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(54) **RE-AUTHENTICATION KEY GENERATION**

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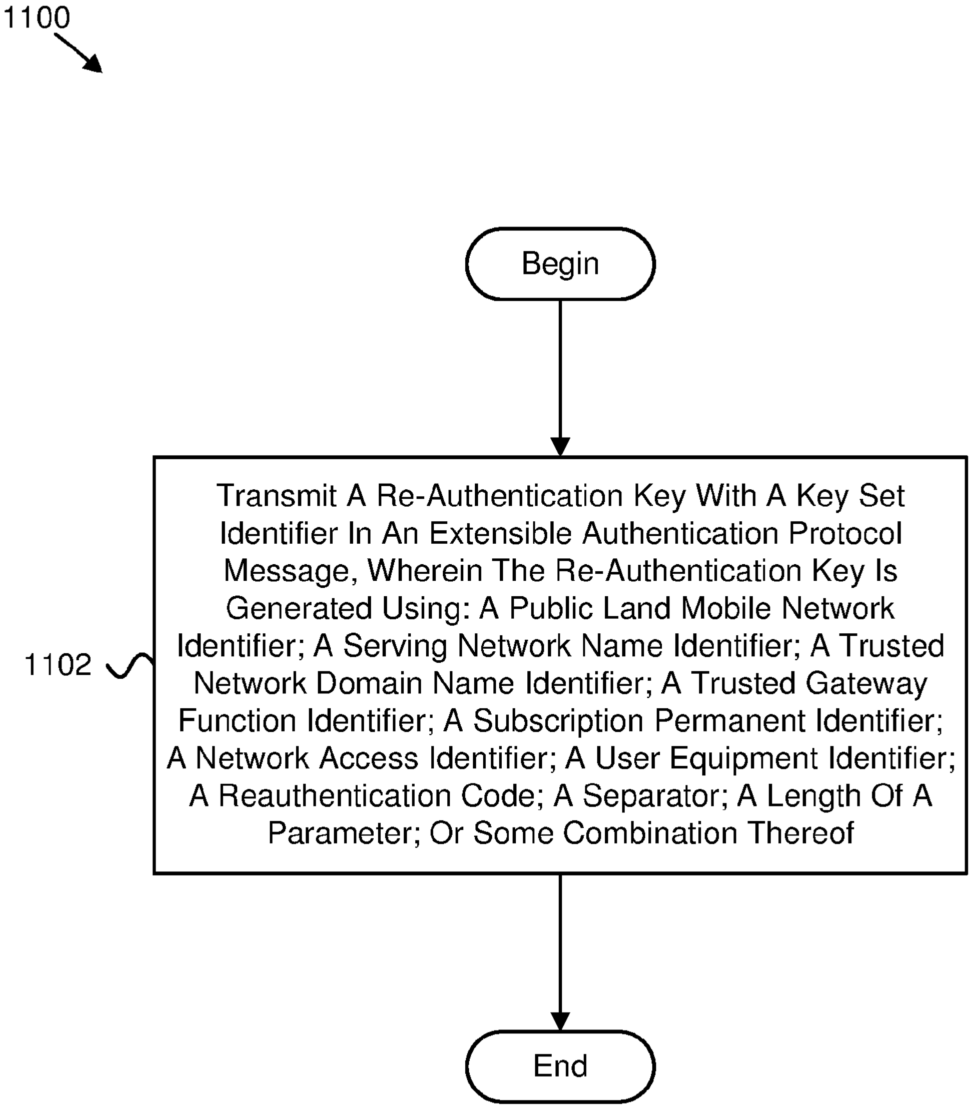
(57) **ABSTRACT**

Apparatuses, methods, and systems are disclosed for re-authentication key generation. One method (**1100**) includes transmitting (**1102**) a re-authentication key with a key set identifier in an extensible authentication protocol message. The re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.


1100
Begin
Transmit A Re-Authentication Key With A Key Set Identifier In An Extensible Authentication Protocol Message, Wherein The Re-Authentication Key Is Generated Using: A Public Land Mobile Network Identifier; A Serving Network Name Identifier; A Trusted Network Domain Name Identifier; A Trusted Gateway Function Identifier; A Subscription Permanent Identifier; A Network Access Identifier; A User Equipment Identifier; A Reauthentication Code; A Separator; A Length Of A Parameter; Or Some Combination Thereof
1102
End

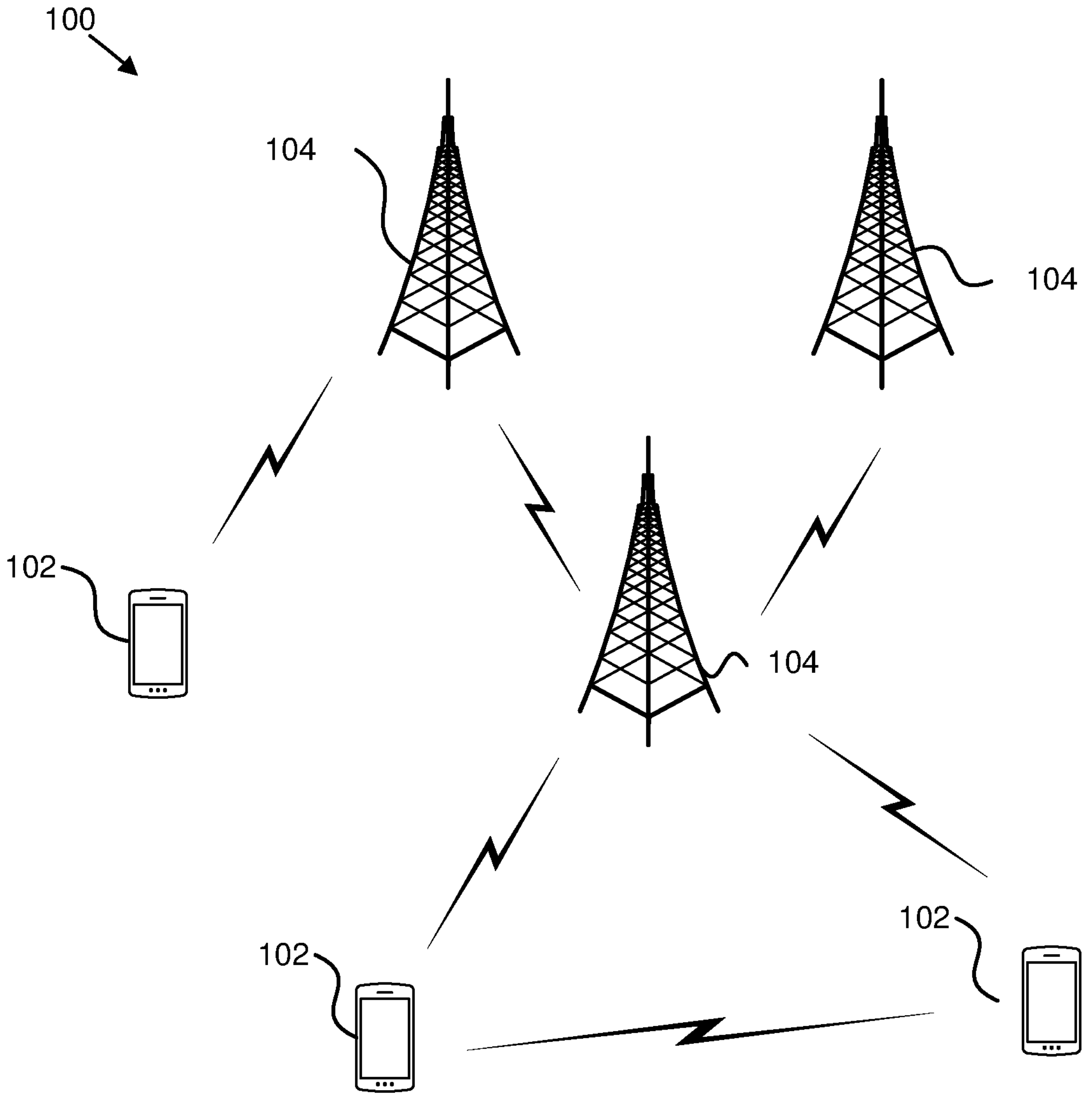


FIG. 1

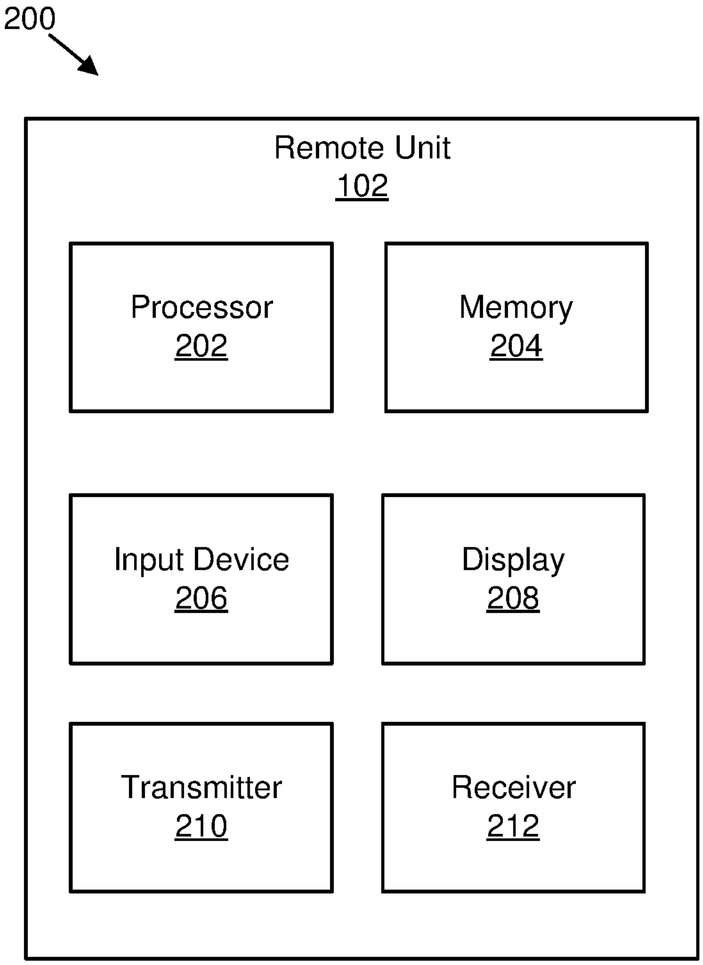

200
Remote Unit
102
Processor
202
Memory
204
Input Device
206
Display
208
Transmitter
210
Receiver
212

FIG. 2

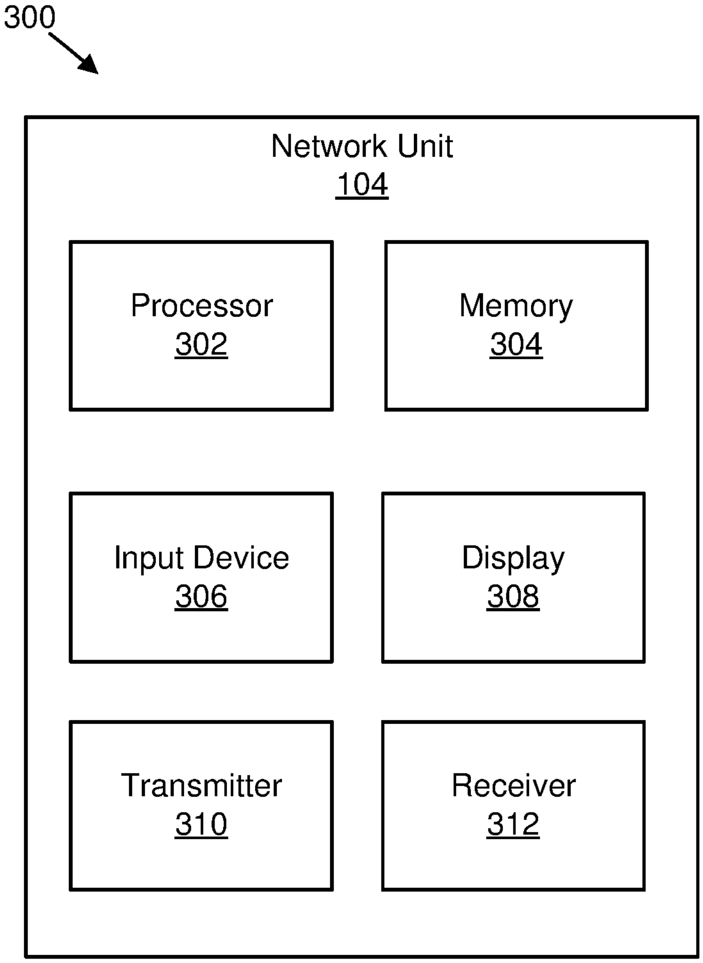

300
Network Unit
104
Processor
302
Memory
304
Input Device
306
Display
308
Transmitter
310
Receiver
312

FIG. 3

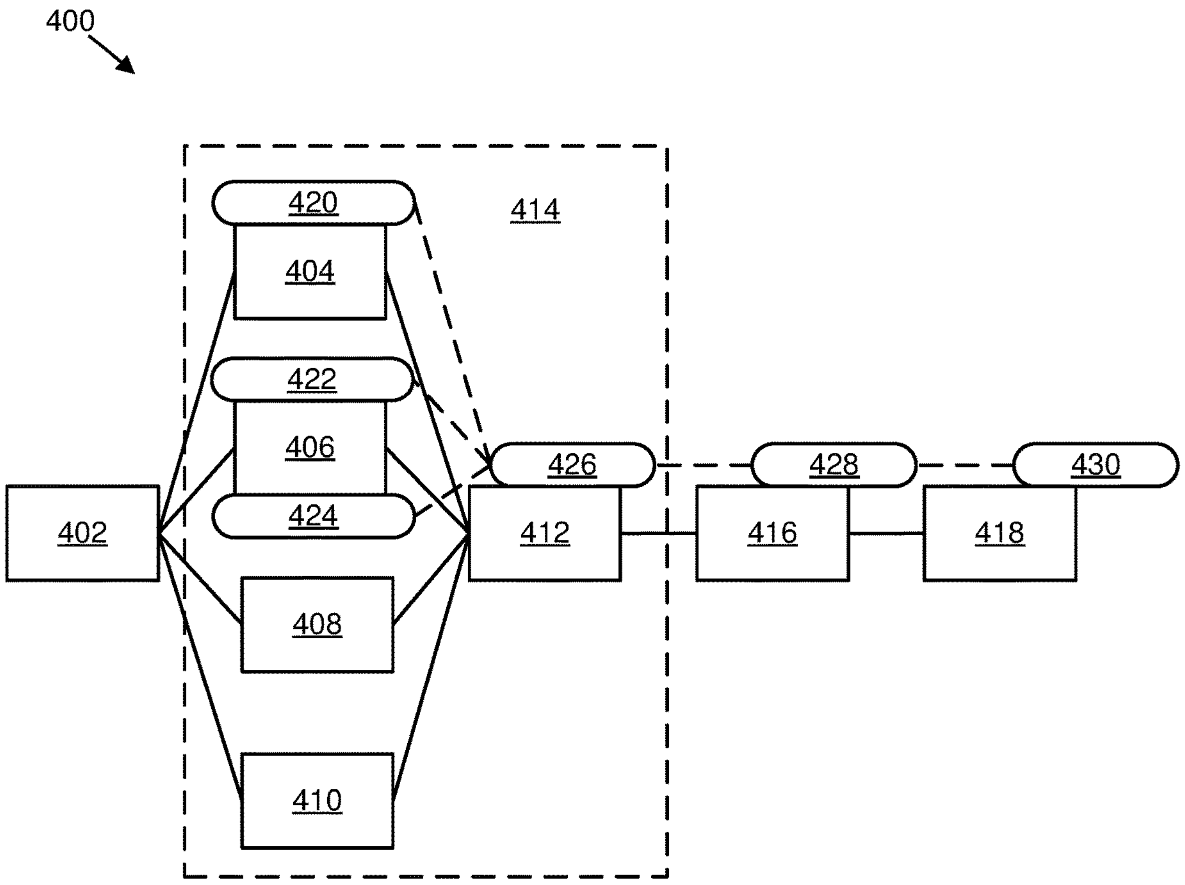


FIG. 4

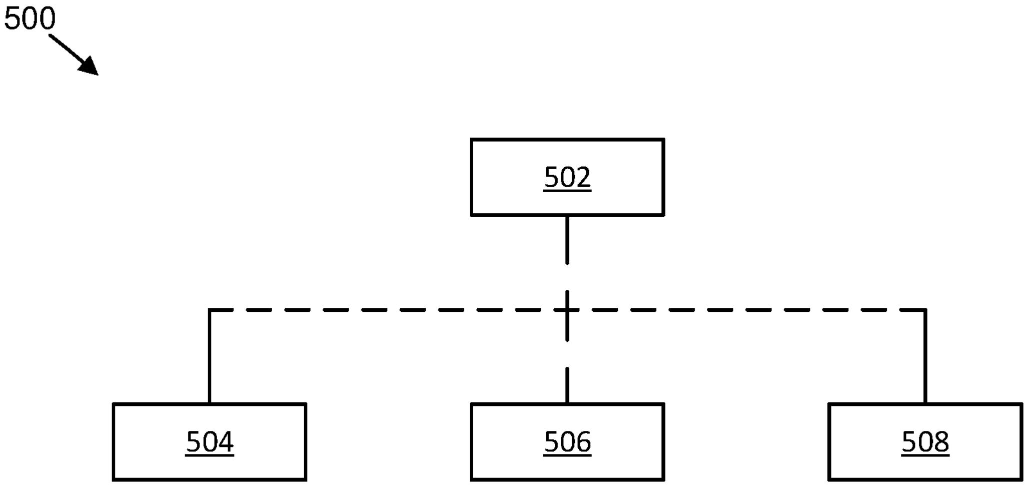
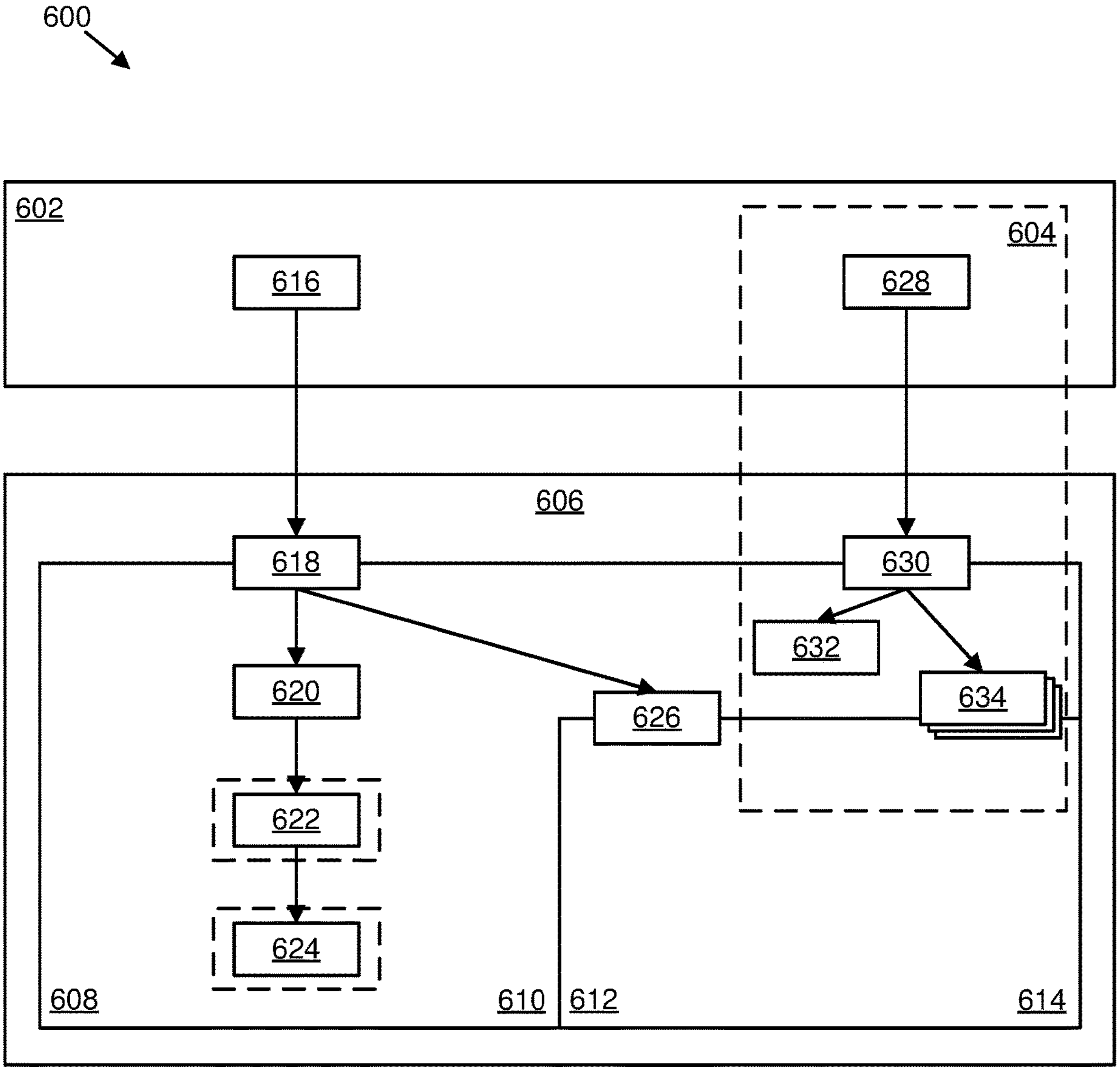


FIG. 5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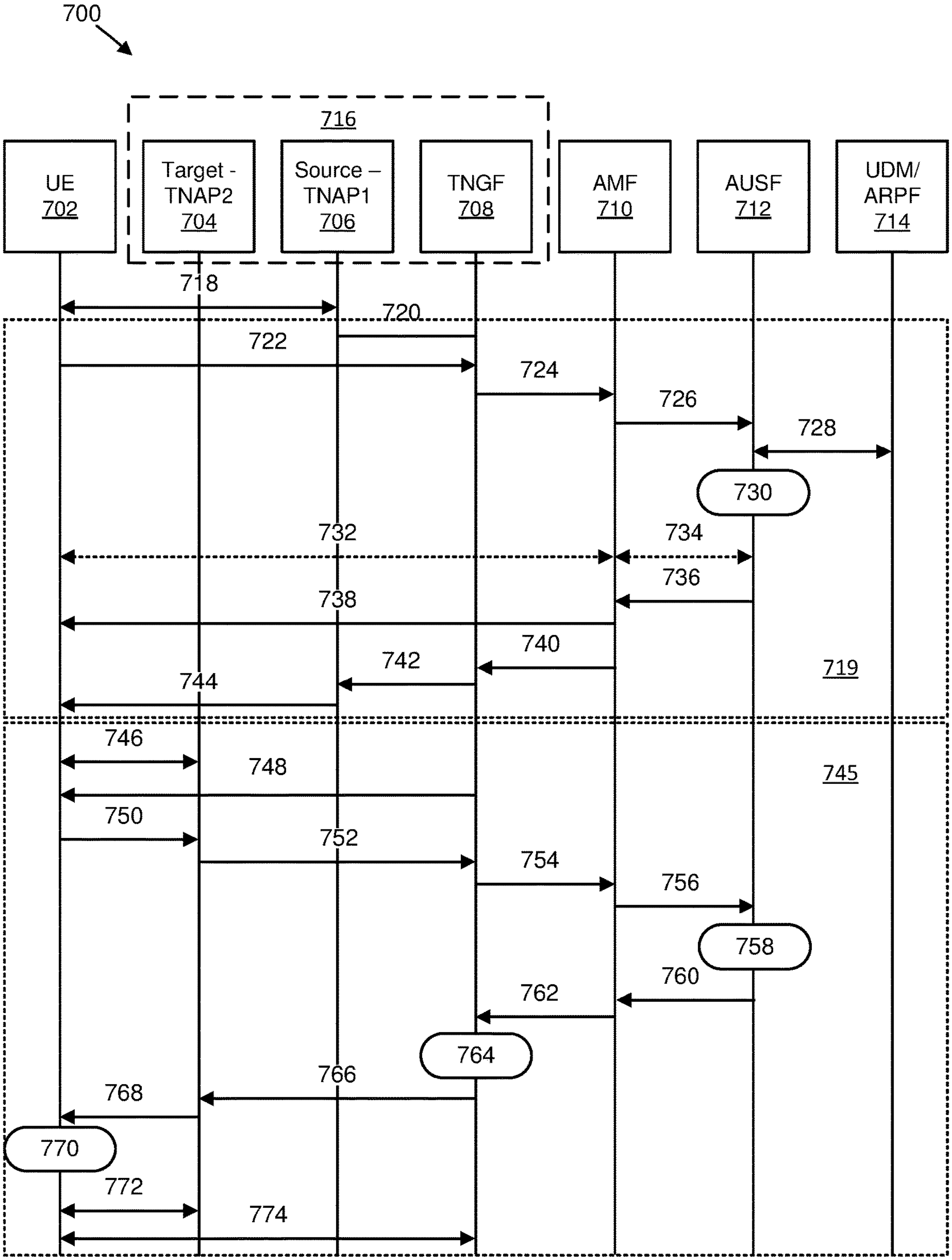
632
634
622
624
608
610
612
614

FIG. 6


700
716
UE
702
Target -
TNAP2
704
Source –
TNAP1
706
TNGF
708
AMF
710
AUSF
712
UDM/
ARPF
714
718
720
722
724
726
728
730
732
734
736
738
740
742
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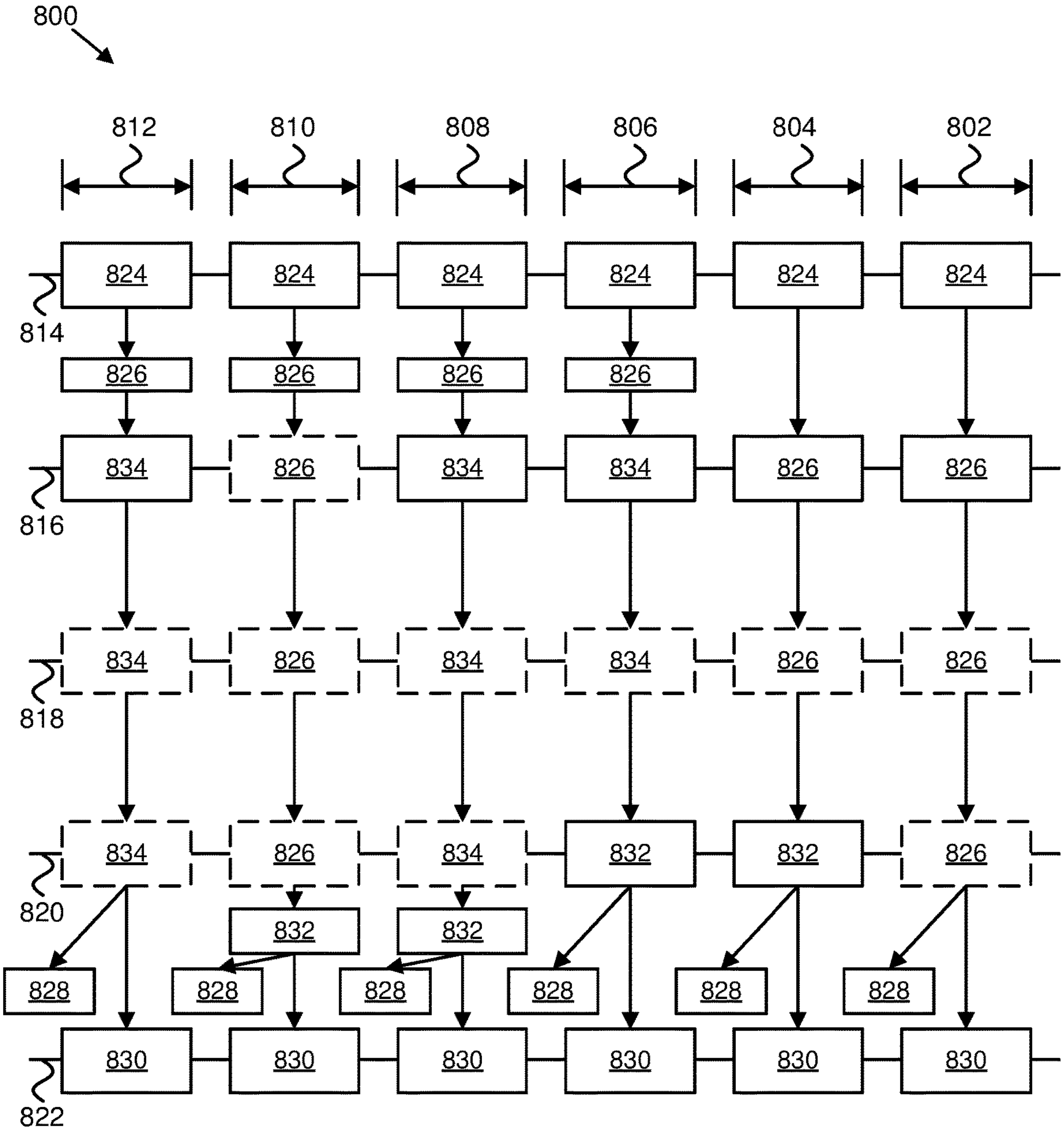
766
768
770
772
774

FIG. 7


800
812
810
808
806
804
802
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814
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820
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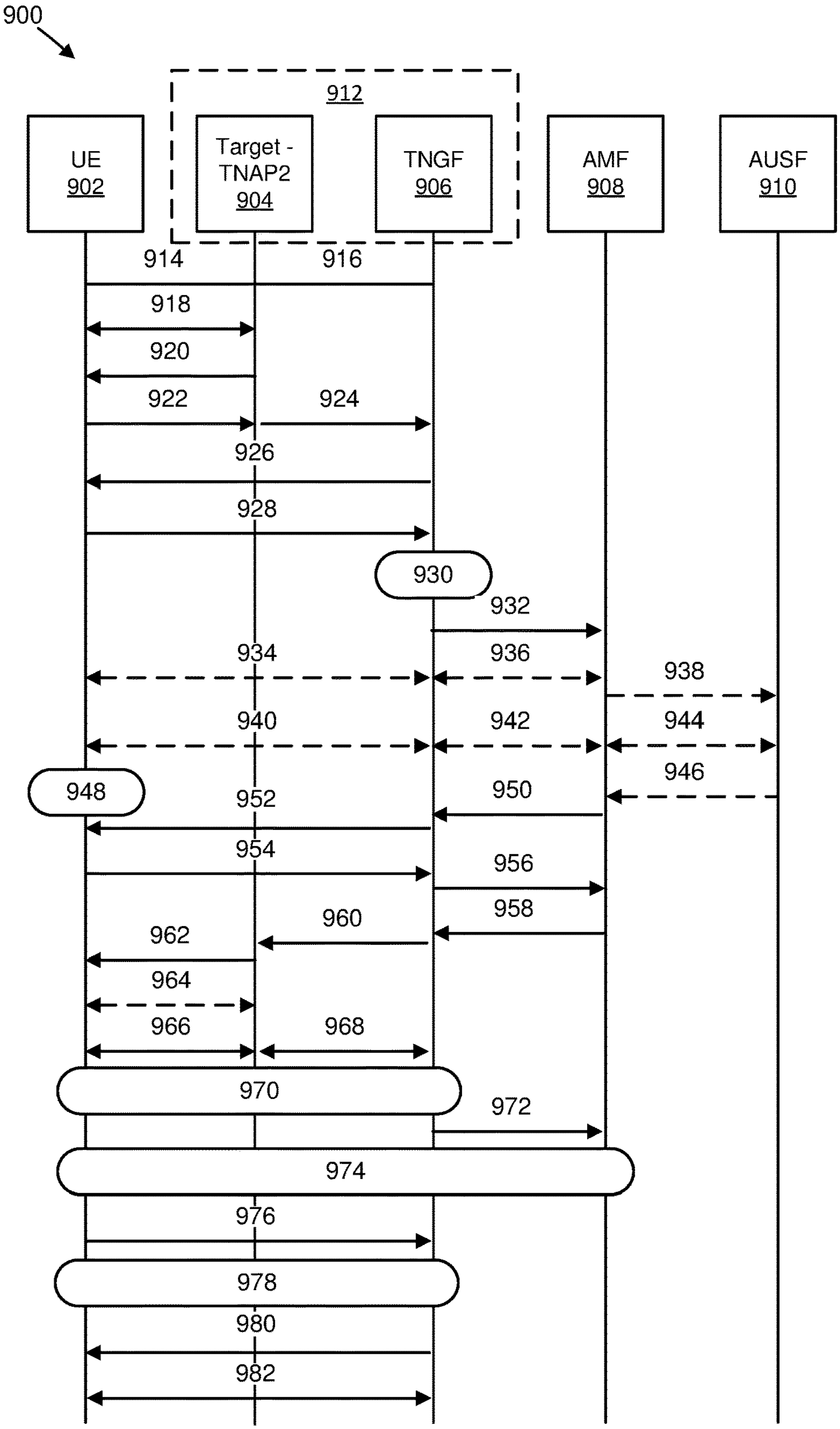
822

FIG. 8


900
912
UE
902
Target -
TNAP2
904
TNGF
906
AMF
908
AUSF
910
914
916
918
920
922
924
926
928
930
932
934
936
938
940
942
944
946
948
950
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982

FIG. 9

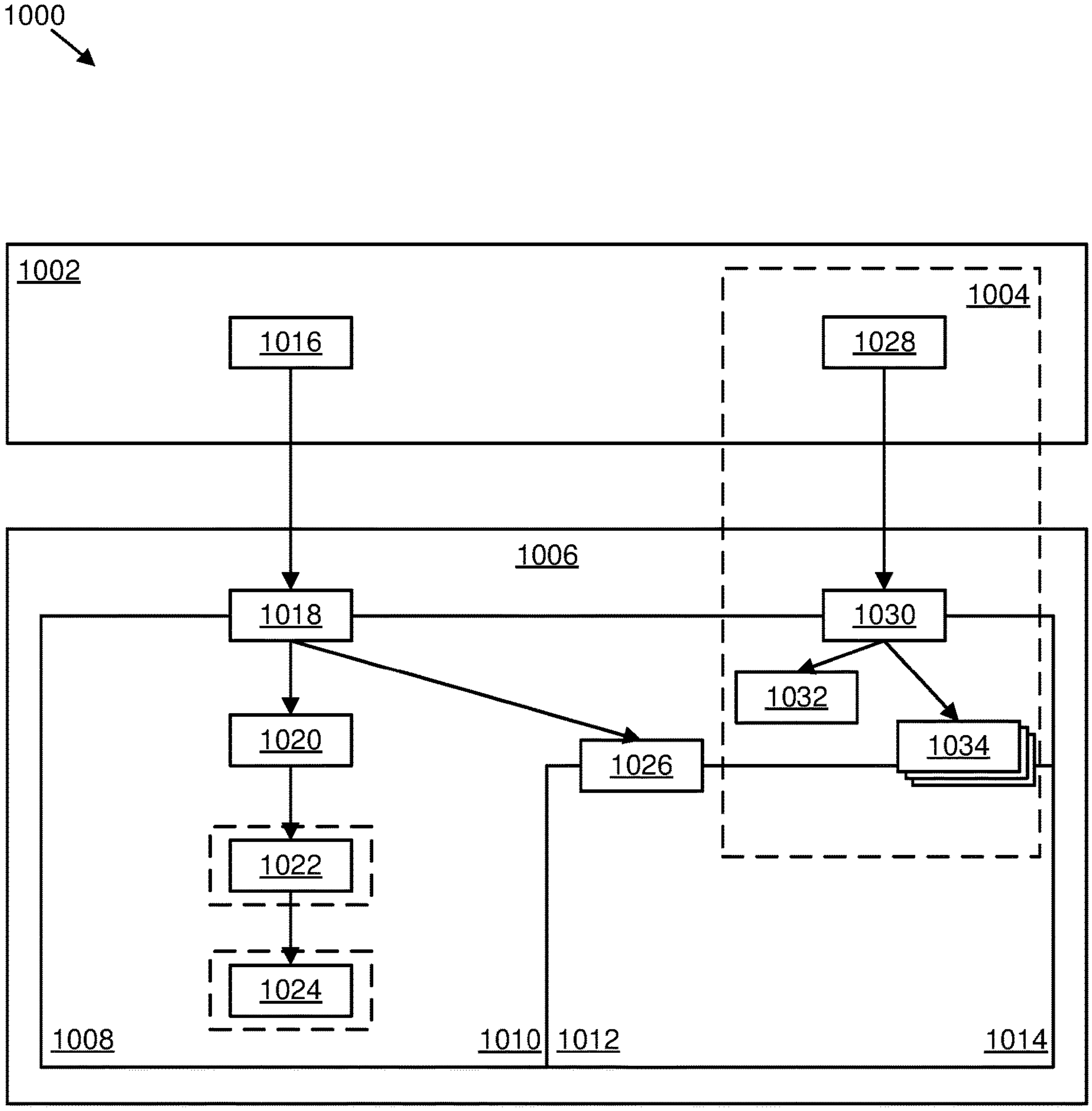
1000
1002
1004
1016
1028
1006
1018
1030
1032
1034
1020
1026
1022
1024
1008
1010
1012
1014

FIG. 10

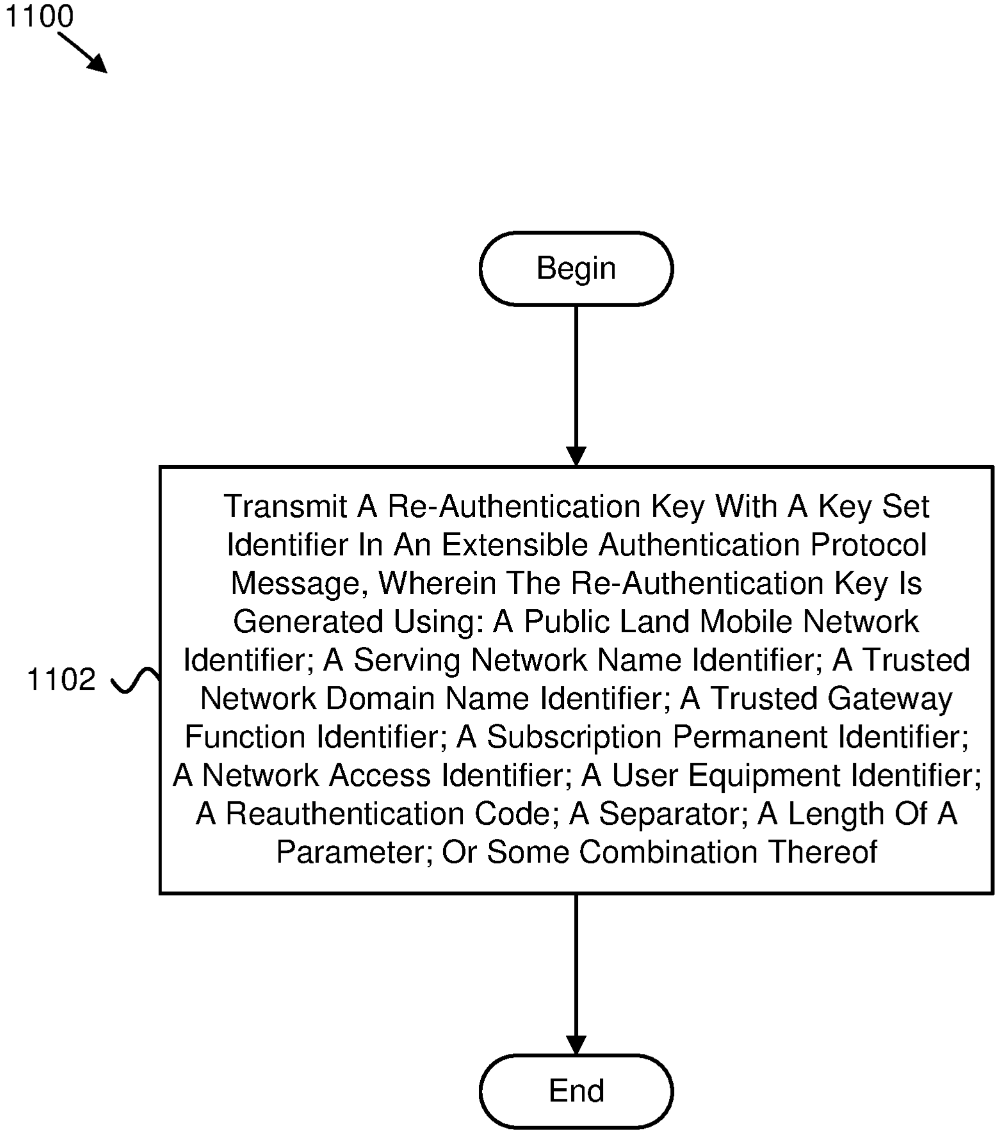
1100
Begin
1102
Transmit A Re-Authentication Key With A Key Set Identifier In An Extensible Authentication Protocol Message, Wherein The Re-Authentication Key Is Generated Using: A Public Land Mobile Network Identifier; A Serving Network Name Identifier; A Trusted Network Domain Name Identifier; A Trusted Gateway Function Identifier; A Subscription Permanent Identifier; A Network Access Identifier; A User Equipment Identifier; A Reauthentication Code; A Separator; A Length Of A Parameter; Or Some Combination Thereof
End

FIG. 11

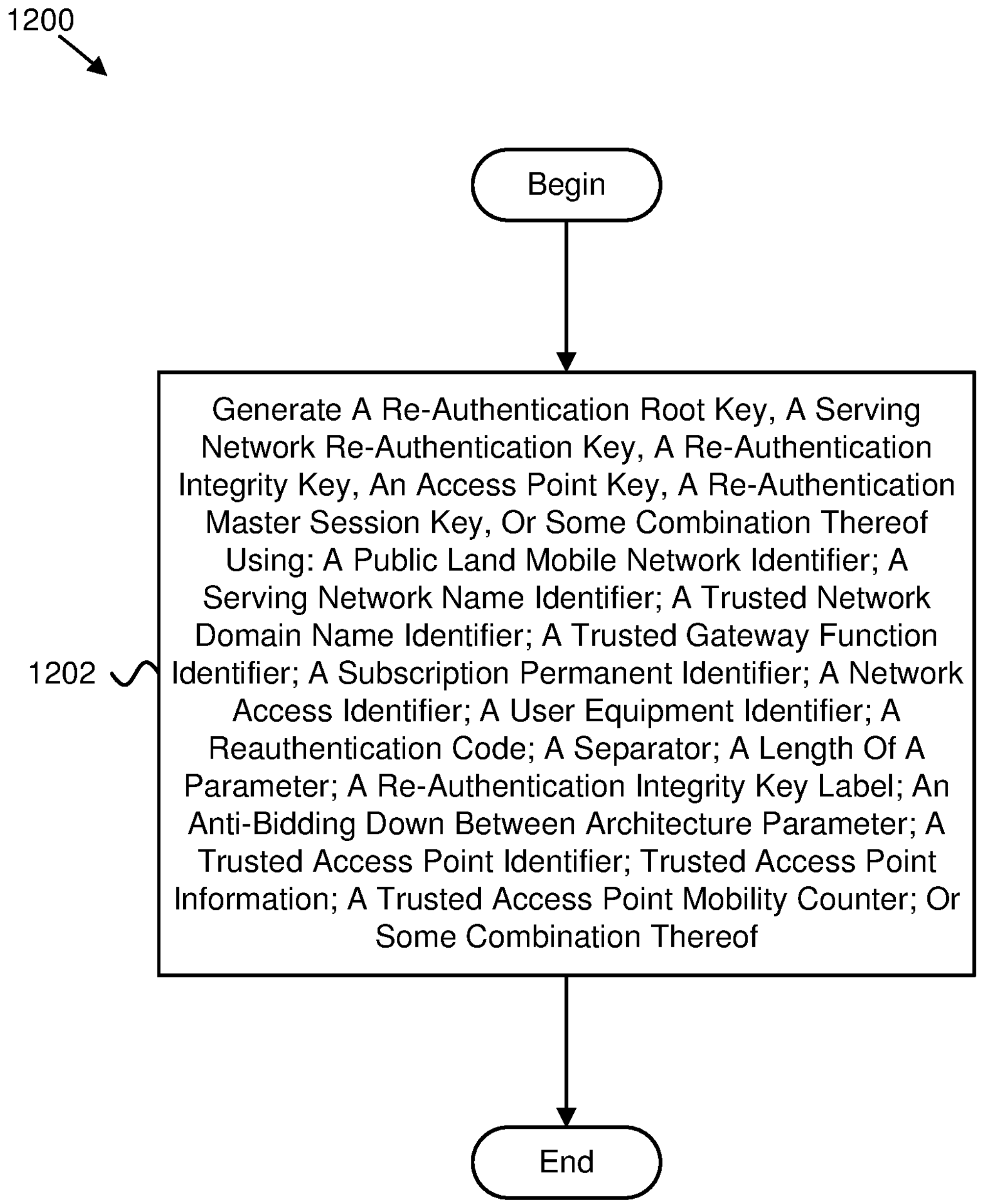
1200
Begin
Generate A Re-Authentication Root Key, A Serving Network Re-Authentication Key, A Re-Authentication Integrity Key, An Access Point Key, A Re-Authentication Master Session Key, Or Some Combination Thereof Using: A Public Land Mobile Network Identifier; A Serving Network Name Identifier; A Trusted Network Domain Name Identifier; A Trusted Gateway Function Identifier; A Subscription Permanent Identifier; A Network Access Identifier; A User Equipment Identifier; A Reauthentication Code; A Separator; A Length Of A Parameter; A Re-Authentication Integrity Key Label; An Anti-Bidding Down Between Architecture Parameter; A Trusted Access Point Identifier; Trusted Access Point Information; A Trusted Access Point Mobility Counter; Or Some Combination Thereof
1202
End

FIG. 12

RE-AUTHENTICATION KEY GENERATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application Ser. No. 62/979,334 entitled “APPARATUSES, METHODS, AND SYSTEMS FOR SECURITY CONTEXT PROVISION FOR TNAP MOBILITY IN 5G/NEXT GENERATION NETWORKS” and filed on Feb. 20, 2020 for Sheeba Backia Mary Baskaran, which is incorporated herein by reference in its entirety.

FIELD

[0002] The subject matter disclosed herein relates generally to wireless communications and more particularly relates to re-authentication key generation.

BACKGROUND

[0003] In certain wireless communications networks, encryption keys may be used. A system may provide and/or generate the encryption keys. For example, a 5G system may be used to provide and/or generate encryption keys, but the process used by the 5G system may be undetermined.

BRIEF SUMMARY

[0004] Methods for re-authentication key generation are disclosed. Apparatuses and systems also perform the functions of the methods. One embodiment of a method includes transmitting a re-authentication key with a key set identifier in an extensible authentication protocol message. The re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.

[0005] One apparatus for re-authentication key generation includes a transmitter that transmits a re-authentication key with a key set identifier in an extensible authentication protocol message. The re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.

[0006] Another embodiment of a method for re-authentication key generation includes generating a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof.

[0007] Another apparatus for re-authentication key generation includes a processor that generates a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A more particular description of the embodiments briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only some embodiments and are not therefore to be considered to be limiting of scope, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

[0009] FIG. **1** is a schematic block diagram illustrating one embodiment of a wireless communication system for re-authentication key generation;

[0010] FIG. **2** is a schematic block diagram illustrating one embodiment of an apparatus that may be used for re-authentication key generation;

[0011] FIG. **3** is a schematic block diagram illustrating one embodiment of an apparatus that may be used for re-authentication key generation;

[0012] FIG. **4** is a schematic block diagram illustrating one embodiment of a trusted network system;

[0013] FIG. **5** is a schematic block diagram illustrating one embodiment of a re-authentication key hierarchy;

[0014] FIG. **6** is a schematic block diagram illustrating another embodiment of a re-authentication key hierarchy;

[0015] FIG. **7** is a communications diagram illustrating one embodiment of communications for key generation and distribution;

[0016] FIG. **8** is a schematic block diagram illustrating a further embodiment of key hierarchy;

[0017] FIG. **9** is a communications diagram illustrating another embodiment of communications for key generation and distribution;

[0018] FIG. **10** is a schematic block diagram illustrating yet another embodiment of key hierarchy;

[0019] FIG. **11** is a flow chart diagram illustrating one embodiment of a method for re-authentication key generation; and

[0020] FIG. **12** is a flow chart diagram illustrating another embodiment of a method for re-authentication key generation.

DETAILED DESCRIPTION

[0021] As will be appreciated by one skilled in the art, aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0022] Certain of the functional units described in this specification may be labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (“VLSI”) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[0023] Modules may also be implemented in code and/or software for execution by various types of processors. An identified module of code may, for instance, include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may include disparate instructions stored in different locations which, when joined logically together, include the module and achieve the stated purpose for the module.

[0024] Indeed, a module of code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different computer readable storage devices. Where a module or portions of a module are implemented in software, the software portions are stored on one or more computer readable storage devices.

[0025] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0026] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (“RAM”), a read-only memory (“ROM”), an erasable programmable read-only memory (“EPROM” or Flash memory), a portable compact disc read-only memory (“CD-ROM”), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0027] Code for carrying out operations for embodiments may be any number of lines and may be written in any combination of one or more programming languages including an object oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the “C” programming language, or the like, and/or machine languages such as assembly languages. The code may execute entirely on the user’s computer, partly on the user’s computer, as a stand-alone software package, partly on the user’s computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user’s computer through any type of network, including a local area network (“LAN”) or a wide area network (“WAN”), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0028] Reference throughout this specification to “one embodiment,” “an embodiment,” or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment,” “in an embodiment,” and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean “one or more but not all embodiments” unless expressly specified otherwise. The terms “including,” “comprising,” “having,” and variations thereof mean “including but not limited to,” unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms “a,” “an,” and “the” also refer to “one or more” unless expressly specified otherwise.

[0029] Furthermore, the described features, structures, or characteristics of the embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of an embodiment.

[0030] Aspects of the embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. The code may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0031] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0032] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the code which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0033] The schematic flowchart diagrams and/or schematic block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods and program products according to various embodiments. In this regard, each block in the schematic flowchart diagrams and/or schematic block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0034] It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0035] Although various arrow types and line types may be employed in the flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0036] The description of elements in each figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

[0037] FIG. **1** depicts an embodiment of a wireless communication system **100** for re-authentication key generation. In one embodiment, the wireless communication system **100** includes remote units **102** and network units **104**. Even though a specific number of remote units **102** and network units **104** are depicted in FIG. **1**, one of skill in the art will recognize that any number of remote units **102** and network units **104** may be included in the wireless communication system **100**.

[0038] In one embodiment, the remote units **102** may include computing devices, such as desktop computers, laptop computers, personal digital assistants ("PDAs"), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), aerial vehicles, drones, or the like. In some embodiments, the remote units **102** include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units **102** may be referred to as subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, UE, user terminals, a device, or by other terminology used in the art. The remote units **102** may communicate directly with one or more of the network units **104** via uplink ("UL") communication signals. In certain embodiments, the remote units **102** may communicate directly with other remote units **102** via sidelink communication.

[0039] The network units **104** may be distributed over a geographic region. In certain embodiments, a network unit **104** may also be referred to and/or may include one or more of an access point, an access terminal, a base, a base station, a Node-B, an evolved node-B ("eNB"), a 5G node-B ("gNB"), a Home Node-B, a relay node, a device, a core network, an aerial server, a radio access node, an access point ("AP"), new radio ("NR"), a network entity, an access and mobility management function ("AMF"), a unified data management ("UDM"), a unified data repository ("UDR"), a UDM/UDR, a policy control function ("PCF"), a radio access network ("RAN"), a network slice selection function ("NSSF"), an operations, administration, and management ("OAM"), a session management function ("SMF"), a user plane function ("UPF"), an application function, an authentication server function ("AUSF"), security anchor functionality ("SEAF"), trusted non-3GPP gateway function ("TNGF"), or by any other terminology used in the art. The network units **104** are generally part of a radio access network that includes one or more controllers communicably coupled to one or more corresponding network units **104**. The radio access network is generally communicably coupled to one or more core networks, which may be coupled to other networks, like the Internet and public switched telephone networks, among other networks. These and other elements of radio access and core networks are not illustrated but are well known generally by those having ordinary skill in the art.

[0040] In one implementation, the wireless communication system **100** is compliant with NR protocols standardized in third generation partnership project ("3GPP"), wherein the network unit **104** transmits using an OFDM modulation scheme on the downlink ("DL") and the remote units **102** transmit on the uplink ("UL") using a single-carrier frequency division multiple access ("SC-FDMA") scheme or an orthogonal frequency division multiplexing ("OFDM") scheme. More generally, however, the wireless communication system **100** may implement some other open or proprietary communication protocol, for example, WiMAX, institute of electrical and electronics engineers ("IEEE") 802.11 variants, global system for mobile communications ("GSM"), general packet radio service ("GPRS"), universal mobile telecommunications system ("UMTS"), long term evolution ("LTE") variants, code division multiple access 2000 ("CDMA2000"), Bluetooth®, ZigBee, Sigfoxx, among other protocols. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0041] The network units **104** may serve a number of remote units **102** within a serving area, for example, a cell or a cell sector via a wireless communication link. The network units **104** transmit DL communication signals to serve the remote units **102** in the time, frequency, and/or spatial domain.

[0042] In various embodiments, a remote unit **102** and/or a network unit **104** may transmit a re-authentication key with a key set identifier in an extensible authentication protocol message The re-authentication key may be generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof. Accordingly, the remote unit **102** and/or the network unit **104** may be used for re-authentication key generation.

[0043] In certain embodiments, a remote unit **102** and/or a network unit **104** may generate a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof. Accordingly, the remote unit **102** and/or the network unit **104** may be used for re-authentication key generation.

[0044] FIG. **2** depicts one embodiment of an apparatus **200** that may be used for re-authentication key generation. The apparatus **200** includes one embodiment of the remote unit **102**. Furthermore, the remote unit **102** may include a processor **202**, a memory **204**, an input device **206**, a display **208**, a transmitter **210**, and a receiver **212**. In some embodiments, the input device **206** and the display **208** are combined into a single device, such as a touchscreen. In certain embodiments, the remote unit **102** may not include any input device **206** and/or display **208**. In various embodiments, the remote unit **102** may include one or more of the processor **202**, the memory **204**, the transmitter **210**, and the receiver **212**, and may not include the input device **206** and/or the display **208**.

[0045] The processor **202**, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor **202** may be a microcontroller, a microprocessor, a central processing unit ("CPU"), a graphics processing unit ("GPU"), an auxiliary processing unit, a field programmable gate array ("FPGA"), or similar programmable controller. In some embodiments, the processor **202** executes instructions stored in the memory **204** to perform the methods and routines described herein. The processor **202** is communicatively coupled to the memory **204**, the input device **206**, the display **208**, the transmitter **210**, and the receiver **212**.

[0046] The memory **204**, in one embodiment, is a computer readable storage medium. In some embodiments, the memory **204** includes volatile computer storage media. For example, the memory **204** may include a RAM, including dynamic RAM ("DRAM"), synchronous dynamic RAM ("SDRAM"), and/or static RAM ("SRAM"). In some embodiments, the memory **204** includes non-volatile computer storage media. For example, the memory **204** may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory **204** includes both volatile and non-volatile computer storage media. In some embodiments, the memory **204** also stores program code and related data, such as an operating system or other controller algorithms operating on the remote unit **102**.

[0047] The input device **206**, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device **206** may be integrated with the display **208**, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device **206** includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device **206** includes two or more different devices, such as a keyboard and a touch panel.

[0048] The display **208**, in one embodiment, may include any known electronically controllable display or display device. The display **208** may be designed to output visual, audible, and/or haptic signals. In some embodiments, the display **208** includes an electronic display capable of outputting visual data to a user. For example, the display **208** may include, but is not limited to, a liquid crystal display ("LCD"), a light emitting diode ("LED") display, an organic light emitting diode ("OLED") display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the display **208** may include a wearable display such as a smart watch, smart glasses, a heads-up display, or the like. Further, the display **208** may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0049] In certain embodiments, the display **208** includes one or more speakers for producing sound. For example, the display **208** may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the display **208** includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all or portions of the display **208** may be integrated with the input device **206**. For example, the input device **206** and display **208** may form a touchscreen or similar touch-sensitive display. In other embodiments, the display **208** may be located near the input device **206**.

[0050] In certain embodiments, the transmitter **210** may transmit a re-authentication key with a key set identifier in an extensible authentication protocol message. The re-authentication key may be generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; and/or a length of a parameter.

[0051] In some embodiments, the processor **202** may generate a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key and/or a re-authentication master session key using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; and/or a trusted access point mobility counter.

[0052] Although only one transmitter **210** and one receiver **212** are illustrated, the remote unit **102** may have any suitable number of transmitters **210** and receivers **212**. The transmitter **210** and the receiver **212** may be any suitable type of transmitters and receivers. In one embodiment, the transmitter **210** and the receiver **212** may be part of a transceiver.

[0053] FIG. **3** depicts one embodiment of an apparatus **300** that may be used for re-authentication key generation. The apparatus **300** includes one embodiment of the network unit **104**. Furthermore, the network unit **104** may include a processor **302**, a memory **304**, an input device **306**, a display **308**, a transmitter **310**, and a receiver **312**. As may be appreciated, the processor **302**, the memory **304**, the input device **306**, the display **308**, the transmitter **310**, and the receiver **312** may be substantially similar to the processor **202**, the memory **204**, the input device **206**, the display **208**, the transmitter **210**, and the receiver **212** of the remote unit **102**, respectively.

[0054] In certain embodiments, the transmitter **310** may transmit a re-authentication key with a key set identifier in an extensible authentication protocol message. The re-authentication key may be generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; and/or a length of a parameter.

[0055] In some embodiments, the processor **302** may generate a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key and/or a re-authentication master session key using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; and/or a trusted access point mobility counter.

[0056] In certain embodiments, if a 5G registered user equipment ("UE") moves between different access points (e.g., trusted network access point ("TNAP"), TNAP mobility) after its primary authentication with a 5G Network, a UE may be expected to perform re-authentication using an extensible authentication protocol ("EAP") re-authentication protocol ("ERP") with a trusted network gateway function ("TNGF"), if the ERP is supported by the UE and the network functions and/or entities (e.g., TNAP, TNGF, AMF and authentication server function ("AUSF")). During re-authentication, a TNGF may need to provide a target TNAP with the security context derived from a root re-authentication key ("rRK") (e.g., a key derived from security context established during primary authentication) to setup access security.

[0057] As may be appreciated, more than one TNAP key (e.g., K_{TNAP} or rMSK (when rMSK, derived from rRK either directly or indirectly, may be used as new K_{TNAP})) for different TNAPs may be derived from the same root re-authentication key ("rRK") to support TNAP mobility for a UE among several TNAPs, thus a key may be used with other TNAPs.

[0058] In various embodiments, a 5G core network ("5GC") supports both untrusted non-3GPP access networks and trusted non-3GPP access networks ("TNANs").

[0059] In some embodiments, a trusted non-3GPP access point ("TNAP") (e.g., trusted wireless LAN ("WLAN") access point) may be connected to a 5GC via a trusted non-3GPP gateway function ("TNGF"). The TNAP and the TNGF together form a trusted non-3GPP access network (TNAN) as shown in FIG. **4**. FIG. **4** is a schematic block diagram illustrating one embodiment of a trusted network system **400**. The system **400** includes a UE **402**, a TNAP1 **404**, a TNAP2 **406**, a TNAP3 **408**, a TNAPN **410**, and a TNGF **412**. A TNAN **414** includes the TNAP1 **404**, the TNAP2 **406**, the TNAP3 **408**, and the TNAPN **410**. The system **400** also includes an AMF **416** and an AUSF **418**. The TNAP1 **404** may have an rMSK1 **420** used as a K_{TNAP}. Moreover, the TNAP2 **406** may have an rMSK1 **422** used as a K_{TNAP} and an rMSK2 **424** used as a K_{TNAP}. The TNGF **412** may derive rMSKi **426** from rRK. However, key reuse of K_{TNAP} among access points may lead to a security breach in certain configurations. The AMF **416** may use an rRK **428**, and the AUSF **418** may derive an rRK **430** from an EMSK.

[0060] The TNAN enables a non-5G-capable over WLAN ("N5CW") devices or a UE to connect to a 5G network through trusted non-3GPP access. The UE connects to a TNAN and it also registers to 5GC over the TNAN by using an EAP-based procedure during a primary authentication. A UE may establish an IPsec tunnel with a TNGF to register with the 5GC over non-3GPP access. The link between the UE and the TNAN may be any data link (e.g., L2) that supports EAP encapsulation (e.g., PPP, PANA, Ethernet, IEEE 802.3, IEEE 802.11, etc.). The interface between the TNAP and TNGF may be an authorization, authentication, and accounting ("AAA") interface. When an EAP procedure is initiated, EAP messages may be encapsulated into layer-2 packets (e.g., into IEEE 802.3/802.1x packets, into IEEE 802.11/802.1x packets, into PPP packets, etc.). Network access identifier ("NAI") provided by a UE indicates that the UE requests "5G connectivity" to a specific public land mobile network ("PLMN") (e.g., NAI="<any_username>@nai.5gc.mnc<MNC>.mcc<MCC>.3gppnetwork.org"). This NAI may trigger a TNAP to send an AAA request to a TNGF which operates as an AAA proxy. Between the TNAP and TNGF, the EAP packets may be encapsulated into AAA messages. The AAA request may include a TNAP identifier ("TNAP ID") which may be treated as user location information. An EAP-5G procedure may be executed between the UE and the TNGF for the untrusted non-3GPP access if a TNGF key ("K_{TNGF}") is created in the UE and in the AMF from the K_{AMF} after successful authentication. The TNGF key may be transferred from the AMF to the TNGF (e.g., within an N2 initial context setup request). The TNGF derives a TNAP key ("K_{TNAP}") which is provided to the TNAP to setup access security. The TNAP key may depend on a non-3GPP access technology (e.g., it is a pairwise master key in IEEE 802.11).

[0061] In certain embodiments, the TNAP key ("K_{TNAP}") may be used to establish layer-2 security between a UE and TNAP. If IEEE 802.11 is used, a 4-way handshake may be executed which establishes a security context between a WLAN AP and a UE that is used to protect unicast and multicast traffic over the air.

[0062] In various embodiments, EAP re-authentication (e.g., using EAP re-authentication protocol ("ERP")) may be used for TNAP mobility in trusted access networks and may enable UEs to move from one access point to another without performing a full primary authentication. In such embodiments, for every new TNAP, a UE tries to access a new TNAP key ("K_{TNAP}") and may be provisioned by the TNGF. In some embodiments, a re-authentication security context may include a re-authentication root key ("rRK"), a re-authentication integrity key ("rIK") and access security key ("rMSK"). For a 5G system, an rMSK may be used as a K_{TNAP} to setup access security. In certain embodiments, a K_{TNAP} may be derived from rRK (e.g., either directly or indirectly) by a TNGF and a UE and may be provided to a TNAP by a TNGF.

[0063] FIG. **5** illustrates various re-authentication key derivations, specifically, FIG. **5** is a schematic block diagram **500** illustrating one embodiment of a re-authentication key hierarchy. The schematic block diagram **500** includes an rRK **502**, and an rIK **504**, an rMSK1 **506**, and an rMSKn **508** derived from the rRK **502**.

[0064] Each time a peer re-authenticates to a network, the peer and an authenticator may establish an rMSK. The rMSK may serve the same purposes of an MSK, which may be a result of full EAP authentication.

[0065] The rRK may be derived from either an EMSK or a DSRK. For the purpose of rRK derivation, derivation of a usage-specific root key ("USRK") or a domain-specific USRK ("DSUSRK") for re-authentication may be used.

[0066] The USRK designated for re-authentication may be rRK. A DSUSRK designated for re-authentication may be a DS-rRK available to a local ER server in a particular domain. For simplicity, keys may be referred to without a DS label herein. However, the scope of the various keys may not be limited to respective domains for which they are derived, in the case of domain-specific keys. Based on the ER server with which a peer performs an ERP exchange, it may know that corresponding keys may be used. rRK may be used to derive an rIK and rMSKs for one or more authenticators.

[0067] In various embodiments, there may be rRK derivation as follows: rRK=KDF (K, S), where K=EMSK or K=DSRK and S=rRK Label|"\ 0" length. The rRK label may be an IANA-assigned 8-bit ASCII string: EAP Re-authentication Root Key@ietf.org assigned from the "USRK Key Labels" name space. The key derivation function ("KDF") and algorithm agility for the KDF may be defined. An rRK derived from a DSRK may be referred to as a DS-rRK.

[0068] In certain embodiments, there may be rIK derivation as follows: rIK=KDF (K, S), where K=rRK and S=rIK Label|"\0" cryptosuite length. The rIK label may be an 8-bit ASCII string: Re-authentication Integrity Key@ietf.org. The length field may refer to a length of the rIK in octets and may be encoded. The cryptosuite and length of the rIK may be part of the input to the KDF to ensure cryptographic separation of keys if different rIKs of different lengths (e.g., for use with different message authentication code ("MAC") algorithms) may be derived from the same rRK. The cryptosuite may be encoded as an 8-bit number. The rIK may be referred to by the EMSKname-NAI within the context of ERP messages. The username part of the EMSKname-NAI may be the EMSKname. The realm may be the domain name of the ER server. If ERP is used with a home ER server, a peer uses the realm from its original NAI. If a local ER server is used, a peer uses a domain name received at a lower layer or through an ERP bootstrapping exchange. An rIK derived from a DS-rRK may be referred to as a DS-rIK.

[0069] In some embodiments, the EAP keying framework may indicate that the EMSK must be named using the EAP Session-ID and a binary or textual indication. Following that requirement, the EMSK name may be derived as follows: EMSKname=KDF (EAP Session-ID, "EMSK"|"\0"length) where: | denotes concatenation "EMSK" consists of the 4 ASCII values for the letters "\0"=is a NULL octet (0x00 in hex) length is the 2-octet unsigned integer 8 in network byte order. In certain embodiments, keys derived from the EMSK may be referred to by the EMSK name and the context of the descendant key usage.

[0070] In various embodiments, there may be rMSK derivation in which the rMSK is derived at a peer and server and delivered to an authenticator. The rMSK may be derived following an ERP exchange. The rMSK may be derived as follows: rMSK=KDF (K, S), where K=rRK and S=rMSK Label|"\0"|SEQ|length. The rMSK label may be an 8-bit ASCII string: Re-authentication Master Session Key@ietf.org. The length field may refer to a length of the rMSK in octets and may be encoded. In some embodiments, SEQ is the sequence number sent by the peer in the EAP-Initiate and/or re-authenticate message. This field may be encoded as a 16-bit number in network byte order. In certain embodiments, SEQ may be an unsigned 16-bit sequence number used for replay protection. The SEQ field may be initialized to 0 every time a new rRK is derived. The field may be encoded in network byte order. An rMSK derived from a DS-rRK may be referred to as a DS-rIK herein.

[0071] FIG. **6** is a schematic block diagram **600** illustrating another embodiment of a re-authentication key hierarchy. The schematic block diagram **600** illustrates an AMF **602**, a first ME **604**, trusted non-3GPP ("N3GPP") access keys **606**, a TNGF **608**, a second ME **610**, a TNAP **612**, and a third ME **614**. The AMF **602** may transmit a K_{TNGF} **616** to the trusted N3GPP access keys **606**. The trusted N3GPP access keys **606** may use a K_{TNGF} **618** to derive a K_{TIPsec} **620** used to setup IPSec security association ("SA") **622** which is used to setup child SAs **624**. The K_{TNGF} **618** may also be used to derive K_{TNAP} **626**. The AMF **602** may transmit an rRK **628** to the TNGF **608**. The TNGF **608** may use an rRK **630** to derive rIK **632** and to derive rMSKi **634**. Moreover, the third ME **614** derives rIK **632** and rMSKi **634** from the rRK **630**.

[0072] In some embodiments, various inputs may be used for re-authentication security context derivation (e.g., rRK, sRK, K_{TNGF}, K_{TNAN}, rIK, rMSK, and/or K_{TNAP} keys) following a re-authentication layout, such as in Figure.

[0073] FIG. **7** is a communications diagram illustrating one embodiment of communications **700** for key generation and distribution. The communications **700** include messages transmitted between a UE **702**, a target-TNAP2 **704**, a source-TNAP1 **706**, a TNGF **708**, an AMF **710**, an AUSF **712**, and a UDM/authentication credential repository and processing function ("ARPF") **714**. The target-TNAP2 **704**, the source-TNAP1 **706**, and the TNGF **708** may all be part of a TNAN **716**. As may be appreciated, any of the communications **700** may include one or more messages.

[0074] In some embodiments, the communications **700** involved in an ERP based re-authentication following a primary authentication are described with pre-requisite communications corresponding to primary authentication.

[0075] In a first communication **718** transmitted between the UE **702** and the source-TNAP1 **706**, layer-2 ("L2") connection setup is performed. The communications **700** include a successful primary authentication using an EAP method **719**. Moreover, in a second communication **720** transmitted from the source-TNAP1 **706** to the TNGF **708**, the source-TNAP1 **706** transmits over an AAA interface.

[0076] Specifically, in the first communication **718** and the second communication **720**, the UE **702** selects a PLMN and the TNAN **716** using a trusted non-3GPP access network selection procedure and an L2 connection is establishment between the UE **702** and the TNAP (e.g., the source-TNAP1 **706**). An EAP authentication procedure is initiated and the EAP messages are encapsulated into the L2 packets. The UE **702** provides an NAI that triggers the TNAP to send an AAA request to the TNGF **708**. Between the TNAP and the TNGF **708** the EAP packets are encapsulated into AAA messages.

[0077] In a third communication **722** transmitted from the UE **702** to the TNGF **708**, the UE **702** transmits a registration request over an L2 interface to the TNGF **708**. Moreover, in a fourth communication **724** transmitted from the TNGF **708** to the AMF **710**, the TNGF **708** transmits the registration request over an N2 interface to the AMF **710**. Specifically, in the third communication **722** and the fourth communication **724**, an EAP-5G procedure is executed over the L2 connection and the UE **702** sends the registration request message over the L2 interface to the TNGF **708** and the TNGF **708** forwards the registration request received from the UE **702** to the AMF **710** over the N2 interface with a TNGF ID. If the AMF **710** receives a 5G globally unique temporary identifier ("5G-GUTI") and the registration is integrity protected, the AMF **710** may use the security context to verify the integrity protection.

[0078] In a fifth communication **726** transmitted from the AMF **710** to the AUSF **712**, if the AMF **710** decides to authenticate the UE **702**, the AMF **710** sends a key request (e.g., AAA key request, subscription permanent identifier ("SUPI"), subscription concealed identifier ("SUCI")) to the AUSF **712** along with the TNGF ID. In a sixth communication **728** transmitted between the AUSF **712** and the UDM/ARPF **714**, the AUSF **712** may initiate an authentication procedure (e.g., authentication request and/or response) involving the UDM/ARPF **714** using either EAP-AKA' or 5G AKA. Between the AMF **710** and the UE **701**, authentication packets are encapsulated within non-access stratum ("NAS") authentication messages and the NAS authentication messages are carried in N2 signaling between the AMF **710** and the TNGF **708**, and then are encapsulated within EAP-5G/5G-NAS packets between the TNGF **708** and the UE **702**.

[0079] In a final authentication message from the home network, considering the trusted access based indicator and/or TNGF identifier ("ID") if the authentication selected and executed is EAP-AKA' by the UDM/ARPF **714**, and if the UDM indicates to AUSF **712** that EAP-AKA' is selected as the authentication method, the AUSF **712** assigns **730** an indicator next generation ("NG") Re-authentication Key Set ID ("ng-RKSI") to identify the EMSK for later use such as a re-authentication use case and stores the EMSK locally. In a seventh communication **732** transmitted between the UE **702** and the AMF **710**, and in an eighth communication **734** transmitted between the AMF **710** and the AUSF **712**, authentication and/or key agreement messages may be transmitted.

[0080] In a ninth communication **736** transmitted from the AUSF **712** to the AMF **710**, the AUSF **712** then sends the derived re-authentication security context identifier ng-RKSI along with the anchor key K_{SEAF} derived from K_{AUSF} to the security anchor functionality ("SEAF") in a key response message. As may be appreciated, rRK may also be sent along with the ng-RKSI.

[0081] The SEAF may derive the K_{AMF} from K_{SEAF} and send K_{AMF} to the AMF **710** which is used by the AMF **710** to derive NAS security keys along with ng-RKSI. It should be noted that the AMF **710** may receive rRK along with ng-RKSI. If EAP-AKA' is used for authentication, then the AUSF **710** also include an EAP success indicator. The UE **702** also derives the anchor key K_{SEAF} and from that key it derives the K_{AMF} followed by NAS security keys. In a tenth communication **738** transmitted from the AMF **710** to the UE **702**, the AMF **710** sends a security mode command ("SMC") to the UE **702** to activate NAS security. The tenth communication **738** may be first sent to the TNGF **708** (within an N2 message). If EAP-AKA' is used for authentication, the AMF **710** encapsulates the EAP success indicator received from the AUSF **710** within the SMC message.

[0082] The TNGF **708** forwards the NAS SMC to the UE **702** within an EAP-Request/5G-NAS packet. The UE **702** completes the authentication and creates an NAS security context or activates another one based on the received ngKSI in the NAS SMC. The UE **702** encapsulates the NAS SMC complete in the EAP-5G response. The TNGF **708** forward the NAS packet containing NAS SMC complete to the AMF **710** over the N2 interface.

[0083] The AMF **710**, upon reception of the NAS SMC complete from the UE **702** or upon success of integrity protection verification, initiates the next generation application protocol ("NGAP") procedure to setup the AN context. In an eleventh communication **740** transmitted from the AMF **710** to the TNGF **708**, the AMF **710** further compute the TNGF key ("K_{TNGF}") and sends K_{TNGF} and ng-RKSI received from the AMF **710** in an NGAP initial context setup request to the TNGF **708**. The AMF **710** may also provide rRK with the ng-RKSI.

[0084] In a twelfth communication **742** transmitted from the TNGF **708** to the source-TNAP1 **706**, the TNGF **708** sends an EAP-Success/EAP-5G toward the UE **702** upon reception of the NGAP initial context setup request containing the TNGF key, K_{TNGF}, and ng-RKSI. This completes the EAP-5G session and no further EAP-5G packets are exchanged. If the TNGF **708** does not receive the K_{TNGF} from the AMF **710**, the TNGF **708** responds with an EAP-Failure. The TNGF **708** locally stores ng-RKSI to support ERP based re-authentication. The TNGF **708** may also store rRK with ng-RKSI.

[0085] The TNGF **708** derives TNAP key ("K_{TNAP}") from K_{TNGF} and sends the TNAP Key (K_{TNAP}) to the source-TNAP1 **706** over the AAA interface along with the EAP success message. In a thirteenth communication **744** transmitted from the source-TNAP1 **706** to the UE **702**, the source-TNAP1 **706** uses the K_{TNAP} to derive keys for security establishment between the UE **702** and the source-TNAP1 **706** and the source-TNAP1 **706** transmits the EAP success message over L2 (including the ng-RKSI). The common TNAP key may be used by the UE **702** and the TNAP (e.g., source-TNAP1 **706**) to derive security keys according to an applied non-3GPP technology and to establish a security association to protect all subsequent traffic. If IEEE 802.11 is used, the K_{TNAP} is a pairwise master key ("PMK") and a 4-way handshake may be executed which establishes a security context between a WLAN AP and the UE **702** that is used to protect unicast and multicast traffic over the air. All messages between the UE **702** and the TNAP may be encrypted and integrity protected from this step onwards.

[0086] In some embodiments, the UE **702** receives an internet protocol ("IP") configuration from the TNAN **716** (e.g., with dynamic host configuration protocol ("DHCP")). The UE **702** may initiate an IKE_INIT exchange with the TNGF **708**. In various embodiments, the UE **702** has received an IP address of the TNGF **708** within EAP-5G signaling In such embodiments, the UE **702** may initiate an IKE_AUTH exchange and provide its SUPI or 5G-GUTI identity. The common K_{TNGF} may be used for mutual authentication. NULL encryption may be negotiated. An IPsec SA may be established between the UE **702** and the TNGF **708** (e.g., an NWt connection—NWt may be a reference point between the UE **702** and the TNGF **708**—a secure NWt connection may be established over this reference point — NAS messages between the UE **702** and the AMF **710** may be transferred via the NWt connection) and may be used to transfer all subsequent NAS messages. The IPsec SA may not apply encryption but may only apply integrity protection. After the NWt connection is successfully established, the TNGF **708** responds to the AMF **710** with an N2 initial context setup response message. Finally, the NAS registration accept message may be sent by the AMF **710** and may be forwarded to the UE **702** via the established NWt connection along with ng-RKSI and TNGF ID. The UE **702** may locally store the ng-RKSI and TNGF ID.

[0087] If the UE **702** moves from a current TNAP to a different TNAP and if the TNGF **708** remains the same, an ERP based re-authentication procedure **745** may be used.

[0088] In a fourteenth communication **746** transmitted between the UE **702** and the target-TNAP2 **704** and in a fifteenth communication **748** transmitted from the TNGF **708** to the UE **702**, in response to the UE **702** moving to a new target TNAP which belongs to the same ERP domain as the domain of the source-TNAP1 **706**, an EAP re-authentication procedure may be initiated (e.g., via L2 connection setup). The UE **702** informs the target-TNAP2 **704** that it supports ERP. The TNAP (e.g., TNGF **708**) sends the EAP-Initiate and/or re-authentication start message to the UE **702** along with target TNAP ID.

[0089] In a sixteenth communication **750** transmitted from the UE **702** to the target-TNAP2 **704**, the UE **702** sends a registration request in an EAP-Initiate and/or re-authentication request over the L2 connection to the target-TNAP2 **704** with the ng-RKSI.

[0090] In a seventeenth communication **752** transmitted from the target-TNAP2 **704** to the TNGF **708**, the target-TNAP2 **704** forwards the registration request to the TNGF **708** over the AAA interface along with the ng-RKSI (e.g., in an EAP-Initiate and/or re-authentication request). In certain embodiments, the communications **700** may end here and one or more of the following communications **700** (e.g., **754**, **756**, **758**, **760**, **762**) may not occur.

[0091] In an eighteenth communication **754** transmitted from the TNGF **708** to the AMF **710**, the TNGF **708** sends the AMF **710** an N2 NAS registration request (e.g., in an EAP-Initiate and/or re-authentication request) with an ERP Request, the TNGF ID, and the ng-RKSI which indicates that an EAP re-authentication root key ("rRK") is needed.

[0092] In a nineteenth communication **756** transmitted from the AMF **710** to the AUSF **712**, the AMF **710** sends an AAA key request (e.g., in an EAP-Initiate and/or re-authentication request) to the AUSF **712** along with the SUPI, the received TNGF ID, and the ng-RKSI.

[0093] The AUSF **712** fetches **758** the EMSK corresponding to the ng-RKSI. The AUSF **712** then may use the TNGF ID, if available, and the EMSK to derive a domain specific root key ("DSRK") and derives the rRK from the EMSK (or DSRK, if available) as specified in an rRK derivation or the 256 least significant bits of EMSK are taken as rRK. The AUSF **712** may derive a serving network re-authentication key ("sRK") as specified in an sRK derivation.

[0094] In a twentieth communication **760** transmitted from the AUSF **712** to the AMF **710**, the AUSF **712** provides the SEAF Key, rRK, DSRK, rSK, and/or an EAP success indication in an AAA key response message along with an EAP-Initiate and/or re-authentication response.

[0095] In a twenty-first communication **762** transmitted from the AMF **710** to the TNGF **708**, the AMF **710** provides an N2 registration response to the TNGF **708** along with the received re-authentication security context including rRK, DSRK, sRK, and/or K_{TNGF} (e.g., with an EAP-Initiate and/or re-authentication response).

[0096] The TNGF **708** derives **764** the rIK, the rMSK, and/or the TNAP key ("KTNAP") specific to the TNAP ID from the rRK, DSRK, and/or sRK based on the key derivation inputs described herein.

[0097] The EAP-Initiate and/or re-authentication request and/or response may be integrity protected using the re-authentication integrity keys ("rIK") created independently in the UE **702** and in the TNGF **708**. If these integrity keys are the same, the EAP re-authentication procedure may be successful and the TNGF **708** may derive the K_{TNAP} (specific to the target TNAP) and the re-authentication MSK ("rMSK") (e.g., K_{TNAP} key is used to establish a security context between the UE **702** and the target-TNAP2 **704** to setup access security).

[0098] In a twenty-second communication **766** transmitted from the TNGF **708** to the target-TNAP2 **704**, the TNGF **708** sends the EAP-Finish and/or re-authentication message in an AAA interface to the target-TNAP2 **704** along with the derived TNAP key to setup access security (e.g., with the rMSK).

[0099] In a twenty-third communication **768** transmitted from the target-TNAP2 **704** to the UE **702**, the target-TNAP2 **704** sends an EAP-Finish and/or re-authentication success message to the UE **702**.

[0100] The UE **702**, on receiving an ERP success message, derives **770** the EAP re-authentication keys such as rRK, DSRK, sRK, and/or rIK. The UE **702** also derives the K_{TNAP} (e.g., specific to the target-TNAP2 **704** using TNAP ID in K_{TNAP} key derivation), and the K_{TNAP} is defined to be used as rMSK.

[0101] In a twenty-fourth communication **772** transmitted between the UE **702** and the target-TNAP2 **704**, security establishment using derived keys is performed. The IP address allocated to the UE **702** may not change during a mobility event. Therefore, in a twenty-fifth communication **774** transmitted between the UE **702** and the TNGF **708**, the UE **702** may use the same IP address to resume communication with the TNGF **708** over the existing NWt connection.

[0102] FIG. **8** is a schematic block diagram **800** illustrating a further embodiment of key hierarchy. The schematic block diagram **800** includes a first option **802**, a second option **804**, a third option **806**, a fourth option **808**, a fifth option **810**, and a sixth option **812** for key derivation. The steps of the key derivation may be performed by an AUSF and UE **814** of a home public land mobile network ("HPLMN"), an SEAF and UE **816** of a visiting public land mobile network ("VPLMN"), an AMF and UE **818**, a TNGF and UE **820**, and a TNAP and UE **822**. The keys that are part of the key derivation include an extended master session key ("EMSK") **824** that is derived and provisioned during primary authentication, and the following keys that are derived during ERP re-authentication: re-authentication root key ("rRK") and/or DSRK **826**, re-authentication integrity key ("rIK") **828**, re-authentication master session key ("rMSK") and/or TNAP key ("K_{TNAP}") **830**, re-authentication root key ("K_{RTNGF}") **832**, and serving network re-authentication key ("sRK") **834**.

[0103] The key derivation shown in FIG. **8** is elaborated herein with inputs required for every key generation involved in the key hierarchy along with locations of key generation. The boxes in FIG. **8** with dotted lines show only key transport and not key derivation. The locations of key derivations are shown with solid lines.

[0104] In some embodiments corresponding to DSRK derivation, a domain name is used as an input and a remaining key derivation may be the same as for rRK derivation.

[0105] In the first option **802** rRK derivation may be by AUSF and ME and/or UE: rRK and/or DSRK **826** is the 256 least significant bits of EMSK **824**.

[0106] In the second option **804** rRK derivation may be by AUSF and ME and/or UE: rRK: KDF (K, S), where K=EMSK, and S may be one or more of the following parameters: PLMN ID, serving network name ("SN Name"), trusted network domain name, TNGF ID, SUPI, NAI, UE ID, re-authentication code, rRK label, separator "\0", and/or length of each 'S' parameter. As may be appreciated, rRK may be derived by the AUSF and ME using EMSK and one or more of the above inputs to a key derivation function ("KDF").

[0107] In the third option **806**: derived only by SEAF and UE: rRK: KDF (K, S), where $K=K_{SEAF}$, and S may be one or more of the following parameters: SN Name, trusted network domain name, TNGF ID, SUPI, NAI, UE ID, re-authentication code, rRK label, separator "\0", and/or length of each 'S' parameter. It should be noted that rRK may be derived by the AUSF and ME using EMSK and one or more of the above inputs to the KDF.

[0108] In various embodiments, sRK derivation may be performed by AUSF and/or SEAF and ME and/or UE (e.g., derived optionally considering home network policy if the HPLMN does not prefer to provide rRK to the VPLMN) and may be as follows: sRK: KDF (K, S), where K=rRK and/or DSRK, and S may be one or more of the following parameters: SN Name, trusted network domain name, TNGF ID, SUPI, NAI, UE ID, re-authentication code, rSK label, separator "\0", and/or length of each 'S' parameter.

[0109] In some embodiments, rIK derivation may be by TNGF and ME and/or UE and may be as follows: rIK: KDF (K, S), where K=rRK, DSRK, sRK, and/or K_{RTNGF}, and S may be one or more of the following parameters: TNGF ID, UE ID, re-authentication code, rIK label, anti-bidding down between architectures ("ABBA") parameter, separator "\0", and/or length of each 'S' parameter. As may be appreciated, TNGF and/or TNAN re-authentication key ("K_{RTNGF}") generation may be done by an access and mobility management function ("AMF") from sRK, rRK, and/or DSRK provided by an AUSF through SEAF. Similarly, a UE and/or ME may derive K_{RTNG} as a network.

[0110] In certain embodiments, rMSK or TNAP key derivation may be performed by TNGF and ME and/or UE.

[0111] In one embodiment, rMSK and/or K_{TNAP} may be derived from rRK and/or DSRK provided by an AUSF in which: rMSK: KDF (K, S), where K=rRK, and S can be any one or more of the following parameters: TNAP ID, TNAP specific information, TNAP mobility counter, ABBA parameter, separator "\0", and/or length of each 'S' parameter. In such embodiments, the TNAP mobility counter may be initialized to 0 at the UE and the TNGF. For every new rMSK and/or TNAP key generation from the same rRK, the TNAP mobility counter may be incremented by both the UE and the TNGF.

[0112] In another embodiment, rMSK and/or K_{TNAP} may be derived from a K_{RTNGF} key provided by an AMF. AUSF may derive rRK and/or DSRK and may provide rRK and/or DSRK to the AMF. The AMF may derive K_{RTNGF} from rRK. K_{TNGF}: KDF (rRK, sRK, and/or DSRK, TNGF ID), rMSK: KDF (K, S), where $K=K_{RTNGF}$, and S may be one or more of the following parameters: TNAP ID, TNAP specific information, TNAP mobility counter, separator "\0", and/or length of each 'S' parameter. In such embodiments, the TNAP mobility counter may be synchronized by the TNGF with the UE by sending the TNAP mobility counter to the UE (e.g., in AAA along with an EAP and/or ERP success message or during any ERP request message).

[0113] In some embodiments, rMSK and/or K_{TNAP} may be derived from rRK, TNGF may provide TNGF ID to AUSF, AUSF may derive rRK including TNGF ID or AMF PLMN ID in KDF, AUSF may provide rRK to AMF and TNGF, and/or TNGF derives rMSK from rRK in which rMSK: KDF (K, S), where K=rRK, and S may be one or more of the following parameters: TNAP ID, TNAP specific information, TNAP mobility counter, ABBA parameter, SEQ, separator "\0", and/or a length of each 'S' parameter.

[0114] In certain embodiments, rRK may be derived in AUSF and used with TNAP ID to derive rMSK in TNGF.

[0115] FIG. **9** is a communications diagram illustrating another embodiment of communications **900** for key generation and distribution. The communications **900** include messages transmitted between a UE **902**, a target-TNAP2 **904**, a TNGF **906**, an AMF **908**, and an AUSF **910**. The target-TNAP2 **904** and the TNGF **906** may all be part of a TNAN **912**. As may be appreciated, any of the communications **900** may include one or more messages.

[0116] In a first communication **914** transmitted between the UE **902** and the target-TNAP2 **904**, L2 interface based communications may be made (e.g., Ethernet, 902.3, 902.11, PPP). In a second communication **916** transmitted between the target-TNAP2 **904** and the TNGF **906** communications may be made over an AAA interface.

[0117] In a third communication **918** transmitted between the UE **902** and the target-TNAP2 **904**, an L2 connection may be established. In a fourth communication **920** transmitted from the target-TNAP2 **904** to the UE **902**, the target-TNAP2 **904** may transmit an EAP request and/or identify message to the UE **902** using the L2 interface. In a fifth communication **922** transmitted from the UE **902** to the target-TNAP2 **904**, the UE **902** may transmit an EAP response and/or identify (e.g., including username@realm) message to the target-TNAP2 **904** using the L2 interface. In a sixth communication **924** transmitted from the target-TNAP2 **904** to the TNGF **906**, the target-TNAP2 **904** may forward the EAP response and/or identify message to the TNGF **906** using the AAA interface.

[0118] In a seventh communication **926** transmitted from the TNGF **906** to the UE **902**, the TNGF **906** may transmit an EAP request and/or 5G start message to the UE **902** using the L2 interface. In an eighth communication **928** transmitted from the UE **902** to the TNGF **906**, the UE **902** may transmit an EAP response and/or 5G NAS message to the TNGF **906** using the L2 interface. The EAP response and/or 5G NAS message may include AN parameters (e.g., single network slice selection assistance information ("S-NSSAI"), SUCI, 5G-GUTI, etc.) and/or NAS-PDU information (e.g., registration request). In certain embodiments, the communications **900** may end here and one or more of the following communications **900** (e.g., **932**, etc.) may not occur.

[0119] The TNGF **906** may perform **930** an AMF selection. In a ninth communication **932** transmitted from the TNGF **906** to the AMF **908**, the TNGF **906** may transmit an N2 message (e.g., registration request). If the trusted non-3GPP access network supports ERP, then the TNGF **906** may send an ERP request together with the registration request to the AMF **908**.

[0120] In a tenth communication **934** (optional) transmitted between the UE **902** and the TNGF **906**, an EAP request, response, 5G NAS, and/or NAS protocol data unit ("PDU") (e.g., identity request and/or response) may be transmitted. In an eleventh communication **936** (optional) transmitted between the TNGF **906** and the AMF **908**, an N2 message (e.g., identity request and/or response) may be transmitted.

[0121] In a twelfth communication **938** (optional) transmitted from the AMF **908** to the AUSF **910**, the AMF **908** may transmit an AAA key request to the AUSF **910** (e.g., SUPI, SUCI) (e.g., message from the ninth communication **932** forwarded from the AMF **908** to the AUSF **910**).

[0122] The AUSF **910** may not send a response to an ERP request if it does not support ERP or if it selects 5G-AKA as an authentication method. The AUSF **910** only sends a response if it supports ERP and the selected authentication method is EAP-AKA'. In such a case, the AUSF **910** derives the EAP re-authentication root key rRK from the EMSK and provides it to the AMF **908** together with an SEAF key in communication **946**. The rRK key is further send from the AMF **908** to the TNGF **906** together with the TNGF **906** key in communication **958**.

[0123] If the TNGF **906** sends an ERP request but does not receive an rRK in communication **958**, then the ERP exchange cannot be performed and the UE **902** may initiate a full re-authentication after moving to a new TNAP.

[0124] The TNGF **906** may derive the rIK and rMSK from the rRK per TNAP and the UE **902** may derive the keys accordingly as well.

[0125] In a thirteenth communication **940** transmitted between the UE **902** and the TNGF **906**, a fourteenth communication **942** transmitted between the TNGF **906** and the AMF **908**, and/or a fifteenth communication **944** transmitted between the AMF **908** and the AUSF **910**, authentication and/or key agreement information may be transmitted and/or received.

[0126] In a sixteenth communication **946** transmitted from the AUSF **910** to the AMF **908**, the AUSF **910** may transmit an AAA key response to the AMF **908** (e.g., SEAF key, EAP success message). The UE **902** may create **948** TNGF and/or TNAP keys.

[0127] In a seventeenth communication **950** transmitted from the AMF **908** to the TNGF **906**, the AMF **908** may transmit an N2 message (e.g., SMC request, EAP success message) to the TNGF **906**. In an eighteenth communication **952** transmitted from the TNGF **906** to the UE **902**, the TNGF **906** may transmit a message over the L2 interface (e.g., EAP request, 5G NAS, NAS PDU, SMC request, EAP success, TNGF address) to the UE **902**.

[0128] In a nineteenth communication **954** transmitted from the UE **902** to the TNGF **906**, the UE **902** may transmit a message over the L2 interface (e.g., EAP response, 5G NAS, NAS PDU, SMC complete) to the TNGF **906**. In a twentieth communication **956** transmitted from the TNGF **906** to the AMF **908**, the TNGF **906** may transmit an N2 message (e.g., SMC complete) to the AMF **908**. In a twenty-first communication **958** transmitted from the AMF **908** to the TNGF **906**, the AMF **908** may transmit an N2 initial setup request (e.g., K_{TNGF}) to the TNGF **906**. In a twenty-second communication **960** transmitted from the TNGF **906** to the target-TNAP2 **904**, the TNGF **906** transmits a message (e.g., MSK, EAP success) over an AAA interface to the target-TNAP2 **904**.

[0129] In a twenty-third communication **962** transmitted from the target-TNAP2 **904** to the UE **902**, the target-TNAP2 **904** transmits a message over an L2 interface (e.g., EAP success) to the UE **902**. In a twenty-fourth communication **964** (optional) transmitted between the UE **902** and the target-TNAP2 **904**, security establishment may be performed using a key derived from the MSK key (e.g., 4-way handshake for WLAN).

[0130] In a twenty-fifth communication **966** transmitted between the UE **902** and the target-TNAP2 **904** and/or a twenty-sixth communication **968** transmitted between the target-TNAP2 **904** and the TNGF **906**, a local IP configuration may be made. In a twenty-seventh communication **970** transmitted between the UE **902** and the TNGF **906**, IKE_INIT and IKE_AUTH messages may be transmitted (e.g., IDi, SA, TSi, TSr, AUTH).

[0131] In a twenty-eighth communication **972** transmitted from the TNGF **906** to the AMF **908**, the TNGF **906** may transmit an N2 initial setup response message to the AMF **908**. In a twenty-ninth communication **974** transmitted between the AMF **908**, the TNGF **906**, and the UE **902**, an N2 message (e.g., NAS registration accept message) may be transmitted. In a thirtieth communication **976** transmitted from the UE **902** to the TNGF **906**, the UE **902** may transmit a PDU session establishment request message (e.g., NAS over IPsec) to the TNGF **906**. In a thirty-first communication **978** transmitted between the UE **902** and the TNGF **906**, an IKE_Create_Child_SA_Request (e.g., SA, PDU session ID) and IKE_Create_Child_SA_Response may be transmitted and/or received.

[0132] In a thirty-second communication **980** transmitted from the TNGF **906** to the UE **902**, the TNGF **906** may transmit a PDU session establishment acceptance message to the UE **902**. In a thirty-third communication **982** transmitted from the UE **902** to the TNGF **906**, IP, ESP, generic routing encapsulation ("GRE"), and/or PDU data may be transmitted.

[0133] FIG. **10** is a schematic block diagram **1000** illustrating yet another embodiment of key hierarchy. The schematic block diagram **1000** illustrates an AMF **1002**, a first ME **1004**, trusted N3GPP access keys **1006**, a TNGF **1008**, a second ME **1010**, a TNAP **1012**, and a third ME **1014**. The AMF **1002** may transmit a K_{TNGF} **1016** to the trusted N3GPP access keys **1006**. The trusted N3GPP access keys **1006** may use a K_{TNGF} **1018** to derive a K_{TIPSec} **1020** used to setup IPSec SA **1022** which is used to setup child SAs **1024**. The K_{TNGF} **1018** may also be used to derive K_{TNAP} **1026**. The AMF **1002** may transmit an rRK **1028** to TNGF **1008**. The TNGF **1008** may use an rRK **1030** to derive rIK **1032** and to derive rMSKi **1034**. Moreover, the third ME **1014** derives rIK **1032** and rMSKi **1034** from the rRK **1030**.

[0134] If ERP is supported for EAP-AKA', then the EAP re-authentication root key rRK may be derived from the EMSK in the AUSF and provided to the TNGF **1008** via the AMF **1002**. The subsequent re-authentication MSK (rMSK) keys and the integrity protection key for the ERP messages may be derived in the ME and the TNGF from rRK. The rMSK may act as the TNAP key and be used to setup access security.

[0135] In various embodiments, there may be an rRK derivation function. If deriving an rRK from EMSK (e.g., for EAP-AKA' only) the following parameters may be used to form the input S to the KDF, where FC=TBD, P0=rRK label, and/or L0=length of rRK label. The FC value may be specified. The input key KEY may be the EMSK. The rRK label may be an IANA-assigned 8-bit American standard code for information interchange ("ASCII") string "EAP Re-authentication Root Key@ietf.org" followed by a separator "\0" assigned from the "USRK Key Labels" name space.

[0136] In certain embodiments, there may be an rIK derivation function. If deriving an rIK from rRK the following parameters may be used to form the input S to the KDF, where FC=TBD, P0=rIK label, L0=length or rIK label, P1=cryptosuite, and/or L1=length of cryptosuite. The FC value may be specified. The rIK label may be 8-bit ASCII string "Re-authentication Integrity Key@ietf.org" followed by a separator "\0". The cryptosuite may be one of the algorithms "128-NIA1", "128-NIA2", and "128-NIA3". The input key KEY may be the rRK.

[0137] In some embodiments, there may be an rMSK derivation function. If deriving an rMSK from rRK the following parameters may be used to form the input S to the KDF, where FC=TBD, P0=TNAP identifier, L0=length of TNAP identifier, P1=sequence number SEQ, and/or L1=length of SEQ. The FC may be specified. The TNAP identifier may be an 8-bit ASCII string followed by a separator "\0". The sequence number SEQ may be a sequence of ERP messages. The input key KEY may be the rRK.

[0138] In various embodiments, a re-authentication security context derived for trusted non-3GPP access may be bounded to a serving trusted non-3GPP network and trusted non-3GPP access point. In such embodiments, the re-authentication security context if used for TNAP mobility may facilitate forward secrecy, backward secrecy, and/or key separation among the access points.

[0139] FIG. **11** is a flow chart diagram illustrating one embodiment of a method **1100** for re-authentication key generation. In some embodiments, the method **1100** is performed by an apparatus, such as the remote unit **102** and/or the network unit **104**. In certain embodiments, the method **1100** may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0140] In various embodiments, the method **1100** includes transmitting **1102** a re-authentication key with a key set identifier in an extensible authentication protocol message The re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.

[0141] In certain embodiments, transmitting the re-authentication key with the key set identifier in the extensible authentical protocol message comprises transmitting the re-authentication key from an authentication server function to a security anchor functionality. In some embodiments, the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key. In various embodiments, the separator comprises "\0".

[0142] In one embodiment, the length of the parameter comprises a length of each S parameter of a set of S parameters. In certain embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; or some combination thereof. In some embodiments, the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

[0143] In various embodiments, a re-authentication integrity key is generated using the trusted gateway function identifier, the user equipment identifier, the reauthentication code, a re-authentication integrity key label, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof. In one embodiment, a trusted access point key or re-authentication master session key is generated using a trusted access point identifier, trusted access point information, a trusted access point mobility counter, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

[0144] FIG. **12** is a flow chart diagram illustrating another embodiment of a method **1200** for re-authentication key generation. In some embodiments, the method **1200** is performed by an apparatus, such as the remote unit **102** and/or the network unit **104**. In certain embodiments, the method **1200** may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0145] In various embodiments, the method **1200** includes generating **1202** a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof.

[0146] In certain embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the re-authentication root key after a successful primary authentication. In some embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the serving network re-authentication key during re-authentication. In various embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the re-authentication integrity key during re-authentication.

[0147] In one embodiment, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the access point key, the re-authentication master session key, or some combination thereof during re-authentication or in response to a re-authentication request. In certain embodiments, the separator comprises "\0". In some embodiments, the length of the parameter comprises a length of each S parameter of a set of S parameters.

[0148] In various embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; the re-authentication integrity key label; the anti-bidding down between architecture parameter; the trusted access point identifier; the trusted access point information; the trusted access point mobility counter; or some combination thereof. In one embodiment, the method **1200** further comprises receiving a re-authentication key set identifier, trusted access point identification information, and trusted gateway function identification information in an extensible authentication protocol success message.

[0149] In certain embodiments, the method **1200** further comprises receiving an extensible authentication protocol initiate re-authentication start message along with a target trusted access point identifier. In some embodiments, the method **1200** further comprises transmitting a registration request to a target trusted access point with a re-authentication key set identifier. In various embodiments, the registration request is transmitted in an extensible authentication protocol initiate request or a re-authentication request.

[0150] In one embodiment, a method comprises: transmitting a re-authentication key with a key set identifier in an extensible authentication protocol message, wherein the re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.

[0151] In certain embodiments, transmitting the re-authentication key with the key set identifier in the extensible authentical protocol message comprises transmitting the re-authentication key from an authentication server function to a security anchor functionality.

[0152] In some embodiments, the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key.

[0153] In various embodiments, the separator comprises "\0".

[0154] In one embodiment, the length of the parameter comprises a length of each S parameter of a set of S parameters.

[0155] In certain embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; or some combination thereof.

[0156] In some embodiments, the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

[0157] In various embodiments, a re-authentication integrity key is generated using the trusted gateway function identifier, the user equipment identifier, the reauthentication code, a re-authentication integrity key label, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

[0158] In one embodiment, a trusted access point key or re-authentication master session key is generated using a trusted access point identifier, trusted access point information, a trusted access point mobility counter, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

[0159] In one embodiment, an apparatus comprises: a transmitter that transmits a re-authentication key with a key set identifier in an extensible authentication protocol message, wherein the re-authentication key is generated using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; or some combination thereof.

[0160] In certain embodiments, the transmitter transmitting the re-authentication key with the key set identifier in the extensible authentical protocol message comprises the transmitter transmitting the re-authentication key from an authentication server function to a security anchor functionality.

[0161] In some embodiments, the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key.

[0162] In various embodiments, the separator comprises "\0".

[0163] In one embodiment, the length of the parameter comprises a length of each S parameter of a set of S parameters.

[0164] In certain embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; or some combination thereof.

[0165] In some embodiments, the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

[0166] In various embodiments, a re-authentication integrity key is generated using the trusted gateway function identifier, the user equipment identifier, the reauthentication code, a re-authentication integrity key label, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

[0167] In one embodiment, a trusted access point key or re-authentication master session key is generated using a trusted access point identifier, trusted access point information, a trusted access point mobility counter, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

[0168] In one embodiment, a method comprises: generating a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof.

[0169] In certain embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the re-authentication root key after a successful primary authentication.

[0170] In some embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the serving network re-authentication key during re-authentication.

[0171] In various embodiments, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the re-authentication integrity key during re-authentication.

[0172] In one embodiment, generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises generating the access point key, the re-authentication master session key, or some combination thereof during re-authentication or in response to a re-authentication request.

[0173] In certain embodiments, the separator comprises "\0".

[0174] In some embodiments, the length of the parameter comprises a length of each S parameter of a set of S parameters.

[0175] In various embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; the re-authentication integrity key label; the anti-bidding down between architecture parameter; the trusted access point identifier; the trusted access point information; the trusted access point mobility counter; or some combination thereof.

[0176] In one embodiment, the method further comprises receiving a re-authentication key set identifier, trusted access point identification information, and trusted gateway function identification information in an extensible authentication protocol success message.

[0177] In certain embodiments, the method further comprises receiving an extensible authentication protocol initiate re-authentication start message along with a target trusted access point identifier.

[0178] In some embodiments, the method further comprises transmitting a registration request to a target trusted access point with a re-authentication key set identifier.

[0179] In various embodiments, the registration request is transmitted in an extensible authentication protocol initiate request or a re-authentication request.

[0180] In one embodiment, an apparatus comprises: a processor that generates a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using: a public land mobile network identifier; a serving network name identifier; a trusted network domain name identifier; a trusted gateway function identifier; a subscription permanent identifier; a network access identifier; a user equipment identifier; a reauthentication code; a separator; a length of a parameter; a re-authentication integrity key label; an anti-bidding down between architecture parameter; a trusted access point identifier; trusted access point information; a trusted access point mobility counter; or some combination thereof.

[0181] In certain embodiments, the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the re-authentication root key after a successful primary authentication.

[0182] In some embodiments, the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the serving network re-authentication key during re-authentication.

[0183] In various embodiments, the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the re-authentication integrity key during re-authentication.

[0184] In one embodiment, the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the access point key, the re-authentication master session key, or some combination thereof during re-authentication or in response to a re-authentication request.

[0185] In certain embodiments, the separator comprises “\0”.

[0186] In some embodiments, the length of the parameter comprises a length of each S parameter of a set of S parameters.

[0187] In various embodiments, the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; the re-authentication integrity key label; the anti-bidding down between architecture parameter; the trusted access point identifier; the trusted access point information; the trusted access point mobility counter; or some combination thereof.

[0188] In one embodiment, the apparatus further comprises a receiver that receives a re-authentication key set identifier, trusted access point identification information, and trusted gateway function identification information in an extensible authentication protocol success message.

[0189] In certain embodiments, the apparatus further comprises a receiver that receives an extensible authentication protocol initiate re-authentication start message along with a target trusted access point identifier.

[0190] In some embodiments, the apparatus further comprises a transmitter that transmits a registration request to a target trusted access point with a re-authentication key set identifier.

[0191] In various embodiments, the registration request is transmitted in an extensible authentication protocol initiate request or a re-authentication request.

[0192] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

1. A method comprising:

transmitting a re-authentication key with a key set identifier in an extensible authentication protocol message, wherein the re-authentication key is generated using:

a public land mobile network identifier;

a serving network name identifier;

a trusted network domain name identifier;

a trusted gateway function identifier;

a subscription permanent identifier;

a network access identifier;

a user equipment identifier;

a reauthentication code;

a separator;

a length of a parameter; or

some combination thereof.

2. The method of claim **1**, wherein transmitting the re-authentication key with the key set identifier in the extensible authentical protocol message comprises transmitting the re-authentication key from an authentication server function to a security anchor functionality, the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key, and the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

3. The method of claim **1**, wherein the separator comprises “\0”, the length of the parameter comprises a length of each S parameter of a set of S parameters, and the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; or some combination thereof.

4. The method of claim **1**, wherein a re-authentication integrity key is generated using the trusted gateway function identifier, the user equipment identifier, the reauthentication code, a re-authentication integrity key label, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

5. The method of claim **1**, wherein a trusted access point key or re-authentication master session key is generated using a trusted access point identifier, trusted access point information, a trusted access point mobility counter, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

6. An apparatus comprising:

a transmitter that transmits a re-authentication key with a key set identifier in an extensible authentication protocol message, wherein the re-authentication key is generated using:
a public land mobile network identifier;
a serving network name identifier;
a trusted network domain name identifier;
a trusted gateway function identifier;
a subscription permanent identifier;
a network access identifier;
a user equipment identifier;
a reauthentication code;
a separator;
a length of a parameter; or
some combination thereof.

7. The apparatus of claim **6**, wherein the transmitter transmitting the re-authentication key with the key set identifier in the extensible authentical protocol message comprises the transmitter transmitting the re-authentication key from an authentication server function to a security anchor functionality, the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key, and the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

8. The apparatus of claim **6**, wherein the separator comprises "\0", the length of the parameter comprises a length of each S parameter of a set of S parameters, and the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; or some combination thereof.

9. The apparatus of claim **6**, wherein a re-authentication integrity key is generated using the trusted gateway function identifier, the user equipment identifier, the reauthentication code, a re-authentication integrity key label, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

10. The apparatus of claim **6**, wherein a trusted access point key or re-authentication master session key is generated using a trusted access point identifier, trusted access point information, a trusted access point mobility counter, an anti-bidding down between architecture parameter, the separator, the length of the parameter, or some combination thereof.

11. (canceled)

12. (canceled)

13. (canceled)

14. (canceled)

15. (canceled)

16. An apparatus comprising:

a processor that generates a re-authentication root key, a serving network re-authentication key, a re-authentication integrity key, an access point key, a re-authentication master session key, or some combination thereof using:
a public land mobile network identifier;
a serving network name identifier;
a trusted network domain name identifier;
a trusted gateway function identifier;
a subscription permanent identifier;
a network access identifier;
a user equipment identifier;
a reauthentication code;
a separator;
a length of a parameter;
a re-authentication integrity key label;
an anti-bidding down between architecture parameter;
a trusted access point identifier;
trusted access point information;
a trusted access point mobility counter; or
some combination thereof.

17. The apparatus of claim **16**, wherein the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the re-authentication root key after a successful primary authentication.

18. The apparatus of claim **16**, wherein the processor generating the re-authentication root key, the serving network re-authentication key, the re-authentication integrity key, the access point key, the re-authentication master session key, or some combination thereof comprises the processor generating the re-authentication integrity key during re-authentication and the processor generating the access point key, the re-authentication master session key, or some combination thereof during re-authentication or in response to a re-authentication request.

19. The apparatus of claim **16**, wherein the separator comprises "\0", the length of the parameter comprises a length of each S parameter of a set of S parameters, and the set of S parameters comprises: the public land mobile network identifier; the serving network name identifier; the trusted network domain name identifier; the trusted gateway function identifier; the subscription permanent identifier; the network access identifier; the user equipment identifier; the reauthentication code; the separator; the re-authentication integrity key label; the anti-bidding down between architecture parameter; the trusted access point identifier; the trusted access point information; the trusted access point mobility counter; or some combination thereof.

20. The apparatus of claim **16**, further comprising:

a receiver:

that receives a re-authentication key set identifier, trusted access point identification information, and trusted gateway function identification information in an extensible authentication protocol success message; and

receives an extensible authentication protocol initiate re-authentication start message along with a target trusted access point identifier; and

a transmitter that transmits a registration request to a target trusted access point with a re-authentication key set identifier, wherein the registration request is transmitted in an extensible authentication protocol initiate request or a re-authentication request.

21. The method of claim **1**, wherein the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

22. The apparatus of claim **6**, wherein the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

23. The apparatus of claim **6**, wherein the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key.

24. The apparatus of claim **16**, wherein the re-authentication key is generated by a key derivation function of an authentication server function, a home public land mobile network, or a combination thereof.

25. The apparatus of claim **16**, wherein the re-authentication key comprises a re-authentication root key, a domain-specific root key, or a serving network re-authentication key.

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