(54) **METHOD AND SYSTEM FOR DYNAMIC CELL CONFIGURATION**

(71) Applicant: **Huawei Technologies Co., Ltd.,** Shenzhen (CN)

(72) Inventors: **Jianglei Ma**, Ottawa (CA); **Peiying Zhu**, Kanata (CA); **Wen Tong**, Ottawa (CA)

(73) Assignee: **Huawei Technologies Co., Ltd.,** Shenzhen (CN)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,141,565 A	10/2000	Feuerstein et al.	
8,265,629 B2	9/2012	Kwon et al.	
8,300,587 B2	10/2012	Chmiel et al.	
8,532,297 B2	9/2013	Hsuan et al.	
8,634,868 B2	1/2014	Hedberg et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CN	101014156 A	8/2007
CN	102026298 A	4/2011

(Continued)

OTHER PUBLICATIONS

Catt, "Further considerations on scenario 3 and 4," 3GPP TSG RAN WG1 Meeting #64, R1-110720, Taipei, Feb. 21-25, 2011, 3 pages.

(Continued)

Primary Examiner — Minh Dieu Nguyen
(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(57) **ABSTRACT**

An apparatus for adapting hyper cells in response to changing conditions of a cellular network is disclosed. During operation, the apparatus collects data regarding network conditions of the cellular network. In accordance with the collected network condition data, the apparatus changes an association of a transmit point from a second cell ID of a second hyper cell to a first cell ID of a first hyper cell. Virtual data channels, broadcast common control channel and virtual dedicated control channel, transmit point optimization, UE-centric channel sounding and measurement, and single frequency network synchronization are also disclosed.

25 Claims, 8 Drawing Sheets
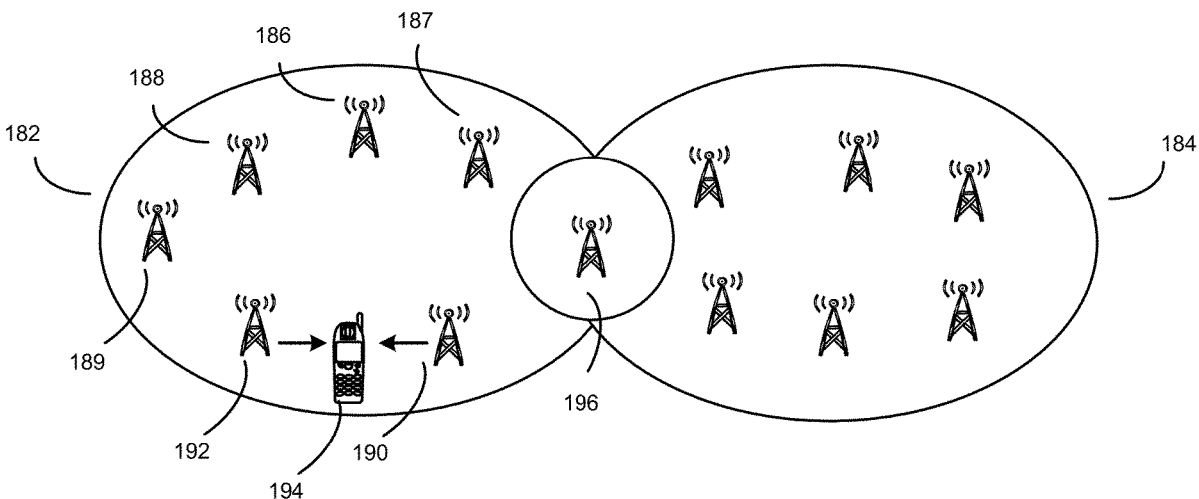
(56)   **References Cited**

U.S. PATENT DOCUMENTS

8,731,001 B2	5/2014	Roman et al.	
8,923,905 B2	12/2014	Montojo et al.	
8,948,096 B2*	2/2015	Tanaka	H04W 48/12
			370/329
8,953,523 B2	2/2015	Mochizuki et al.	
8,953,532 B2	2/2015	Liu et al.	
8,965,443 B2	2/2015	Gao et al.	
8,995,293 B2	3/2015	Jöngren et al.	
9,014,020 B2	4/2015	Gao et al.	
9,225,449 B2	12/2015	Heo et al.	
2004/0131029 A1*	7/2004	Tobe	H04W 52/322
			370/331
2007/0015514 A1	1/2007	Bishop	
2007/0066305 A1	3/2007	Deguchi	
2008/0198798 A1	8/2008	Wu et al.	
2008/0274745 A1	11/2008	Barak et al.	
2009/0047955 A1*	2/2009	Frenger	H04J 11/0093
			455/436
2009/0060003 A1	3/2009	Hayashi et al.	
2009/0238366 A1	9/2009	Park et al.	
2010/0003986 A1*	1/2010	Chen	H04W 36/0088
			455/436
2010/0088410 A1	4/2010	Ridley	
2010/0165942 A1*	7/2010	Liao	H04W 56/0015
			370/329
2010/0208603 A1	8/2010	Ishii	
2010/0303034 A1	12/2010	Chen et al.	
2011/0021205 A1	1/2011	Horneman et al.	
2011/0038310 A1	2/2011	Chmiel et al.	
2011/0039565 A1*	2/2011	Brunel	H04W 36/0088
			455/436
2011/0092220 A1*	4/2011	Bernini et al.	455/452.2
2011/0103287 A1	5/2011	Ma et al.	
2011/0105184 A1	5/2011	Piirainen et al.	
2011/0124341 A1	5/2011	Kubo et al.	
2011/0170437 A1	7/2011	Zhou et al.	
2011/0281526 A1	11/2011	Matsuda et al.	
2011/0312359 A1*	12/2011	Kolding et al.	455/509
2012/0026966 A1	2/2012	Wennstrom et al.	
2012/0039284 A1*	2/2012	Barbieri et al.	370/329
2012/0087299 A1	4/2012	Bhattad et al.	
2012/0140660 A1	6/2012	Kang et al.	
2012/0155423 A1	6/2012	Kishiyama et al.	
2012/0163188 A1	6/2012	Kobayashi	
2012/0184311 A1*	7/2012	Yamamoto	H04W 56/002
			455/502
2012/0207043 A1*	8/2012	Geirhofer	H04L 5/0048
			370/252
2012/0207105 A1	8/2012	Geirhofer et al.	
2012/0213108 A1	8/2012	Ji et al.	
2012/0236741 A1	9/2012	Xu et al.	
2012/0281554 A1	11/2012	Gao et al.	
2012/0281555 A1	11/2012	Gao et al.	
2012/0281567 A1	11/2012	Gao et al.	
2012/0281573 A1*	11/2012	Kazmi	H04W 8/26
			370/252
2012/0281646 A1	11/2012	Liao et al.	
2012/0309291 A1	12/2012	Sawai	

2013/0003639 A1*	1/2013	Noh et al.	
2013/0017776 A1*	1/2013	Takano	H04B 7/15507
			455/7
2013/0021926 A1	1/2013	Geirhofer et al.	
2013/0021987 A1	1/2013	Ho et al.	
2013/0039304 A1	2/2013	Pan et al.	
2013/0051317 A1	2/2013	Ji et al.	
2013/0114514 A1	5/2013	Nissila et al.	
2013/0128760 A1	5/2013	Fujishima et al.	
2013/0210438 A1	8/2013	Martin et al.	
2013/0223264 A1	8/2013	Miki et al.	
2013/0250863 A1	9/2013	Nogami et al.	
2013/0260744 A1	10/2013	Xu et al.	
2013/0279461 A1	10/2013	De Bruin et al.	
2013/0286945 A1	10/2013	Ma et al.	
2013/0286954 A1	10/2013	Ma et al.	
2013/0286997 A1	10/2013	Davydov et al.	
2013/0301439 A1	11/2013	Heo et al.	
2013/0315195 A1	11/2013	Ko et al.	
2014/0003268 A1	1/2014	Zarifi et al.	
2014/0050191 A1	2/2014	Kim et al.	
2014/0064201 A1	3/2014	Zhu et al.	
2014/0079009 A1	3/2014	Liu et al.	
2014/0098779 A1	4/2014	Kim et al.	
2014/0133477 A1*	5/2014	Siomina	H04W 56/0055
			370/350
2014/0369219 A1	12/2014	Wang et al.	
2015/0065145 A1*	3/2015	Huang	H04W 52/40
			455/438

FOREIGN PATENT DOCUMENTS

CN	102265680 A	11/2011
CN	102315871 A	1/2012
CN	102325382 A	1/2012
WO	2011038272 A1	3/2011
WO	2012026318	3/2012
WO	2012134565 A1	10/2012
WO	2014064201 A1	5/2014

OTHER PUBLICATIONS

Fujitsu, "Consideration of antenna virtualization in DL MIMO scenario B," 3GPP TSG RAN WG1 meeting #66bis, R1-113500, Zhuhai, China, Oct. 10-14, 2011, 4 pages.
3GPP TR 36.819 v11.1.0 (Dec. 2011), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Coordinated multi-point operation for LTE physical layer aspects (Release 11), 69 pages.
3GPP TSG RAN WG1 Meeting #66bis, R1-113035, "Considerations on RRH subset selection mechanism," Potevio, Oct. 10-14, 2011, 3 pages.
3GPP TSG RAN WG1 meeting#68, R1-120496, "CoMP Operation and UE Mobility," Alcatel-Lucent, Alcatel-Lucent Shanghai Bell, Feb. 6-10, 2012, 5 pages.
Samsung, "Interference Measurement Resource for Downlink CoMP," 3GPP TSG RAN WG1 #68bis, R1-121627, Jeju, Korea, Mar. 26-30, 2012, 5 pages.
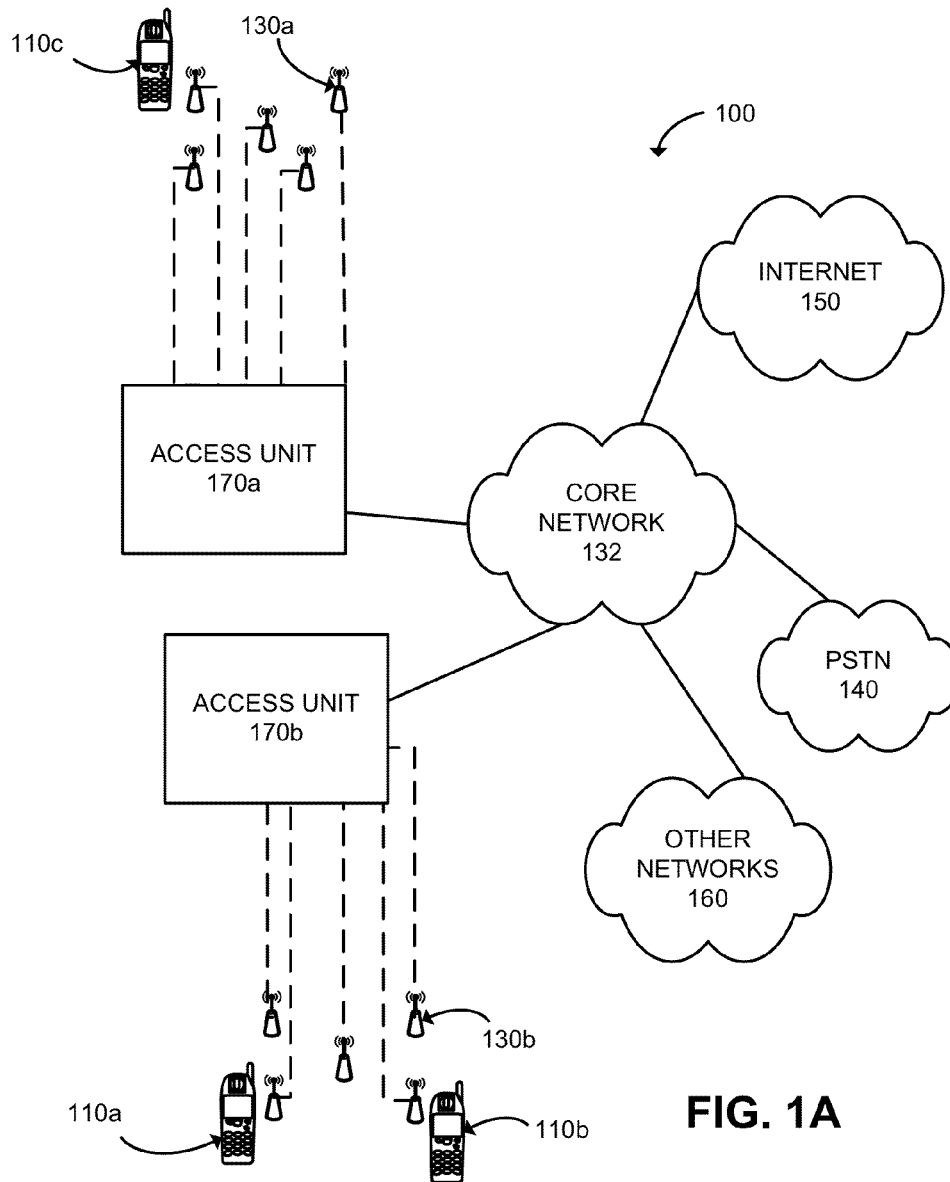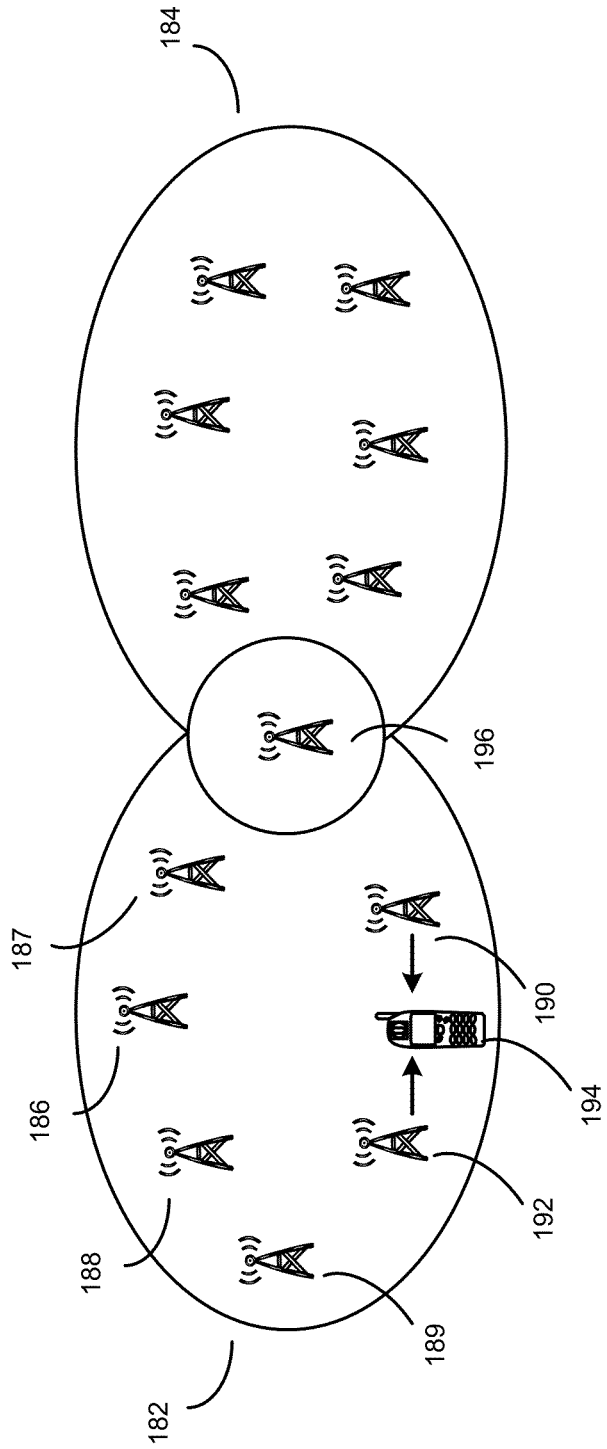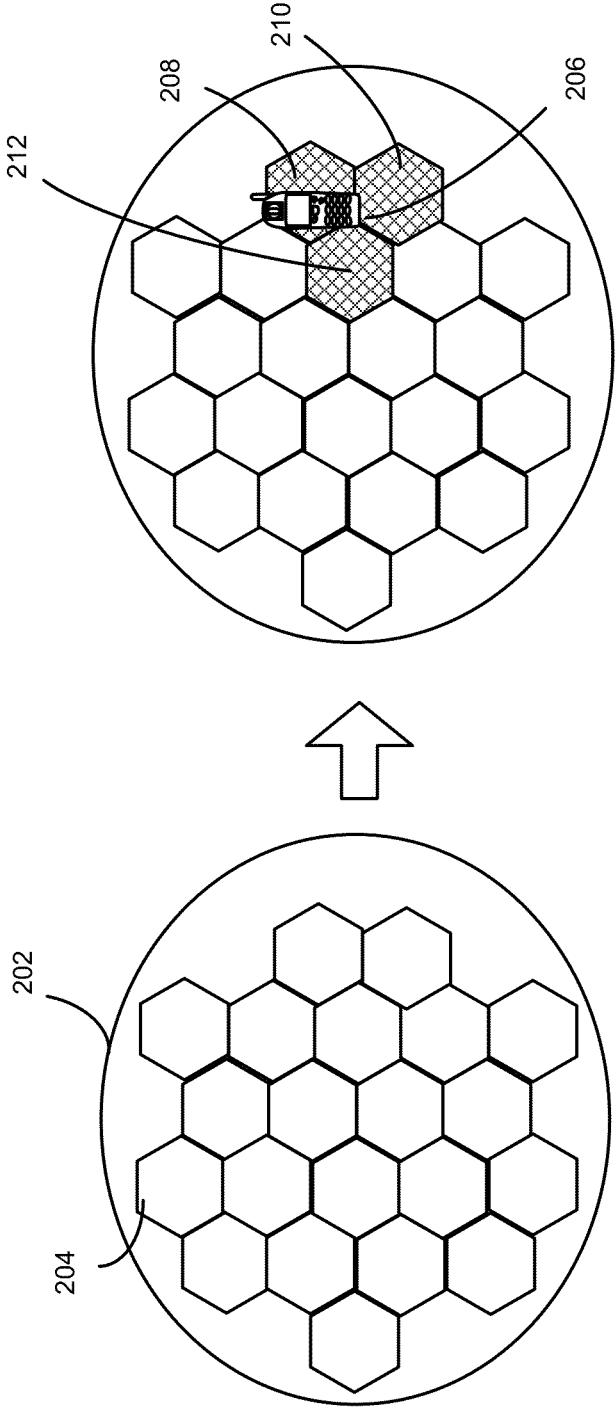
* cited by examiner

110c

130a

100

INTERNET
150

ACCESS UNIT
170a

CORE
NETWORK
132

PSTN
140

ACCESS UNIT
170b

OTHER
NETWORKS
160

130b

110a

110b

FIG. 1A

FIG. 1B

FIG. 2

FIG. 3

FIG. 4

START

TRANSMIT POINTS SEND
SOUNDING REFERENCE
SYMBOLS (SRS)
502

UE MEASURES SIGNAL
STRENGTH OF EACH DL
SRS
504

UE REPORTS
MEASUREMENT RESULTS
TO SUPERNODE
506

SUPERNODE GENERATES A
TABLE WITH UE INDEX AND
CORRESPONDING POTENTIAL
TRANSMIT POINT
508

SUPERNODE SELECTS BEST
TRANSMIT POINTS
510

END

FIG. 5

START

↓

TRANSMIT POINTS DETECT
UL TRANSMISSION
602

↓

FILTER UES WITH
THRESHOLD
604

↓

TRANSMIT POINTS REPORT
MEASUREMENTS TO
SUPERNODE
606

↓

SUPERNODE GENERATES
TABLE WITH UE INDEX AND
CORRESPONDING POTENTIAL
TRANSMIT POINTS
608

↓

SUPERNODE SELECTS BEST
TRANSMIT POINTS
610

↓

END

FIG.6

DISPLAY
714

COMPUTER AND COMMUNICATION SYSTEM
700

PROCESSOR
702

MEMORY
704

STORAGE
706

DYNAMIC CELL
CONFIGURATION
APPLICATION
708

APPLICATION
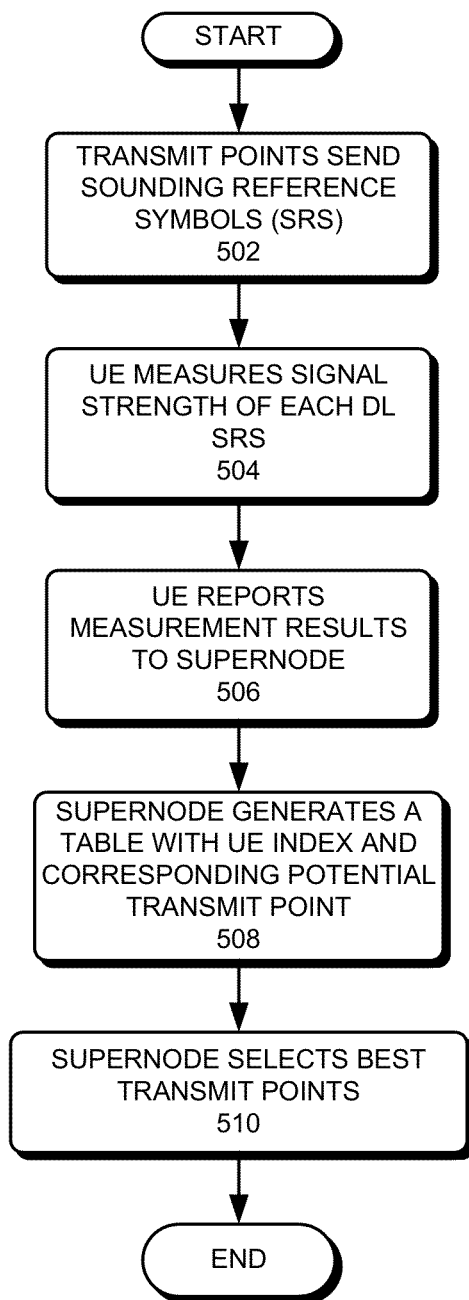710

APPLICATION
712

KEYBOARD
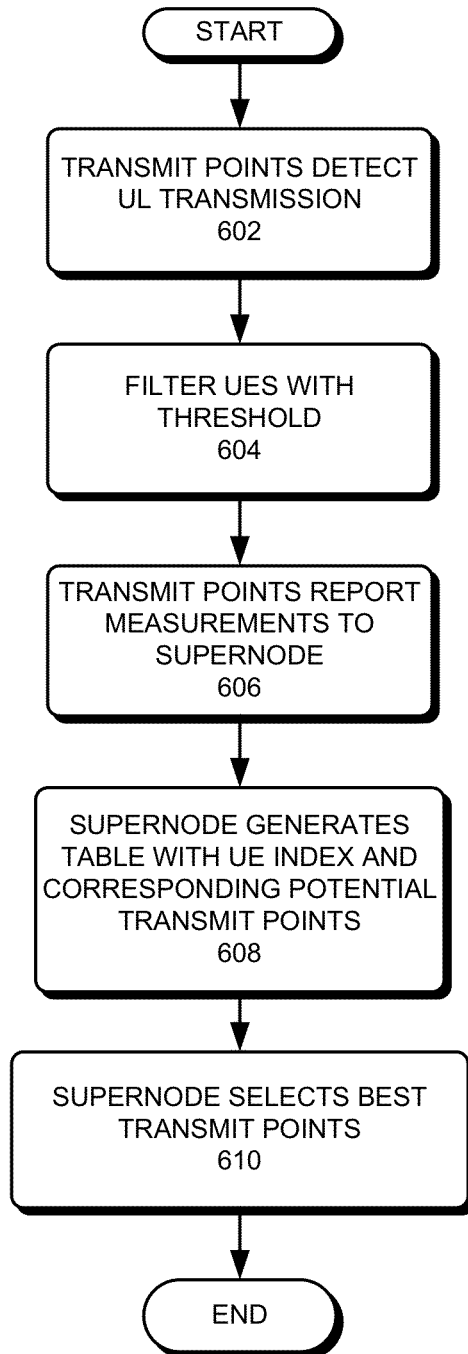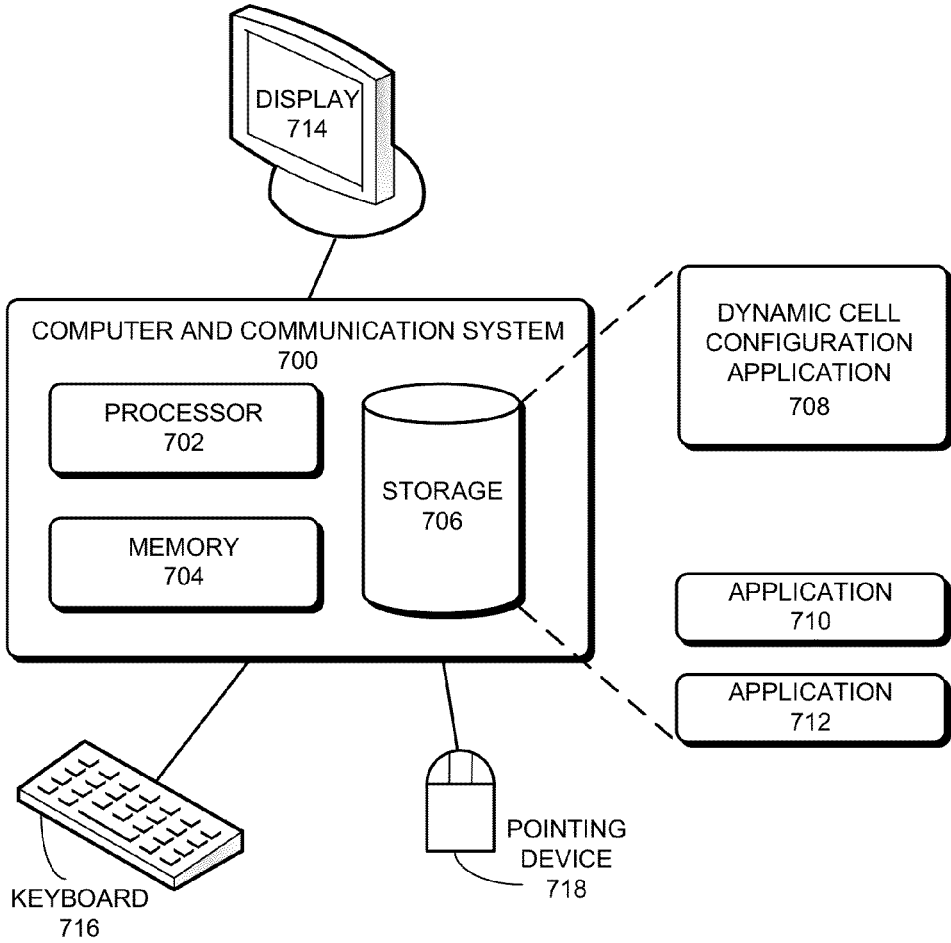716

POINTING
DEVICE
718

FIG. 7

METHOD AND SYSTEM FOR DYNAMIC CELL CONFIGURATION

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

More than one reissue application has been filed for the reissue of U.S. Pat. No. 8,838,119 issued Sep. 16, 2014; the present application is an application for reissue of U.S. Pat. No. 8,838,119, and is a continuation of U.S. patent application Ser. No. 15/261,269 filed Sep. 9, 2016, which also is an application for reissue of U.S. Pat. No. 8,838,119; the present application also is related to U.S. patent application Ser. No. 15/995,803 filed Jun. 4, 2018, Ser. No. 15/996,238 filed Jun. 1, 2018, Ser. No. 16/000,228 filed Jun. 1, 2018, Ser. No. 15/996,239 filed Jun. 1, 2018, Ser. No. 15/996,067 filed Jun. 1, 2018, Ser. No. 15/997,230 filed Jun. 4, 2018, Ser. No. 15/997,280 filed Jun. 4, 2018, Ser. No. 15/997,317 filed Jun. 4, 2018, Ser. No. 15/996,118 filed Jun. 1, 2018, Ser. No. 15/996,242 filed Jun. 1, 2018, and Ser. No. 15/996,228 filed Jun. 5, 2018, all of which are applications for reissue of U.S. Pat. No. 8,838,119 and continuations of U.S. patent application Ser. No. 15/261,269, which also is an application for reissue of U.S. Pat. No. 8,838,119.

BACKGROUND

1. Field

This disclosure is generally related to improving performance of cellular networks. More specifically, this disclosure is related to a method and system for dynamically generating and adapting hyper cells in response to network conditions. Various embodiments are also related to selecting optimal transmit points for virtual channels.

2. Related Art

In traditional cellular networks, the location of each transmit point is carefully planned. Each transmit point creates a cell and is assigned a unique cell identifier (ID) to define the control channel and data channel so that simultaneous transmit point to user equipment (UE) communications can be supported for each cell. A single cell serves each UE, and the network maintains the association between the cell and the UE until handover is triggered.

As the demand on mobile broadband increases, networks are deployed more densely and heterogeneously with a greater number of base stations. Cells become smaller and a corresponding greater number of cell edges are created. Cell ID assignment becomes more difficult and the frequency of handovers increases as the UE moves between cells. Further, the density of the cells creates much interference between neighboring cells.

In one approach, LTE Coordinated Multipoint (CoMP) scenario 4 specifies that one or more remote radio heads (RRHs) share a same cell ID as a macro cell to which the RRHs are connected. However, LTE CoMP scenario 4 (available at http://www.3gpp.org/ftp/Specs/html-info/36819.htm) only allows fixed sharing of a single cell ID between a macro cell and all RRHs controlled by it. There is handover and changing of the cell ID when the user moves away from the macro cell and the connected RRHs. Such an

approach is insufficient for addressing the problems of interference, complex cell ID assignment, and frequent handovers.

SUMMARY

One embodiment of the present invention provides a system for adapting hyper cells in response to changing conditions of a cellular network. During operation, the system collects data regarding network conditions of the cellular network; in accordance with the collected data, determines that a transmit point is to be added to a first hyper cell, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and changes an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID.

Another embodiment of the present invention provides a system for transmitting virtual channels in a cellular network. The system includes a virtual channel transmission mechanism configured to select one or more transmit points from a set of transmit points to transmit a virtual dedicated control channel and/or a virtual data channel to a serviced UE, wherein the one or more transmit points share a common cell ID; and wherein one or more transmission schemes of the virtual data channel and virtual dedicated control channel, including scrambling, pilot design, and/or pilot sequence and location, are created in accordance with a UE ID.

A further embodiment of the present invention provides a method for transmitting virtual channels in a cellular network. The method includes selecting one or more transmit points from a set of transmit points to transmit a virtual dedicated control channel and/or a virtual data channel to a serviced user equipment (UE), wherein the one or more transmit points share a common cell ID; and wherein one or more transmission schemes of the virtual data channel and virtual dedicated control channel, including scrambling, pilot design, and/or pilot sequence and location, are created in accordance with a UE ID.

A further embodiment of the present invention provides a method for adapting hyper cells in response to changing conditions of a cellular network. The method includes collecting data regarding network conditions of the cellular network; in accordance with the collected data, determining that a transmit point is to be added to a first hyper cell, wherein the first hyper cell includes at least one transmit point associated with a first cell ID; and changing an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1A illustrates an exemplary CRAN communication system from which hyper cells may be generated, in accordance with an embodiment of the present invention.

FIG. 1B illustrates two hyper cells with a shared transmit point, in accordance with an embodiment of the present invention.

FIG. 2 presents a diagram illustrating an example of how to create hyper cells in a CRAN cluster, in accordance with an embodiment of the present invention.

FIG. 3 presents a diagram of an example hyper cell with multiple virtual data channels, in accordance with an embodiment of the present invention.

FIG. 4 presents a diagram illustrating an exemplary downlink (DL) control channel design, in accordance with an embodiment of the present invention.

FIG. 5 and FIG. 6 each present a flow chart illustrating a process of selecting transmit points for a virtual data channel and/or a virtual dedicated control channel, in accordance with an embodiment of the present invention.

FIG. 7 illustrates an exemplary computing system for enabling dynamic hyper cell configuration, in accordance with an embodiment of the present invention.

In the figures, like reference numerals refer to the same figure elements.

DETAILED DESCRIPTION

The following description is presented to enable any person skilled in the art to make and use the embodiments, and is provided in the context of a particular application and its requirements. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present disclosure. Thus, the present invention is not limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

Overview

Embodiments of the present invention solve the problems of excessive interference and management overhead in cellular networks by introducing the concept of "hyper cell" and dynamically managing hyper cells to eliminate cell edge UEs and optimally selecting transmit points for UEs. A hyper cell is a virtual entity for dynamical coordination of data and control signaling transmission. It is a logic cell and the coverage of the hyper cell can change depending on the hyper cell's association to the physical transmit point(s). From the perspective of network, a hyper cell includes a group of transmit points which have relatively strong interference and are connected via high capacity backhaul. From the perspective of a UE, a hyper cell is an area covered by a virtual access entity.

A dynamic cell configuration system disassociates the concept of cell IDs from the physical topology of the cellular network, which facilitates greater flexibility and efficiency in network management. By breaking the bind between the cell ID and the physical transmitter, the system can generate hyper cells that include multiple transmit points having the same cell ID. The system adapts the hyper cells according to network topology, load distribution, and UE distribution. This reduces the frequency of handovers and amount of interference. The system can also share transmit points between multiple hyper cells by switching the transmit point between the hyper cells. This hyper cell configuration reduces the number of cell edge UEs, reduces interference, and improves the UE transition between hyper cells. The system can further select optimal transmit points within the hyper cells to boost the capacity of virtual channels. In addition, the virtual control channels and virtual data channel can be de-coupled for optimal performance.

Network Environment

A cloud radio access network (CRAN) cluster consolidates all basic processing power of a cellular network. The CRAN manages a group of transmit points that are connected together with a high-speed backhaul network. A CRAN central processing unit performs the processing for the multiple transmit points. This brings the network intelligence into the cloud, leaving only the radios and antennas

at the transmission site. By centralizing all the active electronics of multiple cell sites at one location, the operating costs are minimized.

In one embodiment, in a CRAN cluster, a supernode generates a hyper cell by assigning the same cell ID to one or more transmit point(s) which have the strongest mutual inter-cell interference. The supernode may estimate inter-cell interference based on UE reports or the measurement at transmit points. A supernode can be a base station, computing station, or controller configured to generate and manage hyper cells. The supernode can manage baseband signal processing of all transmit points controlled by the supernode. In some implementations, the supernode can also be responsible for only part of signal processing, depending on backhaul capability.

The cell ID is a logical assignment to all physical transmit points of the hyper cell. The hyper cell may be dynamically configured. Unlike traditional cellular networks, there is no fixed one-to-one mapping relation between a transmit point and a cell ID. The area served by the hyper cell is amorphous and the system dynamically adds/removes transmit points to/from the hyper cell.

In one embodiment, the system supports overlapped hyper cells where a transmit point can be logically associated with different hyper cells. For the transmitters that are physically located at the boundary of hyper cells, logically the network associates the transmit point with different hyper cells at different points in time, frequency, or space. The hyper cells may share the resources of the transmit point. A shared transmit point can reduce interference for UEs located at the boundary between the two sharing hyper cells. UEs that are located near the boundaries of two hyper cells experience less handovers because the shared transmit point is associated with either hyper cell at different times, frequencies or spatial directions. Further, as a UE moves between the two hyper cells, the transition is a smoother experience for the user. In one embodiment, the network changes the cell ID of the transmit point to transition a user moving between hyper cells.

Embodiments of the present invention also facilitate virtual channels which allow for greater scheduling flexibility, increased data and control channel capacity, energy savings, and improved mobility management. Subsequent sections of this disclosure discuss five aspects of virtual channels and/or hyper cells in greater detail. These five aspects are: virtual data channels, broadcast common control channel and virtual dedicated control channel, transmit point optimization, UE-centric channel sounding and measurement, and single frequency network (SFN) synchronization. The virtual data channel, broadcast common control channel, virtual dedicated control channel, and/or synchronization channel can also be implemented separate from the hyper cells.

In one embodiment, the supernode is a part of a system that manages all aspects of hyper cells and virtual channels. The system can also include a hyper transceiver to enable joint scheduling and joint transmission for a hyper cell. Each hyper cell supports a single centralized data plane and a single centralized control plane. In one embodiment, a CRAN subcluster supernode or CRAN cluster supernode generates the virtual data channels, broadcast common control channel and virtual dedicated control channels of the hyper cell.

CRAN Communication System

FIG. 1A illustrates an exemplary CRAN communication system 100 from which hyper cells may be generated, in accordance with an embodiment of the present invention. Generally, the system 100 enables multiple wireless users to

transmit and receive data and other content. The system **100** may implement one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), or single-carrier FDMA (SC-FDMA). Although FIG. 1A illustrates an example architecture for hyper cells, embodiments of the invention are not limited to a particular architecture. Other network architectures for hyper cells are also possible. For example, any network architecture where transmit points in the network are controlled by one or more supernodes with centralized signal processing capability can also work with hyper cells.

In this example, communication system **100** includes user equipment (UE) **110a-110c**, transmit points **130a-130b**, two access units **170a-170b**, a core network **132**, a public switched telephone network (PSTN) **140**, the Internet **150**, and other networks **160**. While certain numbers of these components or elements are shown in FIG. 1A, any number of these components or elements may be included in the system **100**.

The UEs **110a-110c** are configured to operate and/or communicate in the system **100**. For example, the UEs **110a-110c** are configured to transmit and/or receive wireless signals. Each UE **110a-110c** represents any suitable end user device and may include such devices (or may be referred to) as a user device, wireless transmit/receive unit (WTRU), mobile station, fixed or mobile subscriber unit, pager, cellular telephone, personal digital assistant (PDA), smartphone, laptop, computer, touchpad, wireless sensor, or consumer electronics device.

Access units **170a**, **170b** can each be a base station controlling transmitters or a controller controlling multiple base stations. A base station can control multiple transmitters. Transmit points **130a**, **130b** can be any type of transmitter. The transmitters can be, for example, mobile-relay station, base station transmitter, pico transmitter, or femto transmitter. The transmitters can be remote radio heads (RRHs) in some implementations. The transmit points can also be base stations controlled by a controller. In some embodiments, multiple-input multiple-output (MIMO) technology may be employed having multiple transceivers for each cell.

Each access unit **170a-170b** is configured to wirelessly interface with one or more of the UEs **110a-110c** to enable access to the core network **132**, the PSTN **140**, the Internet **150**, and/or the other networks **160**. In various embodiments, the access units **170a-170b** (or transmit points **130a**, **130b**) may also include (or be) one or more of several well-known devices, such as a base transceiver station (BTS), a Node-B (NodeB), an evolved NodeB (eNodeB), a Home NodeB, a Home eNodeB, a site controller, an access point (AP), or a wireless router. One or more Node-B may be controlled by radio network controllers.

In an embodiment, CRAN systems can include a base station or a centralized node controlling one or more RRHs. Base stations can implement MAC/PHY and antenna array system (AAS) functionality. Each base station operates to transmit and/or receive wireless signals within a particular geographic region or area. For example, access units **170a-170b** can be base stations and, through remote radio heads, may communicate with one or more of the UEs **110a-110c** over one or more air interfaces using wireless communication links. The air interfaces may utilize any suitable radio access technology.

A RRH contains the radio frequency circuitry plus analog-to-digital/digital-to-analog converters and up/down convert-

ers. The RRHs are located between a base station and the UEs, and are connected to a base station using optical fiber or any other communication line. The RRHs receive and convert digital signals to analog, then amplifies the power and sends the radio frequency signals.

It is contemplated that the system **100** may use multiple channel access functionality, including such schemes as described above. In particular embodiments, the base stations and UEs implement LTE, LTE-A, and/or LTE-B. Of course, other multiple access schemes and wireless protocols may be utilized.

Each of the access units **170a**, **170b** are in communication with the core network **132** to provide the UEs **110a-110c** with voice, data, application, Voice over Internet Protocol (VoIP), or other services. The access units and/or the core network **132** may be in direct or indirect communication with one or more other access units (not shown). The core network **132** may also serve as a gateway access for other networks (such as PSTN **140**, Internet **150**, and other networks **160**). In addition, some or all of the UEs **110a-110c** may include functionality for communicating with different wireless networks over different wireless links using different wireless technologies and/or protocols.

Each of the example transmit points **130a-130b**, or any combination of the illustrated transmit points, may be assigned a common cell ID and form a hyper cell. Hyper cells are discussed in greater detail with respect to FIG. 1B.

Although FIG. 1A illustrates one example of a CRAN communication system **100** from which hyper cells may be generated, various changes may be made to FIG. 1A. For example, CRAN communication system **100** could include any number of UEs, base stations, supernodes, networks, or other components in any suitable configuration. Also, the techniques described herein can be used in any other suitable system.

Hyper Cell Examples

FIG. 1B illustrates two hyper cells with a shared transmit point, in accordance with an embodiment of the present invention. Hyper cells **182**, **184** each includes many transmit points that are assigned the same logical cell ID. For example, hyper cell **182** includes transmit points **186**, **187**, **188**, **189**, **190**, and **192**. Transmit points **190**, **192** communicates with UE **194**. Transmit point **196** is assigned to hyper cells **182**, **184** at different times, frequencies or spatial directions and the system switches the logical cell ID for transmit point **196** between the two hyper cells. In one embodiment, a system dynamically updates the hyper cell topology to adapt to changes in network topology, load distribution, and/or UE distribution. The system may include a data collector to collect data regarding network conditions of the cellular network. If the concentration of UEs increases in one region, the system may dynamically expand the hyper cell to include transmit points near the higher concentration of UEs. For example, the system may expand hyper cell **182** to include other transmit points if the concentration of UEs located at the edge of the hyper cell increases above a certain threshold. As another example, the system may expand hyper cell **182** to include a greater concentration of UEs located between two hyper cells. Also, if the traffic load increases significantly at one region, the system may also expand the hyper cell to include transmit points near the increased traffic load. For example, if the traffic load of a portion of the network exceeds a predetermined threshold, the system may change the cell IDs of one or more transmit points that are transmitting to the impacted portion of the cellular network.

Further, the system may change the cell ID associated with transmit point **196** from the cell ID of hyper cell **182** to the cell ID of hyper cell **184**. In one implementation, the system can change the association of a transmit point with different hyper cells every 1 millisecond. With such a flexible cell formation mechanism, all UEs can be served by the best transmit points so that virtually there are no cell edge UEs.

In one embodiment, the system may also save power by turning off silent transmit points (e.g., any transmit point other than transmit points **190, 192**) if there are no UEs to service for those silent transmit points. The system can also save power by turning off transmit points according to some criteria (e.g., turn off those that are serving less than a threshold number of UEs).

FIG. **2** presents a diagram illustrating an example of how to create hyper cells in a CRAN cluster, in accordance with an embodiment of the present invention. A CRAN cluster **202** includes a number of individual cells, such as cell **204**. Without hyper cells, the CRAN network can only assign each transmit point a unique cell ID to form the individual cells. To create a hyper cell, the system assigns a common cell ID to all the cells of the CRAN cluster that form the hyper cell. In one embodiment, the network may create multiple hyper cells within a CRAN cluster. Each hyper cell has a unique cell ID.

FIG. **2** also illustrates exemplary optimal transmit points for facilitating a virtual data channel and virtual dedicated control channel for UE **206**. The three transmit points **208, 210**, and **212** are optimally situated to transmit the virtual channels to UE **206**. The three transmit points form a virtual transmit point. The system can dynamically combine multiple physical transmitters to form a virtual transmit point. From the perspective of a UE, the virtual transmit points appear to be a single transmitter. The system can create many virtual transmit points for a hyper cell and coordinate their transmissions. The system can dynamically change the physical transmitters that make up the hyper cell. Determining optimal transmit points is further discussed with respect to FIG. **5** and FIG. **6**.

Virtual Data Channels

FIG. **3** presents a diagram of an example hyper cell with multiple virtual data channels, in accordance with an embodiment of the present invention. The system can support multiple parallel data channels within a single hyper cell, each serving a different UE. In other words, each virtual data channel is UE-specific. The hyper cell may have multiple different physical transmit points transmitting to create the virtual data channels. The actual physical transmit points of the virtual data channels are also UE-specific and are transparent to each UE. A UE distinguishes virtual data channel signals by examining the UE ID associated with each transmission. The data transmission schemes, including data scrambling, pilot design, and pilot sequence and location, are all created in accordance with the UE ID.

As the UEs move to different locations, the system dynamically assigns different physical transmit points to service the UEs. The physical transmit points form the virtual data channels for the respective serviced UEs. Note that the cell ID transmitted from the different physical transmit points belonging to the same hyper cell remains the same. As illustrated in FIG. **3**, an example hyper cell **300** has three virtual data channels, one for each UE. Three transmit points **302, 304, 306** provide a virtual data channel for UE **307**, two transmit points **302, 304** provide a virtual data channel for UE **309**, and two transmit points **308, 310** provide a virtual data channel for UE **311**. Transmit points

312, 314 are silent and may be turned off to save energy. The description associated with FIG. **5** and FIG. **6** discusses additional details of various embodiments for optimally selecting transmit points.

In one embodiment, with the CRAN framework, the supernode controls the generation of the virtual data channels based on load balancing and UE distribution within a CRAN cluster. A CRAN cluster can support multiple parallel virtual data channels.

Broadcast Common Control Channel/Virtual Dedicated Control Channel

FIG. **4** presents a diagram illustrating an exemplary downlink (DL) control channel design, in accordance with an embodiment of the present invention. The system provides for a broadcast common control channel and a virtual dedicated control channel. A broadcast common control channel **402** carries common system configuration information transmitted by all or partial transmit points sharing the same cell ID. Every UE can decode information from the broadcast common control channel **402** in accordance with a common reference signal (CRS). The CRS sequence and location are tied to the cell ID of the hyper cell.

A virtual dedicated control channel **404** carries UE-specific control information (e.g., DL scheduling, uplink (UL) grant). Each of UEs **406, 408** has a subset of transmit points surrounding the UE. The transmit points transmit the UE-specific virtual dedicated control channels **410, 412**. Virtual dedicated control channel **410** is specific to UE **406**, and virtual dedicated control channel **412** is specific to UE **408**. In some embodiments, one or more transmission schemes of the virtual data channel and/or the virtual dedicated control channel, including scrambling, pilot design, and/or pilot sequence and location, are created in accordance with a UE ID. Further, a hyper cell ID can be applied together with the UE ID to differentiate transmission of the virtual data channel and/or virtual control channel from different hyper cells.

Parallel virtual dedicated control channels can be provided in each hyper cell. The demodulation of each virtual dedicated control channel is performed in accordance with a UE-specific reference signal (RS), the sequence and location of which are linked to the UE ID. To distinguish the virtual dedicated control channels communicated from different hypercells, the sequence of UE-specific RS is covered by a sequence specific to each hyper cell.

The system may apply transmit point selection techniques and transmit power control techniques to minimize intra-hyper cell interference and inter-hyper cell interference. The selected transmit points are transparent to the UEs. In one embodiment, for a UE with a poor Signal to Interference plus Noise Ratio (SINR), the system can transmit the virtual dedicated control channel and/or virtual data channel from multiple transmit points to improve signal quality. In addition, the system may apply Transmit Time Interval (TTI) bundling to a fixed or slow moving UE in order to further enhance the capacity of the UE-specific virtual dedicated control channel.

Selecting Transmit Points for Virtual Channels

FIG. **5** and FIG. **6** each present a flow chart illustrating a process of selecting transmit points for a virtual data channel and/or a virtual dedicated control channel, in accordance with an embodiment of the present invention. A virtual channel transmission mechanism can be configured to select one or more transmit points from a set of transmit points to transmit a virtual dedicated control channel and/or a virtual data channel to a serviced UE. For each UE, there are two techniques for selecting the optimal transmit points for the

virtual data channel and the virtual dedicated control channel. The selection processes attempt to maximize the capacity of the UE-specific virtual dedicated control channel and virtual data channel. FIG. **5** presents a UE-centric technique for selecting the transmit points. FIG. **6** presents a network-centric technique for selecting the transmit points. The transmit points for a virtual data channel can be different from the transmit points for a virtual dedicated control channel, for the same UE. The selected transmit points are transparent to the UE.

During operation of the technique illustrated in FIG. **5**, each of the transmit points sends a DL sounding reference signal (SRS) (operation **502**) as a training sequence. In one embodiment, different transmit points transmit the DL SRS at different frequencies or at different times. After receiving the DL SRS, the UE measures the signal strength of each DL SRS (operation **504**). The UE reports the measurement results to the supernode (operation **506**). The supernode generates a table with a UE index and corresponding potential transmit points (operation **508**). The supernode selects the best transmit points to all served UEs based on the table and the status of network load distribution and UE distribution (operation **510**). In one embodiment, the supernode compares the reported measurement results to previous DL SRS transmissions to determine the best transmit points for each of the UEs.

During operation of the technique illustrated in FIG. **6**, each transmit point detects a UL transmission from a UE within the transmit point's coverage range. The transmissions may be for any data, including any one of a sounding channel, control channel and/or data channel data (operation **602**). The transmit points measure the strength of the UE signals. The transmit point may filter UEs with insufficient signal strength (operation **604**). Each transmit point reports measurements of the detected UL transmissions to the supernode (operation **606**). The supernode generates a table with the UE index and corresponding potential transmit points (operation **608**). In one embodiment, the supernode populates the table with UEs and the strength of signals received by the transmit points. The supernode selects the optimal transmit points for all served UEs based on the generated table and on the status of network load and UE distribution (operation **610**).

In one embodiment, to maintain the transparency of the transmit points in each hyper cell, demodulation of the virtual channels is not tied to the transmit points. In one implementation, the system uses the UE ID to bootstrap all communications between the UE and the transmit points. The system distinguishes between the transmission signals of different UEs with a UE-centric reference signal. The system uses a UE-centric demodulation reference signal (DMRS) to decode the virtual dedicated data channel and the virtual dedicated control channel. The system defines the sequence and location of the UE-centric DMRS with the UE index. The system automatically generates each UE index from a respective UE ID or assigns the UE index. Each UE has a unique UE index.

Each hyper cell is associated with a synchronization channel. All or a portion of transmit points in a hyper cell can transmit the synchronization channel. In one embodiment, a transmit point belonging to multiple hyper cells does not transmit the synchronization channel. In another embodiment, frequency division multiplexing (FDM), code division multiplexing (CDM), or time division multiplexing (TDM) can be applied to enable synchronization channel transmission for transmit points associated with multiple hyper cells.

FIG. **7** illustrates an exemplary computing system for enabling dynamic hyper cell configuration, in accordance with an embodiment of the present invention. In one embodiment, a computing and communication system **700** includes a processor **702**, a memory **704**, and a storage device **706**. Storage device **706** stores a dynamic hyper cell configuration application **708**, as well as other applications, such as applications **710** and **712**. During operation, application **708** is loaded from storage device **706** into memory **704** and then executed by processor **702**. While executing the program, processor **702** performs the aforementioned functions. Computing and communication system **700** is coupled to an optional display **714**, keyboard **716**, and pointing device **718**.

The data structures and code described in this detailed description are typically stored on a machine-readable storage medium, which may be any device or medium that can store code and/or data for use by a computing system. The machine-readable storage medium includes, but is not limited to, volatile memory, non-volatile memory, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact discs), DVDs (digital versatile discs or digital video discs), or other media capable of storing machine-readable media now known or later developed.

The methods and processes described in the detailed description section can be embodied as code and/or data, which can be stored in a machine-readable storage medium as described above. When a computing system reads and executes the code and/or data stored on the machine-readable storage medium, the computing system performs the methods and processes embodied as data structures and code and stored within the machine-readable storage medium.

Furthermore, methods and processes described herein can be included in hardware modules or apparatus. These modules or apparatus may include, but are not limited to, an application-specific integrated circuit (ASIC) chip, a field-programmable gate array (FPGA), a dedicated or shared processor that executes a particular software module or a piece of code at a particular time, and/or other programmable-logic devices now known or later developed. When the hardware modules or apparatus are activated, they perform the methods and processes included within them. Such modules or apparatuses may form part of base stations or supernode machines that manage and enable hyper cells and/or virtual channels or other various features described herein.

An embodiment method for adapting hyper cells in response to changing conditions of a cellular network comprises collecting data regarding network conditions of the cellular network; in accordance with the collected data, determining that a transmit point is to be added to a first hyper cell, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and changing an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID.

Optionally, in the embodiment method, the network conditions include load distribution, and the method further comprises determining that a traffic load of a portion of the cellular network exceeds a predetermined threshold; and changing cell IDs of one or more transmit points transmitting to the portion of the cellular network.

Optionally, in the embodiment method, the network conditions include UE distribution across the network, and the method further comprises determining that a concentration of user equipments (UEs) serviced by the cellular network at a boundary of the first hyper cell is above a predetermined

11

12

threshold; and changing cell IDs of one or more transmit points to the cell ID of the first hyper cell, wherein the one or more transmit points transmit to the boundary of the first hyper cell.

Optionally, the embodiment method further comprises determining that a second transmit point serves less than a threshold number of UEs; and turning off the second transmit point in response to determining that the second transmit point is serving less than the threshold number of UEs.

An embodiment apparatus for adapting hyper cells in response to changing conditions of a cellular network comprises at least one collector configured to collect data regarding network conditions of the cellular network; at least one processing unit configured to: determine that a transmit point is to be added to a first hyper cell in accordance with the collected data, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and change an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID.

Optionally, in the embodiment apparatus, the network conditions include load distribution, and the at least one processing unit is configured to determine that a traffic load of a portion of the cellular network exceeds a predetermined threshold; and change cell IDs of one or more transmit points transmitting to the portion of the cellular network.

Optionally, in the embodiment apparatus the network conditions include user equipment (UE) distribution across the network, and the at least one processing unit is configured to determine that a concentration of UEs serviced by the cellular network at a boundary of the first hyper cell is above a predetermined threshold; and change cell IDs of one or more transmit points to the cell ID of the first hyper cell, wherein the one or more transmit points transmit to the boundary of the first hyper cell.

Optionally, in the embodiment apparatus the at least one processing unit is configured to determine that a second transmit point serves less than a threshold number of UEs; and turn off the second transmit point in response to determining that the second transmit point is serving less than the threshold number of UEs.

Optionally, in the embodiment apparatus the apparatus is a base station controlling one or more remote radio heads and the base station is adapted to dynamically change one or more cell identifier (ID) in response to changing network conditions, wherein the base station is connected to each of the one or more remote radio heads via a communication line; the one or more remote radio heads are adapted to receive and transmit radio frequency signals; the base station includes a data collector configured to collect data regarding network conditions of the cellular network; and the base station includes at least one processing unit configured to determine that a transmit point is to be added to a first hyper cell in accordance with the collected data, wherein the first hyper cell includes at least one transmit point associated with a first cell ID; and change an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID, and wherein the transmit point is a remote radio head.

Although the present invention has been described with reference to specific features and embodiments thereof, it is evident that various modifications and combinations can be made thereto without departing from the spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded simply as an illustration of the inven-

tion as defined by the appended claims, and are contemplated to cover any and all modifications, variations, combinations or equivalents that fall within the scope of the present invention.

What is claimed is:

[1. A method for adapting hyper cells in response to changing conditions of a cellular network, the method comprising:

collecting data regarding network conditions of the cellular network, the cellular network utilizing a wireless protocol;

in accordance with the collected data, determining that a first transmit point associated with a second hyper cell utilizing the wireless protocol is to be added to a first hyper cell utilizing the wireless protocol, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and

changing an association of the first transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of the second hyper cell is associated with the second cell ID.]

[2. The method of claim 1, wherein the network conditions include load distribution, and wherein the method further comprises:

determining that a traffic load of a portion of the cellular network exceeds a predetermined threshold; and

changing cell IDs of one or more transmit points transmitting to the portion of the cellular network.]

[3. The method of claim 1, wherein the network conditions include UE distribution across the network, and wherein the method further comprises:

determining that a concentration of user equipments (UEs) serviced by the cellular network at a boundary of the first hyper cell is above a predetermined threshold; and

changing cell IDs of one or more transmit points to the cell ID of the first hyper cell, wherein the one or more transmit points transmit to the boundary of the first hyper cell.]

[4. The method of claim 1, further comprising:

determining that a second transmit point serves less than a threshold number of UEs; and

turning off the second transmit point in response to determining that the second transmit point is serving less than the threshold number of UEs.]

[5. An apparatus for adapting hyper cells in response to changing conditions of a cellular network, the apparatus comprising:

at least one collector configured to collect data regarding network conditions of the cellular network, the cellular network configured to utilize a wireless protocol;

at least one processing unit configured to:

determine that a first transmit point associated with a second hyper cell utilizing the wireless protocol is to be added to a first hyper cell utilizing the wireless protocol in accordance with the collected data, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and

change an association of the first transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of the second hyper cell is associated with the second cell ID.]

[6. The apparatus of claim 5, wherein the network conditions include load distribution, and the at least one processing unit is configured to:

determine that a traffic load of a portion of the cellular network exceeds a predetermined threshold; and

change cell IDs of one or more transmit points transmitting to the portion of the cellular network.]

[7. The apparatus of claim **5**, wherein the network conditions include user equipment (UE) distribution across the network, and the at least one processing unit is configured to:

determine that a concentration of UEs serviced by the cellular network at a boundary of the first hyper cell is above a predetermined threshold; and

change cell IDs of one or more transmit points to the cell ID of the first hyper cell, wherein the one or more transmit points transmit to the boundary of the first hyper cell.]

[8. The apparatus of claim **5**, wherein the at least one processing unit is configured to:

determine that a second transmit point serves less than a threshold number of UEs; and

turn off the second transmit point in response to determining that the second transmit point is serving less than the threshold number of UEs.]

[9. An apparatus for adapting hyper cells in response to changing conditions of a cellular network, the apparatus comprising:

at least one collector configured to collect data regarding network conditions of the cellular network;

at least one processing unit configured to:

determine that a transmit point is to be added to a first hyper cell in accordance with the collected data, wherein the first hyper cell includes at least one transmit point associated with a first cell identifier (ID); and

change an association of the transmit point from a second cell ID to the first cell ID, wherein at least one transmit point of a second hyper cell is associated with the second cell ID,

wherein the apparatus is a base station controlling one or more remote radio heads and wherein the base station is adapted to dynamically change one or more cell identifier (ID) in response to changing network conditions, wherein:

the base station is connected to each of the one or more remote radio heads via a communication line; and

the one or more remote radio heads are adapted to receive and transmit radio frequency signals, and wherein the transmit point is a remote radio head.]

10. A network system, comprising:

a base station associated with a first hyper cell and a second hyper cell, wherein the first hyper cell comprises a first plurality of base stations including the base station and sharing a first cell identifier (ID), and the second hyper cell comprises a second plurality of base stations including the base station and sharing a second cell ID,

the base station associated with the first hyper cell and the second hyper cell configured to:

transmit a first synchronization channel associated with the first hyper cell in the first hyper cell to a first user equipment (UE); and

transmit a second synchronization channel associated with the second hyper cell in the second hyper cell to a second UE, the first synchronization channel associated with the first hyper cell and the second synchronization channel associated with the second hyper cell being carried in a single frequency network by applying frequency division multiplexing (FDM).

11. The network system of claim 10, wherein the base station is located in an overlapped coverage area of the first hyper cell and the second hyper cell.

12. The network system of claim 10, wherein the base station is assigned to the first hyper cell and the second hyper cell at different times, frequencies, or spatial directions.

13. The network system of claim 10, wherein a resource of the base station is shared by the first hyper cell and the second hyper cell.

14. The network system of claim 10, wherein the first cell ID is unique to the first hyper cell, and the second cell ID is unique to the second hyper cell.

15. A method, comprising:

transmitting, by a base station in a network system, a first synchronization channel associated with a first hyper cell in the first hyper cell to a first user equipment (UE), the base station associated with the first hyper cell and a second hyper cell, wherein the first hyper cell comprises a first plurality of base stations including the base station and sharing a first cell identifier (ID), and the second hyper cell comprises a second plurality of base stations including the base station and sharing a second cell ID; and

transmitting, by the base station, a second synchronization channel associated with the second hyper cell in the second hyper cell to a second UE, the first synchronization channel associated with the first hyper cell and the second synchronization channel associated with the second hyper cell being carried in a single frequency network by applying frequency division multiplexing (FDM).

16. The method of claim 15, wherein the base station is located in an overlapped coverage area of the first hyper cell and the second hyper cell.

17. The method of claim 15, wherein the base station is assigned to the first hyper cell and the second hyper cell at different times, frequencies, or spatial directions.

18. The method of claim 15, wherein a resource of the base station is shared by the first hyper cell and the second hyper cell.

19. The method of claim 15, wherein the first cell ID is unique to the first hyper cell, and the second cell ID is unique to the second hyper cell.

20. A base station that is one of a first plurality of base stations of a first hyper cell and is one of a second plurality of base stations of a second hyper cell, the base station comprising:

at least one processor, wherein the at least one processor is configured to:

transmit a first synchronization channel associated with a the first hyper cell in the first hyper cell to a first user equipment (UE); and

transmit a second synchronization channel associated with the second hyper cell in the second hyper cell to a second UE, the first synchronization channel associated with the first hyper cell and the second synchronization channel associated with the second hyper cell being carried in a single frequency network by applying frequency division multiplexing (FDM),

wherein the base station shares a first cell identifier (ID) with other base stations of the first plurality of base stations, and wherein the base station shares a second cell ID with other base stations of the second plurality of base stations.

21. The base station of claim 20, wherein the base station is located in an overlapped coverage area of the first hyper cell and the second hyper cell.

22. The base station of claim 20, wherein the base station is assigned to the first hyper cell and the second hyper cell at different times, frequencies, or spatial directions.

23. The base station of claim 20, wherein a resource of the base station is shared by the first hyper cell and the second hyper cell.

24. The base station of claim 20, wherein the first cell ID is unique to the first hyper cell, and the second cell ID is unique to the second hyper cell.

25. A method, comprising:

receiving, by an apparatus from a base station in a network system, a first synchronization channel associated with a first hyper cell in the first hyper cell, the base station associated with the first hyper cell and a second hyper cell, wherein the first hyper cell comprises a first plurality of base stations including the base station and sharing a first cell identifier (ID), and the second hyper cell comprises a second plurality of base stations including the base station and sharing a second cell ID; and

receiving, by the apparatus from the base station, a second synchronization channel associated with the second hyper cell in the second hyper cell, the first synchronization channel associated with the first hyper cell and the second synchronization channel associated with the second hyper cell being carried in a single frequency network by applying frequency division multiplexing (FDM).

26. The method of claim 25, wherein the base station is located in an overlapped coverage area of the first hyper cell and the second hyper cell.

27. The method of claim 25, wherein the base station is assigned to the first hyper cell and the second hyper cell at different times, frequencies, or spatial directions.

28. The method of claim 25, wherein a resource of the base station is shared by the first hyper cell and the second hyper cell.

29. The method of claim 25, wherein the first cell ID is unique to the first hyper cell, and the second cell ID is unique to the second hyper cell.

30. An apparatus that is in a first hyper cell including a first plurality of base stations and in a second hyper cell including a second plurality of base stations, the apparatus comprising:

at least one processor, wherein the at least one processor is configured to:

receive, from a base station in a network system, a first synchronization channel associated with the first hyper cell in the first hyper cell; and

receive, from the base station, a second synchronization channel associated with the second hyper cell in the second hyper cell, the first synchronization channel associated with the first hyper cell and the second synchronization channel associated with the second hyper cell being carried in a single frequency network by applying frequency division multiplexing (FDM),

wherein the first plurality of base stations includes the base station, wherein the second plurality of base stations includes the base station, wherein the base station shares a first cell identifier (ID) with other base stations of the first plurality of base stations, and wherein the base station shares a second cell ID with other base stations of the second plurality of base stations.

31. The apparatus of claim 30, wherein the base station is located in an overlapped coverage area of the first hyper cell and the second hyper cell.

32. The apparatus of claim 30, wherein the base station is assigned to the first hyper cell and the second hyper cell at different times, frequencies, or spatial directions.

33. The apparatus of claim 30, wherein a resource of the base station is shared by the first hyper cell and the second hyper cell.

34. The apparatus of claim 30, wherein the first cell ID is unique to the first hyper cell, and the second cell ID is unique to the second hyper cell.

* * * * *