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Methods and apparatus for frequency, phase and time of day synchronization in wireless systems

Abstract

The present invention relates to methods and apparatus for achieving frequency, phase and time of day synchronization in wireless systems. An exemplary method of operating a first wireless base station in a first network in accordance with an embodiment of the present invention comprises the steps of: (i) receiving, at the first wireless base station, a first message; (ii) in response to receiving the first message entering, by the first wireless base station, into a first mode of operation; and (iii) while operating in the first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, the synchronization information including time synchronization information.

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Background/Summary

FIELD OF INVENTION

(1) The present invention relates to methods and apparatus for achieving frequency, phase and time of day synchronization in wireless systems. The present invention further relates to methods and apparatus for providing and/or distributing synchronization information (e.g., frequency, phase, and time of day synchronization information) to devices, e.g., wireless base stations, in wireless networks.

BACKGROUND OF THE INVENTION

(2) Wireless radios, e.g., Citizen Broadband Radio Service Time Division—Long Term Evolution New Radio (CBRS TD-LTE/NR) radios, need Global Positioning System (GPS) signals or Clock Sync such as IEEE 1588 (Precision Time Protocol) for Frequency, Phase and Time of Day (ToD) to operate. Without this synchronization the wireless base stations, e.g., CBSDs, and mobile devices, e.g., mobile phones, will not operate properly. For example, Time division duplex (TDD) refers to duplex communication links where uplink is separated from downlink by the allocation of different time slots in the same frequency band. Wireless communications system that uses TDD based communications protocols to communicate between base stations and user equipment devices require devices, e.g., base stations and user equipment devices, synchronized with a good, e.g.,

accurate, source of timing so that each device can determine where a time slot start and ends. If the timing between devices is not properly synchronized to within system tolerances, the devices which are out of synchronization will not be able to properly function as they will not be able to distinguish the beginning and ending of time slots.
(3) This time synch is usually obtained from a GPS system in outdoor environments via wireless GPS signals. However, the wireless GPS signals are usually not strong enough inside of buildings/basements or even near high rise buildings to be consistently and reliably detected and/or received.
(4) Traditionally, indoor, base stations such as CBRS TD-LTE radios are synchronized using a GrandMaster and a boundary clock approach as shown in system **100** of FIG. **1**. In system **100** of FIG. **1**, the boundary clock is the time sync server **138** which receives its timing information from the GSP grandmaster clock. The indoor base stations, e.g., Citizen Broadband Radio Service Devices (CBSDs) in a CBRS network, are configured with a clock time sync server's **138** Internet Protocol address to obtain Synchronization information. The time sync server **138** receives the Global Positioning System with timing information from GPS receiver **140** via communications link **142**.
(5) The wireless base stations of system **100** are indoor CBSDs located in building **102** with CBSD A**1 116**, . . . , CBSD AN **118** being located on the Pt floor of building **102**; CBSD B**1 120**, . . . , CBSD BN **122** being located on the 2nd floor of building **102**; CBSD C**1 124**, . . . , CBSD CN **126** being located on the third floor of building **102**; CBSD D**1 128**, . . . , CBSD DN **130** being located on the fourth floor of building **102**; and CBSD E**1 132** to CBSD EN **134** being located on the fifth floor of building **102**.
(6) Dashed line **160** shows the demarcation of the first floor of the building from the second floor of the building **102**. Dashed line **162** shows the demarcation of the second floor of the building from the third floor of the building **102**. Dashed line **164** shows the demarcation of the third floor of the building from the fourth floor of the building **102**. Dashed line **166** shows the demarcation of the fourth floor of the building from the fifth floor of the building **102**. Building structures (e.g., ceilings, structural supports, flooring) separates the different floors of the building. The system includes a Main Distribution Frame (MDF) **104** and a plurality of Intermediate Distribution Frames (IDFs) (IDF **1 106**, IDF **2 108**, IDF **3 110**, IDF **4 112**, IDF **5 114**. Each of the intermediate distribution frames (IDFs) includes a rack of network equipment for managing and interconnecting the telecommunications cables between CBSDs and the main distribution frame (MDF).
(7) In system **100**, cable **146** connects the CBSDs on the first floor of building **102** to each other and the IDF **1 106**. IDF **1 106** is located on the first floor of building **102** and routes the cable **144** to the MDF **104** also located on the first floor. Cable **148** connects the CBSDs on the second floor of building **102** to each other and the IDF **2 108**. IDF **2 108** is located on the second floor of building **102** and routes the cable **144** down the wall to the MDF **104** on the first floor. Cable **150** connects the CBSDs on the third floor of building **102** to each other and the IDF **3 110**. IDF **3 110** is located on the third floor of building **102** and routes the cable **144** down the wall to the MDF **104** on the first floor. Cable **152** connects the CBSDs on the fourth floor of building **102** to each other and the IDF **4 112**. IDF **4 112** is located on the fourth floor of building **102** and routes the cable **144** down the wall to the MDF **104** on the first floor. Cable **152** connects the CBSDs on the fourth floor of building **102** to each other and the IDF **5 114**. IDF **5 114** is located on the fourth floor of building **102** and routes the cable **144** down the wall to the MDF **104** on the first floor.
(8) The MDF **104** is a cable rack of equipment that interconnects and manages the wiring and/or cabling between itself and IDFs **106**, **108**, **110**, **112**, **114**. While the IDFs, which connect internal building wiring and/or cabling to the MDF, the MDF **104** connects private or public lines coming into building **102** with the internal network of the building. In system **100**, the MDF **104** is connected to Ethernet switch **135** via cable **145**. The CBSDs are configured with the time sync server **138** Internet Protocol address and connect to the time sync server via an IDF, the MDF **104**

and the Ethernet switch **135** which is connected to the time sync server **138**.
(9) This traditional approach requires expensive hardware for synchronizing the devices of system especially the indoor base stations.
(10) From the foregoing, it should be understood that there is a need for new and/or improved methods and apparatus for achieving frequency, phase and time of day synchronization among devices in wireless networks and/or systems especially those utilizing wireless time division communications protocols. From the foregoing, it should be further understood that there is a need for new and/or improved methods and apparatus for wireless base stations, e.g., CBSDs in LTE TD CBRS networks, to provide, distribute, and/or obtain synchronization information (e.g., Frequency, Phase and/or Time of Day (ToD) information). Furthermore, there is a need for new and/or improved methods and apparatus for providing synchronization information when access to GPS signals is not available. Furthermore, there is a need for new and/or improved methods and apparatus for providing synchronization information utilizing less equipment and/or at less expense. Furthermore, there is a need for a technological solution to the problem of how a wireless base station (e.g., an indoor wireless small cell and/or micro cell base station) can obtain synchronization information (e.g., Frequency, Phase and/or Time of Day (ToD) information) without utilizing a local time synch server and/or when a time sync server goes off-line. There is a further need for new and/or improved methods and apparatus for reducing the equipment and therein the cost of providing frequency, phase and timing synchronization information to devices, e.g., indoor wireless base stations, in Hybrid Mobile Network Operator (HMNO) systems.

SUMMARY OF THE INVENTION

(11) The present invention provides new and/or improved methods and apparatus for achieving timing synchronization, e.g., frequency, phase and/or time of day synchronization, among devices in wireless networks. Various embodiments of the present invention provide new and/or improved methods and apparatus for distributing timing synchronization information to devices, e.g., wireless base station, in system utilizing wireless time division communications protocols. Various embodiments of the present inventions provide new and/or improved methods and apparatus for wireless base stations, e.g., CBSDs in LTE TD CBRS networks, to provide, distribute, and/or obtain synchronization information (e.g., Frequency, Phase and/or Time of Day (ToD) information). Various embodiments of the present invention provide new and/or improved methods and apparatus for providing synchronization information when access to timing synchronization signals such as GPS signals is not available or is unreliable, e.g., when the path delay from a time source is unpredictable such that it cannot be reliably used for synchronization purposes. Various embodiments of the present invention also provide new and/or improved methods and apparatus for providing synchronization information utilizing less equipment and/or at less expense than traditional methods. Various embodiments of the present invention provide a technological solution to the problem of how a wireless base station (e.g., an indoor wireless small cell and/or micro cell base station) can obtain synchronization information (e.g., Frequency, Phase and/or Time of Day (ToD) information) without utilizing a local time synch server and/or when a time sync server goes off-line. Various embodiments of the present invention also provide new and/or improved methods and apparatus for reducing the equipment and therein the cost of providing frequency, phase and timing synchronization information to devices, e.g., indoor wireless base stations, in Hybrid Mobile Network Operator (HMNO) systems. Various embodiments of the present invention solve one or more of the problems discussed above.
(12) In one exemplary embodiment of the present invention, a first wireless base station of a first network requests and obtains synchronization information, e.g., timing synchronization information, from a Dual SIM Dual Subscriber user equipment device via a device to device sidelink communications channel established between the first wireless base station and the Dual SIM Dual Subscriber user equipment device. The synchronization information provided to the first wireless base station by the Dual SIM Dual Subscriber user equipment device is based on

synchronization obtained from a second wireless base station which is part of a second network to which the Dual SIM Dual Subscriber user equipment device has access but to which the first wireless base station does not have access. The Dual SIM Dual Subscriber user equipment device having the capability to communicate with both the first wireless base station in the first network and the second wireless base station in the second network via its dual subscriptions and dual SIMs. The first wireless base station uses the received synchronization information to sync or re-sync its reference clock or timer.

(13) An exemplary method of in accordance with one embodiment of the present invention includes operating a first wireless base station in a first network to perform the following steps and/or operations: receiving, at the first wireless base station, a first message; in response to receiving the first message entering, by the first wireless base station, into a first mode of operation; and while operating in said first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.

(14) In some embodiments, the first wireless base station operates as a subscriber device in connection with the device to device communications with the first user equipment device.

(15) In some embodiments, the first wireless base station is a subscriber with regard to a service which provides synchronization information via device to device sidelink communications with timing synchronized user equipment devices.

(16) In some embodiments, the first wireless base station emulates a user equipment device when obtaining said synchronization information from the first user equipment device using over the air device to device communications.

(17) In some embodiments, the step of obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications includes: receiving, by the first wireless base station, the synchronization information from the first user equipment device, said synchronization information including a block type **18** (SIB **18**) packet with sync information, said synchronization information being communicated over a sidelink device to device communications channel established between the first wireless base station and the first user equipment device, said synchronization information being based on information provided to the first user equipment from a second wireless base station.

(18) In some embodiments, the first network is a hybrid mobile network, the first message is a first control message from a first network equipment device which is part of the hybrid mobile network, and the first message is received by the first wireless base station over a landline. In some such embodiments, the hybrid mobile network includes a Citizens Broadband Radio Service Time Division—Long Term Evolution (CBRS TD-LTE) network with wireless communications devices utilizing CBRS TD-LTE New Radio radios; wherein said first wireless communications devices include the first wireless base station and the first user equipment device. In some embodiments, the first wireless base station is an indoor Hybrid Mobile Network Operator (HMNO) small cell Citizens Broadband Radio Service Device (CBSD).

(19) In various embodiments, the first user equipment device is a Dual Subscriber user equipment device having credentials for two different mobile subscription services (e.g., authentication credentials for a first service provider's mobile network and authentication for a second service provider's mobile network).

(20) In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Subscriber user equipment device.

(21) In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby user equipment device.

(22) In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Active user equipment device.

(23) In some embodiments, the first wireless base station is coupled to a HMNO core network via a

cable modem; and wherein the first wireless base station receives the first message from a network equipment device in the HMNO core network via the cable modem.
(24) In some embodiments, the synchronization information further includes frequency and phase information.
(25) In some embodiments, synchronization information is frequency, phase and time of day information required for operating as a wireless base station.
(26) In some embodiments, the synchronization information is a clock sync or time sync signal (e.g., clock signal such as IEEE 1588 for frequency, phase and time of day).
(27) In some embodiments, the synchronization information is a clock sync or time sync signal derived from information included a Network Time Protocol (NTP) message received from a NTP server via a second wireless base station, said first user equipment device receiving said synchronization information from said second wireless base station, said second wireless base station being operated by a different service provider than said first wireless base station, and wherein said first wireless base station and said second wireless base station are operating using different spectrum bands.
(28) In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby or a Dual Subscriber Identity Module (SIM) Dual Active user equipment device, which includes a first SIM corresponding to the service provider of the first network and a second SIM corresponding to said different service provider. In some such embodiments, the first SIM includes a first authentication key corresponding to a first subscription with the first service provider; and wherein the second SIM includes a second authentication key corresponding to a second subscription with second service provider.
(29) In some embodiments, the first message is a first control message which includes an instruction for the first wireless base station to enter the first mode of operation; and while operating in said first mode of operation the first wireless base station commences wirelessly transmitting device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message. In some such embodiments, the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection.
(30) In some embodiments, the first message is a first control message which includes an instruction for the first wireless base station to enter a discovery mode of operation, said first mode of operation being a discovery mode of operation.
(31) In some embodiments, the first message is a first control message which includes an instruction for the first wireless base station to enter a device to device mode of operation, said first mode of operation being a device to device mode of operation.
(32) In some embodiments, the first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and wherein said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
(33) In various embodiments, the second wireless base station is part of a second wireless network, said first network and said second network being operated by different service providers, said first network being operated by a first service provider and said second network being operated by a second service provider. In some embodiments, the first wireless base station and said second wireless base station utilize different spectrum bands for communicating with subscriber devices; and, the first user equipment device includes a first SIM card with subscriber credentials for the first network and a second SIM card with subscriber credentials for the second network.
(34) In some embodiments, the first user equipment device is a subscriber of the first service provider and a subscriber of the second service provider.

(35) In some embodiments, the first wireless base station operates in a first spectrum band; wherein the second wireless base station operates in a second spectrum band; and wherein said first and second spectrum bands are different.
(36) In some embodiments, the first spectrum band is general authorized access (GAA) spectrum and the second spectrum band is priority access license (PAL) spectrum.
(37) In some embodiments the method further includes the steps of: receiving, by the first wireless base station from the first user equipment device, a discovery request response message in response to the first device to device discovery request message; and establishing a sidelink device to device communications channel with the first user equipment device.
(38) In some embodiments, the step of establishing a sidelink device to device communications channel with the first user equipment device includes obtaining sidelink resource information from a core network for establishing the sidelink device to device communications channel between the first wireless base station and the first user equipment device. In some such embodiments, the resource information includes information specifying spectrum granted or allocated for the sidelink device to device communications channel to be established.
(39) In some embodiments, the sidelink resource information is obtained by the first wireless base station. In some such embodiments, the step of establishing a sidelink device to device communications channel with the first user equipment device includes transmitting the sidelink resource information to the first user equipment device.
(40) In some embodiments, the core network is part of the first network. In various embodiments, the sidelink resource information specifies spectrum authorized for use by subscribers of the first network or available for use by subscribers of the first network.
(41) In some embodiments, the core network is not part of the first network but is a part of a second network. In some embodiments, the first user equipment device obtains the sidelink resource information via a second wireless base station and shares the sidelink resource information with the first wireless base station.
(42) In some embodiments, the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection; and the discovery request response message is Proximity Service discovery response request message.
(43) In various embodiments, the step of obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information includes: (i) transmitting a first sync request message to the first user equipment device over the established device to device sidelink communications channel; and (ii) receiving over the device to device sidelink communications channel from the first user equipment device said synchronization information.
(44) In some embodiments, the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
(45) In some embodiments, the method further includes the step of utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.
(46) In some embodiments, the synchronization information includes a time value and delay information. In some such embodiments, the step of utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer (e.g., reference clock) at the first wireless base station includes using the delay information to adjust the time value.
(47) In some embodiments, the time value is a time stamp value and the delay value is a path

transmission delay value.
(48) In some embodiments, the method further comprises the steps of: transmitting, by the first wireless base station, a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information; and receiving from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation it does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation it performs wireless base station operations and provides wireless base station services to user equipment devices.
(49) In some embodiments, the method further includes the step of re-synching, by the first wireless base station, a timer (e.g., a reference clock) at the first wireless base station using the synchronization information obtained from the first user equipment device.
(50) Another exemplary method in accordance with an embodiment of the present invention is directed to the operation of a dual Subscriber Identity Module (SIM) user equipment device. The method of operating the dual SIM user equipment device including the steps of: receiving, at the dual SIM user equipment device from a first wireless base station, a request message requesting synchronization information, said synchronization information including timing synchronization information; in response to receiving the request for synchronization information from the first wireless base station, generating by the dual SIM user equipment device a synchronization message including the requested synchronization information based on synchronization information obtained by the dual SIM user equipment device from a second wireless base station; and transmitting the synchronization message to the first wireless base station.
(51) In some embodiments the method further includes the steps of: prior to receiving the request message requesting synchronization information from the first wireless base station, receiving, by the dual SIM user equipment device a device to device (D2D) discovery request message from the first wireless base station; and in response to receiving the D2D discovery request message, establishing a device to device (D2D) sidelink communication channel with first wireless base station; and wherein the synchronization message is transmitted to the first wireless base station over the established D2D sidelink communications channel.
(52) In some embodiments, the method further includes the step of: prior to generating the synchronization message, requesting synchronization information from a second wireless base station, said first wireless base station and said second wireless base station belonging to different wireless networks, said dual SIM user equipment device including a first SIM card and a second SIM card, said dual SIM user equipment device being able to communicate with the first wireless base station using information contained on the first SIM card, said dual SIM user equipment device being able to communicate with the second wireless base station using information contained on the second SIM card.
(53) In some such embodiments, the D2D discovery request message is a Proximity Service discovery request message; and the D2D sidelink communications channel is established using Proximity Services.
(54) In some embodiments, the first wireless base station utilizes a time division duplex wireless protocol to communicate with user equipment devices.
(55) In some embodiments, establishing a device to device (D2D) sidelink communication channel with first wireless base station includes receiving information from the first wireless base station indicating the resources (e.g., spectrum) to be used for the D2D sidelink communications channel.
(56) In some embodiments, the first wireless base station is an indoor wireless base station (e.g., small cell CBSD); and the second wireless base station is an eNodeB.
(57) The present invention is also applicable to apparatus and system embodiments wherein one or more devices implement the steps of the method embodiments. In some apparatus embodiments

each of the wireless base station, user equipment devices, network equipment devices and each of the other apparatus/devices/nodes of the system include one or more processors and/or hardware circuitry, input/output interfaces including receivers and transmitters, and a memory. The memory including instructions when executed by one or more of the processors control the apparatus/device/node of the system to operate to perform the steps and/or functions of various method embodiments of the invention.

(58) The present invention is also applicable to and includes apparatus and systems such as for example, apparatus and systems that implement the steps and/or functions of the method embodiments. For example, a communication system in accordance with one embodiment of the present invention includes: a first wireless base station comprising: first receiver (network interface receiver); and a processor configured to operate the first wireless base station to: receive, via the first receiver, a first message; enter into a first mode of operation in response to the received first message; and obtain, while operating in the first mode of operation, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.

(59) In another exemplary system embodiment includes a dual Subscriber Identity Module (SIM) user equipment device comprising: a memory, and a first processor, said processor controlling the dual SIM user equipment device to perform the following operations: receive, at the dual SIM user equipment device from a first wireless base station, a request message requesting synchronization information, said synchronization information including timing synchronization information; in response to receiving the request for synchronization information from the first wireless base station, generate by the dual SIM user equipment device a synchronization message including the requested synchronization information based on synchronization information obtained by the dual SIM user equipment device from a second wireless base station; and transmit the synchronization message to the first wireless base station.

(60) While various embodiments have been discussed in the summary above, it should be appreciated that not necessarily all embodiments include the same features and some of the features described above are not necessary but can be desirable in some embodiments. Numerous additional features, embodiments and benefits of various embodiments are discussed in the detailed description which follows.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** illustrates a traditional system for providing time sync information to indoor wireless base stations in a wireless system.

(2) FIG. **2** illustrates an exemplary system in accordance with an embodiment of the present invention without a time sync server.

(3) FIG. **3** illustrates an exemplary system in accordance with the present invention.

(4) FIG. **4** illustrates details of an exemplary wireless base station, e.g., HMNO indoor base station, in accordance with one embodiment of the present invention.

(5) FIG. **5** illustrates details of an exemplary Dual Subscriber Identity Module Dual Subscriber (DSDE) User Equipment (UE) device, e.g., a mobile device, cell phone, smartphone, wireless tablet, laptop, wireless notebook, in accordance with one embodiment of the present invention.

(6) FIG. **6** illustrates details of an exemplary network equipment device, e.g., mobile management entity, base station discovery device, Proximity Service Function element/node, in accordance with one embodiment of the present invention.

(7) FIG. **7** illustrates an exemplary assembly of components for a wireless base station in accordance with an embodiment of the present invention.

(8) FIG. **8** illustrates an exemplary assembly of components for a user equipment device in accordance with an embodiment of the present invention.
(9) FIG. **9** illustrates an exemplary assembly of components for a network equipment device in accordance with an embodiment of the present invention.
(10) FIG. **10** illustrates a simplified architecture for a system **1300** for providing Proximity Service Function within an exemplary 4G core network to support D2D communications in accordance with an embodiment of the present invention.
(11) FIG. **11** illustrates a diagram with details of an exemplary exchange of messages and information involved in establishing a ProSe D2D communications channel between a wireless base station announcing device and a monitoring user equipment device.
(12) FIG. **12** illustrates the formats and fields of an exemplary ProSe function discovery message in accordance with an embodiment of the present invention.
(13) FIG. **13** illustrates an exemplary building floor plan with a plurality of wireless base stations in accordance with an embodiment of the present invention.
(14) FIG. **14** illustrates a flowchart of an exemplary method in accordance with an embodiment of the present invention.
(15) FIG. **15** comprises FIG. **15**A and FIG. **15**B.
(16) FIG. **15**A is the first part of a signaling diagram which illustrates the steps and signaling of an exemplary method in accordance with an embodiment of the present invention.
(17) FIG. **15**B is the second part of a signaling diagram which illustrates the steps and signaling of an exemplary method in accordance with an embodiment of the present invention.
(18) FIG. **16** illustrates exemplary fields and format of an exemplary time sync packet in accordance with an embodiment of the present invention.
(19) FIG. **17**A is a first part of a flowchart of an exemplary method of operating a first wireless base station in accordance with an exemplary embodiment.
(20) FIG. **17**B is a second part of a flowchart of an exemplary method of operating a first wireless base station in accordance with an exemplary embodiment.
(21) FIG. **17** comprises the combination of FIG. **17**A and FIG. **17**B.
(22) FIG. **18** illustrates the combination of FIG. **18**A, FIG. **18**B and FIG. **18**C.
(23) FIG. **18**A illustrates the steps of the first part of an exemplary method in accordance with an embodiment of the present invention.
(24) FIG. **18**B illustrates the steps of the second part of an exemplary method in accordance with an embodiment of the present invention.
(25) FIG. **18**C illustrates the steps of the third part of an exemplary method in accordance with an embodiment of the present

DETAILED DESCRIPTION

(26) Citizens Broadband Radio Service (CBRS) is a tiered solution with the top tier dedicated for fixed satellite, wireless internet service providers as well as navy radar. The second tier consists of PAL (Priority Access Licensees) and the last tier consists of General Authorized Access (GAA).
(27) FIG. **1** as discussed above illustrates a system that utilizes a traditional approach to obtaining and distributing timing information using a time sync server which obtains it timing information via a GPS system.
(28) FIG. **2** illustrates an exemplary system **200** in accordance with an embodiment of the present invention. FIG. **13** illustrates an exemplary typical building floor plan **1202** with a plurality of wireless base stations that may be, and in some embodiments is, used for example in building **202** of FIG. **2**. The building floor plan includes an Intermediate Distribution Frame (IDF) **1204** which includes a processor **1208**, software instructions in memory **1210** which when executed by the processor **1208** control the operation of the IDF **1204**, communications ports **1206**, and cables connecting the IDF **1204** to plurality of wireless base stations implemented as CBSDs (CBSD **1 1212**, CBSD **2 1214**, CBSD **3 1216**, CBSD **4 1218**, CBSD **5 1220**). The fifth floor of the building

202 may be implemented using the floor plan **1202**. In such a case, CBSD **1 1212**, CBSD **2 1214**, CBSD **3 1216**, CBSD **4 1218**, and CBSD **5 1220** are CBSD E**1 232**, . . . , CBSD EN **234**, where N=5 and IDF **1204** is IDF **5 214**.

(29) In system **200** of FIG. **2**, the timing synchronization information is obtained by an indoor base station via a dual SIM dual subscriber user equipment device. The dual SIM dual subscriber user equipment device obtains the timing synchronization information from a wireless base station which is part of a different wireless network than the indoor wireless base. The indoor base stations, e.g., Citizen Broadband Radio Service Devices (CBSDs) in a CBRS network, are configured with a Proximity Service application that allows them to operate as subscriber devices and establish device to device communications channels with other user equipment devices within range of their radios. The indoor wireless base stations of system **200** are CBSDs located in building **202** with CBSD A**1 216**, . . . , CBSD AN **218** being located on the 1.sup.st floor of building **202** (N being an integer greater than 1); CBSD B**1 220**, . . . , CBSD BN **222** being located on the 2nd floor of building **202** (N being an integer greater than 1); CBSD C**1 224**, . . . , CBSD CN **226** being located on the third floor of building **202** (N being an integer greater than 1); CBSD D**1 228**, . . . , CBSD DN **230** being located on the fourth floor of building **202** (N being an integer greater than 1); and CBSD E**1 232** to CBSD EN **234** being located on the fifth floor of building **202** (N being an integer greater than 1). Dashed line **260** shows the demarcation of the first floor of the building from the second floor of the building **202**. Dashed line **262** shows the demarcation of the second floor of the building from the third floor of the building **202**. Dashed line **264** shows the demarcation of the third floor of the building from the fourth floor of the building **202**. Dashed line **266** shows the demarcation of the fourth floor of the building from the fifth floor of the building **202**. Building structures (e.g., ceilings, structural supports, flooring) separates the different floors of the building. The system includes a Main Distribution Frame (MDF) **204** and a plurality of Intermediate Distribution Frames (IDFs) (IDF **1 206**, IDF **2 208**, IDF **3 210**, IDF **4 212**, IDF **5 214**. Each of the intermediate distribution frames (IDFs) includes a rack of network equipment for managing and interconnecting the telecommunications cables between CBSDs and the main distribution frame (MDF). In system **200**, cable **246** connects the CBSDs on the first floor of building **202** to each other and the IDF **1 206**. IDF **1 206** is located on the first floor of building **202** and routes the cable **244** to the MDF **204** also located on the first floor. Cable **248** connects the CBSDs on the second floor of building **202** to each other and the IDF **2 208**. IDF **2 208** is located on the second floor of building **202** and routes the cable **244** down the wall to the MDF **204** on the first floor. Cable **250** connects the CBSDs on the third floor of building **202** to each other and the IDF **3 210**. IDF **3 210** is located on the third floor of building **202** and routes the cable **244** down the wall to the MDF **204** on the first floor. Cable **252** connects the CBSDs on the fourth floor of building **202** to each other and the IDF **4 212**. IDF **4 212** is located on the fourth floor of building **202** and routes the cable **244** down the wall to the MDF **204** on the first floor. Cable **252** connects the CBSDs on the fourth floor of building **202** to each other and the IDF **5 214**. IDF **5 214** is located on the fourth floor of building **202** and routes the cable **244** down the wall to the MDF **204** on the first floor. The MDF **204** is a cable rack of equipment that interconnects and manages the wiring and/or cabling between itself and IDFs **206**, **208**, **210**, **212**, **214**. While the IDFs, which connect internal building wiring and/or cabling to the MDF, the MDF **204** connects private or public lines coming into building **202** with the internal network of the building. In system **200**, the MDF **204** is connected to a core network **280** via cable **290**. The system also includes an atomic clock **270**, an NTP server **272**, a first wireless base station **282**, e.g., eNodeB, and a plurality of dual SIM dual subscriber (DSDS) user equipment devices (DSDS UE A **284**, . . . , DSDS UE M **286**, M being an integer greater than 1). In some embodiments, first wireless base station **282** is operated by a first service provider and the CBSDs in the building **202** are operated by a second service provider and require two separate subscriptions. The plurality of DSDS UEs are subscribers to both the first service provider and the second service provider and include a first subscription to

the first service provider's services allowing access to the services offered by the first base station and a second subscription to the second service provider's services offered by the CBSDs in the building **202**. Each DSDS user equipment device has a first SIM card having credentials to access the first service provider's network including the first base station **282** and a second SIM card having credentials to access the second service provider's network including the CBSDs in the building **202**. Communications link **276** couples/connects the atomic clock **270** to the Network Time Protocol (NTP) server **272**. The communications link **278** couples/connects the NTP server **272** to the first base station **282**. Communications links **292** and **294** are wireless communications link. Communications link **294** connects/couples CBSD E**1 232** to DSDS UE A **284**. Communications link **292** couples/connections DSDS UE A **284** to first base station **282**. How communications link **292** and **294** are established is discussed below.

(30) The NTP server **276** receives time information from the atomic clock **270**. The NTP server **276** distributes timing information to the first base station **282** via NTP protocol messages. The CBSDs in the building **202** do not have a landline connection to a reliable clock source unlike in system **100**. Instead, the CBSDs obtain there synchronization from the first wireless base station **282** via the DSDS user equipment devices which have dual subscriptions and can communicate with both the CBSDs in the building **202** and the first wireless base station **282**. For example, CBSD E**1 232** acquires timing synchronization in the following manner. The CBSD E**1 232** broadcasts over the air device to device (D2D) discovery request messages, e.g., a Proximity Service discovery request, to user equipment devices within range of its radio transmission. The DSDS user equipment device A **284** receives one of the broadcast discovery request messages and determines to accept the D2D discovery request. In response to the discovery request message, the DSDS UE A **284** send a discovery response message to the CBSD E**1 232**. The DSDS UE A **284** is also receiving wireless signals from first base station **282** because it is within it cell coverage range. After the CBSD E**1 232** receives the DSDS UE A **284** response message, a device to device sidelink communications channel is established between DSDS UE A **284** and CBSD E**1** using resources, e.g., spectrum in time and frequency resource blocks, allocated/assigned for the device to device sidelink communications channel for example by the core network **280** or the first base station **282**. Typically, the core network **280** assigns the resources so that the second service operator's spectrum is used and compatibility of radios and resources, e.g., spectrum, is assured. Once, the D2D sidelink communications channel is established, the CBSD E**1 232** receives timing synchronization information from the DSDS UE A **284** over the D2D sidelink communications channel. In some embodiments, the DSDS UE A **284** sends the timing synchronization information in response to a request sent by the CBSD E**1 232**. The timing synchronization is based on timing synchronization information the DSDS UE A **284** has received from the first base station **282**. In some embodiments, the DSDS UE A **284** will request that its timing synchronization information be updated prior to providing the requested timing synchronization to the CBSD E**1 232** so that it fresh. In some embodiments, once the CBSD E**1 232** has obtained timing synchronization information from the DSDS UE A **284** it can in turn distribute it to other CBSDs in the building to which it is connected. In this example, the CBSDs in the building do not receive the signals transmitted by the first base station due to the structure of the building and/or spectrum utilized for the signals and/or the radios used by the CBSDs and/or wireless protocols which the CBSDs are configured to use. However, the DSDS UE A **284** does receive signals from the first base station. While the invention has been described at a high level with respect to the CBSD E**1 232** and DSDS UE A **284** these devices are only exemplary. For example, the CBSD A**1 216** on the first floor of building **202** can use the same procedure with respect to DSDS UE M **286** when DSDS UE M **286** is within the wireless transmission range of CBSD A**1 216** (even if outside the building **202**) and DSDS UE M **286** is able to obtain timing synchronization information from the first base station **282**.

(31) The exemplary system **200** illustrates how timing synchronization information may be, and in

some embodiments are distributed in a wireless system, e.g., a time division duplex system.
(32) FIG. **3** illustrates another exemplary system **300** in accordance with an embodiment of the present invention. System **300** of FIG. **3** provides further details of the invention with a focus on the interactions between an exemplary first base station, second base station, and a Dual SIM Dual Subscriber user equipment device.
(33) The system includes an atomic clock **314**, a Network Time Protocol (NTP) Server **312** coupled to the Internet **310**, a first wireless base station **308**, a Dual Subscriber Identity Module Dual Subscriber (DSDS) user equipment device **306**, a second wireless base station **304**, and a core network **328**. The first wireless base station **308** in the system **300** is a Mobile Network Operator (MNO) base station, e.g., eNodeB. The first wireless base station **308** and NTP server **312** are part of a first network operated by first service provider also sometimes referred to herein as the Mobile Network Operator (MNO). The second wireless base station **304** is a Hybrid Mobile Network Operator (HMNO) indoor base station, e.g., a Citizen Broadband Radio Service Device (CBSD) implemented as an eNodeB. The second wireless base station **304** is located in a building **302**. The second wireless base station **304**, in at least some embodiments, is not able to receive GPS signals reliably or at all, e.g., due to second wireless base station's location in the building **302**. For example, the building structure may interfere with and/or block wireless GPS signals from being received by the second wireless base station **304**. The core network **328** is a HMNO core network. The core network **330** and second base station **304** are part of a HMNO network operated by a second service provider also referred to herein as an HMNO operator. The core network **330** includes network equipment **332**. The network equipment **332** includes a Mobile Management Entity **334**. The first service provider and the second service provider are different service providers. That is the MNO operator and the HMNO are different operators, e.g., the Mobile Network Operator may be Verizon and the Hybrid Mobile Network Operator is Charter Communications.
(34) The atomic clock **314** is coupled to the NTP server **312** via a communications link **316**. The NTP server **312** is coupled to the Internet **310** via communications link **318**. The Internet **310** is coupled to the first wireless base station **308** via communications link **320**. The first wireless base station is coupled to the DSDE UE **306** via communications link **322**. The DSDE UE **306** is coupled to the second wireless base station **302** via communications link **324**. The second wireless base station **304** is coupled to the core network **330** via communications link **326**. The communications links **322** and **324** are wireless communications link. The communications links **316**, **318**, **320**, and **326** are landline links, e.g., wired or optical cable links. While the communications link in system **300** are bi-directional, the arrows on the links have been provided to illustrate how timing information travels from the atomic clock **314** to the NTP server **312** from the NTP server **312** to first base station **308** from the first base station **308** to the DSDS UE **306** and from the DSDS UE **306** to the second base station **304** as will be explained in detail below.
(35) Generally, wireless operators distribute the clock signal for synchronization via an NTP server and the Internet. For example, with respect to system **300**, the atomic clock **314** generates an atomic clock signal which is communicated over communications link **316** to an NTP server **312** of the mobile network operator or first service provider. The NTP server **312** distributes the atomic clock signal using the Network Time Protocol (NTP) over the Internet **310** to base stations of the first service provider or mobile network operator. These base stations include the first wireless base station **308**. The clock signal is sent from the NTP server **312** via communications link **318**, Internet **310**, communications link **320** to the first wireless base station **308** where it is received. The first wireless base station **308** in turn distributes the clock signal to the DSDS UE **306** over communications link **322**.
(36) In theory, a given wireless device, e.g., CBRS device such as a wireless base station, can listen to another wireless network's signals, e.g., another CBRS network's signals and obtain synch information from those signals as the sync information is embedded in the Master Information

Block (MIB) in the form of Primary Synchronization signal and secondary synchronization signal which is continuously broadcasted by wireless base stations, e.g., CBRS wireless base stations also known as Citizen Broadband Radio Service Device (CBSD). However, wireless base stations such as those located indoors do not always receive synchronization signals. When this is the case, if another in-network device is not available to provide synchronization information then the device will not be able to sync and will go out of service. This is specifically true for indoor wireless base station, e.g., CBRS network devices, that are unable to listen to another CBRS network device. Higher frequency spectrum is used for CBRS networks so the propagation of wireless signals is not as good as wireless networks using spectrum which lower frequency spectrum.

(37) However, if an operator's mobile wireless network is a Hybrid Mobile Network with Hybrid Mobile Network Operation (HMNO) which requires Dual SIM Dual subscription (DSDS) mobile devices, e.g., phones, that are equipped with connection managers to coordinate offload, then the DSDS capability/functionality can be used to provide synch (i.e., synchronization information) to network devices that need time synch. System **300** illustrates a second wireless base station **304**, which is a HMNO indoor wireless base station, which obtains synchronization information, e.g., frequency, phase and Time of Day Synchronization, from the first service provider first base station **308** via DSDS UE **306**. The first wireless base station **308** has been provided synchronization information from the NTP **312** of the first service provider. The DSDS UE **306** is a Dual SIM Dual subscription mobile device, e.g., a smartphone, that is equipped with a connection manager to coordinate offloading of traffic between the second service provider's network and the first service provider's network. Since the DSDS UE **306** is synced from the first base station **308**, the DSDS UE **306** can take on the role of a 3rd level stratum clock and provide synch or synchronization information (e.g., clock information including frequency, phase, time of day information) to base stations which require synchronization information such as second wireless base station **304**. This technique is particularly useful for small cell base stations and/or micro-cell base stations which are out of service because they are unsynched or need to be re-synched to prevent the base station from going out of service. When a base station needs synchronization to operate or continue to operate properly, an internal program will automatically put the base station into a first mode of operation. In some embodiments, the first mode of operation is a Device-to-Device (D2D) mode of operation also sometimes referred to as a D2D discovery mode of operation. With respect to system **300**, when the second base station **304** which may be, and in some embodiments is, a small cell or microcell wireless base station needs synchronization information, the second base station **304** enters the first mode of operation. In various embodiments, the second base station **304** enters the first mode of operation in response to a command or instruction received from the HMNO core network **330**. For example in some embodiments, network equipment **332** upon monitoring the second base station and determining that the second base station **304** requires synch, e.g., because: (i) it is out of synch and out of service, or (ii) it needs to be re-synched to prevent it from going out of synch which can occur due to drift, the network equipment **332** generates and transmits a message including a command and/or instruction to the second base station **304** via communications link **326** indicating that the second base station is to enter the first mode of operation, e.g., a D2D mode of operation.

(38) Once the second wireless base station **304** enters the D2D mode of operation, it generates and begins broadcasting, e.g., wirelessly transmitting, D2D discovery beacon messages looking for a device, e.g., a DSDS subscriber device, to respond. With respect to the D2D operation of the second wireless base station **304**, the second wireless base station **304** operates as a subscriber device and broadcasts messages using the spectrum allocated for subscriber D2D communications as opposed to spectrum reserved or allocated for base station to user equipment device communications.

(39) The DSDS UE **306** receives, detects and/or discovers at least one of the D2D broadcast discovery messages. In response to receiving, detecting, and/or discovering at least one of the D2D

broadcast discovery messages from the second wireless base station **304**, the DSDS UE **306** initiates a D2D discovery response with the wireless network (HMNO). The DSDS UE **306** generates a D2D discovery response message and transmits it to the second wireless base station **304**.

(40) The second wireless base station **304** receives the D2D discovery response message transmitted by the DSDS UE **306**. In response to receiving the D2D discovery response message, the second wireless base station **304** generates a resource request messages for resources, e.g., spectrum, for communicating with the DSDS UE **306**. The second wireless base station **304** transmits this resource request message to HMNO core network **330** via communications link **326**. In various embodiments, the second wireless base station **304** transmits the resource request message to network equipment **332** located in the HMNO core network **330** which receives and processes the resource request. Network equipment, e.g., network equipment **332**, in the HMNO core network **330** reserves the requested resources and generates a resource response message which includes resource information, e.g., identification of HMNO spectrum allocated or granted by the HMNO network for D2D communications between the second wireless base station **304** and the DSDS UE **306**. The HMNO network core **330**, e.g., the network equipment **332** located in the network core, transmit the resource response message to the second wireless base station **304**.

(41) The second wireless base station **304** upon receiving the resource response message, uses the resource information included in the resource message, e.g., identified spectrum, to establish a D2D communications channel with DSDS UE **306**. In various embodiments, the resource request is a request for resources, e.g., spectrum grant, to establish a side link channel between the second wireless base station **304** and the DSDS UE **306** for D2D communications. In some such embodiments, the resource response message includes resource information, e.g., spectrum grant information, for establishing a side link channel between the second wireless base station **304** and the DSDS UE **306**. The D2D communications channel established between the second wireless base station **304** and the DSDS UE **306** is a side link channel using the granted spectrum. The granted spectrum is spectrum that is available to or under control of and/or belongs to the HMNO network.

(42) Upon the establishment of the D2D communications channel, e.g., side link channel, between the second wireless base station **304** and the DSDS UE **306**, second wireless base station **304** uses the D2D communications channel to communicate, transmit and/or share information about itself with the DSDS UE **306**, e.g., such as identification information (e.g., base station identification information and/or Cell Global Identification (CGI)). The second wireless base station **304** will also use the D2D communications channel to request that the DSDS UE **306** provide synchronization information, e.g., timing synchronization information such as phase, frequency, and/or time of day synchronization information. The DSDS UE **306** in response to receiving the shared information about the second wireless base station **304** and/or the request for synchronization information will generate a message including the requested synchronization information, e.g., timing synch information such as frequency, phase and time of day information, and communicate, transmit, and/or share the synchronization information with the second wireless base station **304** via the D2D communications channel, e.g., side link communications channel. The synchronization information communicated, transmitted, and/or shared with the second wireless base station **304** being based on synchronization information received from first wireless base station **308**. The first wireless base station **308** having received synchronization information from the NTP server **312**.

(43) Upon receiving the synchronization information, the second wireless base station **304** will notify the HMNO core network **330**, e.g., network equipment **332** in the HMNO core network **330**, e.g., via a notification message, that it has received the synchronization information. The notification message will also include information identifying the second wireless base station **304** such as for example, a Cell Global Identifier. The Cell Global Identifier includes mobile country

code, mobile network code, location area code, and cell identifier.
(44) One or more network equipment devices in the HMNO core network **330** will in response to being notified that the second wireless base station **304** has received synchronization information will enable auto-configuration for the second wireless base station **304** and turn on or activate the second wireless base station **304**. This is accomplished by updating network equipment **332** in the core network **330** regarding the status of the second wireless base station **304**, e.g., from off-line to on-line with respect to operating as an active wireless base station such as not active wireless base station status to active base station status. Various network equipment devices are configured as part of the process of preparing the core network **330** to bring the second wireless base station **304** on-line. Once the HMNO core network **330** has been prepared for bringing the second wireless base station **304** on-line to become an active wireless base station, the network equipment **332** in core network **330** sends command(s) and/or instructions to the second wireless base station **304** commanding or instructing the second wireless base station **304** to enter a second mode of operation, in which the second wireless base station **304** comes on-line and commences operating as an active wireless base station (e.g., an active wireless base station mode of operation). In response to receiving the command(s) and/or instructions to enter the second mode of operation, the second wireless base station **304** enters a second mode of operation and begins operating as an active wireless base station, e.g., by going on-line. While operating as an active wireless base station, i.e., an on-line wireless base station, the second wireless base station provides wireless communications services by relaying information to and from user equipment devices connected to the second wireless base station.
(45) The second wireless base station **304** implements, performs and/or goes through a synchronization cycle as part of or prior to beginning to operate as an active wireless base station, e.g., as part of or prior to going on-line as an active wireless base station. In various embodiments, the mobility management entity **334** in the HMNO core network **330** will receive the cell global ID and use it to identify the second wireless base station **304**. The Cell Global ID is used by the HMNO core network **330**, e.g., the MME **334** in the HMNO core network **330**, to distinguish the second wireless base station **304** from other nodes, e.g., other nodes or base station in the MNO wireless network or the HMNO wireless network. Based on the CGI (Cell Global ID) the HMNO core network **330**, e.g., MME **334** in the core network **330**, will determine the network operator or service provider to which the second wireless base station **304** belongs, the location of the second wireless base station **304**, location information of second wireless base station **304** in relation to the DSDS UE **306**. The location of the second wireless base station **304** in relation to the DSDS UE **306** may be, and in some embodiments is, used to calculate timing delay information that can be used to adjust the synchronization information provided to the second wireless base station **304** by DSDS UE **306**. In some embodiments, the HMNO **330**, e.g., MME **334** sends the location information and/or timing delay information to the DSDS UE **306** as part of the resource information provided for the D2D sidelink communications channel.
(46) When the timing synchronization from an HMNO NTP server is not available or not implemented, the second wireless base station **304** may utilize the timing information from an MNO base station obtained via a DSDS UE such as DSDS UE **306** for synchronization purposes as discussed above. However, when the synchronization or timing information is provided by the DSDS UE **306** a propagation and processing delay will be introduced which in at least some instances will need to be compensated to ensure that the accuracy of the synchronization information is within acceptable tolerances and/or thresholds. In various embodiments, the synchronization information provided by the DSDS UE **306** is supplemented with information to allow the second wireless base station **304** to compensate for one or more delays (e.g., propagation delays, processing delays) or other inaccuracies introduced into the synchronization information. For example, the synchronization information provided by the DSDS UE **306** may, and in some embodiments, does include information about the delay(s) introduced into the synchronization

information such as for example, pathloss delay offset information and root delay information. This delay information when provided allows the second wireless base station **304** to adjust the receiving timing synchronization information to compensate for delays, e.g., propagation and/or processing delays, introduced into the timing information provided by the DSDS UE **306** to the second wireless base station **304**. In some embodiments, this delay information is generated and/or determined by the DSDS UE **306** and/or provided to the DSDS UE **306** from elements for example the MME **334** in the core network **330**.

(47) The messages, commands, instructions and information communicated between the second wireless base station **304** and the HMNO core network **330** and HMNO elements/devices located therein are communicated over a landline, e.g., communications link **326**. In various embodiments, these communications traverse a cable modem **350** to which the second wireless base station **304** is connected and/or coupled and a cable modem termination system **352** to which the HMNO core network **330** is coupled and/or connected. In some embodiments, the cable modem **350** is incorporated into the second wireless base station **304**. The cable modem **350** is typically located within the same building, e.g., building **302**, as the second wireless base station **304**. The messages, commands, instructions and information sent from the second wireless base station **304** in such embodiments traverse the path of second wireless base station **304**, cable modem **350**, communications link **326**, cable modem termination system **352**, core network **330** while messages, commands, instructions and information sent from the HMNO core network **330** traverse the reverse path. It should be understood that any communications links between the cable modem **350** and second wireless base station **304** will also be traversed as well as any communications links between the cable modem termination system **352** and the HMNO core network **330**.

(48) In some embodiments, the DSDD **306** is located outside the building **302** in which the second wireless base station **304** is located. In such embodiments, the DSDS **306** is still able to receive the second wireless base station wireless transmissions because it is within the cell coverage of the second wireless base station.

(49) In various embodiments, the first wireless base station **308** is connected to the NTP server **312** via a packet gateway of an Evolved Packet Core or Evolved Packet System which is the core network for the first wireless base station **308**. That is it is the core network for the Mobile Network Operator. The core network for the first wireless base station **308** being different than the HMNO core network **330**. In various embodiments, the core network for the Mobile Network Operator is coupled to the core network **330** via an Internet connection.

(50) In various embodiments, the connection between the second wireless base station **304** and the HMNO core network **330** does not allow for the transmission of accurate sync timing information from the HMNO core network **330** to the second wireless base station **304**. This is occurs for example when the delays in the transmission path cannot be reliably determined and compensated for.

(51) In some embodiments, the first wireless base station **308** is operated by the HMNO operator but is a tower base station operating in a first spectrum band and the second wireless base station is operating in a second spectrum band, the first and second spectrum bands being different. The first spectrum band being at a frequency that allows better penetration through structures then the frequencies of the second spectrum band. The user equipment device **306** in such embodiments has dual radios and is able to connect to both the first and second wireless base stations, for example while in the building **302**. The user equipment device **306** in such embodiments obtains the synchronization information from the first wireless base station **308** and provides it to the second wireless base station **302** as previously described.

(52) In some embodiments, the HMNO core network **330** is connected to an NTP server and provides timing synchronization information to the second wireless base station **304** under certain conditions. However, when the synchronization is not available or the conditions do not exist, the second wireless base station **304** obtains the timing synchronization from the first wireless base

station **308** via the DSDS UE **306** using the procedures previously described. FIG. **15** illustrates the details of an exemplary method of a wireless base station obtaining synchronization information from another wireless base station via user equipment device.

(53) As discussed above, the present invention provides new and/or improved methods and apparatus for distributing synchronization information (e.g., frequency, phase and time of day information) in a wireless system. The present invention is also directed to implementing new and/or improved methods of a wireless base station obtaining timing synchronization information from wireless base station(s) in other wireless networks via dual subscriber mobile devices, e.g., dual subscriber smartphones which have dual subscriptions allowing the smartphone to connect to and obtain timing synchronization from a first wireless base station in a first network and provide the timing synchronization to a second wireless base station in a second network. Various features of the present invention relate to methods and apparatus for efficiently (e.g., with reduced cost) and effectively obtaining and distributing timing synchronization information in a wireless network without the need for a GPS receiver. Various features of the present invention relate to methods and apparatus for distributing timing synchronization information to small cell wireless base stations located inside buildings with radio coverage limited to within the building structure.

(54) FIG. **15** comprises FIG. **15**A and FIG. **15**B. FIG. **15**A is the first part (Part A **1501**) of a signaling diagram which illustrates the steps and signaling of an exemplary method **1500** in accordance with an embodiment of the present invention. FIG. **15**B is the second part (Part B **1502**) of a signaling diagram which illustrates the steps and signaling of an exemplary method **1500** in accordance with an embodiment of the present invention. While it will be readily understood that additional steps and signaling are performed in connection with communicating information, messages, and packets between devices, the method **1500** focuses on and discusses the steps and signaling for understanding the invention. Elements or steps with the same reference numbers used in different figures are the same or similar and those elements or steps will not be described in detail again. The signaling diagram/method **1500** is implemented by a system including a first wireless base station WBS **1 1504**, a Dual SIM Dual subscriber user equipment device DSDS UE **1506**, a second wireless base station WBS **2 1508** and a core network **1510**.

(55) The DSDS UE **1506** is a wireless device, e.g., a mobile device such as by way of example a mobile phone, smart phone, laptop, tablet, with a first SIM card with credentials to access a first mobile network operator's network and a second SIM card with credentials to access a second mobile network operator's network. The first mobile network operator's network being a first wireless network having a first set of spectrum available for use. The second mobile network operator's network being a Hybrid Mobile Network Operator (HMNO) network including a second wireless network which utilizes spectrum different than the first wireless network for wireless communications. In some embodiments, the first wireless base station **1504** is an eNodeB. In some embodiments, the second wireless network is a CBRS network. In some such embodiments, the second wireless base station is a CBSD. In some embodiments, the second wireless base station **1508** is an indoor wireless base station located in a building with no access or unreliable access to synchronization information. In some embodiments, the second wireless base station **1508** is a small cell or micro cell wireless base with a small cell size. In some such embodiments, the cell size is limited to interior of the building. In some embodiments, the second wireless network is a time division network. In some such embodiments, the second wireless network is a CBRS Time Division Long Term Evolution network utilizing 5G New Radio (NR) technology. In some embodiments, the second wireless base station **1508** is CBSD with Time Division-Long Term Evolution/New Radio radios which need GPS or clock sync signal information such as IEEE 1588 for Frequency, Phase and ToD (Time of Day) to be able to operate. In some embodiments, the second wireless network is a hybrid mobile network which offloads traffic from the first wireless network. In some such embodiments, the second network operator, which operates the HMNO network, is a Mobile Virtual Network Operator (MVNO) operator for which the first network

operator, which operates the first wireless network and which provides network services, e.g., wireless network services, to the second wireless network operator. In some such embodiments, the first wireless network operator is a Mobile Network Operator or a carrier.
(56) The DSDS UE **1506** includes a dual SIM card and is a subscriber of both the first network operator's services and the second network operator's services. This allows the DSDS UE **1506** to connect to and communicate with devices, e.g., wireless base stations and user equipment devices in both the first wireless network and the second wireless network. User equipment to user equipment device communications are D2D communications. The DSDS UE **1506** include a connection manager which manages communications with both the first network and second network, e.g., handoff of the DSDS UE **1506** from the first network to the second network.
(57) The core network **1510** is a HMNO core network operated by the second network operator as part of the second network. The core network **1510** includes network equipment, e.g., a plurality of network equipment devices and/or entities/functions, which provide core network services and functionality for the second wireless network. In some embodiments the core network **1510** is an Evolved Packet Core/System. In various embodiments, the second wireless base station **1508** is connected to the core network **1510** over a path that includes a landline, e.g., a wire or optical cable. In some such embodiments, the second wireless base station **1508** is coupled or connected to a cable modem which is coupled to a cable connecting the cable modem to a cable modem termination system. The cable modem termination system is coupled to and/or connected to the core network **1510** and/or included in the core network **1510**. Communications from the second wireless base station **1508** to the core network **1510** traverse the following path: second wireless base station **1508**, cable modem, cable, cable modem termination system, core network **1510**; and communications from the core network **1510** to the second wireless base station **1508** traverse the following path: core network **1510**, cable modem termination system, cable, cable modem, second wireless base station **1508**. In various embodiments, the core network **1510** includes an entity, e.g., a network equipment device such as a mobility management entity/device, which determines the location of devices, e.g., user equipment devices and base stations, in the HMNO network based on device identification information, e.g., a CGI provided by a wireless base station.
(58) In various embodiments, the second wireless base station **1508** is implemented in accordance with the wireless base station **400** shown in FIG. **4**. In some embodiments, the DSDS UE **1 1506** is implemented in accordance with user equipment device **500** shown in FIG. **5**. In some embodiments, the network equipment included in the core network **1510** is implemented in accordance with the network equipment device **600** shown in FIG. **6**. In some embodiments, the first wireless base station **1504** is implemented as an eNodeB.
(59) The signaling diagram/method **1500** may be, and in some embodiments is, implemented using exemplary system **300** of FIG. **3**. In such embodiments, the first wireless base station **1504** is the first wireless base station **308** of system **300**. The second wireless base station **1508** is second wireless base station **304** of system **300**. The DSDS user equipment device **1506** is DSDS user equipment device **306** of system **300**. The core network **1510** is HMNO core network **330** of system **300** However, it should be understood that the method **1500** is not limited to the exemplary system **300** and may be, and is used, on other systems and system configurations. The signaling diagram/method **1500** illustrates the exemplary signaling and steps for providing/distributing synchronization information (e.g., frequency, phase, time of day information) to devices, e.g., wireless base stations. The synchronization information or sync information being provided via a Dual SIM Dual Subscriber user equipment device from another network than the network to which the wireless base stations belongs.
(60) The method **1500** starts in start step **1512** shown on FIG. **15**A. Operation proceeds from start step **1512** and proceeds in parallel to steps **1514**, **1516**, **1524** and **1526**.
(61) In step **1514**, the DSDS user equipment **1506** comes within the coverage area of the first wireless base station. The DSDS user equipment device **1506** utilizes a first set of information, e.g.,

first subscriber credentials, stored in its first SIM to connect to the first wireless base station.
(62) In step **1516**, the first wireless base station **1504** generates message **1520**. The message **1520** contains sync information (e.g., synchronization timing information such as frequency, phase and time of day information). Operation proceeds from step **1516** to step **1518**.
(63) In step **1518**, the first wireless base station **1504** transmits the message **1520** to DSDS user equipment device **1506**. The message **1520** is transmitted over first spectrum allocated and/or belonging to the first mobile network operator. Operation proceeds from step **1518** to step **1522**.
(64) In step **1522**, the DSDS user equipment device **1506** receives and processes the message **1520** extracting from the message **1520** the sync information contained in the message **1520**. In various embodiments, the DSDS user equipment device **1506** stores the sync information in its memory.
(65) In step **1524**, the second wireless base station **1508** is out of sync or needs to re-sync its timing information, e.g., because it is about to go out of sync. For example, the second wireless base station **1508** may have just powered on and does not have synchronization information and so cannot operate as a wireless base station or the second wireless base station **1508** may be operating as a wireless base station but be about to lose timing synchronization needed to operate properly as a base station for example due to drift causing its timing information to lose accuracy.
(66) In step **1526**, the core network **1510**, e.g., a network equipment device located in the core network **1510**, determines that the second wireless base station is out of sync or needs to re-sync its timing information. Operation proceeds from step **1526** to step **1528**.
(67) In step **1528**, the core network **1510**, e.g., a network equipment device in the core network **1510**, in response to determining that the second wireless base station **1508** is out of sync or needs to re-sync generates message **1532**. Message **1532** includes information indicating that the receiving device, e.g., the second wireless base station is to enter a discovery mode of operation to acquire sync information. In some embodiments, the message **1532** includes information indicating that the second wireless base station **1508** is out of sync or needs to re-sync its timing synchronization information. In some embodiments, the message **1532** includes a command and/or an instruction for the second wireless base station **1508** to automatically enter a discovery mode of operation to obtain sync information. In some embodiments, the instruction to enter discovery mode of operation is an indication that the second wireless base station **1508** is out of sync. Operation proceeds from step **1528** to step **1530**.
(68) In step **1530**, the core network **1510** transmits the message **1532** to the second wireless base station **1508**. Operation proceeds from step **1530** to step **1534**.
(69) In step **1534**, the second wireless base station **1508** receives the message **1532**. Operation proceeds from step **1534** to step **1536**.
(70) In step **1536**, the second wireless base station **1508** processes the received message **1532**. Operation proceeds from step **1536** to step **1538**.
(71) In step **1538**, the second wireless base station **1508** in response to the message **1532** enters a first mode of operation which is a discovery mode of operation. In some embodiments, the second wireless base station **1508** implements one or more commands and/or instructions included in the message **1532** which include entering a discovery mode of operation. In some embodiments, the second wireless base station **1508** determines from the information in the message **1532** that it is out of sync or needs to re-sync and automatically enters a discovery mode of operation. In some embodiments, the discovery mode of operation is a Proximity Service (ProSe) function discovery mode of operation. In some embodiments, the discovery mode of operation is a mode of operation in which the second wireless base station **1508** discovers synchronization information (e.g., time sync information such as for example frequency, phase and/or time of day information). Operation proceeds from step **1538** to step **1540**.
(72) In step **1540**, while operating in said first mode of operation, e.g., the discovery mode of operation, the second wireless base station **1508** generates discovery request message **1544**. In some embodiments, the discovery request message **1544** is a D2D discovery request message

including information identifying the second wireless base station **1508** and requesting the establishment of a D2D communications link. In various embodiments the discovery request message **1544** is a D2D discovery request message seeking to identify or discover a device, e.g., a user equipment device, with which the second wireless base station **1508** can establish a device to device communications link. In some embodiments, the discovery request message **1544** is a ProSe function D2D discovery request beacon message. FIG. **12** illustrates the formats and fields of an exemplary ProSe function discovery message. Operation proceeds from step **1540** to step **1542**.

(73) In step **1542**, the second wireless base station **1508** wirelessly transmits and/or broadcasts the discovery request message **1544** to other devices, e.g., user equipment devices such as smartphones. The other devices in this example include the DSDS user equipment device **1506** which is within the second wireless base station's broadcast or transmission range. Operation proceeds from **1542** to step **1546**.

(74) In step **1546**, the DSDS user equipment device **1506** receives the discovery request message **1544**. Operation proceeds from step **1546** to step **1548**.

(75) In step **1548**, the DSDS user equipment device **1506** processes the received discovery request message **1544**. In processing the discovery request message the DSDS user equipment device **1506** determines that the second wireless base station **1508** is requesting to establish a D2D communications link, e.g., a ProSe function D2D communications link. The DSDS user equipment device **1506** further determines that is capable of providing the requested D2D communications link. Operation proceeds from step **1548** to step **1550**.

(76) In step **1550**, the DSDS user equipment device **1506** generates a discovery response message **1554** in response to the discovery request message **1544**. In some embodiments, the discovery response message **1554** includes information identifying the DSDS user equipment device **1506**. The discovery response message **1554** includes information indicating that DSDS user equipment device **1506** is available to establish a D2D communication link with the second wireless base station **1508**. In some embodiments, the discovery response message **1554** is a ProSe function discovery response message.

(77) When the discovery request message **1544** is a ProSe function discovery beacon message and the discovery response message **1554** is a ProSe function discovery response message, the second wireless base station **1508** is an announcing device and the DSDS user equipment device **1506** is a monitoring device.

(78) Operation proceeds from step **1550** to step **1552**. In step **1552**, the DSDS user equipment device **1506** transmits over the air the generated discovery response message **1554** to the second wireless base station **1508** in response to the discovery request message **1544**. Operation proceeds from step **1552** to step **1556**.

(79) In step **1556**, the second wireless base station **1508** receives the discovery response message **1554**. Operation proceeds from step **1556** to step **1558**.

(80) In step **1558**, the second wireless base station processes the discovery response message **1554** and determines from information contained in the discovery response message **1554** that the DSDS user equipment device **1506** is available to establish a D2D communications link. Operation proceeds from step **1558** to step **1560**.

(81) In step **1560**, the second wireless base station **1508** generates sidelink request message **1564** which includes information requesting resources, e.g., an allocation of spectrum, to establish a D2D communication link with the DSDS user equipment device **1506**. In some embodiments, the sidelink request message **1564** includes identification information for the second wireless base station **1508**, e.g., a Cell Global Identifier (CGI). In some embodiments, the sidelink request message **1564** includes identification information for the DSDS user equipment device **1506**. Operation proceeds from step **1560** to step **1562**.

(82) In step **1562**, the second wireless base station **1508** transmits the sidelink request message **1564** to the core network **1510**. In some embodiments, the sidelink request message **1564** is

transmitted to a MME (Mobility Management Entity) in the core network **1510**. Operation proceeds from step **1562** to step **1566**.
(83) In step **1566**, the core network **1510** receives the sidelink request message **1564**. In some embodiments, a network equipment device, e.g., the MME in the core network **1510** receives the sidelink request message **1564**. Operation proceeds from step **1566** to step **1568**.
(84) In step **1568**, the core network **1510**, e.g., the MME in the core network, processes the sidelink request message **1564** and determines to grant the request and provide the resources and information/instruction for establishing a sidelink communications channel between the second wireless base station **1508** and the DSDS user equipment device **1506**. Operation proceeds from step **1568** to step **1570**.
(85) In step **1570**, the core network **1510**, e.g., the MME in the core network, generates sidelink response message **1574** in response to the sidelink request message **1564**. The sidelink response message **1574** includes instructions for sidelink resources to establish the D2D sidelink connection between the second wireless base station **1508** and DSDS user equipment device **1506**. The instructions for the sidelink resources include information identifying the spectrum allocated for the sidelink D2D communication channel. Operation proceeds from step **1570** to step **1572**.
(86) In step **1572**, the core network **1510**, e.g., the MME in the core network **1510**, transmits the sidelink response message **1574** to the second wireless base station **1508** in response to the sidelink request message **1564**. Operation proceeds from step **1572** to step **1576**.
(87) In step **1576**, the second wireless base station **1508** receives the sidelink response message **1574** from the core network **1510**, e.g., the MME in the core network **1510**. Operation proceeds from step **1576** to step **1578**.
(88) In step **1578**, the second wireless base station **1508** processes the received sidelink response message **1574** and determines based on the instructions and/or information contained in the sidelink response message that the sidelink request for resources to establish a sidelink communications channel with the DSDS user equipment device **1506** has been granted. Operation proceeds from step **1578** to step **1580**.
(89) In step **1580**, the second wireless base station **1508** generates the sidelink information message **1584** which includes information to establish the sidelink communications channel between the second wireless base station **1508** and the DSDS user equipment device **1506**. This information includes the spectrum allocated for the sidelink communications channel. In some embodiments, this information includes information from which a plurality of resource blocks defined by frequency and time are allocated for the sidelink communications channel. The sidelink information message **1584** is based on the sidelink response message **1574**. The information included in the sidelink information message **1584** is based on the information and/or instructions for the sidelink resources included in the sidelink response message **1574**. Operation proceeds from step **1580** to step **1582**.
(90) In step **1582**, the second wireless base station **1508** transmits the sidelink information message **1584** to the DSDS user equipment device **1506**. Operation proceeds from step **1582** to step **1586**.
(91) In step **1586**, the DSDS user equipment device **1506** receives the sidelink information message **1584** from the second wireless base station **1508**. Operation proceeds from step **1586** to step **1588**
(92) In step **1588**, the DSDS user equipment device **1506** processes the sidelink information message **1584**. In some embodiments, processing the sidelink information message **1584** includes extracting the sidelink information specifying the information/instructions needed to establish the D2D sidelink communications channel between the second wireless base station **1508** and the DSDS user equipment device **1506**. Operation proceeds from step **1588** to steps **1590** and **1594**.
(93) In step **1590** and **1594**, the DSDS user equipment device **1506** and second wireless base station **1508** establish a sidelink communications channel using the resources, e.g., spectrum, granted and/or specified by the core network **1510**. Information about these resources, e.g., granted spectrum, being included in the sidelink resource information/instructions included in the sidelink

response message **1574** and sidelink information message **1584**. As part of establishing the sidelink communications channel between the DSDS user equipment device **1506** and the second wireless base station **1508**, the DSDS user equipment device **1506** and second wireless base station **1508** generate and exchange sidelink channel establishment messages **1592**. Operation proceeds from step **1590** and **1594** to step **1596** shown on Part B **1502** of signaling diagram **1500** illustrated on FIG. **15**B.

(94) In step **1596**, the second wireless base station **1508** generates time sync request message **1600**. The time sync request message **1600** includes information requesting time sync information, e.g., timing synchronization information such as frequency, phase, and time of day information. Operation proceeds from step **1596** to step **1598**.

(95) In step **1598**, the second wireless base station **1508** transmits the time sync request message **1600** to the DSDS UE **1506** over the established sidelink channel. Operation proceeds from step **1598** to step **1602**.

(96) In step **1602**, the DSDS user equipment device **1506** receives the time sync request message **1600**. Operation proceeds from step **1602** to step **1604**.

(97) In step **1604**, the DSDS user equipment device **1506** processes the time sync request message **1600**. Operation proceeds from step **1604** to step **1608**.

(98) In step **1608**, the DSDS user equipment device **1506** generates the requested time sync information based on the sync information received in message **1520** from the first wireless base station **1504**. In various embodiments, the DSDS user equipment device **1506** includes a connection manager which generates the requested time sync information based on the synch information received in the message **1520** from the first wireless base station **1504**. In generating the requested time sync information, the DSDS user equipment device **1506** also generates information to be included with the time sync information such as propagation offset and root delay so that the second wireless base station **1508** can compensate for propagation and/or processing delays in the time sync information. In some embodiments, the DSDS user equipment device **1506** generates System Information Block type **18** (SIB **18**) which contains sidelink information in which the requested time sync information is included. In some embodiments, the sync information is included in the commSyncConfig-r12 parameters/information of the SIB **18**. Operation proceeds from step **1608** to step **1610**.

(99) In step **1610**, the DSDS user equipment device **1506** generates time sync response message **1614** which includes the requested time sync/synchronization information (e.g., frequency, phase and time of day synchronization information). FIG. **16** illustrates the exemplary fields and format of an exemplary time sync packet **1670** in accordance with an embodiment of the present invention. The exemplary fields of time sync packet **1670** includes header field **1672**, stratum field (length 1 byte) **1674**, Internet Protocol (IP) version field (length 2 bits) **1676**, status indicator field (length 2 bits) **1678**, precision field (1 byte) **1680**, root delay field (4 bytes) **1682**, reference time stamp field **1684**, original time stamp field **1686**, frequency field **1688**, phase field **1690**, pathloss delay offset field **1692**, and synch counter field **1694**. The header field **1672** includes information to identify the right receiver, e.g., information similar to a MAC header. The stratum field **1674**, which is 1 byte in length, indicates the level of stratum, e.g., primary, secondary, etc. of the time sync information. The IP version field **1676** indicates IPv4 or IPv6. The status indicator field **1678** indicates the clock synchronized or not synchronized. The precision field **1680** indicates the precision of the local clock in power of 2. The root delay field **1682** indicates the round trip delay to the primary source of the timing information. The reference time stamp field **1684** is the time when the system clock was last set or corrected. The reference time stamp field **1684** is 64 bits in length and is in NTP time stamp format. The original time stamp field **1686** is the time at which the request departed the client for the wireless base station. The original time stamp is 64 bits in length and is in NTP time stamp format. The pathloss delay offset field **1692** contains the pathloss delay offset, which is obtained from channel state information (CSI) and which is used in estimating pathloss and

estimating the time delay for a message to reach a device. The synch counter field **1694** includes a sync counter value, which is decremented each time this synchronization information is received from another wireless base station. For example, a peer to peer establishment of connectivity to share synch information between the primary recipient of synch information, i.e., the first wireless base station **308** will decrement synch counter before forwarding it to the secondary recipient, i.e., the second wireless base station **304**, so on and so forth. The purpose of doing this is to limit the number of hops as the time sensitive information may actually become inaccurate do to unexpected pathloss delays. In some embodiments, the time sync packet also includes fields for Receive Timestamp and Transmit Timestamp. The field for the Receive Timestamp is the time at the user equipment device when the request arrived from the client. Transmit Timestamp is the time at the user equipment device when the response left for the wireless base station. In some embodiments, the time sync packet is in NTP format and includes all NTP fields including the fields for stratum, precision, root delay, reference timestamp, origin timestamp, receive timestamp, and transmit timestamp. The delay for path from the DSDS user equipment device to the wireless base station being calculated based on the round trip delay measured by the either the wireless base station or DSDS user equipment device.

(100) Operation proceeds from step **1610** to step **1612**. In step **1612**, the time sync response message **1614** is transmitted from the DSDS user equipment device **1506** to the second wireless base station **1508**. Operation proceeds from step **1612** to step **1616**.

(101) In step **1616**, the second wireless base station **1508** receives the time sync response message **1614**. Operation proceeds from step **1616** to step **1618**.

(102) In step **1618**, the second wireless base station **1508** processes the time sync response message **1614** and extracts the information, e.g., the time sync information, included in the message.

(103) Operation proceeds from step **1618** to step **1620** when the second wireless base station **1508** is already on-line and operating as an active wireless base station. In step **1620**, the second wireless base station **1508** uses the received timing sync information to re-synch itself, e.g., to re-synch its frequency, phase, and time of day information. The re-synched timing information at the second wireless base station **1508** being based on the sync time information provided in the time sync response message **1614**. In some embodiments, re-syncing timing information including updating the frequency, phase and/or time of day information stored at the second wireless base station **1508**. In some embodiments, re-syncing includes updating timing synchronization information stored at the second wireless base station **1508** to maintain its precision taking into account the timing synchronization information received in the time sync response and the delay information provided, e.g., root delay and pathloss delay offset information. In some embodiments, re-syncing timing information including setting and/or updating a timer or clock (e.g., reference clock) in the second wireless base station **1508**.

(104) Operation proceeds from step **1618** to step **1622** when the second wireless base station **1508** is off-line (i.e., not operating as a base station providing services to user equipment devices). In step **1622**, the second wireless base station **1508** uses the sync information provided in the time sync response message **1614** to obtain synchronization with the HMNO. The second wireless base station **1508** stores the sync information in its memory and/or updates its currently stored synchronization information. The second wireless base station **1508** sets and/or updates a timer or clock (e.g., reference clock) in the second wireless base station **1508**. Operation proceeds from step **1622** to step **1623**.

(105) In step **1623**, the second wireless base station **1508** generates sync reception confirmation message **1626**. Sync reception confirmation message **1626** includes information confirming that the second wireless base station **1508** has received sync information from a user equipment device, e.g., in this case DSDS user equipment device **1506**. The sync reception confirmation message **1626** includes identification information, e.g., CGI, from which the second wireless base station **1508** can be identified. Operation proceeds from step **1623** to step **1624**.

(106) In step **1624**, the second wireless base station **1508** transmits the sync reception confirmation message **1626** to the core network **1510**, e.g., to wireless base station activation and/or provisioning network equipment devices in the core network **1510**. Operation proceeds from step **1624** to step **1628**.
(107) In step **1628**, the core network **1510**, e.g., wireless base station activation and/or provisioning network equipment devices in the core network **1510**, receive the sync reception confirmation message **1626**. Operation proceeds from step **1628** to step **1630**.
(108) In step **1630**, the core network **1510**, e.g., network equipment devices in the core network **1510**, processes the received sync reception confirmation message **1626**. Processing the received sync reception confirmation message includes identifying the second wireless base station based on the identification information provided in the sync reception confirmation **1626** and making the determination to prepare the core network **1510** for provisioning and/or activation of the second wireless base station **1508**. Operation proceeds from step **1630** to step **1632**.
(109) In step **1632**, the core network **1510**, e.g., a network equipment device (e.g., MME) generates message **1636** in response to sync reception confirmation message **1626**. Message **1636** includes information, command(s), and/or instruction(s) for the second wireless base station **1508** to prepare for activation or to come back on-line. Operation proceeds from step **1632** to step **1634**.
(110) In step **1634**, the core network **1510**, e.g., a network equipment device (e.g., MME), transmits the message **1636** to the second wireless base station **1508**. Operation proceeds from step **1634** to step **1638**.
(111) In step **1638**, the second wireless base station receives and processes the message **1636**. Processing the message **1636** includes preparing for activation and/or provisioning and/or going back on-line based on the information, command(s) and/or instruction(s) included in the message **1636**. When the message **1638** indicates that the second wireless base station **1508** is to go back on-line (e.g., when it is already provisioned and activated in the core network), then operation proceeds from step **1638** to step **1646**. Otherwise when the message **1638** indicates that the second wireless base station **1508** is to prepare for provisioning and/or activation, operation proceeds from step **1638** to steps **1640** and **1644**.
(112) In step **1640** and **1644**, the second wireless base station **1508** and core network **1510** (e.g., network equipment devices in the core network **1510**) complete activation and processing operations. As part of completing the activation and processing the second wireless base station **1508** and core network **1510** exchange messages **1642** which include information and/or instructions for completing the provisioning and activation of the second wireless base station **1508** as well as confirmations indicating that the provisioning and activation for the second wireless base station **1508** has been completed. Operation proceeds from steps **1640** and **1644** to step **1646**.
(113) In step **1646**, the second wireless base station **1508** comes on-line and commences operation as a wireless base station, e.g., it begins provides services to user equipment devices. Once the second wireless base station **1508** has been re-synced in step **1620** or comes on-line in step **1646**, the core network **1510** commences monitoring to determine when the second wireless base station **1508** will need to re-sync its synchronization information, e.g., by setting a timer for a period of time, e.g., 20 minutes. When the timer expires the core network **1510**, will generate an out of sync alert and return to step **1528**. The DSDS user equipment device **1506** will obtain updated sync information and the process will be repeated assuming that the DSDS user equipment device **1506** responds to the new discovery request message sent by the second wireless base station **1508**. In various embodiments, a second different DSDS user equipment will receive and respond to the new discovery request message and the process will be repeated with this second DSDS user equipment device wherein the second DSDS user equipment device obtains and provides the timing synchronization information to the second wireless base station **1508** required for re-synchronization of the second user equipment device **1508**.
(114) While the method **1500** illustrated in FIG. **15**, has been explained with respect to a single UE

device and a first wireless base station and a second wireless base station the method may be, and typically is implemented for a plurality of DSDS user equipment devices, e.g., mobile devices, that can connect to different wireless base stations in different network with various DSDS user equipment devices being able to obtain timing synchronization information (e.g., frequency, phase and time of day synchronization information) from one wireless base station and provide the timing synchronization information to another requesting wireless base station.

(115) It should be understood that the operation(s), step(s), and function(s) described in connection with network core **1510** may be implemented by network entities such as network equipment device(s), network service function(s) and/or other components or systems located in the core network **1510**.

(116) Details of features of various embodiments, will now be discussed. It should be appreciated that not necessarily all embodiments include the same features and some of the features described below are not necessary but can be desirable in some embodiments.

(117) FIG. **4** is a drawing of an exemplary wireless base station **400** in accordance with an exemplary embodiment. The wireless base station **400** supports Proximity Service (ProSe) requirements and operations. FIG. **4** is a drawing of an exemplary wireless base station **400**, e.g., a Citizens Broadband Radio Service Wireless Base Station (CBSD) **400**, in accordance with an exemplary embodiment. Exemplary wireless base station **400** includes a wireless interface **404**, a network interface **405**, e.g., a wired or optical interface, a processor **406**, e.g., a CPU, an assembly of hardware components **408**, e.g., an assembly of circuits, and I/O interface **410**, timer, e.g. reference clock **411** including a local oscillator **413**, and memory **412** coupled together via a bus **409** over which the various elements may interchange data and information. Wireless base station **400** further includes a speaker **452**, a display **454**, switches **456**, keypad **458** and mouse **459** coupled to I/O interface **410**, via which the various I/O devices (**452**, **454**, **456**, **458**, **459**) may communicate with other elements (**404**, **405**, **406**, **408**, **411**, **412**) of the wireless base station **400**. Network interface **405** includes a receiver **478** and a transmitter **480**. In some embodiments, receiver **478** and transmitter **480** are part of a transceiver **484**. Wireless interfaces **404** include a plurality of wireless interfaces including first wireless interface **424**, second wireless interface **450**, . . . , Kth wireless interface **455**. The wireless interfaces are used to communicate with the wireless devices, e.g., user equipment device, e.g., DSDS user equipment devices. The first wireless interface **424** is used for example to communicate with a first user equipment device using a first spectrum band. The second wireless interface can be used to communicate with a second user equipment device using a second spectrum band. The first wireless interface **424** includes wireless receiver **438** and a wireless transmitter **440**. In some embodiments, receiver **438** and transmitter **440** are part of a transceiver. In various embodiments, the first wireless interface **424** includes a plurality of wireless receivers and a plurality of wireless transmitters. Wireless receiver **438** is coupled to a plurality of receive antennas (receive antenna **1 439**, . . . , receive antenna M **441**), via which wireless base station **400** can receive wireless signals from other wireless communications devices including a second wireless communications device, e.g., a user equipment device. Wireless transmitter **440** is coupled to a plurality of wireless transmit antennas (transmit antenna **1 443**, . . . , transmit antenna N **445**) via which the wireless base station **400** can transmit signals to other wireless communications devices including a second wireless communications device, e.g., a user equipment device.

(118) The second wireless interface **450** includes wireless receiver **452** and a wireless transmitter **454**. In some embodiments, receiver **452** and transmitter **454** are part of a transceiver. In various embodiments, the second wireless interface **450** includes a plurality of wireless receivers and a plurality of wireless transmitters. Wireless receiver **452** is coupled to one or more receive antennas (receive antenna **1 456**, . . . , receive antenna M **457**), via which wireless base station **400** can receive wireless signals from other wireless communications devices including a second wireless communications device, e.g., CBRS UE device, using the same or a different wireless protocol than

the first wireless interface. Wireless transmitter **454** is coupled to one or more wireless transmit antennas (transmit antenna **1 458**, . . . , transmit antenna N **460**) via which the wireless base station **400** can transmit signals to other wireless communications devices including a second wireless communications device. The wireless base station network interface **405** may be coupled to a cable modem, a core network, other networks, e.g., internet, or other wireless base stations.

(119) Memory **412** includes an assembly of components **414**, e.g., an assembly of software components, and data/information **416**. Data/information **416** includes a received first control message **460**, e.g., a command message to enter a discovery mode of operation, e.g. due to an out of sync alert condition, a generated discovery request message **461**, a received discovery response message **462**, e.g., including information identifying a first UE device with which the base station **400** may establish a device to device connection over a sidelink channel via which sync information may be communicated to the base station, obtained sidelink resource information **463**, generated and/or received sidelink establishment messages **463**, a generated sidelink resource information message **465**, a generated first sync request message **466**, received sync information, e.g., a received packet including sync information **467**, e.g., packet information **1670** of FIG. **16**, a generated message indicating success of reception of the sync information **468**, a set of recovered and/or determined sync information **469** to be used to synchronize or re-synchronize a timer **411**, e.g. a reference clock, of the base station **400**, a determined time value **470**, an adjusted time value **471** based on received and/or determined delay information, generated control information **472** for setting/adjusting a timer **411**, e.g. reference clock, for initial synchronization or for re-synchronization based on the received sync information, information indicating a current mode of operation **473** of the base station **400**, e.g. a first mode of operation, e.g. a discovery mode of operation and/or a device to device mode of operation used to acquire synchronization information, or a second mode of operation, e.g., a base station mode of operation in which the base station is timing synchronized and services UE devices, a received mode change message **474**, and spectrum information **475**, e.g. indicating a GAA spectrum being used by the first base station. While the details of the first and second wireless interfaces are shown, the other wireless interfaces of the wireless base station, e.g., wireless interface K where K is an integer greater than 2 also include multiple receivers and transmitters so that the wireless base station **400** can provide wireless services to for example a plurality of wireless devices such as user equipment devices. In some embodiments, one or more of the wireless base stations discussed and/or shown in the Figures and/or in connection with the methods discussed herein are implemented in accordance with the wireless base station **400**. For example, the CBSDs of system **200** shown in FIG. **2**, the second wireless base station **304** of FIG. **3**, the second wireless base station **1508** of FIG. **15**, the CBSDs illustrated in FIG. **13** may be, and in some embodiments are, implemented in accordance with the wireless base station **400**.

(120) FIG. **5** is a drawing of an exemplary user equipment (UE) device **500** in accordance with an exemplary embodiment. UE device **500** is, e.g., a wireless device, e.g., a mobile device such as a cell phone, a smart phone, wireless tablet or wireless notebook. UE device **500** is a dual SIM dual subscriber device that is enabled to communicate with different wireless base stations utilizing different wireless spectrum and/or wireless protocols, e.g., 5G wireless protocol, CBRS wireless protocol or cellular wireless protocol. In various embodiments, the dual SIM dual subscriber UE **500** servers as an intermediary device, providing synchronization information obtained from a first service provider to a device, e.g. an unsynchronzied or out-of-sync device, e.g. a CBSD of the second service provider's network. Exemplary UE device **500** includes wireless interfaces **504**, a network interface **505**, a processor **506**, e.g., a CPU, an assembly of hardware components **508**, e.g., an assembly of circuits, and I/O interface **510**, a GPS receiver **502** coupled to GPS receive antenna **507**, a timer **511**, e.g., a reference clock including a local oscillator **513**, a dual SIM card interface **570** including a first SIM card, SIM card **1 571**, corresponding a first service provider, and a second SIM card, SIM card **2 572** corresponding to a second service provider, and memory

512 coupled together via a bus **509** over which the various elements may interchange data and information. UE device **500** further includes a microphone **560**, camera **561**, speaker **562**, a display **564**, e.g., a touch screen display, switches **566**, keypad **568** and mouse **569** coupled to I/O interface **510**, via which the various I/O devices (**560**, **561**, **562**, **564**, **566**, **568**, **569**) may communicate with other elements (**502**, **504**, **505**, **506**, **508**, **512**, **570**) of the UE device. Network interface **505** includes a receiver **578** and a transmitter **580**. The network interface **505** can be coupled to routers within the home or customer premises or to wired (e.g., cable) or optical (e.g., fiber-optic) networks. In some embodiments, receiver **578** and transmitter **580** are part of a transceiver **584**. In some embodiments, the assembly of hardware components **508** includes a connection manager component **573**.

(121) Wireless interfaces **504** include a plurality of wireless interfaces including first wireless interface **536** and a second wireless interface **550**. The first wireless interface **536** is, e.g., used to communicate with wireless base stations in a first service provider's communications network, e.g., cellular, e.g., gNB tower base stations of the first service provider's communications network, e.g., using a first set of spectrum and a first communications protocol corresponding to the first service provider. The second wireless interface is, e.g., used to communicate with a device, e.g., a CBSD base station, of a second service provider's communications network. For example, the second wireless interface is used to communicate with a CBDS base station of the second ser vice provider via a device to device communications channel, e.g. using a second set of spectrum and a second communication protocol corresponding to the second service provider. The first wireless interface **536** includes wireless receiver **538** and a wireless transmitter **540**. In some embodiments, receiver **538** and transmitter **540** are part of a transceiver. In various embodiments, the first wireless interface **536** includes a plurality of wireless receivers and a plurality of wireless transmitters. Wireless receiver **538** is coupled to a plurality of receive antennas (receive antenna **1 539**, . . . , receive antenna M **541**), via which user equipment device **500** can receive wireless signals from other wireless communications devices including a wireless base station, e.g., a cellular wireless base station of the first service provider. Wireless transmitter **540** is coupled to a plurality of wireless transmit antennas (transmit antenna **1 543**, . . . , transmit antenna N **545**) via which the user equipment device **500** can transmit signals to other wireless communications devices including a cellular wireless base station of the first service provider. The antennas **539**, . . . , **541** and **543**, . . . , **545** are typically mounted inside the housing of the wireless device but in some embodiments are located outside the user equipment device housing. In some embodiments the various antennas form an antenna array with the antennas pointing in different directions. In some embodiments, one or more of the antennas are included inside the housing of the user equipment device and the user equipment device includes one or more connections to which exterior antennas may be connected.

(122) The second wireless interface **550** includes wireless receiver **552** and a wireless transmitter **554**. In some embodiments, receiver **552** and transmitter **554** are part of a transceiver. In various embodiments, the second wireless interface **550** includes a plurality of wireless receivers and a plurality of wireless transmitters. Wireless receiver **552** is coupled to one or more receive antennas (receive antenna **1 556**, . . . , receive antenna M **557**), via which user device **500** can receive wireless signals from other wireless communications devices including, e.g. a CBSD base station of a second service provider. Wireless transmitter **554** is coupled to one or more wireless transmit antennas (transmit antenna **1 558**, . . . , transmit antenna N **560**) via which the user equipment device **500** can transmit signals to other wireless communications devices including, e.g. a CBSD of a second service provider. The user equipment device network interface **505** may be coupled to LAN or WAN networks or routers so that the user equipment device can also obtain services via a hardwired connection in addition to through the wireless interfaces, e.g. when the UE device **500** is at a location where such a connection is possible.

(123) Memory **512** includes an assembly of components **514**, e.g., an assembly of software

components, and data/information **516**. In some embodiments, the assembly of software components **514** includes a connection manager component **574**. Data/information **516** includes service provider **1** subscription information **517**, e.g. credentials and NAI realm information corresponding to service provide **1**, service provider **2** subscription information **518**, e.g. credentials and NAI realm information corresponding to service provider **2**. Data/information **516** further includes received synchronization information **521** from a base station, e.g., from a cellular base station of the first service provider. The received synchronization information **521** is used by the UE device **500** to set and re-synch its timer **511**, e.g. its reference clock being maintained by the UE device **500**. Data/information **500** further includes a received discovery request message **522**, e.g., from a CBSD base station of the second ser vice provider seeking to establish a device to device connection with UE **500** over wireless spectrum of the second service provider, a generated discovery response message **522**, e.g. to be sent to the CBSD base station in response to the received discovery request message, and received sidelink resource information **524**, e.g. resource information to be used to establish a sidelink communications channel for supporting device to device communications with the CBSD. Data/information **516** further includes a received sync request message **525**, communicated over an established sidelink channel, said synch request, e.g., from the CBSD seeking synchronization information. The received synch request being communicated over the sidelink device to device communications channel established between the CBSD and the UE device **500**. Data/information **516** further includes a generated message **526** communicating the requested sync information, e.g. a packet of sync information, e.g. via the sidelink channel to the CBSD, Data information **516** further includes information **519** identifying the spectrum used by service provider **1** and information **520** identifying the spectrum used by service provider **2**.

(124) In some embodiments, the user equipment devices discussed in the Figures and/or in connection with the embodiments of the present invention described are implemented in accordance with user equipment device **500**. For example, DSDS UE A **284**, . . . , DSDS UE M **286** of system **200**, DSDS user equipment device **306** of system **300**, and DSDS user equipment device **1506** of FIG. **15** may be, and in some embodiments are, implemented in accordance with user equipment device **500**.

(125) FIG. **6** is a drawing of an exemplary network equipment device, e.g., Mobility Management Entity, Proximity Service Function Element, Wireless Base Station Discovery Element, Cable Modem (CM), Cable Modem Termination System, MDF, IDF in accordance with an exemplary embodiment. The network equipment device **600** includes a plurality of network interfaces **605**, . . . , **690**, e.g., a wired or optical interface, a processor(s) **606** (e.g., one or more processors), e.g., a CPU, an assembly of hardware components **608**, e.g., an assembly of circuits, and I/O interface **610** and memory **612** coupled together via a bus **609** over which the various elements may interchange data and information. The network equipment device **600** further includes a speaker **652**, a display **654**, switches **656**, keypad **658** and mouse **659** coupled to I/O interface **610**, via which the various I/O devices (**652**, **654**, **656**, **658**, **659**) may communicate with other elements (**605**, . . . , **690**, **606**, **608**, **612**) of the network equipment device **600**. Network interface **605** includes a receiver **678** and a transmitter **680**. The network interface **605** is typically used to communicate with other devices, e.g., a cable modem termination system, a wireless base station, etc. In some embodiments, receiver **678** and transmitter **680** are part of a transceiver **684**. Network interface **690** includes a receiver **694** and a transmitter **696**. The network interface **690** is typically used to communicate with other devices, e.g., other network nodes in a core, etc. In some embodiments, receiver **694** and transmitter **696** are part of a transceiver **692**. Memory **612** includes an assembly of component **614**, e.g., an assembly of software components, and data/information **616**. Data/information **616** includes information for identifying base stations **630**, proximity service function information **632** and base station activation and provisioning information **634**.

(126) In some embodiments, the network equipment devices discussed in the Figures and/or in

connection with the embodiments of the present invention described are implemented in accordance with network equipment device **600**. For example, network equipment devices in the core network **300**, NTP server **312**, IDFs and MDF shown in system **200**, base station discovery element **1310**, proximity service function element **1309** may be, and in some embodiments are, implemented in accordance with the network equipment device **600**.

(127) FIG. **7** is a drawing of an exemplary assembly of components **700** which may be included in an exemplary wireless base station (e.g., exemplary wireless base station **400** of FIG. **4**), in accordance with an exemplary embodiment. The components in the assembly of components **700** can, and in some embodiments are, implemented fully in hardware within a processor, e.g., processor **406**, e.g., as individual circuits. The components in the assembly of components **700** can, and in some embodiments are, implemented fully in hardware within the assembly of hardware components **408**, e.g., as individual circuits corresponding to the different components. In other embodiments some of the components are implemented, e.g., as circuits, within processor **406** with other components being implemented, e.g., as circuits within assembly of components **408**, external to and coupled to the processor **406**. As should be appreciated the level of integration of components on the processor and/or with some components being external to the processor may be one of design choice. Alternatively, rather than being implemented as circuits, all or some of the components may be implemented in software and stored in the memory **412** of the wireless base station **400**, with the components controlling operation of wireless base station device **400** to implement the functions corresponding to the components when the components are executed by a processor e.g., processor **406**. In some such embodiments, the assembly of components **700** is included in the memory **412** as assembly of software components **414**. In still other embodiments, various components in assembly of components **700** are implemented as a combination of hardware and software, e.g., with another circuit external to the processor providing input to the processor which then under software control operates to perform a portion of a component's function.

(128) When implemented in software the components include code, which when executed by a processor, e.g., processor **406**, configure the processor to implement the function corresponding to the component. In embodiments where the assembly of components **700** is stored in the memory **412**, the memory **412** is a computer program product comprising a computer readable medium comprising code, e.g., individual code for each component, for causing at least one computer, e.g., processor **406**, to implement the functions to which the components correspond.

(129) Completely hardware based or completely software based components may be used. However, it should be appreciated that any combination of software and hardware, e.g., circuit implemented components may be used to implement the functions. As should be appreciated, the components illustrated in FIG. **7** control and/or configure the wireless base station **400** or elements therein such as the processor **406**, to perform the functions of corresponding steps illustrated and/or described in the method of one or more of the flowcharts, signaling diagrams and/or described with respect to any of the Figures. Thus the assembly of components **700** includes various components that perform functions of corresponding one or more described and/or illustrated steps of an exemplary method.

(130) Assembly of components **700** includes a control routines component **702**, a communications component **704**, a message generator component **706**, a message processing component **708**, a determinator component **710**, a proximity service component **712**, a synchronization component **714**, a mode of operation component **716**, and a storage component **730**. In some embodiments, the mode of operation component **716** includes one or more sub-components including a first mode of operation component **718**, a second mode of operation component **720**, a D2D mode of operation component, **722**, a discovery mode of operation component **724**, an on-line/active base station mode of operation component **726** and an off-line/not active base station mode of operation component **728**.

(131) The control routines component **702** is configured to control operation of the wireless base station (e.g., CBSD).
(132) The communication component **704** is configured to handle communications, e.g., transmission and reception of messages, and protocol signaling for the wireless base station (e.g., CBSD).
(133) The message generator component **706** is configured to generate messages for transmission to other devices, e.g., request messages, response messages, discovery request messages, D2D communications messages, proximity service request and response messages, request for resource messages, notification messages that synchronization information has been received, messages requesting synchronization information, messages for sharing information, e.g., D2D resource information, communications messages with network equipment devices, communications messages with user equipment devices. In some embodiments, the message generator component **706** is a sub-component of the communications component **704**.
(134) The message processing component **708** is configured to process messages received from other devices and implement operations in response to instructions and/or information included in the processed message, e.g., processing and implementing operations in connection with messages from user equipment devices, messages from network equipment devices, messages from proximity service monitoring devices, messages from proximity service function elements, messages including synchronization information, and messages from base station discovery elements/nodes. In some embodiments, the message processing component **708** is a sub-component of the communications component **704**.
(135) The determinator component **710** is configured to make determinations and decisions for the wireless base station including for example: determining to enter a first mode of operation, determining when to exit the first mode of operation, determining when to enter a second mode of operation, determining when to exit the second mode of operation, determining whether the wireless base station needs to obtain synchronization to remain in service, determining whether and when to transmit/broadcast D2D discovery request messages, determining whether and when to request D2D resources from network equipment in the core network, determining when to request synchronization information from a DSDS user equipment device, determining clock or timer information to be used to update or synchronize a reference clock based on received synchronization information including for example reference timestamp, original timestamp and pathloss delay offsets, determining contents of request and response messages, determining phase, frequency, and time of day synchronization information for the wireless base station based on synchronization information from a user equipment device, determining information, e.g. resource information to transmit to a DSDS user equipment device for establishing a D2D communication channel with the DSDS user equipment device, determining when to send a notification message to a network equipment device in a core network to confirm receipt of synchronization information by the wireless base station, determine when to commence operating in active/on-line mode of operation, e.g., based on provisioning and activation messages received from a core network, determining when to update synchronization information stored at the wireless base station, determining when and the operations necessary to re-synch the wireless base station reference clock, determining content/information to be included in proximity request messages and proximity response message exchanged with user equipment devices and a proximity service function element.
(136) A proximity service component **712** is configured to perform all operation relating to providing proximity services including receiving, processing, and responding to proximity service requests, generating proximity service requests, exchanging proximity service messages with a Proximity Service function element, performing operations to establish proximity service D2D connections with other devices, e.g., DSDS user equipment devices, and execute operations to perform proximity service applications such as requesting and obtaining synchronization

information over a proximity service D2D wireless communications link.
(137) A synchronization component **714**, is configured to handle all operations relating to obtaining, generating, and distributing synchronization information (e.g., timing synchronization such as phase, frequency and time of day synchronization information). This includes requesting and obtaining synchronization information from a user equipment device, synchronizing a reference clock based on and/or using the synchronization information provided, establishing a D2D communications channel with a user equipment device over which the synchronization information can be transmitted, the transmission of the synchronization information to other devices, and entering into a discovery mode of operation wherein operations are performed to obtain synchronization from a user equipment device.
(138) A mode of operation component **716** is configured to determine when the wireless base station is to enter and exit different wireless base station modes of operation including a first mode of operation, a second mode of operation, a discovery mode of operation, a proximity service mode of operation, a D2D mode of operation, an on-line/active base station mode of operation, and an off-line/not active base station mode of operation. The mode of operation component **716** is also configured to control the wireless base station to perform all of the operations and functions of the wireless base station with respect to each mode of operation. The first mode of operation sub-component **718** is configured to determine when the wireless base station is to enter and exit the first mode of operation and control the wireless base station to perform the operations associated with the first mode of operation. The second mode of operation sub-component **720** is configured to determine when the wireless base station is to enter and exit the second mode of operation and control the wireless base station to perform the operations associated with the second mode of operation. The D2D mode of operation sub-component **722** is configured to determine when the wireless base station is to enter and exit the D2D mode of operation and control the wireless base station to perform the operations associated with the D2D mode of operation. The discovery mode of operation sub-component **724** is configured to determine when the wireless base station is to enter and exit the discovery mode of operation and control the wireless base station to perform the operations associated with the discovery mode of operation. The on-line/active base station mode of operation sub-component **726** is configured to determine when the wireless base station is to enter and exit the on-line/active base station mode of operation and control the wireless base station to perform the operations associated with the on-line/active base station mode of operation. The off-line/not active base station mode of operation sub-component **728** is configured to determine when the wireless base station is to enter and exit the off-line/not active base station of operation and control the wireless base station to perform the operations associated with the off-line not active base station mode of operation.
(139) The storage component **730** is configured to manage the storage, and retrieval of data and/or instructions to/and from memory, buffers in memory, hardware buffers and/or storage device coupled and/or connected to the wireless base station.
(140) FIG. **8** is a drawing of an exemplary assembly of components **800** which may be included in an exemplary user equipment (UE) device, e.g., UE device **500** of FIG. **5**, in accordance with an exemplary embodiment. The components in the assembly of components **800** can, and in some embodiments are, implemented fully in hardware within a processor, e.g., processor **506**, e.g., as individual circuits. The components in the assembly of components **800** can, and in some embodiments are, implemented fully in hardware within the assembly of hardware components **508**, e.g., as individual circuits corresponding to the different components. In other embodiments some of the components are implemented, e.g., as circuits, within processor **506** with other components being implemented, e.g., as circuits within assembly of components **508**, external to and coupled to the processor **506**. As should be appreciated the level of integration of components on the processor and/or with some components being external to the processor may be one of design choice. Alternatively, rather than being implemented as circuits, all or some of the

components may be implemented in software and stored in the memory **512** of the UE device **500**, with the components controlling operation of UE device **500** to implement the functions corresponding to the components when the components are executed by a processor e.g., processor **506**. In some such embodiments, the assembly of components **800** is included in the memory **512** as assembly of software components **514**. In still other embodiments, various components in assembly of components **800** are implemented as a combination of hardware and software, e.g., with another circuit external to the processor providing input to the processor which then under software control operates to perform a portion of a component's function. When implemented in software the components include code, which when executed by a processor, e.g., processor **506**, configure the processor to implement the function corresponding to the component. In embodiments where the assembly of components **800** is stored in the memory **512**, the memory **512** is a computer program product comprising a computer readable medium comprising code, e.g., individual code for each component, for causing at least one computer, e.g., processor **506**, to implement the functions to which the components correspond.

(141) Completely hardware based or completely software based components may be used. However, it should be appreciated that any combination of software and hardware, e.g., circuit implemented components may be used to implement the functions. As should be appreciated, the components illustrated in FIG. **8** control and/or configure the UE device **500** or elements therein such as the processor **506**, to perform the functions of corresponding steps illustrated and/or described in the method of one or more of the flowcharts, signaling diagrams and/or described with respect to any of the Figures. Thus the assembly of components **800** includes various components that perform functions of corresponding one or more described and/or illustrated steps of an exemplary method.

(142) Assembly of components **800** includes a control routines component **802**, a communications component **804**, a message generator component **806**, a message processing component **808**, a determinator component **810**, a first SIM component **812**, a second SIM component **814**, a connection manager component **816**, a synchronization component **818**, a storage component **820**, a proximity service component **822**, a D2D mode of operation component **824**, and a dual SIM dual subscriber mode of operation component **826**.

(143) The control routines component **802** is configured to control operation of the UE.

(144) The communications component **804** is configured to handle communications, e.g., receipt and transmission of signals and provide protocol signal processing for one or protocols for the UE.

(145) The message generator component **806** is configured to generate messages for transmission to wireless base stations (e.g., CBSD devices, eNodeBs) such as messages including request and response messages, etc. In some embodiments, the message generator component **806** is a sub-component of the communications component **804**.

(146) The message processing component **808** processes received messages, e.g., requests for information. In some embodiments, the message processing component **808** is a sub-component of the communications component **804**.

(147) The determinator component **810** makes determination for the user equipment devices such as for example, determining whether to respond to a D2D discovery request message received from a wireless base station, determining synchronization information to provide a wireless base station in response to a request for synchronization information, determining whether to obtain updated synchronization from a wireless base station before generating synchronization information to be provided to a different wireless base station, determining whether to request information related to a received Proximity Service request, determining propagation delays, e.g., round trip delay for communications with a wireless base station to include in synchronization information to be provided.

(148) The first SIM component **812** is configured to store Subscriber Identity Information, e.g., a first set of credentials, for obtaining access to a first service provider/operator's wireless network.

(149) The second SIM component **814** is configured to store Subscriber Identity Information, e.g., a second set of credentials, for obtaining access to a second service provider/operator's wireless network.
(150) The connection manager component **816** is configured to manage the communications between the user equipment device and a first network and a second network including coordinating the off-load and/or handoff of calls from one network to the other network and the generation and sharing of synchronization information between wireless base stations of different networks.
(151) The synchronization component **818** is configured to handle all operations relating to obtaining, generating, and distributing synchronization information (e.g., timing synchronization such as phase, frequency and time of day synchronization information). This includes requesting and obtaining synchronization information from a first wireless base, synchronizing a reference clock, generating synchronization information to be sent to a second wireless base station, and the transmission of the synchronization information to the second wireless base station.
(152) The storage component **820** is configured to perform all operations in storing and retrieving information, e.g., synchronization information, from memory and/or storage devices (e.g., SIMs) located in the user equipment device.
(153) The proximity service component **822** is configured to perform all operation relating to providing proximity services including receiving, processing, and responding to proximity service requests, generating proximity service requests, exchanging proximity service messages with a Proximity Service function element, performing operations to establish proximity service D2D connections with other devices, e.g., wireless base stations, and execute operations to perform proximity service applications such as obtaining and providing synchronization information over a proximity service D2D wireless communications link.
(154) The D2D mode of operation component **824** is configured to operate the user equipment device in device to device mode of operation where it communicates directly with another subscriber device, e.g., a wireless base station requesting a sidelink D2D communications connection for obtaining timing synchronization information or another user equipment device.
(155) The dual SIM dual subscriber mode of operation component **826** is configured to implement all operations for operating as a dual subscriber in which the user equipment device utilizes both SIM cards to communicate with two different wireless base stations using two different subscriptions, e.g., simultaneously or switching back forth between the two different wireless base stations. This component includes the management of the signaling between the two wireless base stations. In some embodiments, the dual SIM dual subscriber mode of operation component is a sub-component of the communications component **804**.
(156) FIG. **9** is a drawing of an exemplary assembly of components **900** which may be included in a network equipment device **600** of FIG. **6**, in accordance with an exemplary embodiment. The components in the assembly of components **900** can, and in some embodiments are, implemented fully in hardware within a processor or one or more processors, e.g., processor(s) **606**, e.g., as individual circuits. The components in the assembly of components **900** can, and in some embodiments are, implemented fully in hardware within the assembly of hardware components **608**, e.g., as individual circuits corresponding to the different components. In other embodiments some of the components are implemented, e.g., as circuits, within processor(s) **606** with other components being implemented, e.g., as circuits within assembly of components **608**, external to and coupled to the processor(s) **606**. As should be appreciated the level of integration of components on the processor and/or with some components being external to the processor may be one of design choice. Alternatively, rather than being implemented as circuits, all or some of the components may be implemented in software and stored in the memory **612** of the network equipment device **600**, with the components controlling operation of the network equipment device **600** to implement the functions corresponding to the components when the components are

executed by a processor e.g., processor **606**. In some such embodiments, the assembly of components **900** is included in the memory **612** as assembly of software components **614**. In still other embodiments, various components in assembly of components **900** are implemented as a combination of hardware and software, e.g., with another circuit external to the processor providing input to the processor which then under software control operates to perform a portion of a component's function.

(157) When implemented in software the components include code, which when executed by a processor or one or more processors, e.g., processor(s) **606**, configure the processor(s) to implement the function corresponding to the component. In embodiments where the assembly of components **900** is stored in the memory **612**, the memory **612** is a computer program product comprising a computer readable medium comprising code, e.g., individual code for each component, for causing at least one computer, e.g., processor **606**, to implement the functions to which the components correspond.

(158) Completely hardware based or completely software based components may be used. However, it should be appreciated that any combination of software and hardware, e.g., circuit implemented components may be used to implement the functions. As should be appreciated, the components illustrated in FIG. **9** control and/or configure the network equipment device **600** or elements therein such as the processor(s) **606**, to perform the functions of corresponding steps illustrated and/or described in the method of one or more of the flowcharts, signaling diagrams and/or described with respect to any of the Figures. Thus the assembly of components **900** includes various components that perform functions of corresponding one or more described and/or illustrated steps of an exemplary method.

(159) Assembly of components **900** includes a control routines component **902**, a communications component **904**, a message generator component **906**, a message processing component **908**, a base station discovery component **910**, determinator component **912**, a storage component **914**, a proximity service function component **916**, a resource allocation component **918**, a wireless base station provisioning and activation component **920**, and a mobility management component **922**.

(160) The control routines component **902** is configured to control operation of the network equipment device.

(161) The communication component **904** is configured to handle communications, e.g., transmission and reception of messages, and protocol signaling for the network equipment device.

(162) The message generator component **906** is configured to generate messages for transmission to other devices. Exemplary messages which are generate include proximity service function messages, messages to base station discovery elements for determining whether a message originated from a base station, messages instructing and/or informing devices that a base station needs to be provisioned and/or activated, messages with resource information for implementing D2D wireless communications, messages to provision and active a wireless base station, messages to inform or instruct a wireless base station to enter a mode of operation or perform operations, messages with instructions for a wireless base station to enter a first mode of operation, messages with instructions for a wireless base station to enter a discovery mode of operation, messages with instructions for wireless base station to enter a D2D mode of operation, messages with instructions for a wireless base station to commence transmitting D2D discovery messages, messages for a wireless base station to enter a synchronization mode of operation wherein timing synchronization information is obtained from a user equipment device via a D2D sidelink communications channel, messages with instructions for a wireless base station to perform operations such as going on-line or becoming an active wireless base station that provides services to subscriber user equipment devices.

(163) The message processing component **908** is configured to process messages and implement procedures/operations in response to messages or based on the contents of messages. This includes messages received from other devices, e.g., messages from wireless base stations, e.g., resource

request messages for D2D communications, Proximity Service request message, base station discovery request messages, provisioning and/or activation messages, notification messages, messages with instructions.

(164) The base station discovery component **910** is configured to determine whether a message request from a subscriber device, e.g., a message request seeking proximity service services/operations, resources for D2D communications, provisioning and/or activation services is from a wireless base station and/or whether the request is for purposes of obtaining synchronization purposes. The base station discovery component is further configured to discover whether the base station which sent a request is off-line or on-line and/or whether or not provisioning and/or activation of the base station will be required for a discovered base station. The base station discovery component **910** is also configured to notify other network devices that a base station needs to be provisioned and/or activated and/or to initiate or commence provisioning and activation procedures for a discovered base station. The base station discovery component **910** also in some embodiments makes a determination as to whether a base station has received synchronization message, e.g., based on a synchronization receipt confirmation message received from a wireless base station.

(165) The determinator component **912** is configured to make determinations and decisions for the network equipment device including for example: determining if a received message is from a wireless base station, e.g., based on the content of the message, e.g., a CGI included in the message; determining whether to provide resources for a D2D communications channel, determining what resources, e.g., spectrum to be provided, for a D2D communications channel; determining whether a device is registered for a proximity service, e.g., D2D wireless communications proximity service; determining whether a wireless base station is on-line or off-line; determining whether or not a wireless base station needs networking provisioning and activation; determining whether to commence or initiate provisioning and activation procedures for a wireless base station for example in response to a D2D request to be used for synchronization purposes or in response to confirmation that a wireless base station has received synchronization information; determining whether a wireless base station needs to be re-synced to ensure that it does not go out of synchronization; determining whether to send a command or instruction to a wireless base station to place it in a mode of operation in which it will occur synchronization from a DSDS user equipment device; determining responses to messages from wireless base stations or user equipment devices in response to receiving proximity service messages, e.g., determining a proximity service application code in response to a proximity service discovery request message including an application ID or CGI.

(166) The storage component **914** is configured to manage the storage, and retrieval of data and/or instructions to/and from memory, and/or storage devices coupled and/or connected to the network equipment device, e.g., storage of a list of proximity service application identifiers and proximity service application codes, on-line and off-line status of wireless base stations, allocation of resource spectrum, location of wireless base stations, propagation models and delays times.

(167) The proximity service function component **914** is configured to perform proximity service operations such as responding to proximity service requests for application codes, requests for resources, determinations of whether a device is registered for Proximity Services and which Proximity Service applications, e.g., direct to direct communications between devices.

(168) The resource allocation component **918** is configured to assign or allocate resources to wireless base stations and user equipment devices, e.g., during provisioning and activation procedures, in response to requests for resources for D2D communications, in response to proximity service requests.

(169) The wireless base station provisioning and activation component **920** is configured to operate to provision a wireless base for the on-line operation such as for example allocating resources, e.g., spectrum for the wireless base station to utilize when activated. The wireless base station

provisioning and activation component **920** is also configured to activate a wireless base station, e.g., instruct it to change its status from off-line to on-line was the wireless base station has been provisioned and sent operating instructions such as for example resources allocated to the wireless base station and transmission power levels to be used.

(170) The mobility management component **922** is configured to perform mobility management operations for a core network, including tracking and managing user equipment devices and wireless base stations.

(171) The specific components of the assembly of components **900** included in any particular network equipment device may, and typically does vary depending on the specific network equipment device and the functionality required for the device and/or the operations the network equipment device is responsible for performing.

(172) FIG. **10** shows a simplified architecture for a system **1300** for providing Proximity Service Function within an exemplary 4G core network to support D2D communications in accordance with an embodiment of the present invention. System **1300** includes a wireless base station **1304**, a user equipment device **1306**, an Evolved Packet Core (EPC) **1308**, a Proximity Service (ProSe) Function element **1309**, and a base station discovery module/element **1310** which is coupled together via communications interfaces and communications links. The wireless base station **1304** is operating in a first mode of operation in which it is operating as a subscriber, e.g., by emulating a terminal or user equipment device, executing a Proximity Service application. The user equipment device **1306** is also executing a Proximity Service application. Wireless communications interface PC5 **1314** couples and/or connects the wireless base station **1304** to the user equipment device **1306**. E-UTRAN (Evolved-UMTS Terrestrial Radio Access Network) **1312** represents the air interface in this LTE cellular network. The S1 interface **1320** connects the E-UTRAN **1312** and the EPC **1308** for both the user and the control planes. Communications link **1324** connects the EPC to the base station discovery module/element **1310**. In some embodiments, the base station discovery module/element **1310** is included in the EPC **1308**. PC3 **1326** represents the communications interface between the user equipment device **1306** and proximity service function element **1309**. Uu interface **1316**, Uu interface **1318**, S1 interface **1320** illustrate the communication protocols used in connecting the wireless base station **1304**, user equipment device **1306** and EPC **1308**. Communications interface PC **3 1322** is the interface that connects the Proximity Service Function Element **1309** to the EPC core **1308**. The Proximity Service Function element provides direct provisioning, direct discovery name management, and EPC level discovery. The direct provisioning functionality includes provisioning the devices (wireless base station **1304** and user equipment device **1306**) with the required parameters for direct discovery and direct device to device communications. The direct discovery name management functionality includes allocating and processing ProSe Application ID's and ProSe Application Codes that are used for direct discovery. This is typically achieved by maintaining a table or other record which includes a listing of the mapping between the Application Identity (App ID) and Proximity Service (ProSe) Application Code that are used for direct discovery. The direct discovery name management functionality also includes the operation of contacting the Home Subscriber Server to check if the device is authorized to perform direct discovery operations and if so, authorizes the device by synchronizing a ProSe Policy. The ProSe Function element also provides the device with integrity parameters to protect discovery messages that are transmitted wirelessly. The wireless base station discovery module/element **1310** keeps a mapping of which devices registered and authorized for ProSe services, e.g., D2D communications services, are wireless base stations. Upon receiving a query or notification, e.g., from the ProSe function element, regarding a discovery request the wireless base station discovery module/element will determine whether the device is a wireless base station or not for example based on CGI information provided by the device. In response to determining the discovery request is for a wireless base station, the wireless base station discovery module/element will send instructions to other network equipment devices that the wireless base station is in

discovery mode of operation and will also send a response to the entity that sent the query that the discovery request corresponds to a wireless base station

(173) In some embodiments, the wireless base station **1304** is second wireless base station **304** system **300** and the user equipment device **1306** is the user equipment device **306** of system **300**. When the user equipment device **1306** discovers/receives an announcement beacon message, e.g., a D2D discovery request message from the wireless base station **1306** which is operating in discovery mode, the user equipment device **1306** will communicate with the wireless base station **1306** (e.g., by sending a discovery response message to the wireless base station **1304**. The wireless base station **1304** will then assign resources or obtain resources to communicate with the wireless base station **1306**. The resources are used to form a sidelink communications channel for D2D communications between the wireless base station **1304** and the user equipment device **1306**. The resources, e.g., spectrum and/or resource blocks, are used for transmitting D2D communications signals between the wireless base station **1304** and user equipment device **1306**.

(174) FIG. **11** illustrates a diagram **1000** with details of an exemplary exchange of messages and information involved in establishing a ProSe D2D communications channel between a wireless base station announcing device **1004** and a monitoring user equipment device **1006**. Referring to diagram **1300** of FIG. **10** is in some instances helpful in understanding the interfaces between the devices/elements in diagram **1000**. The announcing device **1004** is the wireless base station **1304** of system **1300**, the user equipment monitoring device **1006** is the user equipment device **1306** of system **1300**, the ProSe Function element **1009** is the ProSe Function element **1309** of system **1300**.

(175) Returning to FIG. **11**, the announcing device **1004** sends discovery request message **1010** to ProSe function element **1009** with a ProSe Application ID and meta data, e.g., identification information such as the CGI. The ProSe Application ID is a unique identifier the application that has trigger the transmission of the discovery request which in this example is an application to establish a D2D sidelink channel for acquiring timing synchronization information. The ProSe function element **1009** upon receiving the discovery request message **1010** contacts the Home Subscriber Server to verify that the application represented by the ProSe Application ID is authorized for direct discovery and D2D communications. The ProSe function element also contacts the base station discovery element to determine if the announcing device is a wireless base station and provide notification to the core network that the network may need to prepare for the provisioning and activation of this base station. The CGI provided by the announcing device may, and in some embodiments is, used to make the determination of whether or not the announcing device is a wireless base station. Upon receiving an acknowledgement that the announcing device and ProSe application and are authorized for direct discovery and creation of a D2D communications channel, the ProSe function element **1009** responds to the announcing device with discovery response message **1012** which include a ProSe Application code. The announcing device **1004** then transmits discovery message **1014** which is received by monitoring device **1006**. The discovery message **1014** includes the ProSe Application Code included in the discovery response message **1012**.

(176) FIG. **12** illustrates the fields of an exemplary discovery message **1100** in accordance with embodiment of the present invention. In some embodiments, the discovery message **1014** shown in FIG. **11** includes the fields shown in discovery message **1100**. In some embodiments, the discovery request message **1544** of method **1500** is implemented using the fields of discovery message **1100** illustrated in FIG. **12**. Discovery message **1100** includes a message type field **1102** which is 8-bits in length, a ProSe Application code field **1104** which is 184 bits in length, a message integrity check field **1106** which 32 bits in length and a UTC-based counter LSB field which is 8 bits in length. The message type field indicates whether the it is open or restricted discovery or identifies a discovery model to be used. The ProSe Application code is the ProSe Application code received from the ProSe function element. The Message Integrity Check is a 32 bit check sum generated by

the announcing device based on the Coordinated Universal Time (UTC) information derived from message(s) or information provided by the network.
(177) The wireless base station announcing device **1004** transmits the discovery message **1014** over the PC5 interface (shown in FIG. **10**) to the user equipment monitoring device **1006**.
(178) The user equipment monitoring device sends discovery request (interest registration) message **1016** to the ProSe Function element **1009**. The discovery request message **1016** includes a ProSe Application ID which identifies the application executing on the user equipment monitoring device **1006**. The ProSe Function element sends the discovery response message **1018** to the user equipment monitoring device **1006**. The discovery response message **1018** includes reception filter assignment with a ProSe Application Code. When the user equipment monitoring device **1006** receives a discovery message with a ProSe Application Code that matches the ProSe Application Code in the received reception filter assignment included in discovery response message **1018** but which does has no corresponding ProSe Application ID, the user equipment monitoring device **1006** sends match report **1020** to the ProSe Function element with an indication that it wishes to receive meta data about the related ProSe Application ID. The ProSe function element **1009** uses the provided information for validation and verification and in the case this operation is successful sends acknowledgement message **1022** with meta data to the user equipment monitoring device **1006**. The user equipment monitoring device **1006** in this example then accepts the request to establish a D2D communications channel with the wireless base station **1004**. Communications resources, e.g., resources for establishing a sidelink communications channel are obtained from the core network and/or assigned by the wireless base station announcing device **1004** and the D2D communications channel is established between the wireless base station announcing device **1004** and user equipment monitoring device **1006**.
(179) Once a D2D sidelink channel between a wireless base station needing timing synchronization information (e.g., wireless base station **304** of system **300**) and a DSDS user equipment device (e.g., DSDS user equipment device **306** of system **300**) that is already synced with an MSO network, then the connection manager of the DSDS user equipment device can instruct the user equipment device to share the System Information Block Type **18** (packet containing sync information) with the wireless base station over the established D2D sidelink communications channel.
(180) However, before the user equipment devices shares the sync information, the elements/devices in the core network must determine that a given device is actually a wireless base station that needs sync. Additionally, the core network will also need to determine if preparation of core network resources are required to activate the wireless base station and bring it on-line so that the wireless base station can commence operating as an active wireless base station that has been allocated resources, e.g., spectrum for servicing subscriber clients.
(181) This is accomplished by the base station discovery module/element **1310** of system **1300** in FIG. **10** which in at least some embodiments including the system **300** embodiment is a module or element of a network equipment device. As soon as the base station discovery module/element **1310** receives information of a D2D device, the base station discovery module/element requests the identity of the device and with the assistance of ProSe function element **1309**, the base station discovery module/element will distinguish devices that are wireless base stations seeking to be activated from other devices. Upon determining that a device is seeking to be activated, the base station discovery element **1310** will inform the provisioning part of the network (e.g., by sending notification messages to various provisioning network equipment devices) of the wireless base station which is to be activated. The provisioning part of the network (e.g., network equipment devices responsible for performing provisioning operations) will perform operations which activate the wireless base station.
(182) FIG. **14** illustrates a flowchart showing the exemplary steps of wireless base station synchronization/activation method **1400** in accordance with an embodiment of the present

invention with emphasis on the sequence of steps to be taken for activation of a wireless base station at the core network. The method **1400** will be explained in connection of system **300** but the method is not limited to the system **300** and can be implemented in connection with other systems and system configurations.

(183) The method **1400** starts in start step **1402**. Operation proceeds from step **1402** to step **1404**.

(184) In step **1404**, a first network operator base station (e.g., first network operator base station **308** of system **300**) is synced, e.g., first MSO Network Operator EnodeB is synced, e.g., from timing information received from an atomic clock (e.g., atomic clock **314** of system **300**) via an NTP server (e.g., NTP server **318**). Operation proceeds from step **1404** step **1408**.

(185) In step **1408**, a Dual SIM Dual Subscriber (DSDS) user equipment device (e.g., DSDS user equipment device **306** of system **300**) is synced from synchronization information received from the first network operator base station, said synchronization information being received by the DSDS user equipment device using first wireless resources, e.g., first spectrum belonging to and/or controlled by the first network operator and allocated for use by the first network operator base station. Operation proceeds from step **1406** to step **1408**.

(186) In step **1408**, the DSDS user equipment device provides synchronization information to a second network operator wireless base station (second wireless base station **304** of system **300**), e.g., a CBSD operated by a second network operator, said second network operator being different than said first network operator which operates the first network operator base station. In some embodiments step **1408** includes or more sub-steps **1410**, **1412**, and **1414**.

(187) In sub-step **1410**, the DSDS user equipment device transmits the synchronization information to the second network operator wireless base station, e.g., a CBSD operated by the second network operator, the synchronization information being transmitted using second wireless resources, e.g., second spectrum belonging to and/or controlled by the second network operator. In some embodiments, the second spectrum is spectrum generally available to the second network operator as opposed to be belonging to and/or being controlled by the second network operator.

(188) In sub-step **1412**, the DSDS user equipment device generates the synchronization information provided to the second network operator wireless base station based on the synchronization information received from the first network operator base station.

(189) In sub-step **1414**, the DSDS user equipment device includes the synchronization information provided to the second network operator wireless base station in a system information block (e.g., SIB **18** packet(s) which includes the resource information for synchronization signal and Sidelink Broadcast Control Channel (SBCCH) transmission) transmitted to the second network operator wireless base station. Operation proceeds from step **1408** to step **1416**.

(190) In step **1416**, the second network operator wireless base station upon receiving the synchronization information from the DSDS user equipment device uses the synchronization information to synchronize its frequency, phase and/or time of day. Operation proceeds from step **1416** to step **1418**.

(191) In step **1418**, the second network operator wireless base station generates and transmits a notification message to a second network core element, e.g., a network equipment device, informing the second network core element of the receipt of the synchronization information. Operation proceeds from step **1418** to step **1420**.

(192) In step **1420**, the second network core element initiates a base station activation process for the second network operator base station in response to receiving the notification message from the second network operator base station. Operation proceeds from step **1420** to step **1422** which is the end of the method **1400**.

(193) It should also be understood that since the synchronization information is traveling from the DSDS user equipment device to the second network operator wireless base station there will be a propagation delay introduced that may, and typically does, need to be compensated for. This is propagation delay is compensated for by the second network operator wireless base station utilizing

a propagation delay offset factor to sync the second wireless base station's reference clock based on the synchronization time received from the DSDS user equipment device. In some embodiments, the DSDS user equipment device includes a pathloss delay offset value in the synchronization information provided to the second network wireless base station which is used to compensate for the delay introduced into the synchronization time information as it travels from the DSDS user equipment device to the second network operator wireless base station. FIG. **16** illustrates the format of an exemplary synchronization information message packet **1670** which may be, and in some embodiments, is utilized to transmit synchronization information from a DSDS user equipment device to a second network operator wireless base station as described in connection with the method **1400**. Details of the exemplary synchronization information message packet **1670** have been described above.

(194) In various embodiments, wireless base stations, e.g., CBSDs, that are unsynchronized when powered on and do not operate as wireless base station but instead are placed in a first mode of operation in which they operate as subscriber device (e.g., by emulating a user equipment device). Only upon successfully obtaining time synchronization information from a user equipment device via a D2D communications exchange and synchronization its own reference clock using the obtained time synchronization information does the wireless base station commence operating as an active wireless base station. This occurs for example when the wireless base station has been provisioned and activated by network equipment in its core network.

(195) Once the wireless base station has been activated, it will remain activated for a pre-defined time interval, e.g., 20 minutes. However, when the wireless base station is about to go out of sync it will request sync information from the DSDS user equipment device on the sidelink channel to re-establish/renew sync information which might become outdated with time, e.g., because of drift due to the inaccuracy of the wireless base station's reference clock. If the DSDS user equipment device that provided the original synchronization is not available, e.g., because it is no longer in the wireless base station cell coverage range, the wireless base station will repeat the process of transmitting a D2D discovery request for creating another D2D sidelink channel with another DSDS user equipment device, establishing another D2D sidelink channel with a DSDS user equipment device that responds to the D2D discovery request and obtaining synchronization information from this DSDS user equipment device. In various embodiments, the wireless base station obtains periodic sync with time over D2D sidelink channel(s) with help from the connection manager(s) of the DSDS user equipment device(s).

(196) FIG. **17**, comprising the combination of FIG. **17**A and FIG. **17**B, is a flowchart **1700** of an exemplary method of operating a first wireless base station in a first network, in accordance with an exemplary embodiment. Operation of the exemplary method starts in step **1702** and proceeds to step **1704**.

(197) In step **1704** the first wireless base station receives a first message. In some embodiments, the first network is a hybrid mobile network and the first message is a first control message from a first network equipment device, which is part of the hybrid mobile network, said first message being received by the first wireless base station over a landline. In some embodiments, the first message is a first control message, which includes an instruction for the first wireless base station to enter a first mode of operation. Operation proceeds from step **1704** to step **1706**.

(198) In step **1706** the first base station enters into the first mode of operation in response to receiving the first message. In some embodiments, the first message is a first control message and the first control message includes an instruction for the first wireless base station to enter a discovery mode of operation, said first mode of operation being a discovery mode of operation. In some embodiments, the first message is a first control message, and the first control message includes an instruction for the first wireless base station to enter a device to device mode of operation, said first mode of operation being a device to device mode of operation. Operate proceeds from step **1706** to step **1708**.

(199) In step **1708** the first wireless base station commences, while operating in the first mode of operation, wirelessly transmitting device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message. In some embodiments the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection. Operation proceeds from step **1708** to step **1710**.
(200) In step **1710** the first wireless base station receives, from a first user equipment device, a discovery request response message in response to the first device to device discovery request message. In some embodiments, the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection; and the discovery request response message is a Proximity Service discovery response request message.
(201) In some embodiments, the hybrid mobile network includes a Citizens Broadband Radio Service Time Division—Long Term Evolution (CBRS TD-LTE) network with wireless communications devices utilizing CBRS TD-LTE New Radio radios; and said first wireless communications devices include the first wireless base station and the first user equipment device. In some such embodiments, the first wireless base station is an indoor Hybrid Mobile Network Operator (HMNO) small cell Citizens Broadband Radio Service Device (CBSD).
(202) In some embodiments, the first user equipment device is a Dual Subscriber user equipment device having credentials for two different mobile subscription services (e.g., authentication credentials for a first service provider's mobile network and authentication for a second service provider's mobile network). In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Subscriber user equipment device. In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby user equipment device. In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Active user equipment device.
(203) In various embodiments, the first wireless base station is coupled to a HMNO core network via a cable modem; and the first wireless base station receives the first message from a network equipment device in the HMNO core network via the cable modem.
(204) Operation proceeds from step **1710** to step **1712**. In step **1712** the first wireless base station establishes a sidelink device to device communications channel with the first user equipment device. Step **1712** includes step **1714**, and in some embodiments step **1716**.
(205) In step **1714** the first wireless base station obtains sidelink resource information from a core network for establishing the sidelink device to device communications channel between the first wireless base station and the first user equipment device, said resource information including information specifying spectrum granted or allocated for the sidelink device to device communications channel to be established. In some embodiments, the core network is part of the first network. In some other embodiments, the core network is not part of the first network but is a part of a second network, said first user equipment device obtaining the sidelink resource information via a second wireless base station and sharing the sidelink resource information with the first wireless base station.
(206) In some embodiments, e.g., an embodiment in which the core network, which supplied the sidelink resource information is part of the first network, operation proceeds from step **1714** to step **1716**, in which the first wireless base station transmits the sidelink resource information to the first user equipment device. In some embodiments, core network is part of the first network; and said sidelink resource information specifies spectrum authorized for use by subscribers of the first network or available for use by subscribers of the first network.
(207) Operation proceeds from step **1712**, via connecting node A **1718** to step **1720**.

(208) In step **1720** the first wireless base station obtains, while operating in the first mode of operation, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information. Step **1720** includes steps **1722** and **1724**. In step **1722** the first wireless base station transmits a first sync request message to the first user equipment device over the established device to device sidelink communications channel. Operation proceeds from step **1722** to step **1724**. In step **1724** the first wireless base station receives, over the device to device sidelink communications channel, from the first user equipment device said synchronization information. In some embodiments, the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, and said second wireless base station is not part of the first network. In some embodiments, the synchronization information includes a time value, e.g., a time stamp value, and delay information, e.g., a path transmission delay value.
(209) In some embodiments, step **1724** includes step **1725**. In step **1725** the first wireless base station receives the synchronization from the first user equipment device, said synchronization include a packet (e.g., a block type **18** (SIB **18**) packet) with the sync information, said synchronization information being communicated over the sidelink device to device communications channel established between the first wireless base station and the first user equipment device, said synchronization information being based on information provided to the first user equipment device being from a second wireless base station.
(210) In some embodiments, said synchronization information further includes frequency and phase information. In some such embodiments, said synchronization information is frequency, phase and time of day information required for operating as a wireless base station. In some embodiments, said synchronization information is a clock sync or time sync signal (e.g., clock signal such as IEEE 1588 for frequency, phase and time of day). In some embodiments, said synchronization information is a clock sync or time sync signal derived from information included a Network Time Protocol (NTP) message received from a NTP server via a second wireless base station, said first user equipment device receiving said synchronization information from said second wireless base station, said second wireless base station being operated by a different service provider than said first wireless base station, and said first wireless base station and said second wireless base station are operating using different spectrum bands.
(211) In some embodiments, the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby or a Dual Subscriber Identity Module (SIM) Dual Active user equipment device, which includes a first SIM corresponding to the service provider of the first network and a second SIM corresponding to said different service provider. In some such embodiments, first SIM includes a first authentication key corresponding to a first subscription with the first service provider; and the second SIM includes a second authentication key corresponding to a second subscription with second service provider.
(212) Operation proceeds from step **1720** to step **1726**. In step **1726**, the first wireless base station determines whether or not a timer, e.g. a reference clock, of the first wireless base station has been previously synchronized since power on. If the determination is that the timer, e.g. reference clock, of the first wireless base station has not been previously synchronized since power on, then operation proceeds from step **1726** to step **1728**. However, if the determination is that the timer, e.g., reference clock, of the first wireless base station has been previously synchronized since power on, then operation proceeds from step **1726** to step **1730**.
(213) Retuning to step **1728**, in step **1728** the first wireless base station utilizes the synchronization information obtained from the first user equipment device to a set the timer, e.g. the reference clock, in the first wireless base station. Step **1728** includes step **1732**, in which the first wireless base station uses the delay information included the received synchronization information to adjust a time value.

(214) Returning to step **1730**, in step **1730** the first wireless base station utilizes the synchronization information obtained from the first user equipment device to re-synch a timer, e.g. a reference clock, in the first wireless base station. Step **1730** includes step **1734**, in which the first wireless base station uses the delay information included the received synchronization information to adjust a time value.
(215) Operation proceeds from step **1728** or step **1730** to step **1736**. In step **1736** the first wireless base station transmits a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information. Operation proceeds from step **1736** to step **1738**.
(216) In step **1738** the first wireless base station receives from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode operation, said second mode of operation including changing state from off-line to on-on. In some embodiments, when the first wireless base station is in an off-line state of operation, the first wireless base station does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation, the first wireless base station performs wireless base station operations and provides wireless base station services to user equipment devices. Operation proceeds from step **1738**, via connecting node B **1740** to step **1704**.
(217) In some embodiments, said first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network. In some such embodiments, said second wireless base station is part of a second wireless network, said first network and said second network being operated by different service providers, said first network being operated by a first service provider and said second network being operated by a second service provider; and said first wireless base station and said second wireless base station utilize different spectrum bands for communicating with subscriber devices; and the first user equipment device includes a first SIM card with subscriber credentials for the first network and a second SIM card with subscriber credentials for the second network. In some embodiments, said first user equipment device is a subscriber of the first service provider and a subscriber of the second service provider. In some embodiments, the first wireless base station operates in a first spectrum band; the second wireless base station operates in a second spectrum band; and said first and second spectrum bands are different. In some such embodiments, the first spectrum band is general authorized access (GAA) spectrum and the second spectrum band is priority access license (PAL) spectrum.
(218) In some embodiments, the first wireless base station operates as a subscriber device in connection with the device to device communications with the first user equipment device. In some such embodiments, the first wireless base station is a subscriber with regard to a service which provides synchronization information via device to device sidelink communications with timing synchronized user equipment devices. In some embodiments, the first wireless base station emulates a user equipment device when obtaining synchronization from the first user equipment device over the air device to device communications.
(219) In one exemplary embodiment, the first wireless base station implementing the method of flowchart **1700** of FIG. **17** is wireless base station **304** of FIG. **3**; the second wireless based station described with respect to FIG. **17** is wireless base station **308** of FIG. **3**; the first user equipment device described with respect to FIG. **17** is DSDS UE **306** of FIG. **3**; and the core network described with respect to FIG. **17** is core network **330** of FIG. **3**.
(220) In another exemplary embodiment, the first wireless base station implementing the method of flowchart **1700** of FIG. **17** is wireless base station **1508** of FIG. **15**; the second wireless based station described with respect to FIG. **17** is wireless base station **1504** of FIG. **15**; the first user equipment device described with respect to FIG. **17** is DSDS UE **1506** of FIG. **15**; and the core

network described with respect to FIG. **17** is core network **1510** of FIG. **15**.
(221) FIG. **18**, comprising the combination of FIG. **18**A, FIG. **18**B and FIG. **18**C, is a flowchart of an exemplary method **1800** in accordance an embodiment of the present invention. Operation of the exemplary method starts in step **1802** and proceeds to step **1804**.
(222) In step **1804**, a second network operator base station, e.g., a CSBD, operating in a Proximity Service discovery mode of operation broadcasts and/or transmits over the air a Proximity Service (ProSe) beacon discovery request message, said beacon discovery request message requesting device to device (D2D) communications. Operation proceeds from step **1804** to step **1806**.
(223) In step **1806**, a Dual SIM Dual Subscriber (DSDS) user equipment device (e.g., DSDS user equipment device **306** of system **300**) discovers the second network operator base station by receiving and processing the proximity service beacon discovery request message. Operation proceeds from step **1806** to step **1808**.
(224) In step **1808**, the DSDS user equipment device generates and transmits a proximity service discovery response message to the second network operator base station. Operation proceeds from step **1808** to step **1810**.
(225) In step **1810**, the second network operator base station receives and processes the proximity service discovery response message from the DSDS user equipment device. Operation proceeds from step **1810** to step **1812**.
(226) In step **1812**, in response to the received proximity service discovery response message from the DSDS user equipment device, the second network operator base station transmits, e.g., over a wired or optical landline or cable, a device to device sidelink request to a first network equipment device (e.g., network equipment **332** of system **300**) located in a core network (e.g., core network **330** of system **300**). The first network equipment device being operated by a second network operator which also operates the second network operator base station. The first network equipment device including a base station discovery module or element that discovers whether a D2D sidelink request corresponds to a base station in discovery mode of operation, said device to device sidelink request including information identifying the second operator base station, e.g., a Cell Global ID. Operation proceeds from step **1812** to step **1814**.
(227) In step **1814**, the base station discovery module of the first network equipment device, determines from the device to device sidelink request, e.g., from the information identifying the second network operator base station in the request, that the device to device sidelink requet is for a base station. Operation proceeds from step **1814** via connection node A **1816** to step **1820** shown on FIG. **18**B.
(228) In step **1820**, the base station discovery module of the first network equipment device determines whether the second network operator wireless base station requires network provisioning and activation once it obtains synchronization information (e.g., is the second network operator base station currently on-line and is trying to obtain re-sync information or is it off-line and trying to gain initial sync info so it can become an activated on-line wireless base station). When the determination is that the second wireless base station will require provisioning and activation the base station discovery module commences or causes to be commenced preparation for provisioning and activation of the second network operator wireless base station (e.g., preparing resources (e.g., spectrum for the second network operator base station to be allocated for use as a wireless base station to provide wireless services to subscriber devices). When the determination is that the second network operator wireless base station does not require provisioning and activation (e.g., it is already on-line and the synchronization information is for re-sync purposes to remain in synchronization), the base station discovery module does not commence or cause to be commenced preparation for provisioning and activation of the second network operator base station as it is already provisioned and activated. Operation proceeds from step **1820** to step **1822**.
(229) In step **1822**, a sidelink device to device (D2D) wireless connection is established between the DSDS user equipment device and the second network operator base station, the sidelink D2D

wireless connection utilizing spectrum belonging to the either a first network operator or the second network operator allocated for the sidelink D2D communications between the DSDS user equipment device and the second network operator base station. Operation proceeds from step **1822** to step **1824**.

(230) In step **1824**, the DSDS user equipment device obtains synchronization information, e.g., frequency, phase and/or time of day information, from a first network operator base station, e.g., first network operator base station **308** of system **300**). The first network operator base station being operated by a first network operator. The first network operator being different than the second network operator. The synchronization information being received by the DSDS user equipment device using first wireless resources, e.g., first spectrum belonging to and/or controlled by the first network operator. The first spectrum being different than said spectrum allocated for the sidelink D2D communications between the DSDS user equipment device and the second network operator base station. Operation proceeds from step **1824** to step **1826**.

(231) In step **1826**, the DSDS user equipment device prepares and/or generates a message, e.g., a system information block message or packet (e.g., SIB **18** packet), including synchronization information for the second network operator base station, said synchronization information including frequency, phase, and/or time of day synchronization information based on the synchronization received from the first network operator wireless base station information. FIG. **16** illustrates an exemplary synchronization information packet format and exemplary information contained in such a packet. In some embodiments, step **1826**, includes a sub-step **1828**.

(232) In sub-step **1828**, a connection manager component/module of the DSDS user equipment device prepares and/or generates a message, e.g., a system information block message or packet (e.g., SIB **18**), including synchronization information for the second network operator base station, said synchronization information including frequency, phase, and/or time of day synchronization information based on the synchronization received from the first network operator wireless base station information. Operation proceeds from step **1828** via connection node B **1830** to step **1832** shown on FIG. **18**C.

(233) In step **1832**, the DSDS user equipment device transmits the prepared/generated message including synchronization information to the second network operator wireless base station over the sidelink D2D wireless connection. Operation proceeds from step **1832** to step **1834**.

(234) In step **1834**, the second network operator wireless base station upon receiving the synchronization information from the DSDS user equipment device uses the synchronization information to synchronize its frequency, phase, and/or time of day, e.g., by synchronizing its reference clock. Operation proceeds from step **1834** to step **1836**.

(235) In step **1836**, the second network operator wireless base station generates and transmits a notification message to a second network equipment device of the core network informing the second network equipment device of the receipt of the synchronization information from the DSDS user equipment device. In some embodiments, the second network equipment device is the same device as the first network equipment device. Operation proceeds from step **1836** to step **1838**.

(236) In step **1838**, the second network equipment device initiates or causes to be initiated a base station activation process for the second network operator base station in response to receiving the notification message from the second network operator base station that it has received the synchronization information. Operation proceeds from step **1838** to step **1840**.

(237) In step **1840**, the second network operator base station is provisioned (e.g., allocated spectrum for operations and provided operating instructions (maximum power transmission levels, etc.)) and activated by the core network (e.g., network equipment in the core network). Operation proceeds from step **1840** to step **1842**.

(238) In step **1842**, upon becoming activated the second network operator base station goes from an off-line state of operation to an on-line state of operations wherein it commences base station operations providing wireless services to subscriber devices. Operation proceeds from step **1842** to

step **1844**.
(239) In step **1844**, the second network operator wireless base station periodically repeats the process to re-synch/re-new its timing information to remain in synchronization.
(240) Various exemplary numbered embodiments illustrating different features of the present invention will now be discussed. The various features discussed may be used in variety of different combinations. The numbered embodiments are only exemplary and are not meant to be limiting to the scope of the invention. The various method embodiments may be, and in some embodiments are, implemented on system **300** of FIG. **3**.
List of Exemplary Numbered Method Embodiments
(241) Method Embodiment 1. A method of operating a first wireless base station in a first network comprising: receiving, at the first wireless base station, a first message; in response to receiving the first message entering, by the first wireless base station, into a first mode of operation; and while operating in said first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.
(242) Method Embodiment 1A. The method of Method Embodiment 1, wherein the first wireless base station operates as a subscriber device in connection with the device to device communications with the first user equipment device.
(243) Method Embodiment 1AA. The method of Method Embodiment 1A, wherein the first wireless base station is a subscriber with regard to a service which provides synchronization information via device to device sidelink communications with timing synchronized user equipment devices.
(244) Method Embodiment 1AAA. The method of Method Embodiment 1A, wherein the first wireless base station emulates a user equipment device when obtaining said synchronization information from the first user equipment device using over the air device to device communications.
(245) Method Embodiment 1B. The method of Method Embodiment 1, wherein said obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications includes: receiving, by the first wireless base station, the synchronization information from the first user equipment device, said synchronization information including a block type **18** (SIB **18**) packet with sync information, said synchronization information being communicated over a sidelink device to device communications channel established between the first wireless base station and the first user equipment device, said synchronization information being based on information provided to the first user equipment from a second wireless base station.
(246) Method Embodiment 2. The method of Method Embodiment 1, wherein the first network is a hybrid mobile network; and wherein the first message is a first control message from a first network equipment device which is part of the hybrid mobile network, said first message being received by the first wireless base station over a landline.
(247) Method Embodiment 2A. The method of Method Embodiment 2, wherein the hybrid mobile network includes a Citizens Broadband Radio Service Time Division—Long Term Evolution (CBRS TD-LTE) network with wireless communications devices utilizing CBRS TD-LTE New Radio radios; wherein said first wireless communications devices include the first wireless base station and the first user equipment device; and wherein the first wireless base station is an indoor Hybrid Mobile Network Operator (HMNO) small cell Citizens Broadband Radio Service Device (CBSD).
(248) Method Embodiment 2AA. The method of Method Embodiment 2A, wherein the first user equipment device is a Dual Subscriber user equipment device having credentials for two different mobile subscription services (e.g., authentication credentials for a first service provider's mobile network and authentication for a second service provider's mobile network).

(249) Method Embodiment 2AAA. The method of Method Embodiment 2A, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Subscriber user equipment device.
(250) Method Embodiment 2AAAA. The method of Method Embodiment 2A, 2AA, and 2AAA, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby user equipment device.
(251) Method Embodiment 2AAAAA. The method of Method Embodiments 2A, 2AA, and 2AAA, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Active user equipment device.
(252) Method Embodiment 2B. The method of Method Embodiment 2, wherein the first wireless base station is coupled to a HMNO core network via a cable modem; and wherein the first wireless base station receives the first message from a network equipment device in the HMNO core network via the cable modem.
(253) Method Embodiment 2C. The method of Method Embodiment 2 wherein said synchronization information further includes frequency and phase information.
(254) Method Embodiment 2D. The method of Method Embodiment 2C, wherein said synchronization information is frequency, phase and time of day information required for operating as a wireless base station.
(255) Method Embodiment 2E. The method of Method Embodiment 2, wherein said synchronization information is a clock sync or time sync signal (e.g., clock signal such as IEEE 1588 for frequency, phase and time of day).
(256) Method Embodiment 2F. The method of Method Embodiment 2, wherein said synchronization information is a clock sync or time sync signal derived from information included a Network Time Protocol (NTP) message received from a NTP server via a second wireless base station, said first user equipment device receiving said synchronization information from said second wireless base station, said second wireless base station being operated by a different service provider than said first wireless base station, and wherein said first wireless base station and said second wireless base station are operating using different spectrum bands.
(257) Method Embodiment 2G. The method of Method Embodiment 2, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby or a Dual Subscriber Identity Module (SIM) Dual Active user equipment device, which includes a first SIM corresponding to the service provider of the first network and a second SIM corresponding to said different service provider.
(258) Method Embodiment 2G1. The method of Method Embodiment 2G, wherein the first SIM includes a first authentication key corresponding to a first subscription with the first service provider; and wherein the second SIM includes a second authentication key corresponding to a second subscription with second service provider.
(259) Method Embodiment 3. The method of Method Embodiment 1, wherein said first message is a first control message; wherein the first control message includes an instruction for the first wireless base station to enter the first mode of operation; and while operating in said first mode of operation the first wireless base station commences wirelessly transmitting device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message.
(260) Method Embodiment 3A. The method of Method Embodiment 3, wherein the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection.
(261) Method Embodiment 3B. The method of Method Embodiment 1, wherein said first message is a first control message; and wherein the first control message includes an instruction for the first wireless base station to enter a discovery mode of operation, said first mode of operation being a

discovery mode of operation.
(262) Method Embodiment 3C. The method of Method Embodiment 1, wherein said first message is a first control message; and wherein the first control message includes an instruction for the first wireless base station to enter a device to device mode of operation, said first mode of operation being a device to device mode of operation.
(263) Method Embodiment 4. The method of Method Embodiment 1, wherein said first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and wherein said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
(264) Method Embodiment 4A. The method of Method Embodiment 4, wherein said second wireless base station is part of a second wireless network, said first network and said second network being operated by different service providers, said first network being operated by a first service provider and said second network being operated by a second service provider; wherein said first wireless base station and said second wireless base station utilize different spectrum bands for communicating with subscriber devices; and wherein said first user equipment device includes a first SIM card with subscriber credentials for the first network and a second SIM card with subscriber credentials for the second network.
(265) Method Embodiment 4B. The method of Method Embodiment 4A, wherein said first user equipment device is a subscriber of the first service provider and a subscriber of the second service provider.
(266) Method Embodiment 4C. The method of Method Embodiment 4A, wherein the first wireless base station operates in a first spectrum band; wherein the second wireless base station operates in a second spectrum band; and wherein said first and second spectrum bands are different.
(267) Method Embodiment 4D. The method of Method Embodiment 4C, wherein the first spectrum band is general authorized access (GAA) spectrum and the second spectrum band is priority access license (PAL) spectrum.
(268) Method Embodiment 5. The method of Method Embodiment 3, further comprising: receiving, from the first user equipment device, a discovery request response message in response to the first device to device discovery request message; and establishing a sidelink device to device communications channel with the first user equipment device.
(269) Method Embodiment 5A. The method of Method Embodiment 5, wherein said establishing a sidelink device to device communications channel with the first user equipment device includes obtaining sidelink resource information from a core network for establishing the sidelink device to device communications channel between the first wireless base station and the first user equipment device, said resource information including information specifying spectrum granted or allocated for the sidelink device to device communications channel to be established.
(270) Method Embodiment 5B. The method of Method Embodiment 5A, wherein said sidelink resource information is obtained by the first wireless base station; and wherein said establishing a sidelink device to device communications channel with the first user equipment device includes transmitting the sidelink resource information to the first user equipment device.
(271) Method Embodiment 5C. The method of Method Embodiment 5B, wherein said core network is part of the first network; and wherein said sidelink resource information specifies spectrum authorized for use by subscribers of the first network or available for use by subscribers of the first network.
(272) Method Embodiment 5D. The method of Method Embodiment 5A, wherein said core network is not part of the first network but is a part of a second network, said first user equipment device obtaining the sidelink resource information via a second wireless base station and sharing the sidelink resource information with the first wireless base station.
(273) Method Embodiment 5E. The method of Method Embodiment 5, wherein the device to

device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection; and wherein the discovery request response message is Proximity Service discovery response request message.
(274) Method Embodiment 6. The method of Method Embodiment 5, wherein said obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information includes: transmitting a first sync request message to the first user equipment device over the established device to device sidelink communications channel; and receiving over the device to device sidelink communications channel from the first user equipment device said synchronization information.
(275) Method Embodiment 7. The method of Method Embodiment 6, wherein the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
(276) Method Embodiment 8. The method of Method Embodiment 1, further comprising: utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.
(277) Method Embodiment 9. The method of Method Embodiment 1, wherein said synchronization information includes a time value and delay information; and wherein utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station includes using the delay information to adjust the time value.
(278) Method Embodiment 9A. The method of Method Embodiment 9, wherein said time value is a time stamp value; and wherein said delay value is a path transmission delay value.
(279) Method Embodiment 10. The method of Method Embodiment 9, further comprising: transmitting, by the first wireless base station, a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information; and receiving from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation it does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation it performs wireless base station operations and provides wireless base station services to user equipment devices.
(280) Method Embodiment 11. The method of Method Embodiment 1, further comprising: re-synching, by the first wireless base station, a timer at the first wireless base station using the synchronization information obtained from the first user equipment device.
(281) Method Embodiment 12. A method of operating a dual Subscriber Identity Module (SIM) user equipment device comprising: receiving, at the dual SIM user equipment device from a first wireless base station, a request message requesting synchronization information, said synchronization information including timing synchronization information; in response to receiving the request for synchronization information from the first wireless base station, generating by the dual SIM user equipment device a synchronization message including the requested synchronization information based on synchronization information obtained by the dual SIM user equipment device from a second wireless base station; and transmitting the synchronization message to the first wireless base station.
(282) Method Embodiment 13. The method of Method Embodiment 12, further comprising: prior to receiving the request message requesting synchronization information from the first wireless base station, receiving, by the dual SIM user equipment device a device to device (D2D) discovery request message from the first wireless base station; and in response to receiving the D2D discovery request message, establishing a device to device (D2D) sidelink communication channel

with first wireless base station; and wherein the synchronization message is transmitted to the first wireless base station over the established D2D sidelink communications channel.
(283) Method Embodiment 14. The method of Method Embodiment 13, further comprising: prior to generating the synchronization message, requesting synchronization information from a second wireless base station, said first wireless base station and said second wireless base station belonging to different wireless networks, said dual SIM user equipment device including a first SIM card and a second SIM card, said dual SIM user equipment device being able to communicate with the first wireless base station using information contained on the first SIM card, said dual SIM user equipment device being able to communicate with the second wireless base station using information contained on the second SIM card.
(284) Method Embodiment 15. The method of Method Embodiment 12, wherein the D2D discovery request message is a Proximity Service discovery request message; and wherein the D2D sidelink communications channel is established using Proximity Services.
(285) Method Embodiment 16. The method of Method Embodiment 12, wherein the first wireless base station utilizes a time division duplex wireless protocol to communicate with user equipment devices.
(286) Method Embodiment 17. The method of Method Embodiment 13, wherein said establishing a device to device (D2D) sidelink communication channel with first wireless base station includes receiving information from the first wireless base station indicating the resources (e.g., spectrum) to be used for the D2D sidelink communications channel.
(287) Method Embodiment 18. The method of Method Embodiment 12, wherein the first wireless base station is an indoor wireless base station (e.g., small cell CBSD); wherein the second wireless base station is an eNodeB.
(288) List of Exemplary Numbered Apparatus Embodiments:
(289) Apparatus Embodiment 1. A first wireless base station comprising: first receiver (network interface receiver); and a processor configured to operate the first wireless base station to: receive, via the first receiver, a first message; enter into a first mode of operation in response to the received first message; and obtain, while operating in the first mode of operation, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.
(290) Apparatus Embodiment 1A. The first wireless base station of Apparatus Embodiment 1, wherein the first wireless base station operates as a subscriber device in connection with the device to device communications with the first user equipment device.
(291) Apparatus Embodiment 1AA. The first wireless base station of Apparatus Embodiment 1A, wherein the first wireless base station is a subscriber with regard to a service which provides synchronization information via device to device sidelink communications with timing synchronized user equipment devices.
(292) Apparatus Embodiment 1AAA. The first wireless base station of Apparatus Embodiment 1A, wherein the first wireless base station emulates a user equipment device when obtaining said synchronization information from the first user equipment device using over the air device to device communications.
(293) Apparatus Embodiment 1B. The first wireless base station of Apparatus Embodiment 1, further comprising: a first wireless receiver; and wherein said processor is further configured to: operate the first base station to receive, via the first wireless receiver, the synchronization information from the first user equipment device, said synchronization information including a block type **18** (SIB **18**) packet with sync information, said synchronization information being communicated over a sidelink device to device communications channel established between the first wireless base station and the first user equipment device, said synchronization information being based on information provided to the first user equipment from a second wireless base station, as part of being configured to operate the first wireless base station to obtain

synchronization information from a first user equipment device using over the air device to device communications.
(294) Apparatus Embodiment 2. The first wireless base station of Apparatus Embodiment 1, wherein the first network is a hybrid mobile network; and wherein the first message is a first control message from a first network equipment device which is part of the hybrid mobile network, said first message being received by the first wireless base station over a landline.
(295) Apparatus Embodiment 2A. The first wireless base station of Apparatus Embodiment 2, wherein the hybrid mobile network includes a Citizens Broadband Radio Service Time Division—Long Term Evolution (CBRS TD-LTE) network with wireless communications devices utilizing CBRS TD-LTE New Radio radios; wherein said first wireless communications devices include the first wireless base station and the first user equipment device; and wherein the first wireless base station is an indoor Hybrid Mobile Network Operator (HMNO) small cell Citizens Broadband Radio Service Device (CBSD).
(296) Apparatus Embodiment 2AA. The first wireless base station of Apparatus Embodiment 2A, wherein the first user equipment device is a Dual Subscriber user equipment device having credentials for two different mobile subscription services (e.g., authentication credentials for a first service provider's mobile network and authentication for a second service provider's mobile network).
(297) Apparatus Embodiment 2AAA. The first wireless base station of Apparatus Embodiment 2A, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Subscriber user equipment device.
(298) Apparatus Embodiment 2AAAA. The first wireless base station of Apparatus Embodiments 2A, 2AA, and 2AAA, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby user equipment device.
(299) Apparatus Embodiment 2AAAAA. The first wireless base station of Apparatus Embodiments 2A, 2AA, and 2AAA, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Active user equipment device.
(300) Apparatus Embodiment 2B. The first wireless base station of Apparatus Embodiment 2, wherein the first wireless base station is coupled to a HMNO core network via a cable modem; and wherein the first wireless base station receives the first message from a network equipment device in the HMNO core network via the cable modem.
(301) Apparatus Embodiment 2C. The first wireless base station of Apparatus Embodiment 2 wherein said synchronization information further includes frequency and phase information.
(302) Apparatus Embodiment 2D. The first wireless base station of Apparatus Embodiment 2C, wherein said synchronization information is frequency, phase and time of day information required for operating as a wireless base station.
(303) Apparatus Embodiment 2E. The first wireless base station of Apparatus Embodiment 2, wherein said synchronization information is a clock sync or time sync signal (e.g., clock signal such as IEEE 1588 for frequency, phase and time of day).
(304) Apparatus Embodiment 2F. The first wireless base station of Apparatus Embodiment 2, wherein said synchronization information is a clock sync or time sync signal derived from information included a Network Time Protocol (NTP) message received from a NTP server via a second wireless base station, said first user equipment device receiving said synchronization information from said second wireless base station, said second wireless base station being operated by a different service provider than said first wireless base station, and wherein said first wireless base station and said second wireless base station are operating using different spectrum bands.
(305) Apparatus Embodiment 2G. The first wireless base station of Apparatus Embodiment 2, wherein the first user equipment device is a Dual Subscriber Identity Module (SIM) Dual Standby or a Dual Subscriber Identity Module (SIM) Dual Active user equipment device, which includes a

first SIM corresponding to the service provider of the first network and a second SIM corresponding to said different service provider.
(306) Apparatus Embodiment 2G1. The first wireless base station of Apparatus Embodiment 2G, wherein the first SIM includes a first authentication key corresponding to a first subscription with the first service provider; and wherein the second SIM includes a second authentication key corresponding to a second subscription with second service provider.
(307) Apparatus Embodiment 3. The first wireless base station of Apparatus Embodiment 1, further comprising: a wireless transmitter; and wherein said first message is a first control message; wherein the first control message includes an instruction for the first wireless base station to enter the first mode of operation; and wherein said processor is further configured to: operate the first wireless base station to, while operating in said first mode of operation the first wireless base station, commence wirelessly transmitting, via the wireless transmitter, device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message.
(308) Apparatus Embodiment 3A. The first wireless base station of Apparatus Embodiment 3, wherein the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection.
(309) Apparatus Embodiment 3B. The first wireless base station of Apparatus Embodiment 1, wherein said first message is a first control message; and wherein the first control message includes an instruction for the first wireless base station to enter a discovery mode of operation, said first mode of operation being a discovery mode of operation.
(310) Apparatus Embodiment 3C. The first wireless base station of Apparatus Embodiment 1, wherein said first message is a first control message; and wherein the first control message includes an instruction for the first wireless base station to enter a device to device mode of operation, said first mode of operation being a device to device mode of operation.
(311) Apparatus Embodiment 4. The first wireless base station of Apparatus Embodiment 1, wherein said first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and wherein said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
(312) Apparatus Embodiment 4A. The first wireless base station of Apparatus Embodiment 4, wherein said second wireless base station is part of a second wireless network, said first network and said second network being operated by different service providers, said first network being operated by a first service provider and said second network being operated by a second service provider; wherein said first wireless base station and said second wireless base station utilize different spectrum bands for communicating with subscriber devices; and wherein said first user equipment device includes a first SIM card with subscriber credentials for the first network and a second SIM card with subscriber credentials for the second network.
(313) Apparatus Embodiment 4B. The first wireless base station of Apparatus Embodiment 4A, wherein said first user equipment device is a subscriber of the first service provider and a subscriber of the second service provider.
(314) Apparatus Embodiment 4C. The first wireless base station of Apparatus Embodiment 4A, wherein the first wireless base station operates in a first spectrum band; wherein the second wireless base station operates in a second spectrum band; and wherein said first and second spectrum bands are different.
(315) Apparatus Embodiment 4D. The first wireless base station of Apparatus Embodiment 4C, wherein the first spectrum band is general authorized access (GAA) spectrum and the second spectrum band is priority access license (PAL) spectrum.
(316) Apparatus Embodiment 5. The first wireless base station of Apparatus Embodiment 3, further

comprising: a wireless receiver; and wherein said processor is further configured to operate the first wireless base station to: receive via the wireless receiver, from the first user equipment device, a discovery request response message in response to the first device to device discovery request message; and establish a sidelink device to device communications channel with the first user equipment device.

(317) Apparatus Embodiment 5A. The first wireless base station of Apparatus Embodiment 5, wherein said processor is further configured to operate the first wireless base station to: obtain sidelink resource information from a core network for establishing the sidelink device to device communications channel between the first wireless base station and the first user equipment device, said resource information including information specifying spectrum granted or allocated for the sidelink device to device communications channel to be established, as part of being configured to operate the first wireless base station to establish a sidelink device to device communications channel with the first user equipment device.

(318) Apparatus Embodiment 5B. The first wireless base station of Apparatus Embodiment 5A, wherein said sidelink resource information is obtained by the first wireless base station; and wherein said processor is further configured to operate the first wireless base station to: transmit via the wireless transmitter the sidelink resource information to the first user equipment device, as part of being configured to operate the first wireless base station to establish a sidelink device to device communications channel with the first user equipment device.

(319) Apparatus Embodiment 5C. The first wireless base station of Apparatus Embodiment 5B, wherein said core network is part of the first network; and wherein said sidelink resource information specifies spectrum authorized for use by subscribers of the first network or available for use by subscribers of the first network.

(320) Apparatus Embodiment 5D. The first wireless base station of Apparatus Embodiment 5A, wherein said core network is not part of the first network but is a part of a second network, said first user equipment device obtaining the sidelink resource information via a second wireless base station and sharing the sidelink resource information with the first wireless base station.

(321) Apparatus Embodiment 5E. The first wireless base station of Apparatus Embodiment 5, wherein the device to device discovery request messages are device to device Proximity Service discovery request beacon messages announcing to monitoring Proximity Service devices that the first wireless base station is seeking to establish a device to device wireless connection; and wherein the discovery request response message is Proximity Service discovery response request message.

(322) Apparatus Embodiment 6. The first wireless base station of Apparatus Embodiment 5, wherein said processor is further configured to operate the first wireless base station to: transmit, via the wireless transmitter, a first sync request message to the first user equipment device over the established device to device sidelink communications channel; and receive, via the wireless receiver, over the device to device sidelink communications channel from the first user equipment device said synchronization information, as part of being configured to operate the first wireless base station to obtain synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.

(323) Apparatus Embodiment 7. The first wireless base station of Apparatus Embodiment 6, wherein the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.

(324) Apparatus Embodiment 8. The first wireless base station of Apparatus Embodiment 1, wherein said processor is further configured to: utilize the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.

(325) Apparatus Embodiment 9. The first wireless base station of Apparatus Embodiment 1,

wherein said synchronization information includes a time value and delay information; and wherein said processor is further configured to use the delay information to adjust the time value, as part of being configured to utilize the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.

(326) Apparatus Embodiment 9A. The first wireless base station of Apparatus Embodiment 9, wherein said time value is a time stamp value; and wherein said delay value is a path transmission delay value.

(327) Apparatus Embodiment 10. The first wireless base station of Apparatus Embodiment 9, further comprising: a first transmitter (network transmitter); and wherein said processor is further configured to operate the first wireless base station to: transmit, via the first transmitter, a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information; and receive, via the first receiver, from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation it does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation it performs wireless base station operations and provides wireless base station services to user equipment devices.

(328) Apparatus Embodiment 11. The first wireless base station of Apparatus Embodiment 1, wherein said processor is further configured to operate the first wireless base station to: re-synching, by the first wireless base station, a timer at the first wireless base station using the synchronization information obtained from the first user equipment device.

(329) Apparatus Embodiment 12. A dual Subscriber Identity Module (SIM) user equipment device comprising: a memory, and a first processor, said processor controlling the dual SIM user equipment device to perform the following operations: receive, at the dual SIM user equipment device from a first wireless base station, a request message requesting synchronization information, said synchronization information including timing synchronization information; in response to receiving the request for synchronization information from the first wireless base station, generate by the dual SIM user equipment device a synchronization message including the requested synchronization information based on synchronization information obtained by the dual SIM user equipment device from a second wireless base station; and transmit the synchronization message to the first wireless base station.

(330) Apparatus Embodiment 13. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 12, wherein said processor further controls the dual SIM user equipment device to perform the following operation: prior to receiving the request message requesting synchronization information from the first wireless base station, receiving, by the dual SIM user equipment device a device to device (D2D) discovery request message from the first wireless base station; and in response to receiving the D2D discovery request message, establishing a device to device (D2D) sidelink communication channel with first wireless base station; and wherein the synchronization message is transmitted to the first wireless base station over the established D2D sidelink communications channel.

(331) Apparatus Embodiment 14. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 13, wherein said processor further controls the dual SIM user equipment device to perform the following operation: prior to generating the synchronization message, requesting synchronization information from a second wireless base station, said first wireless base station and said second wireless base station belonging to different wireless networks, said dual SIM user equipment device including a first SIM card and a second SIM card, said dual SIM user equipment device being able to communicate with the first wireless base station using information contained on the first SIM card, said dual SIM user equipment device being able to communicate with the second wireless base station using information contained on the second SIM

card.
(332) Apparatus Embodiment 15. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 12, wherein the D2D discovery request message is a Proximity Service discovery request message; and wherein the D2D sidelink communications channel is established using Proximity Services.
(333) Apparatus Embodiment 16. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 12, wherein the first wireless base station utilizes a time division duplex wireless protocol to communicate with user equipment devices.
(334) Apparatus Embodiment 17. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 13, wherein said operation of establishing a device to device (D2D) sidelink communication channel with first wireless base station includes receiving information from the first wireless base station indicating the resources (e.g., spectrum) to be used for the D2D sidelink communications channel.
(335) Apparatus Embodiment 18. The dual Subscriber Identity Module (SIM) user equipment device of Apparatus Embodiment 12, wherein the first wireless base station is an indoor wireless base station (e.g., small cell CBSD); wherein the second wireless base station is an eNodeB.
List of Exemplary Numbered Non-Transitory Computer Readable Medium Embodiments
(336) Non-transitory Computer Readable Medium Embodiment 1. A non-transitory computer readable medium including a first set of computer executable instructions which when executed by a processor of a first wireless base station cause the first wireless base station to perform the steps of: receiving, at the first wireless base station, a first message; in response to receiving the first message entering, by the first wireless base station, into a first mode of operation; while operating in said first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information.
(337) Non-transitory Computer Readable Medium Embodiment 2. The non-transitory computer readable medium of Non-transitory Computer Readable Medium Embodiment 1, wherein the first set of computer executable instructions which when executed by the processor of the first wireless base station further cause the first wireless base station to perform the step of: re-synching, by the first wireless base station, a timer at the first wireless base station using the synchronization information obtained from the first user equipment device.
(338) Non-transitory Computer Readable Medium Embodiment 3. A non-transitory computer readable medium including a first set of computer executable instructions which when executed by a processor of a dual Subscriber Identity Module (SIM) user equipment device cause the dual Subscriber Identity Module user equipment device to perform the steps of: receiving, at the dual SIM user equipment device from a first wireless base station, a request message requesting synchronization information, said synchronization information including timing synchronization information; in response to receiving the request for synchronization information from the first wireless base station, generating by the dual SIM user equipment device a synchronization message including the requested synchronization information based on synchronization information obtained by the dual SIM user equipment device from a second wireless base station; and transmitting the synchronization message to the first wireless base station.
(339) The techniques of various embodiments may be implemented using software, hardware and/or a combination of software and hardware. Various embodiments are directed to apparatus, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements. Various embodiments are also directed to methods, e.g., method of controlling and/or operating wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs,

CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements. Various embodiments are also directed to machine, e.g., computer, readable medium, e.g., ROM, RAM, CDs, hard discs, etc., which include machine readable instructions for controlling a machine to implement one or more steps of a method. The computer readable medium is, e.g., non-transitory computer readable medium.

(340) It is understood that the specific order or hierarchy of steps in the processes and methods disclosed is an example of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes and methods may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented. In some embodiments, one or more processors are used to carry out one or more steps of the each of the described methods.

(341) In various embodiments each of the steps or elements of a method are implemented using one or more processors. In some embodiments, each of elements or steps are implemented using hardware circuitry.

(342) In various embodiments devices, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements described herein are implemented using one or more components to perform the steps corresponding to one or more methods, for example, generating or creating messages, implementing and/or updating timers or clocks, e.g., reference clock, connections, message reception, message transmission, switching modes, synchronizing time of day, phase and frequency, updating synchronization or clock system, signal processing, sending, comparing, determining and/or transmission steps. Thus, in some embodiments various features are implemented using components or in some embodiments logic such as for example logic circuits. Such components may be implemented using software, hardware or a combination of software and hardware. Many of the above described methods or method steps can be implemented using machine executable instructions, such as software, included in a machine readable medium such as a memory device, e.g., RAM, floppy disk, etc. to control a machine, e.g., general purpose computer with or without additional hardware, to implement all or portions of the above described methods, e.g., in one or more devices, servers, nodes and/or elements. Accordingly, among other things, various embodiments are directed to a machine-readable medium, e.g., a non-transitory computer readable medium, including machine executable instructions for causing a machine, e.g., processor and associated hardware, to perform one or more of the steps of the above-described method(s). Some embodiments are directed to a device, e.g., a controller, including a processor configured to implement one, multiple or all of the steps of one or more methods of the invention.

(343) In some embodiments, the processor or processors, e.g., CPUs, of one or more devices, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements are configured to perform the steps of the methods described as being performed by the wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements. The

configuration of the processor may be achieved by using one or more components, e.g., software components, to control processor configuration and/or by including hardware in the processor, e.g., hardware components, to perform the recited steps and/or control processor configuration. Accordingly, some but not all embodiments are directed to a device, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements, with a processor which includes a component corresponding to each of the steps of the various described methods performed by the device in which the processor is included. In some but not all embodiments a device, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements, includes a controller corresponding to each of the steps of the various described methods performed by the device in which the processor is included. The components may be implemented using software and/or hardware.

(344) Some embodiments are directed to a computer program product comprising a computer-readable medium, e.g., a non-transitory computer-readable medium, comprising code for causing a computer, or multiple computers, to implement various functions, steps, acts and/or operations, e.g., one or more steps described above. Depending on the embodiment, the computer program product can, and sometimes does, include different code for each step to be performed. Thus, the computer program product may, and sometimes does, include code for each individual step of a method, e.g., a method of controlling a device, e.g., wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements. The code may be in the form of machine, e.g., computer, executable instructions stored on a computer-readable medium, e.g., a non-transitory computer-readable medium, such as a RAM (Random Access Memory), ROM (Read Only Memory) or other type of storage device. In addition to being directed to a computer program product, some embodiments are directed to a processor configured to implement one or more of the various functions, steps, acts and/or operations of one or more methods described above. Accordingly, some embodiments are directed to a processor, e.g., CPU, configured to implement some or all of the steps of the methods described herein. The processor may be for use in, e.g., a communications device such as a wireless base stations, wireless devices, mobile terminals, network equipment, eNBs, gNBs, CBSDs, CBRS tower base stations, mobility management entities, smart devices, user equipment devices, user devices, computers, smartphones, subscriber devices, core network systems, EPCs, ProSe entities, cable modems, cable modem termination systems, servers, nodes, and/or elements or other device described in the present application.

(345) Numerous additional variations on the methods and apparatus of the various embodiments described above will be apparent to those skilled in the art in view of the above description. Such variations are to be considered within the scope. Numerous additional embodiments, within the scope of the present invention, will be apparent to those of ordinary skill in the art in view of the above description and the claims which follow. Such variations are to be considered within the scope of the invention.

Claims

1. A method of operating a first wireless base station in a first network comprising: receiving, at the first wireless base station, a first message; in response to receiving the first message, entering, by the first wireless base station, into a first mode of operation; while operating in said first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information; transmitting, by the first wireless base station, a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information; receiving from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation the first wireless base station does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation the first wireless base station performs wireless base station operations and provides wireless base station services to user equipment devices.
2. The method of claim 1, wherein the first network is a hybrid mobile network; and wherein the first message is a first control message from the core network equipment device which is part of the hybrid mobile network, said first message being received by the first wireless base station over a landline.
3. The method of claim 1, wherein said first message is a first control message; wherein the first control message includes an instruction for the first wireless base station to enter the first mode of operation; and while operating in said first mode of operation the first wireless base station commences wirelessly transmitting device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message.
4. The method of claim 3, further comprising: receiving, from the first user equipment device, a discovery request response message in response to the first device to device discovery request message; and establishing a sidelink device to device communications channel with the first user equipment device.
5. The method of claim 4, wherein said obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications includes: transmitting a first sync request message to the first user equipment device over the established device to device sidelink communications channel; and receiving over the device to device sidelink communications channel from the first user equipment device said synchronization information.
6. The method of claim 5, wherein the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
7. The method of claim 1, wherein said first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and wherein said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.
8. The method of claim 1, further comprising: utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.
9. The method of claim 8, wherein said synchronization information includes a time value and delay information; and wherein utilizing, by the first wireless base station, the synchronization information obtained from the first user equipment device to set a timer at the first wireless base

station includes using the delay information to adjust the time value.
10. The method of claim 1, further comprising: re-synching, by the first wireless base station, a timer at the first wireless base station using the synchronization information obtained from the first user equipment device.
11. The method of claim 1, further comprising: determining, by the first wireless base station while operating in the second mode of operation, that updated synchronization information is required by the first wireless base station to continue to operate properly; in response to determining that updated synchronization information is required by the first wireless base station to continue to operate properly, entering by the first wireless base station into a device to device discovery mode of operation; while operating in said device to device discovery mode of operation, obtaining, by the first wireless base station, the updated synchronization information from a user equipment device using an over the air sidelink device to device communications channel; and wherein while operating in said device to device discovery mode of operation, said first wireless base station operates as a subscriber device using spectrum allocated for subscriber device to device communications as opposed to spectrum allocated for base station to user equipment device communications.
12. A first wireless base station comprising: a first receiver; and a processor configured to operate the first wireless base station to: receive, via the first receiver, a first message; enter into a first mode of operation in response to the received first message; obtain, while operating in the first mode of operation, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information; transmit a message to a core network equipment device of the first network, said message indicating successful reception of time synchronization information; receive from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation the first wireless base station does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation the first wireless base station performs wireless base station operations and provides wireless base station services to user equipment devices.
13. The first wireless base station of claim 12, wherein the first network is a hybrid mobile network; and wherein the first message is a first control message from a first the core network equipment device which is part of the hybrid mobile network, said first message being received by the first wireless base station over a landline.
14. The first wireless base station of claim 12, further comprising: a wireless transmitter; and wherein said first message is a first control message; wherein the first control message includes an instruction for the first wireless base station to enter the first mode of operation; and wherein said processor is further configured to operate the first wireless base station to: commence, while operating in said first mode of operation, wirelessly transmitting, via the wireless transmitter, device to device discovery request messages, said device to device discovery request messages including a first device to device discovery request message.
15. The first wireless base station of claim 14, further comprising: a wireless receiver; and wherein said processor is further configured to operate the first wireless base station to: receive via the wireless receiver, from the first user equipment device, a discovery request response message in response to the first device to device discovery request message; and establish a sidelink device to device communications channel with the first user equipment device.
16. The first wireless base station of claim 15, wherein as part of being configured to operate the first wireless base station to obtain synchronization information from a first user equipment device using over the air device to device communications said processor is configured to operate the first wireless base station to: transmit, via the wireless transmitter, a first sync request message to the

first user equipment device over the established device to device sidelink communications channel; and receive, via the wireless receiver, over the device to device sidelink communications channel from the first user equipment device said synchronization information.

17. The first wireless base station of claim 16, wherein the synchronization information received from the first user equipment device is based on synchronization information received by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.

18. The first wireless base station of claim 12, wherein said first user equipment device is a mobile device with Dual Subscriber Identity Module (SIM) Dual Subscriber (DSDS) functionality; and wherein said synchronization information is based on synchronization information obtained by the first user equipment device from a second wireless base station, said second wireless base station not being part of the first network.

19. The first wireless base station of claim 12, wherein said processor is further configured to: utilize the synchronization information obtained from the first user equipment device to set a timer at the first wireless base station.

20. A non-transitory computer readable medium including a first set of computer executable instructions which when executed by a processor of a first wireless base station cause the first wireless base station to perform the steps of: receiving, at the first wireless base station, a first message; in response to receiving the first message, entering, by the first wireless base station, into a first mode of operation; while operating in said first mode of operation, obtaining, by the first wireless base station, synchronization information from a first user equipment device using over the air device to device communications, said synchronization information including time synchronization information; transmitting, by the first wireless base station, a message to a core network equipment device of a first network, said message indicating successful reception of time synchronization information; receiving from the core network equipment device a message instructing the first wireless base station to exit the first mode of operation and enter a second mode of operation, said second mode of operation including changing state from off-line to on-line; and wherein when the first wireless base station is in an off-line state of operation the first wireless base station does not operate as a wireless base station and when the first wireless base station is in an on-line state of operation the first wireless base station performs wireless base station operations and provides wireless base station services to user equipment devices.