



US009271270B2

(12) **United States Patent**
Kuchibhotla et al.

(10) **Patent No.:** **US 9,271,270 B2**
(45) **Date of Patent:** **Feb. 23, 2016**

(54) **DOWNLINK CONTROL CHANNEL SIGNALING IN WIRELESS COMMUNICATION SYSTEMS**

(58) **Field of Classification Search**
None
See application file for complete search history.

(71) Applicant: **Google Technology Holdings LLC**,
Mountain View, CA (US)

(56) **References Cited**

(72) Inventors: **Ravi Kuchibhotla**, Gurnee, IL (US);
Brian K. Classon, Palatine, IL (US);
Robert T. Love, Barrington, IL (US);
Ravikiran Nory, Buffalo Grove, IL (US);
Philippe J. Sartori, Algonquin, IL (US);
Kenneth A. Stewart, Grayslake, IL (US);
Yakun Sun, Evanston, IL (US);
Anup K. Talukdar, Schaumburg, IL (US)

U.S. PATENT DOCUMENTS
5,177,739 A 1/1993 Basnuevo et al.
5,396,496 A 3/1995 Ito et al.
(Continued)

(73) Assignee: **Google Technology Holdings LLC**,
Mountain View, CA (US)

FOREIGN PATENT DOCUMENTS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 36 days.

EP 1379020 A1 1/2004
EP 1450505 B1 10/2008
(Continued)

(21) Appl. No.: **13/766,980**

OTHER PUBLICATIONS

(22) Filed: **Feb. 14, 2013**

Yaghoobi; Intel Technology Journal, vol. 08, Issue 03, Published, Aug. 20, 2004; ISSN 1535-864X; "Scalable OFDMA Physical Layer in IEEE 802.16 WirelessMAN"; p. 207.
(Continued)

(65) **Prior Publication Data**
US 2013/0156002 A1 Jun. 20, 2013

Primary Examiner — Otis L Thompson, Jr.
(74) *Attorney, Agent, or Firm* — Faegre Baker Daniels LLP

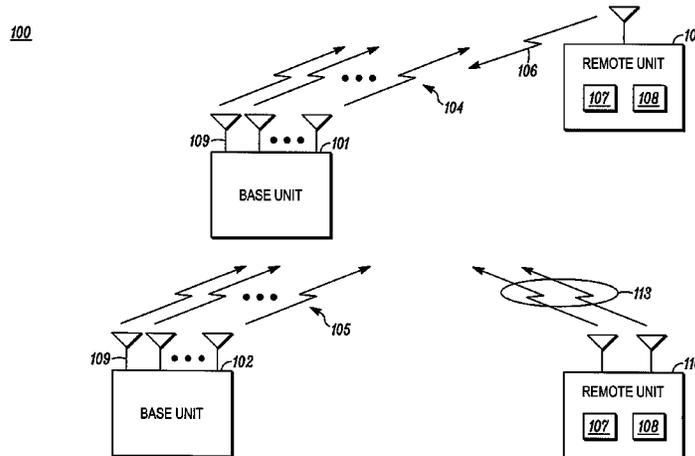
Related U.S. Application Data
(63) Continuation of application No. 11/466,720, filed on Aug. 23, 2006, now Pat. No. 8,400,998.

(57) **ABSTRACT**
A method in a wireless communication device may include receiving a plurality of sub-frames, each sub-frame having time-frequency resource elements, at least one of the sub-frames having a control channel. In some implementations, the plurality of sub-frames forms a continuum of concatenated sub-frames. Each of the plurality of resource allocation fields of the control channel may indicate a resource assignment to the wireless communication device based on a channel quality report, as well as resource assignments in sub-frames of the continuum of concatenated sub-frames. At least one sub-frame of the continuum of concatenated sub-frames may include information indicating that at least some of the resource assignments are frequency diverse.

(51) **Int. Cl.**
H04W 4/00 (2009.01)
H04W 72/04 (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04W 72/0406** (2013.01); **H04L 27/2608** (2013.01); **H04B 7/2615** (2013.01)

14 Claims, 3 Drawing Sheets



- (51) **Int. Cl.**
H04L 27/26 (2006.01)
H04B 7/26 (2006.01)
- (56) **References Cited**
- U.S. PATENT DOCUMENTS
- | | | | |
|--------------|-----|---------|-----------------------------------|
| 5,530,920 | A | 6/1996 | Takeda |
| 5,537,410 | A | 7/1996 | Li |
| 5,732,113 | A | 3/1998 | Schmidl et al. |
| 5,771,226 | A | 6/1998 | Kaku |
| 5,784,683 | A | 7/1998 | Sistanizadeh et al. |
| 5,796,726 | A | 8/1998 | Hassan et al. |
| 5,991,279 | A | 11/1999 | Haugli et al. |
| 6,064,662 | A | 5/2000 | Gitlin et al. |
| 6,115,354 | A | 9/2000 | Weck |
| 6,130,886 | A | 10/2000 | Ketseoglou et al. |
| 6,185,208 | B1 | 2/2001 | Liao |
| 6,192,070 | B1 | 2/2001 | Poon et al. |
| 6,275,990 | B1 | 8/2001 | Dapper et al. |
| 6,356,555 | B1 | 3/2002 | Rakib et al. |
| 6,535,550 | B1 | 3/2003 | Cole |
| 6,549,592 | B1 | 4/2003 | Jones |
| 6,567,416 | B1 | 5/2003 | Chuah |
| 6,813,284 | B2 | 11/2004 | Vayanos et al. |
| 6,827,590 | B2 | 12/2004 | Huss, Jr. et al. |
| 6,868,519 | B2 | 3/2005 | Beacken et al. |
| 6,876,675 | B1 | 4/2005 | Jones et al. |
| 6,885,630 | B2 | 4/2005 | Kostic et al. |
| 6,985,433 | B1 | 1/2006 | Laroia et al. |
| 7,139,239 | B2 | 11/2006 | McFarland |
| 7,142,888 | B2 | 11/2006 | Okawa et al. |
| 7,215,677 | B2 | 5/2007 | Lung |
| 7,302,014 | B1 | 11/2007 | Barsoum |
| 7,366,117 | B2 | 4/2008 | Kim et al. |
| 7,426,196 | B2 | 9/2008 | Gopalakrishnan et al. |
| 7,522,514 | B2 | 4/2009 | Tzannes et al. |
| 7,609,697 | B2 | 10/2009 | Nishida et al. |
| 2001/0017596 | A1 | 8/2001 | Strinnholm |
| 2002/0003773 | A1 | 1/2002 | Okada et al. |
| 2002/0031086 | A1 | 3/2002 | Welin |
| 2002/0075893 | A1 | 6/2002 | Gipson et al. |
| 2002/0118666 | A1 | 8/2002 | Stanwood et al. |
| 2002/0119781 | A1 | 8/2002 | Li et al. |
| 2002/0122395 | A1 | 9/2002 | Bourlas et al. |
| 2002/0126706 | A1 | 9/2002 | Laroia et al. |
| 2002/0157060 | A1 | 10/2002 | Beacken et al. |
| 2003/0026348 | A1 | 2/2003 | Llang et al. |
| 2003/0072255 | A1 | 4/2003 | Ma et al. |
| 2003/0090994 | A1 | 5/2003 | Kakura |
| 2003/0153276 | A1 | 8/2003 | Terry et al. |
| 2003/0171129 | A1 | 9/2003 | Sagne |
| 2003/0189918 | A1 | 10/2003 | Das et al. |
| 2003/0198179 | A1 | 10/2003 | Koo et al. |
| 2003/0202562 | A1 | 10/2003 | Cai |
| 2004/0037263 | A1 | 2/2004 | Zeira |
| 2004/0042492 | A1 | 3/2004 | Suzuki et al. |
| 2004/0047296 | A1 | 3/2004 | Tzannes et al. |
| 2004/0071222 | A1 | 4/2004 | Liang et al. |
| 2004/0082356 | A1 | 4/2004 | Walton et al. |
| 2004/0085934 | A1 | 5/2004 | Balachandran et al. |
| 2004/0087320 | A1 | 5/2004 | Kim et al. |
| 2004/0095907 | A1 | 5/2004 | Agee et al. |
| 2004/0116079 | A1 | 6/2004 | Kim et al. |
| 2004/0162075 | A1 | 8/2004 | Malladi et al. |
| 2004/0213145 | A1 | 10/2004 | Nakamura |
| 2005/0018754 | A1 | 1/2005 | Song |
| 2005/0030927 | A1 | 2/2005 | Mucke |
| 2005/0053088 | A1 | 3/2005 | Cheng et al. |
| 2005/0068973 | A1 | 3/2005 | Taffin et al. |
| 2005/0099936 | A1 | 5/2005 | Fujii et al. |
| 2005/0111397 | A1 | 5/2005 | Attar et al. |
| 2005/0135295 | A1 | 6/2005 | Walton et al. |
| 2005/0153276 | A1 | 7/2005 | Wikswow et al. |
| 2005/0232181 | A1 | 10/2005 | Park et al. |
| 2006/0007881 | A1 | 1/2006 | Kondo |
| 2006/0039409 | A1 | 2/2006 | Lampinen |
| 2006/0106600 | A1 | 5/2006 | Bessette |
| 2006/0176966 | A1 | 8/2006 | Stewart et al. |
| 2006/0187895 | A1 | 8/2006 | Nandagopalan |
| 2006/0245384 | A1 | 11/2006 | Talukdar et al. |
| 2007/0058595 | A1 | 3/2007 | Classon et al. |
| 2007/0064669 | A1 | 3/2007 | Classon et al. |
| 2007/0066362 | A1 | 3/2007 | Ma et al. |
| 2007/0133695 | A1 | 6/2007 | Kotzin |
| 2007/0159993 | A1* | 7/2007 | Classon et al. 370/319 |
| 2007/0211657 | A1 | 9/2007 | McBeath et al. |
| 2007/0214400 | A1 | 9/2007 | Smith et al. |
| 2007/0242653 | A1* | 10/2007 | Yang H04L 1/0006
370/342 |
| 2007/0274203 | A1 | 11/2007 | Kimura et al. |
| 2008/0043708 | A1 | 2/2008 | Muharemovic et al. |
| 2008/0049690 | A1 | 2/2008 | Kuchibhotla et al. |
| 2008/0077837 | A1 | 3/2008 | Lohr et al. |
| 2008/0084845 | A1 | 4/2008 | Kuchibhotla et al. |
| 2008/0137562 | A1 | 6/2008 | Li et al. |
| 2008/0240022 | A1 | 10/2008 | Yoon et al. |
| 2008/0247337 | A1 | 10/2008 | Li et al. |
| 2009/0034486 | A1* | 2/2009 | Takahashi et al. 370/335 |
| 2009/0245188 | A1* | 10/2009 | Fukuoka et al. 370/329 |
| 2009/0264076 | A1* | 10/2009 | Nogami et al. 455/63.1 |
| 2009/0268695 | A1 | 10/2009 | Zhao et al. |
| 2010/0260137 | A1* | 10/2010 | Vrzic et al. 370/330 |
| 2010/0316014 | A1* | 12/2010 | Choi et al. 370/329 |
- FOREIGN PATENT DOCUMENTS
- | | | | |
|----|------------|----|---------|
| GB | 2322525 | A | 8/1998 |
| JP | 11-355195 | A | 12/1999 |
| WO | 9211716 | A1 | 7/1992 |
| WO | 0116314 | A1 | 3/2001 |
| WO | 0241520 | A2 | 5/2002 |
| WO | 0249305 | A2 | 6/2002 |
| WO | 03077457 | A1 | 9/2003 |
| WO | 2004039011 | A2 | 5/2004 |
| WO | 2004039027 | A2 | 5/2004 |
| WO | 2004042954 | A1 | 5/2004 |
| WO | 2004073250 | A1 | 8/2004 |
| WO | 2004097797 | A1 | 11/2004 |
| WO | 2004100569 | A2 | 11/2004 |
| WO | 2004105294 | A2 | 12/2004 |
| WO | 2005109705 | A1 | 11/2005 |
| WO | 2006039812 | A1 | 4/2006 |
| WO | 2006065069 | A1 | 6/2006 |
| WO | 2006083077 | A1 | 8/2006 |
| WO | 2006102746 | A1 | 10/2006 |
| WO | 2006105004 | A2 | 10/2006 |
| WO | 2006105005 | A2 | 10/2006 |
- OTHER PUBLICATIONS
- 3GPP TSG RAN1#45, Shanghai, China, May 8-12, 2006; EUTRA Downlink Distributed Multiplexing and Mapping Rules TP; R1-061173; XP007903801.
- IEEE 802.16 REVd/D5-2004, "Part 16: Air Interface for Fixed Broadband Wireless Access System", May 2004; also known as IEEE Std 80216-2004.
- IEEE 802.16e "Extended rtPS for VoIP services" dated Nov. 4, 2004.
- 3GPP TSG-RAN WG1 Meeting #52; Sorrento, Italy; Feb. 11-15, 2008; 36.211 CR 0003; "Update of uplink reference-signal hopping, downlink reference signals, scrambling sequences, DwPTS/UpPTS lengths to TDD and control channel processing" R1-081155.
- 3GPP TSG RAN2#55; Seoul, Korea, Oct. 9-13, 2006; Agenda 13.2 "Downlink Resource Allocation" R2-062970.
- 3GPP TS 36.211 v8.7.0 (May 2009) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 8).
- TS 25.322, "Radio Link Control (RLC) Protocol Specification", Version 6.2.0, Dec. 2004.
- 3GPP2 C.S0017-010-A, "Data Service Options for Spread Spectrum Systems: Radio Link Protocol Type 3", version 1.0, Jun. 2004.
- 3rd Generation Partnership Project 2, 3GPP2, "cdma2000 High Rate Packet Data Air Interface Specification", 3GPP2 C.s0024-A Version 1.0 Mar. 2004, pp. 3-27 to 3-31, 13-1 to 13-13, 13-25 to 13-52.

(56)

References Cited

OTHER PUBLICATIONS

Classon et al., "Multi-dimensional Adaptation and Multi-user Scheduling Techniques for Wireless OFDM Systems," in Proc. IEEE ICC 2003, pp. 2251-2255, May 2003.

IEEE Std 802.16-2004 (Revision of IEEE Std 802.16-2001), 802.16 IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, IEEE Computer Society and the IEEE Microwave Theory and Techniques.

Das et al., "A2IR: an asynchronous and adaptive hybrid ARQ scheme for 3G evolution", Vehicular Technology Conference, 2001, VTC 2001 Spring, IEEE VTS 53 vol. 1, May 6-9, 2001, pp. 628-632, vol. 1.

Das et al., "Performance of hybrid ARQ for high speed downlink packet access in UMTS", Vehicular Technology Conference, 2001, VTCX 2001 Fall, IEEE VTS 54 vol. 4, Oct. 7-11, 2001, pp. 2133-2137, vol. 4.

Das et al., "Adaptive, asynchronous incremental redundancy (A/sup 2/IR) with fixed transmission time intervals (TTI) for HSDPA", Personal Indoor and Mobile Radio Communications, 2002, The 13th IEEE International Symposium on vol. 3, Sep. 15-18.

3rd Generation Partnership Project 2, 3GPP2, Physical Layer Standard for cdma2000 Spread Spectrum System, Revision D, 3GPP2 C.S0002-D, Version 1.0 Feb. 13, 2004, pp. 3-3, 3-15, 3-21, 3-131, to 3-140.

Motorola: "Layer 1 Data Transfer: Formats and Definitions", Agenda Item 6.2, R2-060122, 3GPP TSG RAN WG2 #50, Sophia Antipolis, France, Jan. 9-13, 2006, all pages.

Siemens: "Signaling for downlink scheduling: Dynamic allocation of distributed and localized configuration with no signaling", R1-060835, EGPP TSG RAN WG1:44bis, Athens, Greece, Mar. 27-31, 2006, all pages.

Intel Technology Journal, IEEE 802.16 Medium Access Control and Service Provisioning; Aug. 20, 2004.

State Intellectual Property Office of the People's Republic of China, Notification of the First Office Action for Chinese Patent Application No. 200780038478.1, mailed Jul. 25, 2011.

State Intellectual Property Office of the People's Republic of China, Notification of the First Office Action for Chinese Patent Application No. 201110409544.X, mailed Dec. 4, 2013.

State Intellectual Property Office of the People's Republic of China, Notification of the First Office Action for Chinese Patent Application No. 201110409544.X, mailed Jun. 30, 2014.

Government of India Patent Office, First Examination Report for Indian Patent Application No. 725/KOLNP/2009, mailed Feb. 19, 2014.

Japan Patent Office, Notification of Reasons for Rejection for Japanese Patent Application No. 2007-216057, mailed Nov. 24, 2009.

Japan Patent Office, Decision of Rejection for Japanese Patent Application No. 2007-216057, mailed Dec. 21, 2010.

Japan Patent Office, Notification of Reasons for Rejection for Japanese Patent Application No. 2011-095291, mailed Oct. 10, 2012.

Japan Patent Office, Notification of Reasons for Rejection for Japanese Patent Application No. 2011-095291, mailed Jun. 25, 2013.

Korean Intellectual Property Office, Preliminary Rejection for Korean Patent Application No. 10-2009-7005772, mailed Oct. 21, 2010.

The Federal Service for Intellectual Property, Patents and Trademarks, Official Action for Russian Patent Application No. 2009110200/09(013844), mailed Mar. 30, 2011.

United States Patent and Trademark Office, International Search Report and Written Opinion for PCT Application No. PCT/US2006/014232, mailed Jan. 29, 2007.

United States Patent and Trademark Office, International Search Report and Written Opinion for PCT Application No. PCT/US2006/011080, mailed Sep. 27, 2006.

United States Patent and Trademark Office, International Search Report and Written Opinion for PCT Application No. PCT/US2006/011079, mailed Nov. 20, 2006.

United States Patent and Trademark Office, International Search Report and Written Opinion for PCT Application No. PCT/US2007/061297, mailed Nov. 1, 2007.

European Patent Office, International Search Report and Written Opinion for PCT Application No. PCT/US2006/000211, mailed Apr. 26, 2006.

European Patent Office, International Search Report and Written Opinion for PCT Application No. PCT/US2007/076941, mailed Aug. 21, 2008.

European Patent Office, International Search Report and Written Opinion for PCT Application No. PCT/US2007/074064, mailed Mar. 14, 2008.

* cited by examiner

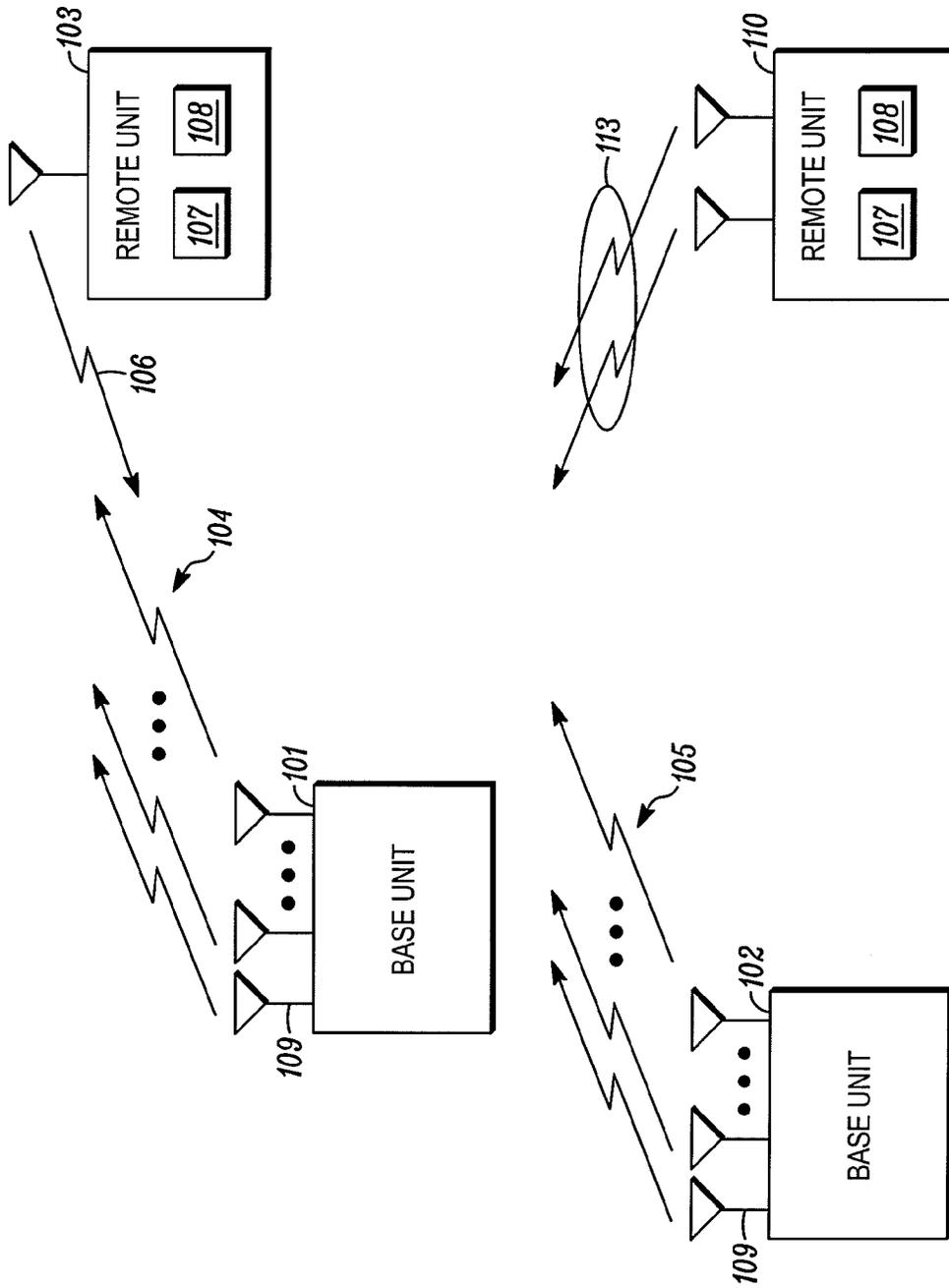


FIG. 1

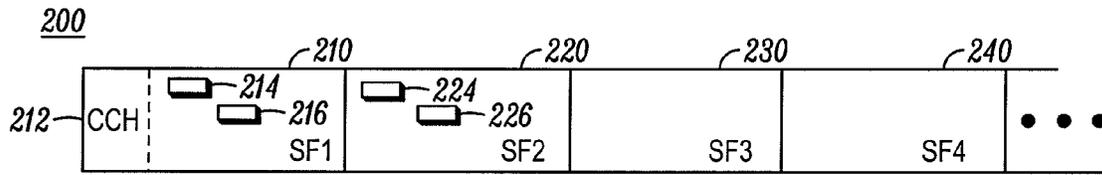


FIG. 2

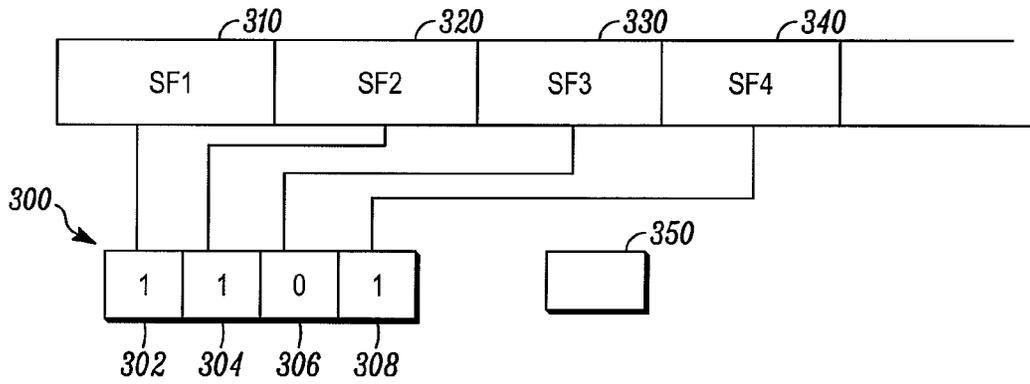


FIG. 3

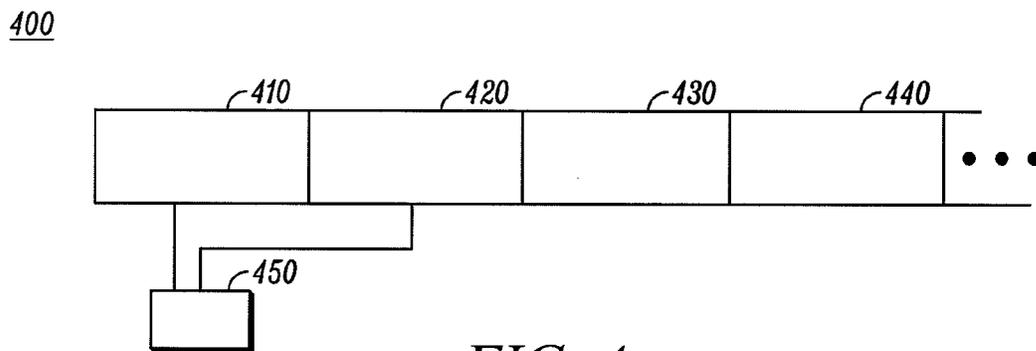


FIG. 4

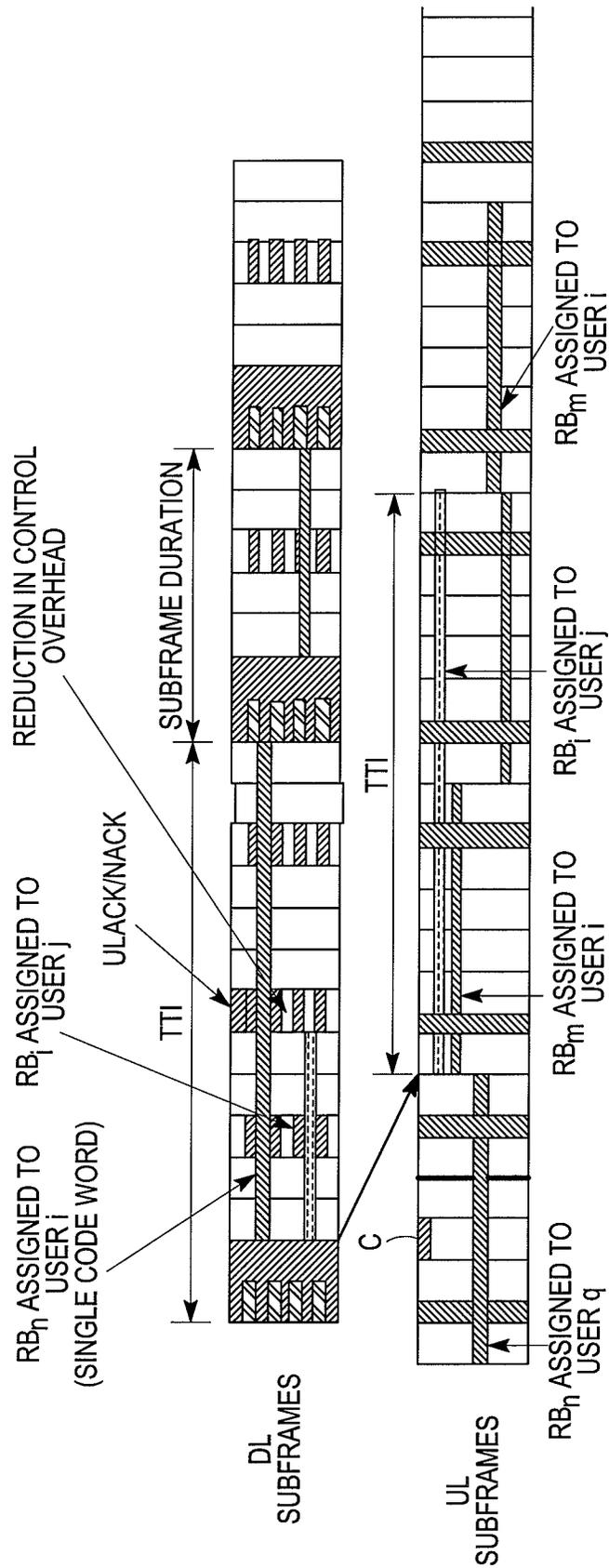


FIG. 5

1

DOWNLINK CONTROL CHANNEL SIGNALING IN WIRELESS COMMUNICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of co-pending U.S. patent application Ser. No. 11/466,720, filed Aug. 23, 2006.

FIELD OF THE DISCLOSURE

The present disclosure relates generally to wireless communications and more particularly to downlink control channel signaling over shared channels in wireless communication networks, corresponding entities and methods.

BACKGROUND

In the Long Term Evolution (LTE) of UMTS Terrestrial Radio Access (UTRA) and UTRA Network (UTRAN) specifications, multiple approaches for scheduling downlink data transmission are being proposed. In particular, time division multiplexing (TDM) and frequency division multiplexing (FDM) methods, including hybrids thereof, have been proposed in addition to separate and joint coding of control channel signaling. In TDM or FDM transmissions of control channel signaling, the control information for downlink and uplink assignments may be transmitted over the first one or two symbols of the downlink frame or may be spread out over the length of a sub-frame, which may be, for example, of 0.5 ms duration, though other values are also possible. In jointly coded downlink and uplink control information schemes, all the control information relates to the sub-frame carrying the control information. A duration field has been proposed to indicate the validity of the current assignment in one sub-frame for subsequent, adjacent sub-frames. All these proposed methods however deal with controlling data transmission based on a sub-frame of 0.5 ms and a transmission time interval (TTI) that is a multiple of 0.5 ms.

The various aspects, features and advantages of the disclosure will become more fully apparent to those having ordinary skill in the art upon careful consideration of the following Detailed Description and the accompanying drawings described below. The drawings may have been simplified for clarity and are not necessarily drawn to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a wireless communication system.

FIG. 2 illustrates a radio frame comprising multiple sub-frames and a control channel.

FIG. 3 illustrates radio frame comprising multiple sub-frames and a control channel including resource allocation fields.

FIG. 4 illustrates another radio frame comprising multiple sub-frames and a control channel including resource allocation fields.

FIG. 5 illustrates another radio frame comprising multiple sub-frames.

DETAILED DESCRIPTION

In FIG. 1, a wireless communication system 100 comprises multiple cell serving base stations forming a cellular network distributed over a geographical region, wherein each cell may

2

comprise one or more sectors. In one embodiment, the communication system utilizes OFDMA or a next generation single-carrier based FDMA architecture for uplink transmissions, such as interleaved FDMA (IFDMA), Localized FDMA (LFDMA), DFT-spread OFDM (DFT-SOFDM) with IFDMA or LFDMA.

Single-carrier based FDMA approaches are attractive in that they improve performance when assessed using contemporary waveform quality metrics, which may include peak-to-average power ratio (PAPR) or the so-called cubic metric (CM). These metrics are good indicators of power backoff or power de-rating necessary to maintain linear power amplifier operation, where "linear" generally means a specified and controllable level of distortion both within the signal bandwidth generally occupied by the desired waveform and in neighboring frequencies. While these SC-FDMA approaches can be classified as single-carrier based transmission schemes with a much lower peak-to-average power ratio than OFDM, they can also be classified as multi-carrier schemes because they are block-oriented like OFDM and can be configured to occupy only a certain set of "sub-carriers" in the frequency domain like OFDM. Thus IFDMA and DFT-SOFDM can be classified as both single-carrier and multi-carrier since they have single carrier characteristics in the time domain and multi-carrier characteristics in the frequency domain. On top of the baseline transmission scheme, the architecture may also include the use of spreading techniques such as direct-sequence CDMA (DS-CDMA), multi-carrier CDMA (MC-CDMA), multi-carrier direct sequence CDMA (MC-DS-CDMA), Orthogonal Frequency and Code Division Multiplexing (OFCDM) with one or two dimensional spreading, or simpler time and frequency division multiplexing/multiple access techniques.

In order to retain the low PAPR or CM property of IFDMA/DFT-SOFDM, only a single IFDMA code could be transmitted by each user which leads to a time division multiplexing (TDM) of pilot or reference symbol blocks, where data and pilots of a particular user are not mixed within the same symbol block. This allows the low PAPR property to be preserved and also enables the pilot to remain orthogonal from the data in multi-path channels, since there is conventionally a cyclic prefix between blocks.

In FIG. 1, the one or more base units 101 and 102 comprise one or more transmitters and one or more receivers that serve a number of remote units or terminals within a sector. The number of transmitters may be related, for example, to the number of transmit antennas 109 at the base unit. The base units 101 and 102 communicate with remote units 103 and 110 and perform functions such as scheduling the mobile terminals to receive or transmit data using available radio resources. A base unit may also be referred to as an access point, access terminal, Node-B, or by similar terminologies from the art. A remote unit comprises one or more transmitters and one or more receivers. The number of transmitters may be related, for example, to the number of transmit antennas at the remote unit. A remote unit may also be referred to as a subscriber unit, a mobile unit, a user, a terminal, a subscriber station, user equipment (UE), a user terminal or by similar terminology in the art. The network also comprises management functionality including data routing, admission control, subscriber billing, terminal authentication, etc., which may be controlled by other network entities, as is known generally by those having ordinary skill in the art. When multiple antennas are used to serve each sector to provide various advanced communication modes (e.g., adaptive beam-forming, transmit diversity, transmit SDMA, and multiple stream transmission, etc.), multiple base units can be

deployed. These base units within a sector may be highly integrated and may share various hardware and software components. For example, all base units co-located together to serve a cell can constitute what is traditionally known as a base station. Base units **101** and **102** transmit downlink communication signals **104** and **105** to serving remote units on at least a portion of the same resources (time and/or frequency). Remote units **103** and **110** communicate with one or more base units **101** and **102** via uplink communication signals **106** and **113**.

Generally, a wireless communication network infrastructure scheduling entity located, for example, in a base station **101**, **102** in FIG. 1, allocates or assigns radio resources to wireless communication entities in the wireless communication network. The base stations **101**, **102** each include a scheduler for scheduling and allocating resources to mobile terminals in corresponding cellular areas. In multiple access schemes such as those based on OFDM methods and the long term evolution of UTRA/UTRAN Study Item in 3GPP (also known as evolved UTRA/UTRAN (EUTRA/EUTRAN)), scheduling may be performed in the time and frequency dimensions using a Frequency Selective (FS) scheduler. In some embodiments, each mobile terminal may provide a per frequency band channel quality indicator (CQI) to the base station scheduler to enable FS scheduling.

In OFDM systems or OFDM like systems such as DFT-SOFDM and IFDMA, a resource allocation is the frequency and time allocation that maps information for a particular UE to sub-carrier resources from a set of available sub-carriers as determined by the scheduler. This allocation may depend, for example, on the frequency-selective channel-quality indication (CQI) reported by the UE to the scheduler. The channel-coding rate and the modulation scheme, which may be different for different portions of the sub-carrier resources, are also determined by the scheduler and may also depend on the reported CQI. In some applications, the UE may not be assigned consecutive sub-carriers. For example, it could be assigned every Qth sub-carrier (equally spaced, non-consecutive) of the entire or a portion of the available system sub-carriers to improve frequency diversity. The available system sub-carriers may be grouped into one or more resource blocks (RB) wherein each resource block comprises the same (common) number of sub-carriers. A resource assignment to a UE can be a resource block or a fraction thereof. More generally, a resource assignment or allocation is a fraction of multiple resource blocks.

In one embodiment, a single TTI has a length of 1 ms or 2 ms wherein the TTI is segmented into two sub-frames each having a 0.5 ms length. Such a construction however implies the need to address multiple resource blocks, i.e., more than the number of resource blocks in a single 0.5 ms sub-frame, unless the resource block (RB) definition is expanded to automatically define the RB as extending over the entire length of the TTI, without regard for the TTI duration. This can lead to inefficiency, however, in the form of excessive per-RB capacity. In case the RB is defined to extend over a fraction of the length of the TTI, it would be possible to independently address each of the resource blocks in the multiple sub-frames making up the TTI. Accordingly mechanisms are required to signal resource assignments in the case of a frame or TTI composed of concatenated sub-frames. Furthermore, mechanisms are required to be able to assign resources based on the needs of individual UE wherein fewer resources are assigned to a UE served smaller packets while more resources are assigned to UE served with larger packets. In the case of UMTS (Universal Mobile Telecommunications System), a TTI is defined as the length of time over which a

transmission or transport block is transmitted. A transmission block or transport block is composed of a block of jointly coded data protected by a single CRC. In the present instance, an alternate definition of TTI could be the length of transmission controlled by a single instance of control channel signaling.

In general, it is possible to define resource blocks of varying dimensionality in frequency and time domains to be operational simultaneously. Different terminals can then be signaled as to the resource block sizes that are operational for that particular terminal. For example, a TTI of 1 ms can be defined using two 0.5 ms sub-frames. In one embodiment, a first terminal can be assigned resources in this TTI using resource blocks consisting of 25 contiguous sub-carriers over a length of 1 ms, while a second terminal can be assigned resources using resource blocks consisting of 25 contiguous sub-carriers over a length of 0.5 ms. The former assignment could be useful in the case of terminals being served with data services requiring the transmission of long packets while the latter could be useful in the case of short packet services such as voice. Thus the resources within a single frame consisting of a continuum of concatenated sub-frames are logically divided into prototype or candidate resource blocks, that is, resource blocks of varying sizes super-posed over each other. Different terminals are signaled the assignment of these resource blocks by first pre-assigning the 'type' of resource block that is being assigned using higher layer or static signaling and then by dynamically assigning the respective resource block type using the control channel. In one embodiment, the resource blocks all have the same dimensions and are non-overlapping. In another embodiment, resource blocks may be defined in the spatial domain. In such a case, all resource blocks may have identical dimensions (frequency and time) and overlap spatially. SDMA transmission to two or more users in the same resource block may therefore be accomplished. In one embodiment of SDMA, paired (or more than two) users share the same resources in a frame, as the pairing is expected to be appropriate for the frame duration. Such resources may vary from sub-frame to sub-frame within the TTI, but vary in the same fashion to retain the pairing.

In one implementation, a scheduling entity allocates a first radio resource comprising at least one time-frequency resource block of a first minimum size, and allocates a second radio resource comprising at least one time-frequency resource block of a second minimum size, wherein the first and second radio resources are allocated from a common set of time-frequency radio resources. The first and second radio resources are allocated for use by at least one wireless communication terminal during a common transmit time interval constituting at least one sub-frame. More generally, the transmit time interval constitutes a concatenated series of at least two sub-frames. The first and second radio resources may be allocated to a common wireless communication terminal or to different terminals.

In FIG. 2, a radio frame **200** comprises a plurality of sub-frames **210**, **220**, **230**, **240** . . . wherein each sub-frame includes time-frequency resource elements and at least one sub-frame includes a control channel. In some embodiments, the plurality of sub-frames forms a continuum of concatenated sub-frames as illustrated in FIG. 2. In other embodiments, sub-frames, for example, sub-frames containing multicast data, are interspersed within a chain of unicast frames. For example, 1 ms TTIs each comprised of 2 sub-frames may be time multiplexed with longer (e.g., 2.5 or 5 ms sub-frames) broadcast TTIs. The multiplexing may be restricted such that only certain combinations of 1 ms unicast and 2.5 ms multi-

cast sub-frames are possible within the boundaries of a radio frame, e.g., a radio frame of length 10 ms.

In some embodiments, the control channel constitutes part of a single frame. In FIG. 2, for example, the control channel 212 is part of sub-frame 210. In other embodiments the control channel is distributed among several radio sub-frames. In yet another embodiment, a portion of the control channel could be contained within one sub-frame and transmitted in a TDM or TDM/FDM fashion by occupying the first one or two symbols, while the remaining part of the control channel is distributed among the many symbols making up one sub-frame or multiple sub-frames in a TDM/FDM fashion. In one example of a TDM/FDM control channel, the TDM portion in a first sub-frame may identify a user and an FDM resource allocation (resource block and/or sub-frame) on which the remainder of the in-band control information is sent. An uplink assignment may instead be sent in a frequency diverse fashion. In FIG. 2, the control channel is also shown distributed as control information 214 and 216 in sub-frame 210 and control channel information 224 and 226 in sub-frame 220. More typically, the control channel information is located in a single frame or distributed among two or more frames.

In one exemplary structure, the first sub-frame can carry control signaling for the downlink while the second carries control signaling for the uplink. This structure permits terminals engaged in data transfer in only one direction to avoid decoding the control channel in the second sub-frame. Individual control channels may be pre-assigned/signaled using the first sub-frame of the radio frame to permit dynamic control channel assignment. This would still permit the use of the control channel resources for data transmission in the event the scheduler does not require the control channel for signaling.

In another embodiment, the first sub-frame of a 1 ms TTI contains control signaling for downlink assignments while the second sub-frame contains control signaling for uplink assignments. The signaling for the uplink assignments may be made in a frequency diverse manner, as it is likely that the network does not have information about the channel conditions experienced by the terminal.

In another embodiment, the resource blocks in a TTI and more generally in a sub-frame making up the TTI can be divided into frequency diverse and frequency non-diverse resource blocks. Such a mapping may be pre-defined based upon the number of such blocks. For example, if 6 of 12 resource blocks are to be frequency diverse, they may comprise every other resource block. Different assignment patterns may also be defined for both frequency diverse and non-diverse resource blocks with the operational pattern being signaled either statically or through higher layer signaling. Frequency diverse allocations may be indicated through a common network environment, for example, system frame number, base station identifier, etc. In some embodiments where the time period between changes of the frequency diverse resource blocks is infrequent, the feedback mechanism, e.g., CQI, for the channel dependent (frequency selective) blocks can be reduced in bandwidth by not sending CQI for frequency diverse resource blocks. In addition, dynamic signaling on the control channel, such as having frequency diverse resource blocks comprise the resource blocks remaining after channel dependent resource allocations are assigned.

Generally, according to one aspect of the disclosure, a control channel provides radio resource allocation information for two or more sub-frames. In one embodiment, the control channel includes a plurality of resource allocation fields, for example, a bit map, wherein each resource allocation

field is associated with at least one corresponding sub-frame. In FIG. 3, for example, the control channel includes a bit map 300 comprising multiple allocation fields 302, 304, 306 and 308. The plurality of resource allocation fields are used to indicate a resource assignment to the wireless communication device. For the case where the resource allocation fields 302, 304, 306 and 308 in FIG. 3 are associated with sub-frames 310, 320, 330 and 340, the bit map 300 configuration [1 1 0 1] may be interpreted to mean that time-frequency resources in sub-frames 310, 320 and 340 have been allocated to the wireless communication terminal. In other embodiments, each bit could indicate that resources in more than one sub-frame have been assigned or allocated to the terminal. In other embodiments, the radio resource allocation to the mobile station may be indicated by pre-encoding the bits in the allocation fields. For example, the terminal may reference a look-up table to determine which resources are allocated by a particular combination of bits in the field. FIG. 5 shows an exemplary embodiment with a 1 ms TTI comprised of two 0.5 ms sub-frames. User i is assigned a resource block over both sub-frames, while user j is assigned a resource block only over 1 sub-frame.

In another embodiment, a frequency diverse resource assignment is indicated by a frequency diverse allocation field. A frequency diverse resource assignment or allocation is a resource allocation wherein the frequency allocation changes among sub-frames. In FIG. 3, for example, at least the frequency component of a time-frequency allocation in sub-frame 310 is different than the frequency component of the time-frequency allocation in sub-frame 320. In some embodiments, the frequency diverse allocation field constitutes part of the control channel, and in other embodiments the frequency diverse allocation field is communicated to the wireless communication terminal over another channel, for example, via layer 3 signaling.

In one implementation, illustrated in FIG. 3, the frequency diverse allocation field 350 is a single bit that indicates to the wireless communication terminal that a radio resource allocation is frequency diverse. In such an implementation, the terminal may use a pre-specified frequency diverse allocation scheme indicated by the frequency diverse allocation field. The pre-specified frequency diverse allocation scheme may be based on the order of the resource allocation to the wireless communication device, or it may be based upon sub-frame numbering information, or the cell in which the terminal is located. More generally, however, a different temporal dimension of the resource allocation may also be indicated in addition to the change in frequency allocation. Alternatively, a change in the temporal allocation may be indicated by some other bit or information field.

In another embodiment, a frequency diverse allocation field resides on the control channel wherein the frequency diverse allocation field indicates frequency diverse resource allocations in multiple sub-frames of the radio frame. In one embodiment, the frequency diverse allocation field resides on a single control channel, wherein the frequency diverse allocation field indicates frequency diverse resource allocations in multiple sub-frames of the radio frame. In FIG. 4, for example, the radio frame 400 comprises sub-frames 410, 420, 430, 440 In one embodiment, a frequency diverse allocation field resides on a control channel associated with two or more sub-frames, wherein the frequency diverse allocation field indicates frequency diverse resource allocations in multiple sub-frames of the radio frame. In FIG. 4, the frequency diverse allocation field 450 indicates frequency diverse resource allocations in sub-frames 410 and 420.

The allocation corresponding to a particular bit setting or a particular combination of bits may be known a priori by the terminal. In one embodiment, a single bit is used to indicate whether the terminal should use frequency diversity. When a frequency diverse allocation is indicated, the particular allocation may be indicated by some other fields or it may be known a priori. For example, the allocation may be based on the order in which the allocation is made by the scheduler or based upon some other factor or criterion. In one embodiment, the frequency diverse allocation field is a bit map comprising one or more bits. The bits may be used to encode different frequency diverse allocations. In one embodiment, the terminal references a look-up table to determine what frequency diverse allocation corresponds to a particular bit combination.

Additional signaling may indicate any of the following possible resource allocations: The UE is assigned the same resource block in the second (and any subsequent) sub-frame (s) of the TTI; or the resource allocation corresponds to a frequency hopped (diverse) resource block; or there is no further assignment in the frame wherein the term "frame" in this disclosure refers to a multi-sub-frame TTI structure. The above set of enumerated possibilities would require a 2 bit field. Another 2 bit example is to signal, in addition to the resource allocation, the following:

Bits	Meaning
00	Both sub-frames
01	Both sub-frames, hopping
10	1 st sub-frame only
11	2 nd sub-frame only

In this example, 'hopping' indicates a known method of changing the resource allocation from one sub-frame to another. For example, a fixed cell-specific offset (modulo the number of resource blocks) may be applied to all resource blocks.

More generally, additional control fields may also be used. For example, a single bit could be used to indicate a contiguous assignment or a frequency diverse pattern, and a bitmap could signal the assignment over the TTI wherein the bitmap length is dictated by the number of concatenated sub frames forming the TTI. In this instance, the assignment of a 'logical' resource block is applicable, where the mapping, i.e. frequency diversity, between the logical and physical resource block (RB) locations in each component sub-frame of the TTI may be constant, i.e. the mapping defined for the first sub-frame of the TTI remains applicable to subsequent sub-frames, or may vary from sub-frame to sub-frame, where it is understood that the logical assignment is constant and only the mapping varies.

In frequency diverse allocation applications, the idea can be extended even in the case where an odd number of sub-frames, or generally more than 2 sub-frames, make up a TTI. In this case, one bit can indicate whether the assignment includes a frequency diverse allocation pattern, i.e. time-varying logical to physical resource block mapping, or whether the same allocation is being extended over the length of the frame (TTI) in order to optimally support frequency selective or frequency diverse scheduling methods. A separate bitmap can indicate whether the terminal is being assigned a logical resource block in each of the sub-frames making up the TTI regardless of whether frequency diversity is enabled.

In one embodiment, a small set of patterns is assigned statically using higher layer signaling, or semi-statically, and then indexed in the dynamic control using the above mentioned bit-map. In another embodiment, this set of patterns could be made dependent on TTI location in a 10 ms radio frame or similar super frame.

In another embodiment, the frequency diverse allocation pattern can be signaled to be applicable to multiple or all users addressed in a particular TTI. The applicable pattern can be determined based on the order in which the terminal is addressed. Additional signaling may be required to signal which of the embodiments was made operational in the event that more than one scheme is supported.

In some embodiments, it may be more complex to permit one assigned user in the TTI to operate on a frequency diverse allocation while other users do not, since this would require the logical-physical channel mapping to exclude physical resource blocks declared as being assigned to non-frequency diverse users. Accordingly, in some implementations, a single control bit may be asserted which is globally applicable to all users in the sub-frame, and which enables or disables frequency diversity for the entire TTI.

When considering implementations where control information is transmitted on or more of the sub-frames of the TTI, the control information transmission may be made with separate coding or joint coding. With separate coding, a UE's control information is not coded together with another UE's control information. In this case bits indicating an assigned subfield or frequency hopping are added to fields constituting the separate assignment. In some cases, blind decoding of potential allocations (e.g., the UE keeps decoding the RB across additional sub-frames of the TTI until a CRC checks) may be used to reduce signaling. For example, a UE may decode each of a number, e.g. 12, resource blocks looking for a downlink control channel assignment corresponding to that UE. If an assignment is found within a RB, that RB can point to other RBs for a data assignment. This indication of other RBs may be in a number of contiguous RBs or via a bitmap. Blind decoding complexity can be reduced by making the RB with the separate control channel assignment be one of the RBs reported on with channel quality indication information.

Joint coding offers efficient source coding of user IDs and resource allocations, in addition to the addressing and frequency diverse bits of the disclosure. In one embodiment, user IDs are listed in an order that determines a short ID, for example, 2 bits for 4 users. Then, in the order of the available RBs the short IDs (or a null ID) are listed. In one embodiment, two short IDs are assigned per RB. In another embodiment, the 1-2 bits are assigned per ID and associated with the short ID. In this case, every RB to a user is treated in the same manner. In another embodiment, a frequency diverse bit may be sent once per frame, applied to all terminals. In yet another embodiment, retransmissions may be done in an a priori manner requiring less signaling, or signaling only in the first transmission.

While the present disclosure and the best modes thereof have been described in a manner establishing possession and enabling those of ordinary skill to make and use the same, it will be understood and appreciated that there are equivalents to the exemplary embodiments disclosed herein and that modifications and variations may be made thereto without departing from the scope and spirit of the inventions, which are to be limited not by the exemplary embodiments but by the appended claims.

What is claimed is:

1. A method in a wireless communication device, the method comprising:

receiving a plurality of sub-frames, each sub-frame having time-frequency resource elements, at least one of the sub-frames having a control channel, the plurality of sub-frames forming a continuum of concatenated sub-frames;

the control channel including a plurality of resource allocation fields, each resource allocation field associated with at least one corresponding sub-frame of the plurality of subframes,

each of the plurality of resource allocation fields indicating a resource assignment to the wireless communication device based on a channel quality report;

the plurality of resource allocation fields indicating resource assignments in sub-frames of the continuum of concatenated sub-frames;

a sub-frame of the continuum of concatenated sub-frames including information indicating that at least some of the resource assignments are frequency diverse; and

allocating, for use by the wireless communication device, frequency diverse resource components based on the information indicating that at least some of the resource assignments are frequency diverse.

2. The method of claim 1, further comprising referencing individual resource assignments in one or more corresponding sub-frames of the continuum of concatenated sub-frames via a look-up table.

3. The method of claim 1, wherein the information indicates that the resource assignments are frequency diverse on the control channel.

4. The method of claim 1, wherein the information indicates that the resource assignments are frequency diverse on signaling other than the control channel.

5. The method of claim 1, wherein the information indicating that the resource assignments are frequency diverse is based on a common network environment.

6. The method of claim 1, wherein the information indicating that the resource assignments are frequency diverse is based on an order of resource allocations to the wireless communication device.

7. The method of claim 1, wherein the information indicating that the resource assignments are frequency diverse is based on sub-frame numbering or on system frame numbering information.

8. The method of claim 1, further comprising receiving a downlink resource assignment in a resource allocation field

on a sub-frame that is different than a sub-frame in which a resource allocation field assigning an uplink assignment is received.

9. The method of claim 1, further comprising receiving a mapping of frequency diverse and frequency non-diverse resources in a sub-frame of the continuum of concatenated sub-frames.

10. The method of claim 1, wherein the information indicating that the resource assignments are frequency diverse is a bit map.

11. The method of claim 1, wherein the information indicating that at least some of the resource assignments frequency diverse includes one or more encoded bits in a bit map.

12. The method of claim 1, wherein the control channel contains an assignment of resources that are not indicated as being frequency diverse.

13. The method of claim 1 further comprising sending a channel quality report for resources not including the resources that are indicated as being frequency diverse.

14. A method in a wireless communication device, the method comprising:

receiving a plurality of sub-frames constituting part of a transmit time interval, each sub-frame having time-frequency resource elements, at least one of the sub-frames having a control channel, the plurality of sub-frames forming a continuum of concatenated sub-frames;

the control channel including a plurality of resource allocation fields, each resource allocation field associated with at least one corresponding sub-frame of the plurality of subframes,

each of the plurality of resource allocation fields indicating a resource assignment to the wireless communication device based on a channel quality report;

the plurality of resource allocation fields indicating resource assignments in sub-frames of the continuum of concatenated sub-frames;

a sub-frame of the continuum of concatenated sub-frames including information indicating that at least some of the resource assignments are frequency diverse among sub-frames in the transmit time interval; and

allocating, for use by the wireless communication device, frequency diverse resource components based on the information indicating that at least some of the resource assignments are frequency diverse among sub-frames in the transit time interval.

* * * * *