

Timing Alignment in a Multicarrier System

BACKGROUND

Field

- [0001] The present application relates generally to wireless communications, and more specifically to systems and methods for multicarrier system timing alignment.

Background

- [0002] Wireless communication systems are widely deployed to provide various types of communication content such as voice, data, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (*e.g.*, bandwidth and transmit power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, 3GPP Long Term Evolution (LTE) systems, and orthogonal frequency division multiple access (OFDMA) systems.
- [0003] Generally, a wireless multiple-access communication system can simultaneously support communication for multiple wireless terminals. Each terminal communicates with one or more base stations via transmissions on the forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. This communication link may be established via a single-in-single-out, multiple-in-single-out, single-in-multiple-out (SIMO), or a multiple-in-multiple-out (MIMO) system.
- [0004] A MIMO system, for example, employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S independent channels, which are also referred to as spatial channels, where $N_S \leq \min\{N_T, N_R\}$. Each of the N_S independent channels corresponds to a dimension. The MIMO system can provide improved performance (*e.g.*, higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0005] Multicarrier systems have developed that allow mobile terminals to communicate over multiple carriers, which allows increased throughput, differentiation in data communications, *etc.* Mobile terminals, in one example, can communicate with the same or disparate base stations over the multiple carriers. In either case, each carrier can have independent timing such that the timing or timing offset can differ across the carriers. In one example, a mobile terminal can maintain and continually update timing for each carrier by receiving an uplink/downlink offset for the carrier. This, however, can burden the network (and mobile terminals) by constantly receiving and processing timing update packets for each of the carriers.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0006] FIG. 1 illustrates an exemplary wireless communication system;
- [0007] FIG. 2. illustrates an exemplary communication system to enable deployment of access points within a network environment;
- [0008] FIG. 3 is a block diagram of an example system that facilitates carrier grouping and updating timing for carrier groups.
- [0009] FIG. 4 is an illustration of an example methodology for grouping carriers into timing groups and performing timing updates for the groups.
- [0010] Appendix A is a document that describes aspects of the claimed subject matter, and this Appendix forms part of this specification.

DETAILED DESCRIPTION

- [0011] The techniques described herein may be used for various wireless communication networks such as Code Division Multiple Access (CDMA) networks, Time Division Multiple Access (TDMA) networks, Frequency Division Multiple Access (FDMA) networks, Orthogonal FDMA (OFDMA) networks, Single-Carrier FDMA (SC-FDMA) networks, etc. The terms “networks” and “systems” are often used interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband-CDMA (W-CDMA) and Low Chip Rate (LCR). cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as Evolved UTRA (E-UTRA), IEEE 802.11, IEEE 802.16, IEEE 802.20, Flash-OFDM®, etc. UTRA, E-UTRA, and GSM are part of Universal Mobile Telecommunication System (UMTS). Long Term Evolution (LTE) is an upcoming release of UMTS that uses E-UTRA. UTRA, E-UTRA, GSM, UMTS and LTE are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). cdma2000 is described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). These various radio technologies and standards are known in the art. For clarity, certain aspects of the techniques are described below for LTE, and LTE terminology is used in much of the description below.

[0012] Single carrier frequency division multiple access (SC-FDMA), which utilizes single carrier modulation and frequency domain equalization is a technique. SC-FDMA has similar performance and essentially the same overall complexity as those of OFDMA system. SC-FDMA signal has lower peak-to-average power ratio (PAPR) because of its inherent single carrier structure. SC-FDMA has drawn great attention, especially in the uplink communications where lower PAPR greatly benefits the mobile terminal in terms of transmit power efficiency. It is currently a working assumption for uplink multiple access scheme in 3GPP Long Term Evolution (LTE), or Evolved UTRA.

[0013] Referring to Fig. 1, a multiple access wireless communication system according to one embodiment is illustrated. An access point 100 (AP) includes multiple antenna groups, one including 104 and 106, another including 108 and 110, and an additional including 112 and 114. In Fig. 1, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Access terminal 116 (AT) is in communication with antennas 112 and 114, where antennas 112 and 114 transmit information to access terminal 116 over forward link 120 and receive information from access terminal 116 over reverse link 118. Access terminal 122 is in communication with antennas 106 and 108, where antennas 106 and 108 transmit information to access terminal 122 over forward link 126 and receive information from access terminal 122 over reverse link 124. In a FDD system, communication links 118, 120, 124 and 126 may use different frequency for communication. For example, forward link 120 may use a different frequency than that used by reverse link 118.

[0014] Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the access point. In the embodiment, antenna groups each are designed to communicate to access terminals in a sector, of the areas covered by access point 100.

[0015] In communication over forward links 120 and 126, the transmitting antennas of access point 100 utilize beamforming in order to improve the signal-to-noise ratio of forward links for the different access terminals 116 and 124. Also, an access point using beamforming to transmit to access terminals scattered randomly through its coverage causes less interference to access terminals in neighboring cells than an access point transmitting through a single antenna to all its access terminals.

- [0016] An access point may be a fixed station used for communicating with the terminals and may also be referred to as an access point, a Node B, or some other terminology. An access terminal may also be called an access terminal, user equipment (UE), a wireless communication device, terminal, access terminal or some other terminology.
- [0017] FIG. 2 is a block diagram of an embodiment of a transmitter system 210 (also known as the access point) and a receiver system 250 (also known as access terminal) in a MIMO system 200. At the transmitter system 210, traffic data for a number of data streams is provided from a data source 212 to a transmit (TX) data processor 214.
- [0018] In an embodiment, each data stream is transmitted over a respective transmit antenna. TX data processor 214 formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.
- [0019] The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response. The multiplexed pilot and coded data for each data stream is then modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QSPK, M-PSK, or M-QAM) selected for that data stream to provide modulation symbols. The data rate, coding, and modulation for each data stream may be determined by instructions performed by processor 230.
- [0020] The modulation symbols for all data streams are then provided to a TX MIMO processor 220, which may further process the modulation symbols (e.g., for OFDM). TX MIMO processor 220 then provides N_T modulation symbol streams to N_T transmitters (TMTR) 222a through 222t. In certain embodiments, TX MIMO processor 220 applies beamforming weights to the symbols of the data streams and to the antenna from which the symbol is being transmitted.
- [0021] Each transmitter 222 receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and upconverts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. N_T modulated signals from transmitters 222a through 222t are then transmitted from N_T antennas 224a through 224t, respectively.

- [0022] At receiver system 250, the transmitted modulated signals are received by N_R antennas 252a through 252r and the received signal from each antenna 252 is provided to a respective receiver (RCVR) 254a through 254r. Each receiver 254 conditions (e.g., filters, amplifies, and downconverts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding “received” symbol stream.
- [0023] An RX data processor 260 then receives and processes the N_R received symbol streams from N_R receivers 254 based on a particular receiver processing technique to provide N_T “detected” symbol streams. The RX data processor 260 then demodulates, deinterleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by RX data processor 260 is complementary to that performed by TX MIMO processor 220 and TX data processor 214 at transmitter system 210.
- [0024] A processor 270 periodically determines which pre-coding matrix to use (discussed below). Processor 270 formulates a reverse link message comprising a matrix index portion and a rank value portion.
- [0025] The reverse link message may comprise various types of information regarding the communication link and/or the received data stream. The reverse link message is then processed by a TX data processor 238, which also receives traffic data for a number of data streams from a data source 236, modulated by a modulator 280, conditioned by transmitters 254a through 254r, and transmitted back to transmitter system 210.
- [0026] At transmitter system 210, the modulated signals from receiver system 250 are received by antennas 224, conditioned by receivers 222, demodulated by a demodulator 240, and processed by a RX data processor 242 to extract the reserve link message transmitted by the receiver system 250. Processor 230 then determines which pre-coding matrix to use for determining the beamforming weights then processes the extracted message.
- [0027] In an aspect, logical channels are classified into Control Channels and Traffic Channels. Logical Control Channels comprises Broadcast Control Channel (BCCH) which is DL channel for broadcasting system control information. Paging Control Channel (PCCH) which is DL channel that transfers paging information. Multicast Control Channel (MCCH) which is Point-to-multipoint DL channel used for

transmitting Multimedia Broadcast and Multicast Service (MBMS) scheduling and control information for one or several MTCHs. Generally, after establishing RRC connection this channel is only used by UEs that receive MBMS (Note: old MCCH+MSCH). Dedicated Control Channel (DCCH) is Point-to-point bi-directional channel that transmits dedicated control information and used by UEs having an RRC connection. In aspect, Logical Traffic Channels comprises a Dedicated Traffic Channel (DTCH) which is Point-to-point bi-directional channel, dedicated to one UE, for the transfer of user information. Also, a Multicast Traffic Channel (MTCH) for Point-to-multipoint DL channel for transmitting traffic data

[0028] In an aspect, Transport Channels are classified into DL and UL. DL Transport Channels comprises a Broadcast Channel (BCH), Downlink Shared Data Channel (DL-SDCH) and a Paging Channel (PCH), the PCH for support of UE power saving (DRX cycle is indicated by the network to the UE), broadcasted over entire cell and mapped to PHY resources which can be used for other control/traffic channels. The UL Transport Channels comprises a Random Access Channel (RACH), a Request Channel (REQCH), a Uplink Shared Data Channel (UL-SDCH) and plurality of PHY channels. The PHY channels comprises a set of DL channels and UL channels.

[0029] The DL PHY channels comprise:

- Common Pilot Channel (CPICH)
- Synchronization Channel (SCH)
- Common Control Channel (CCCH)
- Shared DL Control Channel (SDCCH)
- Multicast Control Channel (MCCH)
- Shared UL Assignment Channel (SUACH)
- Acknowledgement Channel (ACKCH)
- DL Physical Shared Data Channel (DL-PSDCH)
- UL Power Control Channel (UPCCH)
- Paging Indicator Channel (PICH)
- Load Indicator Channel (LICH)

[0030] The UL PHY Channels comprise:

- Physical Random Access Channel (PRACH)
- Channel Quality Indicator Channel (CQICH)
- Acknowledgement Channel (ACKCH)
- Antenna Subset Indicator Channel (ASICH)
- Shared Request Channel (SREQCH)
- UL Physical Shared Data Channel (UL-PSDCH)
- Broadband Pilot Channel (BPICH)
- UL Dedicated Physical Channel (UL DPCH)
- Evolved Dedicated Physical Channel (E-DPCH)

Dedicated Physical Control Channel (DPCCH)
 Physical UL Control Channel (PUCCH)
 Physical UL Shared Channel (PUSCH)

[0031] In an aspect, a channel structure is provided that preserves low PAR (at any given time, the channel is contiguous or uniformly spaced in frequency) properties of a single carrier waveform.

[0032] For the purposes of the present document, the following abbreviations apply:

AM	Acknowledged Mode
AMD	Acknowledged Mode Data
ARQ	Automatic Repeat Request
BCCH	Broadcast Control CHannel
BCH	Broadcast CHannel
C-	Control-
CCCH	Common Control CHannel
CCE	Control Channel Element
CCH	Control CHannel
CCTrCH	Coded Composite Transport Channel
CP	Cyclic Prefix
CRC	Cyclic Redundancy Check
CTCH	Common Traffic CHannel
DCCH	Dedicated Control CHannel
DCH	Dedicated CHannel
DL	DownLink
DSCH	Downlink Shared CHannel
DTCH	Dedicated Traffic CHannel
FACH	Forward link Access CHannel
FDD	Frequency Division Duplex
E-	Evolved
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)
L3	Layer 3 (network layer)
LI	Length Indicator
LLR	Log Likelihood Ratio
LSB	Least Significant Bit
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Service
MCCH	MBMS point-to-multipoint Control CHannel
MSC	Modulation Coding Scheme
MRW	Move Receiving Window
MSB	Most Significant Bit
MSCH	MBMS point-to-multipoint Scheduling CHannel
MTCH	MBMS point-to-multipoint Traffic CHannel
PCCH	Paging Control CHannel
PCH	Paging CHannel
PDU	Protocol Data Unit
PHY	PHYsical layer
PhyCH	Physical CHannels

PRB	Physical Resource Block
RACH	Random Access CHannel
RB	Resource Block
RE	Resource Element
RF	Radio Frequency
RLC	Radio Link Control
RNTI	Radio Network Terminal Identifier
RRC	Radio Resource Control
RS	Reference Signal
RSSI	Received Signal Strength Indication
SAP	Service Access Point
SDU	Service Data Unit
SHCCH	SHared channel Control CHannel
SN	Sequence Number
SRS	Sounding Reference Signal
SUFI	SUper Field
TCH	Traffic CHannel
TDD	Time Division Duplex
TFCI	Transport Format Combination Indicator
TFI	Transport Format Indicator
TM	Transparent Mode
TMD	Transparent Mode Data
TTI	Transmission Time Interval
U-	User-
UE	User Equipment
UL	UpLink
UM	Unacknowledged Mode
UMD	Unacknowledged Mode Data
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
MBSFN	multicast broadcast single frequency network
MCE	MBMS coordinating entity
MCH	multicast channel
DL-SCH	downlink shared channel
MSCH	MBMS control channel
PDCCH	physical downlink control channel
PDSCH	physical downlink shared channel

[0033] According to aspects described herein, carriers from one or more access points can be grouped according to uplink timing. For example, carriers having similar timing (*e.g.*, within a threshold difference) can be grouped for a given UE such that the UE maintains timing for each given group, rather than necessarily each carrier. In one example, the UE can update timing for only one carrier in the group and accordingly update timing for the rest of the carriers in the group according to the same offset. As

described herein, selecting the carrier to utilize for updating can be network- and/or UE-based.

[0034] FIG. 3 illustrates an example system 300 that facilitates grouping carriers by timing to facilitate efficient timing synchronization in multicarrier wireless networks. System 300 includes a wireless device 302, which can be a mobile device, access point, a portion thereof, and/or substantially any device that communicates in a wireless network. Wireless device 302 includes a carrier grouping component 304 that can associate a plurality of carriers in a timing group based on respective timing differences within a threshold range, a carrier candidate selection component 306 that can choose a carrier in the group from which to acquire timing, a timing offset component 308 that can obtain a timing offset for a group of characters, and a timing update component 310 that can update timing for carriers in a group based on the timing offset.

[0035] According to an example, the wireless device 302 can participate in a multicarrier wireless network communicating over multiple carriers to one or more access points or other devices. The carrier grouping component 304 can associate carriers having similar timing into timing groups. For example, where multiple carriers have a timing difference below a threshold value, the multiple carriers can be grouped. In one example, the carrier grouping component 304 can group the carriers according to observed timing. In another example, the carrier grouping component 304 can receive one or more groupings from one or more related access points or the wireless network. Thus, for example, where an access point provides multiple carriers utilized by the wireless device 302, the access point can transmit a grouping to the wireless device 302.

[0036] In an example, carrier candidate selection component 306 can choose a carrier in the group from which to acquire timing updates. Similarly, the carrier candidate selection component 306 can receive a carrier candidate selection from one or more related access points or the wireless network. In one example, the candidate carrier selection component 306 can select the carrier to use in timing updates based on a hash function to attempt even distribution of candidate carriers in a group (*e.g.*, to prevent all UEs using the group to update using the same carrier). The candidate carrier selection component 306, for example, can use a hash function with a varying value so the candidate can change for the UE 302 for each update.

[0037] Timing offset component 308 can acquire a timing offset from the candidate carrier for a given group using a random access procedure and/or the like, and the

timing update component 310 can update timing for the group of carriers based on the offset. In another example, the timing update component 310 can track downlink timing over carriers in a group, add the offset received from the timing offset component 308 to each carrier timing, average the timing differences, and apply the average difference as an offset for use with all carriers in the group.

[0038] In addition, one or more groups of carriers can be entirely controlled at a common site. In this example, the timing offset component 308 can receive timing adjustments for substantially all groups at the common site in a vector from a base station at the common site. In an example, the vector can be absolute measurements or differences relative to a timing of one of the groups. Knowledge regarding which groups are utilized by the UE 302 can be maintained at the wireless network, in one example, at the UE 302, and/or the like.

[0039] FIG. 4 illustrates an example methodology 400 that facilitates grouping carriers and performing group-based timing updates. At 402, a plurality of carriers can be associated into one or more timing groups. As described, the carriers can be associated according to a timing difference such that similarly timed carriers (*e.g.*, below a threshold difference) can be included in a single group. At 404, a candidate carrier can be assigned in a given timing group for receiving timing updates. The candidate carrier can be chosen by a network component or UE, for example, such that the same carrier is not the candidate carrier for the timing group at all devices. As described, the candidate carrier can be chosen according to a hash value, random function, time-based function, and/or the like.

[0040] At 406, a timing offset can be received from the candidate carrier during the timing update. This can be in response to a random access procedure, in one example, and can be related to a timing difference related to the candidate carrier. At 408, timing can be updated for each carrier in the timing group based on the timing offset. In one example, the updating can occur using an average of the offset applied to monitored timings for each carrier, as described. In another example, the offset received from the candidate carrier can be applied to all carriers in the group.

[0041] In an aspect, incorporated is an Appendix A (attached). Appendix A is a document that describes aspects of the claimed subject matter, and the Appendix forms part of this specification. In particular, Appendix A shows examples of timing group formation and alignment in multicarrier systems.

[0042] While the specification describes particular examples of the present invention, those of ordinary skill can devise variations of the present invention without departing from the inventive concept. For example, the teachings herein refer to circuit-switched network elements but are equally applicable to packet-switched domain network elements.

[0043] Those skilled in the art will understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0044] Those skilled in the art will further appreciate that the various illustrative logical blocks, modules, circuits, methods and algorithms described in connection with the examples disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, methods and algorithms have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[0045] The various illustrative logical blocks, modules, and circuits described in connection with the examples disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of

microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0046] The methods or algorithms described in connection with the examples disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. A storage medium may be coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC.

[0047] In one or more exemplary embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0048] The previous description of the disclosed examples is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these examples will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other examples without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the examples shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A method, comprising:
associating a plurality of carriers utilized for communication into one or more timing groups of carriers;
assigning a candidate carrier in at least one of the one or more timing groups for timing updates;
receiving a timing offset from the candidate carrier during a timing update; and
updating timing for each carrier in the at least one timing group based on the timing offset.
2. The method of claim 1, wherein assigning the candidate carrier includes selecting the candidate carrier according to a hash function.
3. The method of claim 2, wherein the hash function utilizes a variable key such that the candidate carrier differs for disparate timing updates.
4. The method of claim 1, wherein assigning the candidate carrier is performed according to a received assignment from a base station associated with a subset of the plurality of carriers.
5. The method of claim 1, wherein associating the plurality of carriers into one or more timing groups includes evaluating a timing difference of each of the plurality of carriers and grouping the plurality of carriers according to a threshold difference.
6. The method of claim 1, wherein associating the plurality of carriers into one or more timing groups is performed according to a grouping received from a base station associated with a subset of the plurality of carriers.

7. The method of claim 1, further comprising monitoring a downlink timing for each carrier in the at least one timing group and modifying the timing offset according to an average of the offset applied to the monitored downlink timings for each carrier.

8. The method of claim 1, wherein carriers in the at least one of the one or more timing groups are transmitted at a common site.

9. The method of claim 8, wherein the timing offset is received in a vector of a plurality of timing offsets for the at least one of the one or more timing groups from the common site.

10. A wireless communications apparatus, comprising:
at least one processor configured to:

generate an association of a plurality of carriers utilized for communication into one or more timing groups according to a timing of each of the plurality of carriers;

select a candidate carrier in at least one of the one or more timing groups for timing updates;

obtain a timing offset from the candidate carrier during a timing update;
and

modify timing for each carrier in the at least one timing group based on the timing offset; and

a memory coupled to the at least one processor.

11. The wireless communications apparatus of claim 10, wherein the at least one processor selects the candidate carrier according to a hash function.

12. The wireless communications apparatus of claim 11, wherein the hash function utilizes a variable key such that the candidate carrier differs for disparate timing updates.

13. The wireless communications apparatus of claim 10, wherein the at least one processor selects the candidate carrier according to an assignment received from a base station associated with a subset of the plurality of carriers.

14. The wireless communications apparatus of claim 10, wherein the at least one processor generates the association of the plurality of carriers into one or more timing groups by evaluating a timing difference of each of the plurality of carriers and grouping the plurality of carriers into the timing groups according to a threshold difference.

15. The wireless communications apparatus of claim 10, wherein the at least one processor generates the association of the plurality of carriers into one or more timing groups according to a grouping received from a base station associated with a subset of the plurality of carriers.

16. The wireless communications apparatus of claim 10, wherein the at least one processor is further configured to monitor a downlink timing for each carrier in the at least one timing group and update the timing offset according to an average of the offset applied to the monitored downlink timings for each carrier.

17. The wireless communications apparatus of claim 10, wherein carriers in the at least one of the one or more timing groups are transmitted at a common site.

18. The wireless communications apparatus of claim 17, wherein the at least one processor obtains the timing offset in a vector of a plurality of timing offsets for the at least one of the one or more timing groups from the common site.

19. An apparatus, comprising:
means for associating a plurality of carriers utilized for communication into one or more timing groups of carriers;
means for assigning a candidate carrier in at least one of the one or more timing groups over which to receive timing updates;
means for receiving a timing offset from the candidate carrier during a timing update; and
means for updating timing for each carrier in the at least one timing group based on the timing offset.

20. The apparatus of claim 19, wherein the means for assigning the candidate carrier selects the candidate carrier according to a hash function.

21. The apparatus of claim 20, wherein the hash function utilizes a variable key such that the candidate carrier differs for disparate timing updates.

22. The apparatus of claim 19, wherein the means for assigning the candidate carrier assigns the candidate carrier according to a received assignment from a base station associated with a subset of the plurality of carriers.

23. The apparatus of claim 19, wherein the means for associating the plurality of carriers into one or more timing groups analyzes a timing difference of each of the plurality of carriers and groups the plurality of carriers according to a threshold difference.

24. The apparatus of claim 19, wherein the means for associating the plurality of carriers into one or more timing groups associates according to a grouping received from a base station associated with a subset of the plurality of carriers.

25. The apparatus of claim 19, further comprising:
means for monitoring a downlink timing for each carrier in the at least one timing group; and
means for modifying the timing offset according to an average of the offset applied to the monitored downlink timings for each carrier.

26. The apparatus of claim 19, wherein carriers in the at least one of the one or more timing groups are transmitted at a common site.

27. The apparatus of claim 26, wherein the timing offset is received in a vector of a plurality of timing offsets for the at least one of the one or more timing groups from the common site.

28. A computer program product, comprising:
a computer readable medium, comprising:
code for causing at least one computer to associate a plurality of carriers utilized for communication into one or more timing groups of carriers;
code for causing the at least one computer to assign a candidate carrier in at least one of the one or more timing groups for timing updates;
code for causing the at least one computer to receive a timing offset from the candidate carrier during a timing update; and
code for causing the at least one computer to update timing for each carrier in the at least one timing group based on the timing offset.

29. The computer program product of claim 28, wherein assigning the candidate carrier includes selecting the candidate carrier according to a hash function.

30. The computer program product of claim 29, wherein the hash function utilizes a variable key such that the candidate carrier differs for disparate timing updates.

31. The computer program product of claim 28, wherein assigning the candidate carrier is performed according to a received assignment from a base station associated with a subset of the plurality of carriers.

32. The computer program product of claim 28, wherein associating the plurality of carriers into one or more timing groups includes evaluating a timing difference of each of the plurality of carriers and grouping the plurality of carriers according to a threshold difference.

33. The computer program product of claim 28, wherein associating the plurality of carriers into one or more timing groups is performed according to a grouping received from a base station associated with a subset of the plurality of carriers.

34. The computer program product of claim 28, wherein the computer-readable medium further comprises:

code for causing the at least one computer to monitor a downlink timing for each carrier in the at least one timing group; and

code for causing the at least one computer to modify the timing offset according to an average of the offset applied to the monitored downlink timings for each carrier.

35. The computer program product of claim 28, wherein carriers in the at least one of the one or more timing groups are transmitted at a common site.

36. The computer program product of claim 35, wherein the timing offset is received in a vector of a plurality of timing offsets for the at least one of the one or more timing groups from the common site.

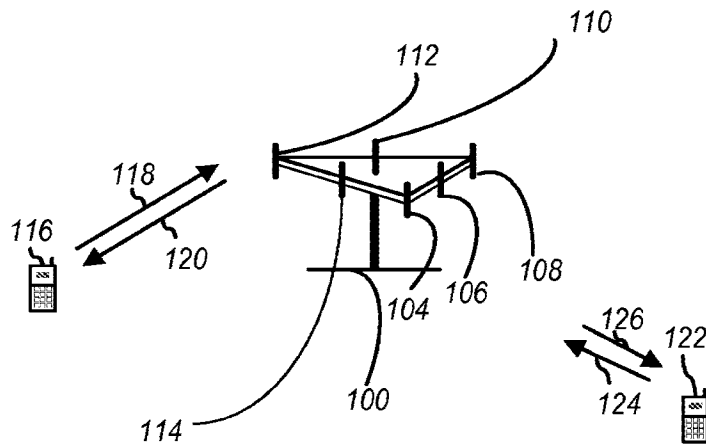


Fig. 1

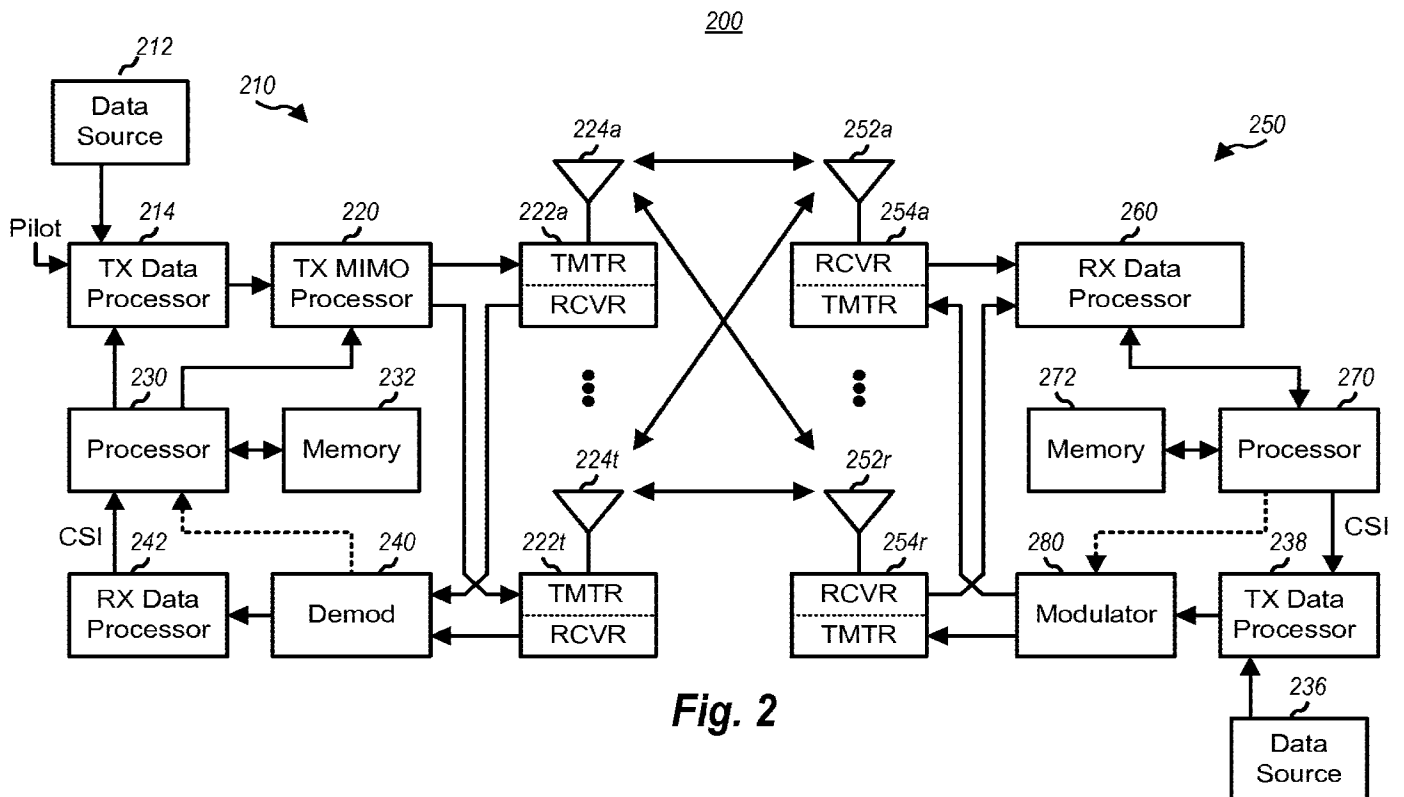


Fig. 2

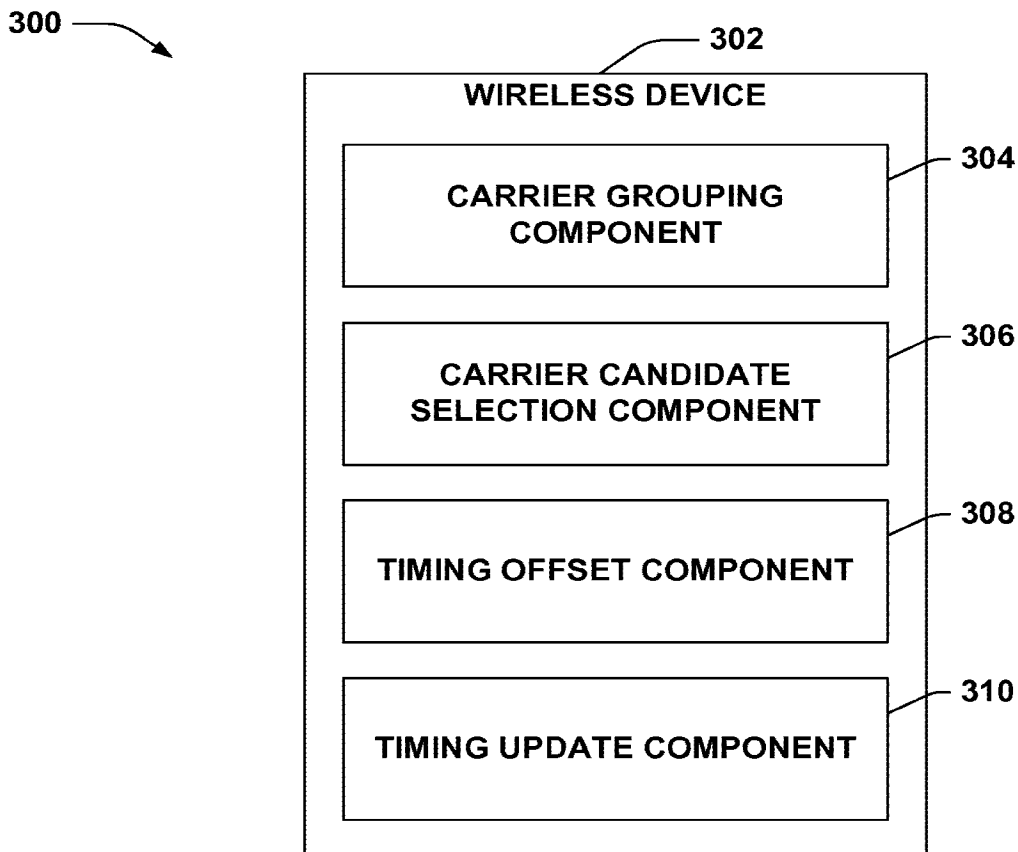


Fig. 3

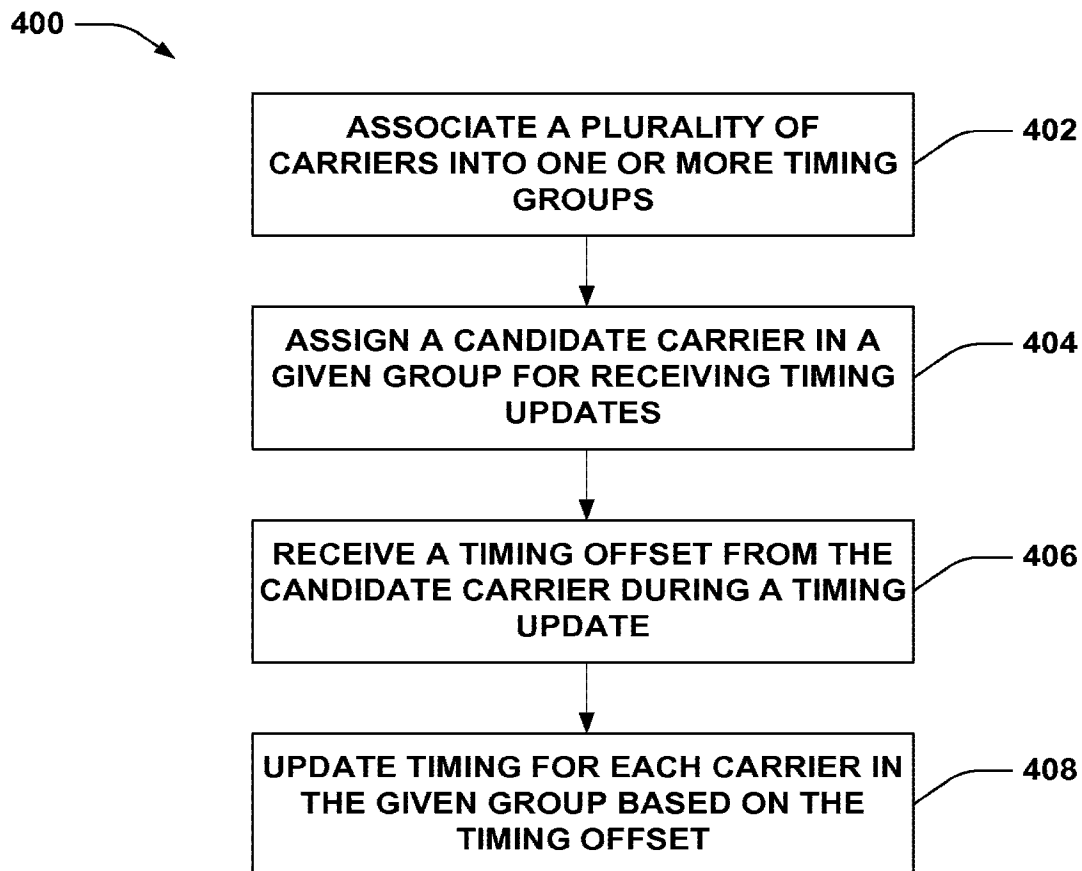


Fig. 4

Appendix A

1. Scope

This document describes solutions to several issues that arise in relation to maintaining timing synchronisation for a UE in a multicarrier LTE-Advanced (LTE-A) system.

2. Background

In a single-carrier environment, the maintenance of timing synchronisation for a UE is well understood; the UE receives an uplink/downlink offset from the network, which occasionally needs to be updated, indicating how it should align its uplink transmissions in relation to the received downlink timing.

In a multicarrier environment, however, the situation is less straightforward. Assuming that all carriers serving a single UE are transmitted from the same cell site, it appears that a common offset should be adequate; however, even co-sited carriers could experience some variation in timing for a number of reasons (e.g., cable delays, distance between the base station site and a remote radio head), which would make separate timing offsets per carrier beneficial or even necessary.

3. Proposal

3.1. Timing groups

As a general framework, we propose that it should be possible to assign a UE to at least one so-called *timing group*, i.e., a group of carriers with uplink timings that are the same to within some tolerance. Depending on the tolerance, a timing group might consist of carriers that share a common controlling site (but may still have fine differences in timing), or only of carriers whose antennae are collocated. Different carriers with synchronised downlinks but significant differences in uplink timing for a given UE (e.g., from different cell sites in a synchronous network) would *not* normally belong to the same timing group in this sense.

There is no fundamental reason to assume that a UE would be assigned carriers from only one timing group; in principle, a UE with enough reception and decoding capabilities could listen to several sets of carriers with independent timing. Such a situation would most obviously arise if a UE were assigned to carriers from different cell sites; however, the current LTE design (with no soft handover), and the complexities that arise when attempting to design such a system, such a multiple-site assignment seems unlikely. Even so, if the tolerances defining a timing group are fine, it is possible that a UE could be assigned carriers from multiple timing groups originating from the same cell site. An example, in which a remote radio head belonging to the eNode B causes some carriers to have different timing from others, is shown in Figure 1.

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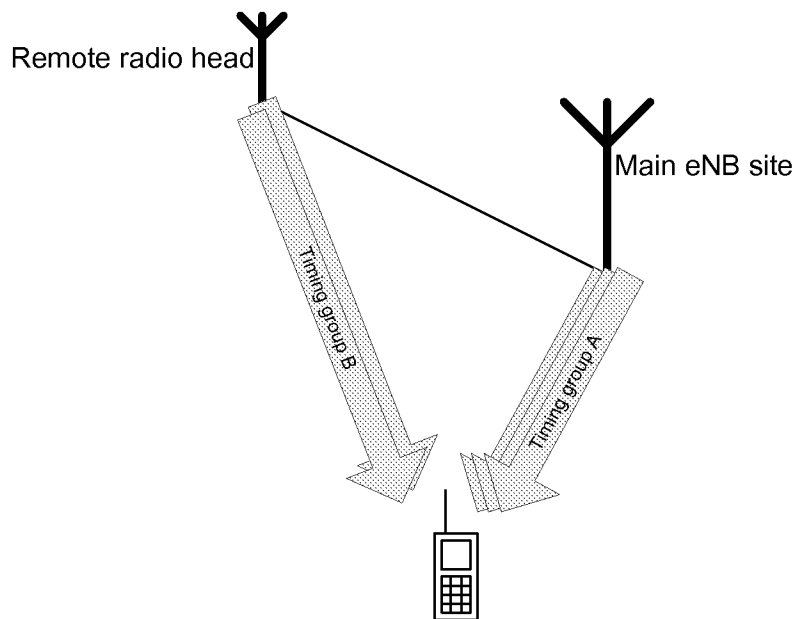


Figure 1: Two timing groups from a single eNode B

In such a case, the UE could be assigned to carriers in both groups A and B, and it would need to maintain timing separately for each group. This might require separate timing advance procedures for each group, or enhanced signalling allowing timing maintenance to take place for all groups in parallel.

3.2. Carrier selection for random access

Within each timing group, the UE may need to occasionally perform random access to update its timing (e.g., if timing is maintained through a separate procedure for each timing group). By definition, this update only needs to be performed with one carrier of each timing group; and the issue arises of how the UE should decide which carrier this is. At a minimum, the UE should be expected to behave intelligently enough not to perform unnecessary timing updates, i.e., to select a single carrier from the timing group to use for its timing control.

In principle, random access on any carrier in the group should work. However, it is desirable to avoid situations in which large numbers of UEs concentrate their random access attempts on a particular carrier, to minimise contention on the random access channel. To this end, we suggest that the system could adopt either a UE-based or a network-based solution.

A network-based solution is extremely simple: When the UE is assigned to carriers in a particular timing group, the network provides the UE with instructions regarding which carrier in that group to use for random access. The instructions could be absolute (“always use this carrier”) or subject to relaxation based on conditions at the UE (“use this carrier preferentially, unless radio conditions on that carrier are worse than indicated by a threshold”).

In a UE-based approach, each UE would select a single carrier for random access for timing updates autonomously, based on some function that tends to distribute UEs more or less evenly across the timing group. A typical example would be a hash function, in which a UE associated with a timing group of n carriers provides some input to a hash function with n possible values,

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and the function's output is the index of the carrier of the group that the UE will (prefer to) use for random access. (Again, the determination of the carrier could be absolute or subject to modification, as with the network-based solution.) There are many options for an appropriate hash function; a UE identifier would be a typical input, with other values such as an eNode B identifier also potentially used. The inputs could be static or time-varying; if they are static (depending on characteristics of the UE and/or the serving eNode B), the UE will tend to use the same carrier for random access throughout its assignment to a particular group, while if the inputs vary with time (e.g., through the use of an input value derived from a time measurement, or a counter), the UE will tend to "cycle" through the available carriers. The latter approach may be preferable, since it means that coincidental "spikes" in concentration (e.g., when a particular site is serving a large number of UEs whose identities result in the same output from the hash function) will tend to correct themselves over time.

Other UE-based distribution mechanisms are feasible; for instance, instead of a fixed hash function, the UE could use a pseudorandom function to choose the carrier. In such a case, the determination could be made only at the time of carrier assignment (so that a given UE consistently uses the same carrier for timing) or at each request for a timing update (so that each UE tends to balance its requests across the available carriers).

3.3. Granularity of timing alignment

Within a timing group, if all carriers are precisely aligned in both downlink and uplink timing, there is no ambiguity about what the "correct" timing alignment for a given UE should be. However, in the case of small differences between carrier transmission timing (e.g., due to cable delays), carriers with the same timing *offset* may nevertheless have different *absolute* timings. An example is shown in Figure 2.

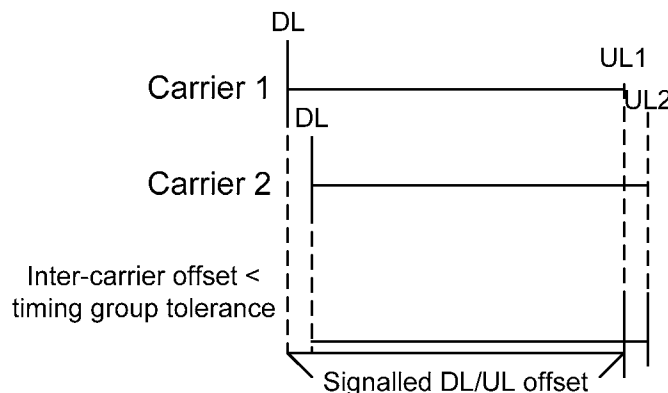


Figure 2: Ambiguous uplink timing

A UE in the environment of Figure 2 could receive its timing information from either carrier 1 or carrier 2. The timings of the two carriers differ, but by less than the tolerance that the deployment requires for a timing group; and it follows that, depending on which carrier the UE received its last update from, a UE connected to both carriers could consider the correct uplink timing to be at either UL1 or UL2 in the figure.

The simplest approach is for the UE simply to apply the timing offset to the carrier on which it received it, and assume that the timing of other carriers in the group is "close enough"; in terms of

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the figure, this would mean that the system considered UL1 and UL2 to be the same for purposes of uplink timing accuracy. As an alternative, however, the UE could apply the offset, not to the received downlink timing from the carrier that transmitted the offset, but to the average timing of the carriers in the timing group. In such a case, although the UE received its timing information from a particular carrier, it tracks the (downlink) timing of each carrier in the group separately, so that when a single DL/UL offset is received, the UE can apply the offset separately to each carrier and take an average of the results to provide a “happy medium” uplink timing for use with all carriers in the group.

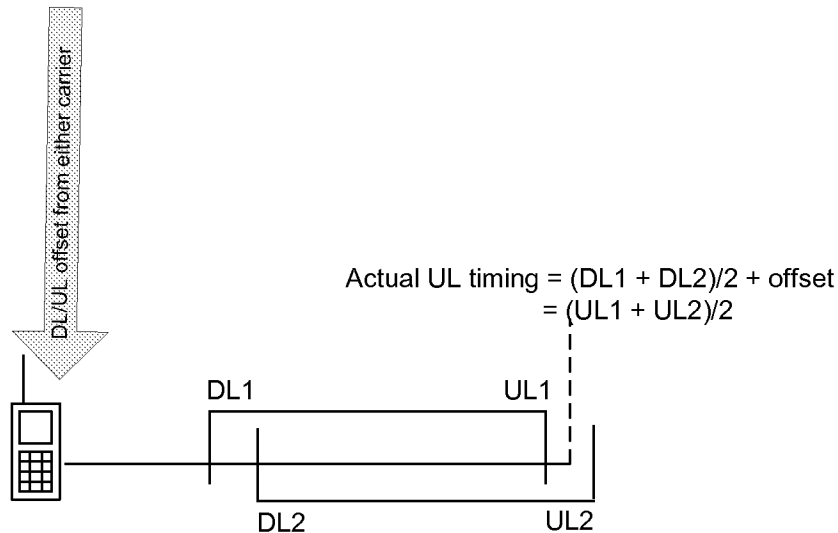


Figure 3: UE averaging of uplink timing from two carriers

Such an averaging behaviour could be either a specified UE behaviour (to allow greater downlink tolerances within a timing group while still keeping the variation in uplink timing acceptable) or left to UE implementation.

3.4. Vector timing adjustment command

In the event that a UE is assigned to several timing groups that are controlled from a common site, it may be able to receive timing adjustments for all groups with a single interaction with the base station. This is essentially a signalling optimisation, in the sense that the UE could in principle receive the same information by performing a separate timing adjustment for each group, but sending the adjustments as a vector reduces over-the-air activity, and in particular random access procedures, which are expensive in terms of radio resources and UE battery life.

To implement such a command, the network would need to be aware of the timing groups in which the UE is assigned to at least one carrier. This knowledge could be maintained autonomously in the network, so that upon determining the need to signal a timing advance to a particular UE, the network automatically includes timing advance commands for all appropriate timing groups. Alternatively, the UE could request timing advance values for a particular set of timing groups (e.g., the groups for which the UE’s time-alignment timers are within some range of expiring). However, the request for particular groups would represent a new MAC control element, which would need to be transmitted over the air at random access with a potentially

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significant cost in radio resources. The preferred solution is therefore for the network to maintain knowledge of what timing groups require timing advance commands towards a particular UE.

In a “degenerate” form of this vector approach, the network could opt to send only a single timing advance command per MAC element, but indicate *which* timing group the value is associated with. This approach would minimise the specification impact to the concerned MAC control element, since the existing information only needs to be augmented by a group identifier. It is presumed that such an identifier could be sent with a small number of bits, e.g., as an index into the set of timing groups with which the UE was configured. Such a mapping could be established by explicit signalling (in higher layers such as the RRC) at the time the UE is configured with particular carriers.

1. A method of maintaining timing alignment between a mobile device and a network operating on a plurality of frequencies, the method comprising an association of the frequencies into one or more timing groups, such that:
 - the carriers in each timing group share common transmission timing to within some first tolerance;
 - a single timing advance value can be indicated to the UE for use with all the carriers in the group, such that the resulting uplink timing when the UE transmits with this timing advance value towards any carrier in the group will be sufficiently accurate for communication with that carrier, where “sufficiently accurate” is defined in terms of some second tolerance.
2. The method of claim 1, wherein the carriers in each timing group are transmitted from antennas located at a common site.
3. The method of claim 1, wherein the UE may be assigned to communicate with carriers in one or more timing groups.
4. The method of claim 3, wherein the UE maintains timing synchronisation for each group to at least one of whose carriers it is assigned.
5. The method of claim 1, wherein the UE may maintain timing synchronisation in association with a random access procedure.
6. The method of claim 5, wherein the UE performs random access for timing synchronisation on a single carrier of the timing group for which it requires timing information.
7. The method of claim 6, wherein the carrier chosen within the group for random access is assigned to the UE by the network in advance of the random access procedure.
8. The method of claim 7, wherein the carrier for random access is signalled to the UE as part of a dedicated radio resource configuration.
9. The method of claim 7, wherein a criterion for using the indicated carrier is provided along with the assignment of the carrier.

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- 1 10. The method of claim 9, wherein the criterion is a minimum signal quality threshold for
2 the associated carrier.
- 3 11. The method of claim 9, wherein the UE is provided with an alternative carrier to use for
4 random access in case the criterion is not met by the assigned carrier.
- 5 12. The method of claim 9, wherein if the criterion is not met by the assigned carrier, the UE
6 determines independently which carrier to use for random access.
- 7 13. The method of claim 6, wherein the carrier for random access is selected independently
8 by the UE.
- 9 14. The method of claim 13, wherein the UE selects the carrier by applying a determination
10 function across the set of available carriers in the timing group.
- 11 15. The method of claim 14, wherein the determination function is a pseudorandom function.
- 12 16. The method of claim 14, wherein the determination function is a hash function.
- 13 17. The method of claim 16, wherein the hash function takes an identity of the UE as an
14 input.
- 15 18. The method of claim 16, wherein the hash function takes an identity of the network node
16 controlling the carriers of the timing group as an input.
- 17 19. The method of claim 16, wherein the hash function takes a time-varying value as an
18 input.
- 19 20. The method of claim 19, wherein the time-varying value is determined by a time
20 measurement from an internal source in the UE.
- 21 21. The method of claim 19, wherein the time-varying value is modified by an arithmetic
22 operation each time it is used.
- 23 22. The method of claim 13, wherein the UE selects the carrier at a time when radio
24 resources are assigned to it on carriers associated with the timing group.
- 25 23. The method of claim 13, wherein the UE selects the carrier when the random access
26 procedure is triggered.
- 27 24. The method of claim 1, wherein the UE determines its uplink timing based on an average
28 of timing information from a plurality of carriers in the group.
- 29 25. The method of claim 24, wherein the plurality of carriers in the group comprises the
30 carriers within the group on which the UE has radio resources assigned.
- 31 26. The method of claim 24, wherein the plurality of carriers in the group comprises a set of
32 carriers indicated to the UE by the network.

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- 1 27. The method of claim 3, wherein timing information for a plurality of timing groups may
2 be provided to the UE in a single message.
- 3 28. The method of claim 27, wherein the message is a timing advance command.
- 4 29. The method of claim 27, wherein the message contains a vector of timing adjustment
5 values for different timing groups.
- 6 30. The method of claim 27, wherein timing information is provided for all timing groups
7 containing at least one carrier on which the UE has assigned radio resources.
- 8 31. The method of claim 27, wherein timing information is provided for a proper subset of
9 the timing groups containing carriers on which the UE has assigned radio resources.
- 10 32. The method of claim 31, wherein the proper subset is determined based on a request from
11 the UE.
- 12 33. The method of claim 31, wherein the proper subset is determined by the network.
- 13 34. The method of claim 33, wherein the message includes an indication of which timing
14 groups are contained in the proper subset.
- 15 35. The method of claim 34, wherein the indication of which timing groups are contained in
16 the proper subset relies on a mapping of group identities shared between the network and
17 the UE.
- 18 36. The method of claim 35, wherein the mapping of group identities is configured in
19 association with the assignment to the UE of dedicated radio resources on carriers in one
20 or more of the concerned timing groups.
- 21 37. The method of claim 3, wherein a message directed to the UE may include timing
22 information for at least one timing group other than the timing group containing the
23 carrier on which the message is transmitted.
- 24 38. The method of claim 37, wherein an indication of the timing group to which the
25 information applies is included in the message.
- 26 39. The method of claim 37, wherein the indication of the timing groups relies on a mapping
27 of group identities shared between the network and the UE.
- 28 40. The method of claim 39, wherein the mapping of group identities is configured in
29 association with the assignment to the UE of dedicated radio resources on carriers in one
30 or more of the concerned timing groups.
- 31 41. (Corresponding apparatus claims, &c.)