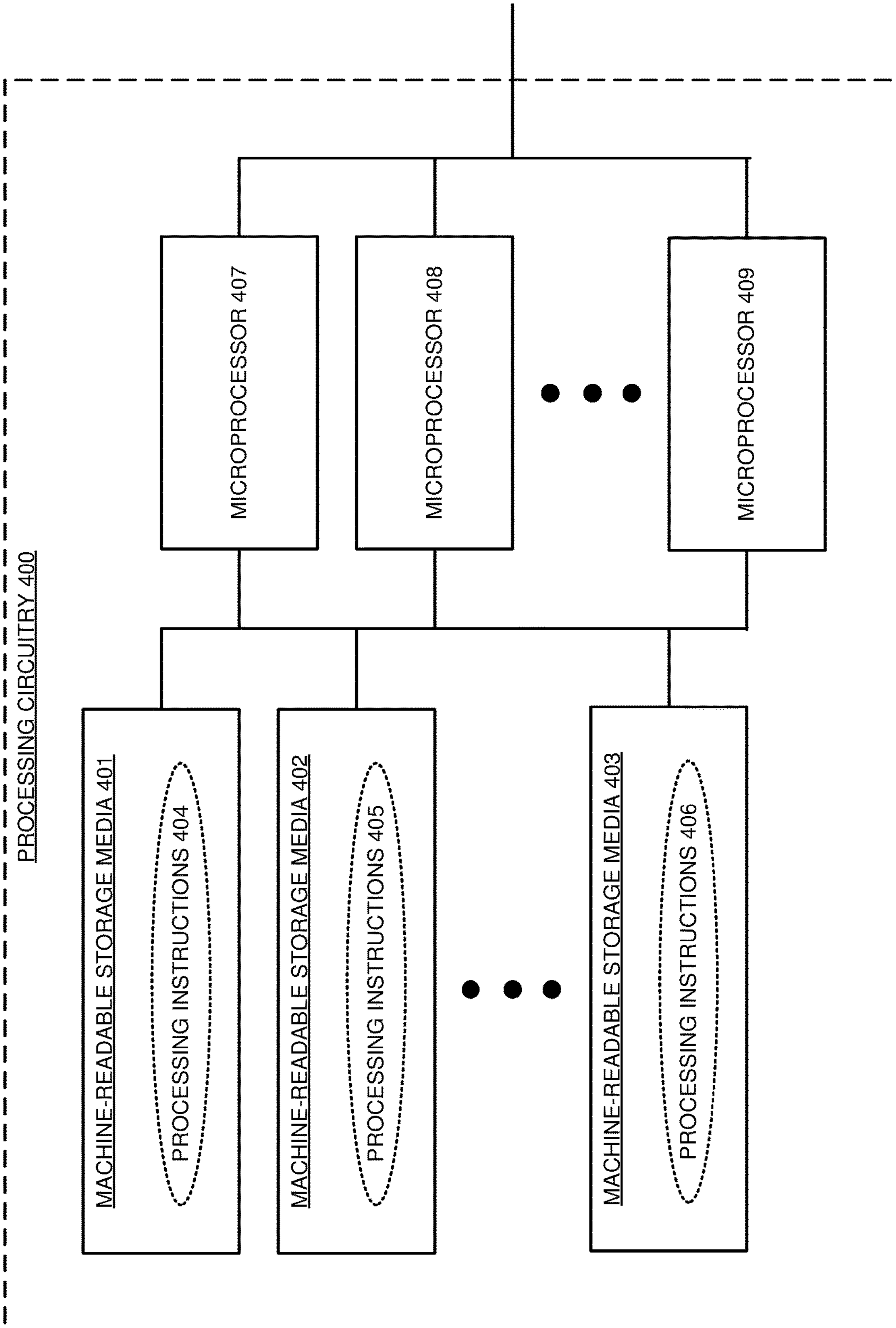
WIRELESS NETWORK SLICE 111
WIRELESS NETWORK SLICE 112
SERVICE REQUEST
PROCESS THE SERVICE REQUEST TO GENERATE A QoS LEVEL
QoS LEVEL
AUTHORIZE QoS LEVEL
QoS LEVEL ACKNOWLEDGEMENT
USE QoS LEVEL TO PROVIDE REQUESTED COMMUNICATION SERVICE
CONTEXT
USER DATA
USER DATA
PROCESS SERVICE USAGE TO GENERATE SERVICE USAGE AMOUNT
SERVICE USAGE AMOUNT
AUTHORIZE SERVICE USAGE AMOUNT
SERVICE USAGE AMOUNT ACKNOWLEDGEMENT
USE SERVICE USAGE AMOUNT TO PROVIDE REQUESTED COMMUNICATION SERVICE
USER DATA
USER DATA

FIGURE 3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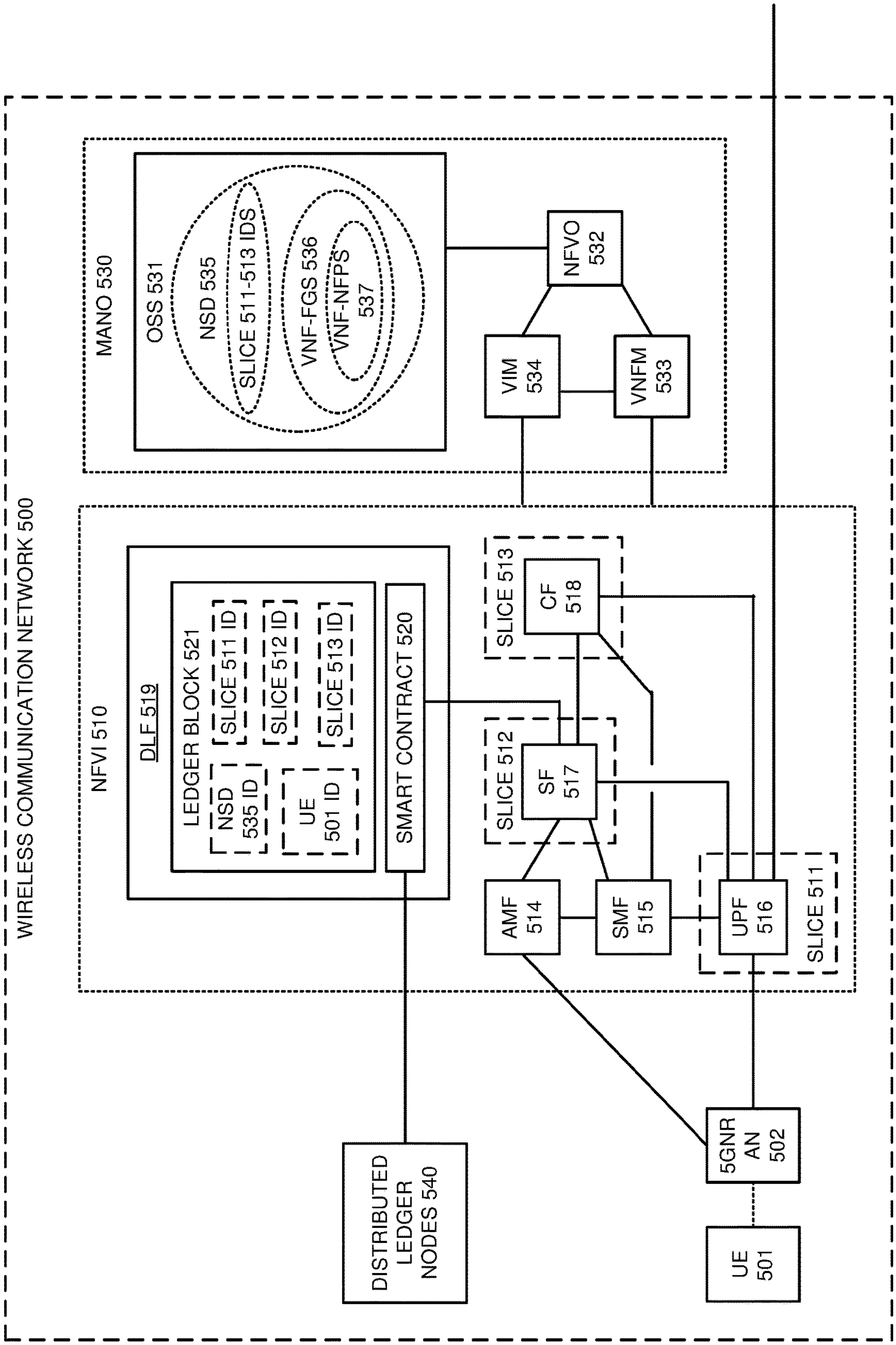
MICROPROCESSOR 407
MICROPROCESSOR 408
MICROPROCESSOR 409
MACHINE-READABLE STORAGE MEDIA 401
PROCESSING INSTRUCTIONS 404
MACHINE-READABLE STORAGE MEDIA 402
PROCESSING INSTRUCTIONS 405
MACHINE-READABLE STORAGE MEDIA 403
PROCESSING INSTRUCTIONS 406

FIGURE 4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MANO 530
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VNF-NFPS 537
NFVO 532
VIM 534
VNFM 533
NFVI 510
DLF 519
LEDGER BLOCK 521
SLICE 511 ID
SLICE 512 ID
SLICE 513 ID
NSD 535 ID
UE 501 ID
SMART CONTRACT 520
SLICE 513
CF 518
SLICE 512
SF 517
AMF 514
SMF 515
UPF 516
SLICE 511
DISTRIBUTED LEDGER NODES 540
5GNR AN 502
UE 501

FIGURE 5

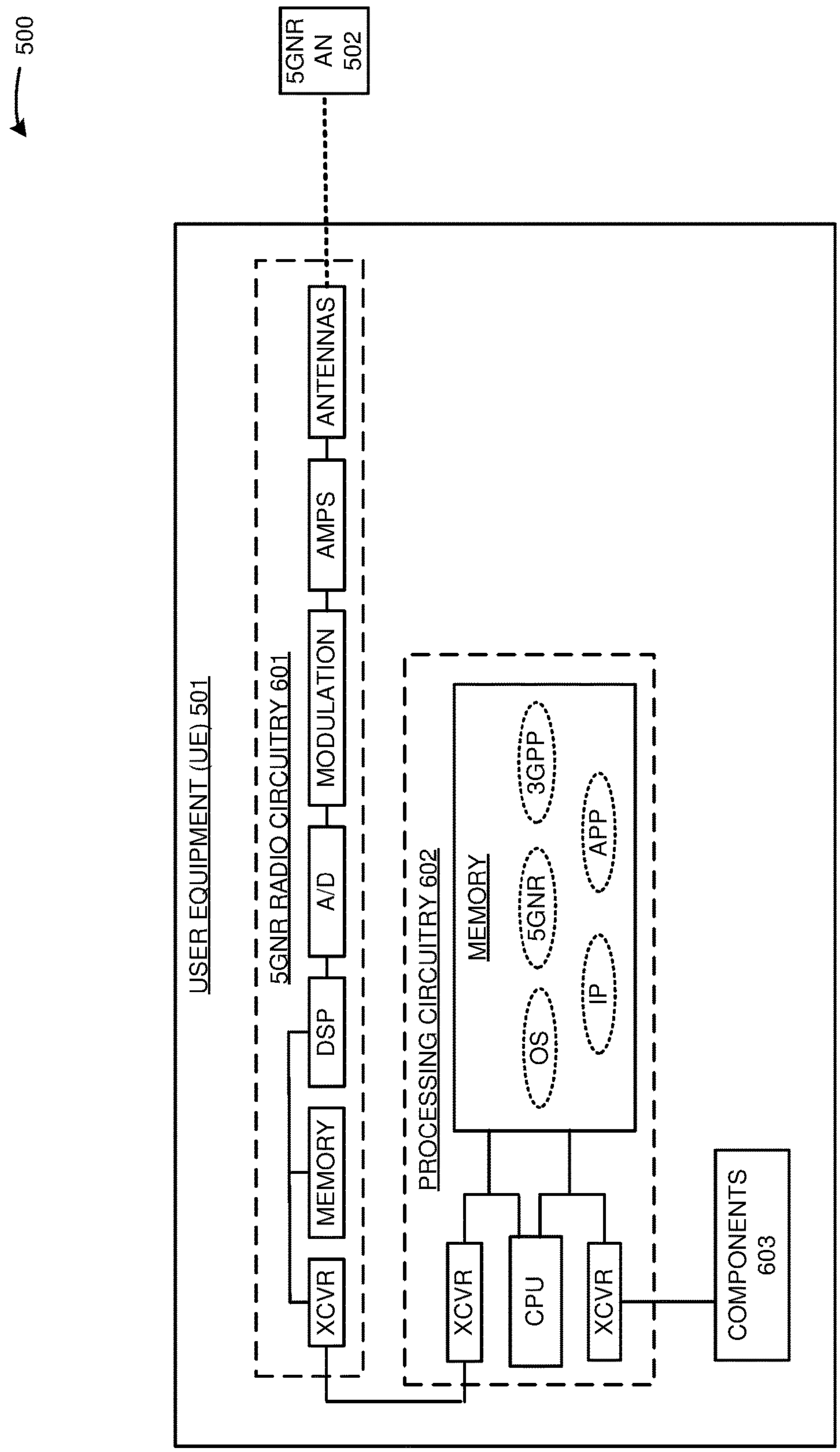
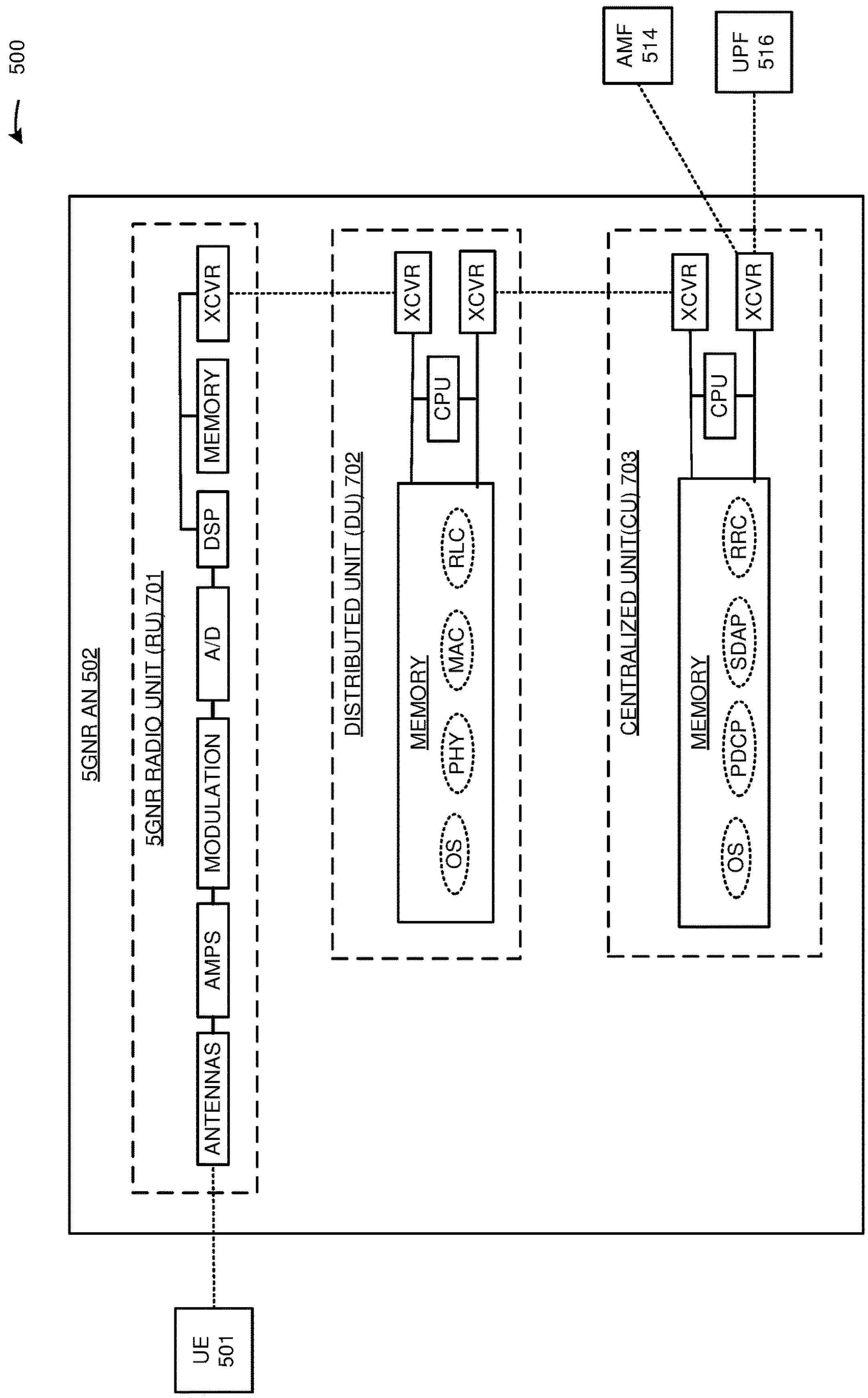

500
5GNR
AN
502
USER EQUIPMENT (UE) 501
5GNR RADIO CIRCUITRY 601
ANTENNAS
AMPS
MODULATION
A/D
DSP
MEMORY
XCVR
PROCESSING CIRCUITRY 602
MEMORY
3GPP
APP
5GNR
IP
OS
XCVR
CPU
XCVR
COMPONENTS
603

FIGURE 6


500
5GNR AN 502
5GNR RADIO UNIT (RU) 701
ANTENNAS
AMPS
MODULATION
A/D
DSP
MEMORY
XCVR
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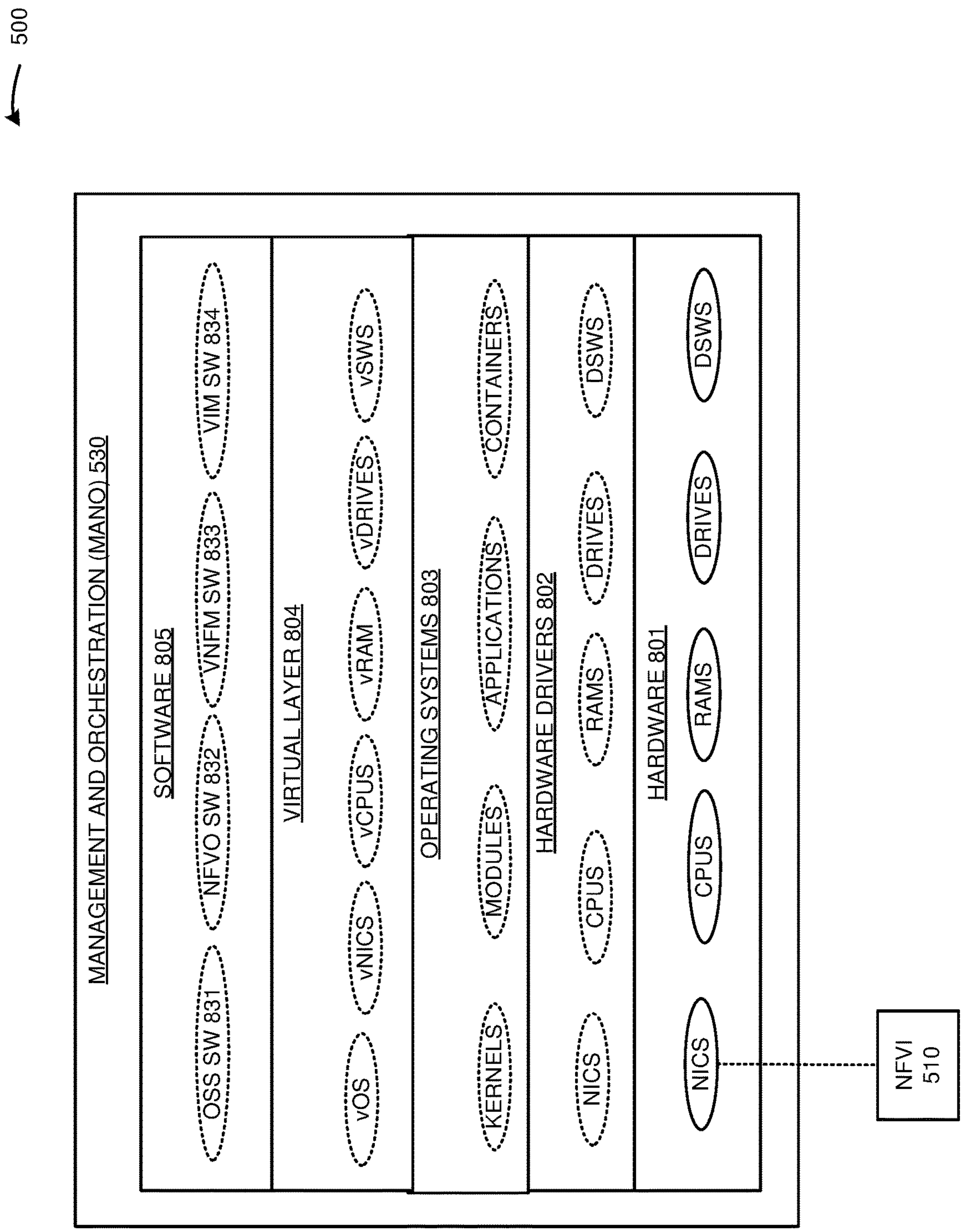
XCVR
XCVR
CPU
MEMORY
OS
PHY
MAC
RLC
CENTRALIZED UNIT(CU) 703
XCVR
XCVR
CPU
MEMORY
OS
PDCP
SDAP
RRC
AMF 514
UPF 516
UE 501

FIGURE 7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MANAGEMENT AND ORCHESTRATION (MANO) 530
SOFTWARE 805
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NFVO SW 832
VNFM SW 833
VIM SW 834
VIRTUAL LAYER 804
vOS
vNICS
vCPUS
vRAM
vDRIVES
vSWS
OPERATING SYSTEMS 803
KERNELS
MODULES
APPLICATIONS
CONTAINERS
HARDWARE DRIVERS 802
NICS
CPUS
RAMS
DRIVES
DSWS
HARDWARE 801
NICS
CPUS
RAMS
DRIVES
DSWS
NFVI
510

FIGURE 8

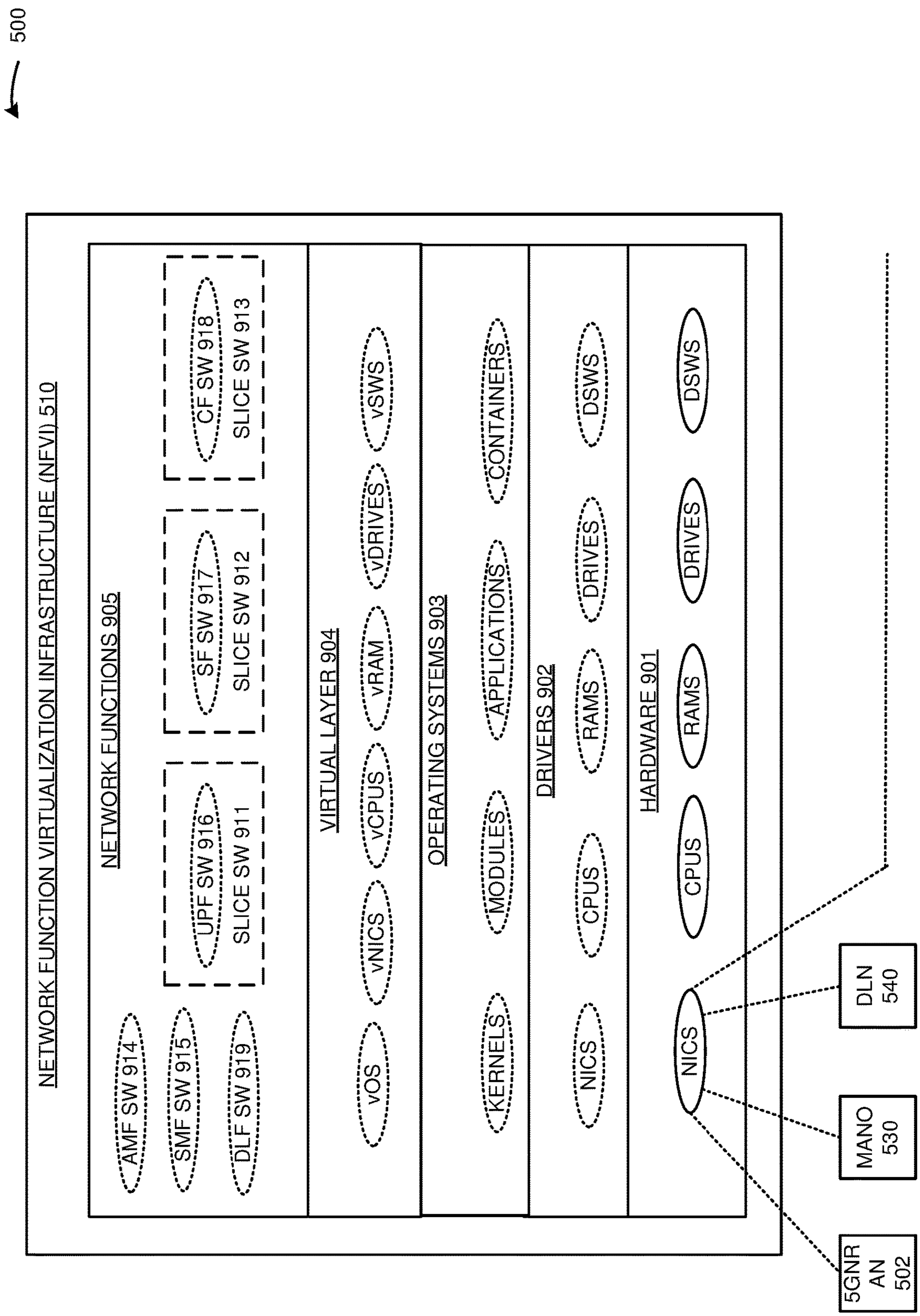
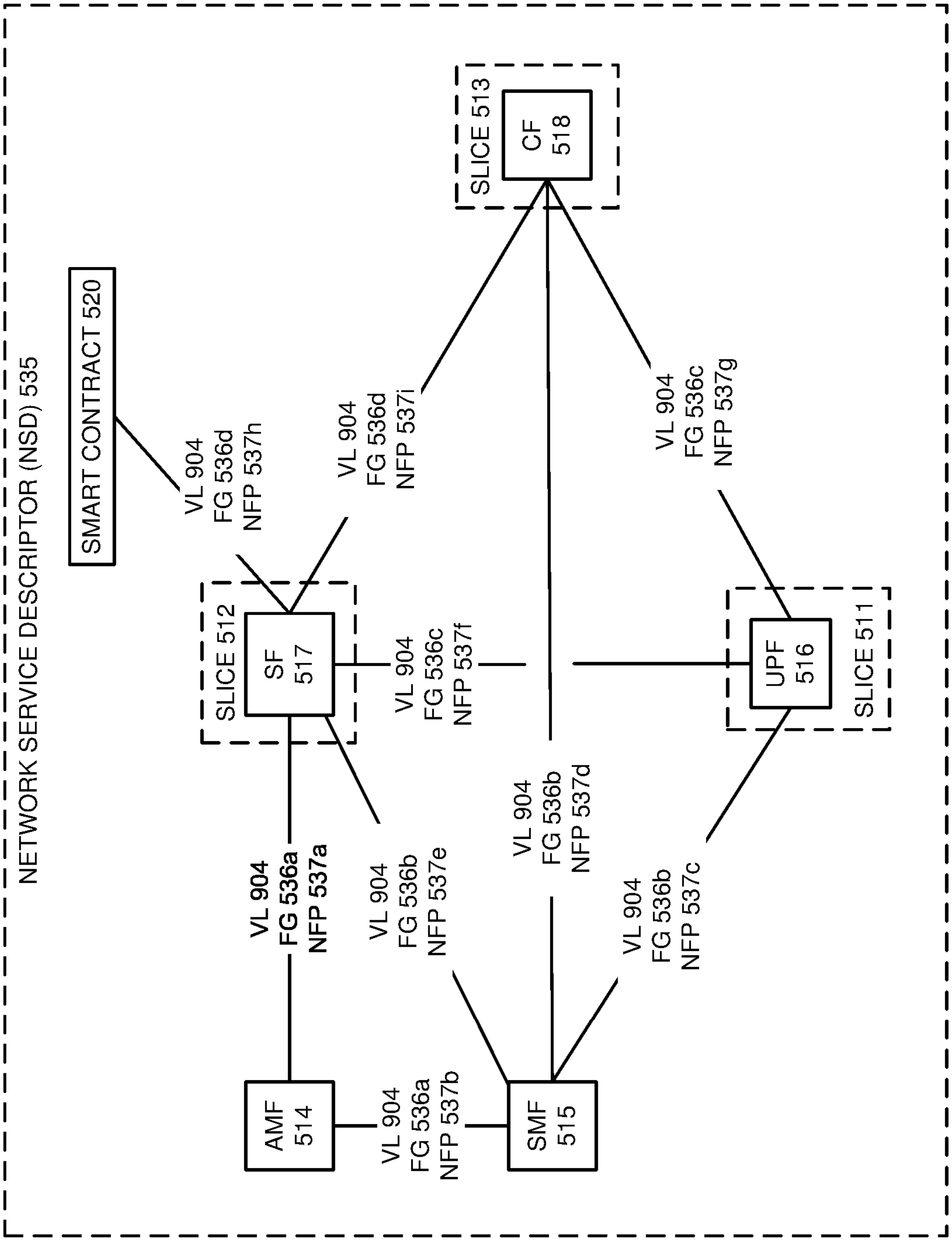

500
NETWORK FUNCTION VIRTUALIZATION INFRASTRUCTURE (NFVI) 510
NETWORK FUNCTIONS 905
AMF SW 914
SMF SW 915
DLF SW 919
UPF SW 916
SLICE SW 911
SF SW 917
SLICE SW 912
CF SW 918
SLICE SW 913
VIRTUAL LAYER 904
vOS
vNICS
vCPUS
vRAM
vDRIVES
vSWS
OPERATING SYSTEMS 903
KERNELS
MODULES
APPLICATIONS
CONTAINERS
DRIVERS 902
NICS
CPUS
RAMS
DRIVES
DSWS
HARDWARE 901
NICS
CPUS
RAMS
DRIVES
DSWS
5GNR AN 502
MANO 530
DLN 540

FIGURE 9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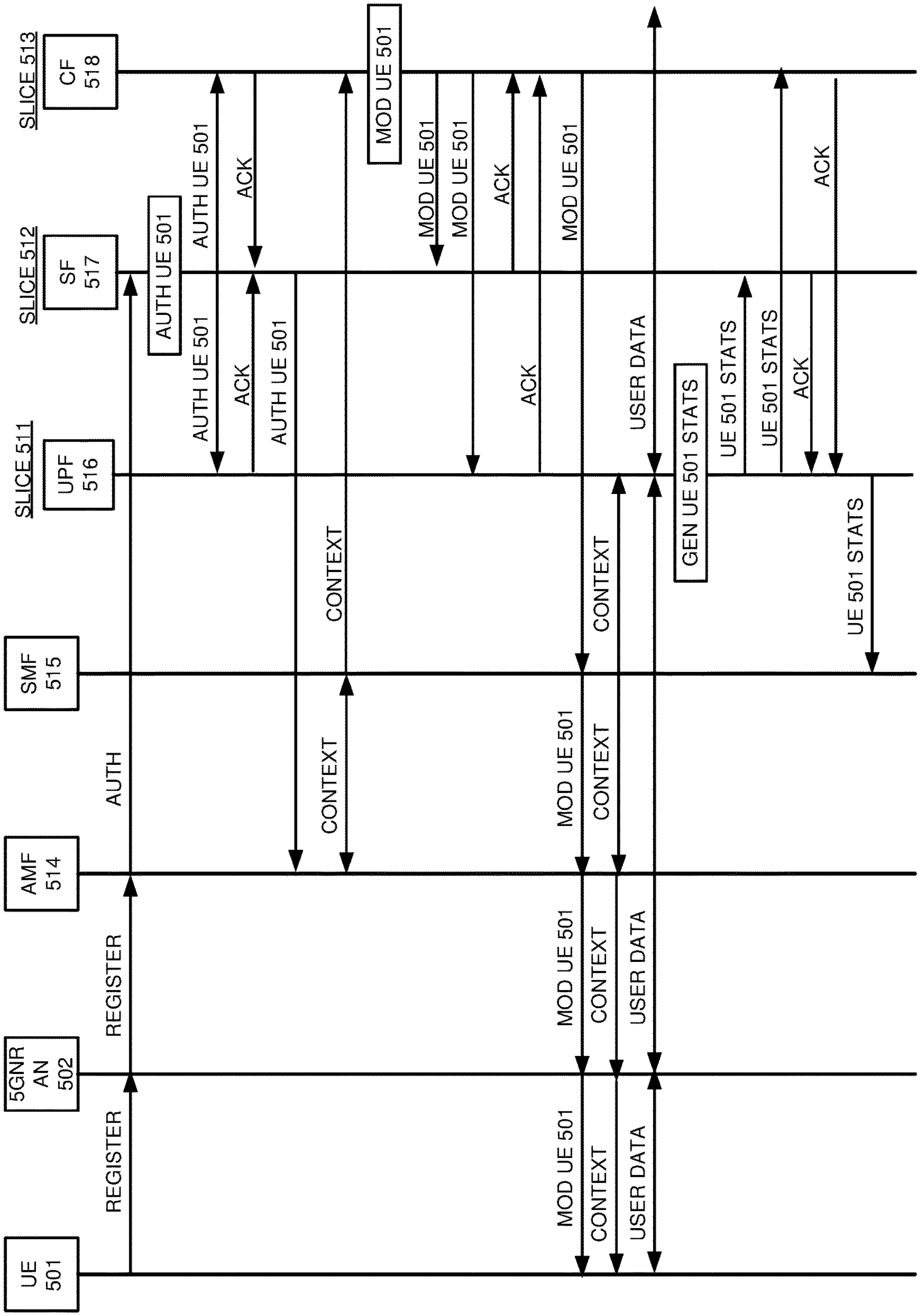
SLICE 512
SF 517
SLICE 513
CF 518
SLICE 511
UPF 516
AMF 514
SMF 515
VL 904 FG 536d NFP 537h
VL 904 FG 536d NFP 537i
VL 904 FG 536c NFP 537g
VL 904 FG 536c NFP 537f
VL 904 FG 536a NFP 537a
VL 904 FG 536b NFP 537e
VL 904 FG 536b NFP 537d
VL 904 FG 536b NFP 537c
VL 904 FG 536a NFP 537b

FIGURE 10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AMF 514
SMF 515
UPF 516
SLICE 511
SF 517
SLICE 512
CF 518
SLICE 513
REGISTER
REGISTER
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AUTH UE 501
ACK
ACK
AUTH UE 501
CONTEXT
CONTEXT
MOD UE 501
MOD UE 501
MOD UE 501
ACK
ACK
MOD UE 501
MOD UE 501
MOD UE 501
MOD UE 501
CONTEXT
CONTEXT
CONTEXT
CONTEXT
USER DATA
USER DATA
USER DATA
GEN UE 501 STATS
UE 501 STATS
UE 501 STATS
ACK
ACK
UE 501 STATS

FIGURE 11

SYNCHRONIZED WIRELESS NETWORK SLICING

TECHNICAL BACKGROUND

Wireless communication networks provide wireless data services to wireless communication devices like phones, computers, and other user devices. The wireless data services may include internet-access, data messaging, video conferencing, or some other data communication product. The wireless communication networks comprise wireless access nodes like Wireless Fidelity (WIFI) hotspots and Fifth Generation New Radio (5GNR) cell towers. The wireless communication networks also comprise wireless network slices. The wireless network slices have customized software that is tailored for their specific wireless data services. For example, an augmented reality device may use an Ultra-Reliable Low Latency Communication (URLLC) slice while a television device may use an enhanced Mobile Broadband (eMBB) slice.

The typical wireless network slice comprises software that executes in a data center to form Virtual Network Functions (VNFs) that transfer user data and/or control the transfer of the user data. Exemplary VNFs that are used to form wireless network slices include User Plane Functions (UPFs) and Policy Control Functions (PCFs). Exemplary data centers include Network Function Virtualization Infrastructures (NFVIs) and Management and Orchestration (MANO) systems. The MANO systems implement Network Service Descriptors (NSDs) that have Virtual Network Function Forwarding Graphs (VNF-FGs). The VNF-NFGs specify Virtual Network Function Network Forwarding Paths (VNF-NFPs) between the VNFs. The VNFs uses the VNF-NFPs to communicate and deliver the data communication services described in the applicable NSDs.

Distributed ledgers have multiple ledger nodes that perform ledger transactions in parallel. The ledger nodes validate a transaction when a consensus is reached among the nodes for the ledger transaction. The typical ledger transaction entails a smart contract that processes a data input to generate a data output. For example, a ledger may process the data inputs of a current balance and an expenditure to generate the data output of a new balance. The distributed ledger nodes each store transaction data in data blocks that also include a hash of the previous data block. Thus, the data blocks are linked by the hashes and the transaction data is immutable.

Unfortunately, the wireless communication networks do not effectively coordinate the parallel operations of different network slices. Moreover, the wireless communication networks fail to efficiently use NSDs and distributed ledgers to synchronize the parallel operations of the different network slices. As a result, the unsynchronized delivery of the data communication services to the wireless user devices suffers or fails.

Technical Overview

In some examples, a data communication service uses synchronized wireless network slicing. A first wireless network slice executes a first slice input, and in response, generates a first slice output to deliver the data communication service. The first slice transfers the first slice output to a second wireless network slice. The second wireless network slice receives and authorizes the first slice output, and in response, transfers a first acknowledgement to the first wireless network slice. The first wireless network slice receives the first acknowledgement, and in response, uses the first slice output to deliver the data communication service. The second wireless network slice executes a second slice input, and in response, generates a second slice output to deliver the data communication service. The second slice transfers the second slice output to the first wireless network slice. The first wireless network slice receives and authorizes the second slice output, and in response, transfers a second acknowledgement to the second wireless network slice. The second wireless network slice receives the second acknowledgement, and in response, uses the second slice output to deliver the data communication service.

In some examples, a Network Function Virtualization Infrastructure (NFVI) delivers a data communication service using wireless network slicing. A first Wireless Network Slice Virtual Network Function (WNS-VNF) executes a first slice input, and in response, generates a first slice output to deliver the data communication service. The first WNS-VNF transfers the first slice output to a second WNS-VNF over an NFVI-Virtual Layer (VL). The second WNS-VNF receives and authorizes the first slice output, and in response, transfers a first acknowledgement to the first WNS-VNF over the NFVI-VL. The first WNS-VNF receives the first acknowledgement, and in response, uses the first slice output to deliver the data communication service. The second WNS-VNF executes a second slice input, and in response, generates a second slice output to deliver the data communication service. The second WNS-VNF transfers the second slice output to the first WNS-VNF over the NFVI-VL. The first WNS-VNF receives and authorizes the second slice output, and in response, transfers a second acknowledgement to the second WNS-VNF over the NFVI-VL. The second WNS-VNF receives the second acknowledgement, and in response, uses the second slice output to deliver the data communication service.

DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary wireless communication system to deliver a data communication service using synchronized wireless network slices.

FIG. **2** illustrates an exemplary operation of the wireless communication system to deliver the data communication service using the synchronized wireless network slices.

FIG. **3** illustrates an exemplary operation of the wireless communication system to deliver the data communication service using the synchronized wireless network slices.

FIG. **4** illustrates exemplary processing circuitry to deliver a data communication service using synchronized wireless network slices.

FIG. **5** illustrates an exemplary wireless communication network to deliver a data communication service using synchronized wireless network slices.

FIG. **6** illustrates an exemplary UE in the wireless communication network that delivers the data communication service using the synchronized wireless network slices.

FIG. **7** illustrates an exemplary Fifth Generation New Radio (5GNR) access node in the wireless communication network that delivers the data communication service using the synchronized wireless network slices.

FIG. **8** illustrates an exemplary Management and Orchestration (MANO) system in the wireless communication network that delivers the data communication service using the synchronized wireless network slices.

FIG. **9** illustrates an exemplary Network Function Virtualization Infrastructure (NFVI) in the wireless communication network that delivers the data communication service using the synchronized wireless network slices.

FIG. **10** illustrates an exemplary Network Services Descriptor (NSD) in the wireless communication network that delivers the data communication service using the synchronized wireless network slices.

FIG. **11** illustrates an exemplary operation of the wireless communication network to deliver the data communication service using the synchronized wireless network slices.

DETAILED DESCRIPTION

FIG. **1** illustrates exemplary wireless communication system **100** to deliver a data communication service using synchronized wireless network slices **111-112**. Wireless communication system **100** comprises wireless network slices **111-112** that deliver the data communication service to wireless communication device **101**. Wireless communication device **101** comprises a phone, computer, vehicle, sensor, or some other user communication apparatus. The data communication service comprises internet-access, data messaging, media conferencing, or some other data communications product. The amount of wireless communication devices and wireless network slices that are shown in FIG. **1** has been restricted for clarity.

In some examples, wireless network slice **111** executes a first slice input, and in response, generates a first slice output to deliver the data communication service. The first slice input and the first slice output comprise user identifiers, user services, quality-of service levels, service usage information, digital certificates, or some other data that is generated and/or consumed by wireless network slices **111-112**. Wireless network slice **111** transfers the first slice output to wireless network slice **112**. Wireless network slice **112** receives and authorizes the first slice output, and in response, transfers a first acknowledgement to wireless network slice **111**. Wireless network slice **112** may perform the authorization based on a data structure of allowed and/or disallowed outputs, successful receipt, current status, authorization script, artificial intelligence, certificate validation, or some other technique. Wireless network slice **111** receives the first acknowledgement, and in response, uses the first slice output to deliver the data communication service to wireless communication device **101**. Wireless network slice **111** will not use the first slice output to deliver the data communication service to wireless communication device **101** without the first acknowledgement and may take some remedial action instead.

Wireless network slice **112** executes a second slice input, and in response, generates a second slice output to deliver the data communication service. The second slice input and the second slice output comprise user identifiers, user services, quality-of service levels, service usage information, digital certificates, or some other data that is generated and/or consumed by wireless network slices **111-112**. Wireless network slice **112** transfers the second slice output to wireless network slice **111**. Wireless network slice **111** receives and authorizes the second slice output, and in response, transfers a second acknowledgement to wireless network slice **112**. Wireless network slice **111** may perform the authorization based on a data structure of allowed and/or disallowed outputs, successful receipt, current status, authorization script, artificial intelligence, certificate validation, or some other technique. Wireless network slice **112** receives the second acknowledgement, and in response, uses the second slice output to deliver the data communication service. Wireless network slice **112** will not use the second slice output to deliver the data communication service to wireless communication device **101** without the second acknowledgement and may take some remedial action instead. The first slice output and the second slice input may be the same.

In some examples, wireless network slice **111** transfers the first slice input to wireless network slice **112** along with the first slice output. Wireless network slice **112** receives and authorizes the first slice input along with the first slice output. Wireless network slice **112** transfers the first acknowledgement to the wireless network slice **111** in response to authorizing the first slice input and the first slice output. Likewise, wireless network slice **112** transfers the second slice input to wireless network slice **111**. Wireless network slice **111** receives and authorizes the second slice input. Wireless network slice transfers the second acknowledgement to the wireless network slice **111** in response to authorizing the second slice input and the second slice output.

In some examples, wireless network slice **111** comprises a first Virtual Network Function (VNF) in a Network Function Virtualization Infrastructure (NFVI), and wireless network slice **112** comprises a second VNF in the NFVI. Wireless network slice **111** may comprise a user-plane VNF in an NFVI, and wireless network slice **112** may comprise a control-plane VNF in the NFVI. User-plane VNFs handle user data while control-plane VNFs use signaling to control the handling of the user data in the user-plane VNFs. Wireless network slice **111** may comprise a first VNF in a Network Function Virtualization Network Service Descriptor (NFV-NSD) in an NFVI, and wireless network slice **112** may comprise a second VNF in the NFV-NSD in the NFVI.

In some examples, wireless network slice **111** transfers the first slice output to wireless network slice **112** and receives the first acknowledgement from wireless network slice **112** over a Virtual Layer (VL) in an NFVI. Wireless network slice **112** may transfer the second slice output to wireless network slice **111** and receive the second acknowledgement from wireless network slice **111** over the VL in the NFVI. Wireless network slice **111** may transfer the first slice output to wireless network slice **112** and receives the first acknowledgement from wireless network slice **112** over a Virtual Network Function Forwarding Graph (VNF-FG) in an NFVI. Wireless network slice **112** may transfer the second slice output to wireless network slice **111** and receive the second acknowledgement from wireless network slice **111** over the VNF-FG in the NFVI.

Wireless communication system **100** comprises wireless access nodes, network controllers, data routers, and/or some other wireless communication apparatus. Wireless communication device **101** and wireless communication system **100** comprise one or more radios that wirelessly communicate using wireless protocols like Wireless Fidelity (WIFI), Fifth Generation New Radio (5GNR), Long Term Evolution (LTE), Low-Power Wide Area Network (LP-WAN), Near-Field Communications (NFC), Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and satellite data communications.

Wireless communication device **101** and wireless network slices **111-112** comprise microprocessors, software, memories, transceivers, bus circuitry, and/or some other data processing components. The microprocessors comprise Digital Signal Processors (DSP), Central Processing Units (CPU), Graphical Processing Units (GPU), Application-Specific Integrated Circuits (ASIC), and/or some other data processing hardware. The memories comprise Random

Access Memory (RAM), flash circuitry, disk drives, and/or some other type of data storage. The memories store software like operating systems, utilities, protocols, applications, and functions. The microprocessors retrieve the software from the memories and execute the software to drive the operation of wireless communication system **100** as described herein.

FIG. **2** illustrates an exemplary operation of wireless communication system **100** to deliver the data communication service using synchronized wireless network slices **111-112**. The operation may vary in other examples. Wireless network slice **111** executes slice input A, and in response, generates a slice output B to deliver the data communication service (**201**). Wireless network slice **111** transfers the slice output B to wireless network slice **112** (**201**). Wireless network slice **112** receives and authorizes the slice output B, and in response, transfers first acknowledgement B to wireless network slice **111** (**202**). Wireless network slice **111** receives acknowledgement B, and in response, uses the slice output B to deliver the data communication service to wireless communication device **101** (**203**). Wireless network slice **111** will not use slice output B for normal operations until the first acknowledgement is received.

Wireless network slice **112** executes slice input C, and in response, generates slice output D to deliver the data communication service (**204**). Wireless network slice **112** transfers the slice output D to wireless network slice **111** (**204**). Wireless network slice **111** receives and authorizes the slice output D, and in response, transfers acknowledgement D to wireless network slice **112** (**205**). Wireless network slice **112** receives acknowledgement D, and in response, uses slice output D to deliver the data communication service to wireless communication device **101** (**206**). Wireless network slice **112** will not use slice output D for normal operations until the second acknowledgement is received.

Slice inputs A and C and slice outputs B and D comprise user identifiers, user services, quality-of service levels, service usage information, digital certificates, or some other data that is generated and/or consumed by wireless network slices. Wireless network slices **111-112** perform their authorizations based on data structures of allowed and/or disallowed outputs, successful receipt, current status, authorization script, artificial intelligence, certificate validation, or some other techniques. Wireless network slices **111-112** can adjust their authorization decisions in response to changing conditions to ensure efficient and secure operation.

FIG. **3** illustrates an exemplary operation of wireless communication system **100** to deliver the data communication service using synchronized wireless network slices **111-112**. The operation may vary in other examples. Wireless communication device **101** transfers a service request to wireless network slice **111** which comprises a control-plane network function in this example. The service request is a slice input. To deliver the requested service, wireless network slice **111** executes the service request to generate a Quality-of-Service (QOS) level. The QoS level is a slice output. Wireless network slice **111** transfers the QoS level to wireless network slice **112**. Wireless network slice **112** comprises a user-plane network function in this example. Wireless network slice **112** receives and authorizes the QoS level. In response, wireless network slice **112** transfers a QoS level acknowledgement to wireless network slice **111**. Wireless network slice **111** receives the service QoS level acknowledgement, and in response, uses the QoS level to deliver the data communication service to wireless communication device **101**. In particular, wireless network slice **111** transfers context to wireless network slice **112** that indicates the QoS level, network addresses, policies, and the like. In response to the context, wireless network slice **112** delivers the data communication service to wireless communication device **101**. To use the data communication service, wireless communication device **101** exchanges user data with an external system (not shown) per the context over wireless network slice **112** under the control of wireless network slice **111**.

Wireless network slice **112** monitors the data exchange to generate a service usage amount. The data exchange is a slice input, and the service usage amount is a slice output. Wireless network slice **112** transfers the service usage amount to wireless network slice **111**. Wireless network slice **111** receives and authorizes the service usage amount. In response, wireless network slice **111** transfers a service usage amount acknowledgement to wireless network slice **112**. Wireless network slice **112** receives the service usage amount acknowledgement, and in response, continues to deliver the data communication service to wireless communication device **101**. Wireless communication device **101** continues to exchange user data with the external system (not shown) over wireless network slice **112** per the context under the control of wireless network slice **111**.

Advantageously, wireless communication system **100** effectively synchronizes the parallel operations of network slices **112-113**. Moreover, wireless communication system **100** may efficiently use NSDs and distributed ledgers to coordinate the parallel operations of the network slices **112-113**. As a result, the delivery of data communication services to wireless communication device **101** is improved and protected.

FIG. **4** illustrates exemplary processing circuitry to deliver a data communication service using synchronized wireless network slicing. Processing circuitry **400** comprises an example of wireless network slices **111-112**, although slices **111-112** may differ. Processing circuitry **400** comprises machine-readable storage media **401-403** and microprocessors **407-409** that are communicatively coupled. Machine-readable storage media **401-403** store processing instructions **404-406** in a non-transitory manner. Microprocessors **407-409** comprise DSPs, CPUs, GPUs, ASICs, and/or some other data processing hardware. Machine-readable storage media **401-403** comprises RAM, flash circuitry, disk drives, and/or some other type of data storage apparatus. Microprocessors **407-409** retrieve processing instructions **404-406** from non-transitory machine-readable storage media **401-403**. Microprocessors **407-409** execute processing instructions **404-406** to deliver a data communication service to wireless communication devices using wireless network slices as described above for wireless communication system **100** and as described below for wireless communication network **500**. The amount of storage media, microprocessors, processing instructions that are shown in FIG. **4** is exemplary and may vary in other examples.

FIG. **5** illustrates exemplary wireless communication network **500** to deliver a data communication service using synchronized wireless network slices **511-513**. Wireless communication network **500** comprises an example of wireless communication system **100** and processing circuitry **400**, although system **100** and circuitry **400** may differ. Wireless communication network **500** comprises User Equipment (UE) **501**, Fifth Generation New Radio Access Node (5GNR AN) **502**, Network Function Virtualization Infrastructure (NFVI) **510**, Management and Orchestration (MANO) **530**, and distributed ledger nodes **540**. NFVI **510** comprises wireless network slices **511**-**513**, Access and Mobility Management Function (AMF) **514**, Session Management Function (SMF) **515**, and Distributed Ledger Function (DLF) **519**. Slice **511** comprises User Plane Function (UPF) **516**. Slice **512** comprises Security Function (SF) **517**. Slice **513** comprises Cybernetic Function (CF) **518**. DLF **519** comprises smart contract **520** and ledger block **521**. MANO **530** comprises Operational Support System (OSS) **531**, Network Function Virtualization Orchestrator (NFVO) **532**, Virtual Network Function Manager (VNFM) **533**, and Virtual Infrastructure Manager (VIM) **534**. OSS **531** comprises Network Service Diagram (NSD) **535** that comprises slice IDs **511**-**513** and Virtual Network Function Forwarding Graphs (VNF-FGs) **536**. VNF-FGs **536** comprise Virtual Network Function Network Forwarding Paths (VNF-NFPs) **537**. MANO ledger block **521** eventually stores Identifiers (IDs) for slices **511**-**513**, NSD **535**, and UE **501** as described below.

In slice **511**, UPF **516** exchanges user data between ANs like 5GNR AN **502** and external systems like the internet. UPF **516** applies Quality-of-Service (QOS) and Network Address Translation (NAT) to the user data exchange in response to signaling from SMF **515**. For example, UPF **516** may exchange the user data based on data rate and latency parameters in signaling from SMF **515**. In slice **512**, SF **517** performs security tasks like verifying UEs, ANs, network addresses, QoS, and the like against expected and allowed data. For example, SF **517** may validate digital certificates from UE **501**, 5GNR AN **502**, and UPF **516** to protect the integrity of the data session. In slice **513**, CF **518** monitors data sessions for modifications to UEs, ANs, and UPFs. For example, CF **518** may direct UE **501** and 5GNR **502** (over SMF **515** and AMF **514**) to use a different form of data encoding, encryption, or error correction.

Slices **511**-**513** exchange peer-to-peer signaling to synchronize their parallel operations. Slices **511**-**513** process data inputs to generate data outputs to perform their functions. Slices **511**-**513** share at least some of these data outputs with one another over the peer-to-peer signaling. Slices **511**-**513** authorize and acknowledge the shared data outputs of the other slices over the peer-to-peer signaling. The authorizations may be based on data receipt, data structures that indicate acceptable outputs, certificate validation, artificial intelligence, code scripts, or some other technique. Slices **511**-**513** may use the shared data outputs for their own operations. When a slice output is not properly acknowledged, slices **511**-**513** stop normal operations and take remedial action like generating an alarm, modifying a service, isolating a device, or performing some other process.

In MANO **530**, OSS **531** launches NSD **535** through NFVO **532**. In response, NFVO **532** directs VNFM **533** and VIM **534** to instantiate slices **511**-**513**, VNF-FGs **536**, and VNF-NFPs **537** in NFVI **510**. VIM **534** establishes an execution environment, VNF-FGs **536**, and VNF-NFPs **537** in NFVI **510**. VNF-FGs **536** specify VNF-NFPs **537** that connect UPF **516**, SF **517**, and CF **518** with one another. VNFM **533** manages UPF **516**, SF **517**, and CF **518** in NFVI **510**.

UE **501** registers with AMF **514** over 5GNR AN **502**. The registration indicates a slice capability for slices **511**-**513** by slice ID or slice type. AMF **514** authenticates UE **501** and selects slices **511**-**513** for UE **501**. AMF **514** directs SMF **515** to manage sessions for UE **501** over slices **511**-**513**. AMF **514** and SMF **515** develop UE context for UE **501** like authorized connections along with their Quality-of-Service (QOS) and network addresses. AMF **514** transfers some of the UE context to UE **501**, 5GNR AN **502**, and SMF **515**. SMF **515** transfers some of the UE context to UPF **516**, SF **517**, and CF **518**. In response to the context, UE **501** exchanges user data with external systems (not shown) over 5GNR AN **502** and UPF **516**.

SF **517** validate digital certificates for UE **501**, 5GNR AN **502**, and UPF **516** that were gathered by AMF **514** and SMF **515**. SF **517** indicates the session data to smart contract **520** including IDs for slices **511**-**513**, NSD **535**, and UE **501**. Smart contract **520** obtains consensus for this transaction with distributed ledger nodes **540**. In response to the consensus, smart contract **520** stores the IDs for slices **511**-**513**, NSD **535**, and UE **501** in ledger block **521** using a blockchain format.

UPF **516** processes various data inputs to generate data outputs that characterize the data sessions like network addresses, data amount, and data rate. UPF **516** transfers the data outputs to SF **517**. SF **517** authorizes these data outputs by comparing the network addresses, data amount, data rate to the UE context or possibly other data. SF **517** transfers an Acknowledgement (ACK) to UPF **516** based on the authorization. UPF **516** continues to serve UE **501** based on the UE context and data outputs in response to the ACK.

SF **517** processes the data outputs from UPF **516** as data inputs against security parameters to generate other data outputs like security status. SF **517** transfers the security status to UPF **516** and CF **518** for authorization. UPF **516** and CF **518** authorize the security status and return ACKs to SF **517**. SF **517** uses the security status to deliver the data communication service in response to the ACKs. For example, SF **517** may generate security alarms and stop data sessions when UE **501** is using an improper destination address for the user data.

UPF **516** and SF **517** transfer session data to CF **518**. CF **518** authorizes the session data by comparing the session data to expected session data and determines session modifications based on the comparisons. CF **518** transfers ACKs to UPF **516** and SMF **517** based on the authorizations. UPF **516** and SF **517** continue to serve UE **501** based on the session data in response to the ACKs. CF **518** processes the session data as data inputs to determine data outputs that comprises modifications for UE **501** like using a different version of a user application, network protocol, or operating system. CF **518** transfers the modifications to UPF **516** and SF **517**. UPF **516** and SF **517** authorize the modifications and transfer ACKs to CF **518**. CF **518** implements the modifications for UE **501** in response to the ACKs.

FIG. **6** illustrates exemplary UE **501** in wireless communication network **500** that delivers the data communication service using synchronized wireless network slices **511**-**513**. UE **501** comprises an example of wireless communication device **101**, although device **101** may differ. UE **501** comprises Fifth Generation New Radio (5GNR) radio circuitry **601**, processing circuitry **602**, and components **603**. 5GNR radio circuitry **601** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSPs, memories, and transceivers (XCVRs) that are coupled over bus circuitry. Processing circuitry **602** comprises one or more CPUs, one or more memories, and one or more transceivers that are coupled over bus circuitry. Components **603** comprise sensors, cameras, medical devices, and/or some other user apparatus. The one or more memories in processing circuitry **602** store software like an Operating System (OS), 5GNR application (5GNR), 3GPP application (3GPP), Internet Protocol application (IP), and user application (APP). The antennas in 5GNR radio circuitry **601** exchange 5GNR signals with 5GNR AN **502**. Transceivers in 5GNR radio circuitry **601** are coupled to transceivers in processing circuitry **602**. In processing circuitry **602**, the one or more CPUs retrieve the software from the one or more memories and execute the software to direct the operation of UE **501** as described herein.

FIG. **7** illustrates exemplary Fifth Generation New Radio Access Node (5GNR AN) **502** in wireless communication network **500** that delivers the data communication service using wireless network slices **511-513**. 5GNR AN **502** comprises an example of wireless communication system **100** and processing circuitry **400**, although system **100** and circuitry **400** may differ. 5GNR AN **502** comprises 5GNR Radio Unit (RU) **701**, Distributed Unit (DU) **702**, and Centralized Unit (CU) **703**. 5GNR RU **701** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, memory, radio applications, and transceivers that are coupled over bus circuitry. DU **702** comprises memory, CPU, user interfaces and components, and transceivers that are coupled over bus circuitry. The memory in DU **702** stores operating system and 5GNR network applications for Physical Layer (PHY), Media Access Control (MAC), and Radio Link Control (RLC). CU **703** comprises memory, CPU, and transceivers that are coupled over bus circuitry. The memory in CU **703** stores an operating system and 5GNR network applications for Packet Data Convergence Protocol (PDCP), Service Data Adaption Protocol (SDAP), and Radio Resource Control (RRC). The antennas in 5GNR RU **701** are wirelessly coupled to UE **501** over 5GNR links. Transceivers in 5GNR RU **701** are coupled to transceivers in DU **702**. Transceivers in DU **702** are coupled to transceivers in CU **703**. Transceivers in CU **703** are coupled to AMF **514** and UPF **516**. The DSP and CPU in RU **701**, DU **702**, and CU **703** execute the radio applications, operating systems, and network applications to exchange data and signaling with UE **501**, AMF **514**, and UPF **516** as described herein.

FIG. **8** illustrates exemplary Management and Orchestration (MANO) **530** in wireless communication network **500** that delivers the data communication service using synchronized wireless network slices **511-513**. MANO **530** comprises an example of wireless communication system **100** and processing circuitry **400**, although system **100** and circuitry **400** may differ. MANO **530** comprises hardware **801**, hardware drivers **802**, operating systems **803**, virtual layer **804**, and Software (SW) **805**. Hardware **801** comprises Network Interface Cards (NICs), CPU, RAM, Flash/Disk Drives (DRIVE), and Data Switches (DSW). Hardware drivers **802** comprise software that is resident in the NIC, CPU, RAM, DRIVE, and DSW. Operating systems **803** comprise kernels, modules, applications, and containers. Virtual layer **804** comprises vNIC, vCPU, vRAM, vDRIVE, and vSW. SW **805** comprises OSS SW **831**, NFVO SW **832**, VNFM SW **833**, and VIM SW **834**. The NIC in NF hardware **801** are coupled to NFVI **510**. Hardware **801** executes hardware drivers **802**, operating systems **803**, virtual layer **804**, and SW **805** to form and operate OSS **531**, NFVO **532**, VNFM **533**, and VIM **534**. Thus, MANO **530** comprises one or more microprocessors and one or more non-transitory machine-readable storage media that store processing instructions that direct MANO **530** to perform the methods described herein. MANO **530** may be located at a single site or be distributed across multiple geographic locations.

FIG. **9** illustrates exemplary Network Function Virtualization Infrastructure (NFVI) **510** in wireless communication network **500** that delivers the data communication service using synchronized wireless network slices **511-513**. NFVI **510** comprises an example of wireless communication system **100**, slices **111-112**, and processing circuitry **400**, although system **100**, slices **111-112**, and circuitry **400** may differ. NFVI **510** comprises hardware **901**, hardware drivers **902**, operating systems **903**, virtual layer **904**, and SW **905**. Hardware **901** comprises NICs, CPU, RAM, DRIVE, and DSW. Hardware drivers **902** comprise software that is resident in the NIC, CPU, RAM, DRIVE, and DSW. Operating systems **903** comprise kernels, modules, applications, and containers. Virtual layer **904** comprises vNIC, vCPU, vRAM, vDRIVE, and vSW. SW **905** comprises AMF SW **914**, SMF SW **915**, slice SW **911-913**, and Distributed Ledger Function (DLF) SW **919**. Slice SW **911** comprises UPF SW **916** for slice **511**. Slice SW **912** comprises SF SW **917** for slice **511**. Slice SW **913** comprises CF SW **918** for slice **513**. The NIC in hardware **901** are coupled to 5GNR AN **502**, MANO **530**, Distributed Ledger Nodes (DLN) **540**, and external systems. Hardware **901** executes hardware drivers **902**, operating systems **903**, virtual layer **904**, and SW **905** to form and operate AMF **514**, SMF **515**, slice **511** including UPF **511**, slice **512** including SF **512**, slice **513** including CF **513**, and DLF **519**. NFVI **510** comprises one or more microprocessors and one or more non-transitory machine-readable storage media that store processing instructions that direct NFVI **510** to perform the methods described herein. NFVI **510** may be located at a single site or be distributed across multiple geographic locations.

FIG. **10** illustrates exemplary Network Services Descriptor (NSD) **535** in wireless communication network **500** that delivers the data communication service using synchronized wireless network slices **511-513**. NSD **535** is implemented in NFVI **510** at the direction of MANO **530**. In NSD **535**, AMF **514** is coupled to SF **517** in slice **512** over VNF Network Function Path (NFP) **537***a* that is in VNF Forwarding Group (FG) **536***a* which is in Virtual Layer (VL) **904**. AMF **514** is coupled to SMF **515** over NFP **537***b* that is in FG **536***a* which is in VL **904**. SMF **515** is coupled to UPF **516** in slice **511** over NFP **537***c* that is in FG **536***b* which is in VL **904**. SMF **515** is coupled to CF **518** in slice **513** over NFP **537***d* that is in FG **536***b* which is in VL **904**. SMF **515** is coupled to SF **517** in slice **512** over NFP **537***e* that is in FG **536***b* which is in VL **904**. UPF **516** in slice **511** is coupled to SF **517** in slice **512** over NFP **537***f* that is in FG **536***c* which is in VL **904**. UPF **516** in slice **511** is coupled to CF **518** in slice **513** over NFP **537***g* that is in FG **536***c* which is in VL **904**. SF **517** in slice **512** is coupled to smart contract **520** over NFP **537***h* that is in FG **536***d* which is in VL **904**. SF **517** in slice **512** is coupled to CF **518** in slice **513** over NFP **537***i* that is in FG **536***d* which is in VL **904**.

FIG. **11** illustrates an exemplary operation of wireless communication network **500** to deliver the data communication service using synchronized wireless network slices **511-513**. The operation may vary in other examples. In this example, slices **511-513** authorize the shared data outputs based on their successful receipt along with the validation of an accompanying digital certificate. For example, CF **518** authorizes data outputs from SF **517** in response to their successful receipt of the data outputs and the validation of the accompanying digital certificate for SF **517**.

UE **501** registers with AMF **514** over 5GNR AN **502** using a UE certificate and indicating slice **512**. Based on the slice indication, AMF **514** transfers the UE certificate to SF **517** in slice **512** for authentication (AUTH). SF **517** validates the UE certificate to authenticate UE **501**. SF **517** indicates to UPF **516** and CF **518** that UE **501** is authenticated and includes its own SF certificate. UPF **516** and CF **518** authorize the authentication based on successful receipt of the data output and validation of the SF certificate. UPF

516 and CF **518** transfer ACKs and their own certificates to SF **517** in response to the authorization. UPF **516** and CF **518** may also use this data output for their own operations. SF **517** validates the certificates and processes the ACKs which indicates that the parallel operations of slices **511-513** are synchronized. In response, SF **517** indicates to AMF **514** that UE **501** is authenticated.

In response to the authentication, AMF **514** and SMF **515** develop context for UE **501** like slices, connections, QoS, policies, and the like. SMF **515** transfers the context to CF **518** for analysis. CF **515** processes the context for UE **501** to determine a modification (MOD) for UE **501**. In this example, the modification is a different type of wireless data encoding than the encoding indicated by the context. CF **518** transfers the UE modification to UPF **516** and SF **517** along with its CF certificate. UPF **516** and SF **517** authorize this data output based on successful receipt of the data output and validation of the CF certificate. UPF **516** and SF **517** may also use this data output for their own operations. UPF **516** and SF **517** return ACKs and their certificates to CF **518**. CF **518** validates the certificates and processes the ACKs which indicates that the parallel operations of slices **511-513** are synchronized. In response, CF **518** directs SMF **515** to modify UE **501** to use the different wireless data encoding. SMF **515** indicates the UE modification to AMF **514**, and AMF **514** directs UE **501** and 5GNR AN **502** to use the different wireless data encoding.

UE **501** and an external data system (not shown) exchange user data over 5GNR AN **502** and UPF **516** per the UE context—although UE **501** and 5GNR AN **502** do use the different wireless data encoding selected by CF **518**. UPF **516** generates statistics (STATS) for the data session like data amount, data rate, latency, error rate, addresses, and the like. UPF **516** transfers the statistics for UE **501** to SF **517** and CF **518** along with its UPF certificate. SF **517** and CF **518** authorize this data output based on successful receipt of the data output and validation of the UPF certificate. SF **517** and CF **518** may also use this data output for their own operations. SF **517** and CF **518** return ACKs and their certificates to UPF **516**. UPF **516** validates the certificates and processes the ACKs which indicates that the parallel operations of slices **511-513** are synchronized. In response, UPF **516** transfers the UE **501** statistics to SMF **515** to use for session management.

The wireless communication system circuitry described above comprises computer hardware and software that form special-purpose data communication circuitry to deliver a data communication service using synchronized wireless network slicing. The computer hardware comprises processing circuitry like CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory. To form these computer hardware structures, semiconductors like silicon or germanium are positively and negatively doped to form transistors. The doping comprises ions like boron or phosphorus that are embedded within the semiconductor material. The transistors and other electronic structures like capacitors and resistors are arranged and metallically connected within the semiconductor to form devices like logic circuitry and storage registers. The logic circuitry and storage registers are arranged to form larger structures like control units, logic units, and Random-Access Memory (RAM). In turn, the control units, logic units, and RAM are metallically connected to form CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory.

In the computer hardware, the control units drive data between the RAM and the logic units, and the logic units operate on the data. The control units also drive interactions with external memory like flash drives, disk drives, and the like. The computer hardware executes machine-level software to control and move data by driving machine-level inputs like voltages and currents to the control units, logic units, and RAM. The machine-level software is typically compiled from higher-level software programs. The higher-level software programs comprise operating systems, utilities, user applications, and the like. Both the higher-level software programs and their compiled machine-level software are stored in memory and retrieved for compilation and execution. On power-up, the computer hardware automatically executes physically-embedded machine-level software that drives the compilation and execution of the other computer software components which then assert control. Due to this automated execution, the presence of the higher-level software in memory physically changes the structure of the computer hardware machines into special-purpose data communication circuitry to deliver a data communication service using synchronized wireless network slicing.

The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will appreciate that the features described above can be combined in various ways to form multiple variations of the invention. Thus, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

What is claimed is:

1. A method to deliver a data communication service using synchronized wireless network slicing, the method comprising:

a first wireless network slice executing a first slice input, and in response, generating a first slice output to deliver the data communication service and transferring the first slice output to a second wireless network slice;

the second wireless network slice receiving and authorizing the first slice output, and in response, transferring a first acknowledgement to the first wireless network slice;

the first wireless network slice receiving the first acknowledgement, and in response, using the first slice output to deliver the data communication service;

the second wireless network slice executing a second slice input, and in response, generating a second slice output to deliver the data communication service and transferring the second slice output to the first wireless network slice;

the first wireless network slice receiving and authorizing the second slice output, and in response, transferring a second acknowledgement to the second wireless network slice; and

the second wireless network slice receiving the second acknowledgement, and in response, using the second slice output to deliver the data communication service.

2. The method of claim **1** further comprising:

the first wireless network slice transferring the first slice input to the second wireless network slice;

the second wireless network slice receiving and authorizing the first slice input wherein the second wireless network slice transferring the first acknowledgement to the first wireless network slice comprises transferring the first acknowledgement to the first wireless network slice in response to authorizing the first slice input and the first slice output;

the second wireless network slice transferring the second slice input to the first wireless network slice; and

the first wireless network slice receiving and authorizing the second slice input wherein the first wireless network slice transferring the second acknowledgement to the second wireless network slice comprises transferring the second acknowledgement to the second wireless network slice in response to authorizing the second slice input and the second slice output.

3. The method of claim 1 wherein:

the first wireless network slice comprises a first Virtual Network Function (VNF) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a second VNF in the NFVI.

4. The method of claim 1 wherein:

the first wireless network slice comprises a user-plane Virtual Network Function (VNF) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a control-plane VNF in the NFVI.

5. The method of claim 1 wherein:

the first wireless network slice comprises a first Virtual Network Function (VNF) in a Network Function Virtualization Network Service Descriptor (NFV-NSD) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a second VNF in the NFV-NSD in the NFVI.

6. The method of claim 1 wherein:

the first wireless network slice transferring the first slice output to the second wireless network slice and receiving the first acknowledgement transferred by the second wireless network slice comprises transferring the first slice output and receiving the first acknowledgement over a virtual layer in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice transferring the second slice output to the first wireless network slice and receiving the second acknowledgement transferred by the first wireless network slice comprises transferring the second slice output and receiving the second acknowledgement over the virtual layer in the NFVI.

7. The method of claim 1 wherein:

the first wireless network slice transferring the first slice output to the second wireless network slice and receiving the first acknowledgement transferred by the second wireless network slice comprises transferring the first slice output and receiving the first acknowledgement over a Virtual Network Function Forwarding Graph (VNF-FG) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice transferring the second slice output to the first wireless network slice and receiving the second acknowledgement transferred by the first wireless network slice comprises transferring the second slice output and receiving the second acknowledgement over the VNF-FG in the NFVI.

8. A method of operating a Network Function Virtualization Infrastructure (NFVI) to deliver a data communication service using wireless network slicing, the method comprising:

a first Wireless Network Slice Virtual Network Function (WNS-VNF) executing a first slice input, and in response, generating a first slice output to deliver the data communication service and transferring the first slice output to a second WNS-VNF over an NFVI-Virtual Layer (VL);

the second WNS-VNF receiving and authorizing the first slice output, and in response, transferring a first acknowledgement to the first WNS-VNF over the NFVI-VL;

the first WNS-VNF receiving the first acknowledgement, and in response, using the first slice output to deliver the data communication service;

the second WNS-VNF executing a second slice input, and in response, generating a second slice output to deliver the data communication service and transferring the second slice output to the first WNS-VNF over the NFVI-VL;

the first WNS-VNF receiving and authorizing the second slice output, and in response, transferring a second acknowledgement to the second WNS-VNF over the NFVI-VL; and

the second WNS-VNF receiving the second acknowledgement, and in response, using the second slice output to deliver the data communication service.

9. The method of claim 8 further comprising:

the first WNS-VNF transferring the first slice input to the second wireless network slice over the NFVI-VL;

the second WNS-VNF receiving and authorizing the first slice input wherein the second WNS-VNF transferring the first acknowledgement to the first WNS-VNF over the NFVI-VL comprises transferring the first acknowledgement to the first WNS-VNF in response to authorizing the first slice input and the first slice output;

the second WNS-VNF transferring the second slice input to the first wireless network slice over the NFVI VL; and

the first WNS-VNF receiving and authorizing the second slice input wherein the first WNS-VNF transferring the second acknowledgement to the second WNS-VNF over the NFVI-VL comprises transferring the second acknowledgement to the second WNS-VNF in response to authorizing the second slice input and the second slice output.

10. The method of claim 8 wherein:

the first WNS-VNF comprises a user-plane WNS-VNF; and

the second WNS-VNF comprises a control-plane WNS-VNF.

11. The method of claim 8 wherein:

the first WNS-VNF comprises a first WNS-VNF in an NFVI-Network Service Descriptor (NFVI-NSD); and

the second WNS-VNF comprises a second WNS-VNF in the NFVI-NSD.

12. The method of claim 8 wherein the NFVI-VL comprises NFVI Virtual Network Function Network Forwarding Paths (NFVI VNF-NFPs) in an NFVI-Network Service Descriptor (NFVI-NSD).

13. The method of claim 8 wherein the NFVI-VL comprises an NFVI Virtual Network Function Forwarding Graph (NFVI VNF-FG) in an NFVI-Network Service Descriptor (NFVI-NSD).

14. A wireless communication system to deliver a data communication service using synchronized wireless network slicing, the wireless communication system comprising:

one or more processors to execute a first wireless network slice and a second wireless network slice;

the first wireless network slice to execute a first slice input, and in response, to generate a first slice output to deliver the data communication service and transfer the first slice output to the second wireless network slice;

the second wireless network slice to receive and authorize the first slice output, and in response, to transfer a first acknowledgement to the first wireless network slice;

the first wireless network slice to receive the first acknowledgement, and in response, to use the first slice output to deliver the data communication service;

the second wireless network slice to execute a second slice input, and in response, to generate a second slice output to deliver the data communication service and transfer the second slice output to the first wireless network slice;

the first wireless network slice to receive and authorize the second slice output, and in response, to transfer a second acknowledgement to the second wireless network slice; and

the second wireless network slice to receive the second acknowledgement, and in response, to use the second slice output to deliver the data communication service.

15. The wireless communication system of claim **14** further comprising:

the first wireless network slice to transfer the first slice input to the second wireless network slice;

the second wireless network slice to receive and authorize the first slice input wherein the second wireless network slice is to transfer the first acknowledgement to the first wireless network slice in response to authorizing the first slice input and the first slice output;

the second wireless network slice is to transfer the second slice input to the first wireless network slice; and

the first wireless network slice is to receive and authorize the second slice input wherein the first wireless network slice is to transfer the second acknowledgement to the second wireless network slice in response to authorizing the second slice input and the second slice output.

16. The wireless communication system of claim **14** wherein:

the first wireless network slice comprises a first Virtual Network Function (VNF) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a second VNF in the NFVI.

17. The wireless communication system of claim **14** wherein:

the first wireless network slice comprises a user-plane Virtual Network Function (VNF) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a control-plane VNF in the NFVI.

18. The wireless communication system of claim **14** wherein:

the first wireless network slice comprises a first Virtual Network Function (VNF) in a Network Function Virtualization Network Service Descriptor (NFV-NSD) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice comprises a second VNF in the NFV-NSD in the NFVI.

19. The wireless communication system of claim **14** wherein:

the first wireless network slice is to transfer the first slice output to the second wireless network slice and receiving the first acknowledgement transferred by the second wireless network slice over a virtual layer in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice is to transfer the second slice output to the first wireless network slice and receive the second acknowledgement transferred by the first wireless network slice over the virtual layer in the NFVI.

20. The wireless communication system of claim **14** wherein:

the first wireless network slice is to transfer the first slice output to the second wireless network slice and receive the first acknowledgement transferred by the second wireless network slice over a Virtual Network Function Forwarding Graph (VNF-FG) in a Network Function Virtualization Infrastructure (NFVI); and

the second wireless network slice is to transfer the second slice output to the first wireless network slice and receive the second acknowledgement transferred by the first wireless network slice over the VNF-FG in the NFVI.

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