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Dabbs et al.

(54) **SYSTEMS, METHODS, AND APPARATUSES FOR IMPROVED CONNECTIVITY DISTRIBUTION**

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(21) Appl. No.: **19/054,494**

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(60) Provisional application No. 63/553,402, filed on Feb. 14, 2024.

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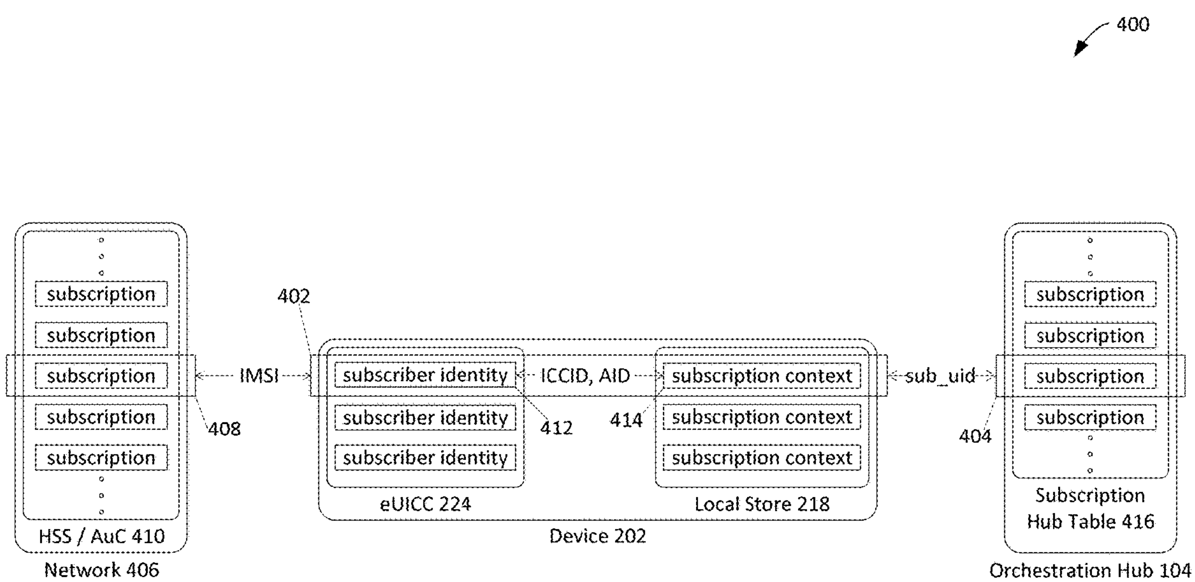
H04L 43/0805 (2022.01)

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

CPC ***H04W 8/18*** (2013.01); ***H04L 43/0805*** (2013.01)

(57) **ABSTRACT**

Systems, processes, and apparatuses are disclosed including an orchestration agent and an orchestration hub. The orchestration agent is operatively connected to an eUICC and memory at a mobile computing device. The orchestration hub includes a processor and a database including centralized network subscription information. The orchestration hub can receive updated network subscription information from a device management and from a network connectivity management platform. The orchestration hub can compare the updated network subscription information to a plurality of subscription records in the centralized network subscription information. The orchestration hub generates a new subscription record including current network subscription information based on the updated network subscription information. The orchestration agent can replace one or more information fields of a subscription edge record at the eUICC and the memory with corresponding information fields from the new subscription record.



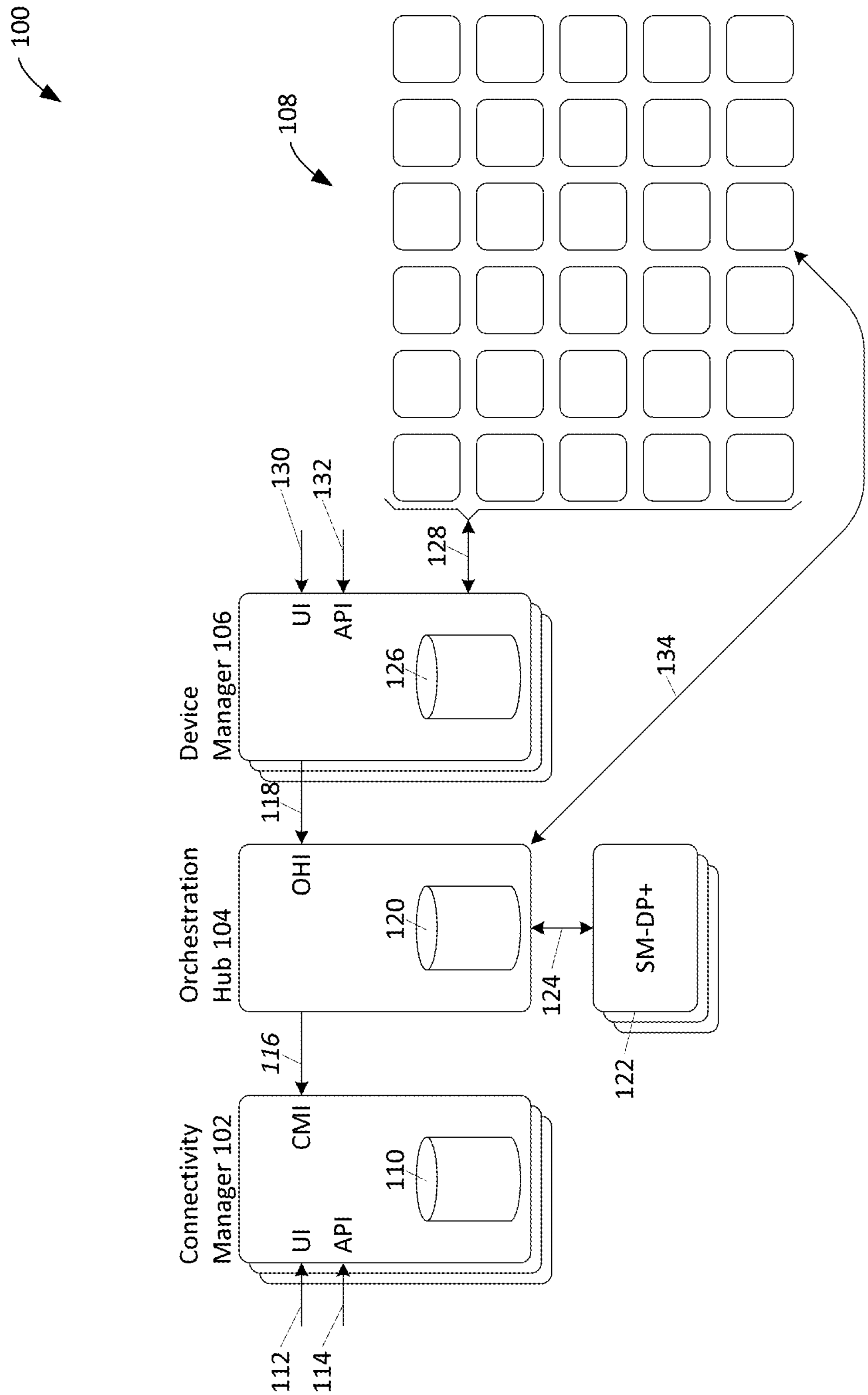

100
108
Connectivity Manager 102
UI
API
CMI
110
112
114
116
Orchestration Hub 104
OHI
120
118
124
SM-DP+
122
Device Manager 106
UI
API
126
128
130
132
134

FIG. 1

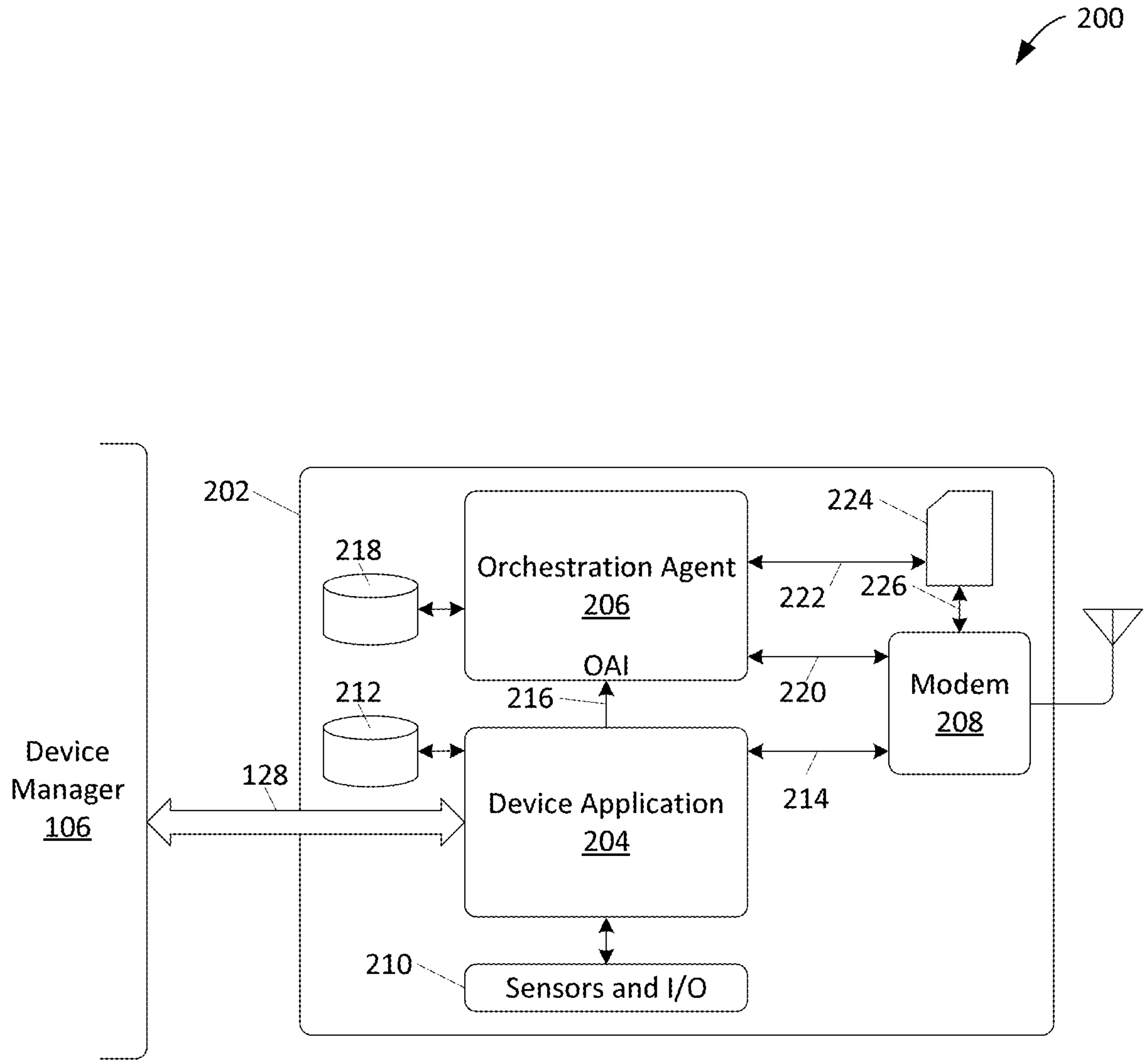

200
202
218
Orchestration Agent
206
OAI
224
222
226
220
Modem
208
212
216
Device Manager
106
128
Device Application
204
214
210
Sensors and I/O

FIG. 2

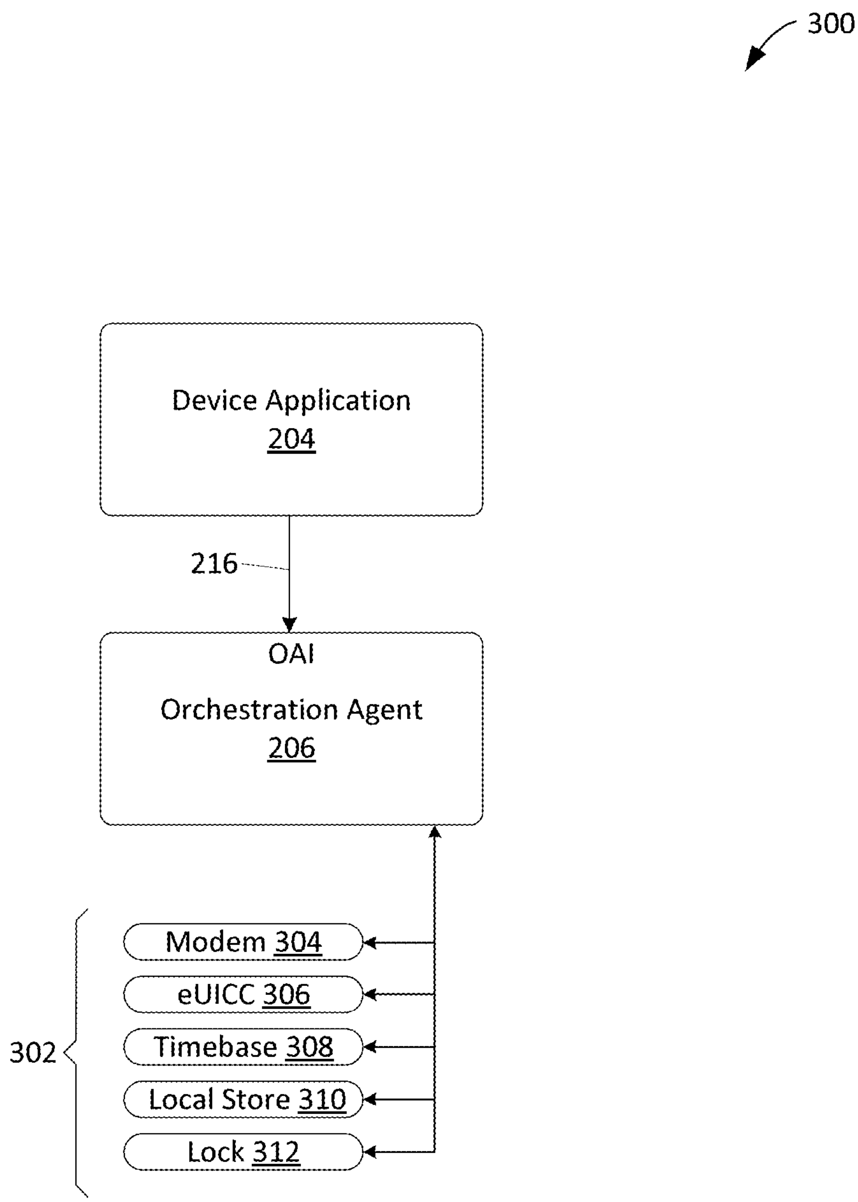

300
Device Application 204
216
OAI
Orchestration Agent 206
302
Modem 304
eUICC 306
Timebase 308
Local Store 310
Lock 312

FIG. 3

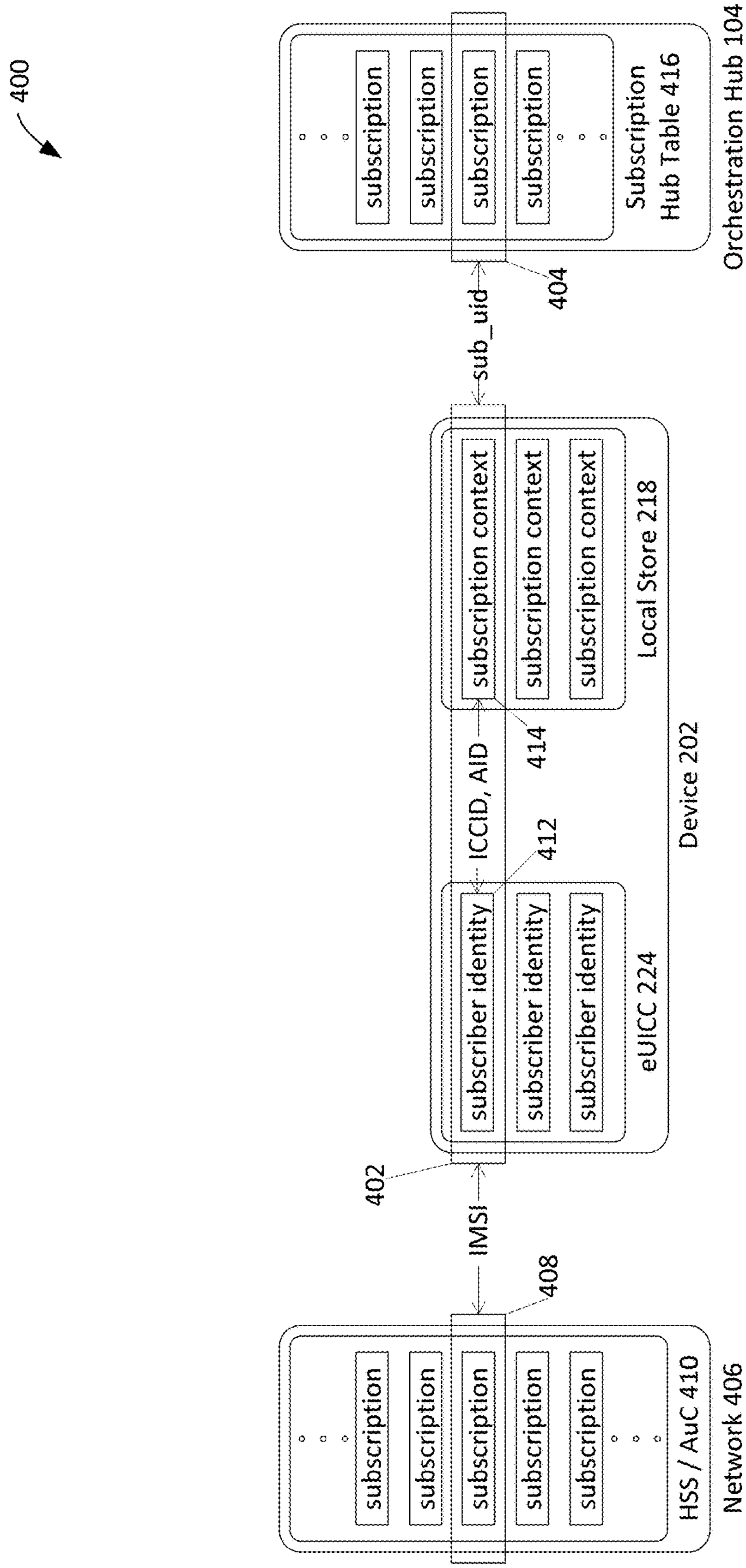

400
subscription
subscription
subscription
subscription
Subscription Hub Table 416
Orchestration Hub 104
404
sub_uid
subscription context
subscription context
subscription context
Local Store 218
ICCID, AID
414
412
Device 202
subscriber identity
subscriber identity
subscriber identity
eUICC 224
402
IMSI
408
subscription
subscription
subscription
subscription
subscription
HSS / AuC 410
Network 406

FIG. 4

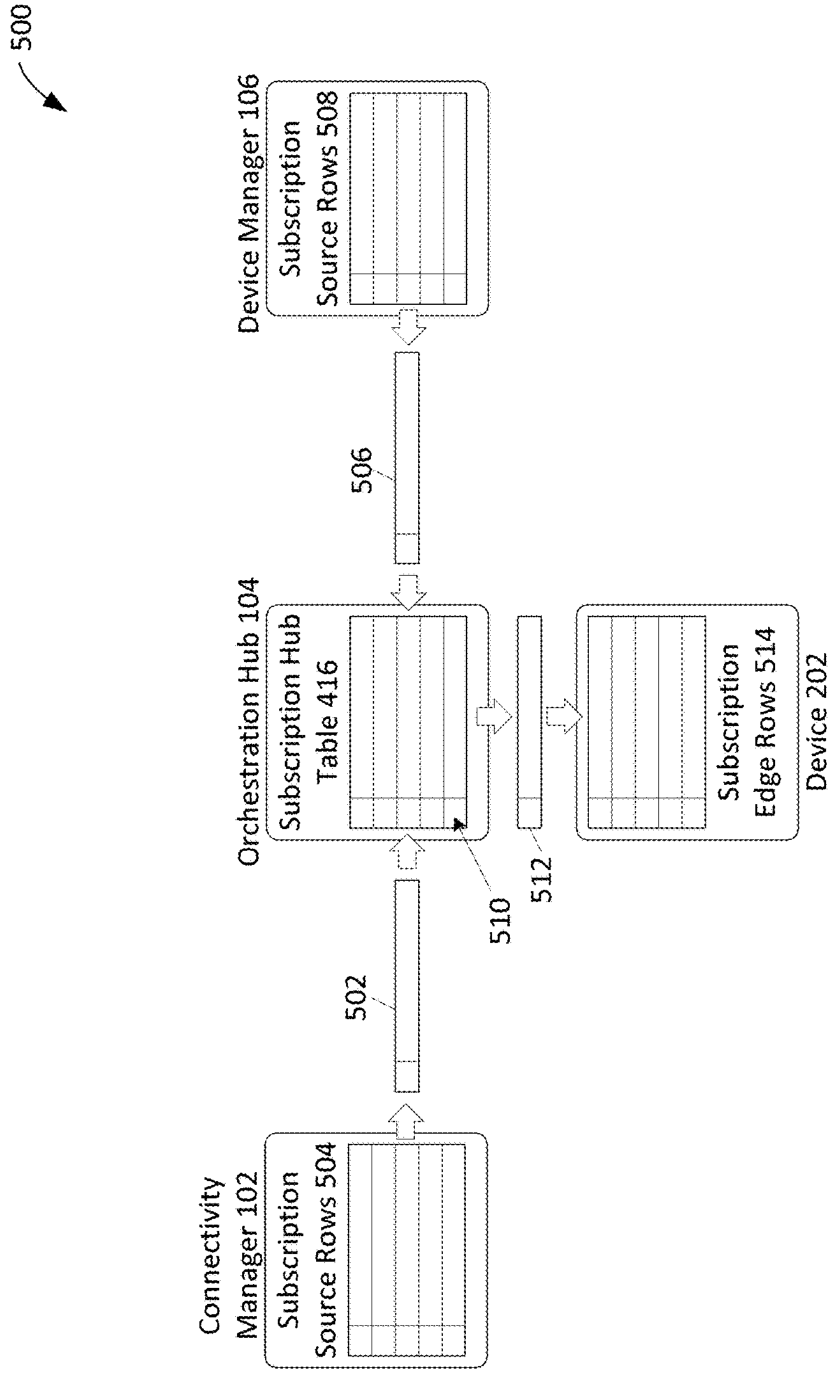

500
Connectivity Manager 102
Subscription Source Rows 504
502
Orchestration Hub 104
Subscription Hub Table 416
510
512
506
Device Manager 106
Subscription Source Rows 508
Subscription Edge Rows 514
Device 202

FIG. 5

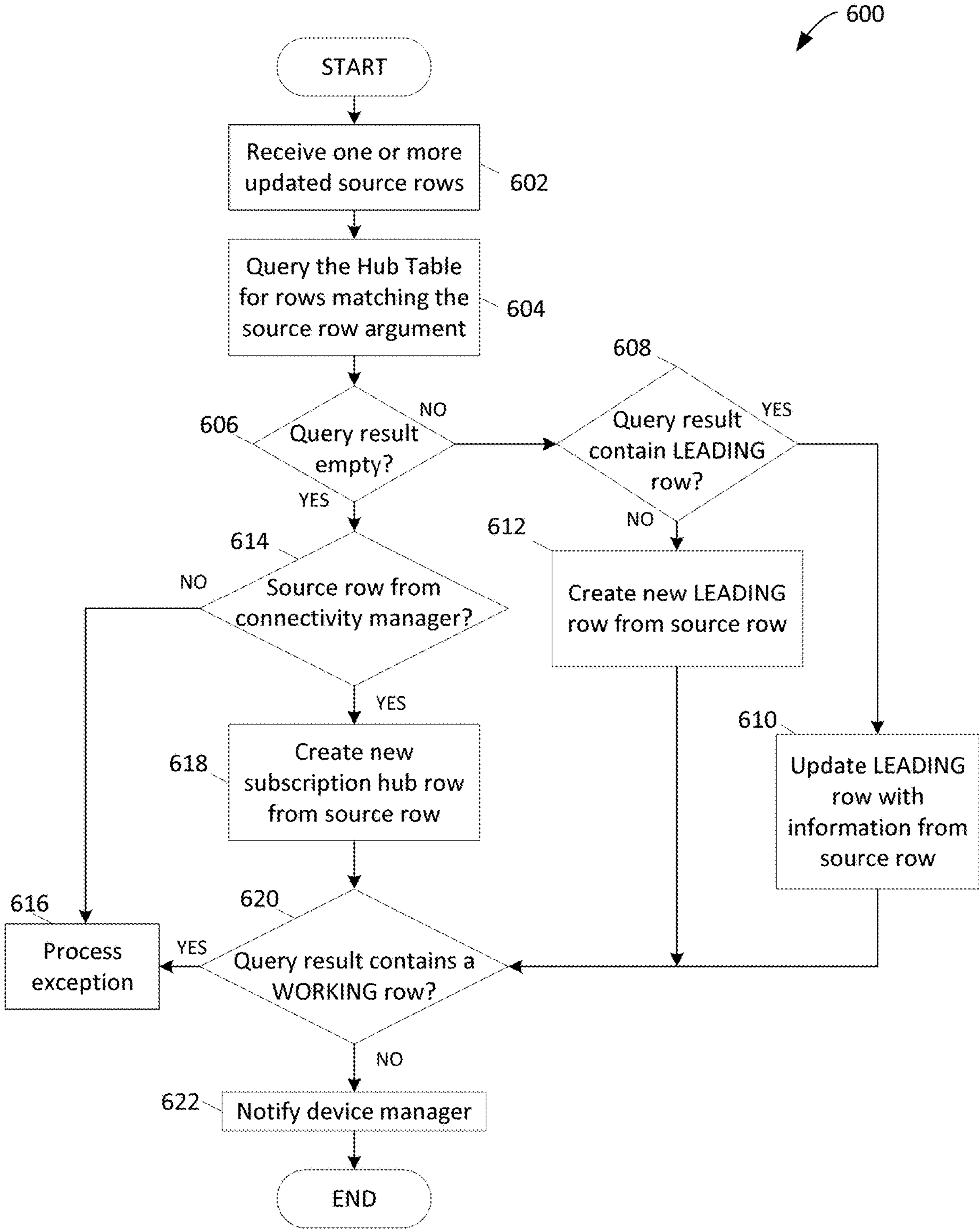

600
START
Receive one or more updated source rows
602
Query the Hub Table for rows matching the source row argument
604
606
Query result empty?
NO
YES
608
Query result contain LEADING row?
YES
NO
612
Create new LEADING row from source row
614
Source row from connectivity manager?
NO
YES
610
Update LEADING row with information from source row
618
Create new subscription hub row from source row
616
Process exception
620
Query result contains a WORKING row?
YES
NO
622
Notify device manager
END

FIG. 6

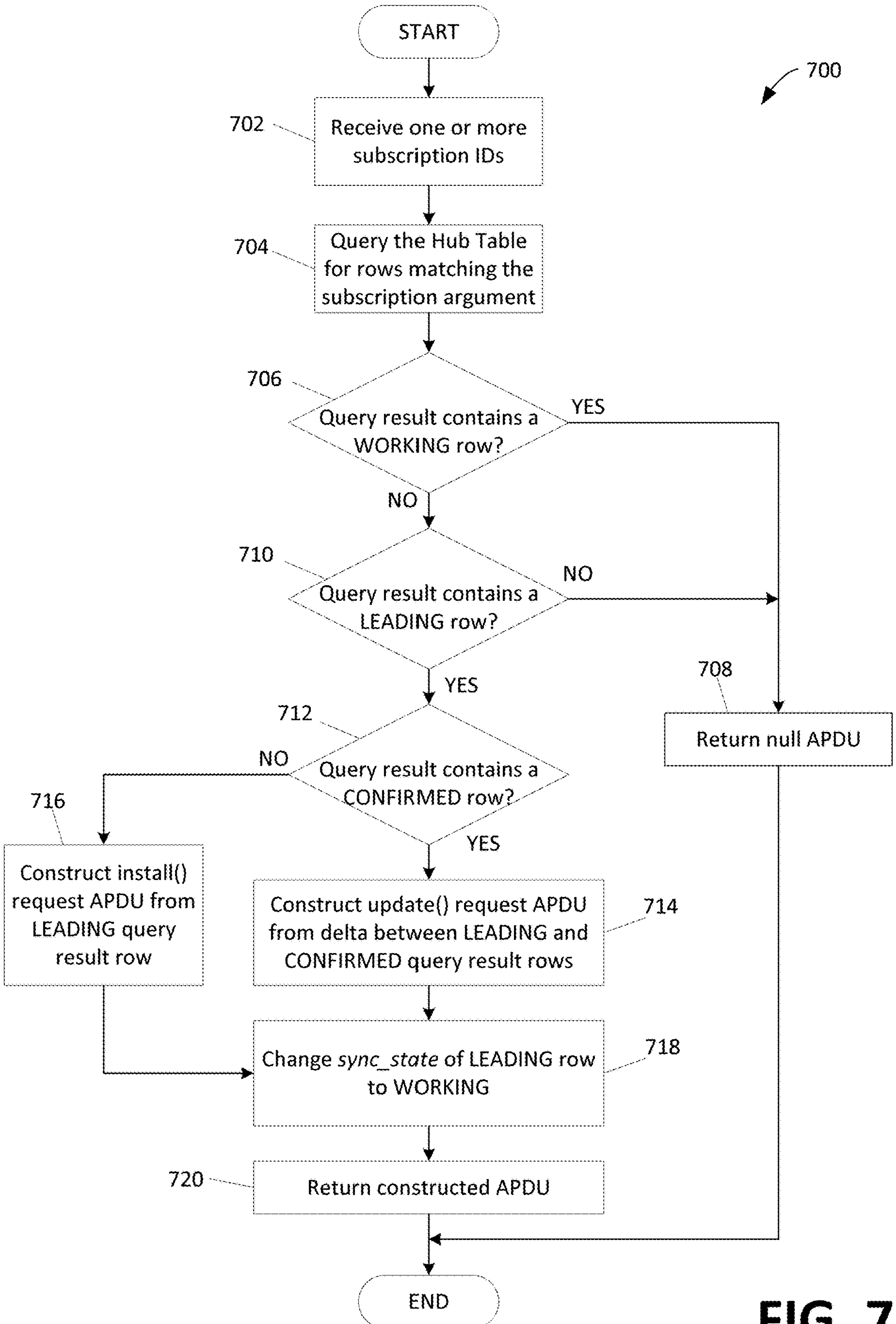

700
START
702
Receive one or more subscription IDs
704
Query the Hub Table for rows matching the subscription argument
706
Query result contains a WORKING row?
YES
NO
710
Query result contains a LEADING row?
NO
YES
708
Return null APDU
712
Query result contains a CONFIRMED row?
NO
YES
716
Construct install() request APDU from LEADING query result row
Construct update() request APDU from delta between LEADING and CONFIRMED query result rows
714
Change sync_state of LEADING row to WORKING
718
720
Return constructed APDU
END

FIG. 7

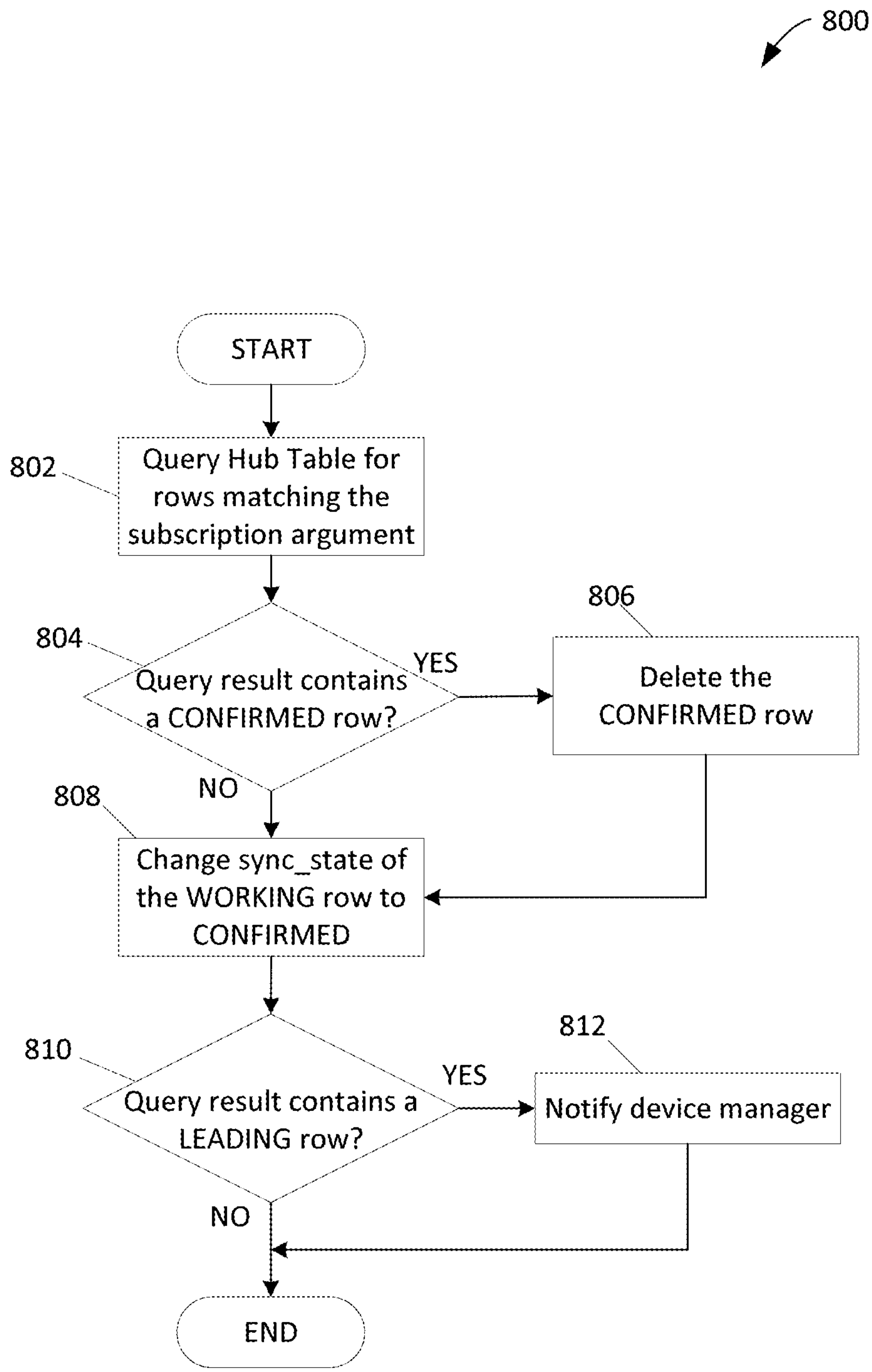

800
START
802
Query Hub Table for rows matching the subscription argument
804
Query result contains a CONFIRMED row?
YES
806
Delete the CONFIRMED row
NO
808
Change sync_state of the WORKING row to CONFIRMED
810
Query result contains a LEADING row?
YES
812
Notify device manager
NO
END

FIG. 8

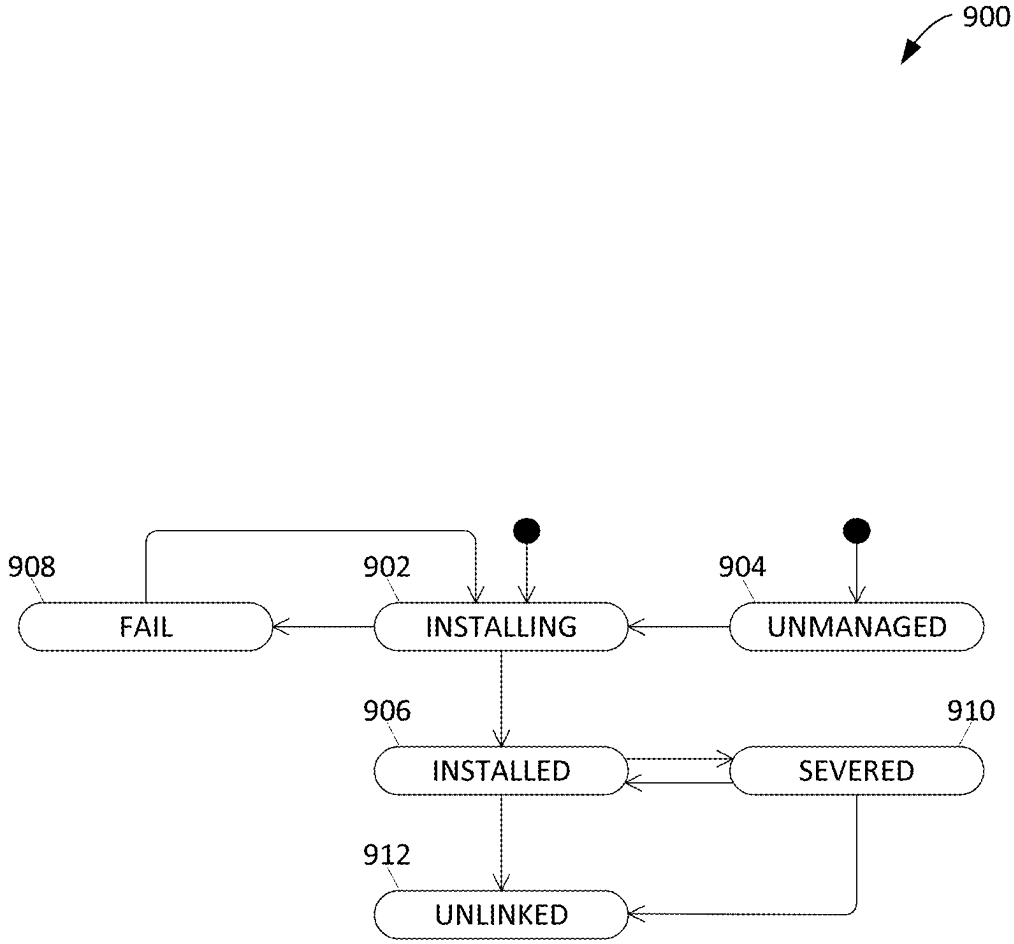

900
908
FAIL
902
INSTALLING
904
UNMANAGED
906
INSTALLED
910
SEVERED
912
UNLINKED

FIG. 9

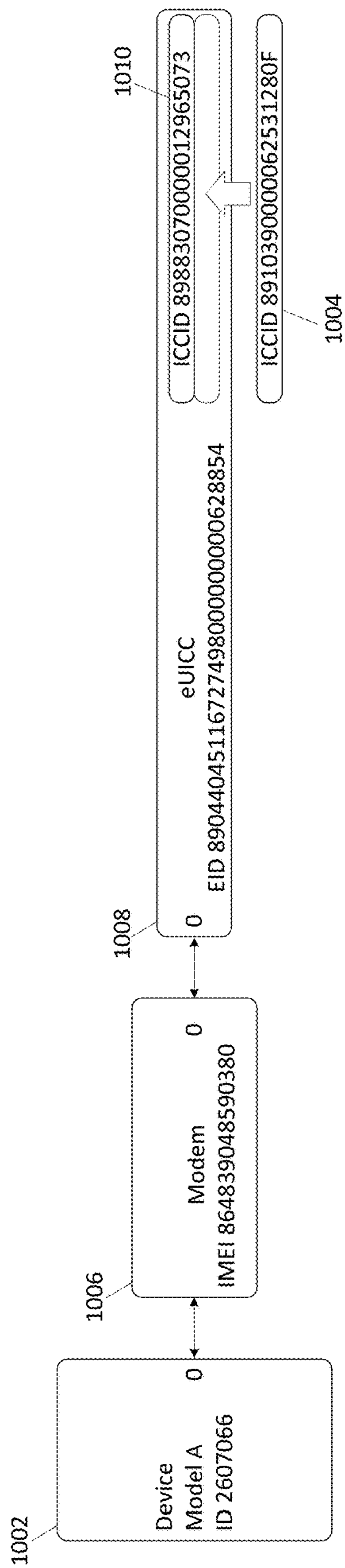

1000
1010
ICCID 89883070000012965073
ICCID 89103900000062531280F
1004
eUICC
EID 89044045116727498000000000628854
0
1008
Modem
IMEI 864839048590380
0
1006
Device
Model A
ID 2607066
0
1002

FIG. 10

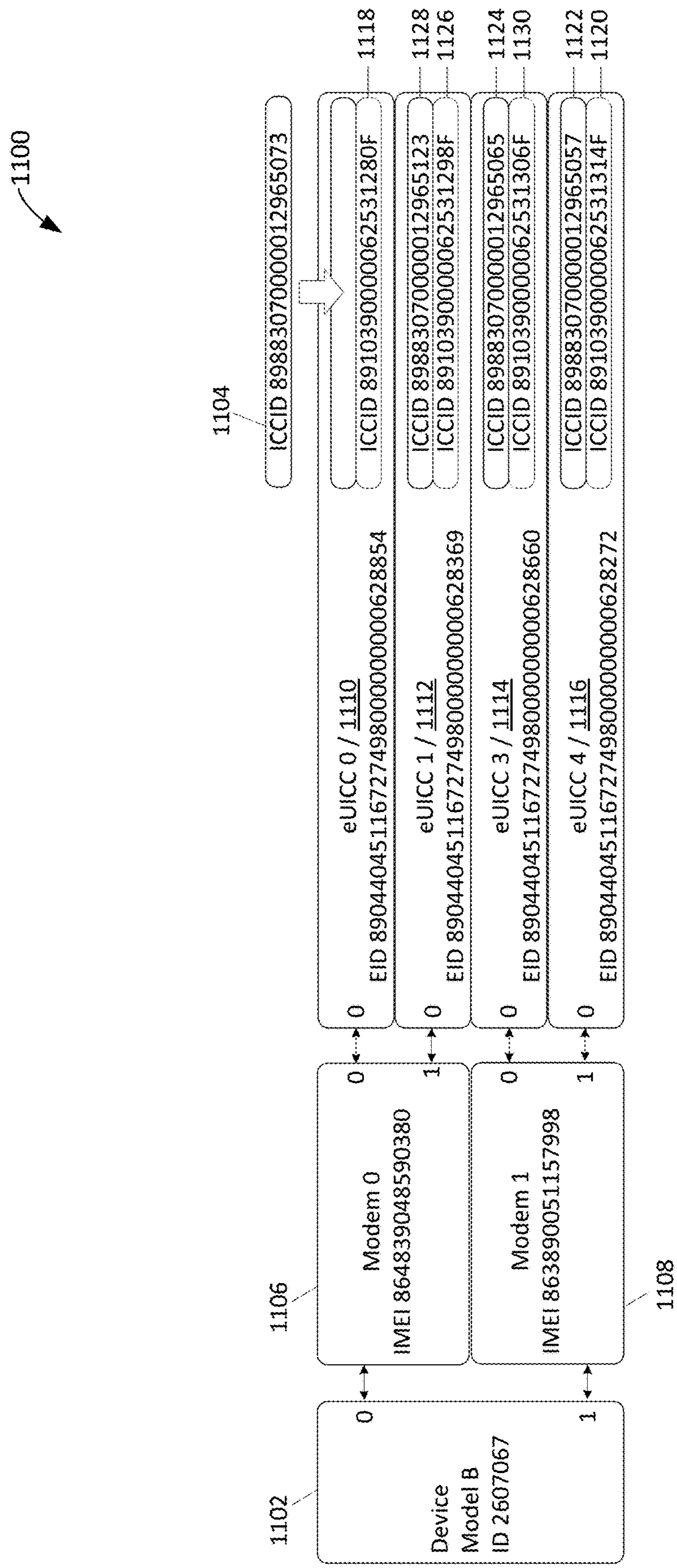

1100
1102
Device
Model B
ID 2607067
0
1
1106
Modem 0
IMEI 864839048590380
0
1
1108
Modem 1
IMEI 863890051157998
0
1
0
eUICC 0 / 1110
EID 89044045116727494800000000628854
0
eUICC 1 / 1112
EID 89044045116727494800000000628369
0
eUICC 3 / 1114
EID 89044045116727494800000000628660
0
eUICC 4 / 1116
EID 89044045116727494800000000628272
1104
ICCID 8988307000001296 5073
ICCID 891039000006253128 0F
ICCID 8988307000001296 5123
ICCID 891039000006253129 8F
ICCID 8988307000001296 5065
ICCID 891039000006253130 6F
ICCID 8988307000001296 5057
ICCID 891039000006253131 4F
1118
1128
1126
1124
1130
1122
1120

FIG. 11

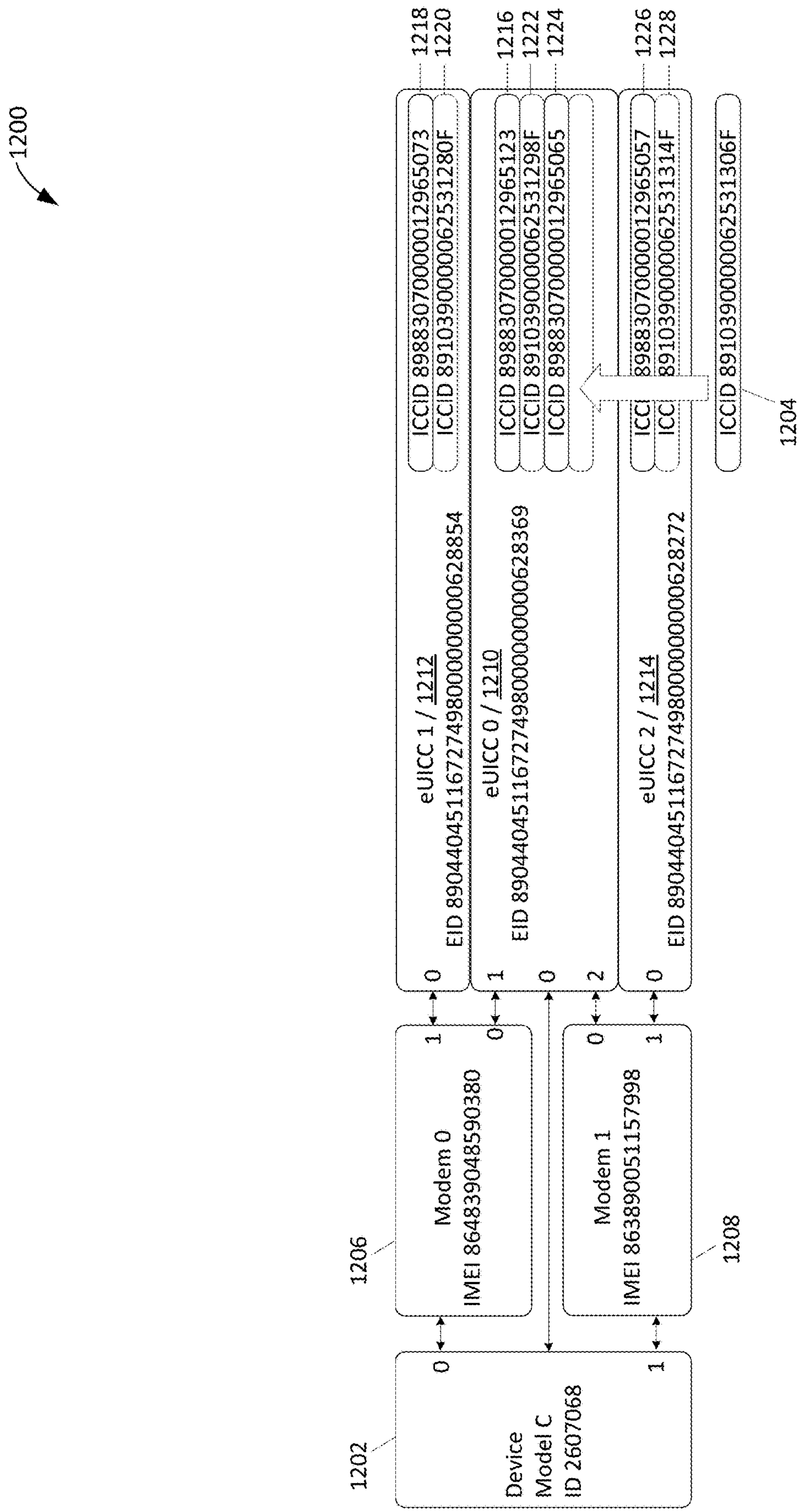

1200
1202
Device
Model C
ID 2607068
1206
Modem 0
IMEI 864839048590380
1208
Modem 1
IMEI 863890051157998
eUICC 1 / 1212
EID 89044045116727498000000000628854
eUICC 0 / 1210
EID 89044045116727498000000000628369
eUICC 2 / 1214
EID 89044045116727498000000000628272
ICCID 89883070000012965073
ICCID 8910390000062531280F
ICCID 89883070000012965123
ICCID 8910390000062531298F
ICCID 89883070000012965065
ICCID 89883070000012965057
ICCID 8910390000062531314F
ICCID 8910390000062531306F
1204
1218
1220
1216
1222
1224
1226
1228

FIG. 12

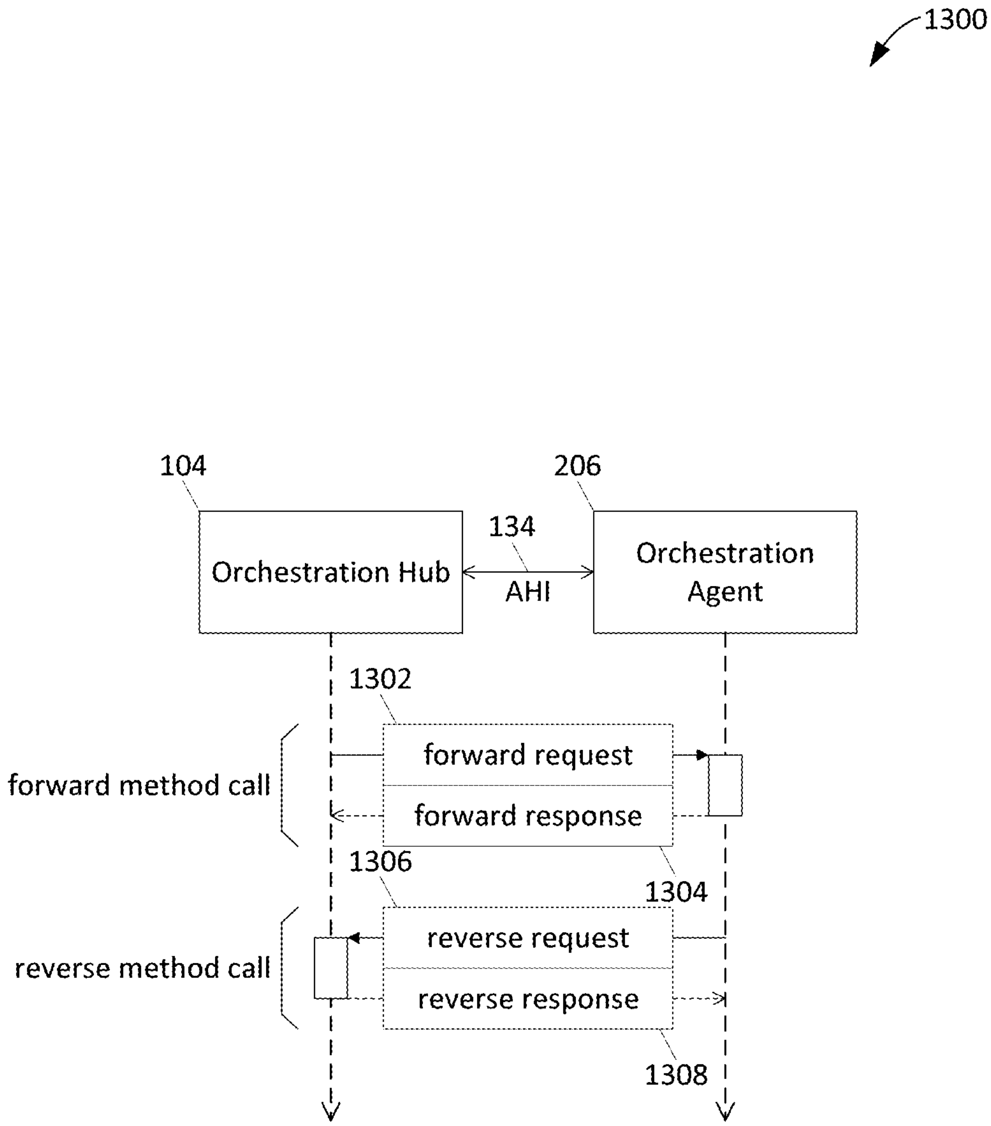

1300
104
206
Orchestration Hub
134
AHI
Orchestration Agent
1302
forward method call
forward request
forward response
1306
1304
reverse method call
reverse request
reverse response
1308

FIG. 13

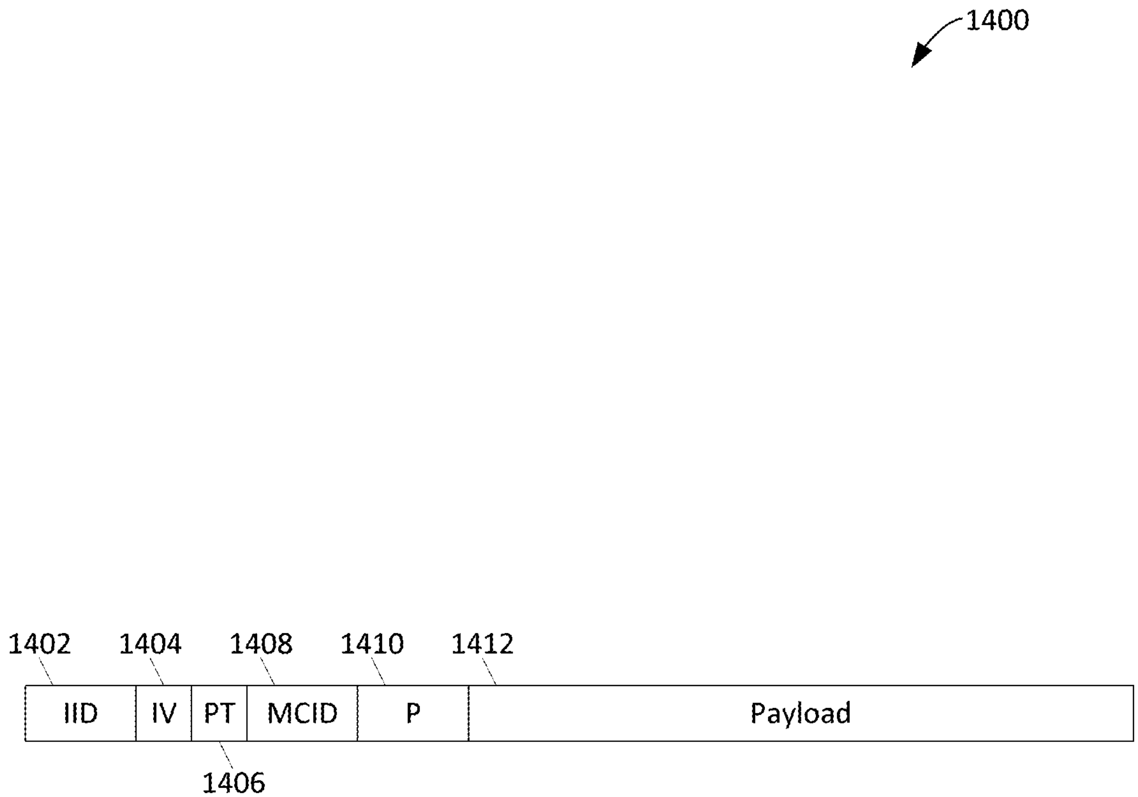
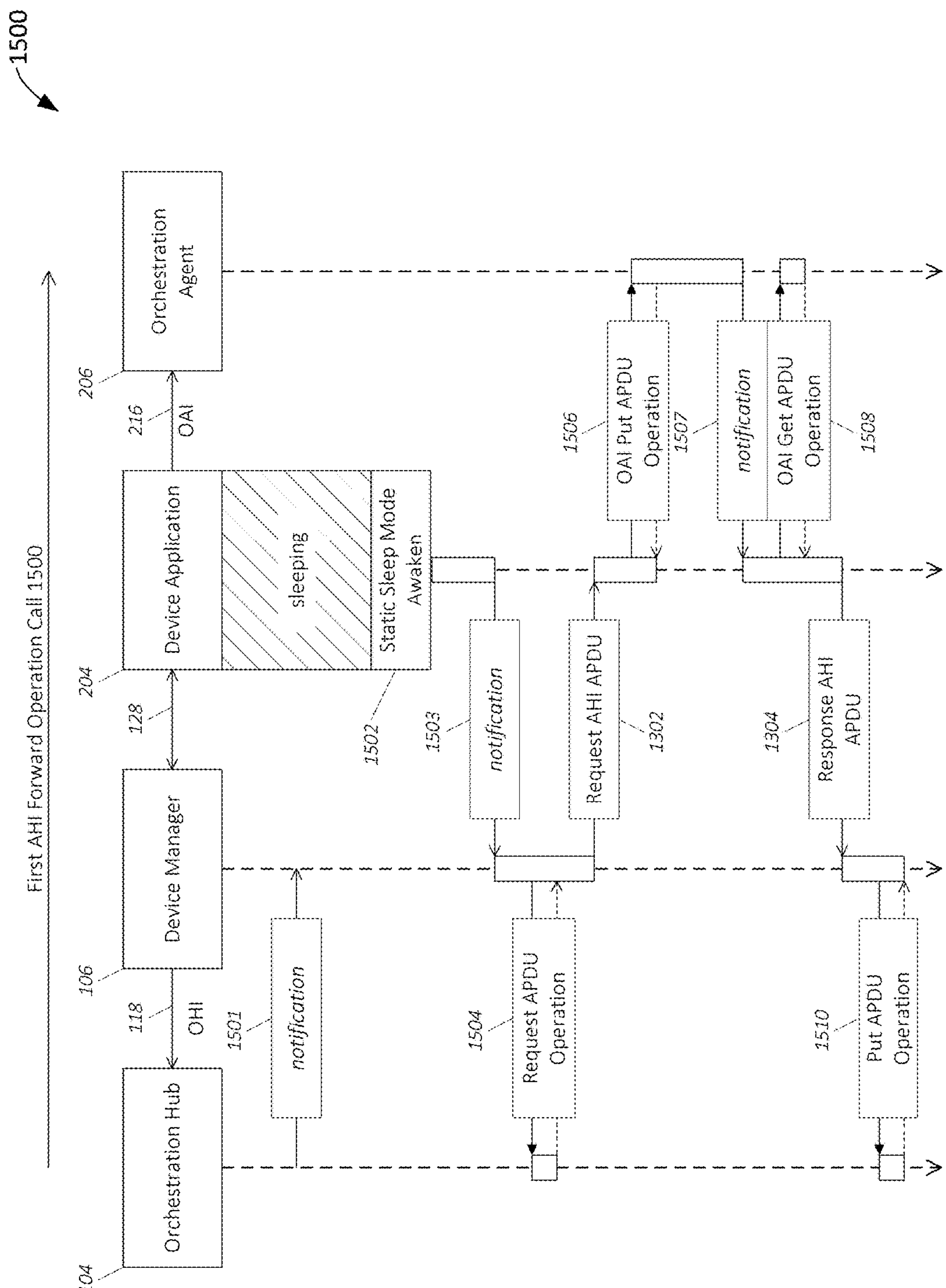


FIG.14



1500
First AHI Forward Operation Call 1500
104
Orchestration Hub
118
OHI
106
Device Manager
128
204
Device Application
sleeping
Static Sleep Mode Awaken
1502
216
OAI
206
Orchestration Agent
1501
notification
1503
notification
1504
Request APDU Operation
1302
Request AHI APDU
1304
Response AHI APDU
1510
Put APDU Operation
1506
OAI Put APDU Operation
1507
notification
1508
OAI Get APDU Operation

FIG. 15

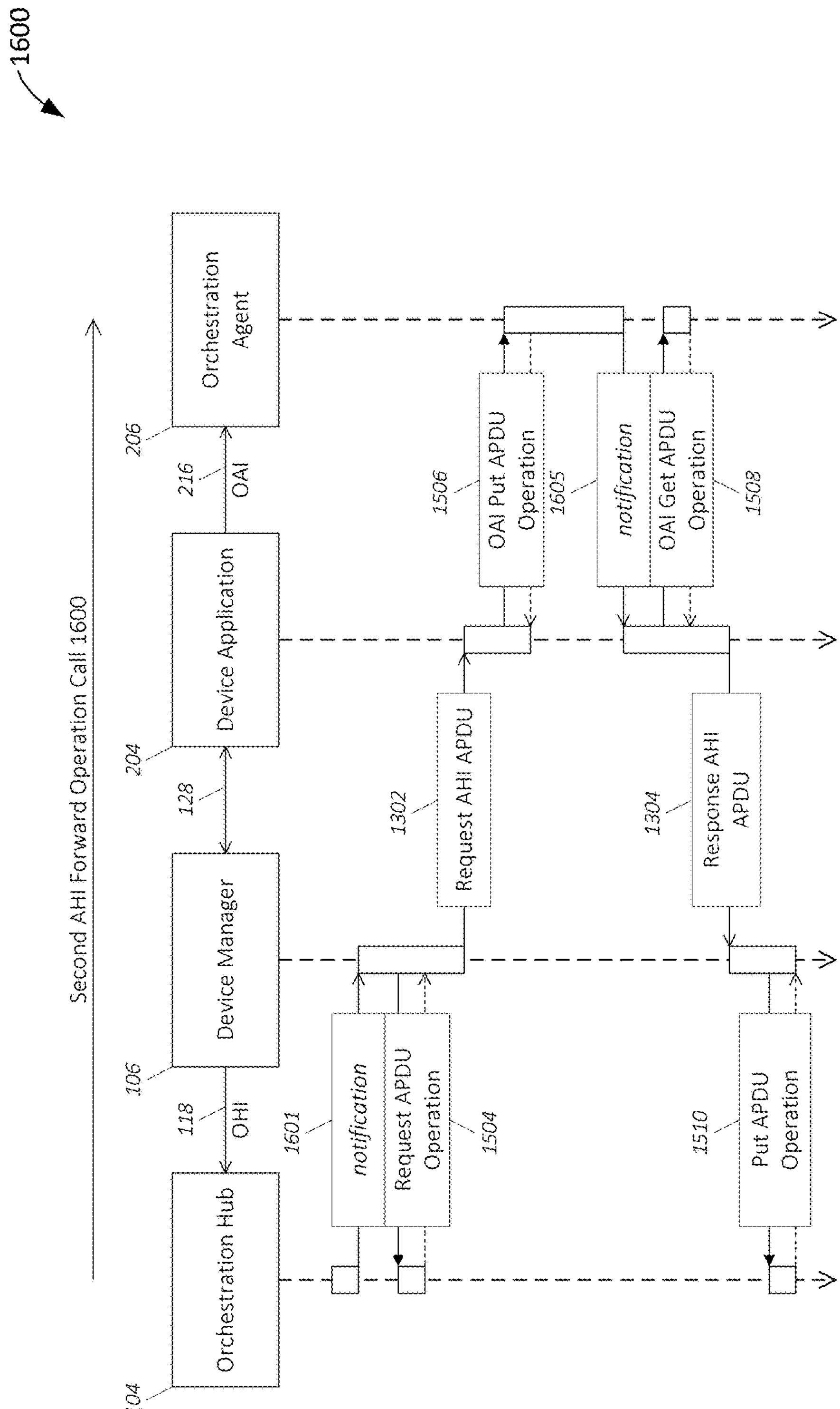

1600
Second AHI Forward Operation Call 1600
104
Orchestration Hub
106
Device Manager
204
Device Application
206
Orchestration Agent
118
OHI
128
216
OAI
1601
notification
Request APDU Operation
1504
1302
Request AHI APDU
1506
OAI Put APDU Operation
1605
notification
OAI Get APDU Operation
1508
1304
Response AHI APDU
1510
Put APDU Operation

FIG. 16

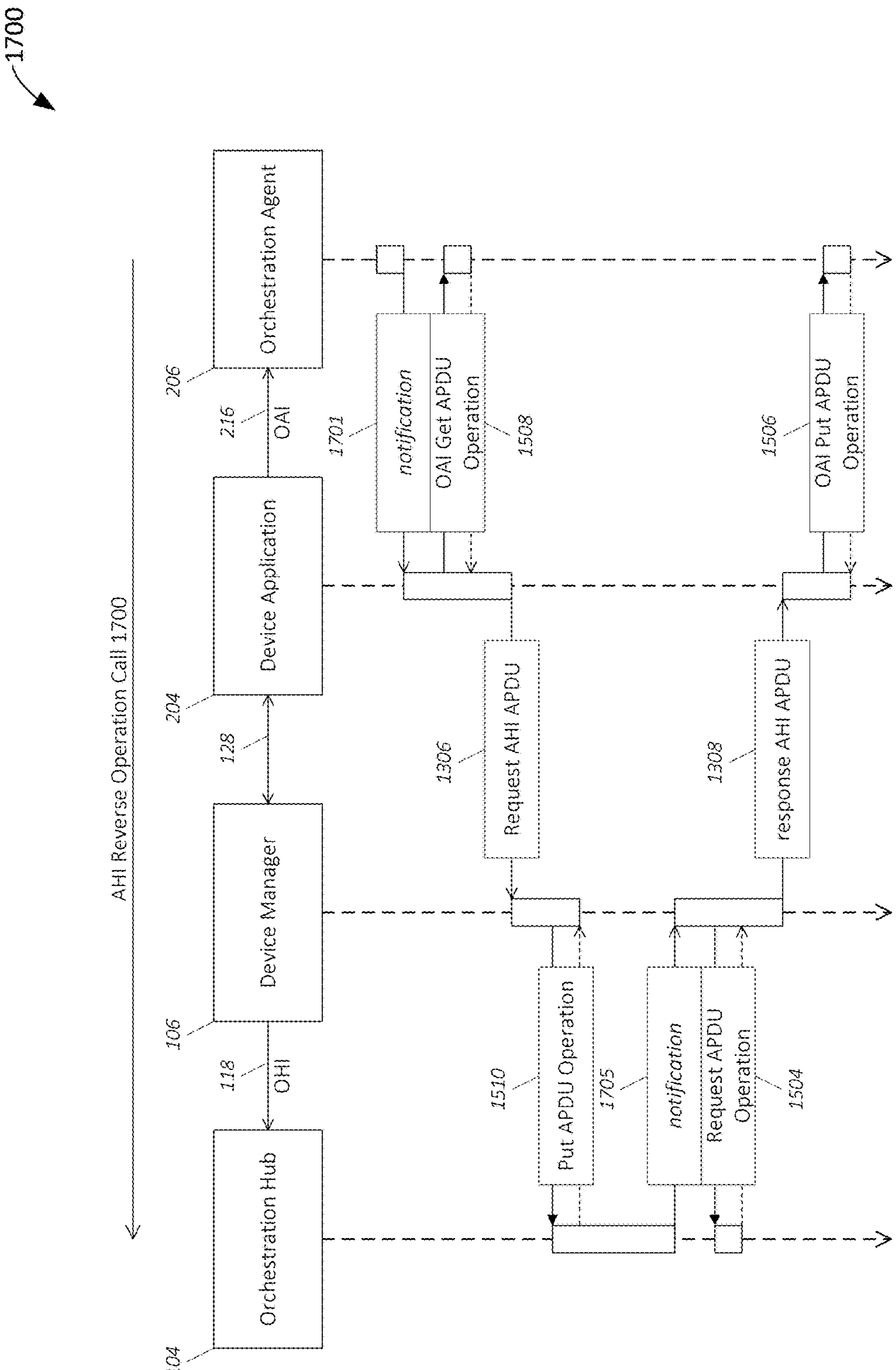

1700
AHI Reverse Operation Call 1700
Orchestration Agent
206
216
OAI
Device Application
204
128
Device Manager
106
118
OHI
Orchestration Hub
104
notification
1701
OAI Get APDU Operation
1508
OAI Put APDU Operation
1506
Request AHI APDU
1306
response AHI APDU
1308
Put APDU Operation
1510
notification
1705
Request APDU Operation
1504

FIG. 17

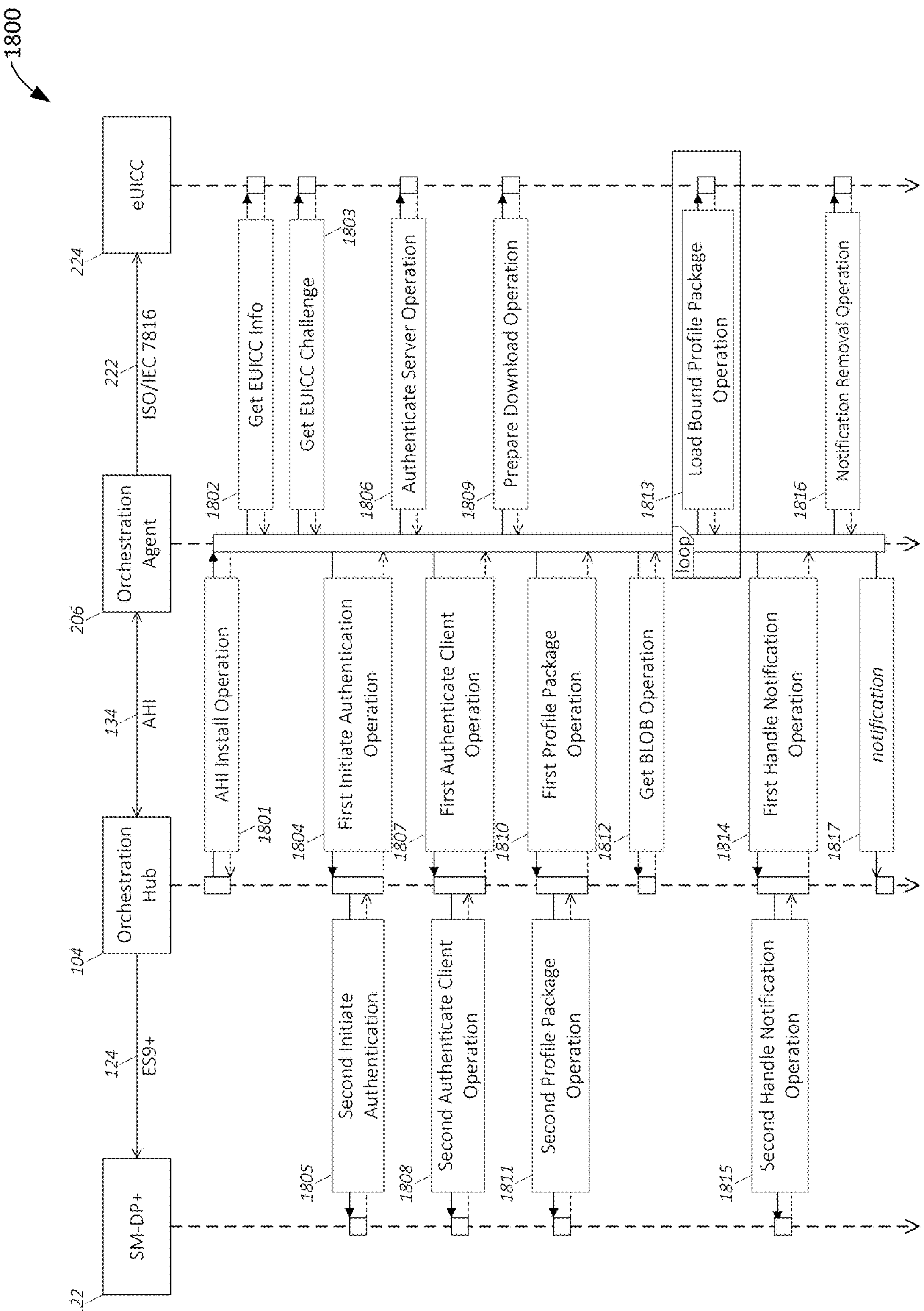

1800
SM-DP+
122
ES9+
124
Orchestration Hub
104
AHI
134
Orchestration Agent
205
ISO/IEC 7816
222
eUICC
224
AHI Install Operation
1801
Get EUICC Info
1802
Get EUICC Challenge
1803
First Initiate Authentication Operation
1804
Second Initiate Authentication
1805
Authenticate Server Operation
1806
First Authenticate Client Operation
1807
Second Authenticate Client Operation
1808
Prepare Download Operation
1809
First Profile Package Operation
1810
Second Profile Package Operation
1811
Get BLOB Operation
1812
loop
Load Bound Profile Package Operation
1813
First Handle Notification Operation
1814
Second Handle Notification Operation
1815
Notification Removal Operation
1816
notification
1817

FIG. 18

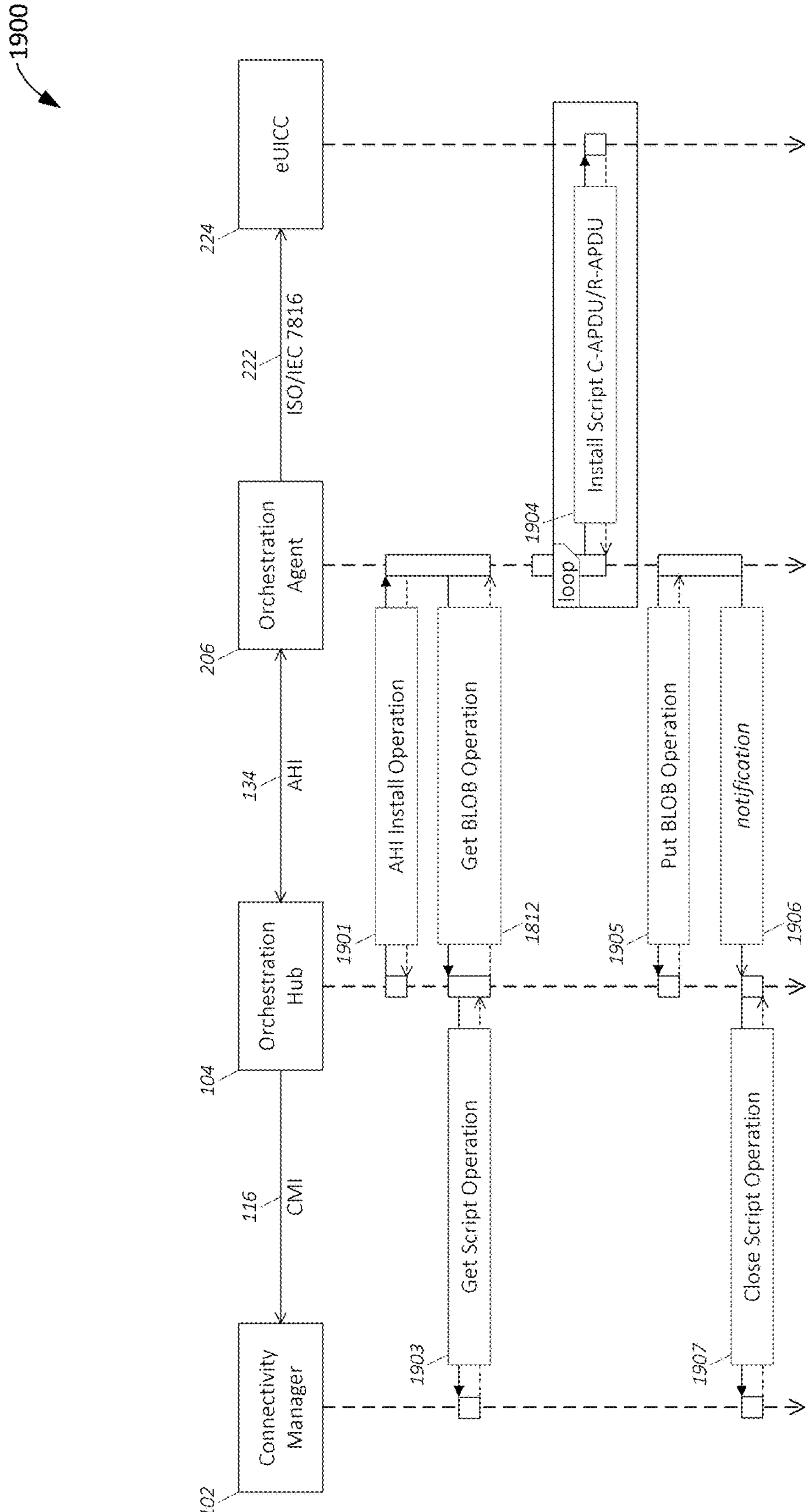

1900
eUICC
224
Orchestration Agent
206
Orchestration Hub
104
Connectivity Manager
102
222
ISO/IEC 7816
134
AHI
116
CMI
1901
AHI Install Operation
Get BLOB Operation
1812
Get Script Operation
1903
1904
loop
Install Script C-APDU/R-APDU
1905
Put BLOB Operation
notification
1906
Close Script Operation
1907

FIG. 19

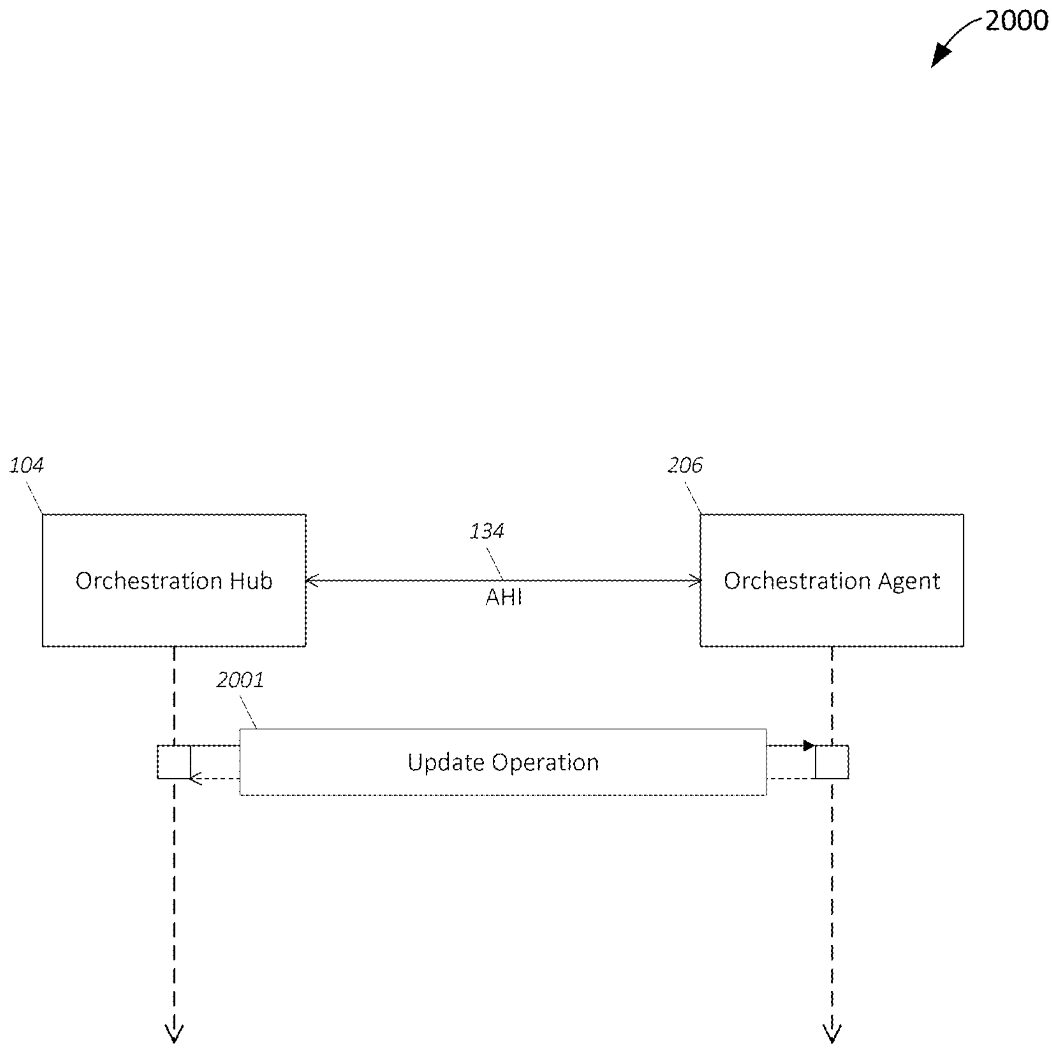

2000
104
206
134
Orchestration Hub
AHI
Orchestration Agent
2001
Update Operation

FIG. 20

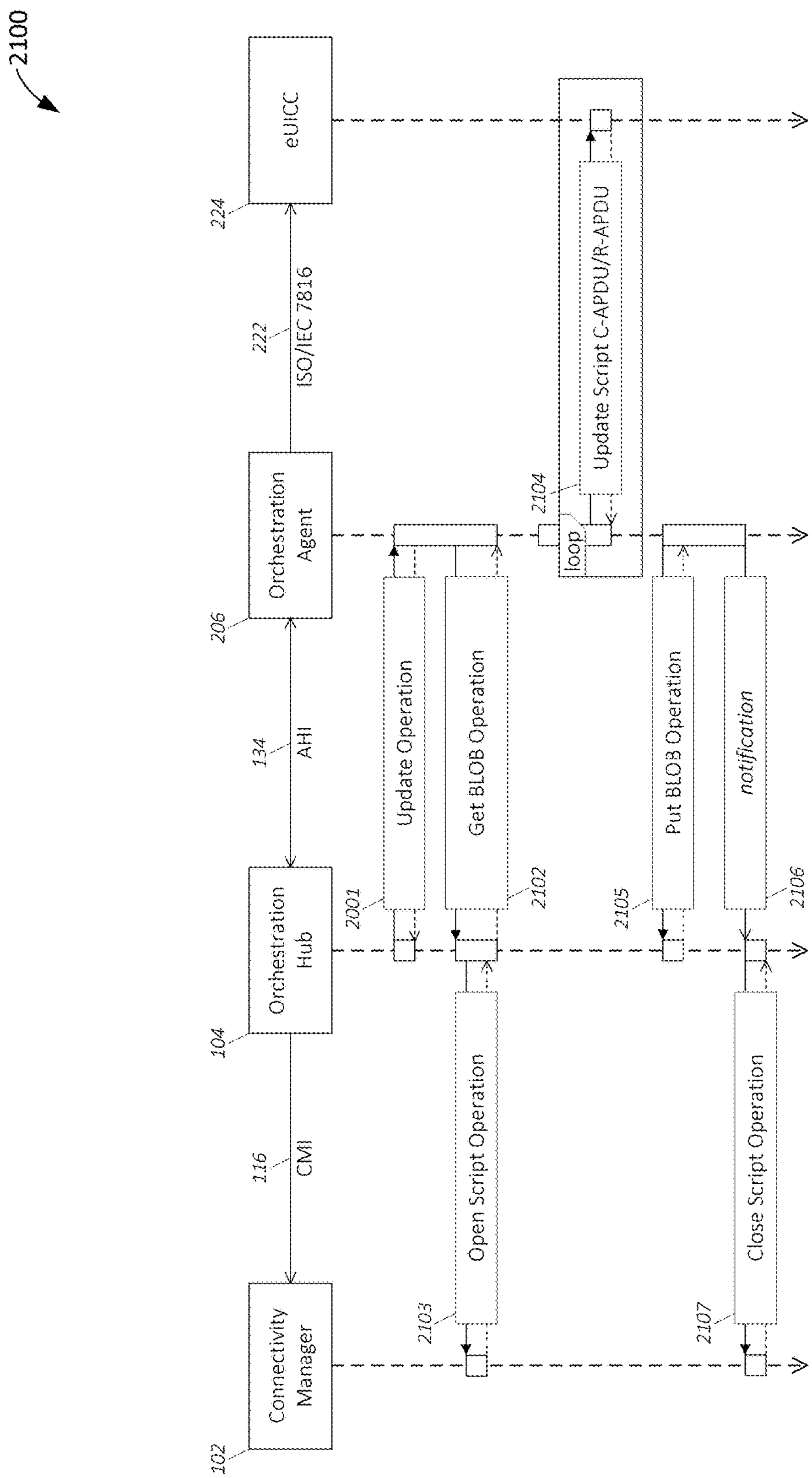

2100
eUICC
224
ISO/IEC 7816
222
Orchestration Agent
206
AHI
134
Orchestration Hub
104
CMI
116
Connectivity Manager
102
Update Script C-APDU/R-APDU
2104
loop
Update Operation
2001
Get BLOB Operation
2102
Open Script Operation
2103
Put BLOB Operation
2105
notification
2106
Close Script Operation
2107

FIG. 21

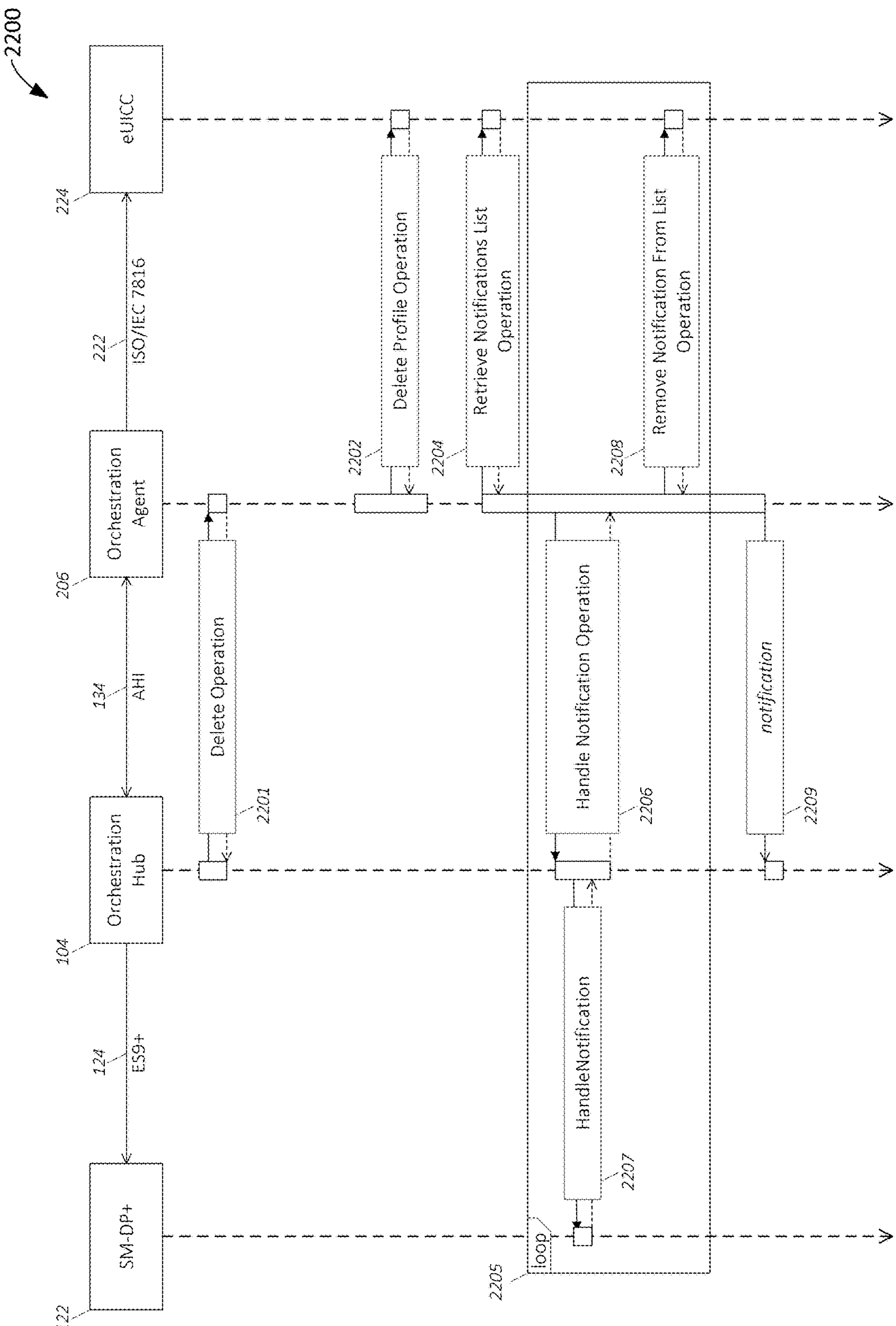

2200
224
eUICC
222
ISO/IEC 7816
206
Orchestration Agent
134
AHI
104
Orchestration Hub
124
ES9+
122
SM-DP+
Delete Operation
2201
2202
Delete Profile Operation
2204
Retrieve Notifications List Operation
2208
Remove Notification From List Operation
Handle Notification Operation
2206
notification
2209
HandleNotification
2207
loop
2205

FIG. 22

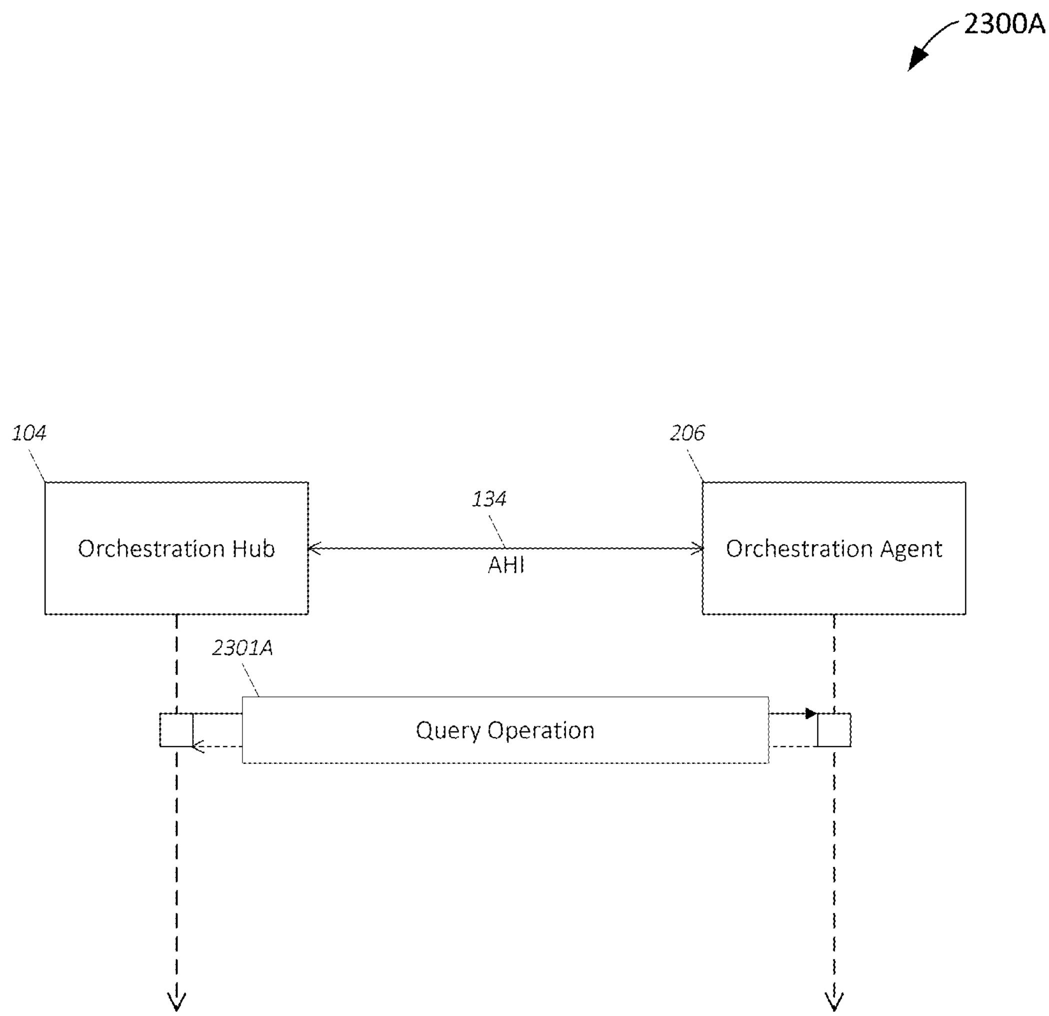

2300A
104
206
134
Orchestration Hub
AHI
Orchestration Agent
2301A
Query Operation

FIG. 23A

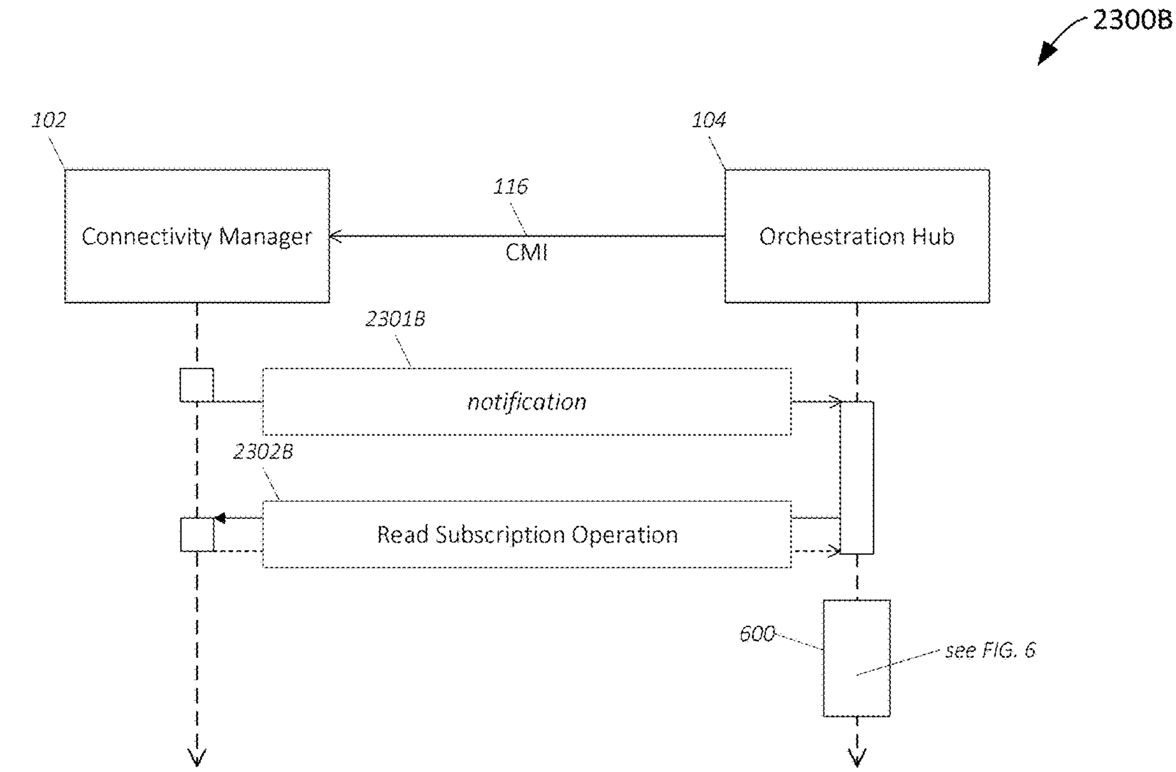


FIG. 23B

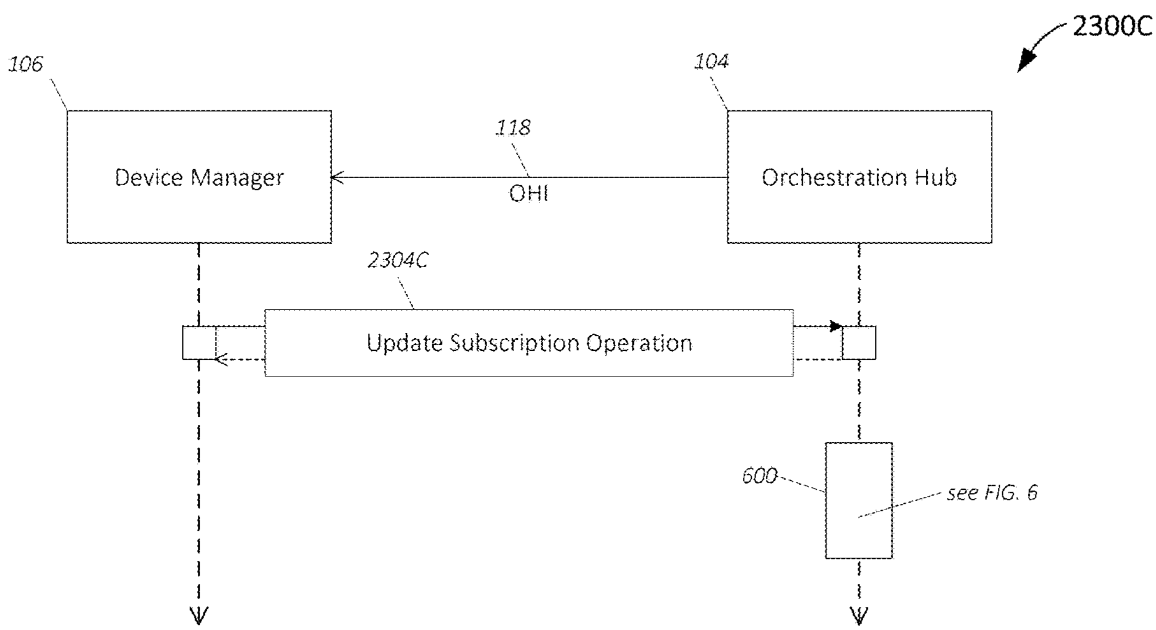


FIG. 23C

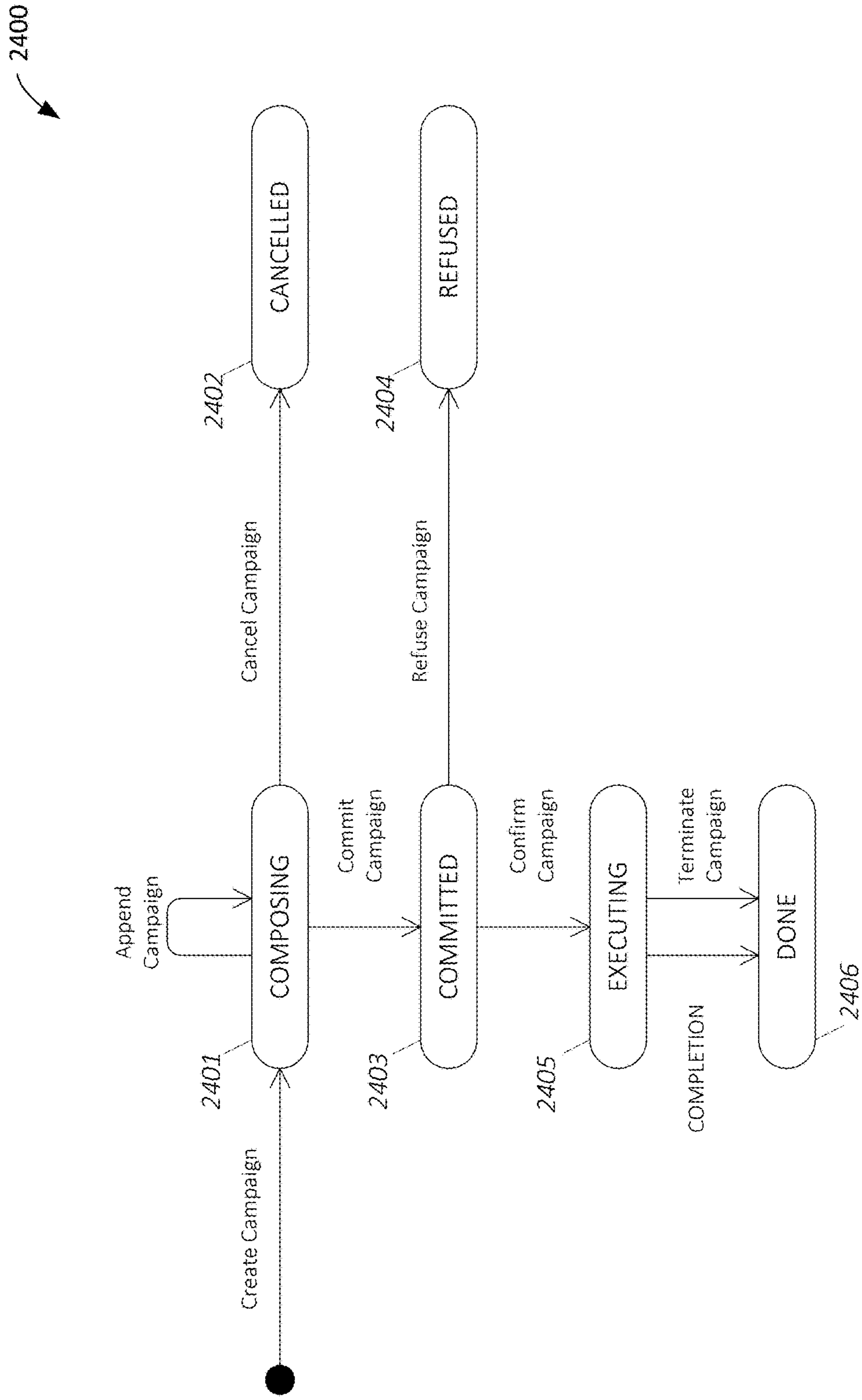

2400
CANCELLED
REFUSED
2402
2404
Cancel Campaign
Refuse Campaign
Append Campaign
COMPOSING
Commit Campaign
COMMITTED
Confirm Campaign
EXECUTING
Terminate Campaign
DONE
2401
2403
2405
2406
COMPLETION
Create Campaign

FIG. 24

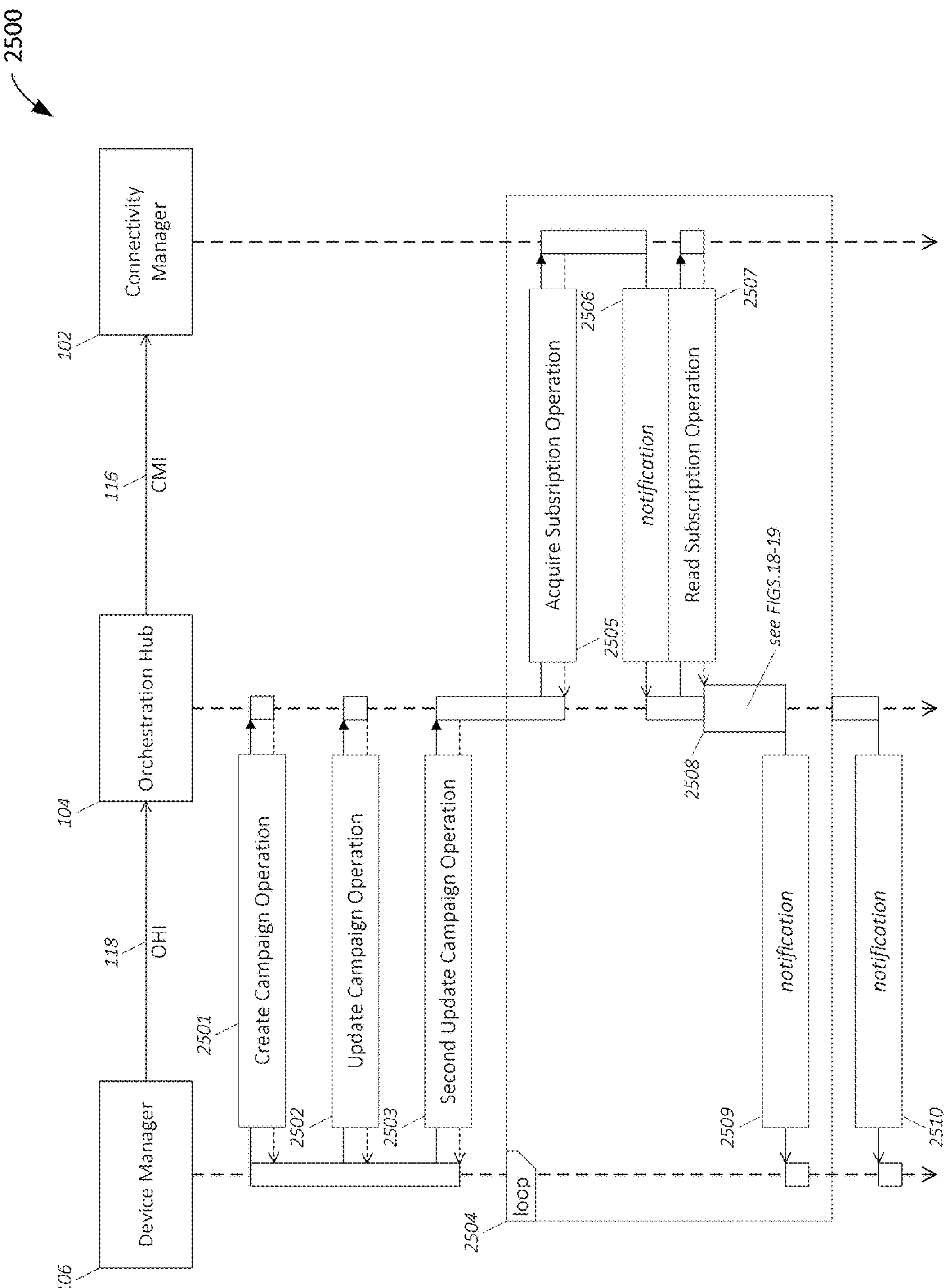

2500
Connectivity Manager
102
Orchestration Hub
104
Device Manager
106
CMI
116
OHI
118
Create Campaign Operation
2501
Update Campaign Operation
2502
Second Update Campaign Operation
2503
loop
2504
Acquire Subsription Operation
2505
notification
2506
Read Subscription Operation
2507
see FIGS.18-19
2508
notification
2509
notification
2510

FIG. 25

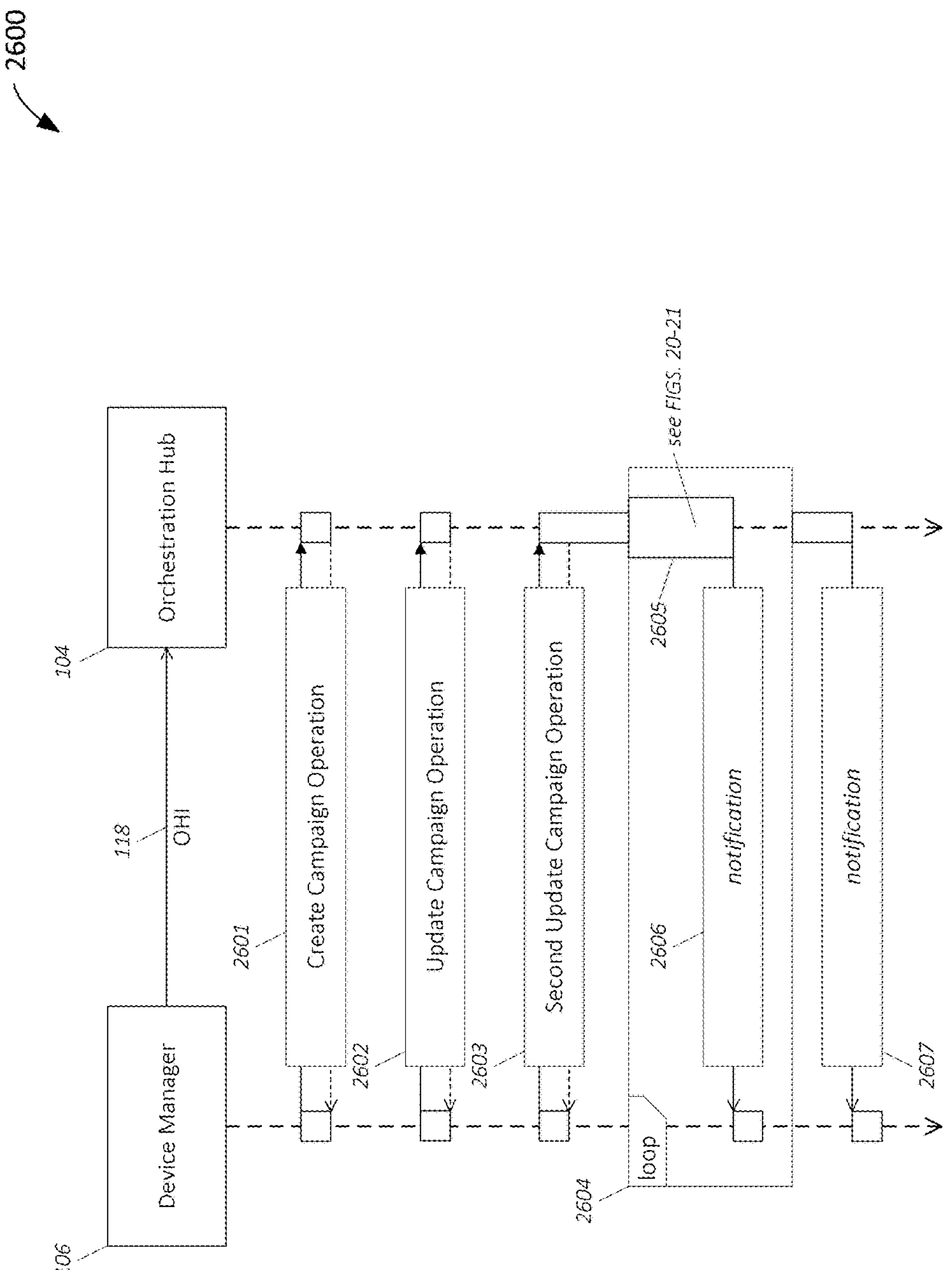

2600
Device Manager
106
Orchestration Hub
104
OHI
118
Create Campaign Operation
2601
Update Campaign Operation
2602
Second Update Campaign Operation
2603
loop
2604
see FIGS. 20-21
2605
notification
2606
notification
2607

FIG. 26

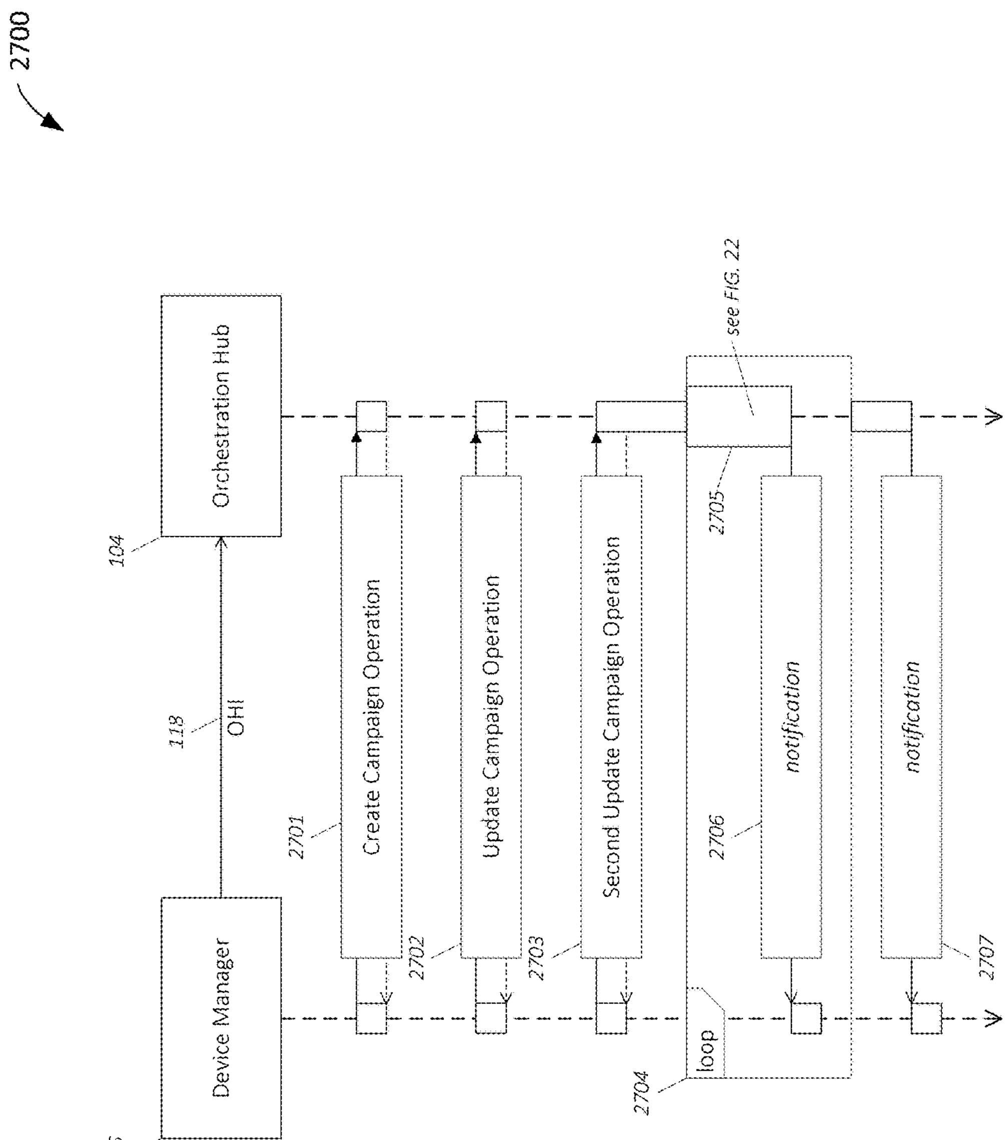

2700
106
Device Manager
104
Orchestration Hub
118
OHI
2701
Create Campaign Operation
2702
Update Campaign Operation
2703
Second Update Campaign Operation
2704
loop
2705
see FIG. 22
2706
notification
2707
notification

FIG. 27

SYSTEMS, METHODS, AND APPARATUSES FOR IMPROVED CONNECTIVITY DISTRIBUTION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation Patent Application of, and claims the benefit of and priority to, International Patent Application No. PCT/US25/16058, filed on Feb. 14, 2025, and entitled "SYSTEMS, METHODS, AND APPARATUSES FOR IMPROVED CONNECTIVITY DISTRIBUTION," which claims the benefit of and priority to U.S. Provisional Patent Application No. 63/553,402, filed on Feb. 14, 2024, and entitled "SYSTEMS, METHODS, AND APPARATUSES FOR IMPROVED CONNECTIVITY DISTRIBUTION," the disclosures of which are incorporated by reference in their entireties as if the same were fully set forth herein.

TECHNICAL FIELD

[0002] The present systems, processes, and apparatuses relate generally to digital telecommunications and, more particularly to systems, methods, and apparatuses for improved connectivity distribution.

BACKGROUND

[0003] Remote SIM Provisioning (RSP) relates to a process for downloading and managing eSIM profiles on mobile devices for connecting to cellular networks. RSP for consumer devices (such as cell phones) has improved over the years due to advancements from organizations such as the Global System for Mobile Communications Associate (GSMA) via standards and specifications including SGP.02, SGP.22, and SGP.32. However, when applied to internet of things (IoT) devices, particularly unattended devices, RSP encounters numerous challenges. But for those numerous challenges, RSP could provide material benefits to IoT system management; however, none of SGP.02, SGP.22, and SGP.32 can provide each of the following capabilities for overcoming the shortcomings of using RSP for IoT system management: synchronizing RSP operations with device operations and availability; including subscription context information with downloaded eSIM profiles; providing access to RSP servers when internet is not available; enabling downloads through non-cellular connectivity; and enabling local profile management. Therefore, there is a long-felt but unmet need for systems, methods, and apparatuses for improved connectivity distribution via deploying mobile network subscriber identities to IoT devices.

BRIEF SUMMARY

[0004] Briefly described, and according to one embodiment, aspects of the present disclosure generally relate to systems, methods, and apparatuses for improved cellular device connectivity distribution.

[0005] In particular, aspects of the present disclosure relate to remote SIM provisioning (RSP) in internet of things (IoT) environments. For example, consider a scenario in which hundreds, thousands, hundreds of thousands, etc., of cellular IoT devices require information relating to accessing one or more cellular networks for receiving and transmitting data. According to various aspects of the present disclosure, the system described herein includes an orchestration hub for transmitting, from a centralized location and synchronized according to device availability, cellular network subscription information to IoT devices. In at least one example, orchestration hub can be operatively connected to one or more device management systems (device managers). The orchestration hub can also be operatively connected to one or more connectivity management systems (connectivity managers). According to various aspects of the present disclosure, the orchestration hub can install, configure, update, and delete subscriptions (including subscriber identity and subscription context) on remote IoT devices. Aspects of the present disclosure further support profile content management and eSIM profiles with multiple IMSIs.

[0006] In at least one example, the orchestration hub can be operatively configured to receive subscription source rows from one or more device managers, connectivity managers, and other management platforms. The orchestration hub can determine whether the subscription source rows include updated subscription configuration information, and the orchestration hub can merge updated subscription configuration information into a record of stored subscription information within the orchestration hub. Merging updated subscription configuration information into a record of stored subscription information within the orchestration hub can include generating a new subscription information record entry (a subscription information "row"), replacing or overwriting existing subscription information stored within the orchestration hub, etc. In certain examples, the orchestration hub can generate and transmit remote SIM provisioning (RSP) application protocol data unit (APDU) messages to IoT devices in response to the devices becoming available (e.g., waking from an idle state, finishing a separate processing task, connecting to the network, etc.). The RSP APDUs can include the updated subscription configuration information which can replace preexisting subscription information at the IoT devices.

[0007] Further, the present disclosure allows for device operations (e.g., queries transmitted to devices to initiate particular actions) to be organized as campaigns. In one example, a campaign can be a set of sequentially ordered operations applied to one or more devices. While operations can be sequential and ordered for each device in a campaign, devices themselves can be handled in parallel. For example, a campaign can include two installation operations, followed by a delete operation, each performed on a plurality of devices. For example, for a campaign applied to 500 devices, the orchestration hub can simultaneously initiate 500 install operations. In at least one example, as the install operations complete, the orchestration hub can begin follow-on operations on a device-by-device basis. Campaigns can offer an advantageous management structure in cases where RSP operations may incur cost, which can be controlled and accounted for differently than other aspects of device management.

[0008] According to a first aspect, or any other aspect, the present disclosure discusses a system including: an orchestration agent including a software configuration installed at a mobile computing device, wherein the orchestration agent is operatively connected to an embedded universal integrated circuit card (eUICC) and memory at the mobile computing device; and an orchestration hub operatively connected to the orchestration agent, wherein the orchestration hub includes a processor and a database including centralized network subscription information sourced from one or more management platforms, wherein the processor is operatively configured to: receive first updated network subscription information from a device management platform of the one or more management platforms; receive second updated network subscription information from a network connectivity management platform of the one or more management platforms; compare the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in the centralized network subscription information; in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generate a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and transmit a replicated version of the new subscription record to the orchestration agent at the mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at the eUICC and the memory with corresponding information fields from the replicated version of the new subscription record.

[0009] According to a second aspect, or any other aspect, the common identifier is an Integrated Circuit Card Identification (ICCID) value.

[0010] According to a third aspect, or any other aspect, transmitting the replicated version of the new subscription record to the orchestration agent includes transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

[0011] According to a fourth aspect, or any other aspect, the orchestration hub is operatively configured to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

[0012] According to a fifth aspect, or any other aspect, the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

[0013] According to a sixth aspect, or any other aspect, the subscription edge record includes an eSIM profile, received from the SM-DP+ server, stored within the eUICC, and the subscription edge record further includes subscription context information, received from the network connectivity management platform, stored within the memory.

[0014] According to a seventh aspect, or any other aspect, the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

[0015] According to an eighth aspect, or any other aspect, the present disclosure describes a method including: receiving first updated network subscription information from a device management platform of one or more management platforms; receiving second updated network subscription information from a network connectivity management platform of the one or more management platforms; comparing the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in centralized network subscription information stored in an orchestration hub; in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generating a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and transmitting a replicated version of the new subscription record to an orchestration agent at a mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at an eUICC and a memory at the mobile computing device with corresponding information fields from the replicated version of the new subscription record.

[0016] According to a nineth aspect, or any other aspect, the common identifier is an Integrated Circuit Card Identification (ICCID) value.

[0017] According to a tenth aspect, or any other aspect, transmitting the replicated version of the new subscription record to the orchestration agent includes transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

[0018] According to an eleventh aspect, or any other aspect, the orchestration hub is operatively configured to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

[0019] According to a twelfth aspect, or any other aspect, the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

[0020] According to a thirteenth aspect, or any other aspect, the subscription edge record includes an eSIM profile, received from the SM-DP+ server, stored within the eUICC, and the subscription edge record further includes subscription context information, received from the network connectivity management platform, stored within the memory.

[0021] According to a fourteenth aspect, or any other aspect, the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

[0022] According to a fifteenth aspect, the present disclosure describes a non-transitory computer readable medium including instructions, that when read by a processor, cause the processor to perform: receiving first updated network subscription information from a device management platform of one or more management platforms; receiving second updated network subscription information from a network connectivity management platform of the one or more management platforms; comparing the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in centralized network subscription information stored in an orchestration hub; in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generating a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and transmitting a replicated version of the new subscription record to an orchestration agent at a mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at an eUICC and a memory at the mobile computing device with corresponding information fields from the replicated version of the new subscription record.

[0023] According to a sixteenth aspect, or any other aspect, the common identifier is an Integrated Circuit Card Identification (ICCID) value.

[0024] According to a seventeenth aspect, or any other aspect, transmitting the replicated version of the new subscription record to the orchestration agent includes transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

[0025] According to an eighteenth aspect, or any other aspect, the non-transitory computer readable medium discussed herein and further including instructions that, when read by the processor, cause the orchestration hub to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

[0026] According to a nineteenth aspect, or any other aspect, the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

[0027] According to a twentieth aspect, or any other aspect, the subscription edge record includes an eSIM profile received from the SM-DP+ server and stored within the eUICC, and the subscription edge record further includes subscription context information received from the network connectivity management platform and stored within the memory, and wherein the wherein the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

[0028] These and other aspects, features, and benefits of the claimed invention(s) will become apparent from the following detailed written description of the preferred embodiments and aspects taken in conjunction with the following drawings, although variations and modifications thereto may be effected without departing from the spirit and scope of the novel concepts of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The accompanying drawings illustrate one or more embodiments and/or aspects of the disclosure and, together with the written description, serve to explain the principles of the disclosure. Wherever possible, the same reference numbers are used throughout the drawings to refer to the same or like elements of an embodiment, and wherein:

[0030] FIG. **1** is a diagram of an example system environment, in accordance with the disclosed technology;

[0031] FIG. **2** is a diagram of an example device of the plurality of devices, in accordance with the disclosed technology;

[0032] FIG. **3** is a diagram of an example interface environment of the orchestration agent, in accordance with the disclosed technology;

[0033] FIG. **4** is a diagram illustrating a subscription edge record, in accordance with the disclosed technology;

[0034] FIG. **5** is a diagram illustrating a subscription row replication process, in accordance with the disclosed technology;

[0035] FIG. **6** is a flowchart of an example subscription source row update process, in accordance with the disclosed technology;

[0036] FIG. **7** is a flowchart of an example edge row update process, in accordance with the disclosed technology;

[0037] FIG. **8** is a flowchart of an example edge row update process, in accordance with the disclosed technology;

[0038] FIG. **9** is a state diagram of an example subscription edge record, in accordance with the disclosed technology;

[0039] FIG. **10** is a diagram illustrating an example subscription installation, in accordance with the disclosed technology;

[0040] FIG. **11** is a diagram illustrating an example subscription installation, in accordance with the disclosed technology;

[0041] FIG. **12** is a diagram illustrating an example subscription installation, in accordance with the disclosed technology;

[0042] FIG. **13** is a sequence diagram illustrating an example agent-hub interface process, in accordance with the disclosed technology;

[0043] FIG. **14** is a diagram of an example data structure, in accordance with the disclosed technology;

[0044] FIG. **15** is a sequence diagram showing a first AHI forward operation call with an initially unavailable device, in accordance with the disclosed technology;

[0045] FIG. **16** is a sequence diagram showing a second AHI forward operation call with an initially available device, in accordance with the disclosed technology;

[0046] FIG. **17** is a sequence diagram showing an AHI reverse operation call, in accordance with the disclosed technology;

[0047] FIG. **18** is a sequence diagram showing a first install operation, in accordance with the disclosed technology;

[0048] FIG. **19** is a sequence diagram showing a second install operation using a profile installation script, in accordance with the disclosed technology;

[0049] FIG. **20** is a sequence diagram showing a first update operation without profile content management, in accordance with the disclosed technology;

[0050] FIG. **21** is a sequence diagram showing a second update operation with profile content management, in accordance with the disclosed technology;

[0051] FIG. **22** is a sequence diagram showing a delete operation, in accordance with the disclosed technology;

[0052] FIG. **23**A-**23**C are sequence diagrams for querying, reading, and updating device subscription information, in accordance with the disclosed technology;

[0053] FIG. **24** is a lifecycle state machine for a campaign, in accordance with the disclosed technology;

[0054] FIG. **25** is a sequence diagram for a campaign of install operations, in accordance with the disclosed technology;

[0055] FIG. **26** is a sequence diagram for a campaign of update operations, in accordance with the disclosed technology; and

[0056] FIG. **27** is a sequence diagram for a campaign of delete operations, in accordance with the disclosed technology.

DETAILED DESCRIPTION

[0057] The disclosed technology generally relates to systems, methods, and apparatuses for improved cellular device connectivity distribution. Some examples of the disclosed technology will be described more fully with reference to the accompanying drawings. However, this disclosed technology may be embodied in many different forms and should not be construed as limited to the implementations set forth herein. The components described hereinafter as making up various elements of the disclosed technology are intended to be illustrative and not restrictive. Indeed, it is to be understood that other examples are contemplated. Many suitable components that would perform the same or similar functions as components described herein are intended to be embraced within the scope of the disclosed electronic devices and methods. Such other components not described herein may include, but are not limited to, for example, components developed after development of the disclosed technology.

[0058] Throughout this disclosure, various aspects of the disclosed technology can be presented in a range of formats (e.g., a range of values). It should be understood that such descriptions are merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed technology. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual rational numerical values within that range. For example, a range described as being "from 1 to 6" or "from approximately 1 to approximately 6" includes the values 1, 6, and all values therebetween. Likewise, a range described as being "between 1 and 6" or "between approximately 1 and approximately 6" includes the values 1, 6, and all values therebetween. The same premise applies to any other language describing a range of values. That is to say, the ranges disclosed herein are inclusive of the respective endpoints, unless otherwise indicated.

[0059] Herein, the use of terms such as "having," "has," "including," or "includes" are open-ended and are intended to have the same meaning as terms such as "comprising" or "comprises" and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as "can" or "may" are intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

[0060] In the following description, numerous specific details are set forth. But it is to be understood that embodiments of the disclosed technology may be practiced without these specific details. In other instances, well-known methods, structures, and techniques have not been shown in detail in order not to obscure an understanding of this description. References to "one embodiment," "an embodiment," "example embodiment," "some embodiments," "certain embodiments," "various embodiments," etc., indicate that the embodiment(s) of the disclosed technology so described may include a particular feature, structure, or characteristic, but not every embodiment necessarily includes the particular feature, structure, or characteristic. Further, repeated use of the phrase "in one embodiment" does not necessarily refer to the same embodiment, although it may.

[0061] Throughout the specification and the claims, the following terms take at least the meanings explicitly associated herein, unless the context clearly dictates otherwise. The term "or" is intended to mean an inclusive "or." Further, the terms "a," "an," and "the" are intended to mean one or more unless specified otherwise or clear from the context to be directed to a singular form.

[0062] Unless otherwise specified, the use of the ordinal adjectives "first," "second," "third," etc., to describe a common object, merely indicates that different instances of like objects are being referred to and are not intended to imply that the objects so described should be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0063] Whether or not a term is capitalized is not considered definitive or limiting of the meaning of a term. As used in this document, a capitalized term shall have the same meaning as an uncapitalized term, unless the context of the usage specifically indicates that a more restrictive meaning for the capitalized term is intended. However, the capitalization or lack thereof within the remainder of this document is not intended to be necessarily limiting unless the context clearly indicates that such limitation is intended.

[0064] For the purpose of promoting an understanding of the principles of the present disclosure, reference will now be made to the illustrative examples provided in the drawings, and specific language will be used to describe the same. It will, nevertheless, be understood that no limitation of the scope of the disclosure is thereby intended; any alterations and further modifications of the described or illustrated embodiments, and any further applications of the principles of the disclosure as illustrated therein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. All limitations of scope should be determined in accordance with and as expressed in the claims.

[0065] For the purpose of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will, nevertheless, be understood that no limitation of the scope of the disclosure is thereby intended; any alterations and further modifications of the described or illustrated embodiments, and any further applications of the principles of the disclosure as illustrated therein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. All limitations of scope should be determined in accordance with and as expressed in the claims. All limitations of scope should be determined in accordance with and as expressed in the claims.

Overview

[0066] Briefly described, and according to one embodiment, aspects of the present disclosure generally relate to systems, methods, and apparatuses for improved cellular device connectivity distribution.

[0067] In particular, aspects of the present disclosure relate to remote SIM provisioning (RSP) in internet of things (IoT) environments. For example, consider a scenario in which hundreds, thousands, hundreds of thousands, etc., of cellular IoT devices require information relating to accessing one or more cellular networks for receiving and transmitting data. According to various aspects of the present disclosure, the system described herein includes an orchestration hub for transmitting, from a centralized location and synchronized according to device availability, cellular network subscription information to IoT devices. In at least one example, orchestration hub can be operatively connected to one or more device management systems (device managers). The orchestration hub can also be operatively connected to one or more connectivity management systems (connectivity managers). According to various aspects of the present disclosure, the orchestration hub can install, configure, update, and delete subscriptions (including subscriber identity and subscription context) on remote IoT devices. Aspects of the present disclosure further support profile content management and eSIM profiles with multiple IMSIs.

[0068] In at least one example, the orchestration hub can be operatively configured to receive subscription source rows from one or more device managers, connectivity managers, and other management platforms. The orchestration hub can determine whether the subscription source rows include updated subscription configuration information, and the orchestration hub can merge updated subscription configuration information into a record of stored subscription information within the orchestration hub. Merging updated subscription configuration information into a record of stored subscription information within the orchestration hub can include generating a new subscription information record entry (a subscription information "row"), replacing or overwriting existing subscription information stored within the orchestration hub, etc. In certain examples, the orchestration hub can generate and transmit remote SIM provisioning (RSP) application protocol data unit (APDU) messages to IoT devices in response to the devices becoming available (e.g., waking from an idle state, finishing a separate processing task, connecting to the network, etc.). The RSP APDUs can include the updated subscription configuration information which can replace preexisting subscription information at the IoT devices.

[0069] Further, the present disclosure allows for device operations (e.g., queries transmitted to devices to initiate particular actions) to be organized as campaigns. In one example, a campaign can be a set of sequentially ordered operations applied to one or more devices. While operations can be sequential and ordered for each device in a campaign, devices themselves can be handled in parallel. For example, a campaign can include two installation operations, followed by a delete operation, each performed on a plurality of devices. For example, for a campaign applied to 500 devices, the orchestration hub can simultaneously initiate 500 install operations. In at least one example, as the install operations complete, the orchestration hub can begin follow-on operations on a device-by-device basis. Campaigns can offer an advantageous management structure in cases where RSP operations may incur cost, which can be controlled and accounted for differently than other aspects of device management.

Example Embodiments

[0070] Referring now to the figures, for the purposes of example and explanation of the fundamental processes and components of the disclosed systems, methods, and apparatuses, reference is made to FIG. **1**, which illustrates an example system environment **100**. As will be understood and appreciated, the example system environment **100** shown in FIG. **1** represents merely one approach or embodiment of the present system, and other aspects are used according to various embodiments of the present system.

[0071] As shown in FIG. **1**, the example system environment **100** can include one or more connectivity managers **102**, one or more orchestration hubs **104**, and one or more device managers **106**. According to various aspects of the present disclosure, the orchestration hub **104** can be operatively connected to one or more devices of a plurality of devices **108**. In one example, the device manager **106** can be operatively connected to one or more devices of the plurality of devices **108**.

[0072] In at least one example, the connectivity manager **102** can be a software and hardware service platform. The connectivity manager **102** can be operatively configured to enable users to obtain and manage subscriptions, such as connectivity subscriptions to wireless networks. In one example, subscriptions can allow devices to transmit and receive data (typically under a defined agreement). Subscriptions, and subscription information or subscription context, can include data such as a subscriber identity, in the form of an International Mobile Subscriber Identity (IMSI), or IMSI's, and a secret key value shared between a Subscriber Identity Module ("SIM" or "eSIM Profile") and a network (home subscriber server (HSS), AuC, 5GC, etc.). In certain examples, subscriptions can also include other configuration information stored in one or more partner networks, information corresponding to agreements between networks, etc.

[0073] The connectivity manager **102** can be operated by mobile network operators, mobile virtual network operators, connectivity resellers, private system operators, satellite system operators, and other enterprises. However, in one example, the connectivity manager **102** can be operated and/or controlled internally (via an administrator of the system **100**). The connectivity manager **102** can include a subscription database **110**. In one example, the subscription database **110** can include data ranging from an HSS or 5GC (as might be implemented by a mobile network operator), to one or more subscription tables (as might be implemented for resale platforms).

[0074] The connectivity manager **102** can include a user interface (UI) **112** and an application programming interface (API) **114**. In one example, the UI **112** and the API **114** can be operatively configured to allow for users and software clients to obtain and manage subscriptions. In at least one example, the connectivity manager **102** can also include a connectivity manager interface (CMI) **116**. According to various aspects of the present disclosure, the CMI **116** can be operatively configured to provide one or more services to the orchestration hub **104**. In various embodiments, the CMI **116** can be implemented using a remote procedure call (RPC) framework, such as gRPC. In this example, the connectivity manager **102** can be the server, and the orchestration hub **104** can be the client. In certain examples, additional client-to-server notification channels can be implemented with the server streaming capabilities of gRPC. In other examples, CMI **116** can be implemented by using REST, GraphQL, WebSockets, an event/stream infrastructure such as Apache Kafka, or other similar means.

[0075] In one example, the orchestration hub **104** can be a software and hardware service platform operatively configured to provide advanced services corresponding to remote SIM provisioning (RSP) and eSIM orchestration. The orchestration hub **104** includes an orchestration hub interface (OHI) **118**, which can provide defined services to the one or more device managers **106**. In the illustrative embodiment, OHI **118** can be implemented using gRPC, with the orchestration hub **104** as server, and device manager(s) **106** as the client, with an additional client-to-server notification channel implemented with the server streaming capabilities of gRPC. In other embodiments, OHI **118** can be implemented by using REST, GraphQL, WebSockets, an event/stream infrastructure such as Apache Kafka, or other similar means.

[0076] The orchestration hub **104** can be operatively configured to interface with the CMI **116** and other connectivity manager **102** services. In one example, and for connectivity managers **102** that do not support CMI **116**, a proxy or adapter service may be constructed to convert a connectivity manager's native API **132** into equivalent CMI **116** services, or a subset thereof, depending on the capabilities of the connectivity manager **102**. The orchestration hub **104** can include a database **120** to store information such as subscription information related to connectivity managers **102**, device information related to device managers **106**, etc.

[0077] In one example, the orchestration hub **104** can be operatively connected to one or more Subscription Manager-Data Preparation Plus (SM-DP+) servers **122**. Accordingly, the orchestration hub **104** can be configured to perform ES9+ operations **124** with SM-DP+ servers **122**, as needed, to assist devices **108** with downloads (eSIM profile downloads) and notification reports (eSIM profile update notifications). A person of ordinary skill in the art would understand that the orchestration hub **104** could also support ES11 connections to SM-DS servers, to allow the example embodiment to make use of GSMA Discovery Service and other similar services.

[0078] In one example, the device manager **106** can be a management platform. In particular, the device manager can be a software platform operatively configured to provide the ability to configure, operate, and manage the devices **108**. Example device managers **106** include systems to manage payment terminals, asset trackers, cellular routers, LTE gateways, utility meters, fleet management devices, sensors, PLCs, and other types of mobile and fixed connected hardware nodes. A device manager **106** can include a device management database **126**. The device management database **126** can include a table of device-related rows and other supporting tables and data structures. The device manager **106** can implement one or more device management protocols **128**. The device management protocols **128** can allow for the device manager **106** to communicate with and manage devices **108**. Device management protocols **128** can be implemented using standards such as MQTT or LwM2M. In at least one example, the device management protocols **128** can be built on top of lower-level IP standards such as TLS, TCP, UDP, CoAP, DTLS. In certain examples, the device management protocols **128** can be built on top of other physical layers such as mesh, multiple-address systems, point-to-multipoint systems, serial links, or other schemes entirely. The device manager **106** can include a UI **130** and an API **132**. The UI **130** and the API **132** can enable users and software clients to manage the devices **108**. The device manager **106** can also include client software for the orchestration hub interface (OHI) service **118**, which access the services of the orchestration hub **104**.

[0079] As will be described in more detail below, an agent hub interface (AHI) **134** can be configured to tunnel through other system interfaces and protocols. In one example, the AHI **134** can enable bidirectional communications between the orchestration hub **104** and the devices **108**.

[0080] For purposes of illustration and for ease of understanding, the connectivity manager **102**, the orchestration hub **104**, and the device managers **106** are shown as monolithic elements in the example system environment **100**. It should be understood from the discussion herein that the connectivity manager **102**, the orchestration hub **104**, and the device manager **106** can be implemented as distributed systems or as subcomponents of larger distributed systems. In one example, the connectivity manager **102**, the orchestration hub **104**, and the device manager **106** can be configured to include overlapping aspects (such as a combined connectivity manager **102** and orchestration hub **104**, a combined orchestration hub **104** and device manager **106**, or other combinations). Despite the example system environment **100** showing a single orchestration hub **104**, the system disclosed herein can support multiple orchestration hubs **104**, as well as multi-tenant orchestration hubs **104**, connectivity managers **102**, and device managers **106** interconnected in a plurality of arrangements (for example, many-to-many type arrangements).

[0081] FIG. **2** is an architecture diagram **200** of an example device **202** of the plurality of devices **108**. In one example, the device **202** can be a processing node. The device **202** can include both hardware and software components. The device **202** can include computing resources such as a central processing unit (CPU) and/or a microcontroller, as well as memory, a power source, I/O, and other computing resources. In one example, the device **202** can be of various types, such as routers, gateways, in-vehicle tracking units, utility meters, and other device types.

[0082] In one example, the device **202** can include components such as a device application **204**, an orchestration agent **206**, a modem **208**, sensors and data input/output (I/O) **210**, and other components. The device application **204** can be a software application. In at least one example, the device application **204** can include software written in the C and C++ languages. The device application **204** can include both an embedded operating system (OS) and application code. The device **202** can be implemented with a distinct OS, and it can host multiple device applications **204** developed in various computer languages and frameworks.

[0083] The device application **204** can be operatively connected to the sensors and I/O **210**. The device application **204** can control the sensors and I/O **210**. In one example, the sensors and I/O **210** can include various sensors and I/O ports and interfaces such as temperature sensors, Ethernet ports, RS-485 ports, MDB interfaces, PID loops, analog ports, GPIO, etc.

[0084] The device application **204** can be operatively connected to a nonvolatile local database (or data storage) **212**. The database **212** can store information such as configuration, operating state, queued sensor measurements, and other data. The device application **204** can connect to the modem **208** using an interface **214** such as TS 127 007, PPP, QMI, MBIM, Android RIL, or other interfaces.

[0085] While the example device **202** shows a single modem **208**, it should be understood from the discussion herein that the device **202** can include one or more modems **208**. In one example, the modem **208** can be a cellular modem. The modem **208** and/or the sensors and I/O **210** can allow for the device application **204** to communicate with the device manager **106**. In one example, the device application **204** communicates with the device manager **106** via the device management protocol **128**.

[0086] In one example, the orchestration agent **206** can be operatively configured to interface with the device application **204** using an orchestration agent interface (OAI) **216**. In the illustrative embodiment, the orchestration agent **206** can be implemented as a C library of procedures (methods) that directly link into the device application **204**. In other embodiments, the orchestration agent **206** can be implemented as a separate task, process, or hardware module, interfacing with the device application **204** (or applications **204**) as using shared memory, pipes, or other inter-process communication mechanisms. In one example, the orchestration agent **206** can be implemented as a kernel module, interfacing with the device application **204** using IOCTL, read, write, or other driver calls.

[0087] The orchestration agent **206** can serve several functions within the illustrative embodiment, including a role similar to that of a local agent as described in the Global Platform SE RAM protocol, a role similar to that of a local profile assistant as described in the SGP.22 specification, and a role as a local subscription server. The orchestration agent **206** can be operatively connected to a local store **218**. The orchestration agent **206** can use the local store **218** for storing and retrieving configuration and state data. The orchestration agent local store **218** can be within the same physical device as the device application database **212**. For example, the orchestration agent local store **218** and the device application database **212** can be arbitrated by a file system or other means. In one example, the orchestration agent local store **218** and the device application database **212** can be separate physical hardware.

[0088] The orchestration agent **206** can include a modem interface **220**. The modem interface **220** can be connected (logically and/or physically) to the modem **208**. The modem interface **220** can be the same physical interface as the device application interface **214**, arbitrated between the device application **204** and orchestration agent **206**, or it may be an independent physical interface. The orchestration agent **206** can also include an interface **222** to an eUICC **224**.

[0089] In one example, the eUICC **224** can be software running on secure hardware such as an ISO/IEC 7816 compliant smart card, trusted execution environment, secure enclave, secure microcontroller, or another similar environment. The eUICC interface **222** can be an ISO/IEC 7816 compliant hardware interface, accessed directly through GPIO pins, or accessed indirectly through the modem **208** via the +CSIM command described in ETSI TS 127 007, or by other means. The eUICC **224** can also be operatively configured to interface with the modem **208** using a physical interface **226**.

[0090] In addition to providing OAI **216** to the device application **204**, the orchestration agent **206** can receive local services from the device **202**.

[0091] Turning now to FIG. **3**, a diagram is shown illustrating an example interface environment **300** of the orchestration agent **206**. In particular, the interface environment **300** shows the orchestration agent **206** operatively connected to the device application **204** via the OAI **216**, as well as a plurality of supporting services and interfaces. In at least one example, the plurality of supporting services and interfaces can be referred to as the support and abstraction layer (SAL) **302**.

[0092] In one example, the SAL **302** can be a library of C programming language procedures (methods) that directly link into the orchestration agent **206**. In other embodiments, the SAL **302** can be implemented as a separate task, process, or hardware module, interfacing with the device application(s) **204** via shared memory, pipes, or other inter-process communication mechanism. In one example, the SAL **302** can be implemented as a kernel module, interfacing with the device application **204** using IOCTL, read, or write, or other driver calls.

[0093] The SAL **302** can include a plurality of support services. For example, the SAL **302** can include a modem service **304**, a eUICC service **306**, a timebase service **308**, a local store service **310**, and a lock service **312**.

[0094] In at least one example, the modem service **304** can provide access to the modem **208** and modem interface **220**. The modem access can be serialized and arbitrated between the orchestration agent **206**, the device application **204**, and other software and hardware elements. The eUICC service **306** can provide access to the eUICC **224** and the eUICC interface **222**. In one example, eUICC **224** access can be serialized and arbitrated between the orchestration agent **206**, the device application **204**, the modem **208**, and other software and hardware elements. In embodiments where the orchestration agent **206** accesses the eUICC **224** through the modem **208**, for example using the +CSIM command described in ETSI TS 127 007, the modem service **304** and eUICC service **306** can share common mutexes and data structures.

[0095] In a particular example, the timebase service **308** can provide access to a UTC, GPS, or other time source for allowing the orchestration agent **206** to set software timers. The local store service **310** provides arbitrated access to the orchestration agent's local store **218** in response to the basic model of open, close, read, write, and other routines seen in the C standard library.

[0096] In one example, the Lock service **312** enables the orchestration agent **206** to acquire several device-scoped resource locks. Table 1 below includes various resource locks.

TABLE 1

Example Resource Locks

Lock	Description
WAKE	Inhibits device from suspending or powering off
HUB	Protects AHI communications
EUICC	Protects access to a specific eUICC

[0097] Referring to Table 1, the WAKE lock can prevent a device (such as the device **202**) from powering down, suspending, or powering off. The WAKE lock can be similar in function to a power manager "WakeLock" object provided by an Android operating system environment. The HUB lock can provide protection similar to a WAKE lock; however, the HUB lock can additionally protect ongoing communications with the orchestration hub **104**, for example, by ensuring a modem stays powered on and connected, inhibiting PSM and eDRX, making Ethernet or BLE available, or by taking other appropriate steps. The orchestration agent **206** can acquire a HUB lock when it expects a response from an AHI **134** method call, for example. The EUICC lock can provide the same protection as a WAKE lock, but it additionally protects ongoing communications with an eUICC, for example by keeping the eUICC powered on. The orchestration agent **206** can acquire an EUICC lock when it is using the ES10 interface or running an APDU script with the eUICC, for example, or when it needs to preserve an open logical channel within the eUICC.

[0098] In at least one example, an EUICC lock can include implicit restrictions placed on the modem hosting the EUICC. For example, an EUICC lock can require that PSM be inhibited, to prevent the modem from suspending or powering down the EUICC as part of its power saving strategy. In cases where a single eUICC serves multiple modems, such as when Multiple Enabled Profiles ("MEP", SGP.22 v3.1 2.12) are implemented, an EUICC lock can also guard physical resources interfacing with eUICC port 0.

[0099] Locks can be acquired through a single library method with parameters describing which lock or locks are requested. An asynchronous callback hook can be used to convey the success or failure of the operation and a lock ID, which can be used later to release the lock. Acquired locks are explicitly released by a subsequent lock acquisition, or implicitly released in response to device power loss or reset.

[0100] Turning now to FIG. **4**, a diagram illustrating a subscription edge record **400** is shown, according to one aspect of the present disclosure. In one example, a subscription can be a set of related data structures distributed throughout a network or throughout a plurality of devices (such as the plurality of devices **108**) that are all mutually linked by a common IMSI value.

[0101] In at least one example, subscription information, and/or subscription-related information, can be stored at individual devices, such as the device **202**. The subscription-related information at the device **202** can be referred to as a subscription edge rows. In the present embodiment, a particular subscription edge row **402** is shown for example purposes. Subscription-related information stored in the orchestration hub **104** can be referred to as a subscription hub rows. In the present embodiment, a particular subscription hub row **404** is shown for example purposes. In certain examples, subscription rows from the connectivity manager **102** and device manager **106** can be referred to as subscription source rows. During normal operations, subscription hub rows can be asynchronously updated with information from subscription source rows. The updated subscription hub rows can be asynchronously replicated to subscription edge rows.

[0102] In one example, a network **406** can include one or more subscription rows, which can include subscription information such as phone numbers, location, service entitlements, cryptographic keys, and other data. In the present embodiment, a particular subscription row **408** is shown for example purposes. The subscription row **408** can be stored in the network's authorization center **410** (e.g., 5GC, home subscriber server (HSS), etc.). Subscription information can also be stored in a subscription edge row **402** in a device **202** and a subscription hub row **404** stored in an orchestration hub **104**. The subscription edge row **402** includes subscriber identity **412** (for example, an eSIM profile installed into an eUICC **224**) and subscription context **414** (saved in a local store **218**). The subscriber identity **412** and subscription context **414** are linked by two shared values, the AID of the eSIM profile's ISD-P, which is unique to the eUICC, and the ICCID of the profile, which is universally unique. The subscription edge row **402** relates to the subscription information in the network's **406** home location register (HLR) by a common IMSI value, stored in both the subscriber identity **412** and network authorization center **410**, and also possibly distributed into other parts of an overall cellular network **406**. The subscription edge row **402** relates to a subscription hub row **404** in a subscription hub table **416** by a common sub_uid integer value, together with a row revision (sub_rev), and a synchronization state value (sync_state). Example synchronization state values are listed below in Table 2.

TABLE 2

Example Sync States.

Sync State	Description
CONFIRMED	The row has been stored and confirmed at the device
WORKING	The row is being sent to the device
LEADING	The row has changes pending that have not been sent to the device

[0103] Referring to Table 2, synchronization state (sync_state) values are shown, describing the state of the replication process between a subscription hub row **404** and its corresponding subscription edge row **402**. The CONFIRMED state can mean that the subscription hub row **404** has been written to the corresponding subscription edge row **402** and acknowledged by the device **202**. The WORKING state can mean that the subscription hub row **404** is in the process of being written to its corresponding subscription edge row **402**, but has not yet been confirmed. The LEADING state can mean that changes are present in the subscription hub row **404** that have not yet been sent to the device **202**.

[0104] FIG. **5** is a diagram illustrating a two-stage asynchronous subscription row replication process **500**. As is discussed throughout the present disclosure, an orchestration hub **104** is operatively configured to merge (combine) subscription information from one or more connectivity managers **102** and one or more device managers **106** for updating corresponding subscription information at edge devices (such as the device **202**). As shown in the subscription row replication process **500**, a connectivity manager **102** forwards one or more subscription source rows **502** from a plurality of subscription source rows **504** to an orchestration hub **104**, asynchronously, as needed. In one example, a device manager **106** can forward one or more subscription source rows **506** from a plurality of subscription source rows **508** to the orchestration hub **104**, asynchronously, as needed. As subscription source row updates are received, the orchestration hub **104** can merge the subscription source rows **502** and **506** into subscription hub rows **510** in a subscription hub table **416**. As this process makes changes to subscription hub rows **510**, the orchestration hub **104** transmits updated subscription information **512** to corresponding subscription edge rows **514**. In one example, the corresponding subscription edge rows **514** can be stored in a device **202**, or in any device of the plurality of devices **108**.

[0105] FIG. **6** is a flowchart of an example subscription source row update process **600**. The process **600** illustrates the procedure performed by an orchestration hub (such as the orchestration hub **104**) when it receives one or more updated subscription source rows (such as the updated subscription source rows **502** and **506**). The process **600** can start at step **602** where the system receives one or more updated source rows. At step **604**, the orchestration hub queries the subscription hub table for rows that match the received updated source rows. In one example, step **604** can include querying the subscription hub table for source row subscription information matching the received updated source rows.

[0106] At step **606**, the system determines whether the query result is empty. If the query result is not empty, the process **600** proceeds to step **608**. At step **608**, the system determines whether the query result contains a LEADING row. If the query result contains a LEADING row, the process **600** proceeds to step **610** where the orchestration hub updates the LEADING row with information/fields from the source row.

[0107] If, at step **608**, the system determines that the query results do not include a LEADING row, the process **600** can proceed to step **612**. At step **612**, the orchestration hub creates a new LEADING row by combining (a) the row with the highest sub_rev value in the query result, (b) this highest sub_rev value incremented by 1, and (c) fields from the source row.

[0108] Referring back to step **606**, if the system determines that the query result is empty, the process **600** proceeds to step **614** to determine whether the updated source row is from a connectivity manager. In general, at step **614**, if the system determines that the query result is empty, it can be determined that the source row represents a new subscription to the orchestration hub, which should only arrive from a connectivity manager. At step **614**, if it is determined that the update is not from a connectivity manager, then the process **600** can proceed to step **616**, where an exception is processed and the process **600** ends. However, at step **614**, if it is determined that the updated source row is from a connectivity manager, the process **600** can proceed to step **618**, where the orchestration hub creates a new subscription hub row with sync_state=LEADING, sub_rev=0, and a unique sub_uid. In various examples, the orchestration hub can accepts new subscription rows from device managers, as placeholder subscription rows, to be completed, populated, or updated at a later time by corresponding source rows from connectivity managers.

[0109] In response to the steps **618**, **612**, and/or step **610**, the process **600** can proceed to step **620**. At step **620**, the orchestration hub can determine whether the query result contains a WORKING row. If a WORKING row exists, the process **600** can proceed to step **616** to process an exception and to terminate the process. If a WORKING row does not exist, the process **600** can proceed to step **622** where the orchestration hub notifies the device manager that an APDU may be ready for the affected device. At this point, the source row has been merged into the subscription hub table.

[0110] FIG. **7** is a flowchart of an example edge row update process **700**. In one example, and in response to notifying a device manager regarding an updated source row, a device manager may invoke an OHI GetApdu ( ) method to generate and return an APDU for the affected device. The orchestration hub processes the GetApdu ( ) method call, in part, by effectively iterating through subscription hub rows associated with the device and initiating the process **700**, with each subscription ID as an argument. In one example, the process **700** can begin at step **702** where the orchestration hub receives a subscription ID passed as an argument.

[0111] At step **704**, the orchestration hub queries the subscription hub table for rows that match the subscription ID argument received at step **702**.

[0112] At step **706**, the orchestration hub determines whether the query result includes a WORKING row. If, at step **706**, the query result includes a WORKING row, then the process **700** proceeds to step **708**, where procedure returns a NULL APDU value and the process **700** ends. If, at step **706**, it is determined that the query does not include a WORKING row, then the process **700** proceeds to step **710** where the orchestration hub determines whether the query result includes a LEADING row. If the query result does not include includes a LEADING row, then the procedure returns a NULL APDU value at step **708**. If at step **710**, it is determined that the query includes a LEADING row, the process **700** proceeds to step **712**.

[0113] At step **712**, the orchestration hub determines whether the query results include a CONFIRMED row. If the query results include a CONFIRMED row, then the orchestration hub, at step **714**, generates an update ( ) AHI request APDU from the delta between the LEADING and CONFIRMED result rows. Otherwise, the process **700** proceeds to step **716**, where the orchestration hub generates an install ( ) AHI request APDU from the LEADING row.

[0114] In response to performing both steps **714** and **716**, the process **700** proceeds to step **718**, where the orchestration hub changes the sync_state of the LEADING row to WORKING. Further, at step **720**, orchestration hub returns the constructed APDU to the caller, which breaks out of the iterative loop and passes the APDU to the device manager as part of the GetApdu ( ) return value. The device manager can then forward the APDU to the device as an AHI update ( ) or AHI install ( ) method call.

[0115] FIG. **8** is a flowchart of an example edge row update process **800**. In at least one example, when the AHI install ( ) or update ( ) method is completed (as discussed above in connection with the process **700** of FIG. **7**), the device manager invokes an OHI PutApdu ( ) method with the response APDU. The orchestration hub processes the PutApdu ( ) method call, in part, by initiating the process **800**, with the subscription ID as an argument.

[0116] In one example, the process **800** can start at step **802**, where the orchestration hub queries the subscription hub table for rows that match the subscription argument. At step **804**, the orchestration hub determines whether the query result includes a CONFIRMED row. If, at step **804** the orchestration hub determines the query result includes a CONFIRMED row, the process **800** proceeds to step **806** where the orchestration row deletes the CONFIRMED row. If, at step **804** the orchestration hub determines the query result does not include a CONFIRMED row, the process proceeds to step **808**.

[0117] At step **808**, and in response to step **804** or **806**, the orchestration hub changes the sync_state field of the WORKING row to CONFIRMED. At step **810**, if it is determined that the query result does not include a LEADING row, the process **800** can end. At step **810**, if the query result includes a LEADING row, the process **800** proceeds to step **812** where the orchestration hub notifies the device manager that an APDU may be ready for the affected device. At this point, the response to the AHI install ( ) or update ( ) method call has been processed and the procedure ends.

[0118] Throughout the present disclosure, subscription rows, such as subscription hub rows, are described in terms of their constituent fields. Table 3, shown below, includes a plurality of subscription hub row fields and their corresponding sources, according to various aspects of the present disclosure.

TABLE 3

Example Subscription Hub Row Fields and Sources

Field	Description	Source
sub_uid	Subscription ID	OH
sub_rev	Subscription revision	OH
state	Subscription state	CM
edge_state	Subscription Edge Row state	OA
sync_state	Synchronization State	OH
flags	Subscription flags	CM
cm_base_rank	Subscription Base Ranking Value	CM
dm_base_rank	Subscription Base Ranking Value	DM
cm	Connectivity Manager ID	OH
cm_id	Connectivity Manager Subsciption ID	CM
iccid	Integrated circuit card identifier of the eSIM profile	CM
eid	ID of eUICC containing the eSIM profile	OA or OH
dp_address	Activation code SM-DP+ address	CM
ac_token	Activation code token	CM
cc	Confirmation code	CM
ins_script	Install script ID	CM
upd_script	Update script ID	CM
ppr1_consent	Consent for PPR1	DM
ppr2_consent	Consent for PPR2	DM
pdp	PDP context parameters	CM
imsi_count	The number of IMSIs contained in the subscription	CM
band_list	Application band list of subscription	CM
cm_plmn_rank	PLMN/IMSI rank	CM
dm_plmn_rank	PLMN/IMSI rank	DM
geo	Geographic coverage area	CM
cm_attributes	Connectivity manager supplied attribute values	CM
dm_attributes	Device manager supplied attribute values	DM
cm_extdata	Connectivity manager supplied extended data	CM
dm_extdata	Device manager supplied extended data	DM

[0119] Referring to Table 3 above, a subscription hub row is described in terms of its constituent fields. In Table 3, the "Field" column includes field names, the "Description" column includes field descriptions, and the "Source" column indicates which element may supply the data. Possible "Source" column values include OH (orchestration hub), OA (orchestration agent), CM (connectivity manager), DM (device manager), DP (SM-DP+). The sub_uid field includes an integer ID of the subscription, unique within the orchestration hub, and the sub_rev field includes the current revision of the subscription hub row. The state field describes the subscription state as detailed in Table 4. The edge_state field describes the subscription edge row state. The sync_state field describes the synchronization state between the subscription hub row and its corresponding subscription edge row **402** as summarized in Table 2 and explained above. The cm_base_rank field includes a base ranking value for the subscription from the connectivity manager, and the dm_base_rank field includes a base ranking value for the subscription from the device manager. Ranking values are lower for more preferable subscriptions and higher for less preferable subscriptions. The cm field identifies the connectivity manager providing the subscription, and the cm_sub_id identifies the subscription within the connectivity manager. The iccid field identifies the eSIM profile related to the subscription. The dp_address contains the URL of an SM-DP+ server to be used for eSIM profile download (SGP.22 v2.4 4.1). The ac_token and cc fields describe the activation code token (SGP.22 v2.4 4.1) and confirmation code (SGP.22 v2.4 4.7), respectively, to be during an SM-DP+ profile download. The ins_script identifies a script to be used to install the subscriber identity. If this value is included, it implies an in-factory profile provisioning ("IFPP") type installation process and the dp_address, ac_token, and cc fields should be ignored. The upd_script describes the most recent update script required for profile content management. The ppr2_consent and ppr2_consent fields indicate whether consent is granted for PPR1 and PPR2 (SGP.22 v2.4 2.4.1). The pdp field specifies the PDP context values to use with the subscription, presented as a list of structures, each including a context ID, APN value, IP type, and other information required by the +CGDCONT command described in ETSI TS 127 007, as well as a maximum MTU sizes and other parameters. The band_list field describes the list of frequency bands that may be required to use the subscription, included as a list of band numbers from the LTE frequency bands, the NR frequency bands 1, 2, NT1, NT2, and other bands as may apply. The cm_plmn_rank and dm_plmn_rank fields each include a list of entries, each entry including MCC, MNC, and optional imsi_ordinal and rank values. The MCC and MNC together describe a mobile network, such as may be seen by the +COPS=? command described in ETSI TS 127 007. The imsi_ordinal value, if present, describes an IMSI that may be used to attach to the network. If imsi_ordinal is not present, then any IMSI of the subscription may be used, or the eSIM profile may automatically select the IMSI. The rank value, if present, overrides the base_rank value as the ranking value for the subscription/IMSI/MCC/MNU combination. In general, MCC/MNU combinations present in the cm_plmn_rank field are recommended for use with the subscription, and values present in dm_plmn_rank override matching rank values present in cm_plmn_rank. The geo field includes a list of geographical regions, such as an MCC value, or a circle or trapezoid mapped onto the surface of the Earth, along with imsi_ordinal and an inside boolean value determining whether the region is inclusive or exclusive. When the device's position meets the geographical requirement, the imsi_ordinal, if present, describes an IMSI that may be used with the subscription. If imsi_ordinal is not present, then any IMSI may be used with the subscription or the eSIM profile may automatically select an IMSI.

[0120] The cm_attribues field describes a list of integer attributes, which may be used to conceptually join the subscription to external data structures supplied by the connectivity manager. These values may be global, coordinated values, or they may be scoped values specific to a connectivity manager. The dm_attributes field contains a list of integer attributes, which may be used to conceptually join to the subscription to external data structures supplied by the device manager. Like the cm_attributes field, dm_attributes values may be global, coordinated values, or they may be scoped values specific to a device manager. Examples of cm_attributes usage may include identifying device-side APDU API models for the eSIM profile, identifying alternate cost models involving system access fees or prepaid plans, or identifying other characteristics. Examples of dm_attibutes usage may include identifying device-specific ranking algorithms, tags to make sure device or modem firmware revisions are up to a certain level before using the subscription, tags to ensure certain randomization intervals for inbound data, or other information. The cm_extdata field may contain raw data supplied by and specific to the connectivity manager, and the dm_extdata field may contain raw data supplied by and specific to the device manager, using global, coordinated formatting, or formatting specific to a connectivity manager or device manager, respectively.

[0121] Table 4, as shown below, illustrates possible state field values. The STOCK state indicates that the subscription is provisioned in the network but not yet available for use. The READY state indicates that the subscription is available for use but not yet generating usage charges. The ACTIVE state means that the subscription is available for use and generating usage charges. SUSPEND means the subscription is temporarily unavailable for use, and TERMINATED means that the subscription has been de-provisioned.

TABLE 4

Example State Field Values.

State	Description
STOCK	Subscription has not yet been activated.
READY	Subscription is active but has not yet incurring cost.
ACTIVE	Subscription is active.
SUSPEND	Subscription has been suspended.
TERMINATED	Subscription has been terminated.

[0122] Table 5, as shown below, illustrates possible subscription context and subscription edge row field values.

TABLE 5

Example Subscription Context and Subscription Edge Row Field Values.

Field	Description	Source
sub_uid	Subscription ID	OH
sub_rev	Subscription revision	OH
state	Subscription state	CM
edge_state	Subscription Edge Row state	OA
flags	Subscription flags	CM
base_rank	Subscription Base Ranking Value	CM or DM
iccid	Integrated circuit card identifier of the eSIM profile	CM
aid	Application ID of ISD-P containing the sSIM profile	EU
eid	ID of eUICC containing the eSIM profile	OA
ac_token	Activation code token	CM
cc	Confirmation code	CM
ins_blob	Install script blob ID	OH
upd_blob	Update script blob ID	OH
ppr1_consent	Consent for PPR1	DM
ppr2_consent	Consent for PPR2	DM
pdp	PDP context parameters	CM
imsi_count	The number of IMSIs contained in the subscription	CM
band_list	Application band list of subscription	CM
plmn_rank	PLMN/IMSI rank	CM and DM
geo	Geographic coverage area	CM
cm_attributes	Connectivity manager supplied attribute values	CM
dm_attributes	Device manager supplied attribute values	DM
cm_extdata	Connectivity manager supplied extended data	CM
dm_extdata	Device manager supplied extended data	DM

[0123] As shown in Table 5, the "Field" column includes field names, the "Description" column contains field descriptions, and the "Source" column indicates which element may supply the data. Possible "Source" column values include OH (orchestration hub), OA (orchestration agent), CM (connectivity manager), DM (device manager), DP (SM-DP+122), and EU (eUICC **224**). The sub_uid and sub_rev field includes an integer ID and revision of the subscription, as described in Table 3 for the subscription hub row. The base rank field includes the value of dm_base_rank from Table 3, or cm_base_rank from Table 3 if dm_base_rank is not present. The iccid and aid fields both match the subscription context to the subscription identity in the eUICC identified by the eid field. The ins_blob and upd_blob refer to the ins_script and upd_script fields in Table 2, using blob identifiers compatible with an AHI get_blob ( ) method. Binary large objects, or "BLOBs," will be discussed in greater detail below. The plmn_rank field includes an aggregate of cm_plmn_rank and dm_plmn_rank such that all the cm_plmn_rank entries are present, with rank values overridden by corresponding MCC/MNC/imsi_ordinal entries in dm_plmn_rank field. Other fields in Table 5 match the identically named fields in Table 3.

[0124] FIG. **9** is an example subscription edge record state diagram **900**. In one example, a subscription can have two possible initial states: INSTALLING **902** when a subscription edge record is initially created by an AHI install ( ) method call (described in more detail below), and UNMANAGED **904** when a subscription is installed locally using a device LPA or preloaded by an EUM. While a subscription is in the INSTALLING **902** state, the orchestration agent securely installs the subscriber identity. If the installation process completes successfully, the edge state transitions to INSTALLED **906**. If the installation process fails, the edge state transitions to FAIL **908**. A failed download may be retried by the orchestration agent, returning the state to INSTALLING **902**. The SEVERED state **910** means that the subscription context is populated but the corresponding subscriber identity is missing. The state may transition from INSTALLED **906** to SEVERED **910** after an eUICC is removed from a device. For example, a technician removing an eUICC from device A and inserting it into device B may result in a SEVERED **910** subscription edge record in device A and an UNMANAGED **904** subscription edge record in device B. The state can move from INSTALLED **906** or SEVERED **910** to UNLINKED **912** if an AHI delete ( ) method call is made. When the state is UNLINKED **912**, the orchestration agent can delete the subscription edge row from the eUICC **224** and store **218** when other local conditions permit.

[0125] When a subscription edge record starts in or transitions to the UNMANAGED state **904**, the orchestration hub and orchestration agent may be able to transition it to the INSTALLED state **906**. For example, if the device and subscription exist in the same orchestration hub account, and if an AHI pathway exists between the orchestration hub and device agent, the orchestration hub may locate the subscription and call the AHI update ( ) method to restore its subscription context information at the device. A person skilled in the art will recognize that this mechanism can manage subscription context with UICCs as well as eUICCs. A UICC inserted into a device will appear as an UNMANAGED **904** subscription, which the hub may find and download appropriate subscription context.

[0126] Subscription templates are discussed throughout the present disclosure. In one example, a subscription template ("template") describes the class or type of a subscription, such as a particular MNO or MVNO, data plan, coverage area, and other attributes. Subscription templates can be provided by connectivity managers and can be enhanced by device managers. Subscription templates can be used as a parameter when new subscriptions are acquired through OHI and CMI. Example subscription template fields are shown below in Table 6.

TABLE 6

Example Subscription Template Fields

Field	Description	Source
tem_id	Template ID	OH
cm	Connectivity Manager ID	OH
cm_id	Connectivity Manager Template ID	CM
cm_name	Connectivity Manager Template Name	CM
cm_desc	Connectivity Manager Template Description	CM
dm_base_rank	Base subscription rank	DM
dm_plmn_rank	PLMN/IMSI rank	DM
ppr1_consent	Consent for PPR1	DM
ppr2_consent	Consent for PPR2	DM
dm_attributes	Device manager supplied attribute values	DM
dm_extdata	Device manager supplied extended data	DM

[0127] In one example, a subscription template can be described in terms of its constituent fields. As shown in Table 6, the "Field" column includes field names, the "Description" column includes field descriptions, and the "Source" column indicates which element may supply the data. Possible "Source" column values include OH (orchestration hub), CM (connectivity manager), and DM (device manager). The cm field includes an identifier of connectivity manager supplying the template. The cm_id field includes the connectivity manager's ID for the template, the cm_name field includes the unique name given to the template by the connectivity manager, and the cm_desc includes a description of the template from the connectivity manager. The remaining fields are copied from the template to the subscription hub row when it is created (for example, following CMI AcquireSubscription and ReadSubscription method invocations as explained in more detail below) with fields from the template copied into identically named fields in Table 3.

[0128] Moreover, aspects of the present disclosure include use of secure elements, trusted execution environments, secure enclaves, and other security structures. In particular, a subscriber identity can be matched to a specific eUICC within a secure element. Additionally, in some cases, the underlying subscription may be eligible for use by a specific modem (but not others). This interdependence between subscription, modem, and eUICC can begin during the Common Mutual Authentication Procedure (SGP.22 v2.4 3.1.2, SGP.22 v3.1 3.0.1, and SGP.32 v3.2 3.2.2), and may begin earlier, such as when API calls used to retrieve Activation Codes require IMEI and EID parameters, or prior to an EUM preloading an eSIM profile into an eUICC.

[0129] Devices may include multiple modems to enable use of different, incompatible radio technologies, different radio bands, or for other reasons. Devices may include multiple eUICCs for component-level redundancy or for other reasons. In examples where a subscription edge record is to be installed into a device with multiple modems or multiple eUICCs, installation instructions must describe the destination device, modem, and eUICC.

[0130] In examples where subscriptions are installed into groups of devices with multiple modems and/or multiple eUICCs, the illustrative embodiment may identify multiple destination eUICCs with a group-wide identifier, including a list of device identifiers, a single modem_ordinal parameter to identify the modem on each device, and a single modem_slot parameter to identify the eUICC on each device. In at least one example, this group abstraction permits a separation of concerns between an orchestration hub and a device manager, enabling the device manager to describe a campaign at a device level without identifying individual eUICC EIDs.

[0131] FIG. **10** is a diagram **1000** illustrating an example subscription installation. As shown in the diagram **1000**, an example device **1002** of type Model A with a device_id of "2607066" is depicted, captured in the process of installing subscription 8910390000062531280F **1004**. Device **1002** includes a single modem **1006** with a single SIM slot connected to an eUICC **1008**. The destination of subscription 8910390000062531280F **1004** is described with a modem_ordinal value of 0, and a modem_slot value of 0. It can be noted that subscription 89883070000012965073 **1010** could also have been installed previously using a modem_ordinal value of 0 and a modem_slot value of 0.

[0132] FIG. **11** is a diagram **1100** illustrating an example subscription installation. As shown in the diagram **1100**, an example device **1102** of type Model B with a device_id of "2607067" is depicted, captured in the process of installing subscription 89883070000012965073 **1104**. Device **1102** includes two modems, modem **0 1106** and modem **1 1108**. Modem **0 1106** has two SIM slots, slot **0** connected to eUICC **0 1110** and slot **1** connected to eUICC **1 1112**. Modem **1 1108** likewise has two SIM slots, slot **0** connected to eUICC **3 1114** and slot **1** connected to eUICC **4 1116**. The destination of subscription **1104** is described with a modem_ordinal value of 0, and a modem_slot value of 0. It can be noted that subscription 8910390000062531280F **1118** could also have been installed previously using a modem_ordinal value of 0 and a modem_slot value of 0, while subscription 8910390000062531314F **1120** could have been installed previously using a modem_ordinal value of 1 and a modem_slot value of 1.

[0133] FIG. **12** is a diagram **1200** illustrating an example subscription installation. As shown in the diagram **1200**, an example device **1202** of type Model C with a device_id of "2607068" is depicted, captured in the process of installing subscription 8910390000062531306F **1204**. Device **1202** includes two modems, modem **0 1206** and modem **1 1208**. Modem **0 1206** has two SIM slots, slot **0** connected to eUICC **0 1210** and slot **1** connected to eUICC **1 1212**. Modem **1 1208** likewise has two SIM slots, slot **0** also connected to eUICC **0 1210** and slot **1** connected to eUICC **2 1214**. Since eUICC **0** is MEP-capable, the destination of subscription **1204** could be described with a modem_ordinal value of 0 and a modem_slot value of 0, or a modem_ordinal value of 1 and a modem_slot value of 0. It can be noted that subscription 89883070000012965123 **1216** could also have been installed previously using a modem_ordinal value of 0 or 1 and a modem_slot value of 0, while subscription 89883070000012965073 **1218** could have been installed previously using a modem_ordinal value of 0 and a modem_slot value of 0.

[0134] In at least one example, the system disclosed herein can include a script in the process of installing or updating a subscription edge row. A script can be a set of command APDUs (C-APDUs) configured to be sent directly to an eUICC by an orchestration agent, which can result in a set of corresponding response APDUs (R-APDUs) from the eUICC as well as changes within the eUICC. In one example, scripts may be used to install profiles ("in-factory profile provisioning") or modify previously installed profiles ("profile content management"). For example, an update operation may include a change in the PLMN list and also a corresponding change to the eSIM profile such as adding, replacing, or remove an IMSI. When running a script, the orchestration agent can take on a role similar to the "Local Agent" as described in the GlobalPlatform SE RAM protocol.

[0135] Further, aspects of the present disclosure can include binary large objects, or "BLOBs". In one example, BLOBs are used to move data between orchestration agents and orchestration hubs when the data is too large to fit entirely into an AHI APDU. In certain examples, BLOBs can be used to contain bound profile packages, scripts, fields required by the Common Mutual Authentication Procedure, or other information.

[0136] FIG. **13** is a sequence diagram illustrating an example agent-hub interface process **1300**. As shown in the example agent-hub interface process **1300**, forward and reverse method calls are shown between an orchestration hub **104** and an orchestration agent **206**. A forward method call is initiated by a forward request APDU **1302** sent by the orchestration hub to the orchestration agent, and it is completed by a forward response APDU **1304** sent by the orchestration agent to the orchestration hub. A reverse method call is initiated by a reverse request APDU **1306** sent by the orchestration agent to the orchestration hub, and it is completed by a reverse response APDU **1308** sent by the orchestration hub to the orchestration agent.

[0137] In one example, AHI is based on bidirectional remote procedure calls (RPC) between an orchestration hub and an orchestration agent. The orchestration hub and orchestration agent may each call methods exposed by the other, with forward method calls initiated by the orchestration hub and reverse method calls initiated by the orchestration agent. Method calls can be implemented with application protocol data units (APDUs), with a request APDU conveying call arguments and a response APDU conveying call return values. In at least one example, the AHI can be operatively configured to implement a plurality of method calls, such as install ( ) update ( ) delete ( ) query ( ) and notify ( ) (a reverse method call in response to updates made to subscription edge rows/records).

[0138] FIG. **14** is an example encoded AHI APDU **1400**. As shown in the example encoded AHI APDU **1400**, bytes 0 and 1 together form a 16-bit interface identifier value (IID **1402**). Byte 2 specifies an interface version (IV **1404**), and byte 3 specifies a payload type (PT **1406**). Bytes 4 and 5 form a 16-bit method call identifier (MCID **1408**). Forward method calls use MCID values in the range 0 through 32767 inclusive, while reverse method calls use MCID values in the range of 32768 through 65535 inclusive. MCIDs advance by 1 for each subsequent method call, wrapping within their range so that 65535 advances to 32768 and 32767 advances to 0. Bytes 6 and 7 include parity information (PAR **1410**), and bytes 8 through the end of the APDU contain an encoded payload (payload **1412**). The IID and MCID fields are encoded with the least significant byte in the lowest byte position (also known as a "little endian" byte layout).

[0139] A PT value of 0 specifies that the "Payload" field includes an encoded request or response APDU payload. A PT value of 1 specifies an error response, with the payload field containing a 32-bit integer error value encoded as four bytes, least significant byte first. A PT value of 255 specifies a window reset request, canceling any pending calls and resetting the MCID to the lowest possible number, 0 for forward transactions and 32768 for reverse transactions. In the illustrative embodiment, the IID is set to a value of 48090, the IV is set to a value of 1, and payload encoding for PT=1 is based on a proto3 specification file. The PAR field is set such that a CCITT CRC-16 value calculated from the first payload byte, to the end of the encoded APDU, followed by the first 8 bytes of the encoded APDU, is zero.

[0140] A person skilled in the art will recognize that typical remote procedure calls can fail during normal operations because of transmission problems, timeouts, synchronization problems, and for other reasons. Accordingly, AHI **134** as discussed herein includes the data structures illustrated in FIG. **14** to ensure packet integrity, enable automatic repeat requests (ARQ), and remove duplicate APDUs. In one example, the data structures illustrated in FIG. **14** are sufficient that AHI could be implemented as a simple length prefixed envelope using rudimentary transport such a UART serial link. AHI **134** could also be implemented using higher level protocols such as UDP or TCP. However, in the illustrative embodiment, AHI **134** is implemented with an explicit tunnel through OHI **118**, a device manager **106**, device management protocols **128**, a device application **204**, and OAI **216**. This arrangement provides a high level of flexibility, with different device management protocols **128** used at different points in a device lifecycle. For example, device management protocols could include a wiring harness during manufacturing, Bluetooth during staging, NBIoT after deployment, and mobile ISM-band base station during recovery from a regional disaster.

[0141] Referring now to FIG. **15**, illustrated is a first AHI forward operation call **1500** with an initially unavailable device, such as the device **202** from the plurality of devices **108**, according to one example of the disclosed technology. The unavailable device can include any particular device in a sleep mode and/or in a non-powered state. The device manager **106** can interface with the orchestration hub **104** via the OHI **118**. The device manager **106** can communicate with the device application **204** using the device management protocols **128**. The device application **204** can interface with the orchestration agent **206** using the OAI **216**. In one example, the OAI **216** can be operatively configured to perform various methods for interfacing with the device application **204** and the orchestration agent **206**, such as oai_start ( ) (which includes a configuration structure and callback hook), oai_stop ( ) oai_reconfig ( ) oai_get_adpu ( ) oai_put_adpu ( ) oai_get_sub ( ) oai_get_sub_list ( ) oai_query ( ) and oai_enable_sub ( ).

[0142] The AHI forward method call illustrated in FIG. **15** can begin when the device is in a powered-off state, a power-saving mode, and/or in any particular unreachable state. The orchestration hub **104** using the OHI **118** can send a notification **1501** to the device manager **106**. The notification **1501** can include a notice for a pending request AHI APDU **1302** for the orchestration agent **206** of the particular device. Because the device may be unavailable, the device manager **106** can withhold a particular AHI transaction. At some arbitrary time later (e.g., several minutes or several weeks later) the device application **204** can awaken from a static sleep mode **1502** and can send a notification **1503** to the device manager **106** through the device management protocols **128**. Using the OHI **118**, the device manager **106** can invoke a request APDU operation **1504** and can retrieve the request AHI APDU **1302** for the device. The request APDU operation **1504** can include an operation that retrieves the next pending request AHI APDU **1302** for the particular device. The request APDU operation **1504** can include parameters such as a device ID, identifying the device that should receive the request AHI APDU **1302**. The request APDU operation **1504** can return the encoded request AHI APDU **1302**, where the device management protocol **128** can deliver the request AHI APDU **1302** to the specified device. The device manager **106** can transport the request AHI APDU **1302** to the device application **204** using the device management protocols **128**. Upon receiving the request AHI APDU **1302**, the device application **204** can forward the request AHI APDU **1302** to the orchestration agent **206** through an OAI put APDU operation **1506** available through the OAI **216**. The OAI put APDU operation **1506** can include an operation that can pass the request AHI APDU **1302** received from the orchestration hub **104** to the orchestration agent **206**. The orchestration agent **206** can acquire an HUB or EUICC locks **312** as appropriate to the method call represented by the request AHI APDU **1302**. The orchestration agent **206** can begin processing the request AHI APDU **1302**. On completion of the processing of the request AHI APDU **1302**, the orchestration agent **206** can send a notification **1507** to the device application stating that the response AHI APDU **1304** is pending. If the orchestration agent **206** does not expect continued communication with the orchestration hub **104**, the orchestration agent **206** can release any acquired Locks **312**. The device application **204** can retrieve the response AHI APDU **1304** by calling an OAI get APDU operation **1508** available through OAI **216**. The OAI get APDU operation **1508** can include an operation that returns the response AHI APDU **1304** if one is available, where the response AHI APDU **1304** can be delivered to the orchestration hub **104**. The device application **204** transports the encoded response AHI APDU **1304** to the device manager **106** using device management protocols **128**. Using the OHI **118**, the device manager **106** can invoke a put APDU operation **1510** to deliver the response AHI APDU **1304** to the orchestration hub **104**. The put APDU operation **1510** can include an operation that delivers the response AHI APDU **1304** from the device. Parameters of the put APDU operation **1510** can include but are not limited to a device ID, which can identify the device sending the response AHI APDU **1304**, and the encoded APDU **1400**.

[0143] Referring now to FIG. **16**, illustrated is a second AHI forward operation call **1600** with an initially available device, according to one example of the disclosed technology. The device manager **106** can interface with the orchestration hub **104** through the OHI **118**. The device manager **106** can communicate with the device application **204** through the device management protocols **128**. The device application **204** can interface with the orchestration agent **206** through the OAI **216**. The example scenario can begin when the particular device is in a reachable state. For example, a reachable state can include but is not limited to a powered-on state, a reduced power state, and/or any particular state that can allow for open connectivity with the particular device.

[0144] Using the OHI **118**, the orchestration hub **104** can send a notification **1601** to the device manager **106**. The notification **1601** can include a notice that a particular AHI APDU **1400** is pending for the orchestration agent **206** of the particular device. Using the OHI **118**, the device manager **106** can invoke the request APDU operation **1504** to retrieve the request AHI APDU **1302** for the device. The device manager **106** can transport the request AHI APDU **1302** to the device application **204** using the device management protocols **128**. Upon receiving the request AHI APDU **1302**, the device application **204** can forward the request AHI APDU **1302** to the orchestration agent **206** using the OAI put APDU operation **1506** available through OAI **216**. The orchestration agent **206** can acquire a HUB or EUICC lock **312** as appropriate to the method call represented by the request AHI APDU **1302**. The orchestration agent **206** can begin processing the request AHI APDU **1302**. When the orchestration agent **206** finishes processing the request AHI APDU **1302**, the orchestration agent **206** can send a notification **1605** to the device application **204** that a response AHI APDU **1304** is pending. If the orchestration agent **206** does not expect continued communication with the orchestration hub **104**, the orchestration agent **206** can release any acquired Locks **312**. The device application **204** can retrieve the response AHI APDU **1304** by calling the OAI get APDU operation **1508** available through OAI **216**. The device application **204** can transport the encoded response AHI APDU **1304** to the device manager **106** using the device management protocols **128**. Using the OHI **118**, the device manager **106** can invoke the put APDU operation **1510** to deliver the response AHI APDU **1304** to the orchestration hub **104**.

[0145] Referring now to FIG. **17**, illustrated is an AHI reverse operation call **1700**, according to one example of the disclosed technology. The device manager **106** can interface with the orchestration hub **104** through the OHI **118**. The device manager **106** can communicate with the device application **204** through the device management protocols **128**. The device application **204** can interface with an orchestration agent **206** through the OAI **216**.

[0146] Using the OAI **216**, the orchestration agent **206** can send a notification **1701** to the device application **204**. The notification **1701** can include a notice that the request AHI APDU **1306** is pending for the orchestration hub **104**. Using the OAI **216**, the device application **204** can trigger the OAI get APDU operation **1508**. The OAI get APDU operation **1508** can retrieve the request AHI APDU **1306** for the orchestration hub **104**. The device application **204** can transport the request AHI APDU **1306** to the device manager **106** using the device management protocols **128**. Using the OHI **118**, the device manager **106** can invoke the put APDU operation **1510** to deliver the request AHI APDU **1306** to the orchestration hub **104**. The orchestration hub **104** can process the request AHI APDU **1306**. When the orchestration hub **104** finishes processing the request APDU, the orchestration hub **104** can use the OAI **216** to send a notification **1705** to the device manager **106**. The notification can include a notice that the orchestration hub **104** has a response AHI APDU **1308** ready. Using the OHI **118**, the device manager **106** can invoke the request APDU operation **1504** to retrieve the response AHI APDU **1308**. The device manager **106** can transport the response AHI APDU **1308** to the device application **204** using the device management protocol **128**. Using the OAI **216**, the device application **204** can call the OAI put APDU operation **1506** to deliver the response AHI APDU **1308** to the orchestration agent **206**.

[0147] Referring generally now to FIGS. **15-17**, the first AHI forward operation call **1500**, the second AHI forward operation call **1600**, and the AHI reverse operation call **1700** can synchronize the device managers **106** and the one or more devices, thereby reducing the rate of transaction interruptions from loss of signal, loss of power, sleep modes, and other adverse events. While these types of interruptions will still occasionally occur as with any communications system, the structure of the AHI APDU **1400**, including the MCID **1408** and parity fields **1410**, can enable recovery.

[0148] As shown in FIG. **15** and FIG. **16**, the orchestration hub **104** can notify a device manager when an AHI APDU **1400** is ready for transport to the device. The orchestration hub **104** can construct the AHI APDU **1400** when the device manager **106** calls the request APDU operation **1504**. By waiting for the request APDU operation **1504**, the orchestration hub **104** can support one or more devices with long periods of unavailability. For example, one or more devices installed in a seasonal venue can be repeatedly powered off and stored for the better part of a year, long enough that business conditions can change before a campaign can be completed. While waiting for the device to become available, business conditions may change and the orchestration hub **104** can manage AHI APDUs **1400** by removing those that are no longer needed or by generating new AHI APDUs **1400** with newer updates or campaigns.

[0149] Referring now to FIGS. **18-22**, illustrated are five distinct example operations performed by the disclosed innovation. The five distinct example operations are not intended to limit the scope of the disclosed innovation and other operations can be performed by the disclosed innovation than those currently appreciated. The five distinct operations can include but are not limited to a first install operation (see FIG. **18** for further details), a second install operation (see FIG. **19** for further details), a first update operation (see FIG. **20** for further details), a second update operation (see FIG. **21** for further details), and a delete operation (see FIG. **22** for further details). The disclosed innovation can further perform activation operations and suspension operations. For example, the first install operation and the second install operation can include installing the subscription edge record, with assistance from an SM-DP+ server or installation script. The first update operation and the second update operation can include updating the subscription edge record. The delete operation can include deleting the subscription edge record. The activation operation and the suspension operation can include activating and suspending the subscription edge records, respectively.

[0150] Referring now to FIG. **18**, illustrated is a first install operation **1800**, according to one example of the disclosed technology. The first install operation **1800** can include a sequence diagram showing an example progression of a particular installation operation, where the disclosed innovation can install a subscription edge record **402** into one or more devices. The orchestration hub **104** can interface with the SM-DP+ server **122** through the ES9+ interface **124**. The orchestration hub **104** can interface with the orchestration agent **206** using the AHI **134**. The orchestration agent **206** can connect to the eUICC **224**. The eUICC **224** can be compatible with SGP.22 version 2.4 and/or any other particular remote sim provisioning architecture.

[0151] The orchestration hub **104** can invoke an AHI install operation **1801** to the orchestration agent **206**. The AHI install operation **1801** can define a request to install a subscription edge record **402**. For example, the AHI install operation **1801** include a technique for beginning an install operation. Continuing this example, the AHI install operation **1801** parameters can include but are not limited to an operation_id and the subscription context fields shown in Table 5. The band_list, plmn_rank, geo, cm_attributes, dm_attributes, cm_extdata, and dm_extdata fields of the subscription context fields shown in Table 5 can contain inline data or BLOB identifiers for subsequent retrieval in cases where the subscription context is larger than the maximum APDU size. During the initial installation phase, the orchestration agent **206** can save the subscription context into a new subscription edge record **402** in the local store **218**. The orchestration agent **206** can return a successful completion of the AHI install operation **1801** call to the orchestration hub **104**.

[0152] The orchestration agent **206** can request an EUICC and/or HUB lock as described in Table 1. When the EUICC and/or HUB lock are acquired (possibly after an arbitrary period of time), the orchestration agent **206** can open a logical channel with the ISD-R of the destination eUICC **224**, perform a get EUICC Info operation **1802**, and then can perform a get EUICC challenge operation **1803**.

[0153] Using EUICC data from the get EUICC info operation **1802** and the EUICC challenge data from the get EUICC challenge operation **1803**, the orchestration agent **206** can invoke an initiate authentication reverse operation **1804**. The first initiate authentication operation **1804** can include a technique for proxying an ES9+ Initiate Authentication operation through the orchestration hub **104** to the SM-DP+ server **122** as part of the Common Mutual Authentication Procedure. In response to the first initiate authentication operation **1804**, the orchestration hub **104** can acquire the SM-DP+ URL from the subscription hub row **404** and can perform a corresponding second initiate authentication operation **1805** with the appropriate SM-DP+ server **122**. The second initiate authentication operation **1805** can trigger a response from the SM-DP+ server to generate transactionID, serverSigned1, serverSignature1, euiccCiPKIdToBeUsed, and serverCertificate fields, which the orchestration hub **104** can return to the orchestration agent **206** through the first initiate authentication operation **1804**.

[0154] The orchestration agent **206** can construct a CtxParams1 value, as described in SGP.22 version 2.4, using a dpp_token field from the subscription context as well as information associated with the modem **208** (received from the device application **204**). With the CtxParams1 value, as well as the transactionID, serverSigned1, serverSignature1, euiccCiPKIdToBeUsed, and serverCertificate fields, the orchestration agent **206** can perform an authenticate server operation **1806**.

[0155] The orchestration agent **206** can invoke a first authenticate client operation **1807** using the transactionID value returned by the first initiate authentication operation **1804** and the authenticateServerResponse value returned by the authenticate server operation **1806**. The orchestration hub **104** can subsequently perform a second authenticate client operation **1808** with the appropriate SM-DP+ server **122**. The second authenticate client operation **1808** can include relaying the transactionID field and an authenticateServerResponse field between the SM-DP+ server **122** and the orchestration hub **104**. The second authenticate client operation **1808** can include transactionID, profileMetadata, smdpSigned2, smdpSignature2, and smdpCertificate fields, which the orchestration hub **104** can relay to the orchestration agent **206** as the return value of the first authenticate client operation **1807**. The first authenticate client operation **1807** and/or the second authentication client operation **1808** can include a technique for proxying an ES9+ Authenticate Client operation through the orchestration hub **104** to the SM-DP+ server **122** as part of a Common Mutual Authentication Procedure.

[0156] Upon completion of the first authenticate client operation **1807** and the second authenticate client operation **1808**, the orchestration agent **206** can examine the profileMetadata field and follow the process described in SGP. 22 version 2.4, 3.1.3, steps 7 and 8. If user consent is required according to the PPR values in the eSIM profile metadata and the eUICC Rules Authorization Table, then the ppr1_consent and ppr2_consent fields in the subscription context can provide consent for PPR1 and PPR2 present the profile metadata. If PPR1 is present in the profile metadata and ppr1_consent is FALSE in the subscription context, or if PPR2 is present in profile metadata and ppr2_consent is FALSE in subscription context, then consent can be denied. If necessary, the orchestration agent **206** can perform ES10b. GetRat and ES10b.GetProfilesInfo functions to complete the evaluation process. If a confirmation_code value is present in the context information, then the orchestration agent **206** can generate a hashcc value from the cc fields of the subscription context using SHA256 as explained in the SGP.22 Specification, 3.1.3, step 8.

[0157] The orchestration agent **206** can perform a prepare download operation **1809**. The prepare download operation can include extracting from the eUICC **224** parameters such as smdpSigned2, smdpSignature2, smdpCertificate, and hashcc (if the cc field is present in the subscription context). The orchestration agent **206** can invoke a first profile package operation **1810**. The first profile package operation **1810** can include the transactionID and a ES10b.PrepareDownload response as parameters. The first profile package operation **1810** can include a technique for proxying an ES9+ GetBoundProfilePackage operation through the orchestration hub **104** to the SM-DP+ server **122**. The orchestration hub can perform a second profile package operation **1811** with the appropriate SM-DP+ server **122**. The SM-DP+ server **122** can reply with an ES9+ GetBoundProfilePackage response. The orchestration hub **104** can store the boundProfilePackage into its database, such as in a table row related to the subscription being installed. In one example, the orchestration hub **104** can return the boundProfilePackage output field to the orchestration agent **206** as part of the first profile package return value. In another example, the orchestration hub **104** can return the BLOB ID of the boundProfilePackage to the orchestration agent as part of the first profile package return value for subsequent retrieval by the orchestration agent **206** using a get BLOB operation **1812**. The get BLOB operation **1812** can include a technique for reading a BLOB from the orchestration hub **104**. The orchestration agent **206** can read the BLOB in its entirety or in segments spanning multiple method calls. Parameters read include but are not limited to blob_id, identifying the BLOB, offset, identifying the data start offset and length, and identifying the maximum byte length of data to return. The return value can include a result code, and, upon success, the requested data from the BLOB.

[0158] The orchestration agent **206** can call a Get BLOB operation **1812**, receiving the BLOB ID returned by the first profile package operation **1810** as a BLOB_id parameter. The Get BLOB operation **1812** can return a bound profile package data to the orchestration agent **206**.

[0159] The orchestration agent **206** can follow the process described in SGP.22 version 2.4 5.7.6, segmenting the bound profile package and invoking a load bound profile package operation **1813** multiple times as necessary. Once the final segment of the profile package is successfully loaded, the load bound profile package operation **1813** can return a ProfileInstallationResult value. In one example, the load bound profile package operation **1813** can be a "loadBoundProfilePackage ( )" operation according to GSMA standards.

[0160] The orchestration agent **206** can invoke a first handle notification operation **1814**, passing the ProfileInstallationResult from the load bound profile package operation **1813** as a parameter. The orchestration hub **104** can invoke a second handle notification operation **1815** with the appropriate SM-DP+ server **122**. Upon successful completion of the second handle notification operation **1815** and the first handle notification operation **1814** return value, the orchestration agent **206** can perform a notification removal operation **1816** with the eUICC **224**. The orchestration agent **206** can send a notification **1817** to the orchestration hub **104** indicating the completion of the operation. The subscription install process of the illustrative embodiment can send more than one notification **1817** after the profile is successfully installed.

[0161] In one example, the subscription install process of the first install operation **1800** can download the complete bound profile package in a single Get BLOB operation **1812**. In another example, the orchestration agent **206** can download the bound profile package using multiple Get BLOB operations **1812**, or the first profile package operation **1810** can include a complete bound profile package in its return call, depending on resources and capabilities.

[0162] Referring now to FIG. **19**, illustrated is a second install operation **1900** using a profile installation script, according to one example of the disclosed technology. The second install operation **1900** can illustrate a sequence diagram for installing the subscription edge record **402** into a particular device. The orchestration hub **104** can interface with the connectivity manager **102** using the CMI **116**. The orchestration hub **104** can interface with the orchestration agent **206** using the AHI **134**. The orchestration agent **206** can connect to the eUICC **224**.

[0163] The orchestration hub **104** can invoke the AHI install operation **1901** to the orchestration agent **206**. The parameters of the AHI install operation **1901** can include the subscription context fields shown in Table 5, including ins_script. The orchestration agent **206** can save the subscription context into a new subscription edge record **402** in its local store **218**, with an initial state of INSTALLING **902**. The orchestration agent **206** can return a successful completion of the AHI install operation **1901** to the orchestration hub **104**. The orchestration agent **206** can invoke the get BLOB operation **1812** to retrieve the installation script from the orchestration hub **104**, using the blob ID included in the ins_script field of the AHI install operation **1901**. The orchestration hub **104** can invoke a CMI get script operation

1903, using the ins_script field of the Subscription Hub Row to retrieve the installation script from the connectivity manager **102**. The get script operation **1903** can return the script, which is in turn returned to the orchestration agent **206** in the get BLOB operation **1902** return value.

[0164] The orchestration agent **206** can acquire an EUICC lock **312** and then execute the C-APDU components of the installation script **1904**, capturing the R-APDU responses of each command. When all C-APDUs have been sent to the eUICC **224** and the loop completes, the orchestration agent **206** can release the EUICC lock, acquire a HUB lock, and invoke a put BLOB operation **1905** to write R-APDU data to the orchestration hub **104**, using ins_script (from the AHI install operation **1901**)+1 as the blob_id, and the R-APDU data as the blob data. The orchestration agent **206** can send a notification **1906** to the orchestration hub **104** indicating the completion of the operation. The orchestration hub **104** can invoke a close script operation **1907** to report the results of the installation script to the connectivity manager **102**.

[0165] Referring now to FIG. **20** illustrated is a first update operation **2000** without profile content management, according to one example of the disclosed technology. The first update operation **2000** can illustrate a sequence diagram, which can include changes to the subscription context **414** of the subscription edge record **402**. the orchestration hub **104** can use the AHI **134** to call an update operation **2001** of the orchestration agent **206**. Since the update operation **2001** parameters only specify changes to the subscription context, the update operation **2001** can complete and return a successful status, thereby completing the operation.

[0166] Referring now to FIG. **21**, illustrated is a second update operation **2100** with profile content management, according to one example of the disclosed technology. The second update operation **2100** can illustrate a technique for updating a subscription edge record **402**, including both its subscriber identity **412** and subscription context **414**. The orchestration hub **104** can use the AHI **134** to call the update operation **1601** of the orchestration agent **206**. Since the update method parameters include a blob ID for an update script, the orchestration agent **206** can preimage an updated subscription context and return a pending status. The orchestration agent **206** can acquire an HUB lock and can invoke a get BLOB operation **2102** to retrieve the update script. Upon receiving the get_blob method call, the orchestration hub **104** can use the CMI **116** to issue a corresponding open script operation **2103** to the connectivity manager **102**. The return value of the open script operation **2103** is relayed to the Orchestration Agent as the return value of the get BLOB operation **2102**.

[0167] The orchestration agent **206** can release the HUB lock and can acquire an EUICC lock **312**. The orchestration agent **206** can loop through the update script C-APDU commands **2104** while recording the R-APDU responses. Upon completion of all script commands, the orchestration agent **206** can release the EUICC lock **312** and can acquire the HUB lock. The orchestration agent **206** can invoke a put BLOB operation **2105** to convey responses to the update script. The orchestration agent **206** can send a notification **2106** indicating that the operation is complete, and releases all locks. The orchestration hub **104** can close the script using a close script operation **2107**.

[0168] In embodiments with limited MTU size and other resource limitations, the orchestration agent **206** can replace the single get BLOB operation **2102** with multiple get BLOB operation **2102**, and it may replace the single put BLOB operation **2105** with multiple put BLOB operation **2105**.

[0169] Referring now to FIG. **22**, illustrated is a delete operation **2200**, according to one example of the disclosed technology. The orchestration hub **104** can use the AHI **134** to invoke a delete operation **2201** of the orchestration agent **206**. After a possible delay of arbitrary duration, the orchestration agent **206** can acquire eUICC and modem lock and perform a delete profile operation **2202**. The eUICC **224** can release its locks.

[0170] Depending on local circumstances and the configuration of the eSIM profile, the delete profile operation **2202** can generate notifications. The orchestration agent **206**, therefore, can obtain EUICC and Hub locks. The orchestration agent **206** can perform a retrieve notifications list operation **2204**. The orchestration agent **206** can begin an iterative loop **2205** for each notification. During each loop iteration **2205**, the orchestration agent **206** can invoke a first handle notification operation **2206**. The orchestration hub **104** can perform a second handle notification operation **2207** with the appropriate SM-DP+ server **122** using the ES9+ interface **124**. The orchestration agent **206** can perform a remove notification from list operation **2208** with the eUICC **224**, thereby clearing the notification from the eUICC memory.

[0171] Once the iterative loop **2205** is complete, the orchestration agent **206** can generate a notification **2209** to the orchestration hub. The notification **2209** can include information notifying the orchestration hub **104** that the subscription edge record **402** has been deleted. The orchestration hub **104** can take appropriate further actions, such as but not limited to termination of the subscription and other steps as appropriate.

[0172] Referring now to FIG. **23**A, illustrated is a general query operation **2300**A, according to one example of the disclosed technology. The general query operation **2300**A can include a technique for querying a particular device regarding the topology of its eUICCs **224**, subscriptions, and modems. The orchestration hub **104** can use the AHI **134** to call the query method **2301**A of an orchestration agent **206** to return the topology of the eUICCs **224**, the subscriptions, and modems associated with the particular device.

[0173] Referring generally now to FIGS. **23**B-C, device managers **106** and connectivity managers **102** can forward subscription source rows to the orchestration hub **104**. By forwarding the subscription source rows to the orchestration hub **104**, the orchestration hub **104** can replicate changes in the subscription hub rows to the subscription edge rows. The orchestration hub **104** can accomplish replicating changes in the subscription hub rows to the subscription edge rows with a two-stage system of asynchronous replication using the sub_uid, sub_rev fields of the Subscription Hub Row and subscription edge rows and the sync_state field of the subscription hub row.

[0174] Referring now to FIG. **23**B, illustrated is a sequence diagram **2300**B, according to one example of the disclosed technology. The sequence diagram **2300**B can illustrate a progression of an asynchronous subscription update operation driven by a subscription source row update from a connectivity manager **102**. the orchestration hub **104** can interface with the connectivity manager **102** using the CMI **116**. After (for example) a rezoning operation that can change the PLMN list of a subscription, the connectivity manager **102** can generate a notification **2301**B for the orchestration hub **104** stating the rezoning operation. The orchestration hub **104** can perform a read subscription operation **2302**B to obtain the subscription source row. The orchestration hub **104** can follow the procedure **600** detailed in FIG. **6** to merge the update into the related subscription hub row.

[0175] Referring now to FIG. **23**C, illustrated is a sequence diagram **2300**C, according to one example of the disclosed technology. The sequence diagram **2300**C can illustrate a progression of an asynchronous subscription update operation driven by the subscription source row update from the device manager **106**. The orchestration hub **104** can interface with the device manager **106** using the OHA **111**. After (for example) a user changes the rank of a particular subscription, the device manager **106** can update the subscription with updated fields in the subscription source row through an update subscription operation **2304**C. The orchestration hub **104** can follow the procedure **600** detailed in FIG. **6** to merge the update into the related subscription hub row.

[0176] Referring generally to FIGS. **24-27**, the disclosed innovation can enable a device manager **106** to organize operations into campaigns. Campaigns can be defined as sets of sequentially ordered operations applied to one or more devices. While operations can be sequential and ordered for each device in a campaign, devices themselves can be handled in parallel. For example, a campaign can include two installation operations, followed by a delete operation, each performed on 500 (or more) devices. The orchestration hub **104** can initiate all 500 install operations simultaneously, and as these operations complete, the orchestration hub **104** can begin the follow-on operations on a device-by-device basis. Campaigns can offer a useful management structure in cases where RSP operations may incur cost, which can be controlled and accounted for differently than other aspects of device management.

[0177] Referring now to FIG. **24**, illustrated is a lifecycle state machine **2400** for a campaign, according to one example of the disclosed technology. The device manager **106** can create a campaign by invoking a create campaign operation of the OHI **118**. The device manager **106** can create the campaign in a COMPOSING state **2401**, at which time the device manager **106** can use subsequent append campaign operations to add additional operations and devices. The device manager **106** can invoke a cancel campaign operation to change the state to CANCELLED **2402**. Alternatively or in addition, once the campaign is built, the device manager **106** can invoke a commit campaign operation to change the state to COMMITTED **2403**. Once the campaign is in the COMMITTED state **2403**, the device manager **106** can invoke a confirm campaign operation to change the state to EXECUTING **2405**, or it can invoke a refuse campaign operation to change the state to REFUSED **2404**. Once the campaign is in the EXECUTING state **2405**, the device manager **106** can run the campaign to completion, unless terminated with a terminate campaign operation. Either condition can run the campaign into the terminal state DONE **2406**.

[0178] The lifecycle state machine **2400** and the operations described above can permit controls and accounting to exist on both sides of OHI **118**, which may be helpful in cases where an orchestration hub **104** may be provided as a service or where large campaigns are managed. For example, a device manager **106** may only permit confirm campaign operations to originate from certain user accounts, with those users following well-defined procedures to confirm or refuse campaigns. In cases where an orchestration hub **104** is more tightly integrated into a device management system, or where campaigns are smaller, these controls can be adjusted in favor of controls implemented primarily within the device manager **106**. In these cases, a single device manager **106** and/or any other particular system of the disclosed technology can originate calls to create campaigns, commit campaigns, and confirm campaigns. The device manager **106** and/or any other particular system of the disclosed technology can prompt a dialog box prompt asking for confirmation before proceeding with the confirm campaign operation.

[0179] Referring now to FIG. **25**, illustrated is a sequence diagram **2500** for a campaign of install operations, according to one example of the disclosed technology. The device manager **106** can invoke a create campaign operation **2501** to create a campaign. The create campaign operation **2501** parameters can include a list of device_id values, a modem_ordinal, a modem_slot, and a template_id. The device manager **106** can commit the campaign using an update command operation **2502**, and subsequently approves the campaign using a second update command operation **2503**. The orchestration hub **104** can begin a loop **2504** to iterate through the devices specified in the list of device_id values. The device manager **106** and/or the orchestration hub **104** can perform the loop **2504** sequentially, one device at a time, or in parallel for all devices, or as a sequence of parallel operations involving multiple devices, depending on available system resources and urgency. For each device, the orchestration hub **104** can acquire a subscription from the connectivity manager **102**, using the CMI **116**, by invoking an acquire subscription operation **2505**. Once the subscription is acquired, the connectivity manager **102** can send a notification **2506** to the orchestration hub **104**. The orchestration hub **104** can retrieve the subscription with a read subscription operation **2507**. The disclosed innovation can subsequently execute the install operation **2508** as described in FIGS. **18-19** to install the desired information on each particular device. For example, for subscriptions installed using the SM-DP+ downloads, the example embodiment can employ the first installation operation **1800** of FIG. **18**. In another example, for subscriptions installed using profile installation scripts, the illustrative embodiment can employ the second update operation **1900** of FIG. **19**. In response to completing the install operation, the orchestration hub **104** can send a progression notification **2509** to the device manager **106**. Once the loop **2504** is complete, the orchestration hub **104** can update the campaign state to DONE **2006** and send a final notification **2510** to the device manager **106** indicating the completion of the campaign.

[0180] Referring now to FIG. **26**, illustrated is a sequence diagram **2600** for a campaign of update operations, according to one example of the disclosed technology. The device manager **106** can invoke the create campaign operation **2601** to create a campaign. The parameters of the create campaign operation **2601** can include a list of subscription identifiers. The device manager **106** can commit the campaign using an update campaign operation **2602**. The device manager **106** can subsequently approve the campaign using a second update campaign operation **2603**. The orchestration hub **104** can organize the subscription identifiers into common devices and begin a loop **2604** to iterate through the devices. The device manager **106** and/or orchestration hub **104** can perform the loop **2604** sequentially, one device at a time, or in parallel for all devices, or as a sequence of parallel operations involving multiple devices, depending on available system resources and urgency. The device manager **106** and/or any other system of the disclosed technology can execute the update operation **2605** as illustrated in FIGS. **20-21** for each particular device. For example, for subscriptions updated without profile content management, the illustrative embodiment can employ the first update operation **2000** of FIG. **20**. In another example, for subscriptions updated with profile content management, the illustrative embodiment can employ the second operation **2100** of FIG. **21**. The orchestration hub **104** can generate the notification **2606** as each device is updated. The orchestration hub **104** can generate the notification **2607** indicating the campaign has been completed.

[0181] Referring now to FIG. **27**, illustrated is a sequence diagram **2700** for a campaign of delete operations, according to one example of the disclosed technology. The device manager **106** can invoke the create campaign operation **2701** to create a campaign. The parameters of the create campaign operation **2701** can include a list of subscription identifiers. The device manager **106** can commit the campaign using an update campaign operation **2702**. The device manager **106** can subsequently approve the campaign using a second update campaign operation **2703**. The orchestration hub **104** can organize the subscription identifiers into common devices and begin a loop **2704** to iterate through the devices. The device manager **106** and/or orchestration hub **104** can perform the loop **2704** sequentially, one device at a time, or in parallel for all devices, or as a sequence of parallel operations involving multiple devices, depending on available system resources and urgency. The device manager **106** and/or any other system of the disclosed technology can execute one or more delete operations (such as the operation **2201** as illustrated in FIG. **22**) for each particular device. In one example, an "UpdateCampaign ( )" operation can be used for updating campaign information, or deleting a campaign or campaign information. The orchestration hub **104** can generate the notification **2706** as each device has its particular data deleted. The orchestration hub **104** can generate the notification **2707** indicating the campaign has been completed.

[0182] In one example, the operations referred to herein (and particularly with respect to the sequence diagrams illustrated and discussed in connection with FIGS. **15-27**) can be GSMA operations, or operations according to other standards, specifications, and protocols. For example, the operations can correspond to operations described in the SGP.02, SGP.22, and SGP.32 standards (and other standards). In at least one example, the "Request APDU Operation" step **1504** of FIG. **15** can correspond to the GSMA "GetApdu ( )" operation. In another example, operations such as "Get EUICC Info" as discussed in connection with step **1802** of FIG. **18**, can correspond to operations described in accordance with the ES10 interface, such as "ES10b. GetEUICCInfo." In other examples, operations such as "First Initiate Authentication Operation" **1804** of FIG. **18**, can correspond to operations described in accordance with ES9+ interface, such as "es9p_InitiateAuthentication ( )" Further, operations such as "Second Initiate Authentication" at step **1805** of FIG. **18**, can correspond to the GSMA "InitiateAuthentication" operation. Accordingly, despite certain operations being referred to in a generalized form (for ease of understanding), it should be understood from the discussion herein that those operations correspond to the one or more standards, specifications, and protocols as described throughout the present disclosure.

CONCLUSION

[0183] The disclosure herein can be carried out wholly or in part by a computing environment, which can include a server computer, or any other system providing computing capability. Alternatively, the computing environment may employ a plurality of computing devices that may be arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices can be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment can include a plurality of computing devices that together may include a hosted computing resource, a grid computing resource, and/or any other distributed computing arrangement. In some cases, the computing environment can correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

[0184] Various applications and/or other functionality may be executed in the computing environment according to various embodiments. Also, various data is stored in a database that is accessible to the computing environment. The database can be representative of a plurality of databases as can be appreciated. The data stored in the database, for example, may be associated with the operation of the various applications and/or functional entities described herein.

[0185] The computing environment can communicate with a plurality of computing devices and querying devices (which may include computing devices) via a network. The network includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, or other suitable networks, etc., or any combination of two or more such networks. For example, such networks can include satellite networks, cable networks, Ethernet networks, and other types of networks.

[0186] Aspects, features, and benefits of the systems, methods, processes, formulations, apparatuses, and products discussed herein will become apparent from the information disclosed in the figures and the other applications as incorporated by reference. Variations and modifications to the disclosed systems and methods may be affected without departing from the spirit and scope of the novel concepts of the disclosure.

[0187] It will, nevertheless, be understood that no limitation of the scope of the disclosure is intended by the information disclosed in the figures or the applications incorporated by reference; any alterations and further modifications of the described or illustrated embodiments, and any further applications of the principles of the disclosure as illustrated therein are contemplated as would normally occur to one skilled in the art to which the disclosure relates.

[0188] The foregoing description of the exemplary embodiments has been presented only for the purposes of illustration and description and is not intended to be exhaustive or to limit the systems and processes to the precise forms disclosed. Many modifications and variations are possible in light of the above teaching.

[0189] The embodiments were chosen and described in order to explain the principles of the systems and processes and their practical application so as to enable others skilled in the art to utilize the systems and processes and various embodiments and with various modifications as are suited to the particular use contemplated. Alternative embodiments will become apparent to those skilled in the art to which the present systems and processes pertain without departing from their spirit and scope. Accordingly, the scope of the present systems and processes is defined by the appended claims rather than the foregoing description and the exemplary embodiments described therein.

[0190] From the foregoing, it will be understood that various aspects of the processes described herein are software processes that execute on computer systems that form parts of the system. Accordingly, it will be understood that various embodiments of the system described herein are generally implemented as specially configured computers including various computer hardware components and, in many cases, significant additional features as compared to conventional or known computers, processes, or the like, as discussed in greater detail herein. Embodiments within the scope of the present disclosure also include computer-readable media for carrying or having computer-executable instructions or data structures stored thereon. Such computer-readable media can be any available media which can be accessed by a computer, or downloadable through communication networks. By way of example, and not limitation, such computer-readable media can comprise various forms of data storage devices or media such as RAM, ROM, flash memory, EEPROM, CD-ROM, DVD, or other optical disk storage, magnetic disk storage, solid state drives (SSDs) or other data storage devices, any type of removable nonvolatile memories such as secure digital (SD), flash memory, memory stick, etc., or any other medium which can be used to carry or store computer program code in the form of computer-executable instructions or data structures and which can be accessed by a computer.

[0191] When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a computer, the computer properly views the connection as a computer-readable medium. Thus, any such a connection is properly termed and considered a computer-readable medium. Combinations of the above should also be included within the scope of computer-readable media. Computer-executable instructions comprise, for example, instructions and data which cause a computer to perform one specific function or a group of functions.

[0192] Those skilled in the art will understand the features and aspects of a suitable computing environment in which aspects of the disclosure may be implemented. Although not required, some of the embodiments of the claimed systems and processes may be described in the context of computer-executable instructions, such as program modules or engines, as described earlier, being executed by computers in networked environments. Such program modules are often reflected and illustrated by flow charts, sequence diagrams, exemplary screen displays, and other techniques used by those skilled in the art to communicate how to make and use such computer program modules. Generally, program modules include routines, programs, functions, objects, components, data structures, application programming interface (API) calls to other computers whether local or remote, etc. that perform particular tasks or implement particular defined data types, within the computer. Computer-executable instructions associated data structures and/or schemas, and program modules represent examples of the program code for executing steps of the methods disclosed herein. The particular sequence of such executable instructions or associated data structures represents examples of corresponding acts for implementing the functions described in such steps.

[0193] Those skilled in the art will also appreciate that the claimed and/or described systems and methods may be practiced in network computing environments with many types of computer system configurations, including personal computers, smartphones, tablets, hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, networked PCs, minicomputers, mainframe computers, and the like. Embodiments of the claimed systems and processes are practiced in distributed computing environments where tasks are performed by local and remote processing devices that are linked (either by hardwired links, wireless links, or by a combination of hardwired or wireless links) through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0194] An exemplary system for implementing various aspects of the described operations, which is not illustrated, includes a computing device including a processing unit, a system memory, and a system bus that couples various system components including the system memory to the processing unit. The computer will typically include one or more data storage devices for reading data from and writing data to. The data storage devices provide nonvolatile storage of computer-executable instructions, data structures, program modules, and other data for the computer.

[0195] Computer program code that implements the functionality described herein typically comprises one or more program modules that may be stored on a data storage device. This program code, as is known to those skilled in the art, usually includes an operating system, one or more application programs, other program modules, and program data. A user may enter commands and information into the computer through keyboard, touch screen, pointing device, a script containing computer program code written in a scripting language or other input devices (not shown), such as a microphone, or in the case of an NFC wrist band or RFID device, by holding it in close proximity or tapping it to an NFC or RFID enabled computer, smartphone or mobile device, etc. These and other input devices are often connected to the processing unit through known electrical, optical, or wireless connections.

[0196] The computer that effects many aspects of the described processes will typically operate in a networked environment using logical connections to one or more remote computers or data sources, which are described further below. Remote computers may be another personal computer, a server, a router, a network PC, a peer device or other common network node, and typically include many or all of the elements described above relative to the main computer system in which the systems and processes are embodied. The logical connections between computers include a local area network (LAN), a wide area network

(WAN), virtual networks (WAN or LAN), and wireless LANs (WLAN) that are presented here by way of example and not limitation. Such networking environments are commonplace in office-wide or enterprise-wide computer networks, intranets, and the Internet.

[0197] When used in a LAN or WLAN networking environment, a computer system implementing aspects of the systems and processes is connected to the local network through a network interface or adapter. When used in a WAN or WLAN networking environment, the computer may include a modem, a wireless link, or other mechanisms for establishing communications over the wide area network, such as the Internet. In a networked environment, program modules depicted relative to the computer, or portions thereof, may be stored in a remote data storage device. It will be appreciated that the network connections described or shown are exemplary and other mechanisms of establishing communications over wide area networks or the Internet may be used.

[0198] While various aspects have been described in the context of a preferred embodiment, additional aspects, features, and methodologies of the claimed systems and processes will be readily discernible from the description herein, by those of ordinary skill in the art. Many embodiments and adaptations of the disclosure and claimed systems and processes other than those herein described, as well as many variations, modifications, and equivalent arrangements and methodologies, will be apparent from or reasonably suggested by the disclosure and the foregoing description thereof, without departing from the substance or scope of the claims. Furthermore, any sequence(s) and/or temporal order of steps of various processes described and claimed herein are those considered to be the best mode contemplated for carrying out the claimed systems and processes. It should also be understood that, although steps of various processes may be shown and described as being in a preferred sequence or temporal order, the steps of any such processes are not limited to being carried out in any particular sequence or order, absent a specific indication of such to achieve a particular intended result. In most cases, the steps of such processes may be carried out in a variety of different sequences and orders, while still falling within the scope of the claimed systems and processes. In addition, some steps may be carried out simultaneously, contemporaneously, or in synchronization with other steps.

[0199] The embodiments were chosen and described in order to explain the principles of the claimed systems and processes and their practical application so as to enable others skilled in the art to utilize the systems and processes and various embodiments and with various modifications as are suited to the particular use contemplated. Alternative embodiments will become apparent to those skilled in the art to which the claimed systems and processes pertain without departing from their spirit and scope. Accordingly, the scope of the claimed systems and processes is defined by the appended claims rather than the foregoing description and the exemplary embodiments described therein.

What is claimed is:

1. A system comprising:

an orchestration agent comprising a software configuration installed at a mobile computing device, wherein the orchestration agent is operatively connected to an embedded universal integrated circuit card (eUICC) and memory at the mobile computing device; and

an orchestration hub operatively connected to the orchestration agent, wherein the orchestration hub comprises a processor and a database including centralized network subscription information sourced from one or more management platforms, wherein the processor is operatively configured to:

receive first updated network subscription information from a device management platform of the one or more management platforms;

receive second updated network subscription information from a network connectivity management platform of the one or more management platforms;

compare the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in the centralized network subscription information;

in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generate a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and

transmit a replicated version of the new subscription record to the orchestration agent at the mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at the eUICC and the memory with corresponding information fields from the replicated version of the new subscription record.

2. The system of claim **1**, wherein the common identifier is an Integrated Circuit Card Identification (ICCID) value.

3. The system of claim **1**, wherein transmitting the replicated version of the new subscription record to the orchestration agent comprises transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

4. The system of claim **1**, wherein the orchestration hub is operatively configured to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

5. The system of claim **1**, wherein the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

6. The system of claim **5**, wherein the subscription edge record comprises an eSIM profile received from the SM-DP+ server and stored within the eUICC, and the subscription edge record further comprises subscription context information received from the network connectivity management platform and stored within the memory.

7. The system of claim **6**, wherein the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

8. A method comprising:

receiving first updated network subscription information from a device management platform of one or more management platforms;

receiving second updated network subscription information from a network connectivity management platform of the one or more management platforms;

comparing the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in centralized network subscription information stored in an orchestration hub;

in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generating a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and

transmitting a replicated version of the new subscription record to an orchestration agent at a mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at an eUICC and a memory at the mobile computing device with corresponding information fields from the replicated version of the new subscription record.

9. The method of claim **8**, wherein the common identifier is an Integrated Circuit Card Identification (ICCID) value.

10. The method of claim **8**, wherein transmitting the replicated version of the new subscription record to the orchestration agent comprises transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

11. The method of claim **8**, wherein the orchestration hub is operatively configured to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

12. The method of claim **8**, wherein the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

13. The method of claim **8**, wherein the subscription edge record comprises an eSIM profile received from the SM-DP+ server and stored within the eUICC, and the subscription edge record further comprises subscription context information received from the network connectivity management platform and stored within the memory.

14. The method of claim **13**, wherein the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

15. A non-transitory computer readable medium comprising instructions, that when read by a processor, cause the processor to perform:

receiving first updated network subscription information from a device management platform of one or more management platforms;

receiving second updated network subscription information from a network connectivity management platform of the one or more management platforms;

comparing the first updated network subscription information and the second updated network subscription information to a plurality of subscription records in centralized network subscription information stored in an orchestration hub;

in response to determining a common identifier between a particular subscription record of the plurality of subscription records, the first updated network subscription information, and the second updated network subscription information, generating a new subscription record including current network subscription information based on the first updated network subscription information and the second updated network subscription information; and

transmitting a replicated version of the new subscription record to an orchestration agent at a mobile computing device, wherein the orchestration agent is operatively configured to replace one or more information fields of a subscription edge record at an eUICC and a memory at the mobile computing device with corresponding information fields from the replicated version of the new subscription record.

16. The non-transitory computer readable medium of claim **15**, wherein the common identifier is an Integrated Circuit Card Identification (ICCID) value.

17. The non-transitory computer readable medium of claim **15**, wherein transmitting the replicated version of the new subscription record to the orchestration agent comprises transmitting the replicated version of the new subscription record to the orchestration agent through a network tunnel.

18. The non-transitory computer readable medium of claim **15** further comprising instructions that, when read by the processor, cause the orchestration hub to transmit the replicated version of the new subscription record in response to receiving an indication of device availability.

19. The non-transitory computer readable medium of claim **15**, wherein the orchestration hub is operatively connected to a subscription manager data preparation plus (SM-DP+) server.

20. The non-transitory computer readable medium of claim **19**, wherein the subscription edge record comprises an eSIM profile received from the SM-DP+ server and stored within the eUICC, and the subscription edge record further comprises subscription context information received from the network connectivity management platform and stored within the memory, and wherein the wherein the orchestration hub is operatively configured to update the eSIM profile via one or more APDU scripts.

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