Title

Methods and System for Multiple Uplink Timing Synchronization

Introduction

In order to provide easier or faster information transfer and convenience, telecommunication industry service providers are continually developing improvements to existing networks. While the demand for mobile broadband data services continues to grow, there may be a relative shortage of contiguous spectrum for deployment of access networks. Accordingly, it is expected that next generation broadband wireless access networks may be deployed using a combination of different spectrums. As next generation systems are deployed and the need for higher data rates continues to grow, the same technology may be deployed based on wider band radio frequency (RF) carriers, motivating a potential need to support a combination/concatenation of channel bandwidths to best fit the available spectrum while enabling data transmission over multiple carriers. With the application of a scheme referred to as Carrier Aggregation or Multiple "Component Carriers" (CCs), networks may be enabled to operate over continuous or discontinuous carriers having different bandwidths. Thus, for example, a base station (BS) may be enabled to configure its control structure to improve system performance.

The carrier aggregation scheme may utilize separate FFT and RF modules for each respective band that is used, and one Medium Access Control (MAC) entity may be employed to support multiple CC functionalities. Based on user capabilities, network entities (e.g., a BS, a NodeB, an access point (AP), network device, network apparatus, repeater, etc.) may be enabled to serve different users with corresponding different bandwidths. With the support of multiple CCs, a BS can flexibly use limited bandwidth to achieve high throughput and capacity to improve user experience at the user equipment (UE).

In addition, it may have deployments where the different component carriers from the same eNB have different coverage and different interference characteristics. Furthermore, with respect to the timing advance (TA) issue, there may be scenarios where the same timing advance is sufficient. However, in the following illustrated scenarios, separate timing advance per component carrier may be required.

Scenario #1: Frequency Selective Repeaters

The different component carriers could see substantially different propagation environments due to different frequency selective repeaters and hence see different time-of-flights.

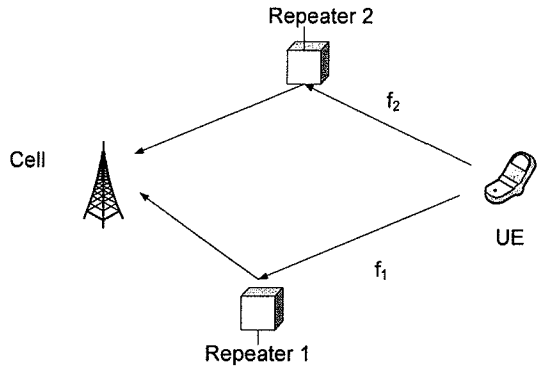


Figure 1: Frequency Selective Repeaters

Scenario #2: Non-Collocated Sites

The UE may communicate with two non-collocated sites on the two carriers. Such a scenario could occur with remote antennas or remote radio heads.

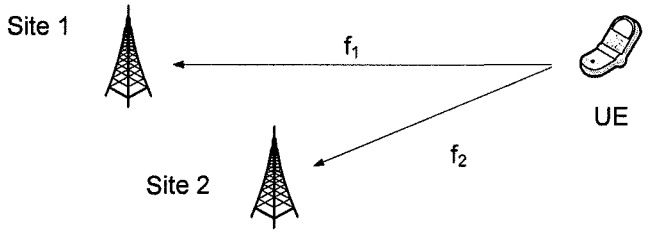


Figure 2: Non-collocated Sites

Scenario #3: Co-ordinated MultiPoint (CoMP)

In the context of uplink CoMP, where different cells could be receiving the UE's signals on any carrier. The timing advance could therefore be chosen to target any of the cells, and thus different carriers could have different timing advance commands.

In this invention, methods and system for multiple uplink (UL) timing synchronization are proposed. More details can be found in the next section.

Our Proposed Methods and System

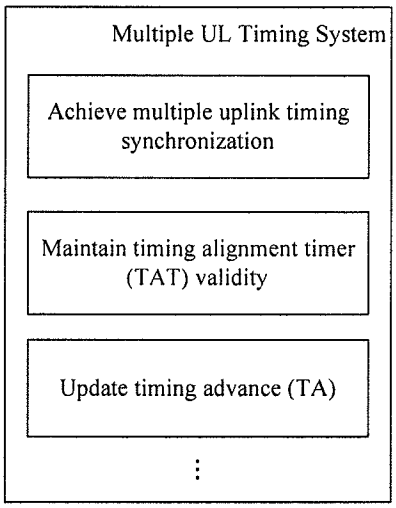


Figure 3

As shown in the above figure, at least one of three functions may be applied to achieve a multiple CC system with multiple UL TAs.

A. *Functional block 1:* Achieve UL timing synchronization on multiple CCs
B. *Functional block 2:* Maintain time alignment timer (TAT) validity
C. *Functional block 3:* Update timing advance (TA) for multiple CCs

Detailed description for each functional block is presented in the following sections. Note that we use 3GPP-like keywords to present our ideas in this paper; however, our ideas (inventions) can be applied to any other systems (e.g., IEEE 802.11, IEEE 802.16, etc.) for achieving multiple UL synchronization.

Besides, this paper uses the term "CC" to represent a component carrier. However, a CC can also be considered as a cell, which may operate on FDD (frequency division duplex) and/or TDD (time division duplex). A cell may have downlink resource to transmit signals from BS to UE, and/or may have uplink resource to transmit signals from UE to BS.

Multiple CCs may operate on the same or different frequency band, and may have the same or different center frequency. Multiple CCs may belong to the same BS or different BSs. The term "base station" (BS) in this paper may be, for example, a Node-B, an eNode B, a base transceiver system (BTS), an access point, a home base station, a relay station, a scatterer, a repeater, an intermediate node, an intermediary, and/or satellite-based communication base station, etc.

The term "user equipment" (UE) in this paper may be, for example, a server, a client, a desktop computer, a laptop computer, a network computer, a workstation, a personal digital assistant (PDA), a tablet personal computer (PC), a scanner, a telephony device, a pager, a camera, a television, a hand-held video game device, a musical device, a wireless sensor, etc. In some applications, a UE may be a fixed computing device operating in a mobile environment, such as a bus, a train, an airplane, a boat, a car, etc.

Exemplary embodiments

A. Functional Block 1: Achieve Multiple UL Timing Synchronization

In order to achieve UL timing synchronization in a multiple component carrier system, a new random access procedure is proposed as follows. More detailed description and exemplary embodiments can also be found in our slide.

Exemplary embodiment #1-1: Contention based RACH in multiple UL timing advances. In some exemplary embodiments, several RACH procedures may be performed in parallel.

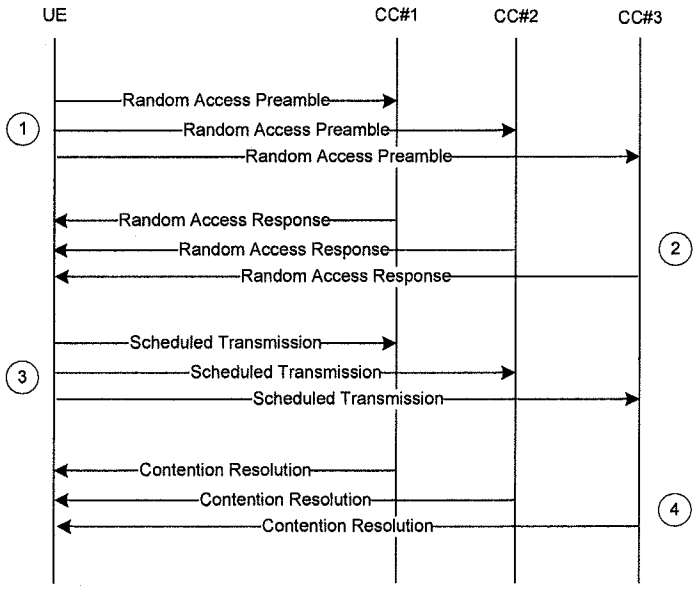


Figure: exemplary embodiment #1-1

In this invention, three CCs are illustrated. However, all proposals in this invention can be applied to any number of CCs. Furthermore, as shown in the following figure, these CCs (e.g., CC#1, CC#2, CC#3) may belong to the same BS or different BSs.

Exemplary embodiment #1-2: In some exemplary embodiments, some messages may be aggregated together and sent through the same CC. or example, the network side may aggregate multiple msg 4 (i.e., *Contention Resolution* messages) into one message, and send the message through the CC#2. Details can be found as below.

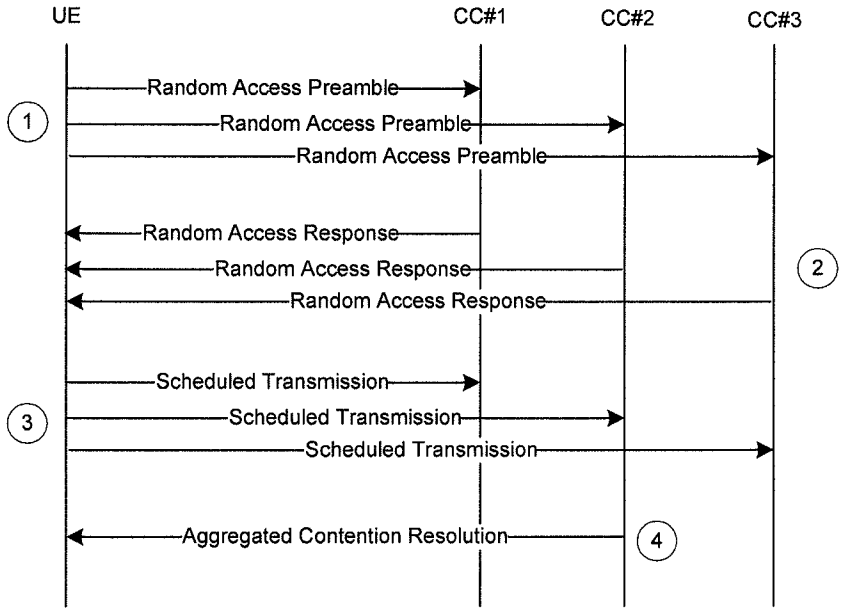


Figure: exemplary embodiment #1-2

The basic idea of the following exemplary embodiments is that UE may not need to perform contention-based RACH procedure on all CCs. UE may perform contention-based RACH on some CCs, and perform non-contention based RACH on another CCs.

The advantage of this invention is to save the radio resource (fewer "Scheduled Transmission" messages and "Contention Resolution" messages are needed), to reduce the RACH collision probability, and to shorten the time duration to achieve UL synchronization due to RACH collisions.

Exemplary embodiment #2-1:

In some exemplary embodiments, the dedicated RACH preamble may be assign by the msg 4 (Contention Resolution message). In the following example, UE performs contention-based RACH on CC#1, and perform non-contention based RACH on CC#2 and CC#3.

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The procedure for the above exemplary embodiment:

- Step 1: the UE may randomly transmit a random access preamble on RACH resource on any CC.
- Step 2: the network may respond with TA information and/or UL scheduling grant, and possibly a C-RNTI assignment associated with the detected preamble.
- Step 3: The UE may transmit a message indicating the UE_ID.
  - Optionally, this message may include the buffer status information of the UE.
  - This message may be conveyed in terms of *RRC Connection Request* message, *RRC Connection Re-establishment* message, *RRC Connection Reconfiguration Complete* message, etc..
  - After receiving the *msg 3*, the network may identify the UE, and may determine whether to command the UE to perform non-contention based RACH procedure.
- Step 4: the network may transmit a message indicating the identity (UE_ID) of the UE.
  - eNB may reserve some dedicated non-contention random access preamble. And this message may include dedicated RACH preambles and/or dedicated RACH resource for CC#2 and/or CC#3.
- Step 5: the UE may transmit the dedicated Random Access Preamble (and/or transmit on the dedicated RACH resource).
- Step 6: the Network may reply a message with the Timing Advance (TA) information for CC#2 and/or CC#3.

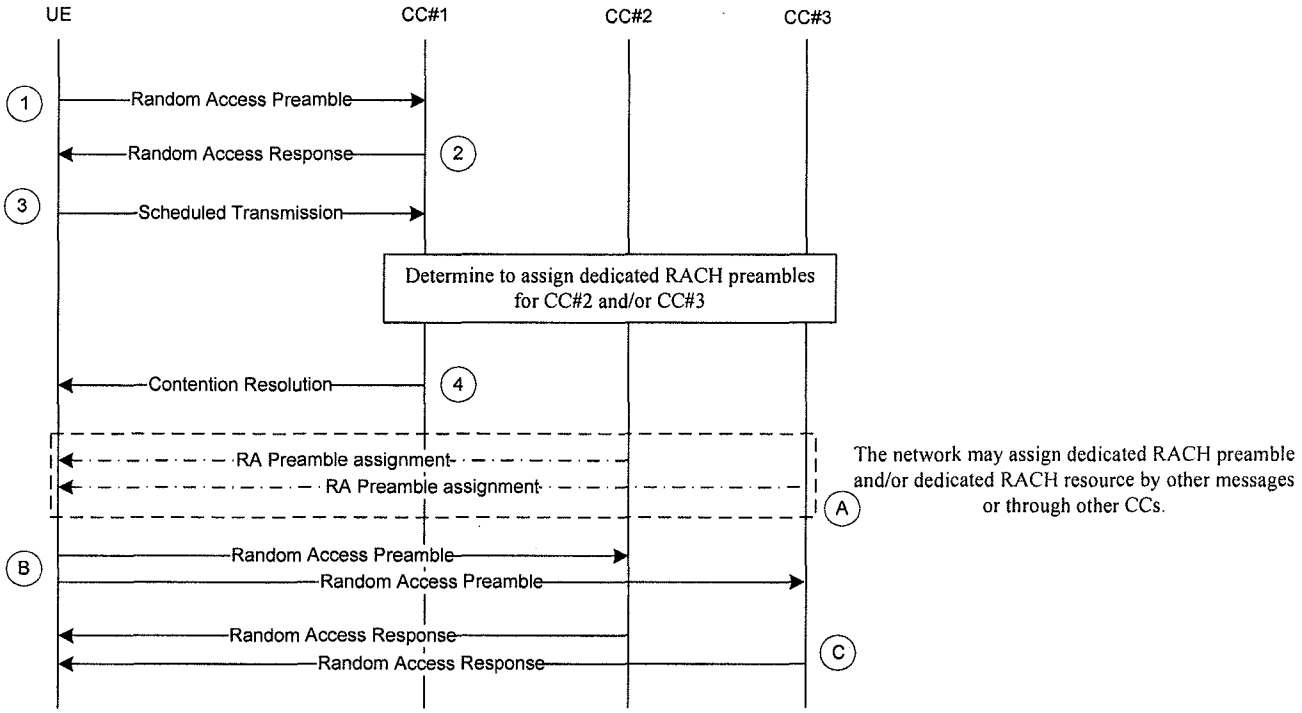
Note that the message 4, Contention Resolution message, may be sent through any CCs. The UE may receive the message 4 on the same CC, where it sends the Random Access Preamble. In other exemplary embodiment, the UE may receive the message 4 on the other CC. For example, the following figure illustrates the case in which the message 4 is sent by CC#2.

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In some exemplary embodiments, the network may respond the Random Access Response message through the same or different CCs, where the UE sends the Random Access Preamble.
In some exemplary embodiments, the network may aggregate multiple Random Access Response messages into one or at least one message, and send the message through any CCs (e.g., CC#1, CC#2, CC#3, etc.).
An example in which the network sends the Aggregated Random Access Response message through the CC#1 is shown as below.

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Exemplary embodiment #3-1:



In addition to the message 4, the network may assign the *dedicated RACH preambles* and/or *dedicated RACH resources* by another messages.

- The message is called "RA Preamble Assignment" message as shown in the figure.
- The *RA Preamble Assignment* may be a PDCCH, MAC, or RRC message.
- The *RA Preamble Assignment* may be transmitted by the DCI format 1A in PDCCH, and then it may include at least one of the following information
  - Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A
  - Localized/Distributed VRB assignment flag
  - Resource block assignment
  - PRACH Preamble Index
  - PRACH Mask Index
  - All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zeroes

Again, the *msg 4* may be or may be not send on the same carrier, where the Random Access Preamble is sent.

Exemplary embodiment #3-3:

In some exemplary embodiments, several RA Preamble Assignment messages may be aggregated. In addition to the parameters carried in the RA preamble message in previous exemplary embodiments, this Aggregated RA Preamble Assignment message may include the information of CC Identity.

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Exemplary embodiment #3-5:

In some exemplary embodiments, the network may respond the Random Access Response message through the same or different CCs, where the UE sends the Random Access Preamble.

In some exemplary embodiments, the network may aggregate multiple Random Access Response messages into one or at least one message, and send the message through any CCs (e.g., CC#1, CC#2, CC#3, etc.).

An example in which the network sends the *Aggregated Random Access Response* message through the CC#1 is shown as below.

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Note that the message transmission order in previous exemplary embodiments may follow $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$ and/or $A \rightarrow B \rightarrow C$. But the message transmission order between the sets (1, 2, 3, 4) and (*A*, *B*, *C*) is not limited. In the following figure, we show the example in which the *msg 4* is sent later than *msgs A* and *B*.

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Exemplary embodiment #4: In some exemplary embodiments, the *Contention Resolution* message and *Random Access Response* messages are aggregated. In this case, this new message may include the information carried in the *Contention Resolution* message and the information carried in the *Random Access Response* message.

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B. Functional Block 2: Maintain Time Alignment Timer (TAT) Validity

The design of Time Alignment Timer

In the mobile network, the mobile stations need to adjust the uplink timing in order to make sure that the signals from the mobile stations would be aligned at the base station. The adjusted time is called timing advance (TA). In other words, timing advance is the length of time that a signal from the mobile station takes to reach the base station.

In the multi-carrier communication system, the component carriers (CC) may have different Timing Advance (TA) values for a UE, i.e., an eNB may need to adjust the Timing Advance per UL CC for a UE. However, some of UL CCs may share the same Timing Advance. In this case, these UL CCs which share the same Timing Advance could be grouped, say TA group. In a TA group, the UE may perform random access on one UL CC to obtain the Timing Advance Command (TAC). On the other hand, the eNB may assign one Timing Advance Command in MAC Control Element (MAC CE) for those UL CCs in the same TA group. The UE adjusts the uplink timing of all the UL CCs in the same TA group according to the received Timing Advance Command.

In LTE system, the Time Alignment Timer (TAT) is used to indicate whether the uplink (UL) timing is aligned or not in the eNB and UE, i.e., when the TAT is running, the uplink is considered as being synchronized; otherwise, the uplink is considered as out-of-sync. However, in multi-carrier system, there are several ways to maintain the TAT as follows:

1. ***One TAT per UL CC:*** A UE maintains one TAT per UL CC. The update of a TAT (start, restart or stop) follows LTE procedure.
2. ***One TAT per TA group***: A UE maintains one TAT per TA group, i.e., the UL CCs in the same TA group share the same TAT. The update of TAT in a TA group may follow LTE procedure.
3. ***One common TAT:*** All UL CCs share a common TAT.

The update of a TAT in LTE system could be triggered by Timing Advance Command received in Random Access Response (RAR) or in MAC Control Element (MAC CE).

In the one common TAT scheme, the TAT running may not represent all UL CCs alignment. For example as shown in Fig. 4, when TAT expires and UL data arrive, a UE performs random access on UL CC#1 to obtain the Timing Advance. When the UE receives the Timing Advance Command, the TAT starts. In LTE system, the TAT running means that uplink

timing is aligned and the UE needs to monitor the possible UL grant and UE needs to feedback Ack/Nack on the UL CCs. In this example, the UE have not adjusted the uplink timing of UL CC#2 and UL CC#3 so the UE should not use these UL CC#2 and UL CC#3. Therefore, we need a scheme to indicate the out of sync of UL CC#2 and UL CC#3.

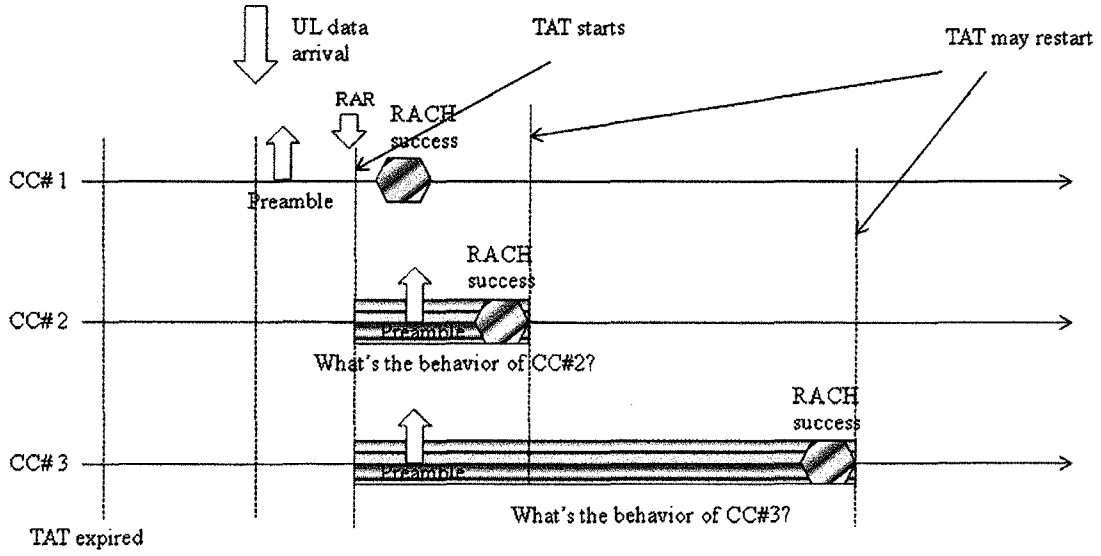


Fig. 4 Example of one common TAT problem

In this invention, we propose CC or TA group valid/invalid tag for TAT. The valid or invalid of a TAT for a UL CC is described below:

- In the case of when the TAT is expiry or stopped, the TAT is invalid for all UL CCs.
- In the case of when the TAT expired and the UE performs random access on a particular UL CC to obtain the Timing Advance Command in RAR, the TAT starts and is valid for this particular UL CC (or the UL CCs in this TA group which this particular UL CC belongs to). If the random access fails due to the contention resolution failure, the UE should stop the TAT and set invalid for this UL CC. For the other UL CCs which do not receive a valid Timing Advance Command, the UE needs to keep TAT to be invalid for these UL CCs.
- In the case of when the TAT is running and the UE performs random access procedure on the UL CC which has an invalid TAT in order to adjust the uplink timing, after the random access successes, the UE sets the TAT to be valid for this UL CC (or UL CCs in the TA group which this UL CC belongs to). If the random access fails, the UE set

the TAT to be invalid for this UL CC (or UL CCs in the TA group which this UL CC belongs to).

- If the TAT is invalid for all UL CCs, the UE should stop the TAT.

Fig.5 shows an example of valid/invalid for one common TAT. After the UE obtains the Timing Advance Command for UL CC#1, the TAT starts running. But the TAT is invalid for UL CC#2 and UL CC#3. Until the random access is successful on UL CC#2 and UL CC#3, the TAT is valid for UL CC#2 and UL CC#3. When the UE receives the Timing Advance Command on UL CC#2 or UL CC#3, the TAT may restart (or reset).

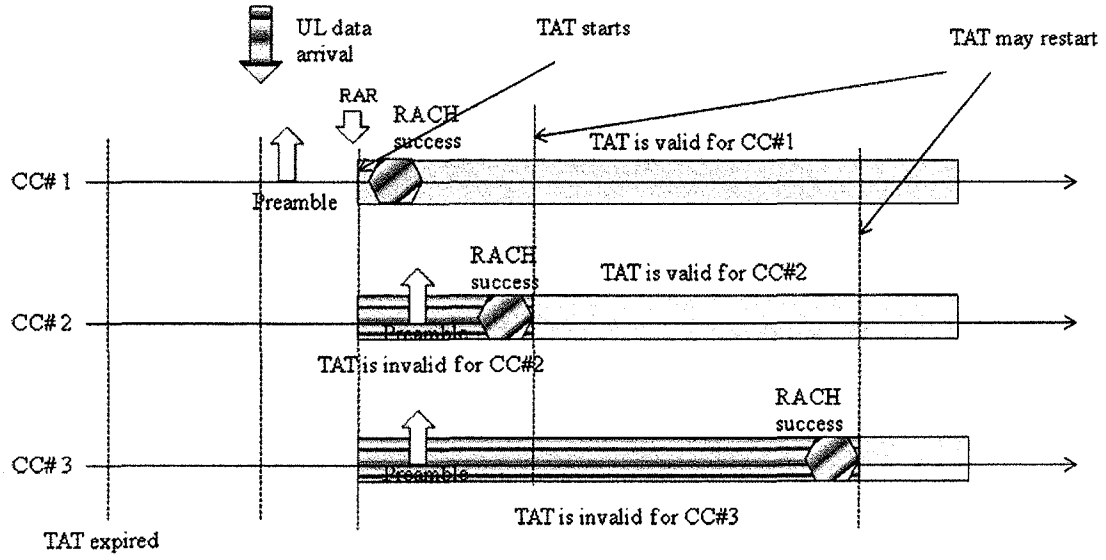


Fig. 5 Example of valid/invalid for one common TAT

Exemplary embodiment#B1

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Fig. Exemplary embodiment #B1

The detail descriptions of Fig. Exemplary embodiment #B1 are as follows:

Initial: TAT is expiry. TAT is invalid for all UL CCs.

Step 1. The UE transmits preamble on UL CC#1.

Step 2. The UE receives the Random Access Response (RAR) and adjusts the timing advance according to the Timing Advance Command in RAR. The UE starts the TAT. The TAT is valid for UL CC#1.

Step 3 – Step 4. Contention resolution is successful. The Random Access procedure completes.

Step 5 – Step 6. The eNB may assign the dedicated preambles to the UE for performing Random Access on UL CC#2 and UL CC#3.

Step 7 – Step 8. The UE performs Random Access on UL CC#2 and receives the TA in the RAR. The UE adjusts the TA and sets the TAT valid for UL CC#2. The UE may restart TAT.

Step 9 – Step 10. The UE performs Random Access on UL CC#3 and receives the TA in the RAR. The UE adjusts the TA and sets the TAT valid for UL CC#3. The UE may restart TAT.

Note: The UE may perform contention based random access on UL CC#2 and on UL CC#3. For example, the eNB assigns the dedicated preamble with all 0s, i.e., the UE needs to select a preamble randomly.

Exemplary embodiment#B1-2

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Fig. Exemplary embodiment #B1-2

In Exemplary embodiment #B1-2 as shown in Fig. , if the contention resolution is failure in Step 4, TAT should stop and TAT is invalid for UL CC#1.

Exemplary embodiment#B1-3

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Fig. Exemplary embodiment #B1-3

In Fig. Exemplary embodiment#1-3, if UE performs contention based random access, after Step 8, TAT is valid for UL CC#2. However, the contention resolution fails in Step 10 so the UE needs to set the TAT invalid for UL CC#2. Then UE continues to perform random access on UL CC#2.

C. *Functional Block 3: Maintain Time Alignment Timer (TAT) Validity*

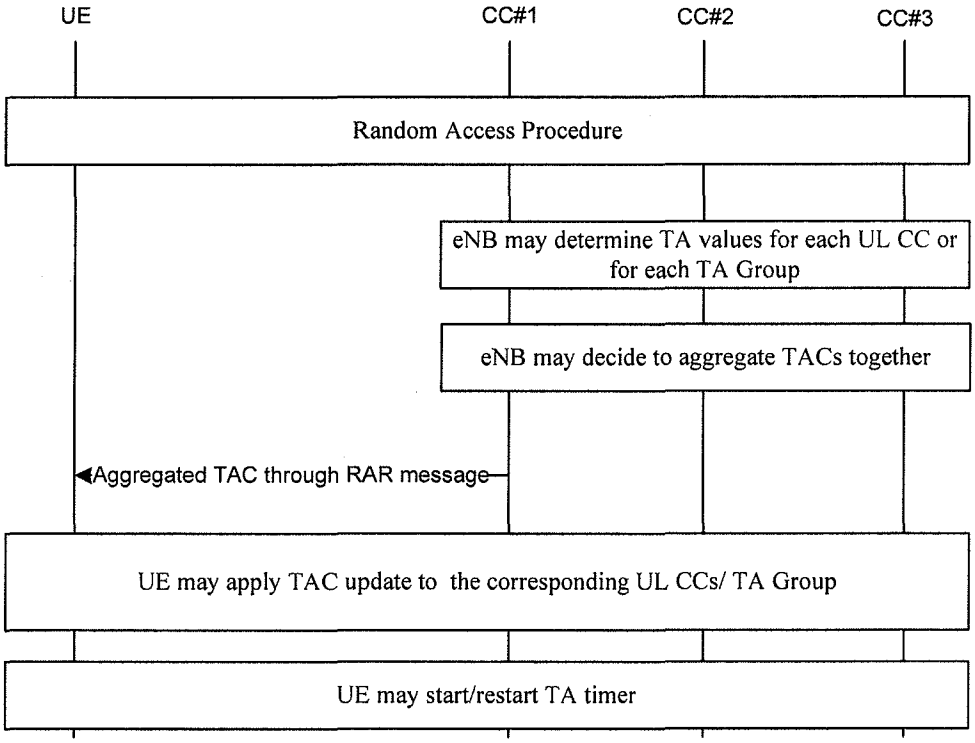
Timing Advance (TA) Adjustment—Timing Advance Command in Multiple CCs Applications

Note that at most 5 UL CCs are supported in LTE-Advanced. In the following exemplary embodiments, the case of supporting 5 CCs is illustrated. However, the basic invention can be applied to support any number of CC configurations. In the following exemplary embodiments, the case of TAC MAC control element (or RAR) is illustrated. However, the basic invention may be applied to other MAC control elements for alone/ aggregated MAC control element transmissions in multiple CCs applications.

Procedure of exemplary embodiment #1:

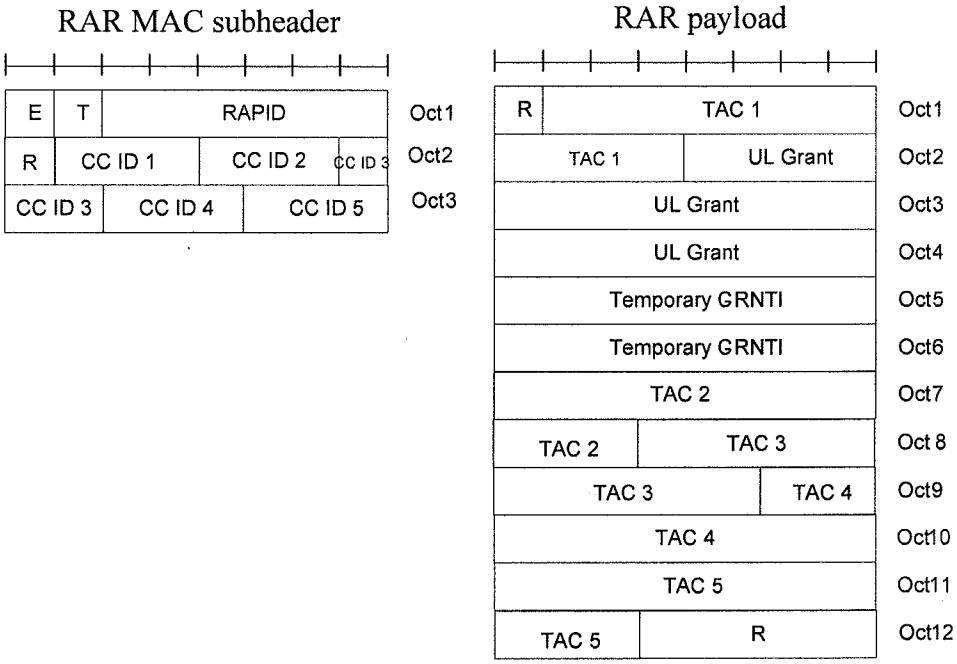
Aggregated TAC transmission procedure of exemplary embodiment through RAR

In this procedure of exemplary embodiment, TAC may be aggregated together and sent through RAR message through any CCs. E.g., UE may perform Random Access Procedure on the CC#1 to CC#3, and network may determine the TAs for CC#1 to CC#3. Afterwards, the network may decide to aggregate TACs together, and the aggregated TAC may sent through RAR message through any CCs. After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may start/restart TA timer.

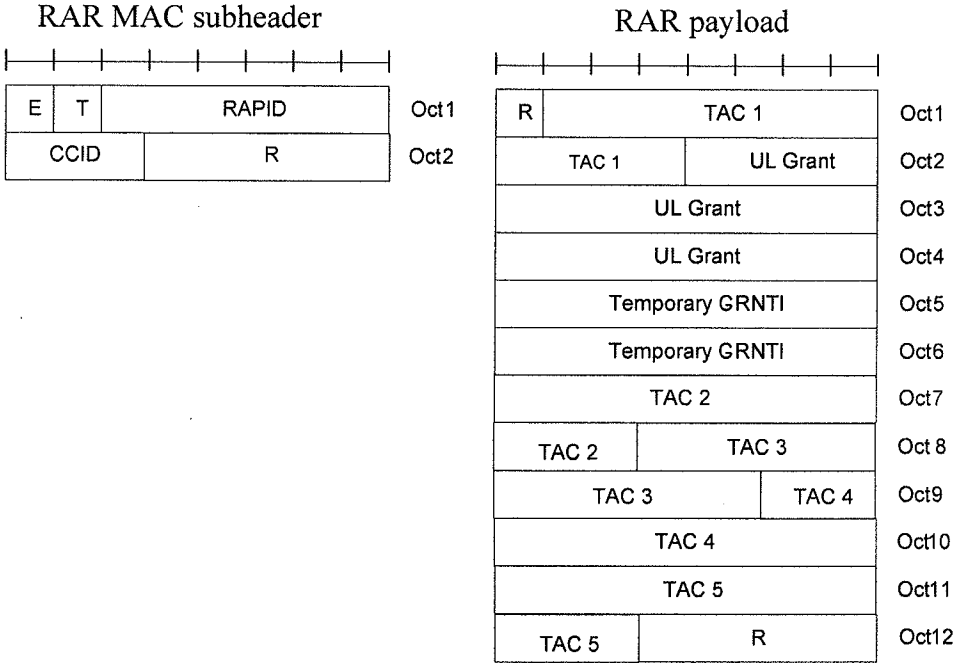


Exemplary embodiment # 1-1

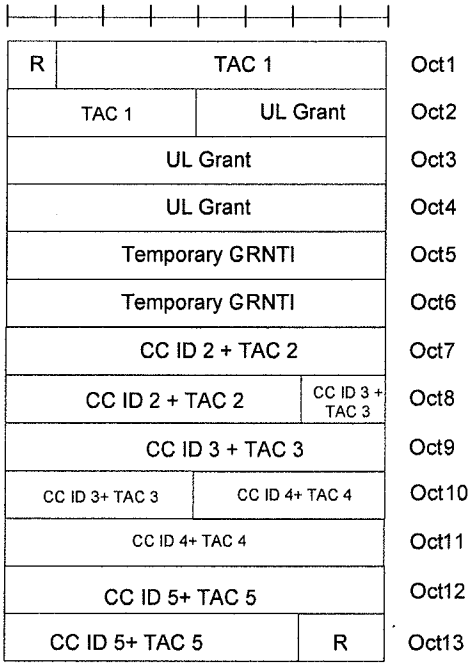
In this exemplary embodiment, UE supports multiple CCs or not may be distinguished in PHY layer by using different RA-RNTI for DCI scrambling. For example, different resource for RACH may be used for UE supports multiple CCs and UE does not support multiple CCs so that different RA-RNTI may be used to scramble RAR DCI. In this case, UE supports multiple CCs may use new RAR MAC subheader and MAC RAR payload format for aggregated RAR transmissions. E.g., one or more CC ID information may be included in RAR MAC subheader.



E.g., to avoid duplicate RAPID chosen by multiple UEs, CC ID information may be included in RAR MAC subheader.

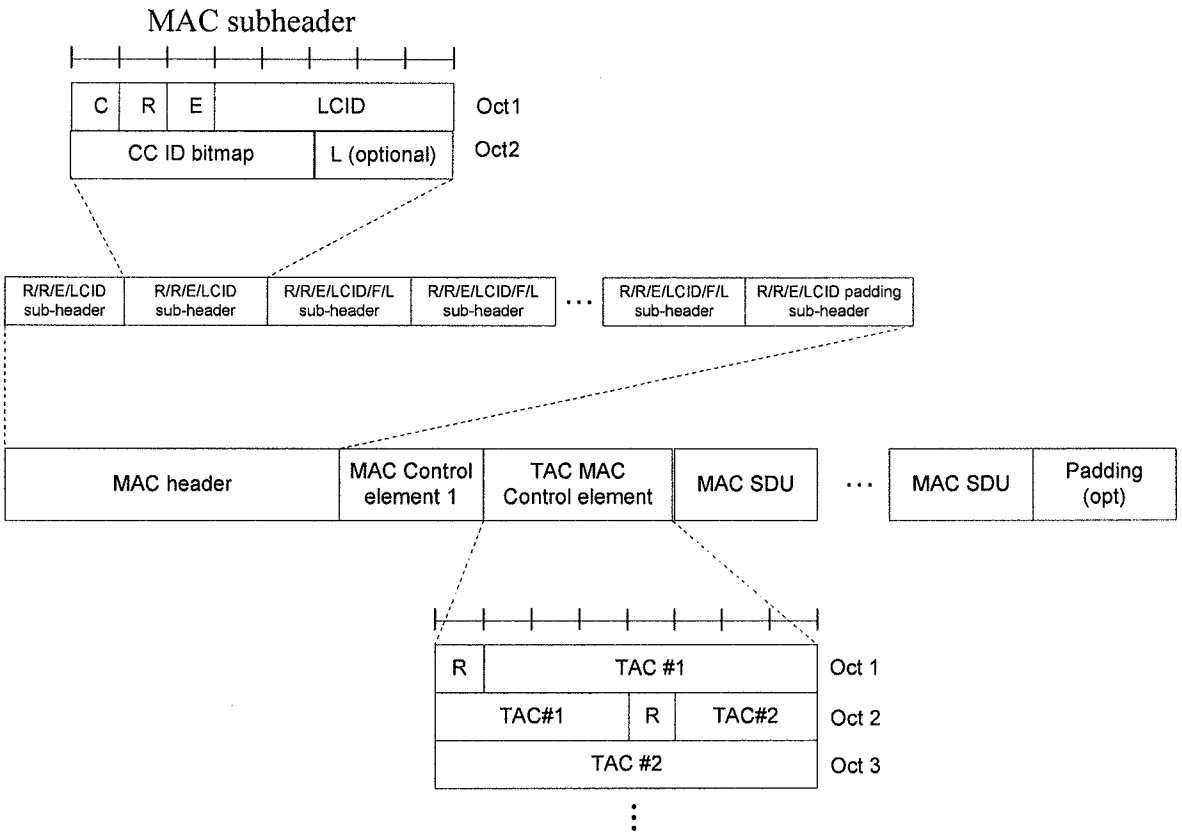


E.g., CC ID information may be included in RAR MAC payload



Exemplary embodiment # 1-2

In this exemplary embodiment, UE specific RNTI (e.g., C-RNTI) may be used in DCI scrambling to indicate RAR MAC PDU. For example,



Exemplary embodiment # 1-3

In this exemplary embodiment, multiple TACs may be aggregated RAR message and the aggregated RAR TAC may include CC ID information explicitly and/or implicitly. For example, CC ID information may be included the RAR MAC subheader. For example, CC ID information may be included the RAR MAC payload.

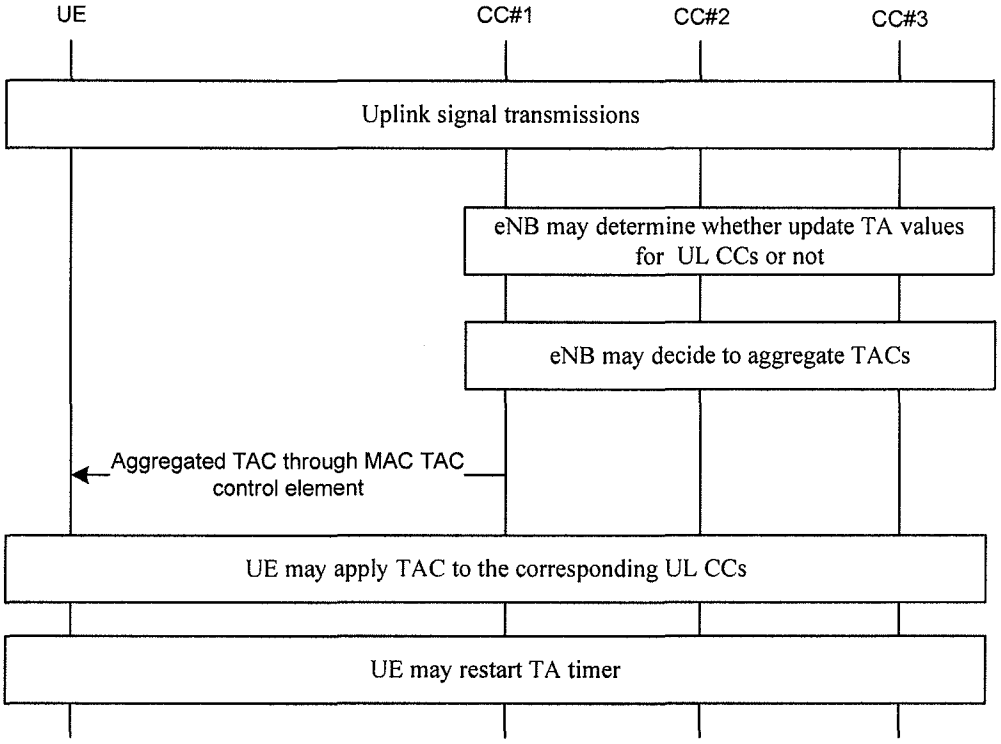
Exemplary embodiment # 1-4

In this exemplary embodiment, multiple TACs may be aggregated RAR message and the aggregated RAR TAC may include CC ID bitmap information explicitly and/or implicitly. For example, CC ID bitmap information may be included the RAR MAC subheader. For example, CC ID bitmap information may be included the RAR MAC payload.

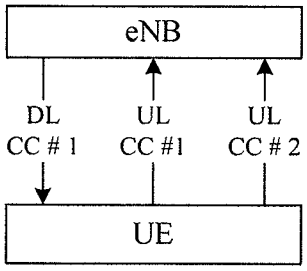
Procedure of exemplary embodiment # 2:

Aggregated TAC transmission procedure through MAC TAC control element

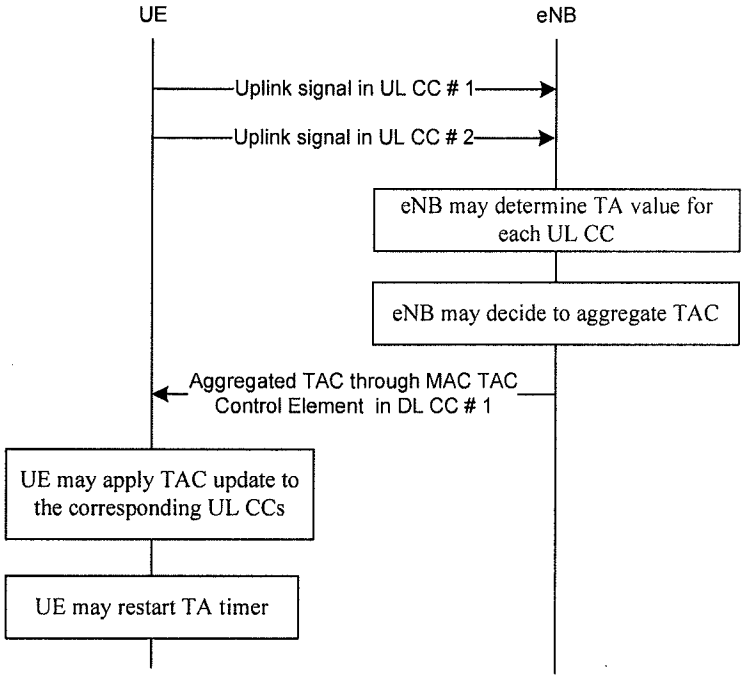
In this procedure of exemplary embodiment, TAC update message may be aggregated together and sent through MAC control element through any CCs. E.g. # 1, the network may measure the timing of the UE uplink signal and may determine the TAs for CC#1 to CC#3. Afterwards, the network may decide to aggregate TACs together, and the aggregated TAC may sent through MAC TAC control element message through any CCs (CC#1 to CC# 3). After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may restart TA timer



E.g., # 2: Aggregated TAC update in asymmetric DL/UL CC configuration scenario. E.g., one DL CC (DL CC#1) may link to 2 UL CCs (UL CC#1 and UL CC#2) and UE may send Uplink signal through UL CC#1 and CC#2. Afterwards, the network may determine TA value for each UL CC and the network may decide to aggregate TACs together and send the TAC through MAC control element through DL CC#1. After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may restart TA timer.



DL/ UL CCs configuration

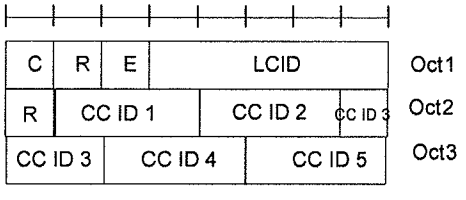


TAC update procedure

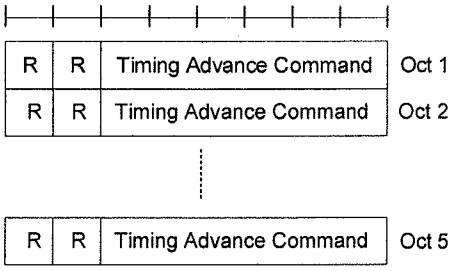
Exemplary embodiment # 2-1

In this exemplary embodiment, multiple TACs may be aggregated in a MAC control elements and the aggregated TAC may include CC ID information explicitly and/or implicitly. For example, CC ID information may be in the MAC subheader. For example, "R" bit(s) may indicate that multiple TAC is included in the MAC subheader. E.g. # 1, a "R" bit is used as C bit to indicate CC ID is included in the MAC subheader. 5 CC IDs may be used to indicate the following TAC for the corresponding UL CC

subheader



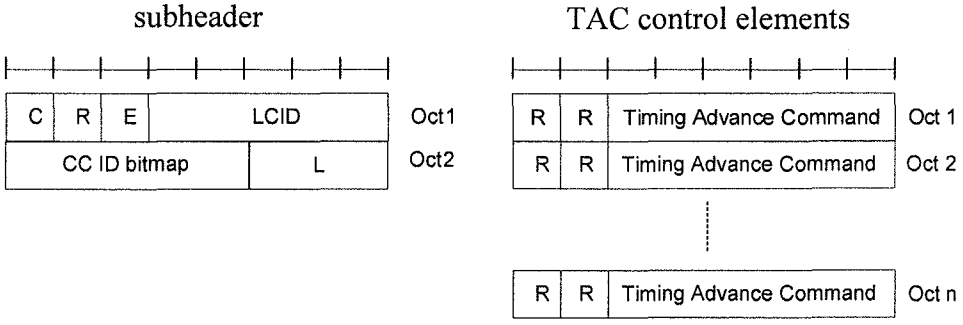
TAC control elements



For example, CC ID information may be in the TAC control element explicitly. For example, CC ID information may be in the TAC control element implicitly.

Exemplary embodiment # 2-2

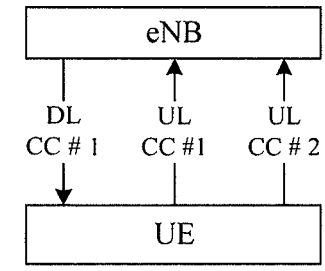
In this exemplary embodiment, multiple TACs may be aggregated in a MAC control elements and the aggregated TAC may include CC ID bitmap information explicitly and/or implicitly. For example, CC ID bitmap information may be in the MAC subheader. We may use "R" bit to indicate CC ID bitmap is included in the MAC subheader. E.g., 5 bits CC ID bitmap is to indicate the following TAC for the corresponding UL CC. It is optional to have a length filed "L" to indicate the TAC octet number. E.g., CC ID bitmap is set to be 01001 (L may be 010), and then the corresponding TACs are for CC ID 2 and CC ID 5.



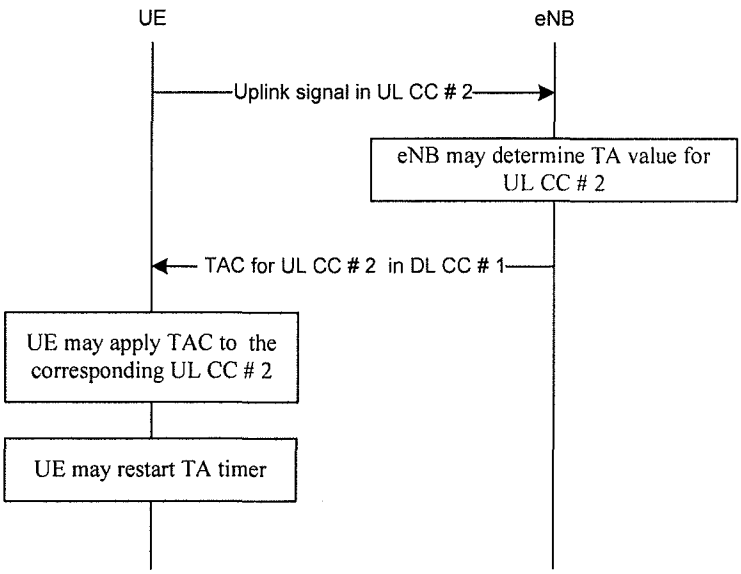
For example, CC ID bitmap information may be in the TAC control element explicitly. For example, CC ID bitmap information may be in the TAC control element implicitly.

Procedure of exemplary embodiment # 3:
TAC update in asymmetric DL/UL CC configuration scenario

In this procedure of exemplary embodiment, TAC update message may be sent through MAC control element through any DL CCs in asymmetric DL/UL CC configuration scenario. For example, one DL CC (DL CC#1) may link to 2 UL CCs (UL CC#1 and UL CC#2) and UE may send Uplink signal through UL CC#2. Afterwards, the network may determine TA value for the UL CC#2 and the network may send the TAC through MAC control element through DL CC#1. After receiving TAC, UE may apply TAC to UL CC#2 and then UE may restart TA timer.



DL/ UL CCs configuration

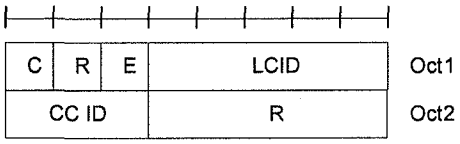


TAC update procedure

Exemplary embodiment # 3-1

In this exemplary embodiment, MAC subheader may include the CC ID information. For example, a original "R" bit is used as C bit to indicate CC ID is included in the MAC subheader. E.g. #1, TAC MAC control element subheader.

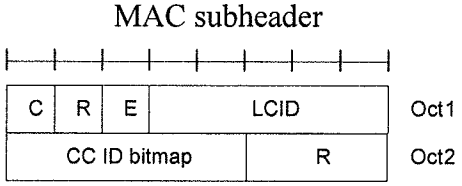
subheader



Exemplary embodiment # 3-2

In this exemplary embodiment, MAC subheader may include a CC ID bitmap. For example, if the i-th bit in the bitmap is set to 1, then it means the TAC may apply to the corresponding CC # i. E.g., Use a "R" bit as C bit to indicate a CC ID bitmap is included in the MAC subheader. 5 bits CC ID bitmap is to indicate the corresponding UL CC to update its/their TA value according to TAC

E.g.,

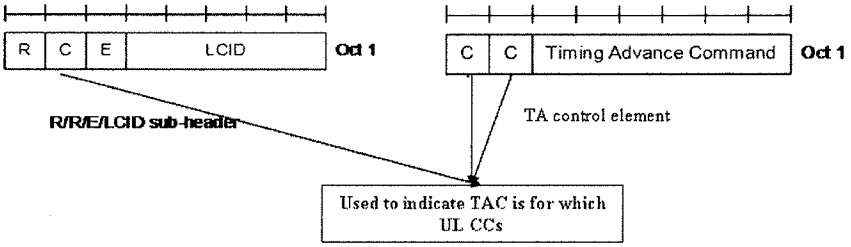


E.g., CC ID bitmap= 01001 => UL CC ID 2 and 5 should update their TA according to the corresponding TAC

Exemplary embodiment # 3-3

In this exemplary embodiment, the CC ID information is indicated by MAC subheader and TA control element. For example, there may be four Reserved bits in the MAC subheader and TA control element. We may use 3 bits to indicate TAC is for certain CC and/or for all CCs, and keep an unused bit as "R" bit

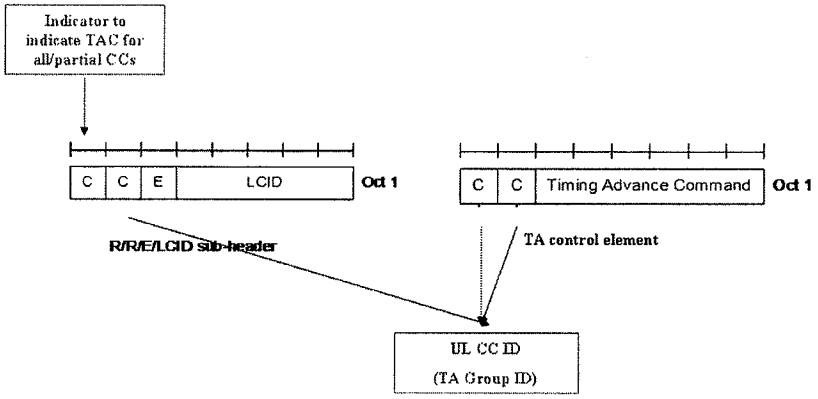
E.g., to support 3 UL CCs, we set 3 bits to indicate the TAC is for 3 UL CCs or for a certain CC, and other bit keep as "R". E.g., 111=> for all UL CCs, 001=> UL ID 1, 010=> UL ID 2, 011 => UL ID 3



Exemplary embodiment # 3-4

In this exemplary embodiment, the CC ID information is indicated by MAC subheader and TA control element and MAC subheader may indicate if the TAC is applied to all CCs. For example, one "R" bit is to indicate TAC is for all or for partial CCs. If the bit is set to 0, then the TAC is applied to all CCs;

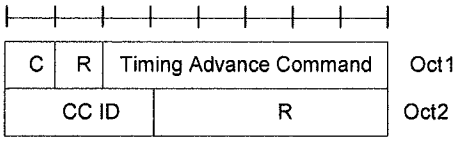
else the TAC is applied to partial CCs. We may use the remaining 3 "R" bits to indicate a certain CC ID as illustrated in exemplary embodiment #1.



Exemplary embodiment # 3-5

In this exemplary embodiment, MAC TA Control Element may include CC ID information. For example, a "R" bit is used as C bit to indicate CC ID is included in the MAC TA control element

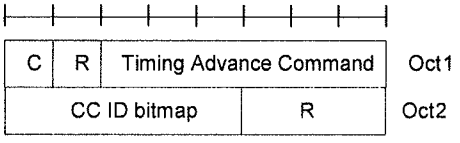
TA control element



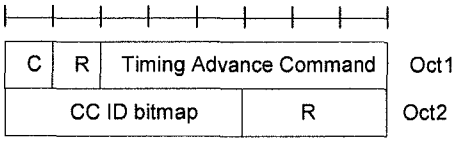
Exemplary embodiment # 3-6

In this exemplary embodiment, MAC TA Control Element may include CC ID bitmap information. For example, if the i-th bit in the bitmap is set to 1, then it means the TA Command may apply to the corresponding CC #i. E.g., Use a "R" bit as C bit to indicate a CC ID bitmap is included in the TA Control Element. 5 bits CC ID bitmap is to indicate the corresponding UL CC to update its /their TA value according to TAC. E.g., CC ID bitmap= 01001 => UL CC ID 2 and 5 should update their TA according to the TAC

TAC control element



TAC control element



The text and figures included herein provide examples of embodiments of the present invention, and provide support for a system, method, apparatus, and computer program product according to exemplary embodiments of the invention. It will be understood that each operation of the figures and/or text, and/or combinations of operations in the figures and/or text, can be implemented by various means. Means for implementing the operations of the figures and/or text, and/or combinations of the operations in the flowcharts and/or associated text may include hardware such as circuitry, integrated circuit devices, or the like. A hardware embodiment or means may include a hardware device that is specifically designed and configured for implementation of the operations described herein, a hardware element that is configured under the direction of program code or instructions according to the operations described herein, or a combination of both. Examples of such hardware embodiments or means may include an Application Specific Integrated Circuit (ASIC), a Programmable Logic Device (PLD), a Field Programmable Logic Array (FPGA), a processor, or other programmable apparatus. Embodiments of the present invention may also take the form of one or more of the operations described herein embodied as program code instructions stored on a computer-readable storage medium. As defined herein a "computer-readable storage medium," which refers to a physical storage medium (e.g., volatile or non-volatile memory device), can be differentiated from a "computer-readable transmission medium," which refers to an electromagnetic signal.

The program code instructions which embody the operations may be stored by or on a computer-readable storage medium, such as a memory device of an apparatus, and executed by one or more hardware devices. As will be appreciated, program code instructions may be loaded onto a hardware device to produce a particular and specially configured machine for implementing the operations described in the figures and/or text. Embodiments of the present invention may include hardware devices that load and execute the operations in a sequential manner, or hardware devices that load and/or execute some or all of the operations simultaneously.

It will be appreciated by one of skill in the art that the example embodiments of the present invention provided herein describe some, but not all embodiments of the invention. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Moreover, although the foregoing descriptions and the associated drawings describe example embodiments in the context of certain example combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions may be provided by alternative embodiments without departing from the scope of the present invention. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

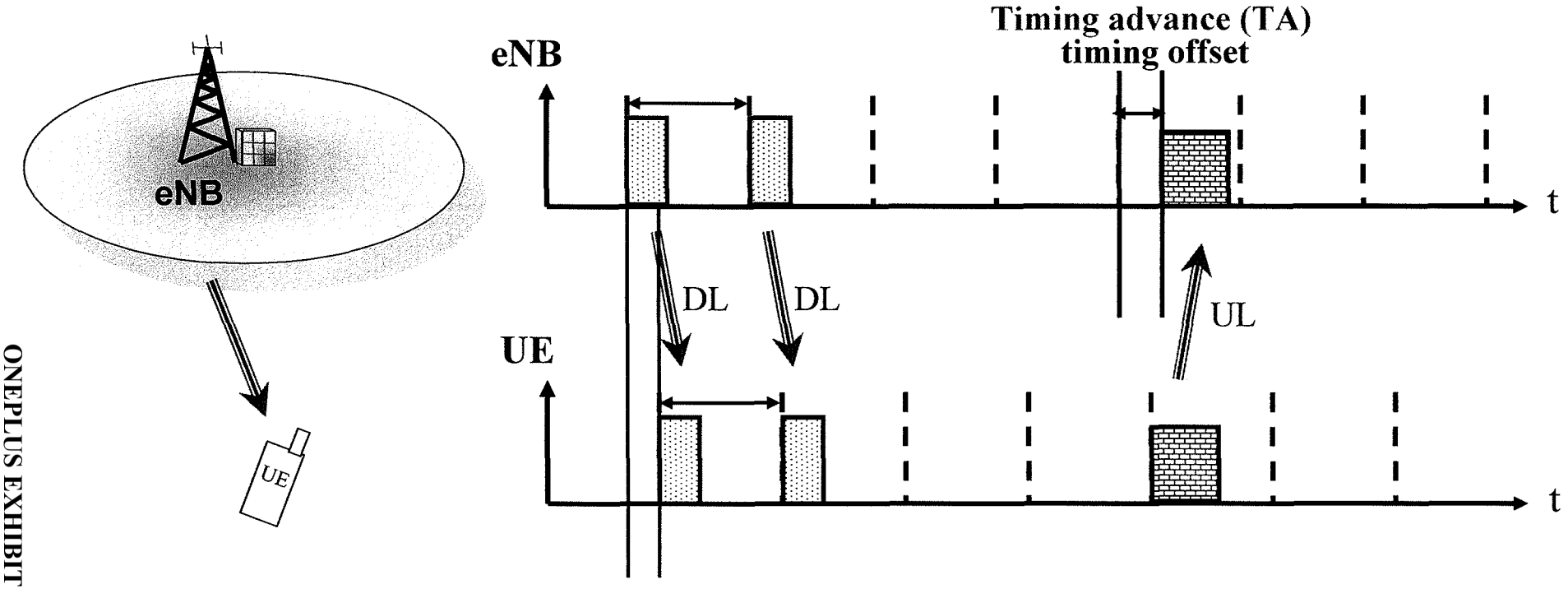
Methods and System for Multiple Uplink Timing Synchronization

Inventors: Chun-Yen Wang, Chun-Chia Chen, Shiang-Jiun Lin

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Introduction (Uplink Synchronization)

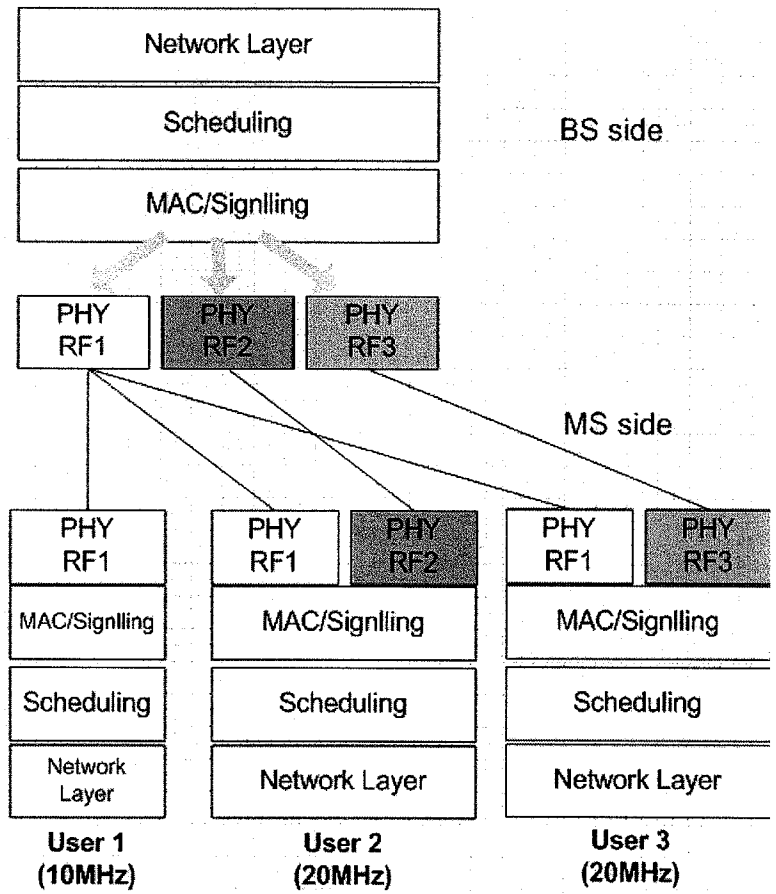
- The non-synchronized RACH procedure could be a solution to achieve UL synchronization (i.e., inform the UE to adjust the timing offset at the UE side to compensate for the round trip delay).



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Background (Multiple Component Carrier (CC))

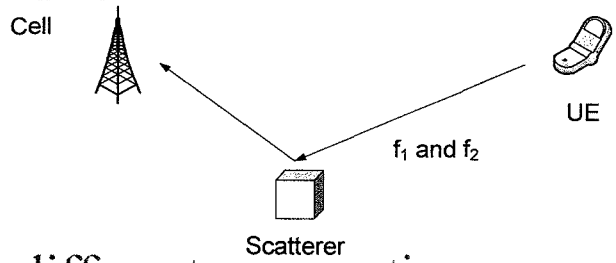
- The operations of multiple component carriers (CCs)
  - A separate FFT and RF module is used at each carrier
    - Low cost
  - One MAC entity & above layers
  - Scalar bandwidth can be achieved in wireless network
- With the application of a scheme referred to as "Multicarrier", networks may be enabled to operate over continuous or discontinuous carriers having different bandwidths.



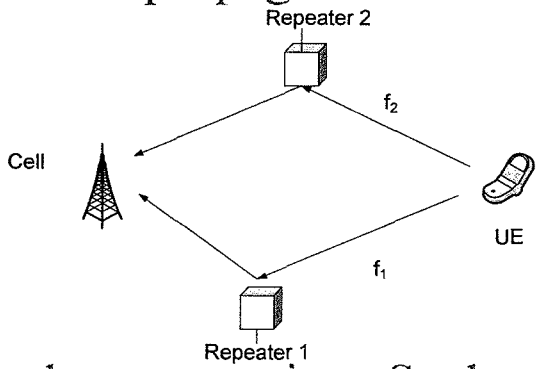
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Multiple UL TA Scenario

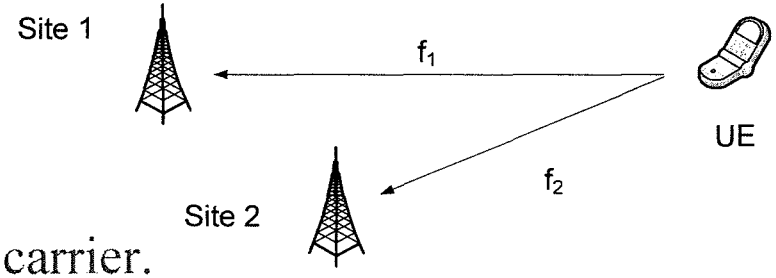
- Scenario #1: Component Carriers in the absence of repeaters, RRUs, CoMP.
  - Same timing advance could be acceptable as a similar propagation environment is possible on both carriers



- Scenario #2: Frequency Selective Repeaters
  - The different component carriers could see substantially different propagation environments due to different frequency selective repeaters and hence see different time-of-flights.



- Scenario #3: Non-Collocated Sites
  - The UE may communicate with two non-collocated sites on the two carriers. Such a scenario could occur with remote antennas or remote radio heads.

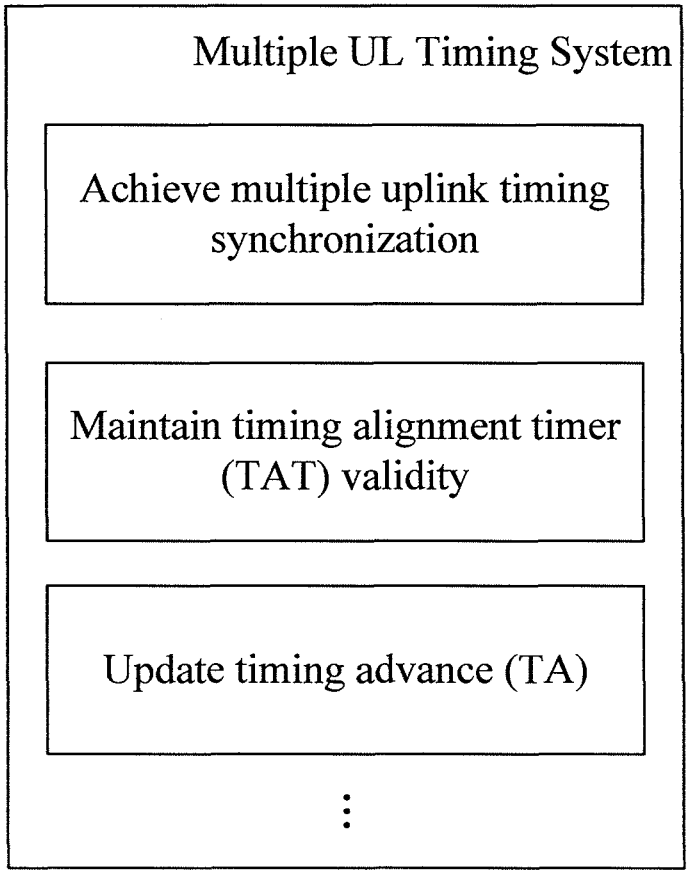


- Scenario #4: Co-ordinated MultiPoint (CoMP)
  - In the context of uplink CoMP, where different cells could be receiving the UE's signals on any carrier. The timing advance could therefore be chosen to target any of the cells, and thus different carriers could have different timing advance commands.

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Our Proposed Methods

- In order to achieve a multiple CC system with multiple UL timing, at least one of the following three functions may be applied.
  - Achieve UL timing synchronization on multiple CCs
  - Maintain time alignment timer (TAT) validity
  - Update timing advance (TA) for multiple CCs



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Note

- Note that this disclosure uses 3GPP-like keywords; however, embodiments can be applied to any other systems (e.g., IEEE 802.11, IEEE 802.16, etc.) for achieving multiple UL synchronization.
- In this paper, we use the term CC to represent a component carrier. However, a CC can also be considered as a cell, which may operate on FDD (frequency division duplex) and/or TDD (time division duplex). A cell may have downlink resource to transmit signals from BS to UE, and/or may have uplink resource to transmit signals from UE to BS.
- Multiple CCs may operate on the same or different frequency band, and may have the same or different center frequency.
- Multiple CCs may belong to the same BS or different BSs. The term "base station" (BS) in this paper may be, for example, a Node-B, an eNode B, a base transceiver system (BTS), an access point, a home base station, a relay station, a scatterer, a repeater, an intermediate node, an intermediary, and/or satellite-based communication base station, etc.
- The term "user equipment" (UE) in this paper may be, for example, a server, a client, a desktop computer, a laptop computer, a network computer, a workstation, a personal digital assistant (PDA), a tablet personal computer (PC), a scanner, a telephony device, a pager, a camera, a television, a hand-held video game device, a musical device, a wireless sensor, etc.
  - In some applications, a UE may be a fixed computing device operating in a mobile environment, such as a bus, a train, an airplane, a boat, a car, etc.

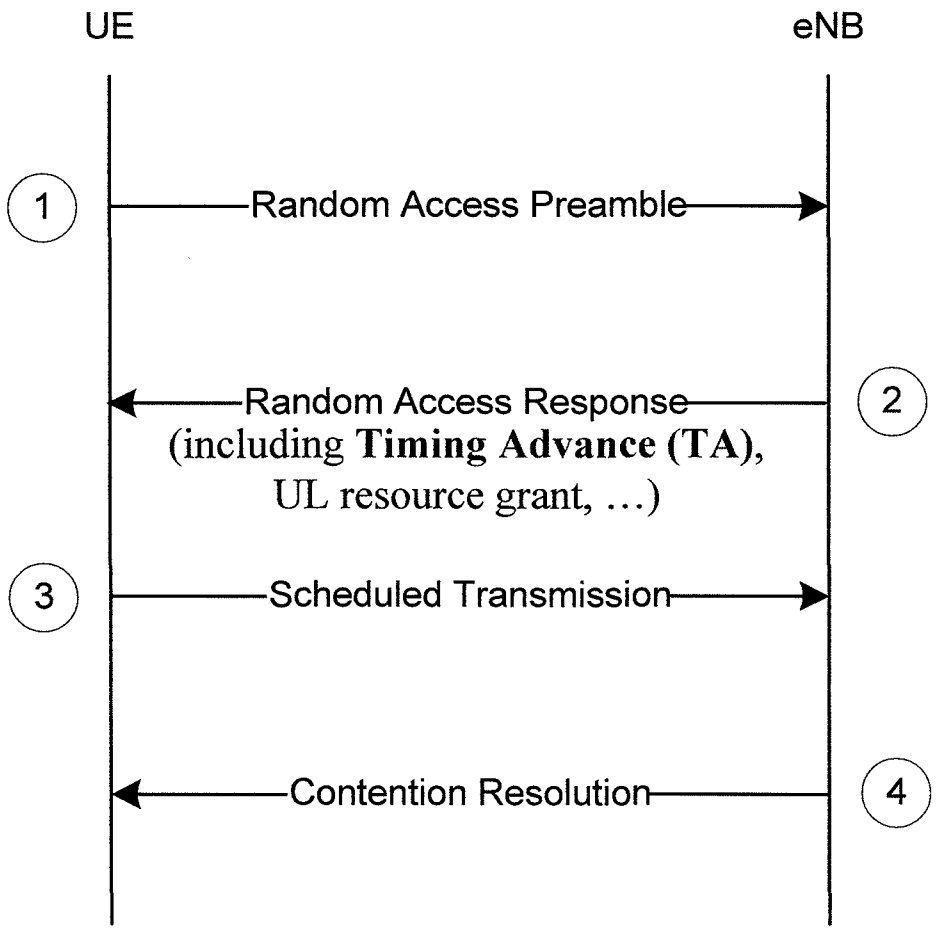
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Functional Block 1:
Achieve Multiple UL Timing Synchronization

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Contention-based Random Access Channel

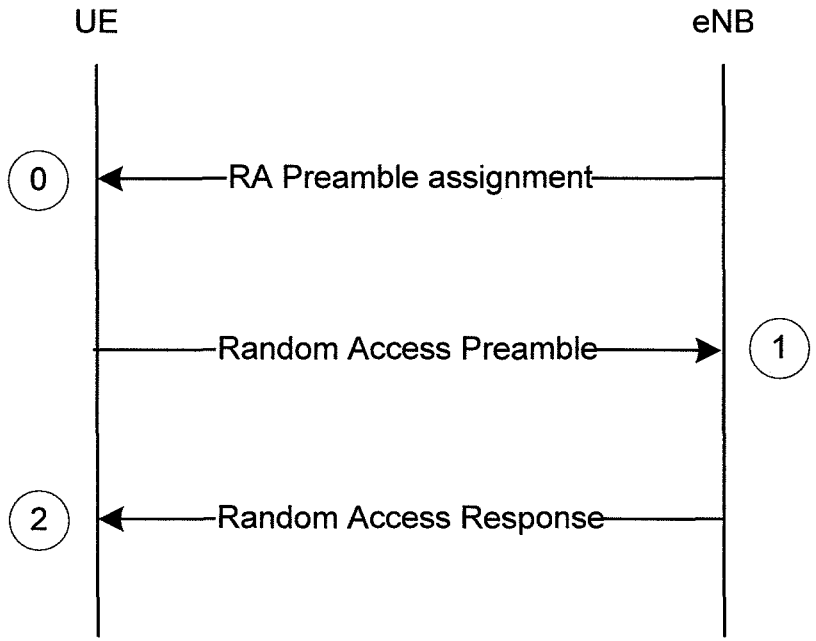
- Step 1: One or more UEs may randomly transmit a random access preamble on RACH resource in uplink.
- Step 2: The eNB may respond with Timing Alignment or Timing Advance (TA) information, UL scheduling grant and possibly a C-RNTI assignment associated with the detected preamble.
- Step 3: The UE may transmit a message indicating the UE_ID on the granted UL resource.
- Step 4: To resolve contention, the eNB may transmit a message indicating the identity (UE_ID) of the UE for which the eNB successfully decoded message 3.



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Non-Contention based Random Access Channel

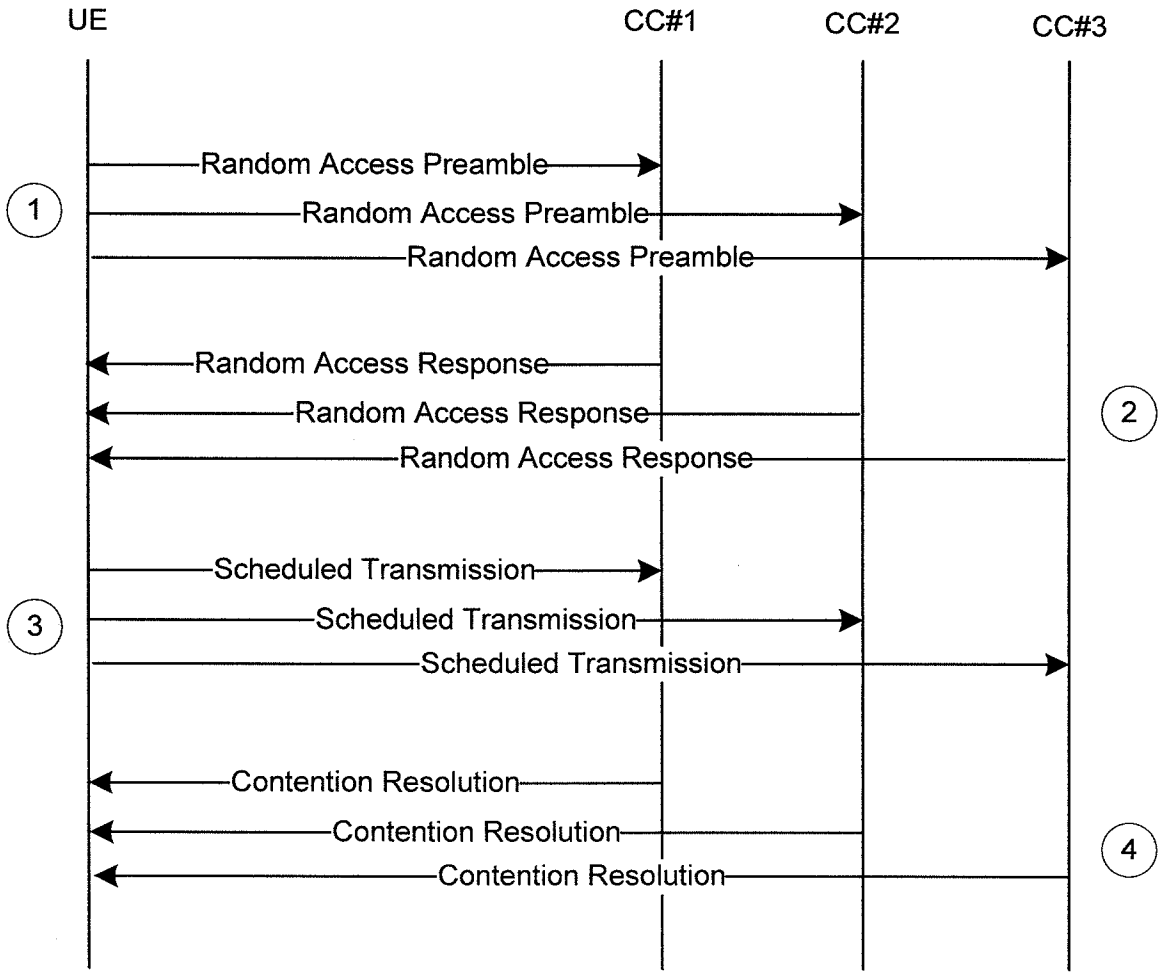
- Step 0: eNB may reserve some dedicated non-contention random access preamble, and assign to UE a non-contention Random Access Preamble.
- Step 1: UE may transmit the assigned non-contention Random Access Preamble.
- Step 2: The eNB may respond the Random Access Response message including the Timing Advance (TA) information.
  - It is optional that this message may include UL resource grant information.



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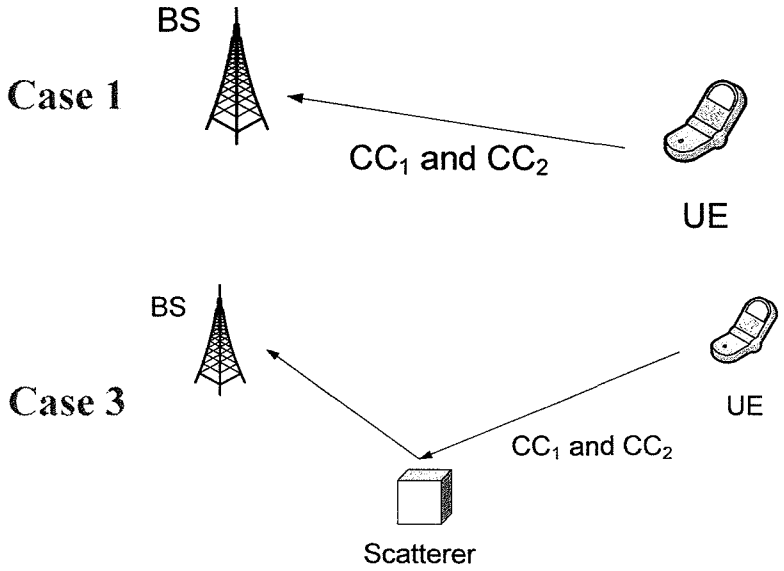
Embodiment #1-1: Contention based RACH in multiple UL TAs

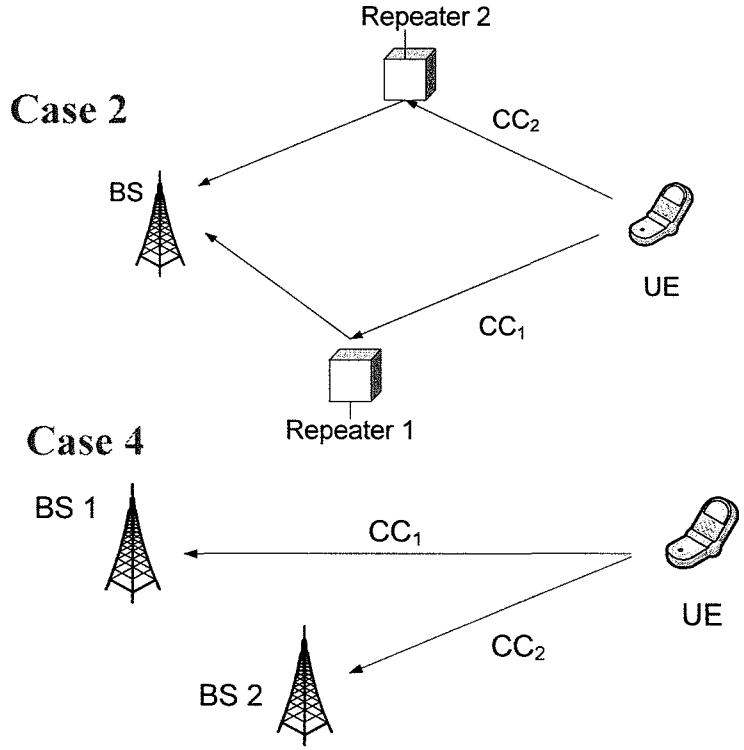
- In this embodiment, several RACH procedures may be perform in parallel. An example is illustrated as below.



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- In an example embodiment of the present invention, three CCs are illustrated. However, examples can be applied to any number of CCs.
- In some examples, CCs may operate on the same and/or different frequency band. In addition, these CCs may operate on FDD (frequency division duplex) and/or TDD (time division duplex).
- These CCs (e.g., CC#1, CC#2, CC#3) may belong to the same BS or different BSs. The term base station (BS) in this invention may be a Node-B, an eNode B, a base transceiver system (BTS), an access point, a home base station, a relay station, a repeater, an intermediate node, an intermediary, and/or satellite-based communication base station, etc.
  - For example,

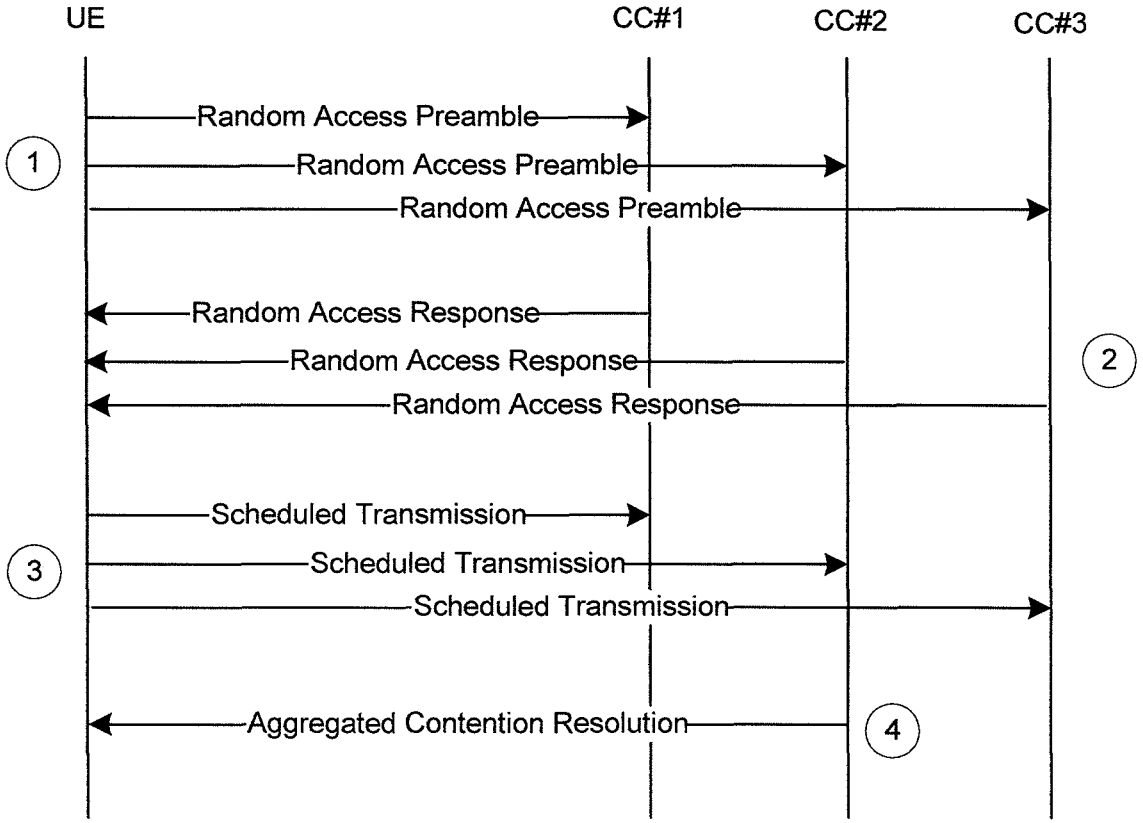




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Embodiment #1-2

- In some embodiments, some messages may be aggregated together and sent through any CCs.
  - For example, the network side may aggregate multiple *msg 4* (i.e., *Contention Resolution* messages) into one (or at least one) message, and send the message through the CC#2 as follows.



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Embodiment #2

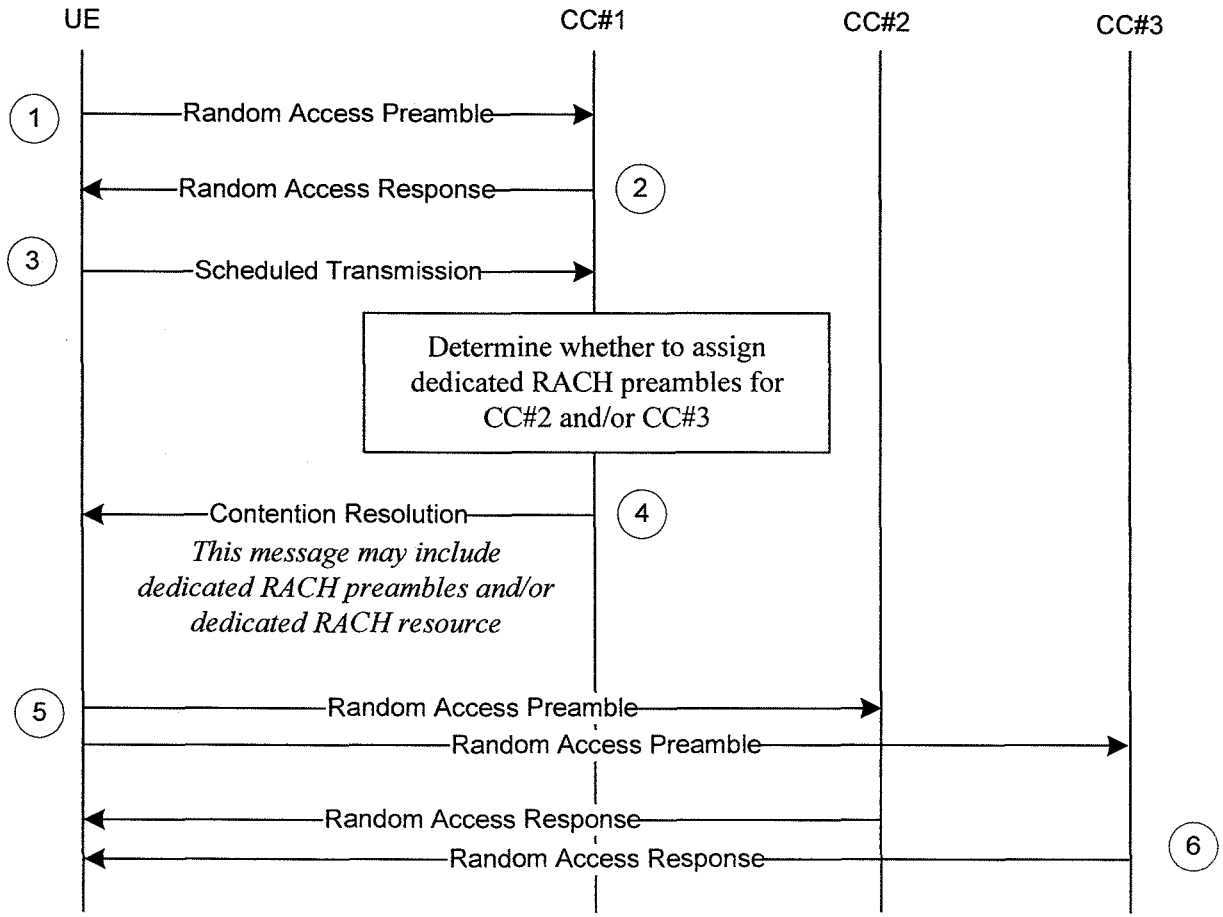
- The basic idea of this embodiment is that UE may not need to perform contention-based RACH procedure on all CCs.
  - UE may perform contention-based RACH on some CCs, and perform non-contention based RACH on another CCs.

- Some advantage of this concept is to
  - Save the radio resource (fewer "Scheduled Transmission" messages and "Contention Resolution" messages are needed).
  - Reduce the RACH collision probability
  - Shorten the time duration to achieve UL synchronization due to RACH collisions.

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Embodiment #2-1

- In some embodiments, the dedicated RACH preamble may be assign by the *msg 4* (*Contention Resolution* message)
  - In the following example, UE performs contention-based RACH on CC#1, and perform non-contention based RACH on CC#2 and CC#3.



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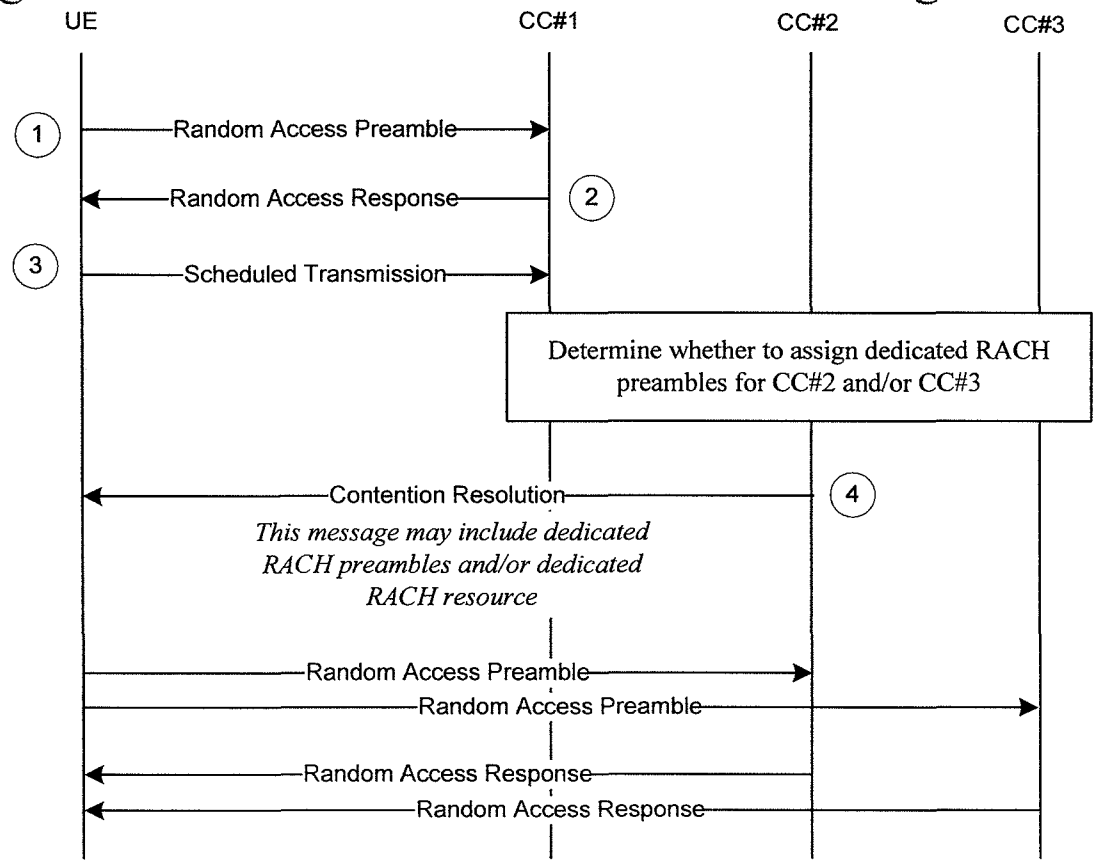
Procedure for the Embodiment #2-1

- Step 1: the UE may randomly transmit a random access preamble on RACH resource on any CC.
- Step 2: the network may respond with TA information and/or UL scheduling grant, and possibly a C-RNTI assignment associated with the detected preamble.
- Step 3: The UE may transmit a message indicating the UE_ID.
  - Optionally, this message may include the buffer status information of the UE.
  - This message may be conveyed in terms of *RRC Connection Request* message, *RRC Connection Re-establishment* message, *RRC Connection Reconfiguration Complete* message, etc..
  - After receiving the *msg 3*, the network may identify the UE, and may determine whether to command the UE to perform non-contention based RACH procedure.
- Step 4: the network may transmit a message indicating the identity (UE_ID) of the UE.
  - eNB may reserve some dedicated non-contention random access preamble. And this message may include dedicated RACH preambles and/or dedicated RACH resource for CC#2 and/or CC#3.
- Step 5: the UE may transmit the dedicated Random Access Preamble (and/or transmit on the dedicated RACH resource).
- Step 6: the Network may reply a message with the Timing Advance (TA) information for CC#2 and/or CC#3.

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Embodiment #2-2

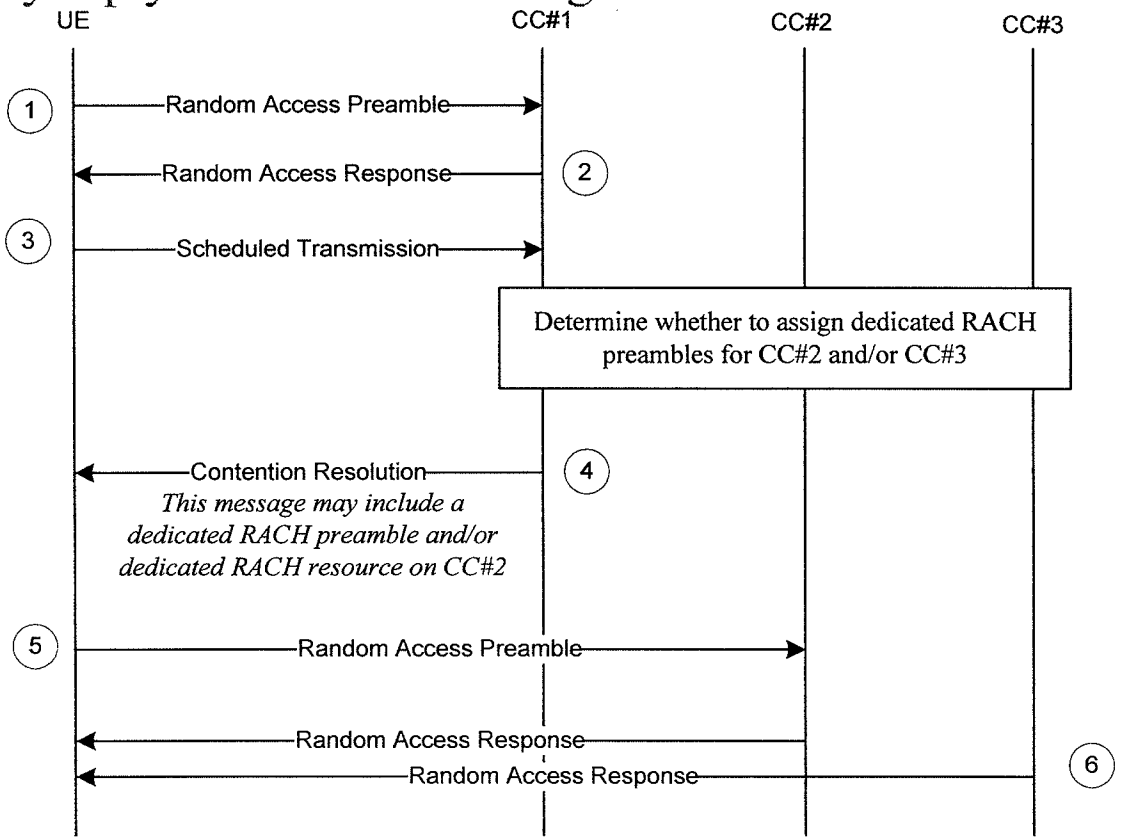
- In addition, the message 4 *Contention Resolution* message, may be sent through any CCs.
  - The UE may receive the *msg 4* on the same CC, where it sends the Random Access Preamble.
  - In some embodiments, the UE may receive the *msg* 4 on other CCs. For example, the following figure illustrates the case in which the message 4 is sent by CC#2.



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Embodiment #2-3

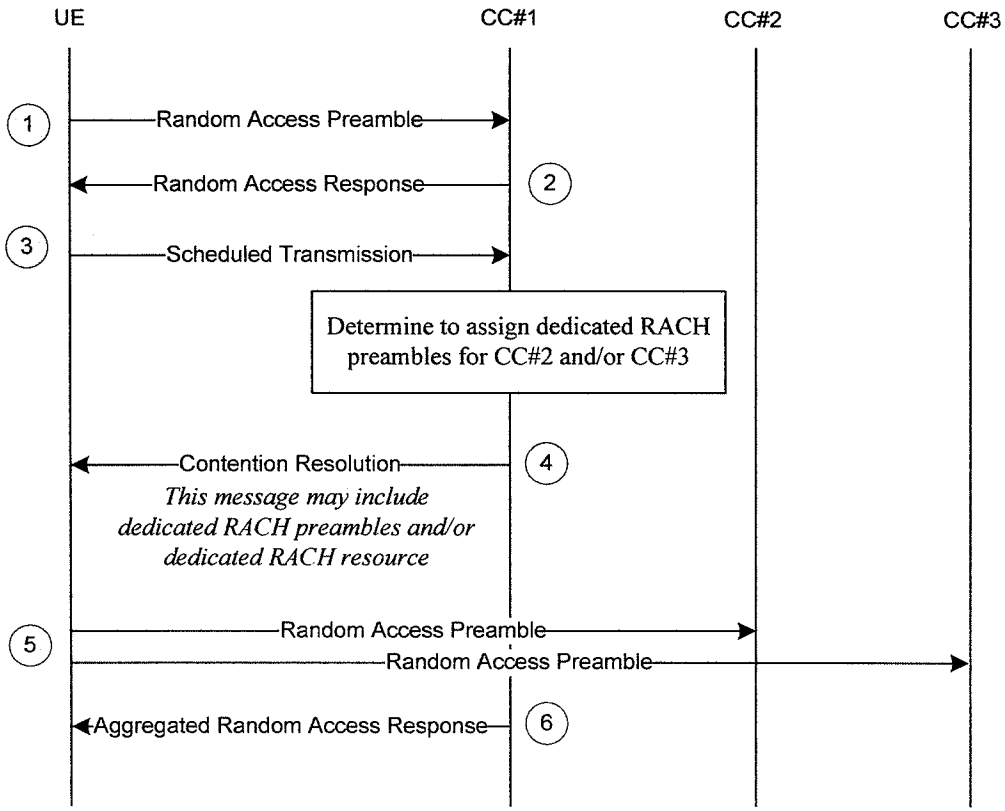
- In some embodiments, UE may only send a *Random Access Preamble* message, and the network can determine TAs for multiple CCs based on the same *Random Access Preamble* message.
  - For example, UE may only send a *Random Access Preamble* message on the CC#2, and network may determine the TAs for CC#2 and CC#3.
  - Afterwards, the network may reply at least one message with TA information for CC#2 and/or CC#3.



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Embodiment #2-4

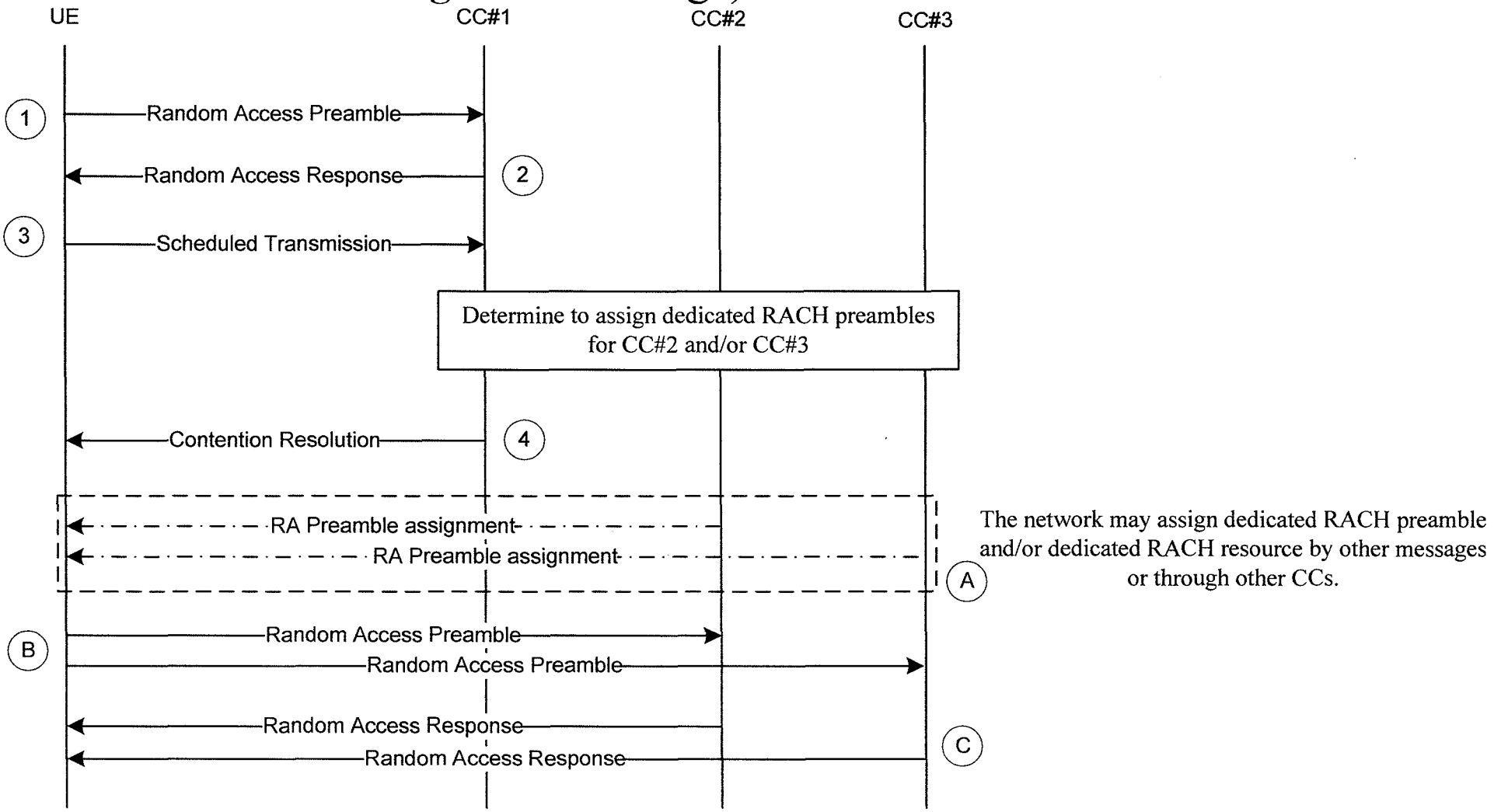
- In some embodiments, the network may respond the *Random Access Response* message through the same or different CCs, where the UE sends the Random Access Preamble.
- In some embodiments, the network may aggregate multiple Random Access Response messages into one or at least one message, and send the message through any CCs (e.g., CC#1, CC#2, CC#3, etc.).
  - The resource location information for receiving the *Aggregated Random Access Response* message may be indicated by the **PDCCH** scrambled (or CRC masked) by **C-RNTI**.
  - An example in which the network sends the *Aggregated Random Access Response* message through the CC#1 is shown as below.



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Embodiment #3-1

- In addition to the message 4, the network may assign the *dedicated RACH preambles* and/or *dedicated RACH resources* by another messages (e.g., *RA Preamble assignment* message).



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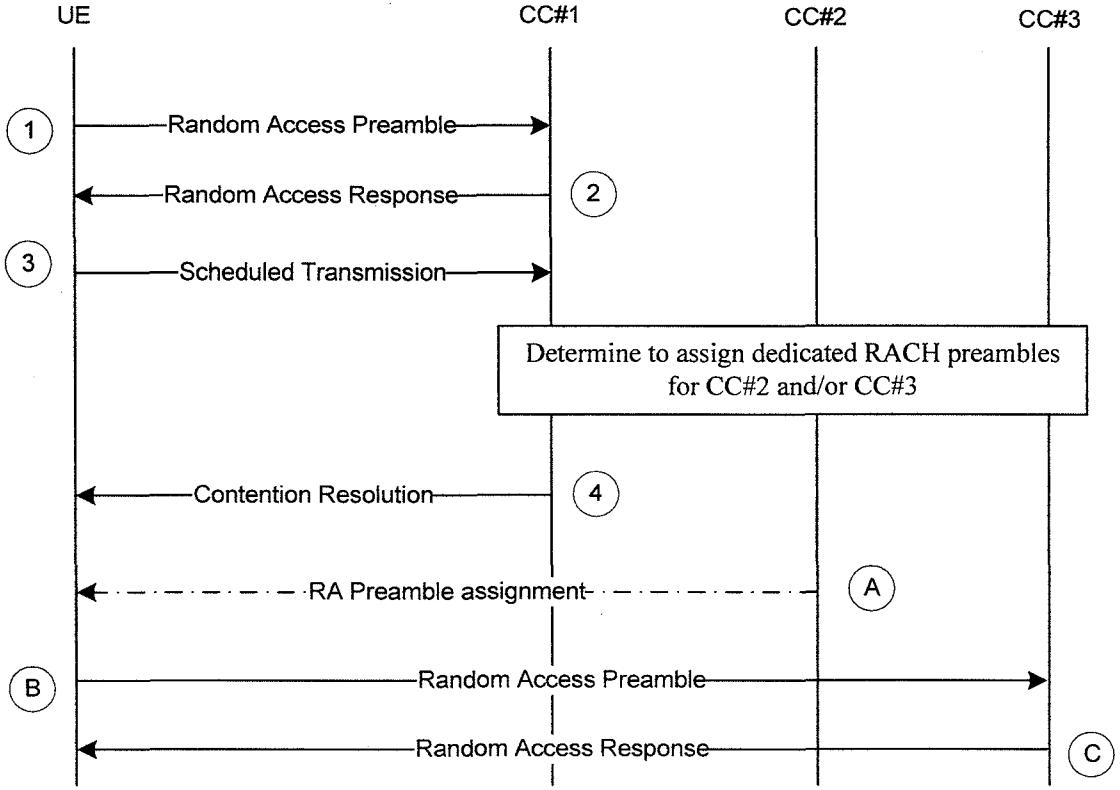
- In addition to the message 4, the network may assign the *dedicated RACH preambles* and/or *dedicated RACH resources* by another messages.
  - The message is called "RA Preamble Assignment" message shown in the above figure.
  - The *RA Preamble Assignment* may be a PDCCH, MAC, or RRC message.
  - The *RA Preamble Assignment* may be transmitted by the DCI format 1A in PDCCH, and then it may include at least one of the following information
    - Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A
    - Localized/Distributed VRB assignment flag
    - Resource block assignment
    - PRACH Preamble Index
    - PRACH Mask Index
    - All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zeroes

- Again, the *msg 4* may be or may be not send on the same carrier, where the Random Access Preamble is sent.

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Embodiment #3-2

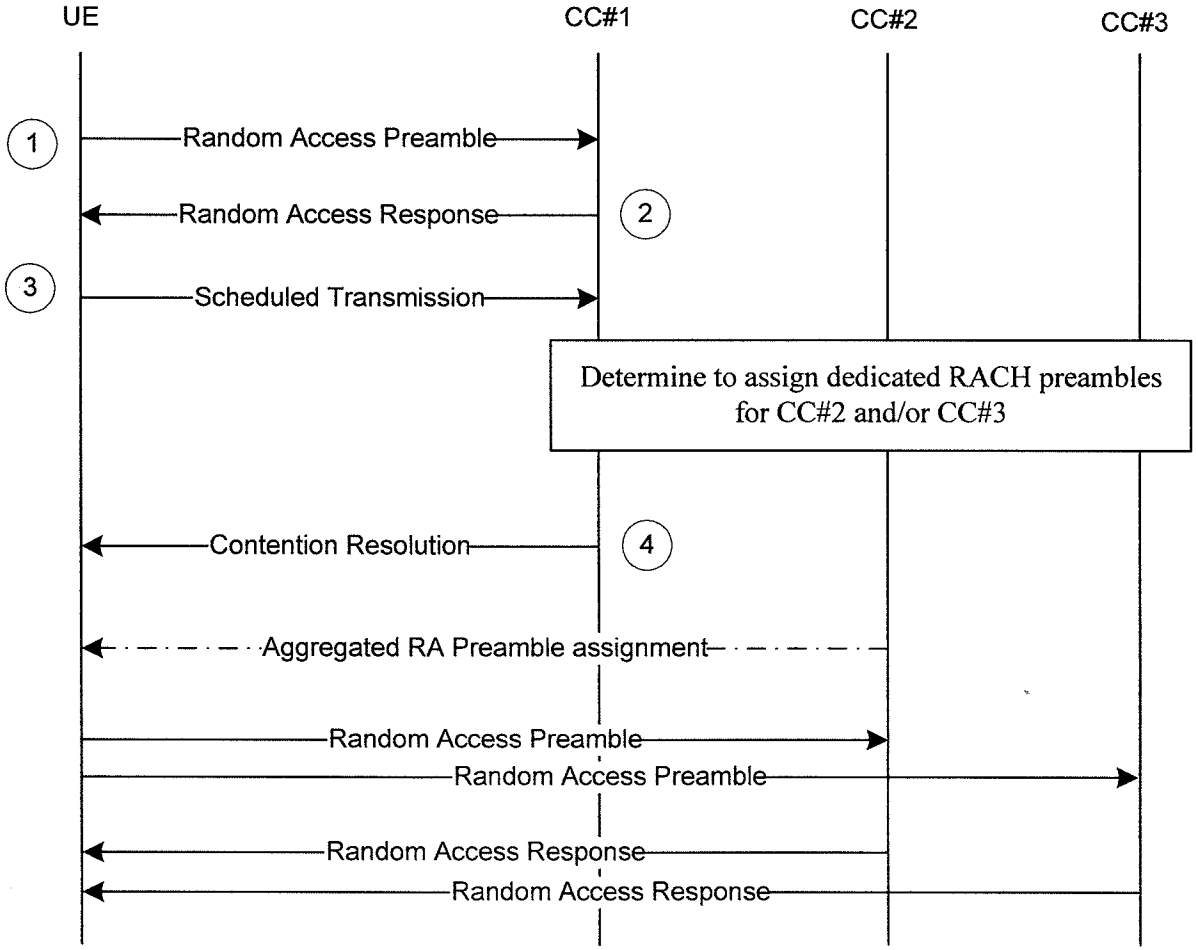
- The *RA Preamble Assignment* may assign the dedicated RACH preambles and/or dedicated RACH resources for other CC.
  - In this case, the *RA Preamble Assignment* message may include a CC Identity (ID) to indicate the target CC for which the dedicated RACH preambles and/or resources are assigned.
    - This information may be carried by a ***Carrier Indicator Field*** (***CIF***).
  - For example, the *RA Preamble Assignment* message sent by the CC#2 assigned the dedicated RACH preambles and/or dedicated RACH resources for CC#3 is illustrated as below.



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Embodiment #3-3

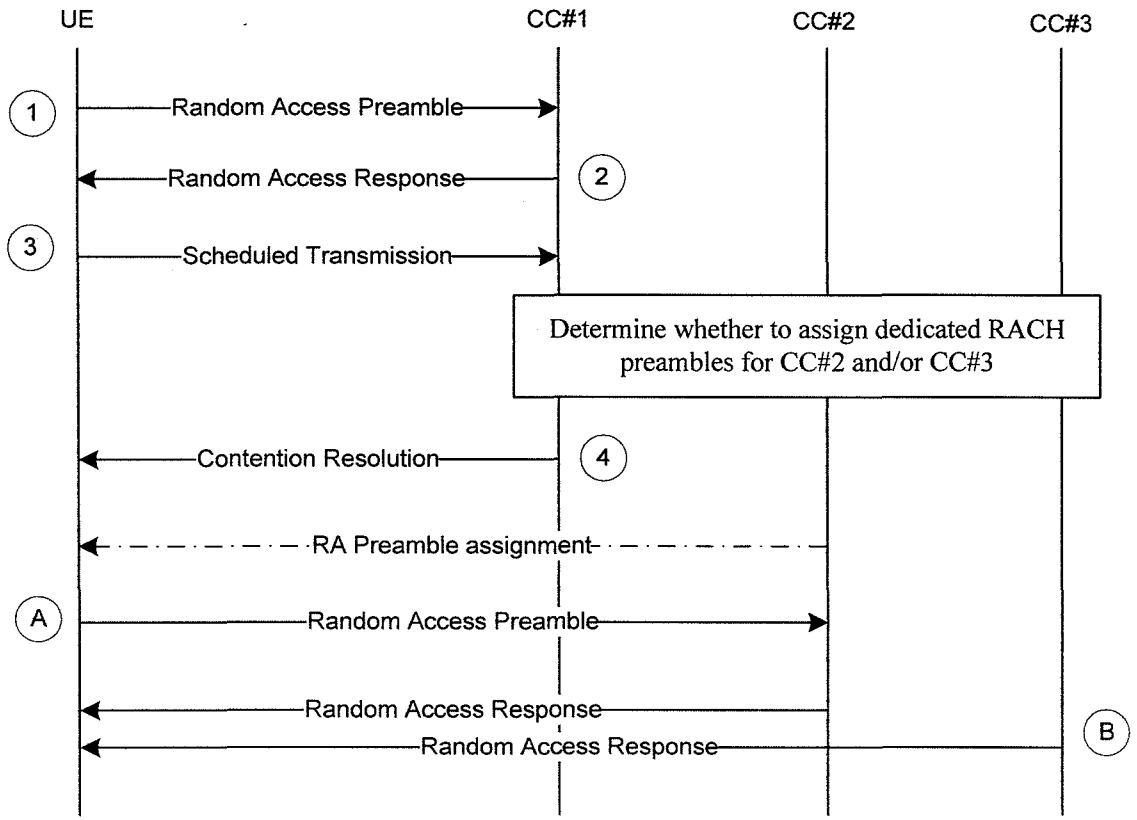
- In some embodiments, several *RA Preamble Assignment* messages may be aggregated.
  - This *Aggregated RA Preamble Assignment* message may include RACH preambles and/or RACH resources for one or more CCs, and/or the message may include the information of CC IDs for these CCs.



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Embodiment #3-4

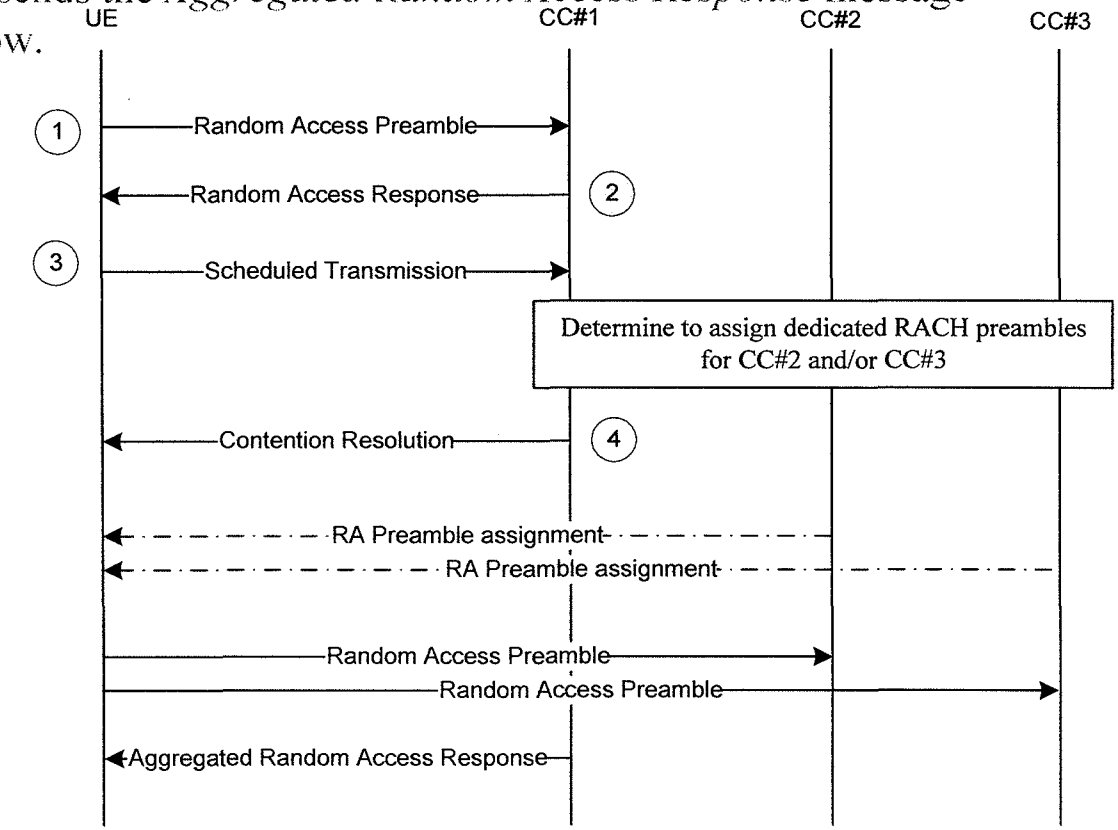
- In some embodiments, UE may only send a *Random Access Preamble* message, and the network can determine TAs for multiple CCs based on the same *Random Access Preamble* message.
  - For example, UE may only send a *Random Access Preamble* message on the CC#2, and network may determine the TAs for CC#2 and CC#3.
  - Afterwards, the network may reply at least one message with TA information for CC#2 and/or CC#3.



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Embodiment #3-5

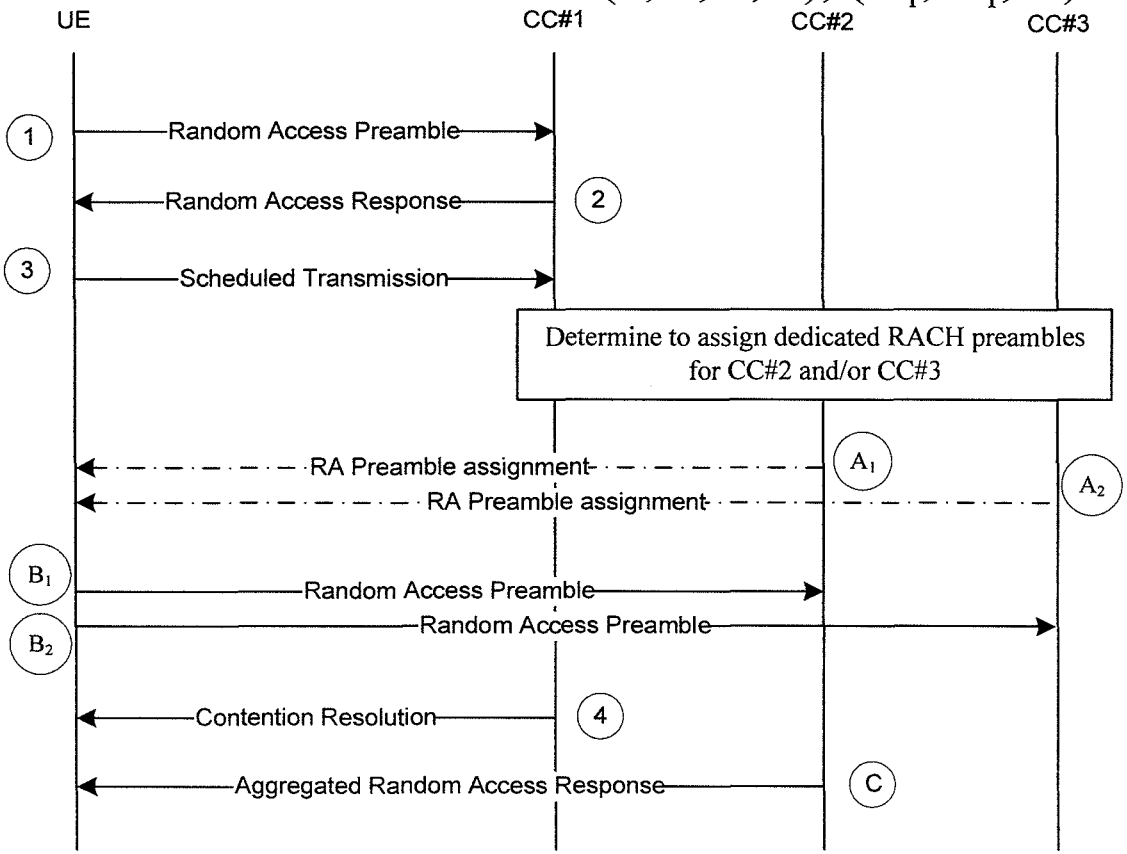
- In some embodiments, the network may respond the *Random Access Response* message through the same or different CCs, where the UE sends the Random Access Preamble.
- In some embodiments, the network may aggregate multiple Random Access Response messages into one or at least one message, and send the message through any CCs (e.g., CC#1, CC#2, CC#3, etc.).
  - The resource location information for receiving the *Aggregated Random Access Response* message may be indicated by the **PDCCH** scrambled (or CRC masked) by ***C-RNTI***.
  - An example in which the network sends the *Aggregated Random Access Response* message through the CC#1 is shown as below.



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Transmission order

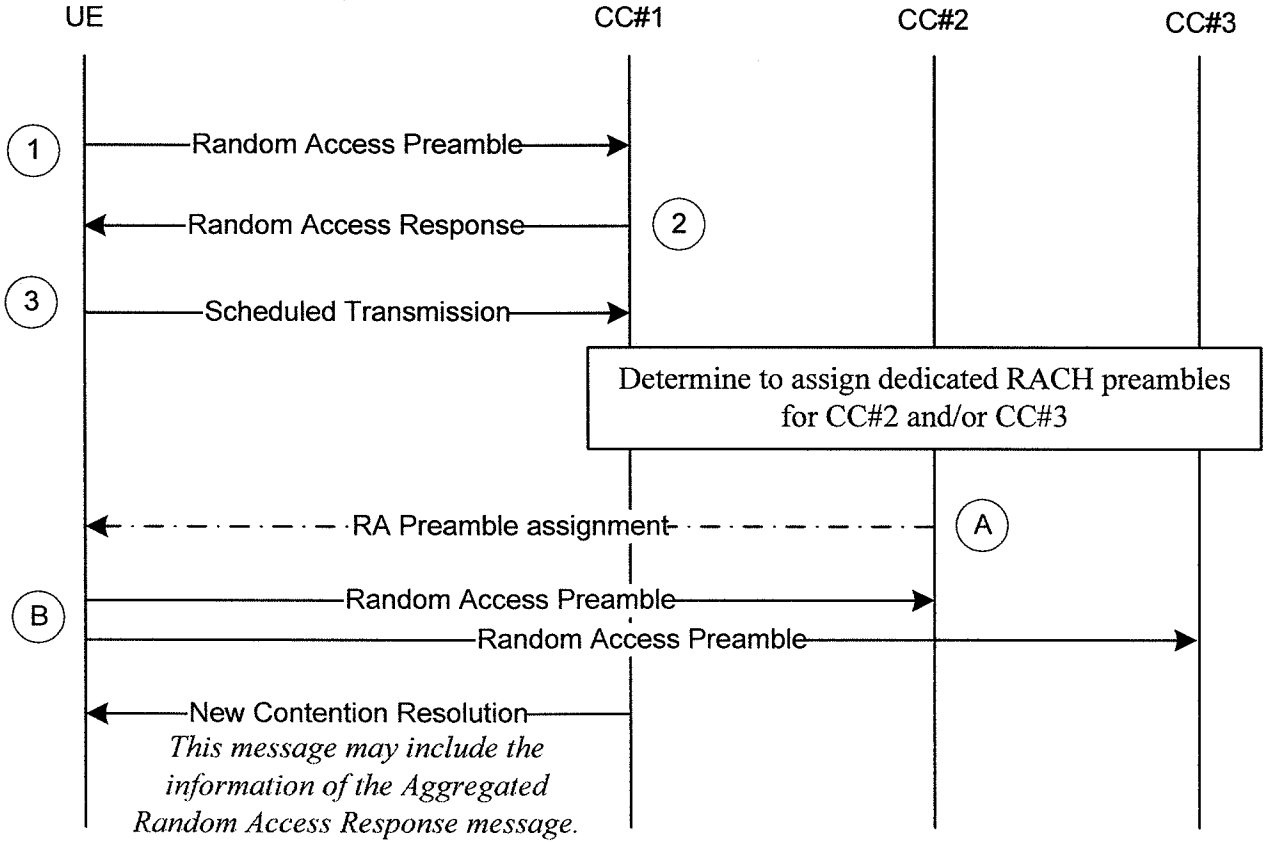
- The message transmission order may follow:
  - $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$
  - $A_1 \rightarrow B_1 \rightarrow C$
  - $A_2 \rightarrow B_2 \rightarrow C$
- However, the message transmission order between the sets (1, 2, 3, 4), (A_1, B_1, C) and (A_2, B_2, C) is not limited.
  - In the figure, we show the example in which the *msg 4* is sent later than *msgs A* and *B*.



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Embodiment #4

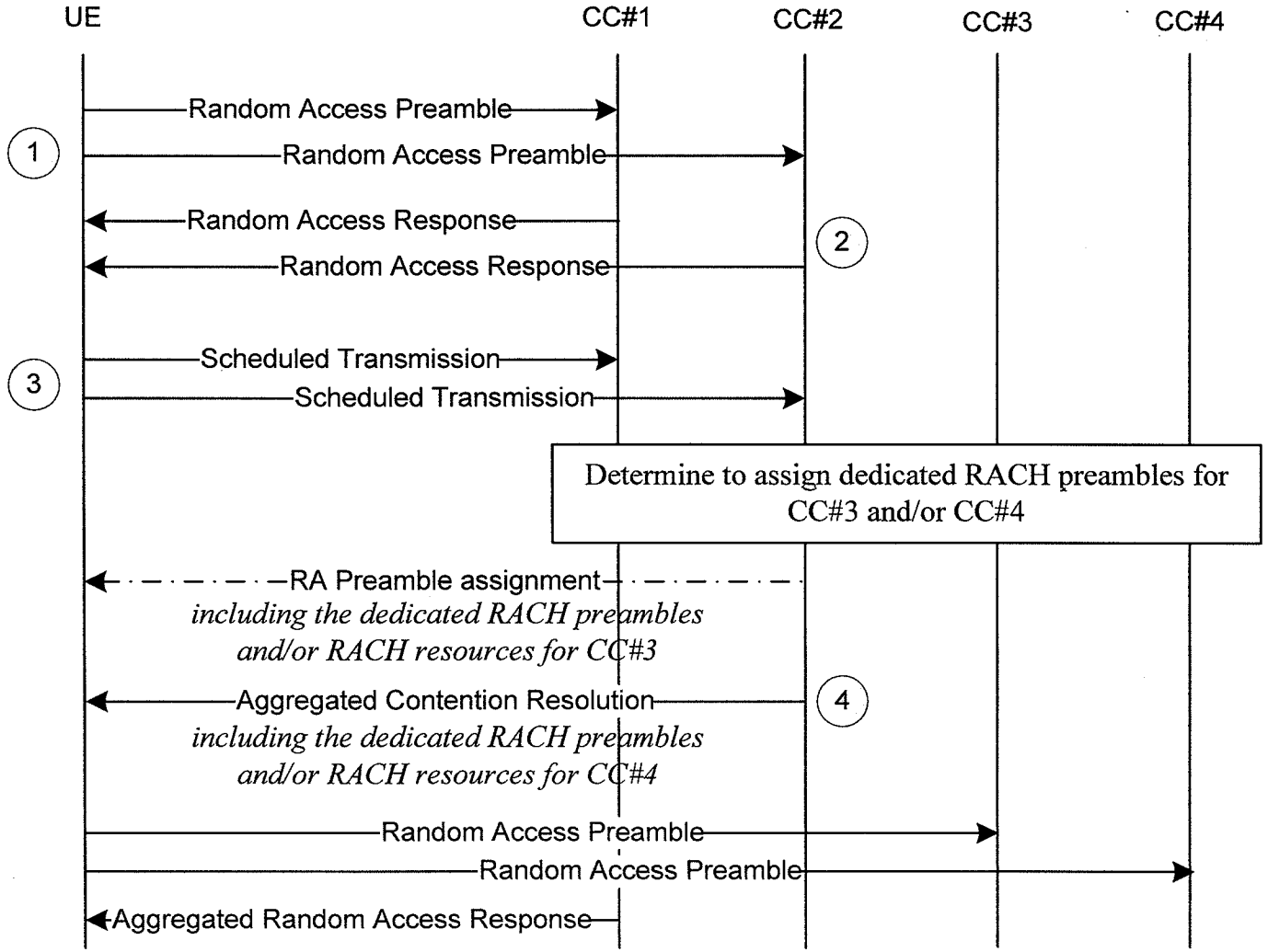
- In some embodiments, the *Contention Resolution* message and (Aggregated) *Random Access Response* messages may be aggregated. An example is shown as follows.
  - In this case, this new message may include the information carried in the *Contention Resolution* message and the information carried in the *Random Access Response* message.



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Embodiment #5

- Any combination of previous embodiments may be used.
  - An example, which applies the concepts of the embodiment #1-2, #2-1, #2-3, #3-2, and #3-4, is illustrated as below.



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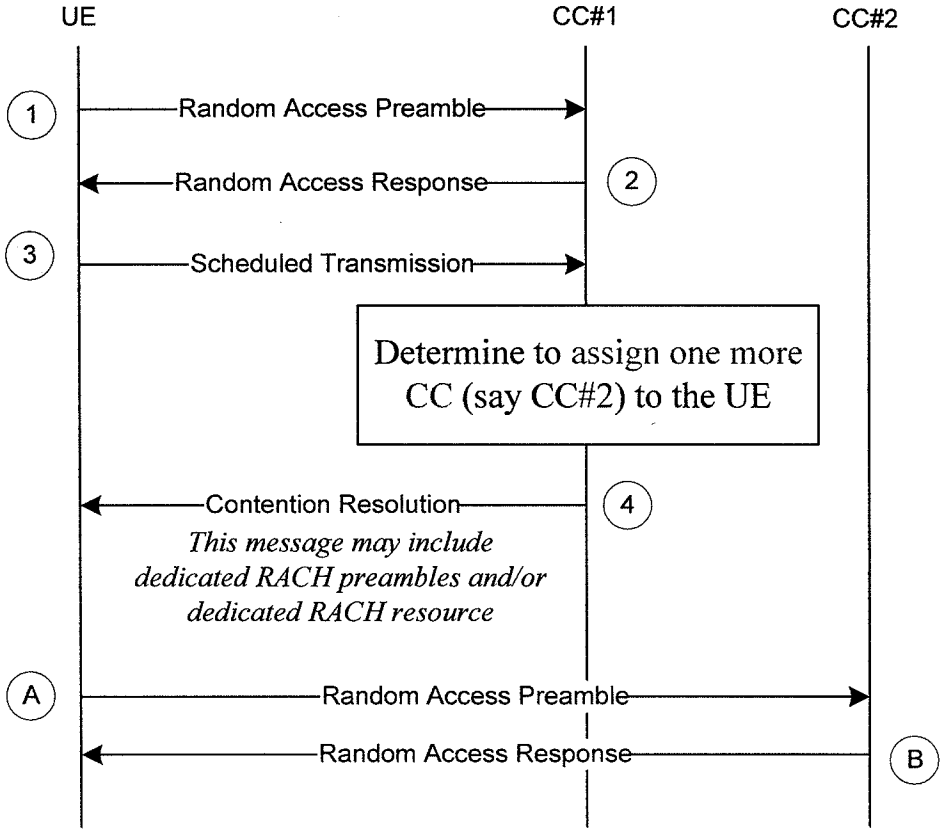
Possible Applied Scenario

- CC Configuration (e.g., adding a new CC)
- Co-ordinated MultiPoint (CoMP)
- In the case when TA expires and some UL data arrive
- Handover

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CC Configuration (e.g., adding a new CC)

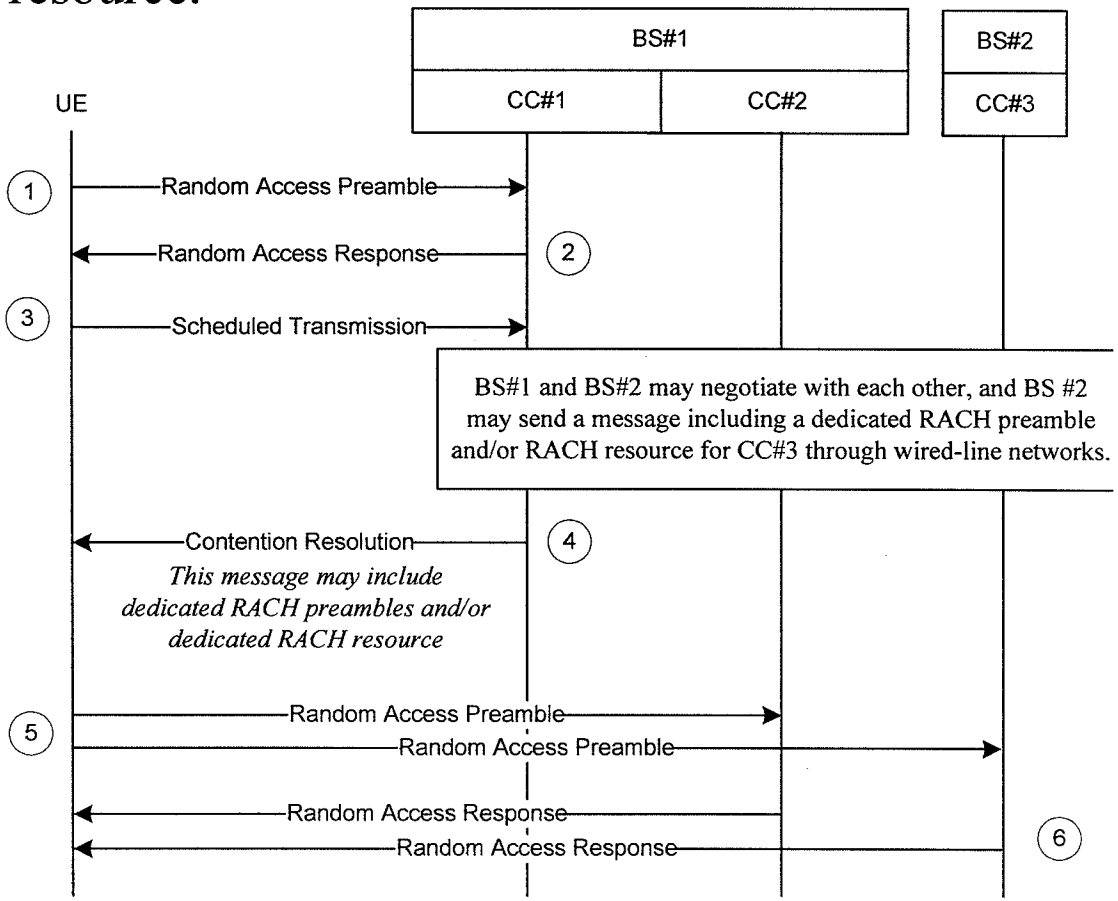
- In some embodiments, the network may decide to add one or more CCs to the UE for communication.
- The network may send a message (e.g., *RRC Connection Reconfiguration* message) including information the *Contention Resolution* message and the information for UE to add (configure) a new CC.
  - This information may include dedicated RACH preambles and/or dedicated RACH resources for the new added CC.



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Co-ordinated MultiPoint (CoMP)

- CCs (e.g., CC#1, CC#2, CC#3) may belong to different BSs. In these cases, BSs may have the information about the dedicated RACH preambles and/or dedicated RACH resources controlled by other BSs. So BSs may negotiate with each other through a wired-line network to get the information about the dedicated RACH preambles and/or dedicated RACH resource.
  - An example in which CC#1 & CC#2 belong to the BS#1, and CC #3 belongs to the BS#2 is illustrated in the figure.



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Functional Block 2:
Maintain time alignment timer (TAT) validity

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Outline

- Time Alignment Timer (TAT) in LTE
- Time Alignment Timer in multi-carrier system
- The problem for one common Time Alignment Timer
- The proposed solution
- Embodiments

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Time Alignment Timer in LTE

- When the Time Alignment Timer (TAT) is running, the UE may start to monitor the UL grant on the DL carrier and sends the feedback (Ack/Nack) on this UL carrier.
- TAT starts or restarts
  - A Timing Advance Command (TAC) in MAC Control Element is received
  - A Timing Advance Command is received in a Random Access Response message
    - (Preamble was not selected by UE MAC)
    - The *timeAlignmentTimer* is not running
- TAT expiry
  - flush all HARQ buffers;
  - notify RRC to release PUCCH/SRS;
  - clear any configured downlink assignments and uplink grants.

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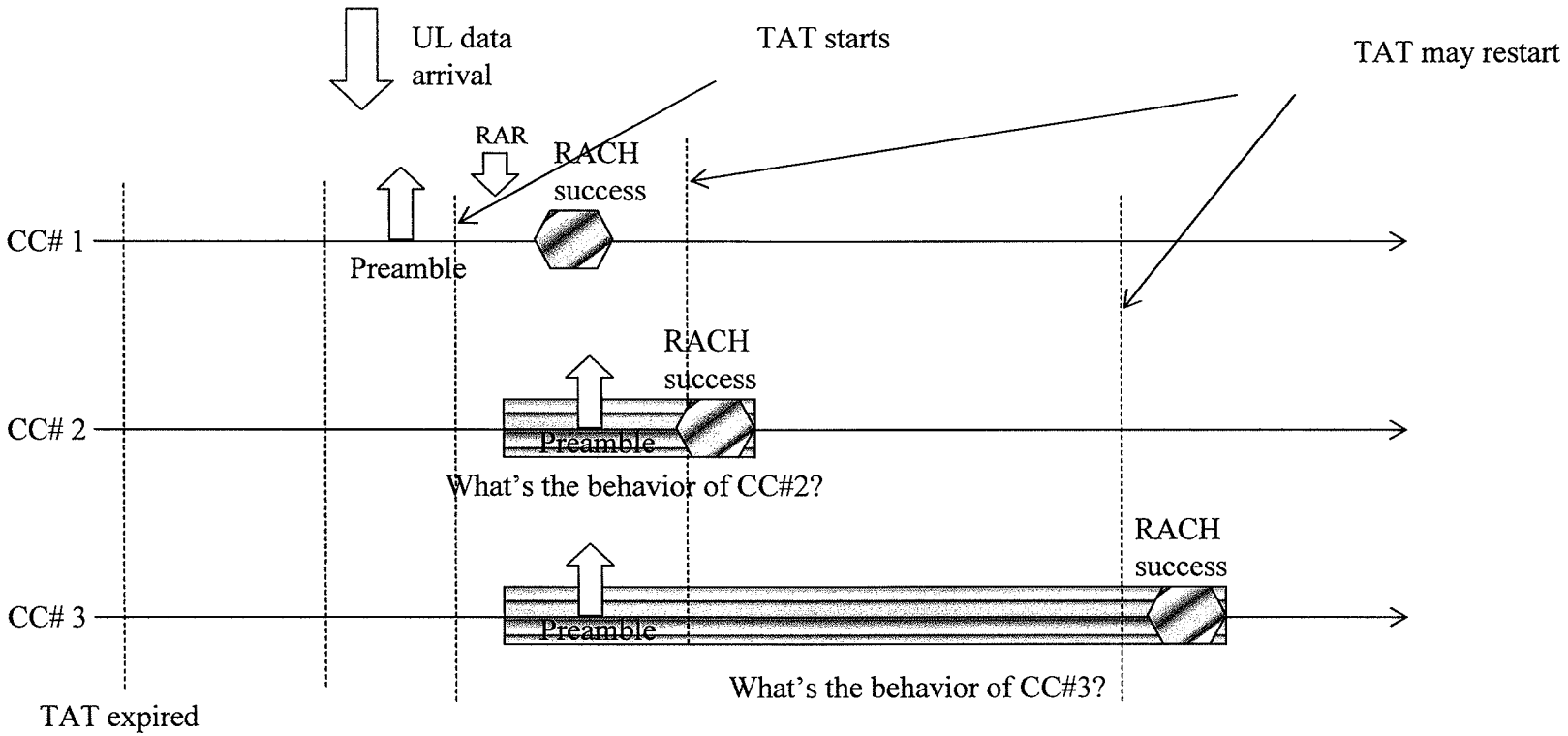
Time Alignment Timer in LTE-A

- The CCs under the same eNB may have different Timing Advance (TA) values.
- Time Alignment Timer (TAT)
  - One TAT per CC
    - Time Alignment Timer updates as the same as LTE-r8
  - One TAT per TA (Timing Advance) group
    - TA group: CCs share a common TA.
    - TAT updates as the same as LTE-r8
    - Only one CC in the TA group needs to perform RACH
    - Group ID (ADD configuration)
  - One Common TAT
    - TAT updates depending on Timing Advance Command (TAC) (in RAR or MAC CE)
    - May have TA groups

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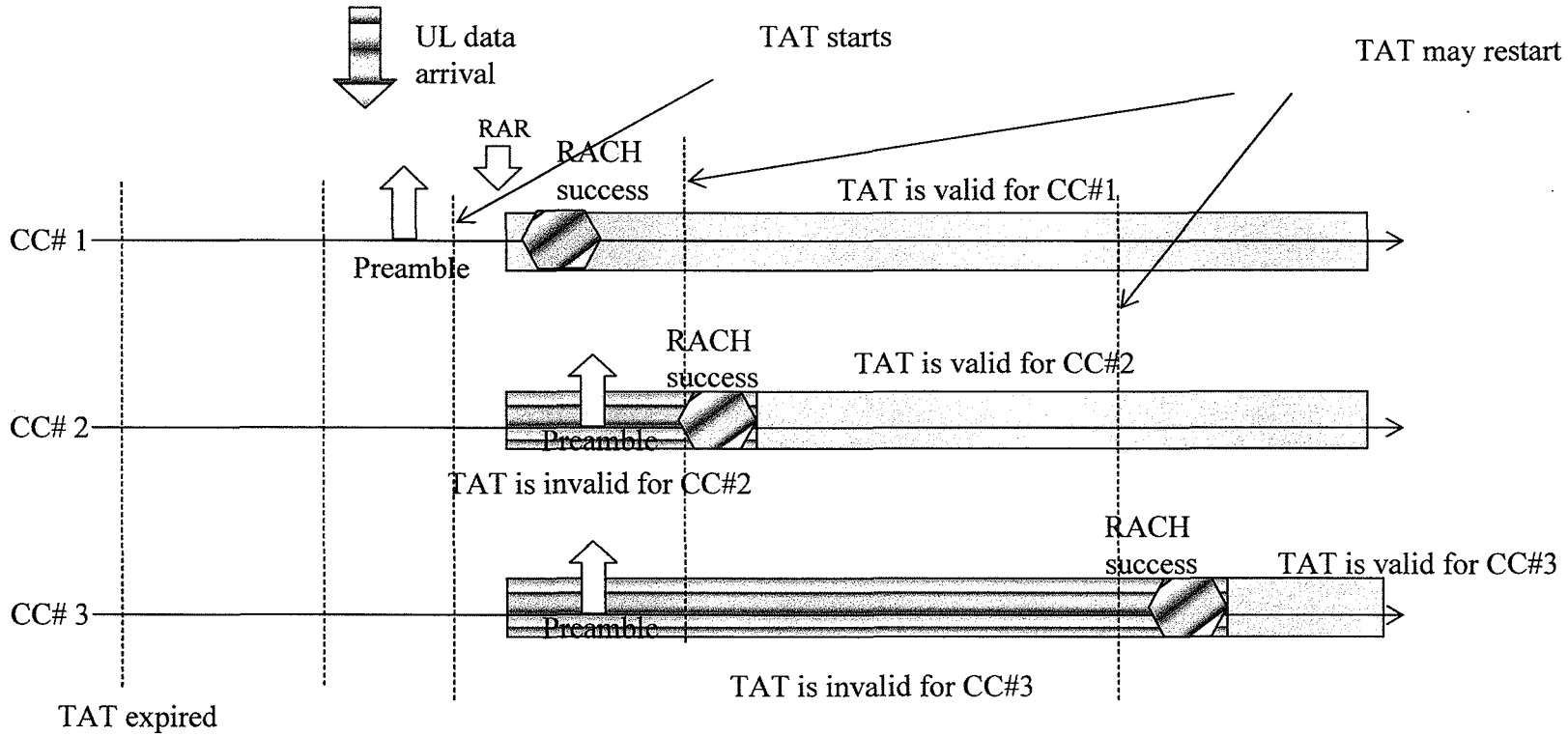
One Common TAT : Problem?

- Scenario I: CC#1, CC#2 and CC#3 have different TAs.



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Possible solution: indicator for valid TAT

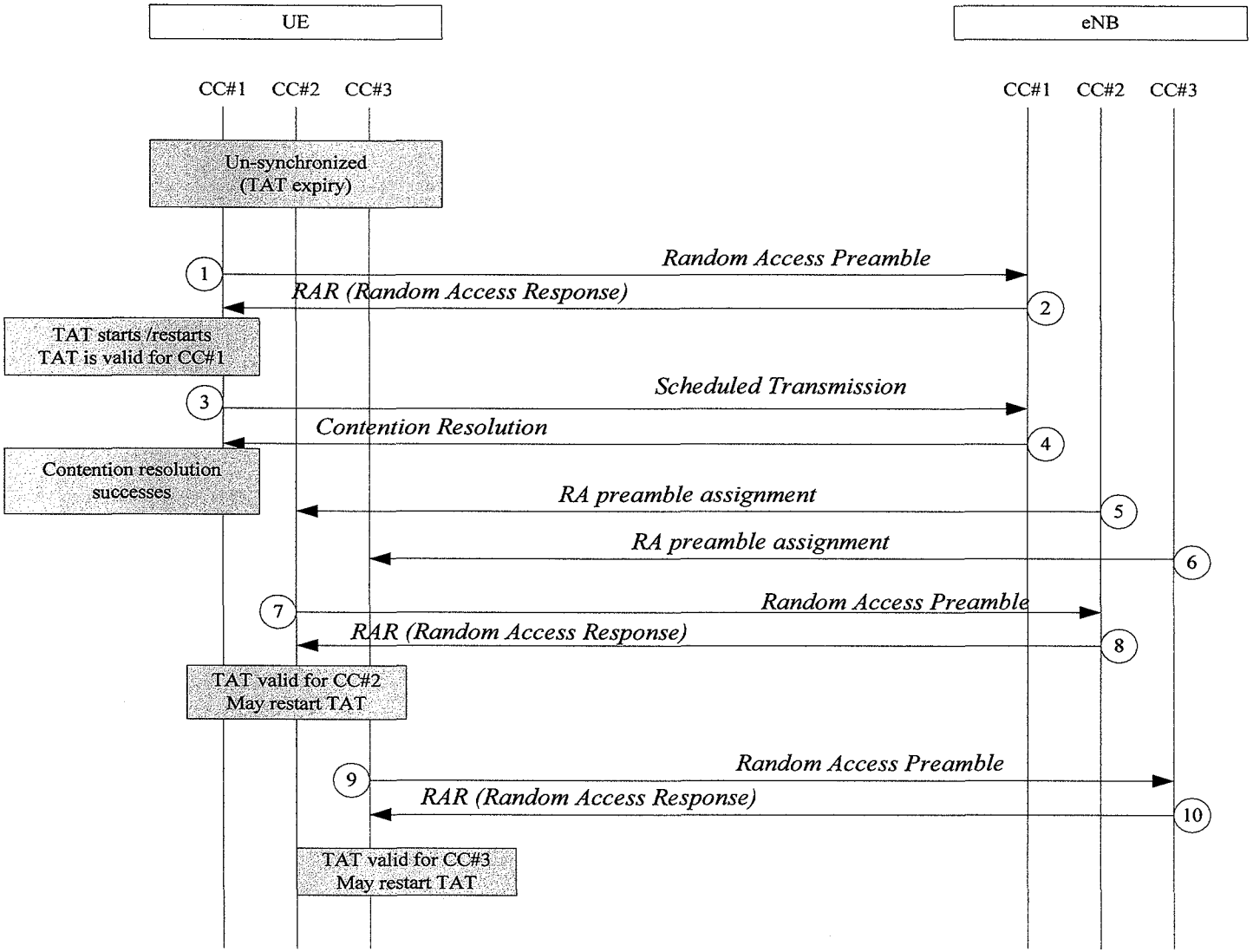


Set indicator:

- Valid: obtaining the Timing Advance Command
- Invalid: TAT expires or random access fails

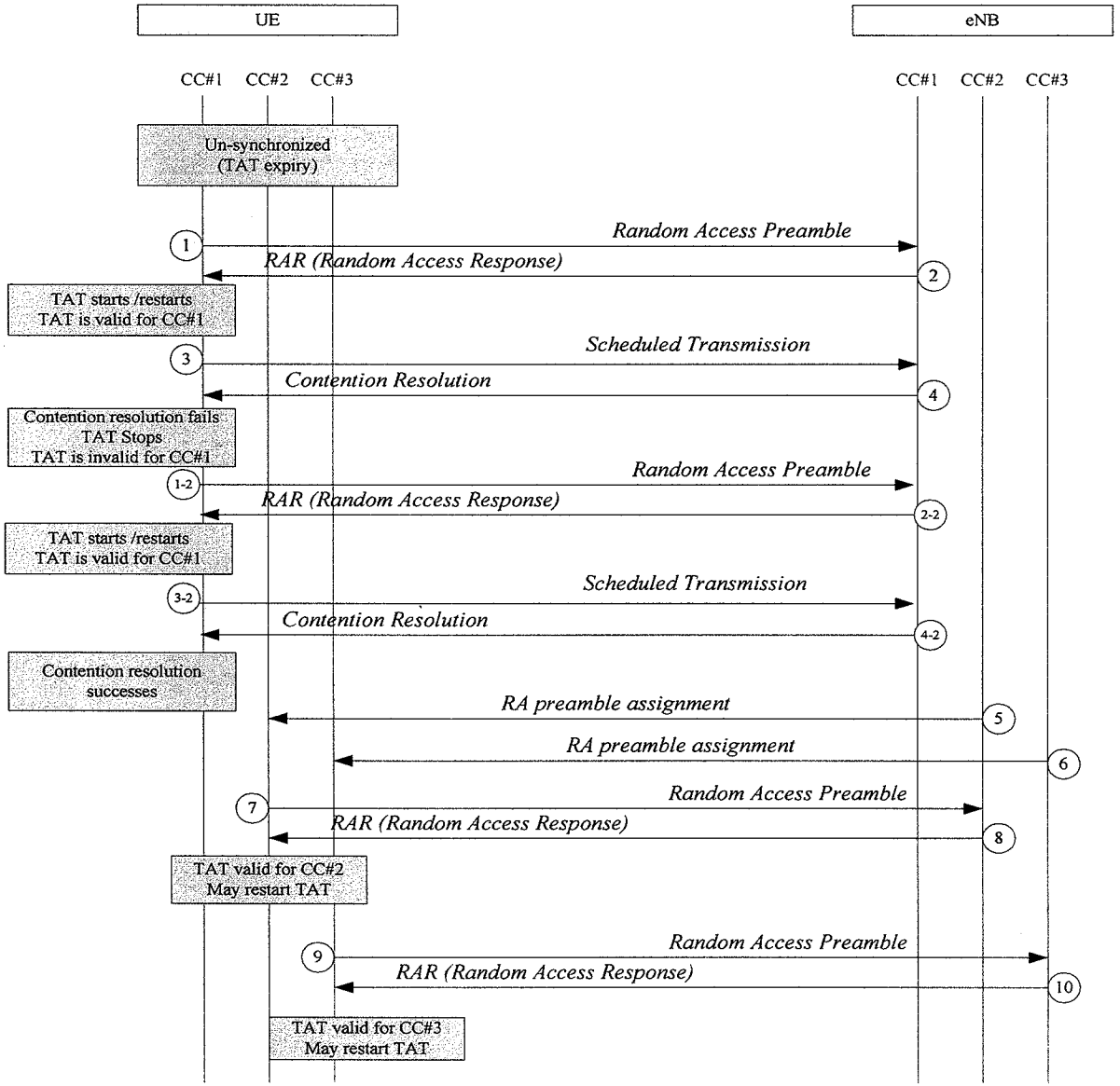
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Embodiment #1



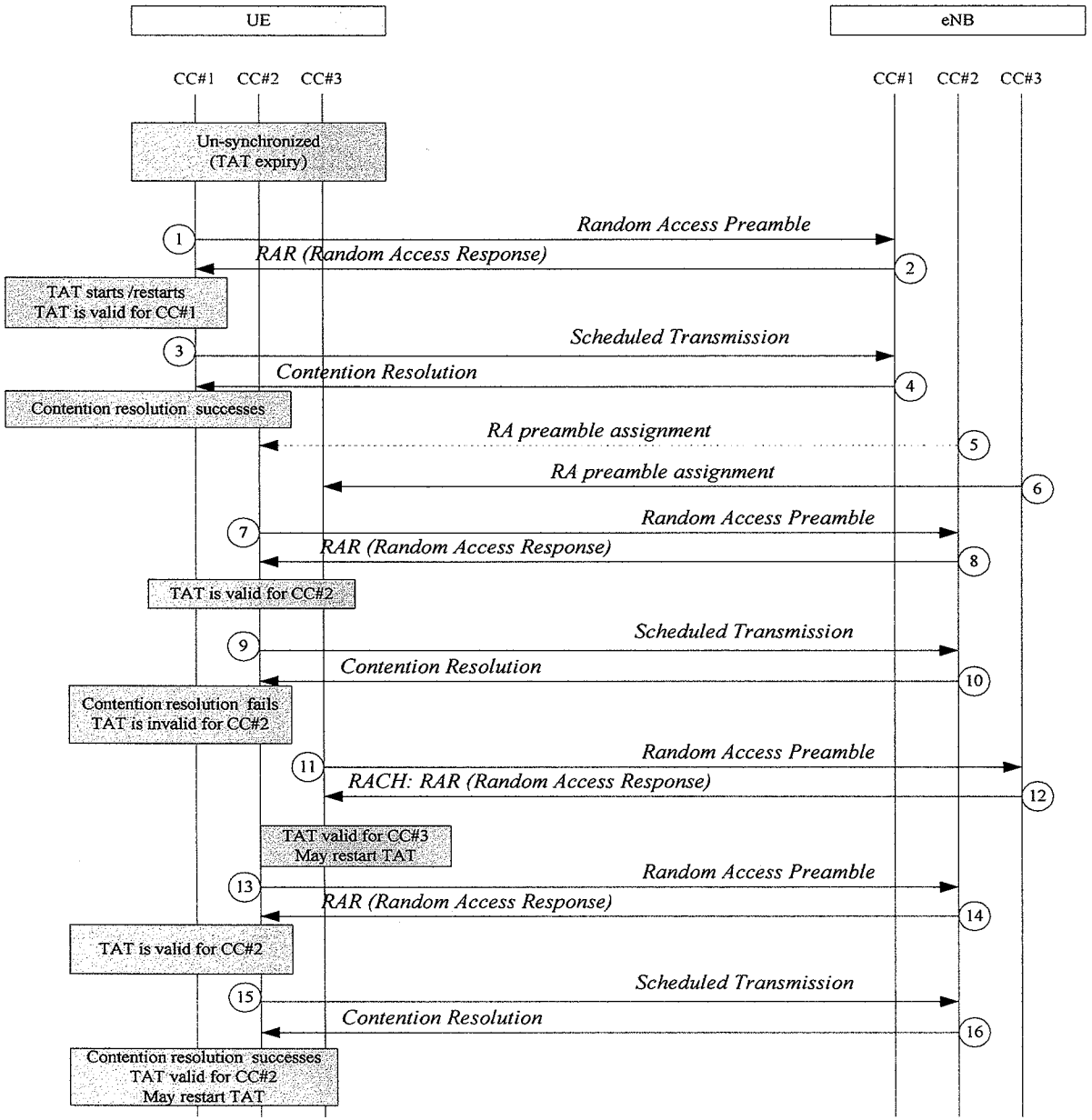
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Embodiment #1-2



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Embodiment #1-3



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Valid and Invalid Indicator for One Common TAT

- Valid/invalid TAT
  - Valid: obtaining the Timing Advance Command
  - Invalid: TAT expires, stops or random access fails

- Timing Advance command may be received in MAC CE or RAR
  - TAT may update (start or restart).

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Functional Block 3:
Update Timing Advance (TA)

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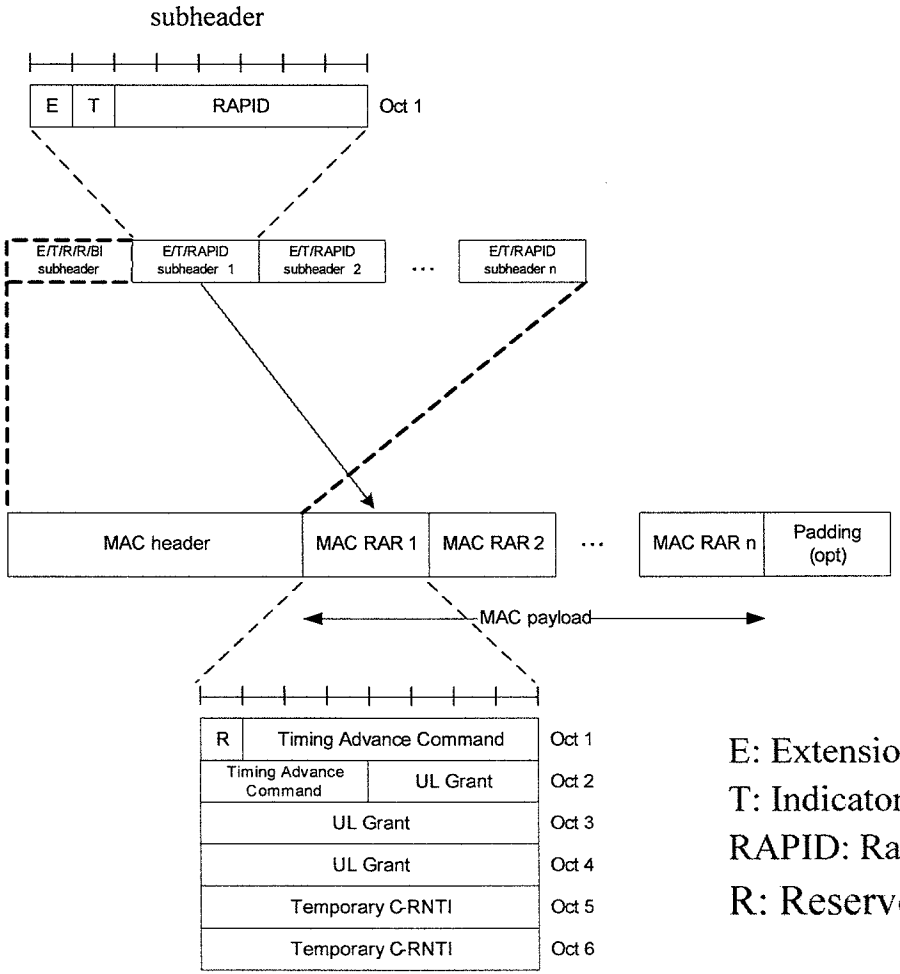
Background
Uplink Synchronization in LTE

- Uplink synchronization is important to avoid interference between the users with uplink transmissions scheduled on the same subframe.
- Uplink synchronization is maintained by adjusting timing advance (TA) value of UE for ensuring that the uplink transmissions from different users arrive at the eNB essentially within the cyclic prefix
- In LTE, TA value is measured of UE uplink signal by eNB
  - If UE does not have a valid TA, the initial TA value is measured from RACH (random access) transmission and informed by eNB through RAR (random access response)
  - Otherwise, eNB continuously measures the timing of the UE uplink signal and adjusts the uplink transmission timing through TA Command (TAC) MAC control element
    - UE uplink signal may be SRSs, CQI, ACK/NACKs, uplink data, DMRS, etc.

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Initial TAC through RAR

- RAR MAC subheader and payload



E: Extension field

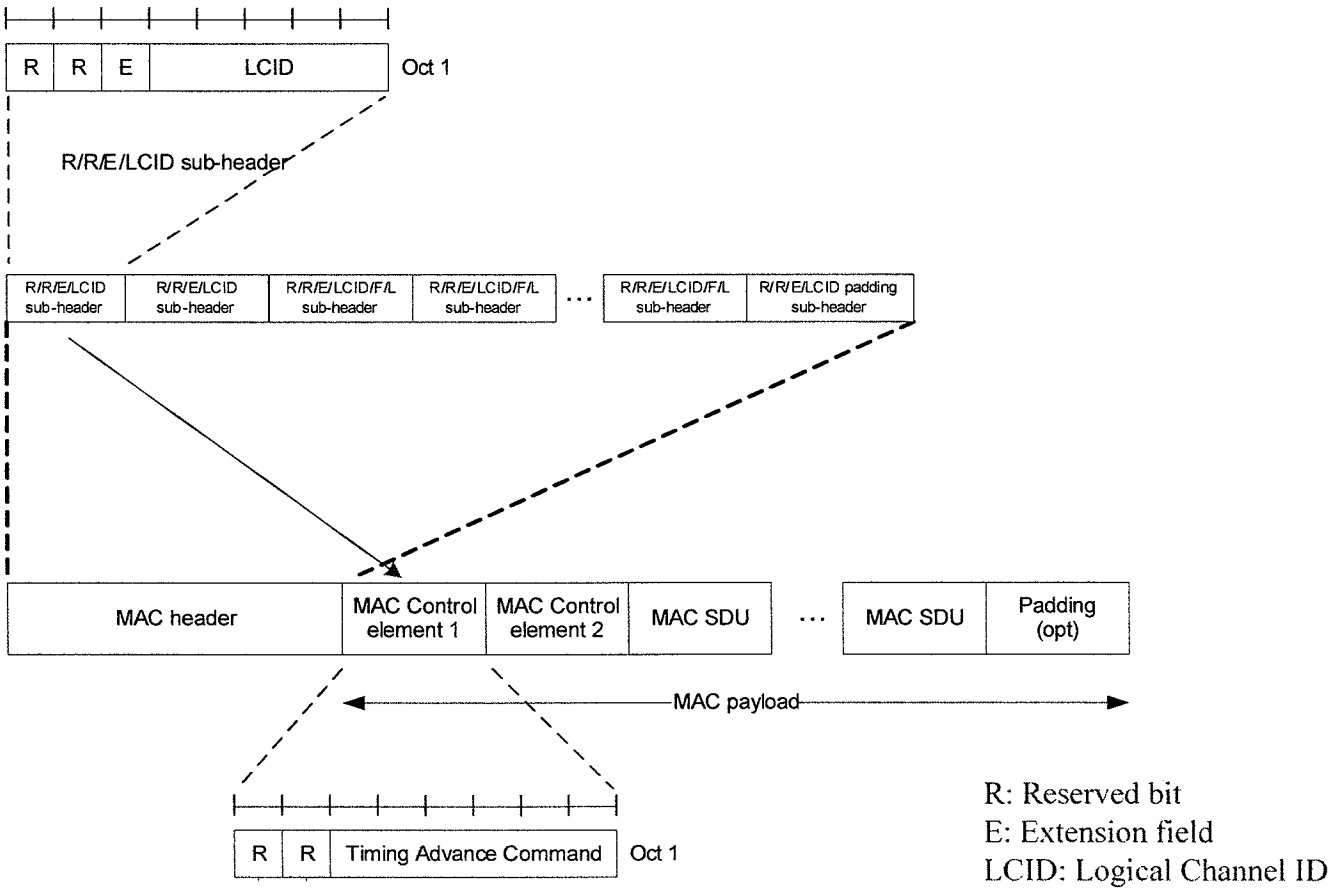
T: Indicator

RAPID: Random Access Preamble ID field

R: Reserved bit

TAC Update through MAC TA Control Element

- LTE R.8 MAC PDU



R: Reserved bit
E: Extension field
LCID: Logical Channel ID

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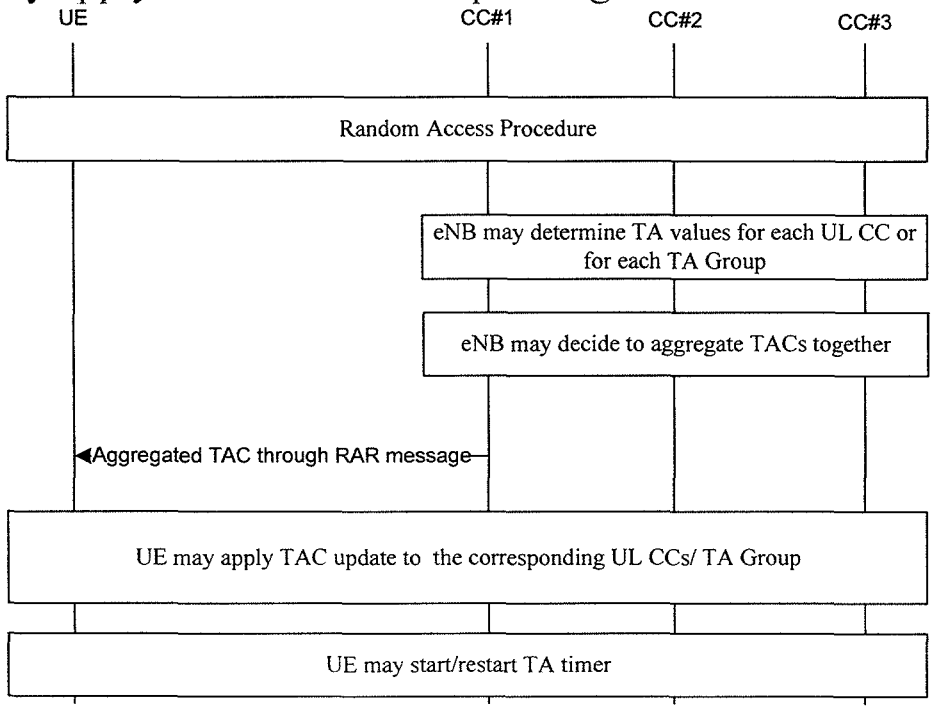
The present example procedures and methods

- In the present example procedures and methods, the case of supporting 5 CCs is illustrated in LTE-Advanced. However, the basic concepts of these examples may be applied to support any number of CC configurations.
- In the present example procedures and methods, the case of TAC MAC control element (or RAR) is illustrated. However, the basic concepts of these examples may be applied to other MAC control elements for alone/ aggregated MAC control element transmissions in multiple CCs applications.

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Procedure # 1:
Aggregated TAC transmission procedure through RAR

- In this procedure, TAC may be aggregated together and sent through RAR message through any CCs.
  - E.g., UE may perform *Random Access Procedure* on the CC#1 to CC#3, and network may determine the TAs for CC#1 to CC#3
  - Afterwards, the network may decide to aggregate TACs together, and the aggregated TAC may sent through RAR message through any CCs
  - After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may start/restart TA timer



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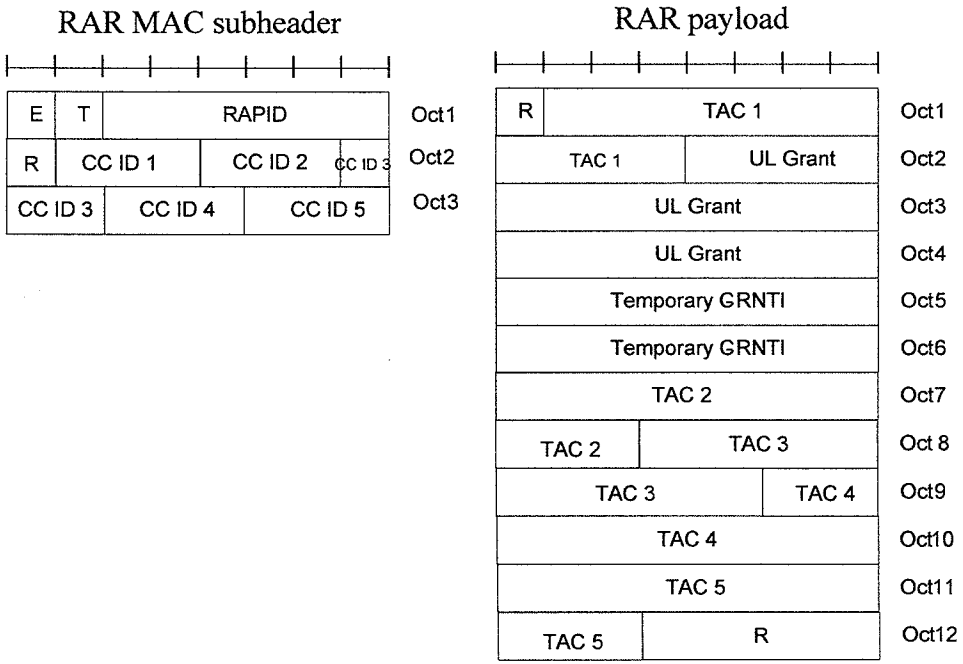
Method # 1-1

- In this method, UE supports multiple CCs or not may be distinguished in PHY layer by using different RA-RNTI for DCI scrambling
  - For example, different resource for RACH may be used for UE supports multiple CCs and UE does not support multiple CCs so that different RA-RNTI may be used to scramble RAR DCI
  - In this case, UE supports multiple CCs may use new RAR MAC subheader and MAC RAR payload format for aggregated RAR transmissions

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Method # 1-1 (cont.)

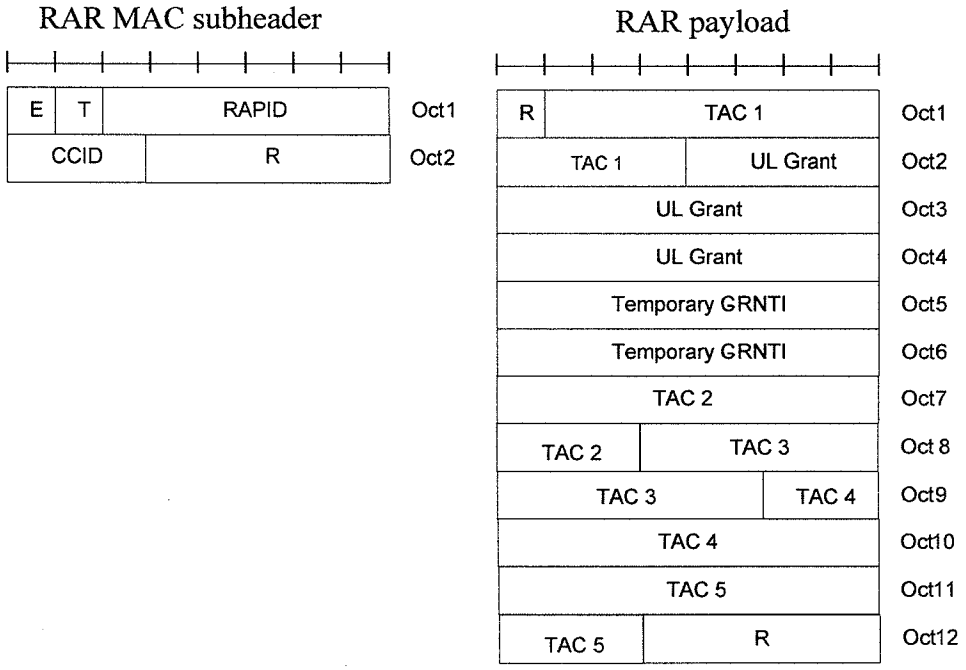
- E.g., one or more CC ID information may be included in RAR MAC subheader



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Method # 1-1 (cont.)

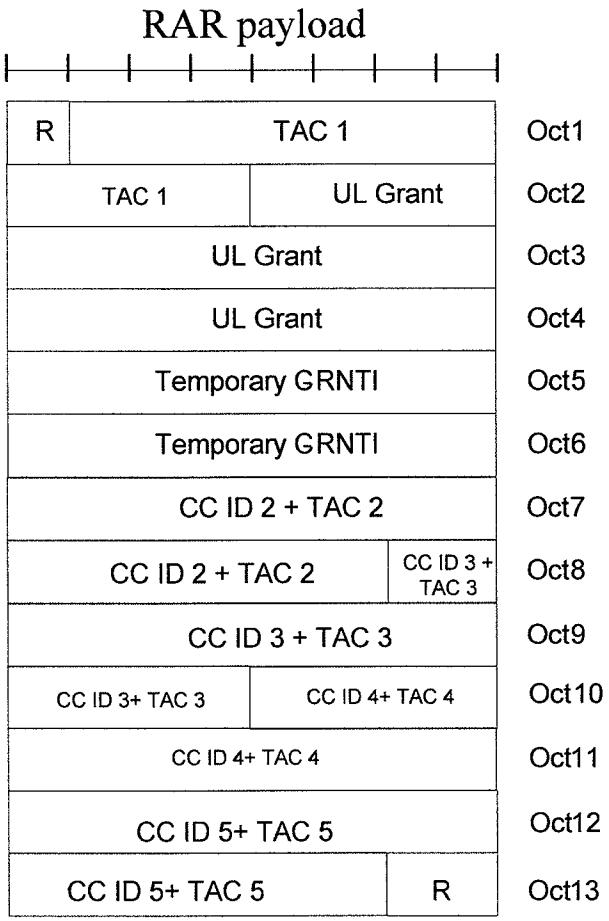
- E.g., to avoid duplicate RAPID chosen by multiple UEs, CC ID information may be included in RAR MAC subheader



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Method # 1-1 (cont.)

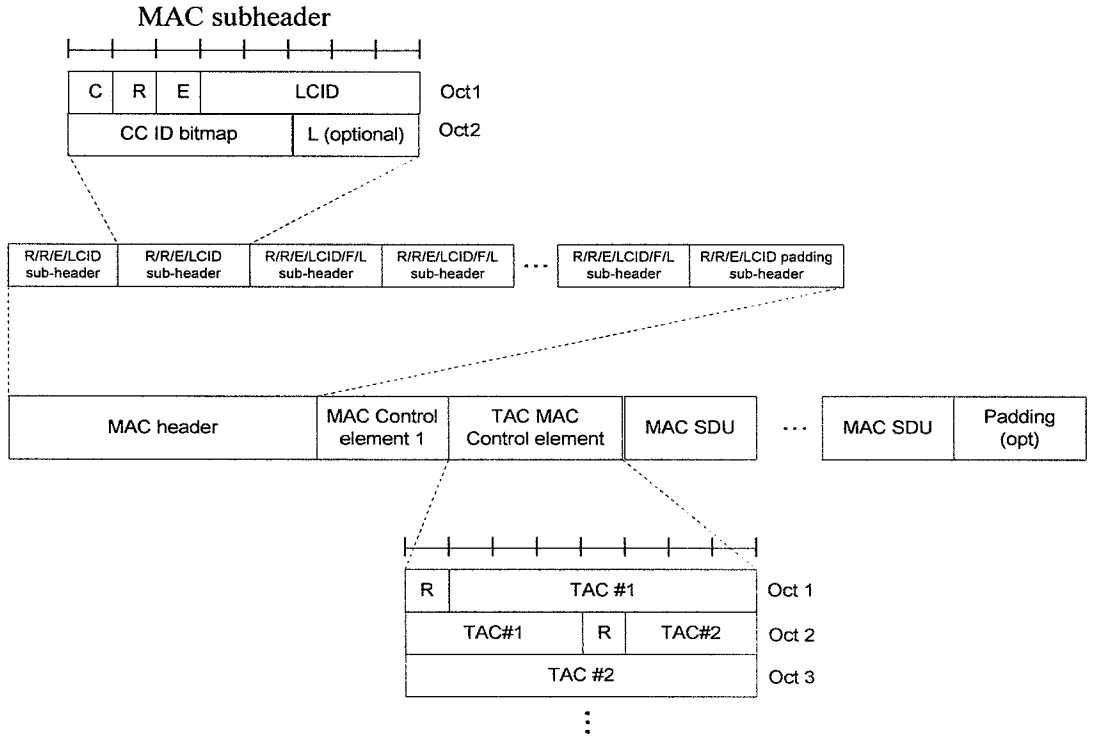
- E.g., CC ID information may be included in RAR MAC payload



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Method # 1-2

- In this method, UE specific RNTI may be used in DCI scrambling to indicate RAR MAC PDU.
  - For example, C-RNTI may be used in DCI scrambling to indicate UE-specific RAR MAC PDU.
  - E.g., the aggregated TAC may include CC ID information explicitly and/or implicitly in the UE-specific RAR MAC PDU.



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Method # 1-3

- In this method, multiple TACs may be aggregated RAR message and the aggregated RAR TAC may include CC ID information explicitly and/or implicitly.
  - For example, CC ID information may be included the RAR MAC subheader.
  - For example, CC ID information may be included the RAR MAC payload.

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Method # 1-4

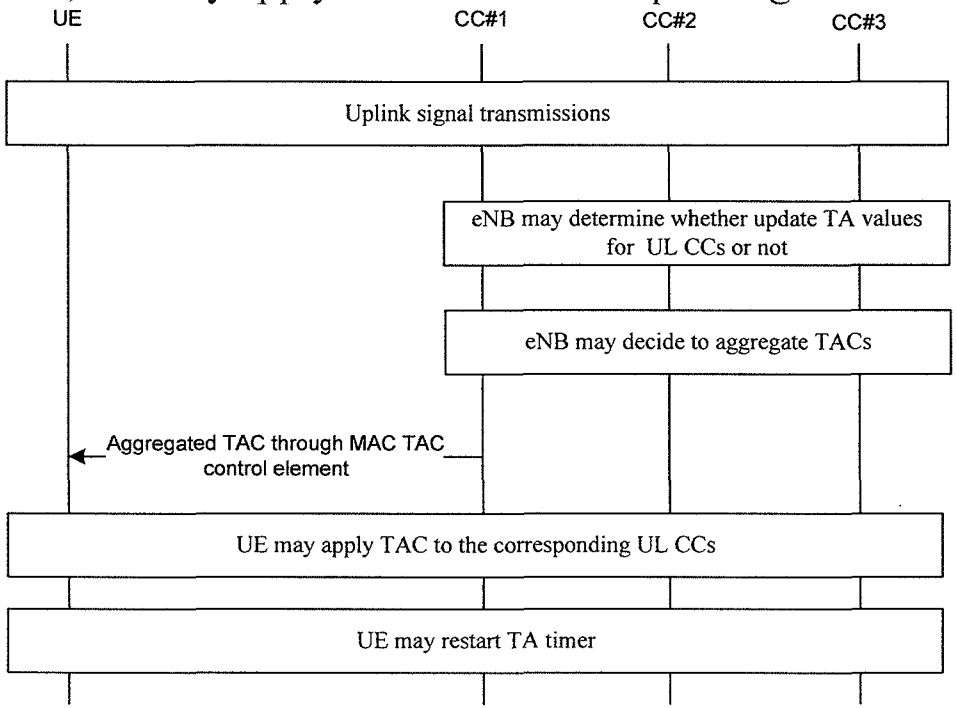
- In this method, multiple TACs may be aggregated RAR message and the aggregated RAR TAC may include CC ID bitmap information explicitly and/or implicitly.
  - For example, CC ID bitmap information may be included the RAR MAC subheader.
  - For example, CC ID bitmap information may be included the RAR MAC payload.

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Procedure # 2:

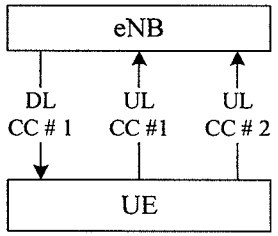
Aggregated TAC transmission procedure through MAC TAC control element

- In this procedure, TAC update message may be aggregated together and sent through MAC control element through any CCs.
  - E.g. Procedure# 1, the network may measure the timing of the UE uplink signal and may determine the TAs for CC#1 to CC#3
  - Afterwards, the network may decide to aggregate TACs together, and the aggregated TAC may sent through MAC TAC control element message through any CCs (CC#1 to CC# 3)
  - After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may restart TA timer

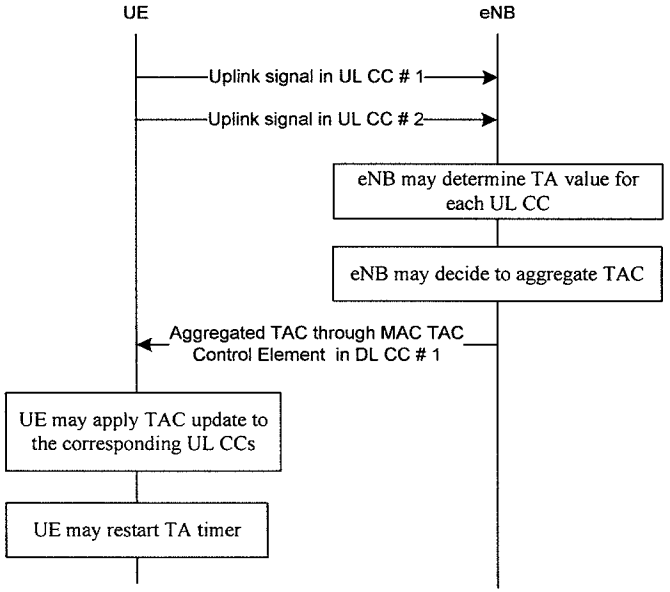


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- E.g., Procedure# 2: Aggregated TAC update in asymmetric DL/UL CC configuration scenario,
- E.g., one DL CC (DL CC#1) may link to 2 UL CCs (UL CC#1 and UL CC#2) and UE may send Uplink signal through UL CC#1 and CC#2
- Afterwards, the network may determine TA value for each UL CC and the network may decide to aggregate TACs together and send the TAC through MAC control element through DL CC#1
- After receiving TAC, UE may apply TAC to the corresponding UL CCs and then UE may restart TA timer



DL/ UL CCs configuration

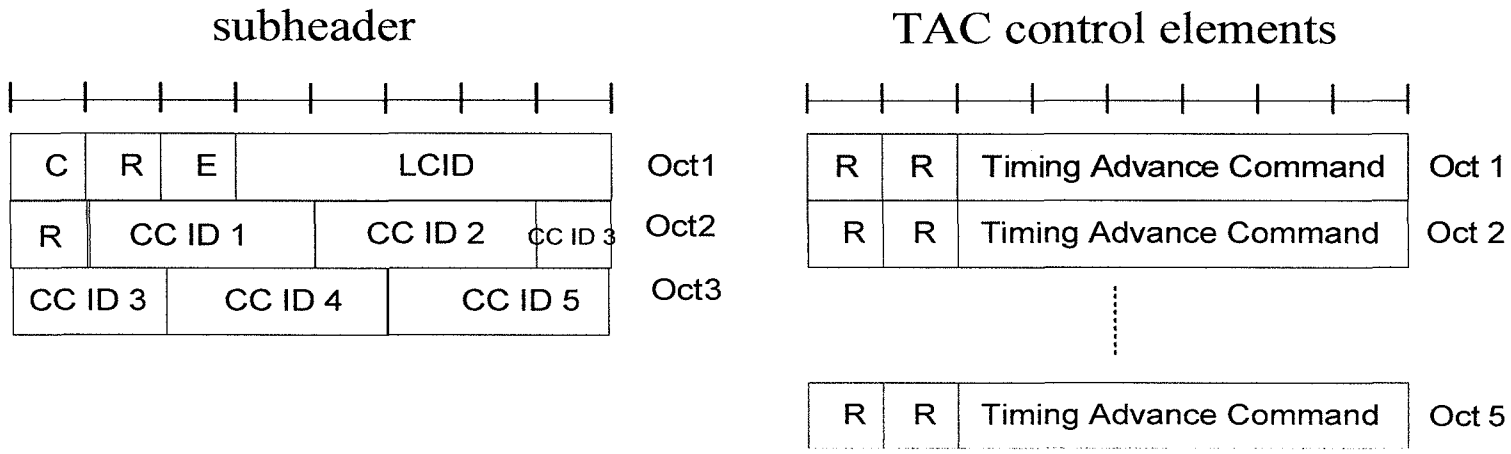


TAC update procedure

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Method # 2-1

- In this method, multiple TACs may be aggregated in a MAC control elements and the aggregated TAC may include CC ID information explicitly and/or implicitly.
  - For example, CC ID information may be in the MAC subheader.
  - E.g., "R" bit(s) may indicate that multiple TAC is included in the MAC subheader.
    - E.g. # 1, a "R" bit is used as C bit to indicate CC ID is included in the MAC subheader
    - 5 CC IDs may be used to indicate the following TAC for the corresponding UL CC



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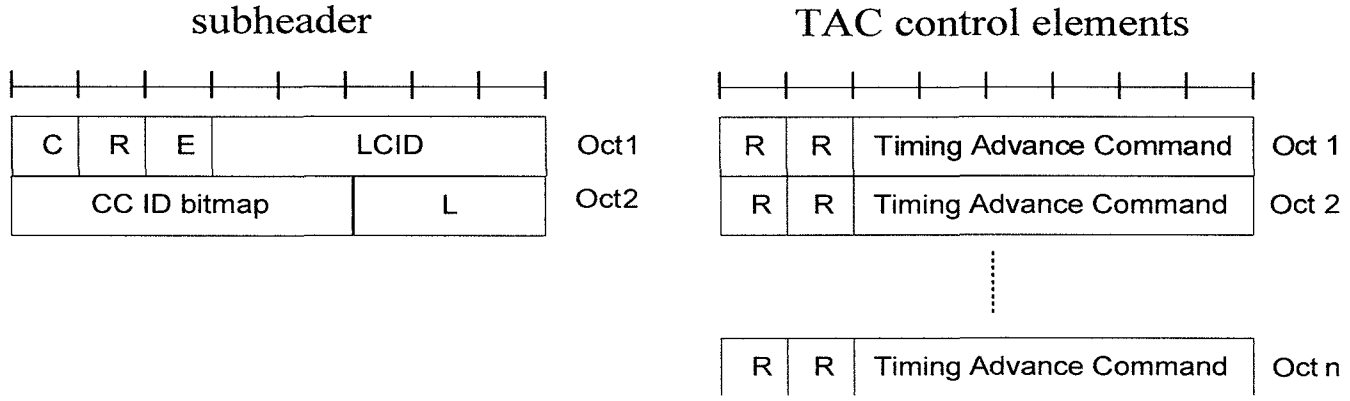
Method # 2-1 (cont.)

- For example, CC ID information may be in the TAC control element explicitly.
- For example, CC ID information may be in the TAC control element implicitly.

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Method # 2-2

- In this method, multiple TACs may be aggregated in a MAC control elements and the aggregated TAC may include CC ID bitmap information explicitly and/or implicitly.
  - For example, CC ID bitmap information may be in the MAC subheader. We may use "R" bit to indicate CC ID bitmap is included in the MAC subheader.
    - E.g., 5 bits CC ID bitmap is to indicate the following TAC for the corresponding UL CC
    - It is optional to have a length filed "*L*" to indicate the TAC octet number
    - E.g., CC ID bitmap is set to be 01001 (L may be 010), and then the corresponding TACs are for CC ID 2 and CC ID 5



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Method # 2-2 (cont.)

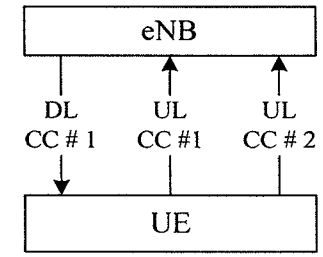
- For example, CC ID bitmap information may be in the TAC control element explicitly.
- For example, CC ID bitmap information may be in the TAC control element implicitly.

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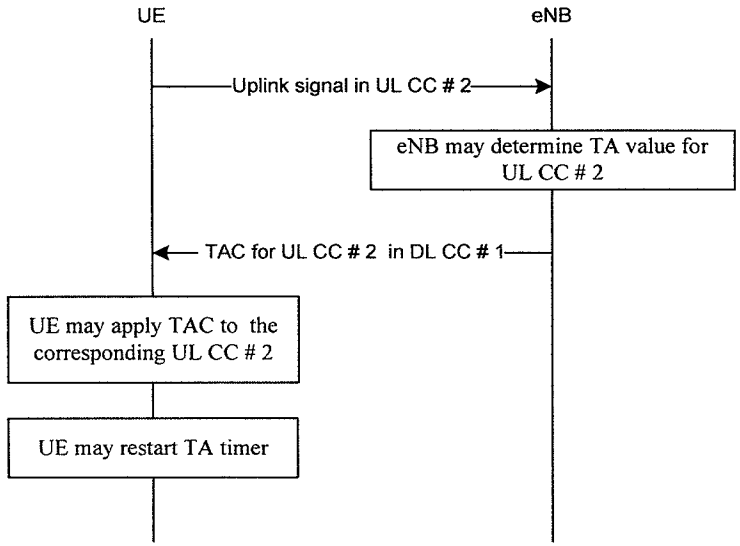
Procedure # 3:

TAC update in asymmetric DL/UL CC configuration scenario

- In this procedure, TAC update message may be sent through MAC control element through any DL CCs in asymmetric DL/UL CC configuration scenario.
  - For example, one DL CC (DL CC#1) may link to 2 UL CCs (UL CC#1 and UL CC#2) and UE may send Uplink signal through UL CC#2
  - Afterwards, the network may determine TA value for the UL CC#2 and the network may send the TAC through MAC control element through DL CC#1
  - After receiving TAC, UE may apply TAC to UL CC#2 and then UE may restart TA timer



DL/ UL CCs configuration

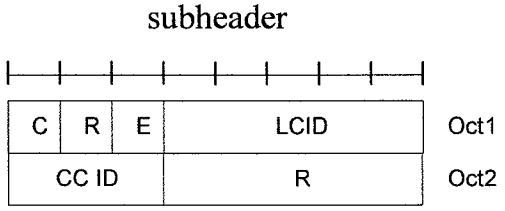


TAC update procedure

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Method # 3-1

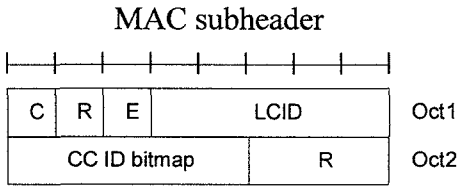
- In this method, MAC subheader may include the CC ID information.
  - For example, a original "R" bit is used as C bit to indicate CC ID is included in the MAC subheader
    - E.g. #1, TAC MAC control element subheader



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Method # 3-2

- In this method, MAC subheader may include a CC ID bitmap.
  - For example, if the *i*-th bit in the bitmap is set to 1, then it means the TAC may apply to the corresponding CC # *i*
    - E.g., Use a "R" bit as C bit to indicate a CC ID bitmap is included in the MAC subheader
    - 5 bits CC ID bitmap is to indicate the corresponding UL CC to update its/their TA value according to TAC
      - E.g.,

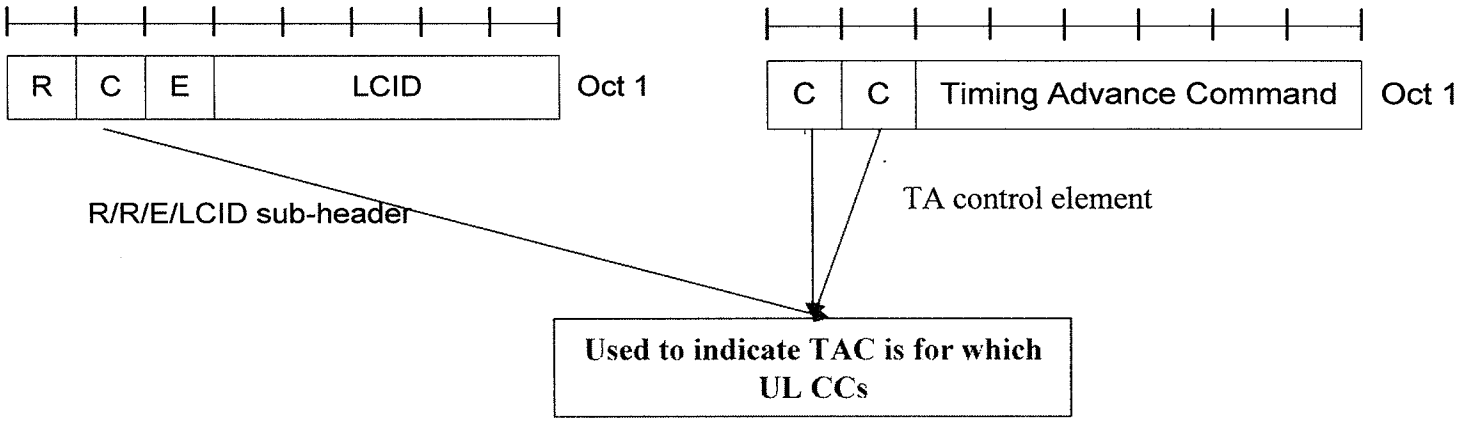


        - E.g., CC ID bitmap= 01001 => UL CC ID 2 and 5 should update their TA according to the corresponding TAC

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Method # 3-3

- In this method, the CC ID information is indicated by MAC subheader and TA control element.
  - For example, there may be four Reserved bits in the MAC subheader and TA control element. We may use 3 bits to indicate TAC is for certain CC and/or for all CCs, and keep an unused bit as "R" bit
  - E.g., to support 3 UL CCs, we set 3 bits to indicate the TAC is for 3 UL CCs or for a certain CC, and other bit keep as "R"
    - E.g., 111=> for all UL CCs, 001=> UL ID 1, 010=> UL ID 2, 011 => UL ID 3

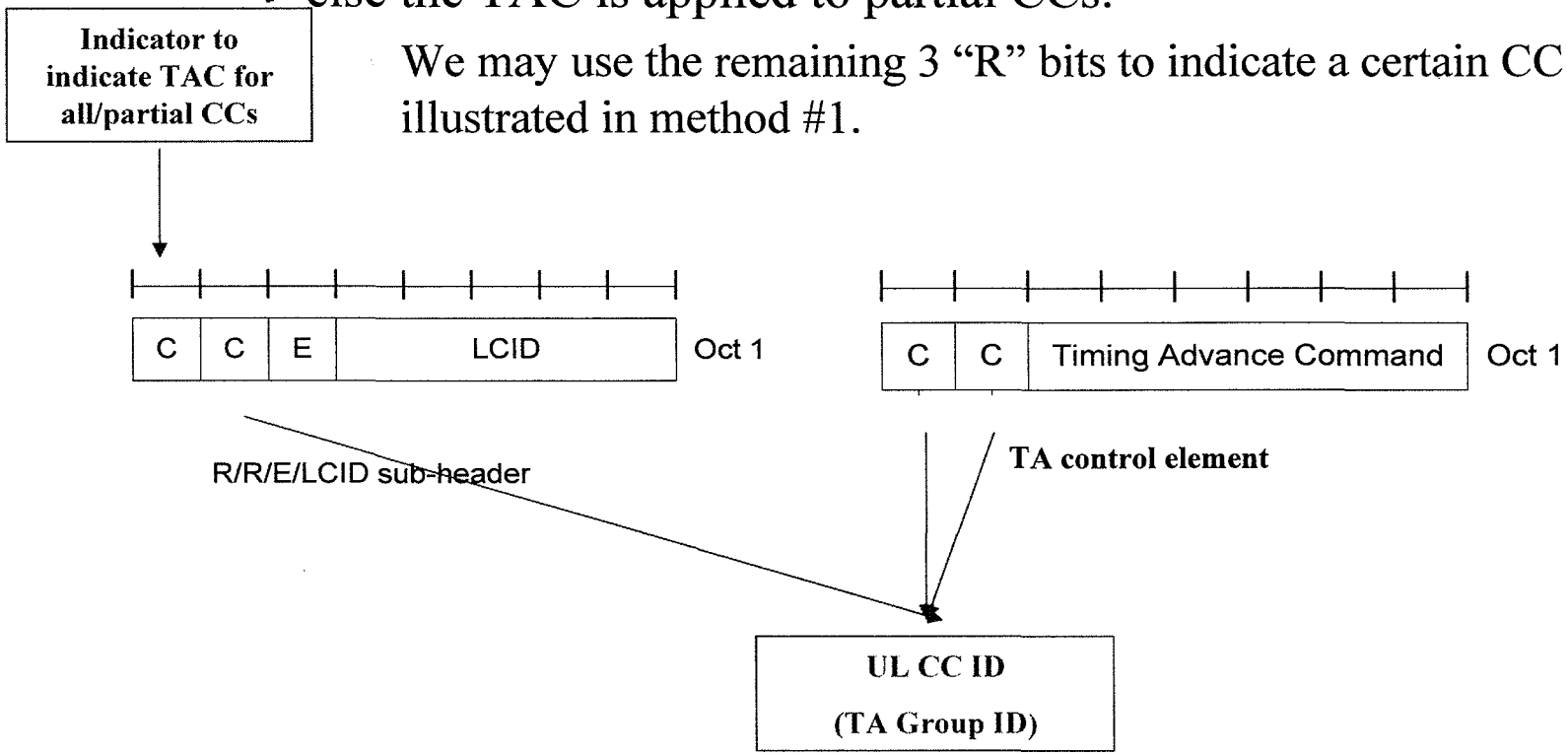


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Method # 3-4

- In this method, the CC ID information is indicated by MAC subheader and TA control element and MAC subheader may indicate if the TAC is applied to all CCs.
  - For example, one "R" bit is to indicate TAC is for all or for partial CCs
    - If the bit is set to 0, then the TAC is applied to all CCs;
    - else the TAC is applied to partial CCs.

We may use the remaining 3 "R" bits to indicate a certain CC ID as illustrated in method #1.

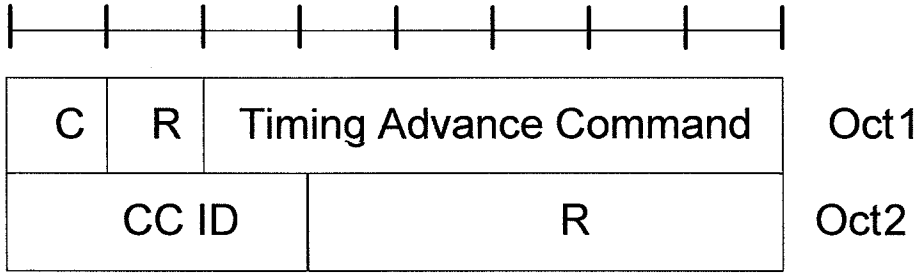


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Method # 3-5

- In this method, MAC TA Control Element may include CC ID information.
  - For example, a "R" bit is used as C bit to indicate CC ID is included in the MAC TA control element

TA control element

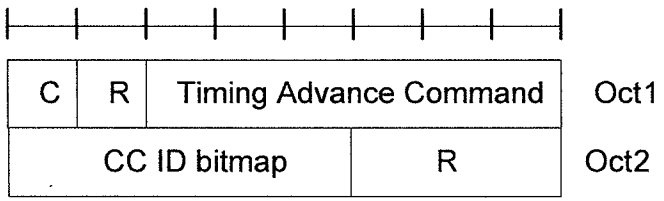


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Method # 3-6

- In this method, MAC TA Control Element may include CC ID bitmap information.
  - For example, if the *i*-th bit in the bitmap is set to 1, then it means the TA Command may apply to the corresponding CC #*i*
    - e.g., Use a "R" bit as C bit to indicate a CC ID bitmap is included in the TA Control Element
    - 5 bits CC ID bitmap is to indicate the corresponding UL CC to update its /their TA value according to TAC
      - E.g., CC ID bitmap= 01001 => UL CC ID 2 and 5 should update their TA according to the TAC

TAC control element



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