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On-Device Multi-Network Switching Enhancements

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Abstract:

This publication describes systems and techniques directed to on-device multi-network switching using cell measurements. The described systems and techniques include an on-device network-switching manager application that directs the user equipment to perform operations that include proceeding with a handover of a wireless connection between the user equipment and a serving cell of a first wireless network to a neighboring cell of the first wireless network. The user equipment determines that a signal received from a cell of a second wireless network meets a quality threshold. After completing the handover of the wireless connection to the neighboring cell of the first wireless network, the user equipment determines that another signal received from the neighboring cell of the first wireless network does not meet the quality threshold. The user equipment then initiates a handover of the wireless connection, between the user equipment and the neighboring cell of the first wireless network, to the cell of the second wireless network.

Keywords:

cell handover, network handover, network switching, serving cell, neighboring cell, geofence, geolocation, multiple-service operator, MSO, mobile-network operator, MNO

Background:

The proliferation of wireless-communication operators provides a user with multiple options for communicating wirelessly. For example, a multiple-service operator (MSO), such as a cable company that offers access to cable television, internet, and wireless services, may offer access to a wireless network that enables the user to communicate within a local region using a limited range of radio spectrums. As another example, a mobile-network operator (MNO), such

as a cellular service provider, may offer access to a wireless network that enables the user to communicate globally and across a wide range of radio spectrums.

Today, a user equipment may be equipped with multiple subscriber identity modules (SIMs) that enable the user equipment to switch between cells of different wireless networks as provided by different wireless-communication operators. Fig. 1 below illustrates an example of a user equipment that can switch between cells of an MSO wireless network and a cell of an MNO wireless network.

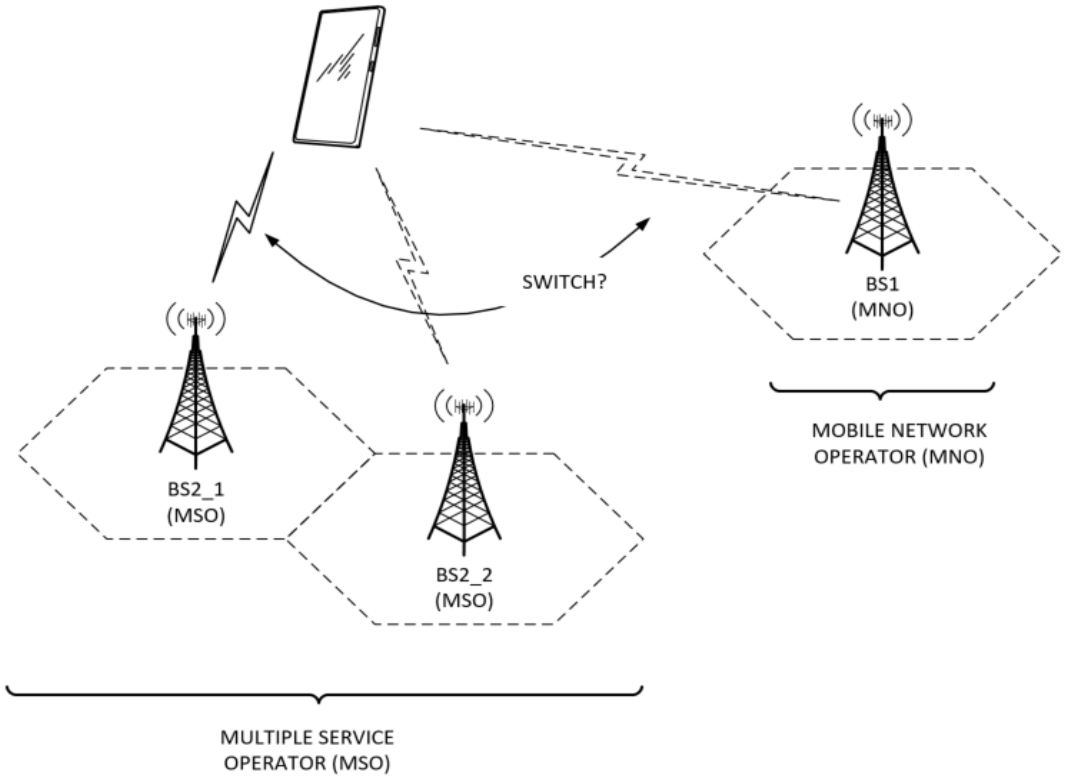

Fig. 1

As illustrated, the user equipment (*e.g.*, a smartphone) connects to a first wireless network through a wireless link to a serving cell of the first wireless network (*e.g.*, a cell provided by a base station BS2_1). The first wireless network, a multiple-service operator (MSO) network, includes

a neighboring cell (*e.g.*, a cell provided by a base station BS2_2) that too is within range of the user equipment. Also, within range of the user equipment is a cell of a second wireless network (*e.g.*, BS1), where the second wireless network is a mobile-network operator (MNO) network.

In certain instances, such as when a signal between the user equipment and the serving cell of the first wireless network (*e.g.*, a signal received from BS2_1) degrades below a quality threshold, it may be desirable for the user equipment to switch, or handover, the wireless connection to either the neighboring cell of the first wireless network (*e.g.*, the neighboring cell provided by BS2_2) or to the cell of the second wireless network (*e.g.*, the cell provided by BS1) In other instances, the quality of signaling received from the neighboring cell of the first wireless network or the cell of the second wireless network may exceed the quality of signaling received from the serving cell of the first wireless network (*e.g.*, signaling received from BS2_2 or BS1 is of higher quality than that of signaling received from BS2_1) and it may be desirable for the user equipment to switch to either the neighboring cell of the first wireless network or to the cell of the second wireless network.

Under different circumstances, if the user equipment "blindly" hands over the wireless connection, negative consequences can result. As a first example negative consequence, if the user equipment determines to handover the wireless connection to the cell of the second wireless network *(e.g.*, handover the wireless connection to BS1 which provides access to the MNO network), it is possible that a user of the user equipment will incur an increase in service charges or fees. As a second example negative consequence, and in an instance in which the user equipment by default is instructed to maintain a connection within a network (*e.g.*, handover the wireless connection from BS2_1 to BS2_2 and remain within the MSO network), it is possible that signaling within the network (*e.g.*, signaling from BS2_2 to the user equipment) is of poor quality

and the wireless connection cannot be maintained. As a third example of a negative consequence, a scenario can manifest where the user equipment performs a handover of the wireless connection to the cell of second wireless network and immediately performs another handover back to the neighboring cell of the first wireless network (*e.g.*, handover the wireless connection to the BS1 and then back to BS2_2).

Description:

This publication describes systems and techniques directed to on-device multi-network switching using neighboring cell measurements. The described systems and techniques include an on-device network-switching manager application that directs the user equipment to perform operations that include proceeding with a handover of a wireless connection between the user equipment and a serving cell of a first wireless network to a neighboring cell of the first wireless network. The user equipment determines that a signal received from a cell of a second wireless network meets a quality threshold. After completing the handover of the wireless connection to the neighboring cell of the first wireless network, the user equipment determines that another signal received from the neighboring cell of the first wireless network does not meet the quality threshold. The user equipment then initiates a handover of the wireless connection, between the user equipment and the neighboring cell of the first wireless network, to the other cell of the second wireless network.

Fig. 2, below, illustrates an example user equipment (UE) that supports on-device multi-network switching as described herein.

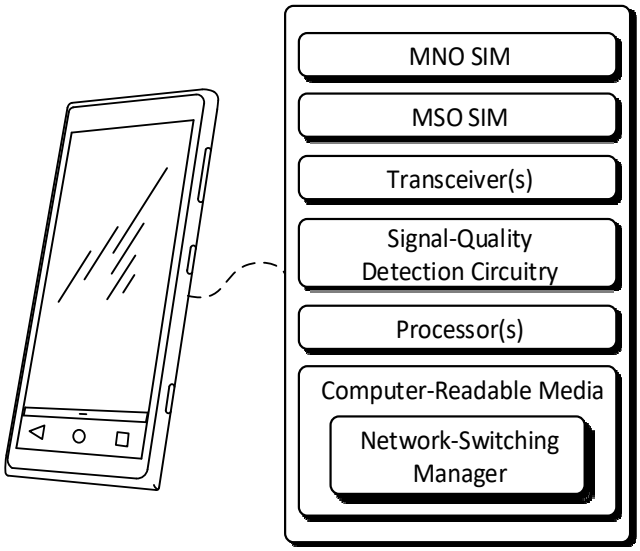

Fig. 2

As illustrated, and as a non-limiting example, the user equipment is a smartphone. Other examples of the user equipment include a wearable device, a tablet, and a laptop computer. The user equipment includes a mobile-network operator (MNO) subscriber identity module (SIM) and a multiple-service operator (MSO) SIM that provide the user equipment access to a respective MNO wireless network and a respective MSO wireless network. The user equipment also includes one or more transceivers for communicating with access points (*e.g.*, base stations) providing the cells of the MNO and MSO wireless networks. The transceivers can include, for example, a fourth generation long term evolution (4G LTE) transceiver and a fifth generation new radio (5G NR) transceiver.

The user equipment includes signal-quality detection circuitry that can detect qualities of a signal received through the transceivers. Examples of such qualities include a received signal strength indicator (RSSI), a signal-to-noise (SNR) ratio, and a reference signal received power (RSRP) indicator.

The user equipment includes at least one processor having logic for executing instructions. The processor may be a single-core processor or a multiple-core processor composed of a variety

of materials, such as silicon, polysilicon, high-K dielectric, copper, and so on. The user equipment also includes a computer-readable medium (CRM). The CRM may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory. The CRM stores a network-switching manager application that, when executed by the processor, perform operations described herein.

The user equipment, under direction of the processor executing the network-switching manager application, can perform a combination of wireless connection handover operations that take into account qualities of signals received from cells of different wireless networks. In contrast to methods that rely on network-switching determinations being made by a wireless-network entity (such as a base station), the use of on-device multi-network switching techniques performed by the processor executing the network-switching manager application enhances cell selection processes such that a more stable wireless connection can be realized and/or such that a wireless connection within a desired network (*e.g.*, a network provided by a certain wireless-communication operator) can be managed by the user of the user equipment. In general, the techniques include the user equipment accounting for neighboring cell signal qualities and wireless-communication operators when switching (*e.g.*, performing a handover of a wireless connection) between cells.

In a first example technique, the user equipment can initiate a handover of a wireless connection. As part of the first example technique, the user equipment can compare a metric (*e.g.*, a quality measurement) of a first signal received from serving cell to which the user equipment is connected and a metric of a second signal received from another cell to which the user equipment is not connected, determine that the handover is necessary, and initiate the handover. For example,

and in a 5G NR environment, the user equipment may detect a signal that is a demodulation reference signal (DMRS) or a sounding reference signal (SRS) from the serving cell and detect another signal (*e.g.*, another DMRS or another SRS) from the other cell. In this example instance, and if a quality (*e.g.*, an RSSI, an SNR, or an RRSP) of the first signal is below a threshold, while the quality of the second signal meets or exceeds the threshold, the user equipment may determine to initiate the handover.

In some instances, determining to initiate the handover may include determining that the wireless networks associated with the serving cell and the other cell meet a requirement that they are both a same type of wireless network (*e.g.*, the wireless networks are both an MSO wireless network or both an MNO wireless network) and that the other cell is a neighboring cell. In other instances, determining to initiate the handover may include determining that although the wireless networks associated with the serving cell and the other cell are a different wireless network and the other cell is not a neighboring cell (*e.g.*, the wireless network of the serving cell is an MSO network and the wireless network of the other cell is an MNO network, or vice versa), that the handover may proceed.

In a second example technique, the user equipment may proceed with a handover of a wireless connection from a serving cell of a first wireless network to a neighboring cell of the first wireless network. In contrast to initiating the handover of the wireless connection, as described in the first example technique above, the second example technique includes the user equipment proceeding with the handover in response to receiving an instruction to perform the handover (*e.g.*, the instruction may be associated with a radio resource control (RRC) reconfiguration message that is received from the first wireless network, a message for handover measurements that is

received from the first wireless network, a handover command entered by a user of the user equipment, and so on).

While proceeding with the handover, the user equipment may determine that a signal received from a cell of a second wireless network meets a quality threshold. In this second example technique, the user equipment may delay handing over the wireless connection to the cell of the second wireless network while the user equipment is in the process of handing over the wireless connection to the neighboring cell of the first wireless network. In general, and to prioritize handing over to the neighboring cell of the first wireless network in accordance with the received instructions, the user equipment delays handing over the wireless connection to the other cell of the second wireless network until signal quality measurements from the neighboring cell of the first wireless network are available.

Continuing, the user equipment completes the handover of the wireless connection from the serving cell of the first wireless network to the neighboring cell of the first wireless network. The user equipment then determines that another signal received from the neighboring cell of the first wireless network fails to meet the quality threshold. After determining that the other signal fails to meet the quality threshold, the user equipment initiates a handover of the wireless connection with the neighboring cell of the first wireless network to the other cell of the second wireless network.

In some instances of the second example technique, the user equipment may also rely on geolocation data of cells and their respective associations with different wireless networks. The user equipment (*e.g.*, the network-switching manager application) may maintain a table of geolocations of cells and the respective associations with the different wireless networks to explore available cells of a preferred wireless network before handing over the wireless connection outside

the network. In the context of the present example of the second example technique, this means that the user equipment may delay handing over the wireless connection to the cell of the second wireless network while it searches for other neighboring cells within the first wireless network (in the event signaling received from a first-identified neighboring cell of the first wireless network fails to meet the quality threshold).

Fig. 3, below, illustrates a summary of operations of the second example technique. The operations are performed by the user equipment of Fig. 2, under direction of the processor executing the instructions of the network-switching manager application.

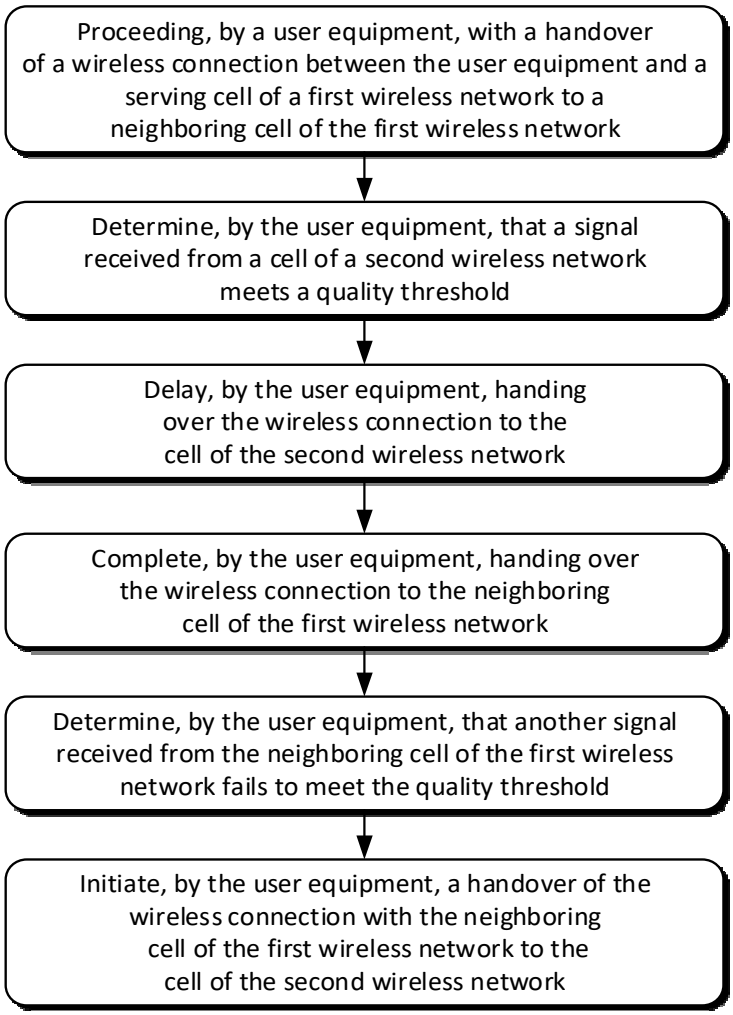

Fig. 3

The first and second example techniques, as described, are non-limiting examples of on-device multi-network switching. As described, the first wireless network and the second wireless network can each be a same network or a different wireless network. Furthermore, although described in terms of MNO and MSO networks, base stations, and 5G NR radio access technologies, the example techniques may apply to cells of other networks (*e.g.*, a wireless local area network (WLAN)), other radio access technologies (*e.g.*, fourth generation long term evolution (4G LTE), sixth generation (6G), and so on), and other access points (*e.g.*, routers and so on). The techniques are also applicable to "hotspots" that are provided by other user equipment.

In conclusion, the described systems and techniques, as associated with on-device multi-network switching, offer enhancements over systems and techniques relying on off-device multi-network switching. Such enhancements, which take into account neighboring cell signal qualities and wireless networks, can improve continuity of wireless communications during a handover and/or ensure maintaining a wireless connection within a network offered by a desired wireless-communication operator.

References:

[1] Yang, Ming, and Tom Chin. Reduced Handover Failure for Single Radio Voice Call Continuity. US Pub. 2016/0366619 A1, filed June 10, 2015, and published December 15, 2016.

[2] Bi, Hao. Methods for Handing Over Calls Between Communication Networks Using Dissimilar Air Interfaces. US Patent 8620320 B2, filed on June 19, 2007, and issued on December 31, 2013.