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Method and system for providing communication services using a plurality of remote subscriber identity modules

Abstract

A method and a wireless communication device for providing communication service to devices connected to the wireless communication device. By establishing a starter wireless carrier connection using a starter SIM from a plurality of local SIMs, the wireless communication device establishes one or more logical data connections with one or more SIM banks. Remote-SIMs are selected from the one or more SIM banks and used to establish further wireless carrier connections to allow communication service to be provided to the devices over wireless carrier connections.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This patent application is a non-provisional continuation application, which claims the benefit of and is based on U.S. patent application Ser. No. 17/688,888 filed on Mar. 7, 2022, which is a non-provisional continuation and claims the benefit of U.S. patent application Ser. No. 17/029,024 filed on Sep. 22, 2020, now U.S. Pat. No. 11,272,355 issued on Mar. 8, 2022, which is a non-provisional continuation-in-part and claims the benefit of U.S. patent application Ser. No. 17/040,527 filed on Sep. 22, 2020, now U.S. Pat. No. 11,490,437 issued on Nov. 1, 2022, which is a 371 National Stage entry of Patent Cooperation Treaty Application No. PCT/IB2020/054671 filed on May 18, 2020, the disclosures of which are hereby incorporated by specific reference thereto.

TECHNICAL FIELD

(1) The present invention generally relates to wireless communication devices that use remote SIM to establish wireless carrier connections, and more particularly to select a plurality of remote SIMs and establish the wireless carrier connections through a plurality of wireless communication modules.

BACKGROUND ART

(2) A wireless communication device, such as a cellular router, provides communication services to other devices. The wireless communication device may establish a wireless carrier connection and then allow the other devices to send and receive data over the wireless carrier connection. In order to establish wireless carrier connections, one or more subscriber identity module (SIM) cards are used.

(3) When the wireless communication device moves to another location, a different SIM card may be required. Further, when the data quota of a SIM card is used up or about to be used up, another different SIM card may be swapped with the SIM card. Also, when a SIM card is out-of-order, a new SIM will be required to replace the SIM card. There is a myriad of reasons why a SIM card may need to be replaced at the wireless communication device.

(4) One of the solutions is to use remote SIM. The remote SIM is placed at SIM bank. The wireless communication device communicates with the SIM bank over a logic data connection in order to use the remote SIM; and the logical data connection is established over the already established wireless carrier connection.

(5) In case there is disruption, at the logical data connection or/and at the wireless carrier connection, communications with the SIM bank may be affected adversely. Then a remote SIM that has been being used may become unavailable. In such circumstances, the wireless communication device will not be able to provide communication services to other devices.

SUMMARY OF INVENTION

(6) The present invention discloses a method to select subscriber identity module (SIM) card at a wireless communication device. The selection comprises: establish a starter wireless carrier connection using a starter local SIM. Then, a starter authentication connection is established between the wireless communication device and a SIM bank. When the starter authentication connection is established, select a first local SIM or a first remote SIM from the SIM bank to establish a first wireless carrier connection. After that, disconnect the starter wireless carrier connection. A second local SIM or a second remote SIM is selected from the SIM bank to establish a second wireless carrier connection. Finally, communication service is provided to devices

connected to the wireless communication device over one of or both of the first wireless carrier connection and second wireless carrier connection.

Description

BRIEF DESCRIPTION OF DRAWINGS

- (1) FIG. 1A illustrates a schematic block diagram of wireless communication device according to one of the embodiments of the present invention.
- (2) FIG. 1B illustrates a schematic block diagram of wireless communication device according to one of the embodiments of the present invention.
- (3) FIG. 1C illustrates a schematic block diagram of SIM bank according to the present invention.
- (4) FIG. 1D illustrates a schematic block diagram of SIM bank management server according to the present invention.
- (5) FIG. 2A illustrates a network diagram according to the present invention.
- (6) FIG. 2B illustrates a wireless carrier connection according to the present invention.
- (7) FIG. 3A is a process flowchart illustrating a method for selecting R-SIM according to the present invention.
- (8) FIG. 3B is a process flowchart illustrating a method for providing authentication information according to the present invention.
- (9) FIG. 4A is a process flowchart illustrating a method according to one embodiment of the present invention.
- (10) FIG. 4B is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (11) FIG. 5A is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (12) FIG. 5B is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (13) FIG. 5C is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (14) FIG. 6 is a process flowchart illustrating a method according to one embodiment of the present invention.
- (15) FIG. 7 is a process flowchart illustrating a method according to one embodiment of the present invention.
- (16) FIG. 8A is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (17) FIG. 8B is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (18) FIG. 8C is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (19) FIG. 8D is a process flowchart for one of the embodiments according to the present invention.
- (20) FIG. 9A is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (21) FIG. 9B is a process flowchart illustrating a method according to one example embodiment of the present invention.
- (22) FIG. 10 is a timing diagram of an exemplary embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

(23) The ensuing description provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the invention. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling

description for implementing a preferred exemplary embodiment of the invention. It is being understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention as set forth in the appended claims.

(24) Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

(25) Also, it is noted that the embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed, but could have additional steps not included in the figure. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

(26) Embodiments, or portions thereof, may be embodied in program instructions operable upon a processing unit for performing functions and operations as described herein. The program instructions making up the various embodiments may be stored in a storage medium.

(27) The program instructions making up the various embodiments may be stored in a storage medium. Moreover, as disclosed herein, the term “storage medium” may represent one or more devices for storing data, including read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), random access memory (RAM), magnetic RAM, core memory, floppy disk, flexible disk, hard disk, magnetic tape, CD-ROM, flash memory devices, a memory card and/or other machine-readable mediums for storing information.

(28) The term “machine-readable medium” includes, but is not limited to portable or fixed storage devices, optical storage devices, wireless channels and various other mediums capable of storing, containing or carrying instruction(s) and/or data. A machine-readable medium can be realized by virtualization, and can be a virtual machine-readable medium including a virtual machine-readable medium in a cloud-based instance. Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description, languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine-readable medium such as storage medium.

(29) The term computer-readable medium, main memory, secondary storage, or other storage medium as used herein refers to any medium that participates in providing instructions to a processing unit for execution. The processing unit reads the data written in the primary storage medium and writes the data in the secondary storage medium. Therefore, even if the data written in the primary storage medium is lost due to a momentary power failure and the like, the data can be restored by transferring the data held in the secondary storage medium to the primary storage medium. The computer-readable medium is just one example of a machine-readable medium, which may carry instructions for implementing any of the methods and/or techniques described herein. Such a medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical or magnetic disks. Volatile storage includes dynamic memory. Transmission media includes coaxial cables, copper wire and fiber optics. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infrared data communications.

(30) A volatile storage may be used for storing temporary variables or other intermediate information during execution of instructions by a processing unit. A non-volatile storage or static

storage may be used for storing static information and instructions for processor, as well as various system configuration parameters.

(31) The storage medium may include a number of software modules that may be implemented as software codes to be executed by the processing unit using any suitable computer instruction type. The software code may be stored as a series of instructions or commands, or as a program in the storage medium.

(32) Various forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to the processor for execution. For example, the instructions may initially be carried on a magnetic disk from a remote computer. Alternatively, a remote computer can load the instructions into its dynamic memory and send the instructions to the system that runs one or more sequences of one or more instructions.

(33) A processing unit may be a microprocessor, a microcontroller, a digital signal processor (DSP), any combination of those devices, or any other circuitry configured to process information.

(34) A processing unit executes program instructions or code segments for implementing embodiments of the present invention. Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program instructions to perform the necessary tasks may be stored in a computer readable storage medium. A processing unit(s) can be realized by virtualization, and can be a virtual processing unit(s) including a virtual processing unit in a cloud-based instance.

(35) Embodiments of the present invention are related to the use of a computer system for implementing the techniques described herein. In an embodiment, the inventive processing units may reside on a machine such as a computer platform. According to one embodiment of the invention, the techniques described herein are performed by computer system in response to the processing unit executing one or more sequences of one or more instructions contained in the volatile memory. Such instructions may be read into the volatile memory from another computer-readable medium. Execution of the sequences of instructions contained in the volatile memory causes the processing unit to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

(36) Alternatively, hardware circuitry may be used in place of, or in combination with, software instructions to implement processes consistent with the principles of the invention. Thus, implementations consistent with principles of the invention are not limited to any specific combination of hardware circuitry and software.

(37) A network interface may be implemented by a standalone electronic component or may be integrated with other electronic components. A network interface may have no network connection or at least one network connection depending on the configuration. A network interface, such as network interfaces **135** and **136** in **WCD 100** may be an Ethernet interface, a frame relay interface, a fiber optic interface, a cable interface, a Digital Subscriber Line (DSL) interface, a token ring interface, a serial bus interface, a universal serial bus (USB) interface, Firewire interface, Peripheral Component Interconnect (PCI) interface, cellular network interface, etc.

(38) A network interface may connect to a wired or wireless access network. An access network may carry one or more network protocol data. A wired access network may be implemented using Ethernet, fiber optic, cable, DSL, frame relay, token ring, serial bus, USB, Firewire, PCI, or any material that can pass information. A wireless access network may be implemented using infrared, High-Speed Packet Access (HSPA), HSPA+, Long Term Evolution (LTE), WiMAX, General packet radio service (GPRS), Global System for Mobile Communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), Code division multiple access (CDMA), Wi-Fi, CDMA2000, Wideband CDMA (WCDMA), Time Division CDMA (TD-SCDMA), BLUETOOTH, WiBRO,

Evolution-Data Optimized (EV-DO); Digital Enhanced Cordless Telecommunications (DECT); Digital AMPS (IS-136/TDMA); Integrated Digital Enhanced (iDEN) or any other wireless technologies. For example, a network interface may be used as a local area network (LAN) interface or a wide area network (WAN) interface.

(39) As disclosed herein the term “wireless communication module” may represent a transceiver module to provide network capabilities to a power controller or power controller server using 3G, GPRS or GPS modules, through wires or through an Ethernet cable. The wireless communication module has a processing unit to obtain user information and communications port of the wireless communication module can connect to a personal computer or other power controller or power controller server (PCS) through wires or wirelessly by using serial bus or Ethernet or using 2G/3G/4G or LTE technology. The wireless communication module can be used as a network interface for applications that require data to be shared between a power controller and an intelligent device such as a host computer and/or a server.

(40) FIG. 1A is a schematic block diagram illustrating the hardware blocks of Wireless Communication Device (WCD) **100**. WCD **100** comprises a plurality of SIM card interfaces **117** and a plurality of Embedded Universal Integrated Circuit Cards (eUICCs) **116**. Each of the plurality of SIM card interfaces **117** is configurable to connect one or more removable SIMs. For illustration purposes, one removable SIM is described herein for each of the SIM card interfaces. For example, SIM card interface **117a** is connected to removable SIM **112a** and SIM card interface **117b** is connected to removable SIM **112b**. A removable SIM may be a Universal Integrated Circuit Card. Each of the SIM card interfaces may be connected to a SIM slot for placing the removable SIM.

(41) eUICCs **116** may be built into the WCD and are not removable. Each of the eUICCs **116** is configurable to implement one or more electronic SIMs (eSIMs). For illustration purposes, one eSIM is described herein for each of the eUICCs. For example, eUICC **116a** is used to implement eSIM **111a** and eSIM **111c**; and eUICC **116b** is used to implement eSIM **111b** and eSIM **111d**. An eSIM may represent a SIM profile. The SIM profile may be derived from a remote eSIM subscription management server based on the information provided by a wireless carrier network. A SIM profile contains information which provides access to a specific wireless carrier network for wireless communication. eSIMs **111a-d** may be from the same or different wireless carrier networks. eSIMs **111** and removable SIMs **112**, hereinafter, are also referred to as local SIMs (L-SIMs). A local SIM (L-SIM) is a SIM that is placed in WCD **100**. There is no limitation on the number of SIMs that may be placed in WCD **100**.

(42) WCD **100** is also configurable to connect one or more remote SIMs (R-SIMs) through the Internet. A remote SIM (R-SIM) is a SIM that is placed in a SIM bank. For illustration purposes, R-SIMs **113a** and **113b** are shown. R-SIMs **113a** and **113b** may be placed in one or more SIM banks configurable to connect with WCD **100** through one or more data connections. There is no limitation on the number of SIMs that may be placed in a SIM bank. There is no limitation on the number of SIM banks that may be connected to WCD **100**. For example, R-SIMs **113a** and **113b** may be placed in two different SIM banks.

(43) WCD **100** further comprises a plurality of wireless communication modules (WCMs), such as WCMs **101a-101c**. Each of the plurality of WCMs **101** is configurable to connect any one of the L-SIMs or R-SIMs at a time. The Wireless communication modules, such as WCMs **101**, may be connected to embedded/external antennas and perform wireless communication via the antennas. An example of WCM is Sierra Wireless EM7511.

(44) A processing unit, such as processing unit **160**, executes program instructions or code segments for implementing embodiments of the present invention. Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program instructions to perform the necessary tasks may be stored in a computer-

readable storage medium.

(45) Processing unit **160** may be a complex programmable logic device (CPLD), a field-programmable gate array (FPGA), a central processing unit (CPU), a microprocessor, a microcontroller, a digital signal processor (DSP), any combination of those devices, or any other circuitry configurable to execute the program instructions for implementing the embodiments disclosed herein. In one exemplary embodiment, processing unit **160** has an adequate number of input/output pins and processing power. Therefore, processing unit **160** may be directly connected to SIM card interfaces **117**, eUICCs **116**, WCMs **101** and other hardware components, such as, main memory **132** and system bus **137**.

(46) In another exemplary embodiment, as shown in FIG. **1B**, processing unit **160** does not have an adequate number of input/output pins to connect to all hardware components. Therefore, a complex programmable logic device (CPLD), for example, CPLD **150** is connected to processing unit **160** in order to provide an adequate number of input/output pins. Some of the hardware components such as eUICCs **116**, SIM card interfaces **117** and WCMs **101** may be connected to the processing unit through the CPLD while the other hardware components, such as main memory **132** and system bus **137** may be connected to the processing unit directly, through another circuit, and/or through another CPLD. There are no limitations that a CPLD must be used. Any logic circuit configurable to realize multiplexing may be used. For example, an FPGA or a multiplexer may also be used.

(47) Network interfaces **135** and **136** may be connected to processing unit **160** through system bus **137**. System bus **137** can be any of several types of bus structures including a memory bus, a peripheral bus, and a local bus using any of a variety of bus architectures.

(48) In one variant, WCM **101a-c**, eUICC **116a-b**, SIM interfaces **117a-b** and main memory **132** are not connected to processing unit **160** directly. Instead they are connected to processing unit **160** indirectly through a bus, such as system bus **137**. In one variant, they are connected to processing unit **160** indirectly through multiple buses.

(49) FIG. **2A** is a schematic block diagram illustrating an exemplary network environment operable to utilize a plurality of SIMs for data communication in accordance with the embodiments disclosed herein. FIG. **2A** includes three wireless carrier networks, for example, wireless carrier networks **201a-201c**. Each wireless carrier network may provide communication coverage for a corresponding particular geographic area using cellular technologies. Wireless carrier networks **201a-201c** may be operated by the same company or different companies.

(50) WCD **100** may communicate with web server **208**, network node **210**, SIM banks **212**, SIM bank management server **216** and eSIM subscription management server **214** through interconnected networks **217**. For readability, the eSIM subscription management server is hereinafter referred to as eSIM server. WCD **100** may connect with interconnected network **217** through one or more wireless carrier connection(s) established through wireless carrier networks **201a-201c**. WCD **100** may establish the wireless carrier connection(s) by using any SIMs including L-SIMs and R-SIMs discussed under FIG. **1A**.

(51) Optionally, FIG. **2A** also includes a satellite carrier network, for example, satellite carrier network **205**. Satellite carrier network **205** may be realized using a geostationary satellite or a low earth orbit (LEO) satellite which provides communication coverage for a larger geographic area compared to a wireless carrier network. For example, WCD **100** may be under respective coverage of satellite carrier network **205** and may connect with interconnected network **217** optionally through one or more satellite data connections established through satellite carrier network **205**.

(52) Optionally, WCD **100** is also capable of being connected with one or more wired communication networks. An example wired communication network may include network nodes **209**. WCD **100** may connect to interconnected network **217** optionally through one or more wired data connections established using one or more network nodes including, but not limited to, **209**.

(53) WCD **100** may be connected with one or more local hosts directly or through a connected local area network (LAN). For illustration purposes, WCD **100** is connected to local host Laptop

206 directly and to local host IoT **204** through LAN **202**. Each of the local hosts **204** and **206** may connect to interconnected network **217** through WCD **100**. Thus, WCD **100** acts as a gateway to allow data packets to be routed through one or more wireless carrier connection(s) established through wireless carrier networks **201a-201c**.

(54) According to one embodiment of the present invention, when a first group of data packets is received at WCD **100** from a local host which is destined for a remote host reachable through any of the wireless carrier connections established, WCD **100** first decides which wireless carrier connections should be used for sending the data packets. For illustration purposes, WCD **100** receives data packets from laptop **206** which are destined for website server **208**. The decision for selecting the wireless carrier connection(s) to send the data packets may be based on a policy. The policy may be based on one or more of the following criteria: network performance, network security, user access, user preference, device preference, signal strength, billing cycle, time.

(55) FIG. **1C** is a schematic block diagram of an exemplary SIM bank according to one embodiment of the present invention. For example, the exemplary SIM bank is SIM bank **212a**. SIM bank **212a** comprises at least one processing unit **153** and at least one main memory **154**. Processing unit **153** may be connected with main memory **154** directly and with other hardware components, for example, with at least one secondary storage **155**, one or more network interfaces **156** and a plurality of SIM interfaces **152**, through a system bus, such as system bus **157**. System bus **157** may be any of several types of bus structures including a memory bus, a peripheral bus or a local bus using any of a variety of bus architecture.

(56) Each of the plurality of SIM interfaces **152** may be connected with a corresponding SIM slot, such as SIM slots **151** to place or to connect to a SIM. A SIM interface, such as SIM interfaces **152**, is used to access and write information to and from a SIM. There are many SIM interfaces available from different manufacturers. Some of the SIM interfaces provide functions of power supply, card reset signal, card clock signal and data exchange. A data exchange may be performed between the SIM and the processing unit of SIM bank **212a** through the SIM interfaces. Some of the SIM interfaces may only be connected with one SIM, while some may be connected with a plurality of SIMs.

(57) In one variant, hardware components such as secondary storage **155**, network interfaces **156**, and SIM interfaces **152** may be directly connected with processing unit **153** when the processing unit has an adequate number of I/O pins. System bus **157** may be omitted. Alternatively, when processing unit **153** does not have an adequate number of I/O pins, some or all of the hardware components may be connected to the processing unit using one or more CPLDs. There is no limitation that CPLDs must be used. Multiplexers, FPGAs or any logic circuits which serve the purpose of providing the required number of I/O pins may also be used.

(58) The one or more SIM banks may be managed by one or more SIM bank management servers. For example, one SIM bank management server **216** is shown in FIG. **2A**. SIM bank management server **216** may be remotely or locally coupled to the SIM banks. Connection of WCD **100** to SIM bank **212a** may be managed through a SIM bank management server, for example, SIM bank management server **216** shown in FIG. **2A**. There is no limitation that a SIM bank and a SIM bank management server must be separated. A device may comprise a SIM bank and a SIM bank management server together.

(59) The SIM bank management server may perform a device authentication procedure before providing access to WCD **100** to any of the SIM banks. For availing the device authentication information, WCD **100** may need to be registered with the SIM bank management server. The registration may be performed online, such as through a user interface (e.g. web page or web form) or offline. The authentication information to authenticate WCD **100** may be duly provided by WCD **100** or by an administrator of WCD **100** to SIM bank management server **216**. SIM bank management server **216** may store necessary information including, but not limited to, WCD information, administrator information, registration information, authentication information,

number of SIM banks connected, SIM banks' location and information of SIMs placed in the SIM banks.

(60) WCD **100** may communicate with SIM bank management server **216** for accessing information of SIM banks **212**. At first, WCD **100** may not have access information of a SIM bank, after communicating with the SIM bank management server **216**, WCD **100** may receive access information, such as IP address and hostname of a SIM bank and/or a security code. After receiving the access information, WCD **100** may become able to access the corresponding SIM bank.

(61) FIG. 1D is a schematic block diagram of an exemplary SIM bank management server **216** shown in FIG. 2A. SIM bank management server **216** comprises at least one processing unit **161** and at least one main memory **162**. Processing unit **161** may be connected with main memory **162** directly and with other components, for example, with at least one secondary storage **163** and one or more network interfaces **164a** and **164b**, through a system bus **165**. System bus **165** may be any of several types of bus structures including a memory bus, a peripheral bus or a local bus using any of a variety of bus architecture.

(62) FIG. 2B illustrates how a wireless carrier connection carries different logical data connections. Wireless carrier connection **230** may be one of the wireless carrier connections established by WCD **100** over any of wireless carrier networks **201a-201c**. Wireless carrier connection **230** may be established using 2G/3G/4G/5G, LTE, Wi-Fi, or any other wireless communication technologies. Logical data connections **231-233** may be established using TCP/IP, UDP/IP, IP or any logical data connection protocol. For example, logical data connection **231** may be established between WCD **100** and network node **210**; logical data connection **232** may be established between WCD **100** and SIM bank **212a**; and logical data connection **233** may be established between WCD **100** and SIM bank **212b**. There is no limitation that all logical data connections **231-233** must be established using the same or different logical data connection protocols. There is no limit on the number of logical data connections that may comprise in a wireless carrier connection. A logical data connection may also be a tunnel to encapsulate another logical data connection. A plurality of logical data connections may also be aggregated together to form an aggregated logical data connection.

(63) As WCD **100** may have established a plurality of wireless carrier connections concurrently, WCD **100** may establish a logical data connection with a device reachable through interconnected networks **217** through any of the plurality of wireless carrier connections. WCD **100** may also establish a plurality of logical data connections with a device reachable through interconnected networks **217** through the plurality of wireless carrier connections concurrently.

(64) FIG. 3A is a process flowchart illustrating a method performed at WCD **100**, SIM bank **212** and/or SIM bank management server **216** to select R-SIM. In process **311**, the processing unit determines the identities of wireless carrier networks that are being used by WCD **100**. WCD **100** may be using no, one or a plurality of wireless carrier networks. In process **312**, the processing unit determines the number of R-SIMs to be selected, which should be equal to or fewer than the number of WCMs available. The selected R-SIMs will be used by the WCMs to establish wireless carrier connection(s).

(65) In process **313**, the processing unit determines the wireless carrier networks to be used, which will be based on the wireless carrier networks identified at the location of WCD **100**. In process **314**, the processing unit selects R-SIMs that satisfy a SIM selection policy per wireless carrier network with the goal to maximize the number of wireless carrier networks. When trying to maximize the number of wireless carrier networks, the processing unit may take into account the wireless carrier network(s) identified in process **311**. The number of R-SIMs selected may be zero, one or more than one.

(66) In an example scenario, WCD **100** in FIG. 2A has three WCMs, namely WCMs **101a-c** in FIG. 1A. WCM **101a** has already established a wireless carrier connection with wireless carrier network **201a** using L-SIM **112a**. Therefore, the wireless network carrier determined in process **311**

is wireless carrier network **201a**.

(67) Therefore, there are still two available WCMs, namely WCM **101b** and WCM **101c**. In process **312**, the number of R-SIMs to be selected will be two, i.e. two R-SIMs may then be selected for the WCM **101b** and WCM **101c**.

(68) In process **313**, the wireless networks determined to be used are wireless carrier network **201a-201c** as these three networks are identified at the location of WCD **100**.

(69) In process **314**, when selecting the two R-SIMs, the processing unit takes into account wireless carrier network A in order to maximize the number of different wireless carrier networks. The selected R-SIMs should also satisfy the SIM selection policy. If a selected R-SIM is a roaming R-SIM, the wireless carrier networks available to use the roaming R-SIM will also be considered to maximize the number of different wireless carrier networks. For example, there are a plurality of R-SIMs that satisfy the SIM selection policy, R-SIMs that are capable to be used for establishing wireless carrier connections with wireless carrier network **201a**, wireless carrier network **201b** and wireless carrier network **201c** may be selected. However, in order to maximize the number of wireless carrier networks, only one R-SIM that is capable of establishing wireless carrier connections over wireless carrier network **201b** and one R-SIM that is capable of being used for establishing wireless carrier connections over wireless carrier network **201c** are selected.

(70) Further, International Mobile Subscriber Identity (IMSI) and International Mobile Equipment Identity (IMEI) of the selected R-SIMs may then be forwarded by the SIM bank **212** or SIM bank management server **216** to WCD **100** in process **314**.

(71) There is no limitation that the number of R-SIMs selected must be two. The number of R-SIMs selected may be different depends on the number of WCMs available,

(72) When the number of wireless carrier networks at the location of WCD **100** is smaller than the number of R-SIMs to be selected, at least two R-SIMs may belong to one same wireless carrier network. If a selected R-SIM is a roaming R-SIM, the roaming R-SIM may be configured to use the same wireless carrier network with another R-SIM.

(73) Processes **311** to **314** may be performed by the processing unit of WCD **100**, the processing unit of SIM bank **212** or the processing unit of WCD **100** individually or together. For example, process **311** may be performed by processing unit **160** of WCD **100** to determine the wireless carrier networks using one of WCMs **101**. Process **311** may also be performed by the processing unit of SIM bank **212** or the processing unit of WCD **100**. The processing unit of SIM bank **212** or the processing unit of WCD **100** may search a database for wireless carrier networks based on location information provided by WCD **100**.

(74) In one variant, the processes shown in FIG. **3A** also applies to L-SIM.

(75) FIG. **3B** is a process flowchart illustrating a method performed by SIM bank **212** and/or SIM bank management server **216** to provide authentication information to WCD **100**. At process **321**, SIM bank **212** and/or SIM bank management server **216** receives one or more authentication requests from WCD **100**. An authentication request is originally sent by a wireless carrier network to a WCM in WCD **100** for an R-SIM selected. When the WCM **100** sends an IMSI or IMEI to a wireless carrier network, the wireless carrier network may send the authentication request, such as a random challenge (RAND), to the WCM.

(76) At process **321**, SIM bank **212** forwards the authentication request to the selected SIM, which is accessible by the SIM bank **212**. In the case that the authentication request is sent to SIM management server **216**, SIM management server **216** will forward the authentication request to a corresponding SIM bank, such as SIM **212**, for processing.

(77) At process **322**, the selected SIM processes the authentication request and then creates the authentication information, such as signed response (SRES), in response to the authentication requests. SIM bank **212a** then forwards the authentication information received from the selected SIM to WCD **100** in process **323**.

(78) In one variant, WCD **100** may send a plurality of authentication requests together. When SIM

bank **212a** and/or SIM bank management server **216** receives the authentication requests in process **321**, it may process processes **322** and **323** in parallel or in sequence for each authentication request.

(79) In one variant, when a plurality of authentication requests is sent to SIM bank management server **216**, SIM bank management server **216** may forward the authentication requests to a plurality of SIM banks based on where the selected SIMs are located.

(80) FIG. **4A** is a process flowchart illustrating a method according to one embodiment of the present invention. The method may be performed at processing unit **160** of WCD **100**. FIG. **4A** should be viewed in conjunction with FIG. **1A** and FIG. **2A**. The method begins at process **400**. At process **401**, processing unit **160** selects an L-SIM from a plurality of available L-SIMs as a starter SIM to establish a starter wireless carrier connection with a starter wireless carrier network, for example, wireless carrier network **201c**. The starter SIM is the first SIM in sequence being selected and used.

(81) An available L-SIM is an L-SIM placed in WCD **100** and is not assigned with a WCM yet. A starter SIM refers to a SIM that is selected to establish a starter wireless carrier connection with a wireless carrier network. Once the connection is established, the wireless carrier network is referred to as the starter wireless carrier network and the connection is referred to as the starter wireless carrier connection. The selection of the L-SIM to be the starter SIM may be based on instructions manually provided by an administrator of the WCD or maybe be based on a starter SIM selection policy. The starter SIM selection policy may be configured by the administrator of WCD **100** or retrieved from a remote server. The starter SIM selection policy may be based on one or more of the following criteria: geolocation of WCD **100**, position of SIM placed in WCD **100**, SIM category, network performance history of a SIM, identity of wireless carrier network issuing a SIM, services offered by wireless carrier network of a SIM, service quality of wireless carrier network of a SIM, administrator's preference, tariffs, remaining using usage quota of available L-SIMs, billing cycle information and time. In one variant, in the case that one or more L-SIMs are eSIM(s) from eUICC(s), wireless carrier networks configured in the eSIM(s), may be used for selection. When an eSIM, which is a SIM profile, is added, changed or deleted in the eUICC(s), the starter SIM selection policy will take into account of the modification.

(82) When geolocation of WCD is used for starter SIM selection policy, longitude and latitude information based on GPS information obtained from a GPS receiver at WCD **100** may be used to look-up for available wireless carrier networks at the geographical location of WCD **100**.

(83) When a SIM is selected based on the position of SIM placed in WCD **100**, a SIM that is positioned first will be selected first. For example, SIMs placed in WCD **100** may be positioned in a numerical or alphabetical order.

(84) For example, when a SIM is selected based on the tariff price, a SIM with the lowest tariff may be selected. It is possible that wireless carrier networks may change tariffs. A SIM with the lowest tariff may no longer be the SIM with the lowest tariff. Therefore, the processing unit of WCD **100**, may monitor the tariff price information from time to time and whenever a change in tariff is detected, the processing unit redetermines on which SIM having the lowest tariff price.

(85) A SIM may also be selected based on billing cycle information. A billing cycle is the period of a cellular subscription for communication service. A billing cycle may be weekly, monthly or yearly. In one example scenario, where using billing cycle information may be beneficial is, data usage limit per billing cycle may be capped and exceeding the allowed data usage limit may incur high premiums. Therefore, when a SIM is selected based on billing cycle information, the SIM for which data usage limit of a billing cycle is about to reach, may not be selected.

(86) A SIM may also be selected based on the time of a day. There are many reasons for selecting a SIM based on time, one example may be for the changes in tariff pricing. Some wireless carrier networks may offer different tariff prices for different times of the day. It is very common that wireless carrier networks offer lower tariff rates during off-peak periods. Therefore, a SIM from the

wireless carrier network which offers the lowest tariff price for a specific time of the day may be selected when the selection occurs during that specified time period.

(87) A SIM may be selected based on administrator's preference. An administrator of WCD **100** or SIM banks **212** may assign priority level to each SIM. Thus, when selecting a SIM based on the administrator's preference, a SIM with higher priority assigned will be selected. An administrator may assign priority level to a SIM based on different bases including the conditions of R-SIM selection criteria disclosed herein.

(88) A SIM may also be selected based on service quality of the wireless carrier network of a SIM. When selecting a SIM based service quality, a SIM from the wireless carrier network which provides better quality of service will be selected. The service quality of a wireless carrier network may be evaluated based on different criteria including, but not limited to, signal strength, network coverage, security and simplicity of configuration.

(89) At process **402**, the processing unit **160** assigns an available WCM from a plurality of WCMs **101** to use the starter SIM. An available WCM is a WCM which is not assigned to any SIM yet and is operable. For illustration purposes, the starter SIM is SIM **112a** and the available WCM is WCM **101a**. Processing unit **160** assigns WCM **101a** to SIM **112a**. At process **403**, processing unit **160** initiates actions to establish a starter wireless carrier connection using WCM **101a** and SIM **112a**. An assigned WCM may become un-assigned when it fails to establish a wireless carrier connection or its established wireless carrier connection is disconnected.

(90) At process **404**, processing unit **160** determines whether the starter wireless carrier connection has been established or not. If the starter wireless carrier connection has not been established, processing unit **160** loops back to process **401** and selects another SIM as starter SIM from the plurality of L-SIMs and performs processes **401-404**. Processes **401-404** are iterated until the starter wireless carrier connection is successfully established. If each of the plurality of L-SIMs is attempted and the starter wireless carrier connection is not established, no further attempt will be performed. Optionally, a message is sent to its administrator informing that establishing a starter wireless carrier connection has failed and the method is stopped. In one variant, the loop between processes **401** to **404** will not be performed after a preset number of iterations has reached or a specific period of time is reached. In another variant, the method is restarted after a predetermined time interval. The time interval may be set as a default time interval by the manufacturer or may be manually set by the administrator of the WCD. The message may be displayed on a user interface (UI) of the WCD.

(91) When the starter wireless carrier connection is established, WCD **100** connects a remote SIM bank, for example, SIM bank **212a** by establishing a logical data connection through the starter wireless carrier connection at process **405**. The logical data connection may be established using TCP, UDP or other communication protocols. The logical data connection with SIM bank **212a** may be used to carry authentication request and authentication information while establishing one or more subsequent wireless carrier connection(s), thus, the logical data connection hereinafter is referred to as starter authentication connection.

(92) In process **406**, another SIM is selected from available L-SIMs and R-SIMs. An available R-SIM is a SIM in a SIM bank that is not assigned with a WCM yet. The selection of the another SIM may be performed manually by an administrator of WCD **100** or maybe be based on a SIM selection policy, which is different from the starter SIM selection policy. The SIM selection policy is similar to the starter SIM selection policy. However, the SIM selection policy may also select R-SIM while the starter SIM selection policy does not select R-SIM. The SIM selection policy may have the same or different selection criteria.

(93) At process **407**, an available WCM is assigned with the SIM selected at process **406** and a wireless carrier connection is established using the SIM selected at process **406** and the assigned WCM. In the course of establishing the wireless carrier connection, if the SIM selected at process **406** is an R-SIM, authentication request and authentication information related to the R-SIM

selected at process **406** are transmitted between WCD **100** and SIM bank **212a** using the starter authentication connection. On the other hand, if the SIM selected at process **406** is an L-SIM, the starter authentication connection may not be used as authentication request and authentication information with L-SIM does not go through the authentication connection. The starter authentication connection may be continued to be used onwards for transmitting authentication requests and authentication information when required. In one variant, the starter authentication connection is replaced by a replacement authentication connection, which will be described later. (94) In one variant, the starter authentication connection is only used for sending and receiving authentication requests and authentication information only. The starter authentication connection is not used for providing communication services to devices connected to WCD **100**. In one variant, the starter authentication connection is allowed for providing communication services to devices connected to WCD **100**.

(95) At process **408**, the processing unit of WCD **100** determines whether a threshold is reached. When the threshold is reached, the process ends at process **409**. The threshold may be evaluated based on one or more conditions including, but not limited to, the number of WCMs being used, the number of R-SIMs being used and/or the total number of WCMs in WCD **100**.

(96) In one example, when the threshold is based on the number of WCMs being used, the processing unit of WCD **100** determines whether the number of WCMs being used is equal to the threshold number of WCMs being used. If the number of WCMs being used is equal to the threshold number of WCMs being used, the process ends at process **409**. If the number of WCMs being used is smaller than the threshold number of WCMs being used, the processing unit of WCD **100** will go back to process **406** and continue to establish an additional wireless carrier connection using another SIM and another available WCM. The loop from process **406-408** is iterated until the threshold is reached. There is no limitation on how many wireless carrier connections may be established. In one variant, the total number of wireless carrier connections to be established is the total number of WCMs placed in WCD **100**.

(97) In another example, when the threshold is based on the number of SIMs being used, the method determines whether the number of SIMs being used is equal to the threshold. If the number of SIMs being used is equal to the threshold number of SIMs being used, the method ends. If the number of SIMs being used is not equal to the threshold number of SIMs being used, then the method moves back to process **406** for selecting another SIM from a plurality of available L-SIMs and R-SIMs and iterates loop **406-408** until the threshold is reached.

(98) In one variant, a predetermined time is set to reach the threshold, when the threshold is not met within the predetermined time, the method stops looping back to process **406** and ends. Setting a predetermined time to reach the threshold is beneficial for saving energy and resources. For example, in some scenarios, it may happen that the threshold may not be met because while looping back to process **406** there may be no SIM available to select. As a result, the loop from process **406** to process **408** may continue running until more SIM(s) are inserted into the SIM bank or the WCD, and waste energy and resources.

(99) FIG. **4B** is a process flowchart illustrating a method according to one example embodiment of the present invention. The method may be performed at processing unit **160** of WCD **100**. FIG. **4B** should be viewed in conjunction with FIG. **1A** and FIG. **2A**. The method begins at process **420**. In process **421**, the method selects a plurality of available L-SIMs as starter SIMs. The method illustrated in FIG. **4B** is similar to the method illustrated in FIG. **4A**. The selection of the first plurality of available L-SIMs to be starter SIMs may be performed in the same manner discussed in process **401** in FIG. **4A**, except that, in this example embodiment, multiple SIMs are selected as starter SIMs.

(100) In process **422**, each starter SIM of the plurality of starter SIMs is assigned with an available WCM. For example, in FIG. **1A**, WCMs **101a-101c** are shown, if WCM **101a** is already in use, the available WCMs are WCM **101b** and **101c**.

(101) In process **423**, the processing unit of WCD **100** initiates actions to establish starter wireless carrier connections using the plurality of starter SIMs and their corresponding WCMs assigned.

(102) In process **424**, the processing unit of WCD **100** determines whether at least one starter wireless carrier connection has been established or not. If at least one starter wireless carrier connection is successfully established, the processing unit of WCD **100** will use the at least one starter wireless carrier connection(s) to connect at least one SIM bank, such as SIM bank **212a**, by establishing at least one starter authentication connection(s), in process **425**.

(103) If, in process **424**, it is determined that no starter wireless carrier connection has been established, the method moves from process **424** back to process **421** and selects another plurality of L-SIMs as starter SIMs from available L-SIMs and iterates processes **421-423** until at least one starter wireless carrier connection is established. The another plurality of L-SIMs should not include L-SIMs which have already been attempted and failed to establish a connection with. In one variant, attempted L-SIMs may be selected again after a certain period of time. In another variant, attempted L-SIMs may be selected again if all the L-SIMs are attempted at least once still no starter wireless carrier connection is established.

(104) In process **425**, if a plurality of starter wireless carrier connection is established, the processing unit of WCD **100** may use any one of the starter wireless carrier connections for connecting a SIM bank by establishing a starter authentication connection and the other starter wireless carrier connection(s) may be used for data communication. In one variant, when the use of an L-SIM may incur roaming charges and an authentication connection is already established using a less expensive wireless carrier connection, the wireless carrier connection of the L-SIM will be disconnected to save cost. In another variant, at least two logical data connections are aggregated together to form an aggregated logical connection for connecting to the SIM bank. The aggregated logical connection may be used as an authentication connection. In one variant, if a plurality of starter wireless carrier connections is established, the processing unit of WCD **100** may use a plurality of starter wireless carrier connections for connecting to a plurality of SIM banks by establishing a plurality of starter authentication connections.

(105) In the case that after all L-SIMs are tried and no starter wireless carrier connection is established, WCD **100** sends a message to its administrator informing that establishing a starter wireless carrier connection has failed and stops the process. In one variant, the message may be displayed on the user interface (UI) of the WCD. In one variant, WCD **100** stops the method without sending the message.

(106) In another variant, a predetermined waiting time is set for establishing at least one starter wireless carrier connection. If no starter wireless carrier connection is established after the predetermined waiting time, WCD **100** sends a message to its administrator informing that establishing a starter wireless carrier connection has failed and stops the method. The message may be displayed on a user interface (UI) of the WCD. In another variant, the method is restarted after a predetermined time interval. The time interval may be set as a default time interval by the manufacturer or maybe manually set by the administrator of WCD **100**.

(107) In process **426**, the processing unit of WCD **100** selects another plurality of SIMs from available L-SIMs and R-SIMs as SIMs. However, it is preferable that when R-SIMs are selected in process **426**, the R-SIMs are selected only from available R-SIMs which are provided by local wireless carrier networks in order to avoid roaming charges. The selection of the SIMs at process **426** may be performed in the same manner discussed in process **406** of FIG. 4A, however in this example embodiment, a plurality of SIMs is selected. In another variant, R-SIMs have higher priority than L-SIMs to be selected at process **426**.

(108) In process **427**, the processing unit of WCD **100** assigns a corresponding available WCM with each of the plurality of SIMs selected at process **426** and establishes wireless carrier connections using the plurality of SIMs selected at process **426** and the corresponding WCMs. In the course of establishing the wireless carrier connections, authentication requests and

authentication information regarding the L-SIMs and R-SIMs are communicated according to the same process as described earlier in process **407** of FIG. **4A**.

(109) In process **428**, the processing unit of WCD **100** determines whether a threshold is reached. When the threshold is reached, the method proceeds to process **429** and ends. The threshold may be evaluated in the same process as discussed in process **408** of FIG. **4A**. When the threshold is not reached, the method loops back to process **426** and selects another plurality of SIMs from available L-SIMs and R-SIMs then iterates processes **427-428**. Processes **426-428** are iterated until the threshold is reached.

(110) In one variant, WCD **100** may connect to a plurality of SIM banks at process **425**. WCD **100** may connect to each SIM bank of the plurality of SIM banks by establishing one or more logical data connection(s) through one or more wireless carrier connection(s). When WCD **100** connects to a SIM bank through a plurality of logical data connections, the plurality of logical data connections may be carried by a plurality of wireless carrier connections. Therefore, WCD **100** may establish a plurality of aggregated logical data connections for connecting to the plurality of SIM banks.

(111) In one variant, a SIM bank management server is used to manage the plurality of SIM banks. For example, a SIM bank management server **216** shown in FIG. **2A**. WCD **100** may communicate with SIM bank management server **216** first for accessing the SIM banks. Before communicating with SIM bank management server **216**, WCD **100** may not have the access information of one or more SIM banks **212**. After having the access information of SIM banks **212**, WCD **100** is then able to communicate with SIM banks **212**.

(112) The embodiments described in FIGS. **4A** and **4B** are applicable for establishing a plurality of wireless carrier connections in any geographical area where the WCD is being used regardless of whether the WCD is being used in its home geographical area in a visited geographical area (i.e. foreign geographical area). The home geographical area is the geographical area where the user/subscriber has their wireless carrier account. The visited or foreign geographical area is the geographical area where the user's or subscriber's WCD is not otherwise considered local. For illustration purposes only, application of the embodiment described in FIG. **4A**, in home location and in a visited location, is demonstrated in the following paragraphs.

(113) In one example scenario, WCD **100** is being used in its home geographical area. There may be a plurality of wireless carrier networks available in its home geographical area. For example, wireless carrier networks **201a-201c** are available in the home geographical area. WCD **100** may access the wireless carrier networks using SIMs from the respective wireless carrier networks. The SIMs may be placed in WCD **100** or in one or more remote SIM banks. For illustration purposes, L-SIMs **111** and **112** are placed in WCD **100**, and R-SIMs **113** are placed in one or more SIM banks **212**, for example in SIM bank **212a**. Also, for illustration purpose, an eSIM, such as eSIM **111a** from eUICC **116a** and eSIM **111b** from eUICC **116b**, are from wireless carrier network **201a** and **201b** respectively, and L-SIMs **112a** and **112b** are from wireless carrier network **201c**. R-SIMs **113a** and **113b** are from wireless carrier network **201a** and wireless carrier network **201b** respectively. In one variant, R-SIM **113a** may be placed in SIM bank **212a** and R-SIM **113b** may be placed in SIM bank **212b**. Alternatively, both of the R-SIMs **113a** and **113b** may be placed in SIM bank **212b**. There is no limitation on the number of SIMs that can be placed in a SIM bank.

(114) Continuing with this exemplary scenario, eSIM **111a** is selected as the starter SIM for establishing a starter wireless carrier connection using a WCM, for example, WCM **101a**. As a result, a starter wireless carrier connection is established through wireless carrier network **201a**. WCD **100** then connects SIM bank **212a** through the starter wireless carrier connection by establishing a starter authentication connection through the starter wireless carrier connection. The starter wireless carrier connection may be reserved for carrying authentication requests and authentication information or may also be used for data communication by establishing more logical data connections. After establishing the starter authentication connection, another SIM is selected from available L-SIMs and R-SIMs for establishing another wireless carrier connection.

The selection of the another SIM may be performed manually by an administrator of WCD **100** or maybe be based on a SIM selection policy

(115) For example, R-SIM **113b** is selected from SIM bank **212a** and WCM **101b** is assigned with R-SIM **113b**. Then another wireless carrier connection is established using R-SIM **113b** and WCM **101b** through wireless carrier network **201b**.

(116) Continuing with this exemplary scenario, when establishing the wireless carrier connection using R-SIM **113b**, wireless carrier network **201b** may send a request for authentication information to WCM **101b** regarding R-SIM **113b**. The authentication request is then forwarded by WCD **100** to SIM bank **212a** through the starter authentication connection. SIM bank **212a** replies to the authentication request by providing authentication information regarding R-SIM **113b** and sends the authentication information to WCD **100**. WCD **100** forwards the reply sent by SIM bank **212a** to the authentication request to wireless carrier network **201b**. Based on the authentication information provided in the reply, wireless carrier network **201b** may then accept or refuse R-SIM **113b** for establishing the wireless carrier connection.

(117) If accepted, the wireless carrier connection using R-SIM **113b** will be established. If refused, the establishment of the wireless carrier connection using R-SIM **113b** fails and WCD **100** may select another R-SIM, for example, R-SIM **113a** and attempts to establish a wireless carrier connection over wireless carrier network **201a** following the same process.

(118) For illustration purposes, the wireless carrier connection using R-SIM **113b** has been successfully established. After that, the starter wireless carrier connection may optionally be disconnected and a replacement authentication connection is established through the wireless carrier connection established using R-SIM **113b**. When the starter wireless carrier connection is disconnected, WCM **101a** may be unassigned from eSIM **111a** and become available to be assigned with another SIM to establish another wireless carrier connection. In the case that the another SIM is an R-SIM, the replacement authentication connection may be used for carrying authentication information and authentication requests. In the case that the another SIM, is an L-SIM, there is no need for an authentication connection, as local SIMs are placed in the WCD and the authentication information regarding local SIMs can be accessed directly.

(119) After successful establishment of the wireless carrier connection using R-SIM **113b**, the processing unit of WCD **100** determines whether a threshold is reached. When a threshold is reached the process ends and the wireless carrier connections are used for data communications which is described later. On the other hand, if the threshold is not reached, the processing unit of WCD **100** keeps establishing another wireless carrier connection using another L-SIM or R-SIM until the threshold is reached.

(120) In another exemplary scenario, WCD **100** is being used in a visited geographical area. Wireless carrier networks **201a-201c** may not be available in the visited geographical area. For example, wireless carrier networks P, Q, R, S are available in the visited geographical area. However, WCD **100** may still place SIMs from wireless carrier networks **201a-201c** and does not have any SIMs from wireless carrier networks P, Q, R and S.

(121) For example, eSIMs **111a** and **111b** are from wireless carrier network **201a** and wireless carrier network **201b** respectively, and L-SIMs **112a** and **112b** are from wireless carrier network **201c**. R-SIM **113a** is from wireless carrier network **201a** and R-SIM **113b** is from wireless carrier network P. Different from the previous exemplary scenario where both of R-SIMs **113** were from wireless carrier networks of home geographical area, in this exemplary scenario, R-SIM **113a** is from a wireless carrier network of home geographical area and R-SIM **113b** is from wireless carrier network of the visited geographical area. Each of the SIM banks **212** may place SIMs from different wireless carrier networks of different geographical areas. For illustration purposes, R-SIMs **113a** and **113b** are placed in SIM bank **212a**. In one variant, the SIM banks may be managed through a SIM bank management server.

(122) For example, eSIM **111a** is selected as the starter SIM and WCM **101a** is assigned with it. As

eSIM **111a** is from wireless carrier network **201a** and WCD **100** is in a visited geographical area, eSIM **111a** is now a foreign SIM as it's not from a local wireless carrier network of the visited geographical area. WCD **100** then initiates establishing a starter wireless carrier connection using eSIM **111a** and WCM **101a**. For establishing the starter wireless carrier connection, WCD **100** first generates a request for data connection using authentication information of eSIM **111a**. The request for data connection may be received by one or more local wireless carrier networks of the visited geographical area. For example, wireless carrier network Q has received the request for data connection. In one variant, the request for data connection may be mechanically generated by WCD **100** when it opens or enters in the visited geographical area.

(123) If wireless carrier networks **201a** and Q have a roaming agreement, then wireless carrier network Q may check the validity of the authentication information provided by communicating with wireless carrier network **201a** and decide on whether to provide Internet access to WCD **100** based on the authentication information. If the authentication information is valid, then the starter wireless carrier connection will be established.

(124) If the authentication information is not valid, wireless carrier network Q may not provide Internet access to WCD **100** and the establishment of the starter wireless carrier connection may be failed. WCD **100** may again try to establish wireless carrier connection following the same process using another L-SIM from a different wireless carrier network, for example, using L-SIM **112a** from wireless carrier network **201c**. For illustration purposes, the starter wireless carrier connection using eSIM **111a** is successfully established.

(125) Since the starter wireless carrier connection is established using eSIM **111a** and eSIM **111a** is from wireless carrier network **201a** which is a non-local wireless carrier network of the visited geographical area, as a result, data communication using the starter wireless carrier connection will involve roaming charges.

(126) Therefore, after successful establishment of the starter wireless carrier connection, WCD **100** connects with a remote SIM bank, for example, SIM bank **212a**, by establishing a starter authentication connection through the starter wireless carrier connection. An R-SIM is then selected from SIM bank **212a**. It should be noted that, in this exemplary scenario, after establishing the starter authentication connection, the subsequent SIMs (SIMs that are selected after the establishment of the starter wireless carrier connection) are selected only from available R-SIMs based on the SIM selection policy unlike to the previous exemplary scenario where the subsequent SIMs were selected from available L-SIMs and R-SIMs. This is due to avoid roaming charges, as in this exemplary scenario, WCD **100** is being used in a visited geographical area, therefore, using of L-SIMs may involve roaming charges since the L-SIMs are from the wireless carrier networks of home geographical area. The selection of R-SIM may be performed by a processing unit of WCD **100**, SIM bank **212a** or SIM bank management server **216**. When the selection is performed by the processing unit of SIM bank **212a** or SIM bank management server **216**, after selecting an R-SIM, the selection information is sent to WCD **100**. The processing unit of WCD **100** then assigns the selected R-SIM with an available WCM. For example, R-SIM **113b** is selected and is assigned with WCM **101b**.

(127) The SIM selection policy may be based on one or more of the following criteria: position of an R-SIM placed in a SIM bank, R-SIM category, tariff price of an R-SIM, network's performance history of a SIM, services offered by the wireless carrier network of an R-SIM, service quality of the wireless carrier network of an R-SIM, administrator's preference, geolocation of WCD **100**, billing cycle information and time. For example, when an R-SIM is selected based on the geolocation of WCD **100**, the R-SIM should be selected from a local wireless carrier network corresponding to the current location of or wireless carrier networks available at WCD **100**. In this case, R-SIM **113b** is selected as it is from wireless carrier network P which is a local wireless carrier network of the visited geographical area.

(128) For illustration purposes, R-SIM **113b** is from wireless carrier network P. When establishing

the wireless carrier connection using R-SIM **113b**, wireless carrier network P may send a request to WCD **101b** for authentication information regarding R-SIM **113b**. The authentication request is then forwarded by WCD **100** to SIM bank **212a** through the starter authentication connection. SIM bank **212a** replies to the authentication request by providing authentication information regarding R-SIM **113b** to WCD **100**. The authentication information may also include other information depending on the requirements. WCD **100** forwards the authentication information to wireless carrier network P as a reply to the authentication request. Based on the authentication information provided in the reply, wireless carrier network P may accept or refuse the establishment of the wireless carrier connection using R-SIM **113b**.

(129) If accepted, the wireless carrier connection over wireless carrier network P is successfully established. If refused, the establishment of the wireless carrier connection using R-SIM **113b** fails. After that, another R-SIM may be selected and attempted to establish a wireless carrier connection using it according to the same processes as disclosed above.

(130) For illustration purposes, wireless carrier connection using R-SIM **113b** is successfully established. The processing unit of WCD **100** then determines whether a threshold is reached. When a threshold is reached the process ends and wireless carrier connections are used for data communications which is described later. On the other hand, if the threshold is not reached, the processing unit of WCD **100** keeps establishing another wireless carrier connection using another R-SIM until the threshold is reached.

(131) In one variant, after successful establishment of the wireless carrier connection using R-SIM **113b**, the starter wireless carrier connection is retained standby and not used or disconnected in order to reduce roaming charges and save resources. In that case, a replacement authentication connection is established through the wireless carrier connection established using R-SIM **113b** for transmitting authentication information and authentication requests.

(132) There is no limitation on the number of SIM banks may be utilized. When one SIM bank is used for placing all R-SIMs, the SIM bank may be placed in a centralized location, for example, in the home geographical area of the WCD and may place SIMs from different wireless carrier networks of the home geographical area and foreign geographical area. If multiple SIM banks are used, some of the SIM banks may be placed in the home geographical area and some may be placed in different foreign geographical areas. When SIM banks are placed in different foreign geographical areas, each SIM bank may place SIMs from the local wireless carrier networks of the corresponding geographical area. For example, SIM bank **212a** may be placed in the home geographical area of WCD **100** and places SIMs from different local wireless carrier networks of the home geographical area. On the other hand, SIM bank **212b** may be placed in a foreign geographical area and has SIMs from different local wireless carrier networks of the foreign geographical area.

(133) In one variant, there is no restriction that an authentication connection must also be used for data communication when not being used to communicate SIM authentication information. For example, the authentication connection may be used for data communication, such as web browsing and file transfer, when the bandwidth provided by non-authentication connection(s) is not adequate or below a threshold. When the bandwidth provided by the non-authentication connection(s) is adequate or above the threshold, the authentication connection will not be used for data communication. In another example, when WCD **100** is being used in a foreign country or may incur roaming charges, the authentication connection will not be used for data communication unless there is no other wireless carrier connection could be established. This may reduce roaming charges.

(134) In one variant, the authentication connection is also used for data connection without any limitation. After the establishment of the second data connection, the first and the second data connection may also be used to carry authentication information for establishing additional wireless carrier connections, such as the third data connection and so on.

(135) In one variant, any wireless carrier connection or a plurality of wireless carrier connections may be used to carry for establishing one or more authentication connections. There is also no limitation on the number of connections to be used as an authentication connection, any one or more established data connections may be used as authentication connection(s).

(136) In one variant, only the first data connection established using the starter SIM is used as an authentication connection. In another variant, WCD **100** is being used in a foreign country the data connection established using the starter SIM is disconnected after successfully establishing the second wireless carrier connection in order to avoid roaming charges and the second data connection is used as authentication connection. In another variant, both the first and the second data connections are used as authentication connections.

(137) The process flowcharts illustrated by FIGS. **5A**, **5B** and **5C** are to allow WCD **100** to use one or more R-SIMs to provide communication service to devices and users over wireless carrier networks but not the starter wireless carrier network. The starter wireless carrier network may not be the most preferred wireless carrier network to use in terms of tariffs, network performance, time and location. Therefore, once the starter wireless carrier connection is established, the processing unit of WCD **100** starts trying to establish other wireless carrier connections to replace starter wireless carrier connection or to reduce the usage of the starter wireless carrier connection. FIG. **5A** is a process flowchart illustrating a method according to one example embodiment of the present invention. The method may be performed at processing unit **160** of WCD **100**.

(138) FIG. **5A** should be viewed in conjunction with FIG. **1A**, FIG. **2A** and FIG. **4A**. FIG. **5A** may also be viewed in conjunction with FIG. **1A**, FIG. **2A** and FIG. **4B**. After process **408** or process **427**, there should be at least two wireless carrier connections established with at least two wireless carrier networks.

(139) For clarity, the authentication connection over a wireless carrier network using the starter SIM is referred to as the starter authentication connection, and the wireless carrier network is referred to as the starter wireless carrier network. For example, the processing unit has used a starter SIM to establish a wireless carrier connection with wireless carrier network **201c**. Then the processing unit of WCD **100** may connect to SIM bank **212a** through a logical data connection over wireless carrier network **201c** to carry authentication requests and authentication information. Therefore, wireless carrier network **201c** is the starter wireless carrier network; the wireless carrier connection established with wireless carrier network **201c** is the starter wireless carrier connection; and the logical data connection is referred to as the starter authentication connection.

(140) FIG. **5A** is a process flowchart illustrating a method according to one example embodiment of the present invention. The processes in FIG. **5A** illustrates how the starter authentication connection is replaced by a replacement authentication connection. Under different circumstances, there may be one or more motivations not to continue to use the starter authentication connection over the starter wireless carrier network. The motivations may include: the network performance of the starter wireless carrier network is not adequate; the cost of using the starter wireless carrier network is expensive; the availability of the starter wireless carrier network is not stable. By using a replacement authentication connection over a replacement wireless carrier connection, which is established using an R-SIM with a wireless carrier network, may enjoy better network performance, lower tariffs and/or more stable network availability.

(141) At process **501**, the processing unit of WCD **100** selects one wireless carrier network that is already connected to using an R-SIM to be the replacement wireless carrier network. For illustration purposes, WCD **100** has already established one wireless carrier connection with wireless carrier network **201a** using an R-SIM from SIM bank **212a**, and selects wireless carrier network **201a** to be the replacement wireless carrier network. The wireless carrier connection established with the replacement wireless carrier network becomes the replacement wireless carrier connection. For illustration purposes, SIM bank **212a** is the SIM bank that the starter authentication connected to.

(142) At process **502**, the processing unit of WCD **100** then establishes a logical data connection, over the replacement wireless carrier connection, with SIM bank **212a**. The logical data connection then becomes the replacement authentication connection.

(143) At process **503**, the processing unit of WCD **100** then starts using the replacement authentication connection to carry SIM authentication requests and SIM authentication information that is originally carried through the starter authentication connection.

(144) At process **504**, the processing unit of WCD **100** disconnects the starter wireless carrier connection established over wireless carrier network **201c**. It is preferred that the processing unit of WCD **100** disconnects the starter authentication connection gracefully before disconnecting the starter wireless carrier connection. When the starter wireless carrier connection is disconnected, the starter authentication connection will also be terminated. Once the starter wireless carrier connection is disconnected, there will be no more connection with the wireless carrier network **201c**. This may be cost-saving if wireless carrier network **201c** has more expensive tariffs than wireless carrier network **201a** using the R-SIM.

(145) At process **505**, the processing unit of WCD **100** may start to or continue to transmit and receive data packets through a plurality of logical data connections using the remaining wireless carrier connections. The remaining wireless carrier connections are connections already established with wireless carrier networks, excluding the replacement wireless carrier connection. For example, when there is a plurality of wireless carrier connections established before process **501**, one wireless carrier connection of the plurality of wireless carrier connections has become the replacement wireless carrier connection and the rest of the plurality of wireless carrier connections are remaining wireless carrier connections. By only using logical data connections over the remaining wireless carrier connections to transmit data packets, not related to authentication, allows the replacement wireless carrier connection to be exclusively to carry the replacement authentication connection. This may improve stability and speed of the replacement authentication connection compared to allowing other logical data connections to be established over the replacement wireless carrier connection.

(146) In one variant, other logical data connections are allowed to be established over the replacement wireless carrier connection. This may increase data throughput between WCD **100** and interconnected networks **217**.

(147) In one variant, process **504** is not performed. Therefore, the starter wireless carrier connection will still be available. The starter wireless carrier connection may still be used to carry the starter authentication connection. This may improve the network performance between WCD **100** and SIM bank **212a**. The starter wireless carrier connection may also be used to carry other logical data connections. This may improve the network performance between WCD **100** and interconnected networks **217**.

(148) In one variant, after the starter wireless carrier network is disconnected at process **504**, the processing unit of WCD **100** will establish a wireless carrier connection using the WCM that was originally used for the starter wireless carrier network with an R-SIM. Then logical data connections and/or an authentication connection may be established over this newly established wireless carrier connection. As a result, the overall network performance of WCD **100** may improve.

(149) FIG. 5B is a process flowchart illustrating a method according to one example embodiment of the present invention. The method may be performed at processing unit **160** of WCD **100**. FIG. 5B should be viewed in conjunction with FIG. 1A, FIG. 2A and FIG. 4A. FIG. 5B may also be viewed in conjunction with FIG. 1A, FIG. 2A and FIG. 4B. After process **408** or process **427**, there should be at least two wireless carrier connections established with at least two wireless carrier networks.

(150) The method illustrated in FIG. 5B is similar to the method illustrated in FIG. 5A. In the method illustrated in FIG. 5B, a plurality of wireless carrier connections, which are already

established with respective wireless carrier networks using a plurality of L-SIMs and/or R-SIMs, to be the replacement wireless carrier connections. In the method illustrated in FIG. 5A, there is one replacement wireless carrier connection.

(151) At process **511**, the processing unit of WCD **100** selects a plurality of wireless carrier networks, which are already connected to using a plurality of L-SIMs and/or R-SIMs, to be the replacement wireless carrier networks. For illustration purpose, WCD **100** has already established a wireless carrier connection with wireless carrier network **201a** using an R-SIM from SIM bank **212a**; a wireless carrier connection with wireless carrier network **201b** using an R-SIM from SIM bank **212b**; and a wireless carrier connection with wireless carrier network **201c** using an L-SIM. Also for illustration purposes, the processing unit of WCD **100** selects wireless carrier networks **201a** and **201b** to be the replacement wireless carrier network; wireless carrier network **201c** is the starter wireless carrier network; the wireless carrier connection established with wireless carrier network **201c** is the starter wireless carrier connection; and SIM bank **212a** is the SIM bank that the starter authentication connection connected to. Wireless carrier connections established with the replacement wireless carrier networks, i.e. wireless carrier networks **201a** and **201b**, become the replacement wireless carrier connections.

(152) At process **512**, the processing unit of WCD **100** then establishes two logical data connections through the replacement wireless carrier connections established over the replacement wireless carrier networks **201a** and **201b**, with SIM bank **212a**. The logical data connections then become the replacement authentication connections.

(153) At process **513**, the processing unit of WCD **100** then starts using the two replacement authentication connections to carry SIM authentication requests and SIM authentication information that are originally carried through the starter authentication connection.

(154) At process **514**, the processing unit of WCD **100** disconnects the starter wireless carrier connection established using wireless carrier network **201c**. It is preferred that the processing unit of WCD **100** disconnects the starter authentication connection gracefully before disconnecting the starter wireless carrier connection. When the starter wireless carrier connection is disconnected, the starter authentication connection will also be terminated. Once the starter wireless carrier connection is disconnected, there will be no more connection with wireless carrier network **201c**.

(155) At process **515**, the processing unit of WCD **100** may start to or continue to transmit and receive data packets through a plurality of logical data connections using the remaining wireless carrier connections.

(156) In one variant, the replacement authentication connections are aggregated together to form an aggregated authentication connection. The aggregated authentication connection may be an aggregated tunnel that comprises a plurality of tunnels. Each tunnel of the plurality tunnel is established over a replacement wireless carrier connection. There is no limitation on the number of authentication connections or tunnels that may be established over a replacement wireless carrier connection. For example, one replacement authentication tunnel with SIM bank **212a** and one replacement authentication tunnel with SIM bank **212b** may be established over a wireless carrier connection with wireless carrier network **201b**.

(157) In one variant, process **514** is not performed. Therefore, the starter wireless carrier connection will still be available. The starter wireless carrier connection may also be used to carry other logical data connections. The starter wireless carrier connection may continue to be an authentication connection.

(158) In one variant, after the starter wireless carrier network is disconnected at process **514**, the processing unit of WCD **100** will establish a wireless carrier connection using the WCM that was originally used for the starter wireless carrier network with an R-SIM. Then logical data connections and/or an authentication connection may be established over this newly established wireless carrier connection.

(159) FIG. 5C illustrates one example embodiment for managing authentication connections over

wireless carrier networks after at least one replacement authentication connection is established, over at least one replacement wireless carrier network. At process **531**, the processing unit of WCD **100** establishes a starter authentication connection over a starter wireless carrier network. At process **532**, the processing unit of WCD **100** establishes a first replacement authentication connection over a first replacement wireless carrier network. The first replacement wireless carrier network is a wireless carrier network firstly connected and used to connect to the SIM bank, which is the SIM bank that the starter authentication connection connects to.

(160) At process **533**, the processing unit of WCD **100** disconnects the starter wireless carrier network and therefore the starter authentication connection is also disconnected. When the starter authentication connection is disconnected, authentication requests and authentication information are carried using the first replacement authentication connection. At process **534**, the processing unit of WCD **100** establishes a second replacement authentication connection over a second replacement wireless carrier network. The second replacement wireless carrier network is a wireless carrier network connected and used to connect to the SIM bank after the first replacement wireless carrier network. The second replacement wireless carrier network may be any of the replacement wireless carrier networks except the first replacement wireless carrier network and starter wireless carrier network. The processing unit of WCD **100** uses the second replacement authentication connection to connect to the same SIM bank that the starter authentication connection connects to and the first replacement authentication connection connects to.

(161) At process **535**, the processing unit of WCD **100** disconnects the first replacement wireless carrier network and therefore the first replacement authentication connection is also disconnected.

(162) The details of establishing the starter authentication connection and the replacement authentication connections have been already disclosed in earlier embodiments of the present invention. Further, the details of using L-SIM and R-SIMs for establishing wireless carrier connections with wireless carrier networks have also been already disclosed in earlier embodiments of the present invention. For example, the starter wireless carrier network may be connected to using an L-SIM while the first and the second wireless carrier networks may be connected to using R-SIMs. The WCM used for using the L-SIM to connect to the starter wireless carrier network may be reused for the R-SIM to connect to the second replacement wireless carrier network.

(163) There is no limitation that process **534** must be performed after process **533**. For example, process **534** may be performed before process **533**. Further process **533** may be performed after process **535**.

(164) In one variant, when there is a plurality of replacement wireless carrier networks, the processing unit of WCD **100** may establish a plurality of replacement authentication connections at process **534**.

(165) In one variant, transmitting and receiving of data by devices, such as IoT **204** and laptop **206**, connected directly or through a LAN to WCD **100** may be started after the starter wireless carrier connection is established. This allows the devices to communicate with hosts reachable through interconnected networks **217** as soon as possible. In one variant, transmitting and receiving of data by devices may be limited or not allowed through the starter wireless carrier connection.

Transmitting and receiving of data by the devices may be started only after the first replacement authentication connection over the first replacement wireless carrier network is established at process **532**, in order to reduce the use of the starter wireless carrier connection. This may reduce tariffs and/or roaming charges imposed by the starter wireless carrier or improving network performance. The use of R-SIMs at the SIM banks may reduce tariffs and/or roaming charges as the R-SIMs selected may not incur roaming charges and may offer better network performance. In one variant, transmitting and receiving of data by devices may be limited or not allowed through the starter wireless carrier connection and/or the first replacement authentication connection. Transmitting and receiving of data by the devices may be started only after the second replacement wireless carrier connection over the second replacement wireless carrier network is established at

process **534**, in order to reduce the use of the starter wireless carrier connection and/or the first replacement wireless carrier connection. In addition to the possibility of reducing tariffs and/or roaming charges imposed by the starter wireless carrier network, performance may be improved and more flexibility on selecting wireless carrier networks may be achieved.

(166) FIG. **6** is a process flowchart illustrating a method according to one embodiment of the present invention. The processing unit of WCD **100** is used to determine when to disconnect a logical data connection and establish a new logical data connection. FIG. **6** should be viewed in conjunction with FIG. **1A** and FIG. **2A**. In process **601**, The processing unit of WCD **100** establishes a plurality of logical data connections through one or more wireless carrier connections. The one or more wireless carrier connections may be established over one or more wireless carrier networks according to any of the methods described in FIGS. **4A** and **4B**. In one variant, one or more of the logical data connections may also be established through one or more wired network connections established through one or more wide area network (WAN) interfaces of WCD **100**. (167) In process **602**, the processing unit of WCD **100** allows data communications through the plurality of logical data connections established through the one or more wireless carrier connections. For illustration purposes, data communications may be performed between a host connected directly or through a local area network to WCD **100** and another host reachable via interconnected networks **217**. For example, a host connected to WCD **100** may be laptop **206** or IoT device **204** and another host reachable via interconnected network **217** may be web server **208**, SIM banks **212**, SIM bank management server **216**, eSIM server **214**, or a host connected to the network node **210**. In one variant, the plurality of logical data connections may be aggregated to form an aggregated tunnel.

(168) In process **603**, the processing unit of WCD **100** monitors the one or more wireless carrier connections for satisfaction criteria. The satisfaction criteria may include, but not limited to, connection type, tariff cost, latency, bandwidth and network congestion. In process **604**, the processing unit of WCD **100** determines whether there is any wireless carrier connection(s) not satisfying the satisfaction criteria. When the determination result is “No”, indicating the satisfaction criteria are met, “No” branch is followed and processes **603-604** are iterated. In one variant, the processing unit of WCD **100** waits for a predetermined time before each iteration of loop **603-604**, as this would help to reduce the processing workload of the processor and save energy and resources. If in process **604**, the result is “Yes”, indicating satisfaction criteria are not met, “Yes” branch is followed and process **605** is performed.

(169) In process **605**, the processing unit of WCD **100** disconnects the wireless carrier connection(s) not fulfilling the satisfaction criteria. However, in some example scenarios, it is possible that all wireless carrier connections are failing to fulfill the satisfaction criteria, in such cases, one wireless carrier connection is retained operational while the rest of the wireless carrier connections are disconnected. It is preferable that comparatively the best performing wireless carrier connection is retained operative.

(170) In one variant, each item of the satisfaction criteria may be assigned with a priority level that is configured by an administrator or a user of WCD **100**. For example, when tariff cost is given top priority, the connection(s) with high tariff cost should be disconnected first. If all the wireless carrier connections fail to fulfill at least one criterion of the satisfaction criteria, the wireless carrier connection having the least priority level should be retained operative.

(171) In process **606**, the processing unit of WCD **100** establishes a replacement wireless carrier connection each of the disconnected wireless carrier connections. After establishing the replacement wireless carrier connection(s), the processing unit of WCD **100** establishes another logical data connection of the plurality of logical data connections through the replacement wireless carrier connection(s) at process **601**. The another plurality of logical data connections then may be used for data communication in process **602**. In one variant, a replacement wireless carrier connection is established for each of the wireless carrier connections not satisfying the satisfaction

criteria even though it is not disconnected. Processes **605** and **606** may be performed interchangeably. As such, replacement wireless carrier connection(s) may be established at process **606** before disconnecting the wireless carrier connections at process **605**.

(172) FIG. **7** is a progress flowchart illustrating one embodiment of the present invention. At process **701**, a starter SIM is used with one of WCMs of WCD **100** and the WCM is referred to as the first WCM as it is the first WCM used sequentially. The starter SIM may be an L-SIM, R-SIM or a roaming R-SIM. It is known that a roaming SIM is a SIM card that is capable of operation on more than one network. A roaming R-SIM, as referred in this present invention, is an R-SIM placed in a SIM bank and is capable of operating on more than one wireless carrier network. If there is no logical data connection able to be established with a SIM bank or SIM bank management server, the starter SIM should be an L-SIM as WCD **100** could not be able to use an R-SIM. A starter authentication connection is established with a SIM bank using the starter SIM with the first WCM. In process **702**, as an authentication connection is now established, an R-SIM from a SIM bank could be used to establish a wireless carrier connection using a second WCM. As the R-SIM is the first in sequence, the R-SIM is referred to as the first R-SIM and the wireless carrier connection is referred to as the first wireless carrier connection. Authentication requests and authentication information may be transmitted and received through the starter authentication connection.

(173) In process **703**, a next R-SIM, referred to as the second R-SIM, will be used to establish a second wireless carrier connection using a next WCM, referred to as the third WCM. Authentication requests and authentication information may be transmitted and received through the starter authentication connection and/or through a replacement authentication connection established through the first wireless carrier connection.

(174) In process **704**, a $(n-1)$ th R-SIM, will be used to establish a n th wireless carrier connection using a $(n-1)$ th WCM. Authentication requests and authentication information may be transmitted and received through one or a combination of the authentication connections established through the wireless carrier connections. The processes may continue unless n reaches a threshold or n reaches the number of WCMs in WCD **100**. As there are usually numerous R-SIMs in a SIM bank and WCD **100** may connect to a plurality of SIM banks, the number of R-SIMs available should be more than WCMs available. The purpose of these processes is to use as many WCMs as possible.

(175) The authentication connection is not used for transmitting and receiving data for network devices connected to WCD **100**, such as local area network **202**, IoT **204** and laptop **206**. Data to and from network devices connected to WCD **100** is allowed to be transmitted and received through one or a combination of the $(n-1)$ th data connections.

(176) In one variant, the first m th wireless carrier connections are not used for transmitting and receiving data for network devices connected to WCD **100**. Data to and from network devices connected to WCD **100** is allowed to be transmitted and received through one or a combination of the $(m+1)$ th to $(n-1)$ th data connections. For illustration purposes, m is five and n is ten, then data to and from network devices connected to WCD **100** is allowed to be transmitted and received through one or a combination of the sixth, seventh, eighth and ninth data connections, but not the first to the fourth wireless carrier connections.

(177) FIG. **8A** is a process flowchart that illustrates an R-SIM selection and authentication process of one exemplary embodiment. When an R-SIM is to be selected by a SIM bank or processing unit of WCD **100**, a SIM selection policy may be used to select an R-SIM. Information may be required for the SIM selection policy. At process **801**, the information for the SIM selection policy is collected by the processing unit of WCD **100**.

(178) At process **802**, an R-SIM is selected according to the R-SIM selection process, as illustrated in FIG. **3B**, based on the information collected. When the R-SIM selection process is performed by SIM bank, the information collected will be transmitted to the SIM bank through a logical connection, a plurality of logical connection or an aggregated logical connection. The logical connection, the plurality of logical connections or the aggregated logical connection may or may

not be a starter. For example, the logical data connection connecting to the SIM bank may be a starter authentication connection or a replacement authentication connection. Information of the selected R-SIM will then be sent to WCD **100**.

(179) When the R-SIM selection process is performed by the processing unit of WCD **100**, information of a plurality of R-SIMs in at least one SIM bank will be sent to WCD **100**. Then the processing unit of WCD **100** will select an R-SIM according to the SIM selection policy with the information collected.

(180) Once an R-SIM is selected, authentication requests received from the corresponding wireless carrier network and authentication information from the R-SIM will be transmitted through an authentication connection established between the SIM bank and WCD **100**. There is no limitation that the authentication connection must be a starter or a replacement authentication connection.

(181) FIG. **8B** is a more detailed process flowchart for further exemplary embodiments of processes **801** and **802**. At process **811**, the processing unit of WCD **100** identifies available wireless carrier networks by using at least one WCM of a plurality of WCMs. At process **812**, the processing unit of WCD **100** determines signal quality of each of the available wireless carrier networks identified by the at least one WCM. The availability of wireless carrier networks and the corresponding signal quality are then used for the SIM selection policy. In one variant, process **812** is not performed and only the availability of wireless carrier networks is used for the SIM selection policy.

(182) At process **813** an R-SIM or a roaming R-SIM is selected based on wireless carrier networks that meet the signal quality requirement and further based on the tariffs and/or allowed usage of wireless carrier networks. If the signal quality of an available wireless carrier network does not meet a signal quality requirement, the available wireless carrier should not be used and R-SIMs and roaming R-SIMs that have to use that available wireless carrier network will not be selected. In one example, when there are two available wireless carrier networks meeting the signal quality requirement, an R-SIM which uses the wireless carrier network with lower tariffs will be selected. For illustration purposes, the two available wireless carrier networks are **201a** and **201b**. When wireless carrier network **201a** has lower tariffs than the tariffs of wireless carrier network **201b**, an R-SIM or a roaming R-SIM which uses wireless carrier network **201a** will be selected.

(183) In one variant, there are three available wireless carrier networks **201a-201c** meet the signal quality requirement and WCD **100** has two available WCMs. For illustration purposes, wireless carrier networks **201a** and **201c** both have the same tariffs and are less expensive than the wireless carrier network **201b**. Therefore, only R-SIMs and roaming R-SIMs using wireless carrier networks **201a** and/or **201c** will be selected and R-SIMs and roaming R-SIMs using wireless carrier network **201b** will not be selected. For roaming R-SIMs that are configurable to use any of the three wireless carrier networks, they may still be selected but will be configured to use wireless carrier networks **201a** and/or **201c** in process **814**.

(184) The R-SIM selection process may be performed by the processing unit of WCD **100**, a processing unit of a SIM bank **212** or a processing unit of a SIM bank management server **216**. When the R-SIM selection process is performed by the processing unit of WCD **100**, information, such as identity of the wireless carrier networks, tariffs and allowed usage of the R-SIMs and roaming R-SIMs, will be sent to the WCD **100** by the processing unit of SIM bank **212** or SIM bank management server **216** for the processing unit to select. Similarly, when the R-SIM selection process is performed by the processing unit of the SIM bank management server, the information will also be sent to SIM bank management server **216**. In one example, a SIM bank may select a plurality of R-SIMs and/or roaming R-SIMs first, then the processing unit of WCD **100** may select one or more R-SIMs and/or roaming R-SIMs from the plurality of R-SIMs and/or roaming R-SIMs selected by the SIM bank.

(185) FIG. **8C** is a more detailed process flowchart for further exemplary embodiments of processes **801** and **802**. At process **821**, the processing unit of WCD **100** identifies its geographical

location. Geographical location may be determined by using GPS. At process **822**, an R-SIM or a roaming R-SIM is selected based on the geographical location information and is further based on the tariffs and/or data usage allowance. A database or a look-up table may be used to search for wireless carrier networks that may be used in the geographical location. The database or the look-up table may be stored in WCD **100**, a SIM bank, a plurality of SIM banks and/or a SIM bank management server. For example, longitude and latitude information, based on GPS information obtained from a GPS receiver at WCD **100**, may be used to look-up for available wireless carrier networks at the geographical location of WCD **100**.

(186) Similar to the processes illustrated in FIG. **8B**, there is no limitation that only one R-SIM or roaming R-SIM is selected. For example, a plurality of R-SIMs and/or roaming R-SIMs may be selected.

(187) In one example, based on the GPS location information of WCD **100**, a database is searched for available wireless carrier networks. For illustration purposes, the records in the database indicate that there are two available wireless carrier networks at the location of WCD **100**. For example, the two available wireless carrier networks are **201a** and **201b** and wireless carrier network **201a** has a lower tariff than the tariffs of wireless carrier network **201b**, thus, an R-SIM or a roaming R-SIM using wireless carrier network **201a** will be selected.

(188) In one variant, there are three available wireless carrier networks **201a-201c**, according to the database records and WCD **100** has two available WCMs. For illustration purposes, wireless carrier networks **201a** and **201c** both have the same tariffs and are less expensive than the tariffs of wireless carrier network **201b**. Therefore, only R-SIMs and roaming R-SIMs using wireless carrier networks **201a** and/or **201c** will be selected and R-SIMs and roaming R-SIMs using wireless carrier network **201b** will not be selected. For roaming R-SIMs that are configurable to use any of the three wireless carrier networks, they may still be selected but will be configured to use wireless carrier networks **201a** and/or **201c** in process **823**.

(189) FIG. **8D** illustrates a method for configuring WCMs when a roaming R-SIM is selected in processes **813** and **822**. When a roaming R-SIM is selected, mobile country code (MCC) and mobile network code (MNC) of the wireless carrier network selected will be first determined at process **831** and then will be sent from SIM bank **212** to WCD **100** over an authentication connection in process **832**. Then WCD **100** will configure an available WCM with the MCC and MNC in process **833** to allow the WCM to use the wireless carrier network selected. The authentication connection may be a starter authentication connection, a replacement authentication connection or an aggregated authentication connection. For example, wireless carrier network **201a** is the wireless carrier network selected in the USA, then MCC and MNC of wireless carrier network **201a** will be determined in process **831**. MCC and MNC will be sent in process **832** and will be used to configure an available WCM in process **833**. In one variant, MCC and MNC information is already stored in WCD **100**, and the process unit of WCD **100** may be able to determine the MCC and MNC information itself and is not required to retrieve MCC and MNC information from SIM bank **212**. Therefore, process **832** is skipped. One of the benefits of using MCC and MNC is to reduce the process of identifying geographical location of WCD **100**.

(190) In another detailed example, an access point name (APN) of an R-SIM or a roaming R-SIM may be sent from SIM bank **212** to WCD **100** to allow an available WCM to establish a desired connection with a wireless carrier network. For example, WCD **100** may be able to access a private network using the APN. In one variant, APN information is already stored in WCD **100**, and WCD **100** may be able to provide the APN itself and is not required to retrieve APN information from SIM bank **212**.

(191) The R-SIM selection process may be performed by the processing unit of WCD **100**, a processing unit of a SIM bank **212** or a processing unit of a SIM bank management server **216**.

(192) In one variant, the SIM selection policy is aimed to diversify the use of wireless carrier networks that meet the selection criteria. For example, one R-SIM is needed, three R-SIMs from

wireless carrier networks **201a-201c** meet the selection criteria respectively and WCD **100** has a WCM that has already established a wireless carrier connection using an R-SIM from wireless carrier network **201a**. Thus, SIM bank **212** will not select the R-SIMs belonging to wireless carrier network **201a** among the three R-SIMs due to diversification. SIM bank **212** will select the R-SIM from either wireless carrier network **201b** or **201c**.

(193) FIG. **9A** is a process flowchart illustrating a method performed at WCD **100** according to one example embodiment of the present invention. Processes **901** to **908** may be performed solely or jointly at WCD **100**, at one or more SIM banks **212**, and SIM bank management server **216**. For illustration purposes, the processing unit of WCD **100** performs processes **901** to **908**. The processes start at process **901**. For illustration purposes, WCD **100** has three WCMs. Each WCM uses one R-SIM from SIM bank **212a** to establish a wireless carrier connection with one of wireless carrier networks **201a-201c**. Therefore, WCD **100** has established three wireless carrier connections. WCD **100** communicates with SIM bank **212a** using one or more logical data connections established over one or more of the three wireless carrier connections. At process **902**, the processing unit of WCD **100** monitors at least one condition associated with R-SIMs being used. For example, the at least one condition is less than 2% packet drop rate of a wireless carrier connection. Therefore, the processing unit monitors the packet drops rate for each of the three wireless carrier connections.

(194) At process **903**, determines whether the at least one condition associated with one or more R-SIMs is failed or not. As according to the example, the at least one condition is less than 2% packet drop rate of a wireless carrier connection, thus, the at least one condition fails when the packet drop rate of a wireless carrier connection is more than 2%. For example, packet drop rate of the wireless carrier connection established with wireless carrier network **201b** has increased to 3%. Therefore, wireless carrier connection established with wireless carrier network **201b** fails the at least one condition. For illustration purposes, (m+2) R-SIM is used to establish the wireless carrier connection with wireless carrier network **201b** and therefore becomes a failed R-SIM. A failed R-SIM is an R-SIM used for connecting to the wireless carrier network that failed to satisfy at least one condition.

(195) At process **904**, the processing unit of WCD **100** determines if WCD **100** may still communicate with SIM bank **212a** over the wireless carrier connections established with wireless carrier networks **201a** and/or **201c**. If WCD **100** is able to communicate with SIM bank **212a** through one or both of the wireless carrier connections established with wireless carrier networks **201a** or **201c**, the processing unit of WCD **100** will stop using the failed R-SIM at process **905**. The processing unit of WCD **100** will select another R-SIM, for example, (m+1) R-SIM to replace the failed R-SIM at step **906** and start using (m+1) R-SIM at step **907**.

(196) If determined at process **904** that there are no other wireless carrier connections that could be used to communicate with SIM bank **212a**, the processing unit may continue to use the wireless carrier connection established with wireless carrier network **201b** and end the processes at process **908**.

(197) There is no limitation that all the processes in FIG. **9A** must be performed by the processing unit of WCD **100**. Some or all of the processes could be performed by the processing unit of SIM bank **212** and/or SIM bank management server **216**. In one example, the condition at step **902** may be the amount of data usage allowed per R-SIM is approaching the limit. The process to verify the amount of data usage may be performed by the processing unit of WCD **100**, the processing unit of SIM bank **212** and/or SIM bank management server **216**.

(198) In another example, the selection of R-SIM at step **906** may be performed by the processing unit of SIM banks **212** and/or SIM bank management server **216**.

(199) In one variant, a same wireless carrier network may be used by a plurality of WCMs. For example, WCMs **101a** and **101b** may both connect to wireless carrier network **201b** concurrently through corresponding R-SIMs. When the wireless carrier network is performing at a lower quality,

both WCMs **101a** and **101b** may experience the same lower quality performance and the corresponding R-SIMs may also fail the condition at process **903**. Therefore, at process **905**, the processing unit of WCD **100** will stop using the R-SIMs corresponding to WCMs **101a** and **101b**. At processes **906** and **907**, two R-SIMs will be selected and used.

(200) In one variant, the failed R-SIM is a roaming R-SIM. When a condition associated with the roaming R-SIM fails, the processing unit of WCD **100** or the processing unit of SIM banks **212** may be able to continue to use the same roaming R-SIM to establish another wireless carrier connection with another wireless carrier network. Therefore, processes **905**, **906** and **907** are replaced by processes **915** to **917** shown in FIG. **9B**.

(201) For example, the roaming R-SIM is capable of using wireless carrier network **201a** or **201b**, where **201b** was the original wireless carrier network that was being used. When WCD **100** is moved to an area that has no wireless carrier network **201b** coverage, the condition of receiving coverage may fail at process **903**. Therefore, at process **915**, the processing unit of WCD **100** will disconnect the roaming R-SIM from wireless carrier network **201b**. At process **916**, the processing unit of WCD **100** will select another wireless carrier network for connecting with the roaming R-SIM. At process **917**, the processing unit of WCD **100** will start using the roaming R-SIM by establishing another wireless carrier connection using the roaming R-SIM and the selected wireless carrier network. There is no limitation that all the processes in FIG. **9B** must be performed by the processing unit of WCD **100**. Some or all of the processes could be performed by the processing unit of SIM bank **212** and/or SIM bank management server **216**. There is no limitation that processes **915** to **917** are limited to one roaming R-SIM. Processes **915** to **917** may also be applied to plurality of roaming R-SIMs. There is also no limitation that a roaming R-SIM is capable of using only two wireless carrier networks. There may be more than two wireless carrier networks for selection.

(202) In a detailed example, when a roaming R-SIM is selected, mobile country code (MCC) and mobile network node (MNC) of the wireless carrier network selected may be sent from SIM bank **212** to WCD **100** over an authentication connection. Then WCD **100** will configure an available WCM with the MCC and MNC to allow the WCM to use the wireless carrier network selected. The authentication connection may be a starter authentication connection, a replacement authentication connection or an aggregated authentication connection. For example, wireless carrier network **201a** is the wireless carrier network selected in the USA, then MCC and MNC of wireless carrier network **201a** will be used to configure the available WCM. In one variant, MCC and MNC information is already stored in WCD **100**, and WCD **100** may be able to provide the MCC and MNC information itself and is not required to retrieve MCC and MNC information from SIM bank **212**.

(203) In another detailed example, an access point name (APN) of an R-SIM or a roaming R-SIM may be sent from SIM bank **212** to WCD **100** to allow an available WCM to establish a desired connection with a wireless carrier network. For example, WCD **100** may be able to access a private network using the APN. In one variant, APN information is already stored in WCD **100**, and WCD **100** may be able to provide the APN itself and is not required to retrieve APN information from SIM bank **212**.

(204) FIG. **10** illustrates maintenance of SIM bank connections when multiple wireless carrier connections are established according to the embodiments. For illustration purposes, a first wireless carrier connection is established using WCM **1001** and a first SIM over the wireless carrier network of the SIM, wherein the first SIM is a local SIM. At **1021**, the processing unit of WCD **100** sends authentication request **1051** through a starter authentication connection established with SIM bank **1010** through the first wireless carrier connection. Wherein authentication request **1051** was initially received at WCD **100** from a wireless carrier network and then forwarded to SIM bank **1010** by the WCD.

(205) At **1022**, WCD **100** receives authentication information **1052** through the starter

authentication connection in response to authentication request **1051**. Wherein authentication information **1052** contains necessary information corresponding to an R-SIM (second SIM) for establishing a second wireless carrier connection. The processing unit of WCD **100** forwards authentication information **1052** to the wireless carrier network from which authentication request **1051** was initially received. The second wireless carrier connection is then successfully established using a WCM from the available WCMs and the second SIM. For example, WCM **1002** is used from available WCMs **1002-1004**.

(206) After successful establishment of the second wireless carrier connection, the first wireless carrier connection may be disconnected. Therefore, WCM **1001** becomes available for being used to establish another wireless carrier connection.

(207) At **1023**, the processing unit of WCD **100** sends another authentication request, for example authentication request **1053**, to SIM bank **1010**. Authentication request **1053** may be sent through a replacement authentication connection established through the second wireless carrier connection. Authentication request **1053** was initially received at WCD **100** from a wireless carrier network and then forwarded to SIM bank **1010** by the WCD.

(208) At **1024**, WCD **100** receives authentication information **1054** in response to authentication request **1053** through the replacement authentication connection established through the second wireless carrier connection. Wherein authentication information **1054** contains necessary information corresponding to an R-SIM (third SIM) for establishing a third wireless carrier connection. The processing unit of WCD **100** forwards authentication information **1054** to the wireless carrier network from which authentication request **1053** was initially received. The third wireless carrier connection is then successfully established using a WCM from the available WCMs and the third SIM. For example, WCM **1003** is used from available WCMs **1001, 1003 and 1004**.

(209) At **1025**, the processing unit of WCD **100** sends another authentication request, for example authentication request **1055**, to SIM bank **1010**. Authentication request **1055** may be sent through the replacement authentication connection established through the second wireless carrier connection or a replacement authentication connection established through the third wireless carrier connection. For illustration purposes, authentication request **1055** is sent through the replacement authentication connection established through the third wireless carrier connection. Authentication request **1055** was initially received at WCD **100** from a wireless carrier network and then forwarded to SIM bank **1010** by the WCD.

(210) At **1026**, WCD **100** receives authentication information **1056** in response to authentication request **1055** through the replacement authentication connection established through the third wireless carrier connection. Wherein authentication information **1056** contains necessary information corresponding to an R-SIM (fourth SIM) for establishing a fourth wireless carrier connection. The processing unit of WCD **100** forwards authentication information **1056** to the wireless carrier network from which authentication request **1055** was initially received. The fourth wireless carrier connection is then successfully established using a WCM from the available WCMs and the fourth SIM. For example, WCM **1001** is used from available WCMs **1001 and 1004**.

(211) At **1027**, the processing unit of WCD **100** sends another authentication request, for example authentication request **1057**, to SIM bank **1010**. Authentication request **1057** may be sent through the replacement authentication connection established through the second wireless carrier connection, the replacement authentication connection established through the third wireless carrier connection or a replacement authentication connection established through the fourth wireless carrier connection. For illustration purposes, authentication request **1057** is sent through the replacement authentication connection established through the fourth wireless carrier connection. Authentication request **1057** was initially received at WCD **100** from a wireless carrier network and then forwarded to SIM bank **1010** by the WCD.

(212) At **1028**, WCD **100** receives authentication information **1058** in response to authentication request **1057** through the replacement authentication connection established through the fourth wireless carrier connection. Wherein authentication information **1058** contains necessary information corresponding to an R-SIM (fifth SIM) for establishing a fifth wireless carrier connection. The processing unit of WCD **100** forwards authentication information **1058** to the wireless carrier network from which authentication request **1057** was initially received. The fifth wireless carrier connection is then successfully established using an available WCM, for example, WCM **1004** and the fifth SIM.

(213) There is no limitation that the first wireless carrier connection should be disconnected after the second wireless carrier connection is established, it may be disconnected later (e.g. after establishing the third, fourth, fifth or a following wireless carrier connection) or it may not be disconnected at all. In one variant, when the first wireless carrier connection is not disconnected, authentication request and authentication information for the third, fourth, fifth or a following wireless carrier connection may also be carried through the starter authentication connection established through the first wireless carrier connection.

Claims

1. A method for replacing wireless carrier connections at a wireless communication device, comprising: (a) establishing a wireless carrier connection with one of wireless carrier networks by using a remote SIM from a SIM bank; (b) monitoring at least one condition associated with the remote SIM; and (c) when the at least one condition associated with the remote SIM is not satisfied: (i) if at least one different wireless carrier connection is capable of being used to communicate with the SIM bank, stopping usage of the remote SIM; (ii) selecting a replacement SIM; (iii) establishing a replacement wireless carrier connection using the replacement SIM; and (iv) starting to use the replacement wireless carrier connection.
2. The method of claim 1, wherein the wireless carrier connection is to be maintained if no other wireless carrier connections are capable of being used to communicate with the SIM bank.
3. The method of claim 1, wherein the replacement SIM is selected based on a SIM selection policy.
4. The method of claim 3, wherein the SIM selection policy is based on one or more of the following: position of a SIM placed in the wireless communication device, a SIM category, network performance history of a SIM and identity of wireless carrier network issuing a SIM.
5. The method of claim 1, wherein the at least one condition is selected from one or more of the following: packet drop rate of the wireless carrier connection, amount of data usage of the remote SIM, quality of the wireless carrier network, and coverage of the wireless carrier network.
6. The method of claim 1, wherein the remote SIM is a foreign SIM.
7. The method of claim 1, wherein the remote SIM is an embedded Universal Integrated Circuit Card (eUICC).
8. The method of claim 1, wherein the replacement SIM is a foreign SIM.
9. The method of claim 1, wherein the replacement SIM is an eUICC.
10. The method of claim 1, further comprising: establishing an aggregated logical data connection over the replacement wireless carrier connection.
11. A wireless communication device, comprising: at least one processing unit; at least one main memory; at least one logic circuit to perform multiplexing; a plurality of wireless communication modules; at least one SIM card interface; and at least one storage medium comprising program instructions executable by the at least one processing unit for: (a) establishing a wireless carrier connection with one of wireless carrier networks by using a remote SIM from a SIM bank; (b) monitoring at least one condition associated with the remote SIM; and (c) when the at least one condition associated with the remote SIM is not satisfied: (i) if at least one different wireless carrier

connection is capable of being used to communicate with the SIM bank, stopping usage of the remote SIM; (ii) selecting a replacement SIM; (iii) establishing a replacement wireless carrier connection using the replacement SIM; and (iv) starting to use the replacement wireless carrier connection.

12. The wireless communication device of claim 11, wherein the wireless carrier connection is to be maintained if no other wireless carrier connections are capable of being used to communicate with the SIM bank.

13. The wireless communication device of claim 11, wherein the replacement SIM is selected based on a SIM selection policy.

14. The wireless communication device of claim 13, wherein the SIM selection policy is based on one or more of the following: position of a SIM placed in the wireless communication device, a SIM category, network performance history of a SIM and identity of wireless carrier network issuing a SIM.

15. The wireless communication device of claim 11, wherein the at least one condition is selected from one or more of the following: packet drop rate of the wireless carrier connection, amount of data usage of the remote SIM, quality of the wireless carrier network, and coverage of the wireless carrier network.

16. The wireless communication device of claim 11, wherein the remote SIM is a foreign SIM.

17. The wireless communication device of claim 11, wherein the remote SIM is an embedded Universal Integrated Circuit Card (eUICC).

18. The wireless communication device of claim 11, wherein the replacement SIM is a foreign SIM.

19. The wireless communication device of claim 11, wherein the replacement SIM is an eUICC.

20. The wireless communication device of claim 11, wherein the at least one storage medium further comprises program instructions executable by the at least one processing unit for: establishing an aggregated logical data connection over the replacement wireless carrier connection.
