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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
62/334,706	05/11/2016		260	0203-1891		

CONFIRMATION NO. 6608

FILING RECEIPT

68103

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Date Mailed: 05/27/2016

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The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/334,706**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM AND METHOD OF SIGNALING SYSTEM INFORMATION

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

page 1 of 3

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INVENTION TITLE: System & Method of Signaling System Information**DESCRIPTION OF THE INVENTION**

This description should be written in the Inventor's own words and should follow this guideline:

- 1. Describe the disadvantages of the prior art without mentioning your invention (Including any related publicly available documentation, such as journal articles or patents).**

In the recent years several broadband wireless technologies have been developed to meet the growing number of broadband subscribers and to provide more and better applications and services. The second generation wireless communication system has been developed to provide voice services while ensuring the mobility of users. Third generation wireless communication system supports not only the voice service but also data service. In recent years, the fourth wireless communication system has been developed to provide high-speed data service. However, currently, the fourth generation wireless communication system suffers from lack of resources to meet the growing demand for high speed data services. So fifth generation wireless communication system is being developed to meet the growing demand for high speed data services, support ultra-reliability and low latency applications and support massive machine type communication.

In the fourth generation wireless communication system, enhanced node B (eNB) or base station in cell broadcast system information. System information is structured into master information block (MIB) and a set of system information blocks (SIBs). MIB consists of System Frame Number (SFN), Downlink System bandwidth and Physical Hybrid ARQ Feedback Indicator Channel (PHICH) configuration. MIB is transmitted every 40ms. It is repeated every 10ms wherein the first transmission occurs in subframe #0 when SFN mod 4 equals zero. MIB is transmitted on physical broadcast channel. System Information Block Type 1 carries cell identity, tracking area code, cell barring information, value tag (common for all scheduling units), and scheduling information of other SIBs. SIB 1 is transmitted every 80ms in subframe #5 when SFN mod 8 equals zero. SIB 1 is repeated in subframe#5 when SFN mod 2 equals zero. SIB 1 is transmitted on Physical downlink shared channel. Other SIBs (SIB 2 to SIB 19) are transmitted in System Information (SI) message wherein scheduling info of these SIBs are indicated in SIB 1. SIBs having same periodicity can be transmitted in one SI message. SI message is broadcasted on Physical downlink shared channel. Various SIBs, their usage and typical size is indicated in Table 1 below.

Table 1 System Information in 4G System

SIB Type	Content	SIB Size
SIB 1	Cell ID, value tag & Scheduling info	~500bits
SIB 2	AC-Barring, RACH Info	2216 bits (Max)
SIB 3	Common Cell reselection info & intra frequency cell reselection parameters	~100bits
SIB 4	Intra frequency neighbor cell info	~750bits
SIB 5	Inter frequency cell reselection information	~1000bits
SIB 6	UTRA cell reselection information	~1000bits
SIB 7	GERAN cell reselection information	~1000bits
SIB 8	CDMA 2000 cell reselection information	2216 bits (Max)
SIB 9	Home eNB Info	~56bits
SIB 10	ETWS Primary Notification	2216 bits (Max)
SIB 11	ETWS Secondary Notification	2216 bits (Max)

SIB 12	CMAS Notification	2216 bits (Max)
SIB 13	MBMS Information to acquire MBMS Control information	~300bits
SIB 14	Extended Access Class Barring Information	~100bits
SIB 15	MBMS Service Area Identifiers of the current and neighboring frequencies	2216 bits (Max)
SIB 16	UTC Time	~60bits
SIB 17	Information for traffic steering between E-UTRAN and WLAN	2216 bits (Max)
SIB 18	Intra Frequency D2D Communication Information	2216 bits (Max)
SIB 19	Intra/inter frequency D2D Discovery Information	2216 bits (Max)

UE acquires the system information at cell selection, cell reselection, after handover completion, after entering E-UTRA from another RAT, upon re-entering service area, upon receiving a notification (paging), and upon exceeding the maximum validity duration (3 hr). In RRC idle state, UE needs to acquire MIB, SIB 1, SIB 2 to SIB 5, SIB 6 to SIB 8 (depending on RAT supported), SIB 17 (if LTE-WLAN IWK is supported), and SIB 18 to SIB 19 (if D2D is supported). In RRC connected state, UE needs to acquire MIB, SIB 1, SIB 2, SIB 8 (depending on RAT supported), SIB 17 (if LTE-WLAN IWK is supported), and SIB 18 to SIB 19 (if D2D is supported). System information acquired and stored is considered invalid if value tag in received SIB 1 is different from the one in stored SI.

System information can be changed and is notified as follows: Change is notified through *paging* message (in RRC_IDLE or RRC_CONNECTED) with cause systemInfoModification to let UE know that some SI is changing in the next modification period. Modification period boundaries are in terms of SFN such that $\text{SFN mod modificationPeriod} = 0$. Change of SI only occurs at specific radio frames. Notification of changes in modification period N will be reflected in N+1. SIB1 also carries value tag to indicate change in SI. UE finds the change in SI by looking at value tag in SIB1 at the end modificationPeriod (if missed checking page) or receiving paging with systemInfoModification.

One of the issues in current method of transmitting system information using the MIB/SIBs is that MIB/SIBs are periodically broadcasted irrespective of whether a UE is there in cell or not; whether any UE in cell needs that information. In case of small cell deployment, broadcasting all these SIBs periodically is unnecessary and leads to significant wastage of resources. So an enhanced method of signaling system information is needed.

1. **Description of the invention in detail (Including its operation, purpose, environment and how your invention overcomes the shortcomings of the prior art). Begin with a system level diagram and associated high level description of your invention in the context of a possible product deployment of your invention, for example a handset, a base station, and/or a wireless network comprising one or more base stations and one or more handsets.**

Method 1:

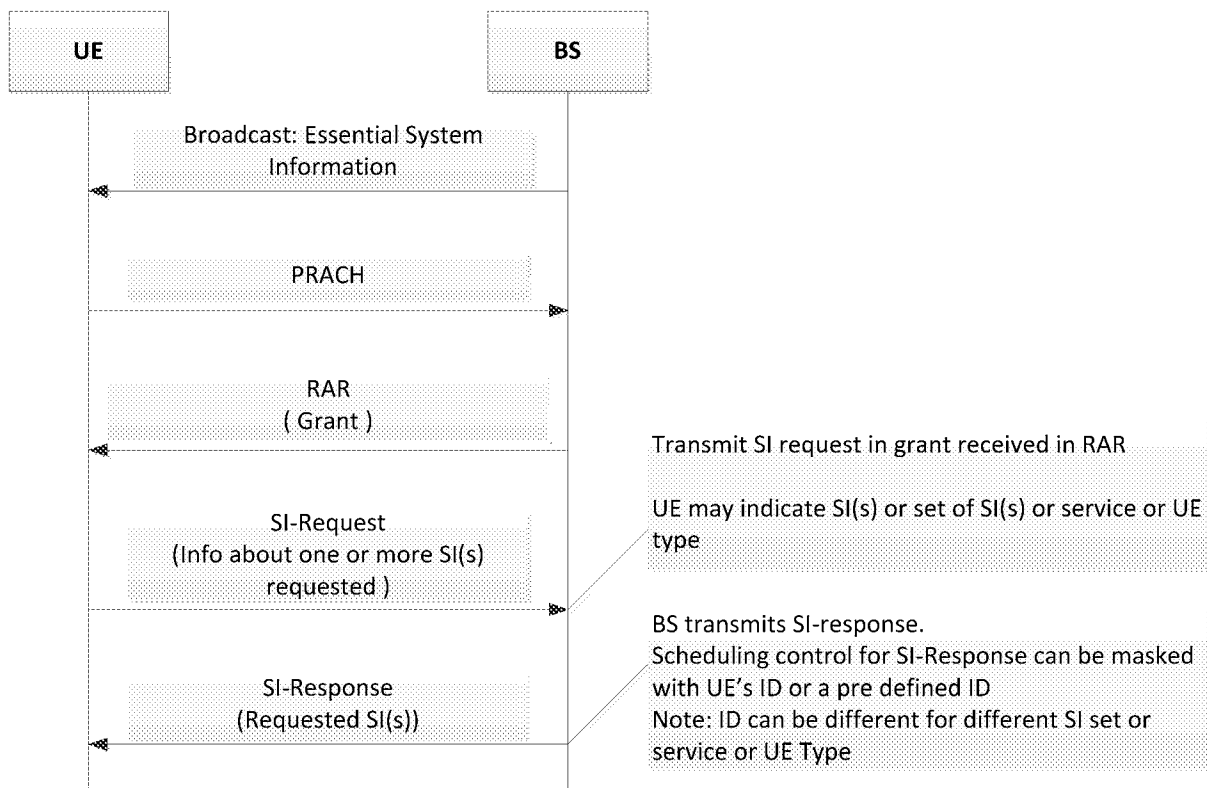


Figure 1

In one embodiment of the proposed invention the UE can acquire the system information as shown in Figure 1. System information is categorized into two categories: First category comprises of one or more System information which is broadcasted periodically by the cell and/or TRP. Second category comprises of one or more system information which is provided to UE on demand. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell and/or TRP. UE acquires essential system information from broadcasted information. In order to receive the other system information, UE sends random access preamble (PRACH). On receiving the random access preamble, BS transmits a random access response and includes UL grant for transmitting the system information (SI) request message. RAR may also include timing advance and/or back off indicator and or preamble identifier (identifies the PRACH preamble). UE validates that RAR corresponds to PRACH transmitted by it. If the validation is successful, UE transmits SI request message in the UL grant. SI request message indicates one or more system information which UE needs or indicates one or more set of system information which UE needs or indicates service (e.g. eMBB, MTC, URLL, etc) for which UE needs system information or UE type. UE may transmit its UE ID (i.e. S-TMSI, C-RNTI, RA-RNTI, etc) along with SI request message. In response to SI request, ENB transmits SI-response wherein the SI-response includes the requested system information. Scheduling control information indicating the SI-response can be masked with UE's ID (e.g. C-RNTI, RA-RNTI) or a pre-defined ID (e.g. SI-RNTI). Pre-defined ID can be different for different system information or system information set or service or UE type.

In one embodiment, eNB may provide the requested system information for one or more cells and/or TRPs. ENB may indicate the cells and/or TRPs for which system information provided in SI response is applicable. As a result the UE does not need to request for system information when the UE changes cell and/or TRP. After the cell and/or TRP change, if the UE does not have system information for the new cell and/or TRP then UE request for system information.

In one embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not. If not broadcasted then UE can request using the method (Figure 1) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted whereas small cells may indicate that system information is not broadcasted.

In another embodiment of proposed invention BS can indicate supported SI(s) in essential system information. UE can then request one or more of the supported SIs using the method (Figure 1) explained earlier. In one embodiment a default configuration for system information can be defined which the UE uses until it obtains them from the cell.

UE can indicate the needed system information in SI-Request using one of the following options:

Option 1:

In this method as illustrated in Figure 2, system information parameters are categorized into system information blocks. In SI request a bitmap of size N bits is included wherein each bit corresponds to a system information block. Bit corresponding to a system information block can be set to one to indicate that UE needs that system information block or Bit corresponding to a system information block can be set to zero to indicate that UE needs that system information block. Alternately, instead of bitmap, UE can include a list of SIBs in SI-request.

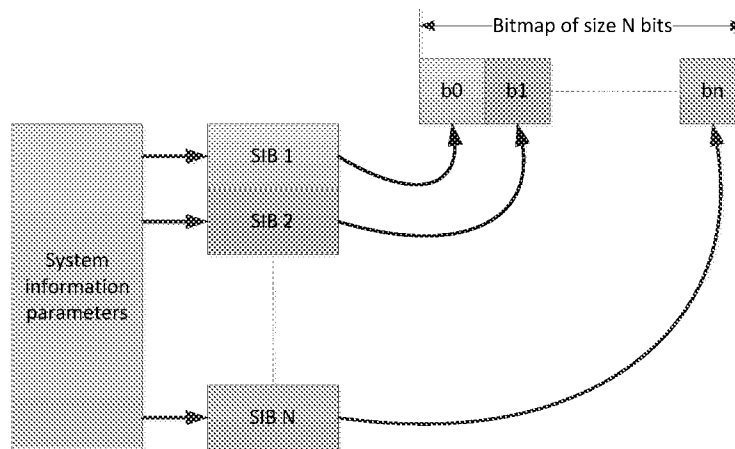


Figure 2

Option 2:

In this method as illustrated in Figure 3, system information parameters are categorized into system information blocks. System information blocks are then grouped into system information block set wherein each set comprises of one or more system

information blocks. A system information block can be present in more than one system information block set. Grouping of system information blocks into system information block set can be done based on service (e.g. MBB, URLL, MTC, D2D, D2D-discovery, D2D-Communication, V2X, V2V etc) or UE type (MTC UE, MBB UE, D2D UE, etc). In SI request a bitmap of size P bits is included wherein each bit corresponds to a system information block set. Bit corresponding to a system information block set can be set to one to indicate that UE needs that system information block. Alternately, instead of bitmap, UE can include a list of SIB set in SI-request.

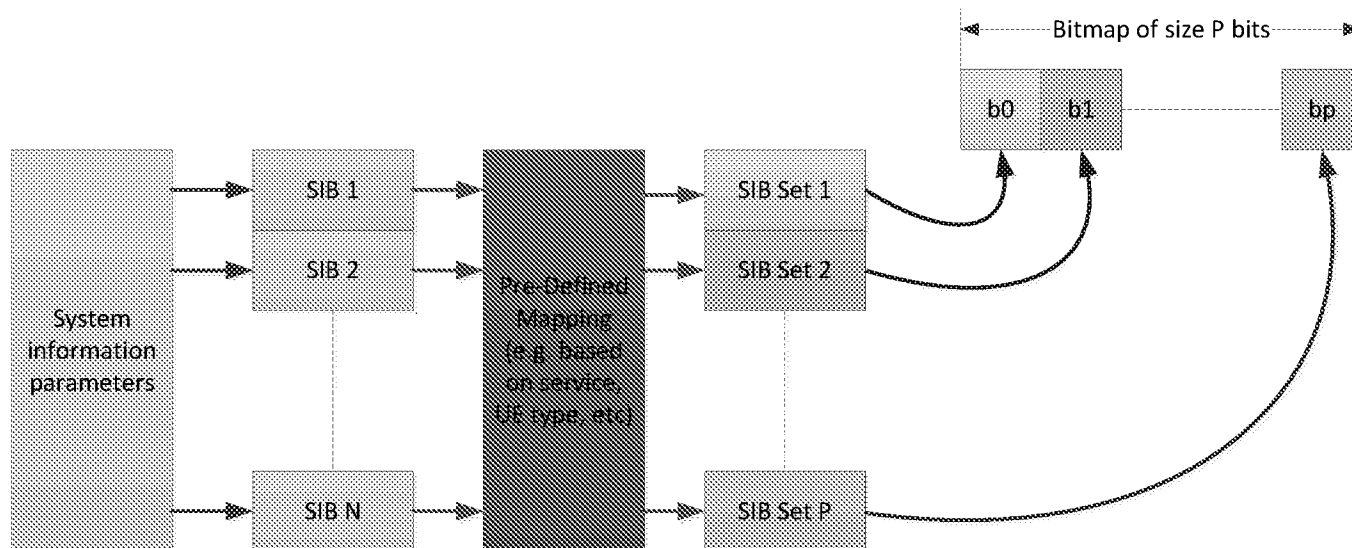


Figure 3

Option 3:

In this method as illustrated in Figure 4, system information parameters are categorized into system information set. Grouping of system information parameters into system information set can be done based on service (e.g. MBB, URLL, MTC, D2D, D2D-discovery, D2D-Communication, V2X, V2V etc) or UE type (MTC UE, MBB UE, D2D UE, etc). In SI request a bitmap of size P bits is included wherein each bit corresponds to a system information set. Bit corresponding to system information set can be set to one to indicate that UE needs that system information set. Alternately, instead of bitmap, UE can include a list of SI sets in SI-request.

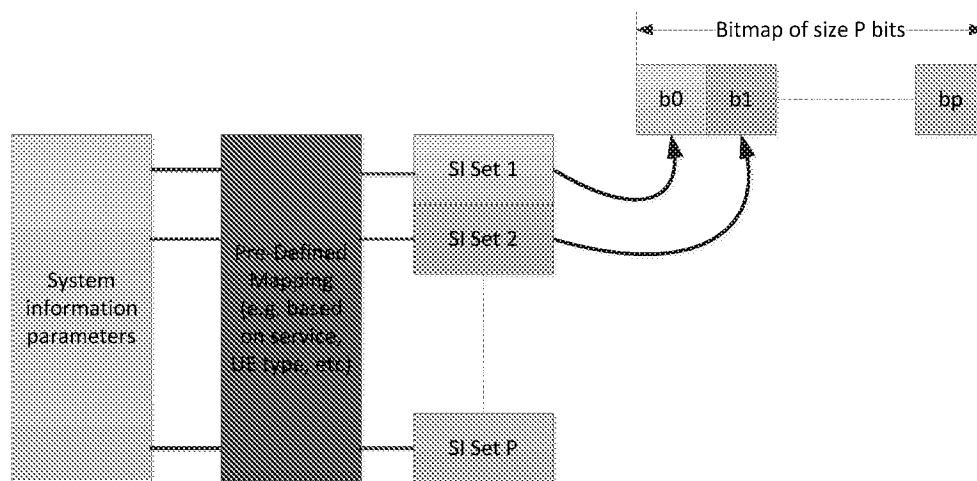
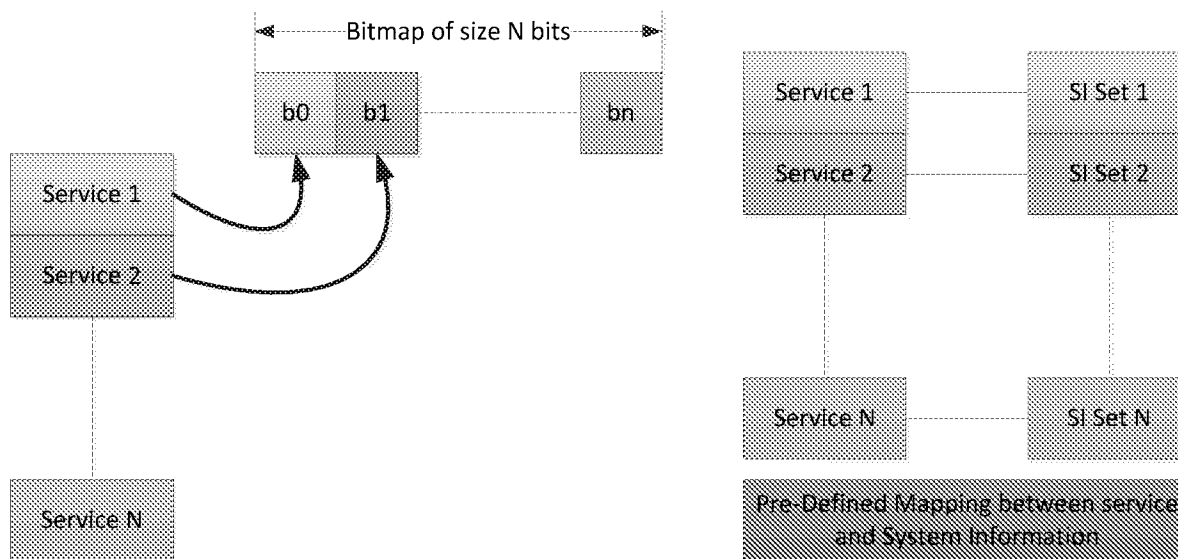


Figure 4Option 4:

In this method as illustrated in Figure 5, there is pre-defined mapping between one or more system information parameters and service. In SI request a bitmap of size N bits is included wherein each bit corresponds to a service. Bit corresponding to service can be set to one to indicate that UE needs system information for this service. Alternately, instead of bitmap, UE can include a list of one or more services in SI-request wherein each service can be identified by a service type.

**Figure 5**Option 5:

In this method, UE can indicate UE type in SI request. UE type indicates the service supported by the UE. There is pre-defined mapping between one or more system information parameters and service. So on receiving the SI request with UE type, BS can know the system information parameters needed by UE.

In another embodiment of the proposed invention the UE can acquire the system information as shown in Figure 6. System information is categorized into two categories: First category comprises of one or more System information which is broadcasted periodically by the cell. Second category comprises of one or more system information which is provided to UE on demand. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell. UE acquires essential system information from broadcasted information. In order to receive the other system information, UE sends random access preamble (PRACH). On receiving the random access preamble, BS transmits a random access response and includes UL grant for transmitting the system information (SI) request message. RAR may also include timing advance and/or back off indicator and or preamble identifier (identifies the PRACH preamble). UE validates that RAR corresponds to PRACH transmitted by it. If the validation is successful, UE transmits SI request message in the UL grant. UE may not indicate which system information is needed by UE. The carrier on which UE sends SI request supports only one service. UE only indicates that it needs system information. BS provides system information for the service supported on carrier. There can be pre-defined mapping between carrier and service. Alternately, service supported can be indicated in

essential system information.

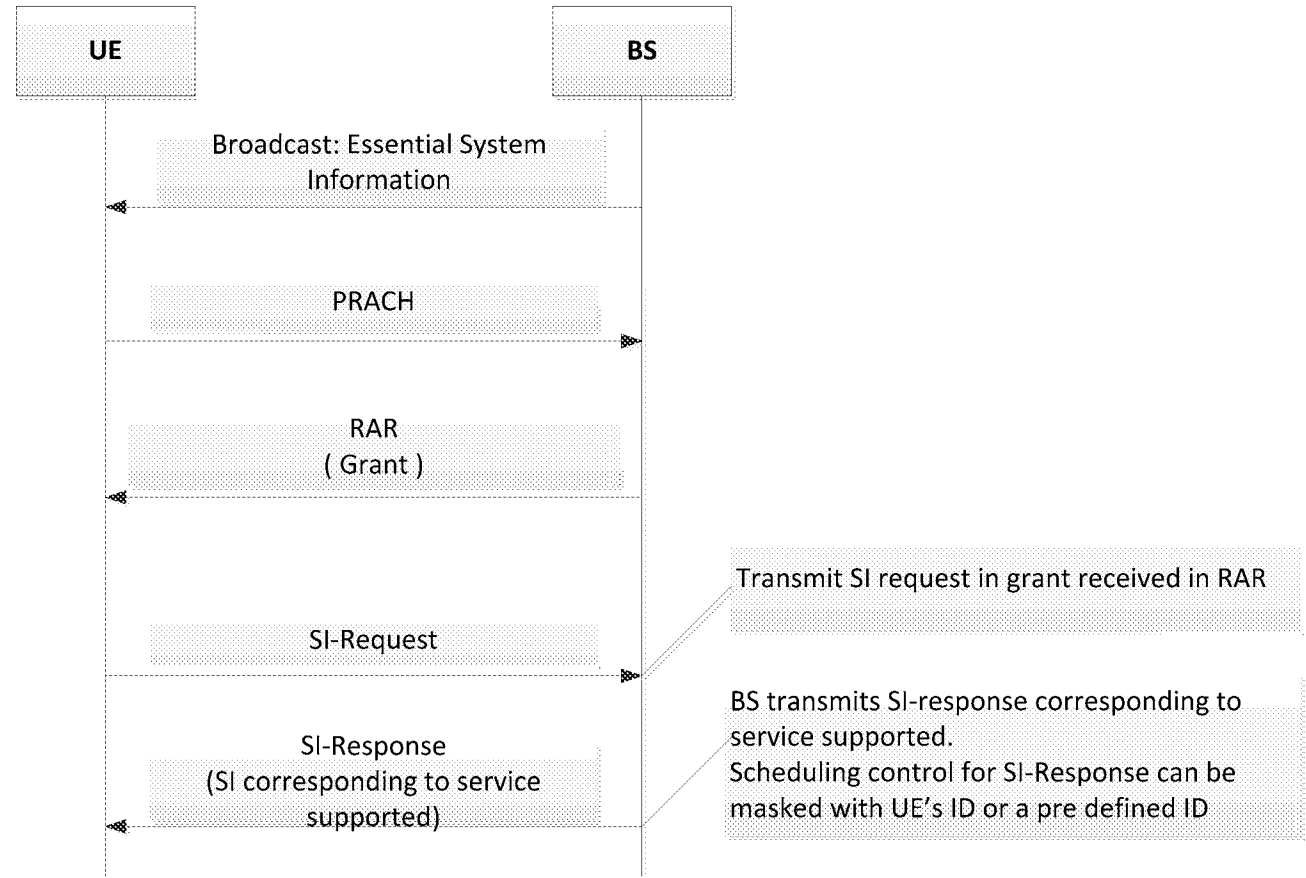


Figure 6

In another embodiment of proposed invention essential system information may not be broadcasted. Essential system information is also requested by UE like the other system information.

In another embodiment of proposed invention the second category of system information can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not. If not broadcasted then UE can request using the methods explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted whereas small cells may indicate that system information is not broadcasted.

In another embodiment of proposed invention BS can indicate supported SI(s) in essential system information. UE can then request one or more of the supported SIs using the method (Figure 1) explained earlier.

Method 2:

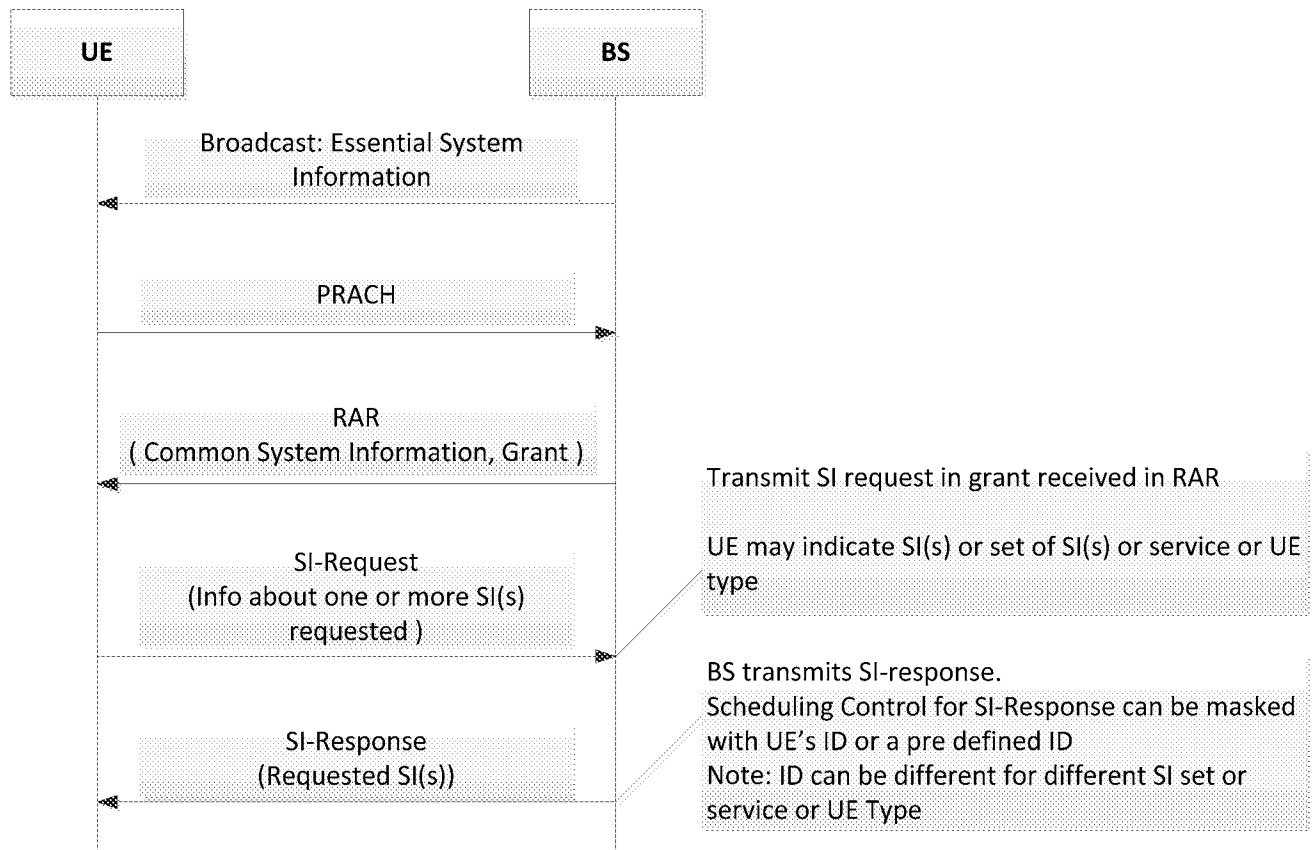


Figure 7

In this method of the proposed invention the UE can acquire the system information as shown in Figure 7. System information is categorized into three categories: First category comprises of one or more System information which is broadcasted periodically by the cell and/or TRP. Second category comprises of one or more common system information which is provided to UE on demand in random access response. Third category comprises of one or more system information which is provided to UE on demand in SI-response. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell and/or TRP. UE acquires essential system information from broadcasted information. In order to receive the other common system information, UE sends random access preamble (PRACH). PRACH preamble or PRACH opportunity (i.e. time/frequency resource) for obtaining system information in RAR can be different from the PRACH or PRACH opportunity for other purposes. PRACH preamble or PRACH opportunity for obtaining system information can be predefined or signaled by network in essential system information. On receiving the random access preamble, BS transmits a random access response and may include UL grant for transmitting the system information request message. RAR includes the common system information. RAR may also include timing advance and/or back off indicator and or preamble identifier (identifies the PRACH preamble). UE validates that RAR corresponds to PRACH transmitted by it. If the validation is successful, UE transmits SI request message in the UL grant to request one or more system information according to its need. SI request message indicates system information or set of system information or service or UE type. UE may transmit its UE ID (i.e. S-TMSI, C-RNTI, RA-RNTI, etc) along with SI request message. In response to SI request, ENB transmits SI-response wherein the SI-response includes the requested system information. Scheduling control information indicating the SI-response can be masked with UE's ID (e.g. C-RNTI, RA-RNTI) or a pre-defined ID (e.g. SI-RNTI). Pre-defined ID can be different for different system information or system information set or service or UE type. UE can indicate the needed system information in SI-Request using the options explained in description of method 1.

In one embodiment, based on PRACH, content of RAR can be one of the following:

1. Common system information and No UL grant
2. Common system information and UL grant
3. UL grant

PRACH preamble and/or PRACH opportunity can be different for each of the above. UE select the appropriate PRACH preamble and/or PRACH opportunity accordingly. For example, UE may only need common system information. If UE needs only common system information it indicates to eNB using the appropriate PRACH preamble and/or PRACH opportunity. PRACH preamble(s) and/or PRACH opportunity(s) for this purpose is different from other purposes. In this case UE will not send SI request after receiving the RAR. In another scenario UE needs common system information and also wants to request additional system information. In this case UE needs common system information and UL grant in RAR. UE indicates to eNB using the appropriate PRACH preamble and/or PRACH opportunity. PRACH preamble(s) and/or PRACH opportunity(s) for this purpose is different from other purposes. In this case UE will send SI request after receiving the RAR. In another scenario UE may want to request system information and needs UL grant in RAR. UE indicates to eNB using the appropriate PRACH preamble and/or PRACH opportunity. PRACH preamble(s) and/or PRACH opportunity(s) for this purpose is different from other purposes.

In one embodiment, eNB may provide the requested system information for one or more cells and/or TRPs. ENB may indicate the cells and/or TRPs for which system information provided in SI response is applicable. As a result the UE does not need to request for system information when the UE changes cell and/or TRP. After the cell and/or TRP change, if the UE does not have system information for the new cell and/or TRP then UE request for system information.

In another embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not. If not broadcasted then UE can request using the method (Figure 7) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted whereas small cells may indicate that system information is not broadcasted.

In another embodiment of proposed invention BS can indicate supported SI(s) in essential system information. UE can then request one or more of the supported SIs using the method (Figure 1) explained earlier.

Method 3:

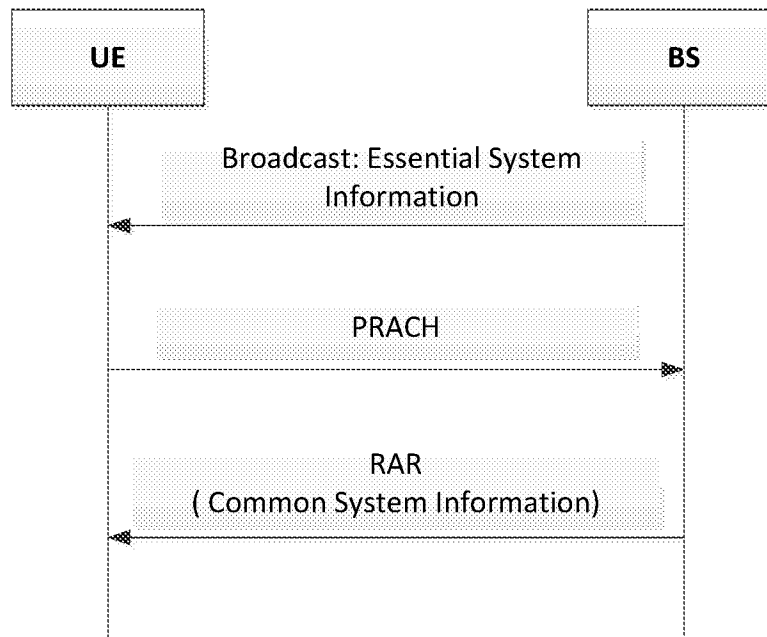


Figure 8

In this method of the proposed invention the UE can acquire the system information as shown in Figure 8. System information is categorized into two categories: First category comprises of one or more System information which is broadcasted periodically by the cell and/or TRP. Second category comprises of one or more common system information which is provided to UE on demand in random access response. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell and/or TRP. UE acquires essential system information from broadcasted information. In order to receive the other system information, UE sends random access preamble (PRACH). PRACH preamble for obtaining system information in RAR can be different from the PRACH for other purposes. On receiving the random access preamble, BS transmits a random access response. RAR includes the common system information. In one embodiment, UE may obtain other system information specific to its need using dedicated signaling (For example, UE may enter connected state and request system information in dedicated manner to eNB).

In one embodiment, eNB may provide the system information for one or more cells and/or TRPs. ENB may indicate the cells and/or TRPs for which system information provided in RAR is applicable. As a result the UE does not need to request for system information when the UE changes cell and/or TRP. After the cell and/or TRP change, if the UE does not have system information for the new cell and/or TRP then UE request for system information.

In one embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not. If not broadcasted then UE can request using the method (Figure 1) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted whereas small cells may indicate that system information is not broadcasted.

Method 4:

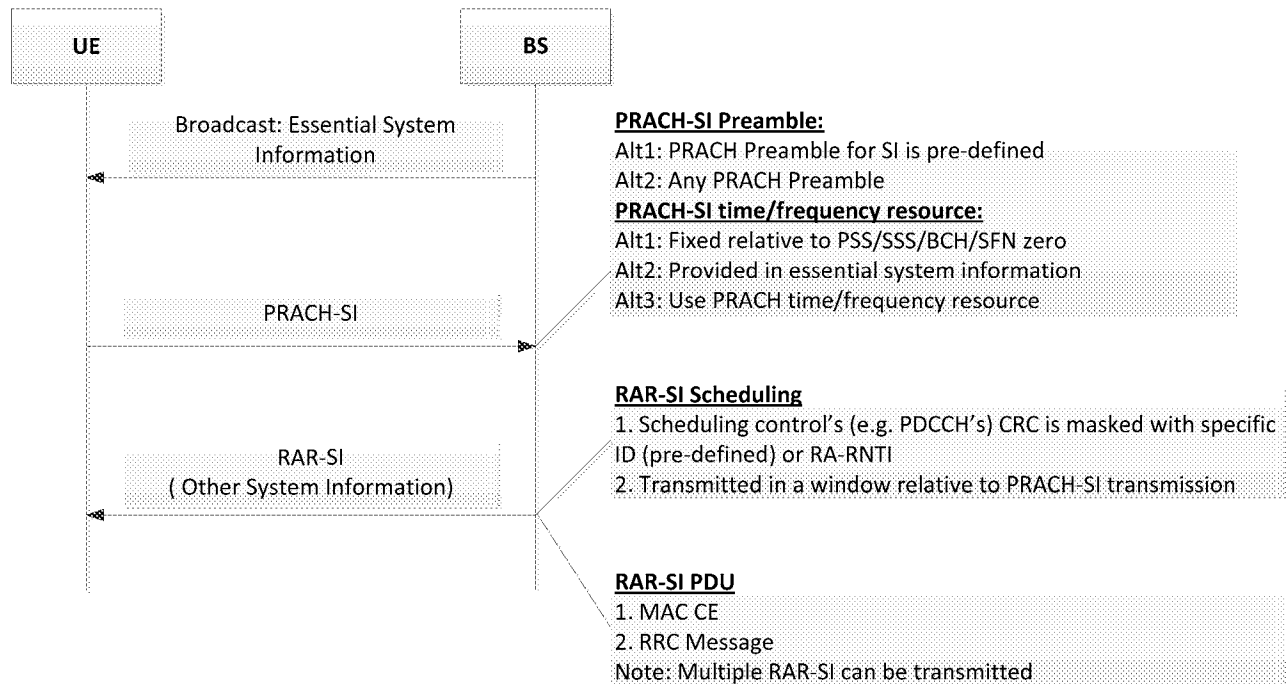


Figure 9

In this method of the proposed invention the UE can acquire the system information as shown in Figure 9. System information is categorized into two categories: First category comprises of one or more System information which is broadcasted periodically by the cell and/or TRP. Second category comprises of one or more common system information which is provided to UE on demand in random access response. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell and/or TRP. UE acquires essential system information from broadcasted information. In order to receive the other system information, UE sends random access preamble (PRACH-SI).

- In one embodiment, PRACH-SI preamble for obtaining system information in RAR is pre-defined. In this option, PRACH time/frequency resource can be one of following:
 - Alt1: Fixed relative to PSS/SSS/BCH/SFN 0
 - Alt2: Provided in essential system information
 - Alt3: Use normal PRACH time/frequency resource
- In another embodiment, PRACH-SI preamble for obtaining system information in RAR is not pre-defined. UE can use any PRACH preamble. In this option, PRACH time/frequency resource is specific to PRACH-SI and can be one of the following:
 - Alt1: Fixed relative to PSS/SSS/BCH/SFN 0
 - Alt2: Provided in essential system information

UE determines the PRACH-SI Transmit Power using one of the following options:

- Alt1: Open loop power control similar to PRACH

- Alt2: Transmit at max power
- Alt3: Transmit power is configured

On receiving the PRACH-SI, BS transmits a random access response. RAR includes the other system information.

In another embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not as shown in Figure 10. If not broadcasted then UE can request using the method (Figure 9) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted (e.g. set SI_TX_Indication to one) whereas small cells may indicate that system information is not broadcasted (e.g. set SI_TX_Indication to zero).

In one embodiment, eNB may provide the requested system information for one or more cells. ENB may indicate the cells for which system information provided in RAR-SI is applicable. As a result the UE does not need to request for system information when the UE changes cell. After the cell change, if the UE does not have system information for the new cell then UE request for system information.

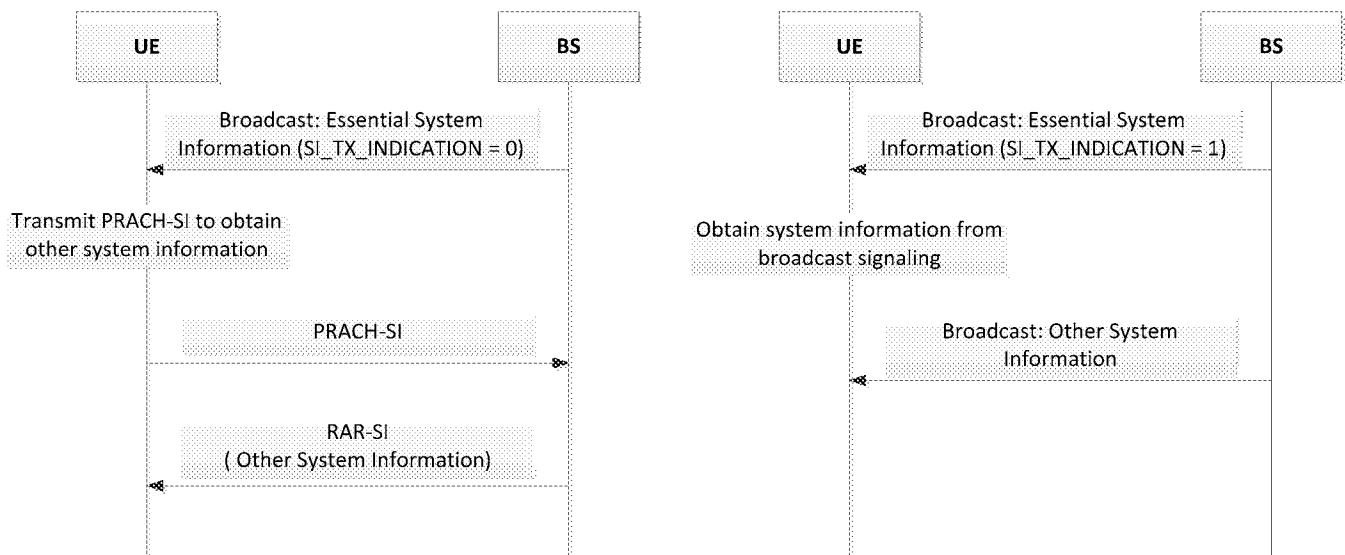
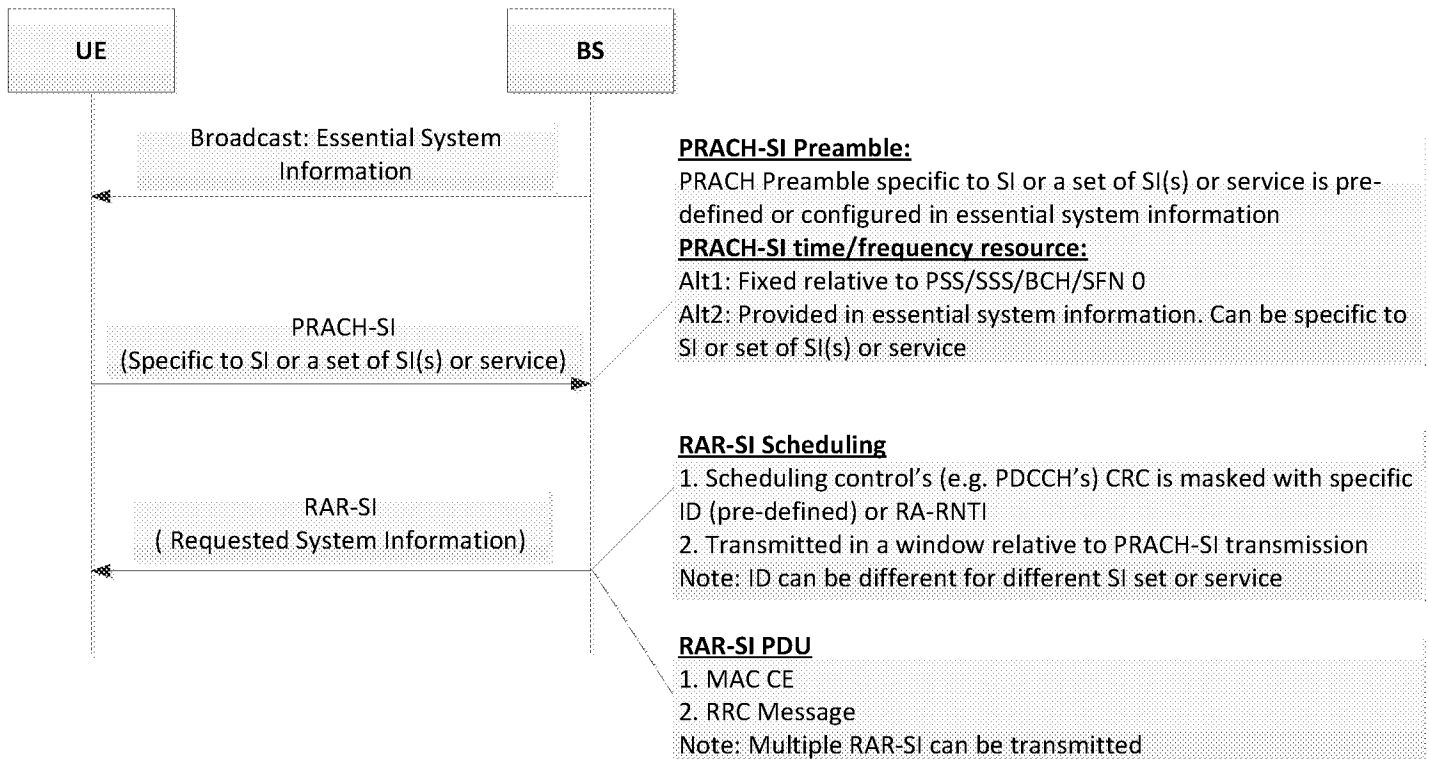


Figure 10

Method 5:

**Figure 11**

In this method of the proposed invention the UE can acquire the system information as shown in Figure 11. System information is categorized into two categories: First category comprises of one or more System information which is broadcasted periodically by the cell and/or TRP. Second category comprises of one or more common system information which is provided to UE on demand in random access response. First category comprises of essential system information. Essential system information is periodically broadcasted by the cell and/or TRP. UE acquires essential system information from broadcasted information. In order to receive the other system information, UE sends random access preamble (PRACH-SI).

- In one embodiment, PRACH-SI preamble for obtaining system information in RAR is pre-defined. PRACH-SI preamble can be specific to system information or a set of system information or service of UE type. In this option, PRACH time/frequency resource can be one of following:
 - Alt1: Fixed relative to PSS/SSS/BCH/SFN 0
 - Alt2: Provided in essential system information. This can be specific to system information or a set of system information or service or UE type.
 - Alt3: Use PRACH time/frequency resource
- In another embodiment, PRACH-SI preamble for obtaining system information in RAR is not pre-defined. UE can use any PRACH preamble. In this option, PRACH time/frequency resource is specific to PRACH-SI and can be one of the following:
 - Alt1: Fixed relative to PSS/SSS/BCH/SFN 0
 - Alt2: Provided in essential system information. This can be specific to system information or a set of system

information or service or UE type.

UE determines the PRACH-SI Transmit Power using one of the following options:

- Alt1: Open loop power control similar to PRACH
- Alt2: Transmit at max power
- Alt3: Transmit power is configured

On receiving the PRACH-SI, BS transmits a random access response. RAR includes the requested system information.

In another embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not as shown in Figure 12. If system information is not broadcasted then UE can request using the method (Figure 11) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case PRACH-SI information is broadcasted for on demand signaling i.e. for requesting system information, absence of this information in broadcasted essential system information may indicate that UE should read system information from broadcast signaling. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted (e.g. set SI_TX_Indication to one) whereas small cells may indicate that system information is not broadcasted (e.g. set SI_TX_Indication to zero).

In one embodiment, eNB may provide the requested system information for one or more cells. ENB may indicate the cells for which system information provided in RAR-SI is applicable. As a result the UE does not need to request for system information when the UE changes cell. After the cell change, if the UE does not have system information for the new cell then UE request for system information.

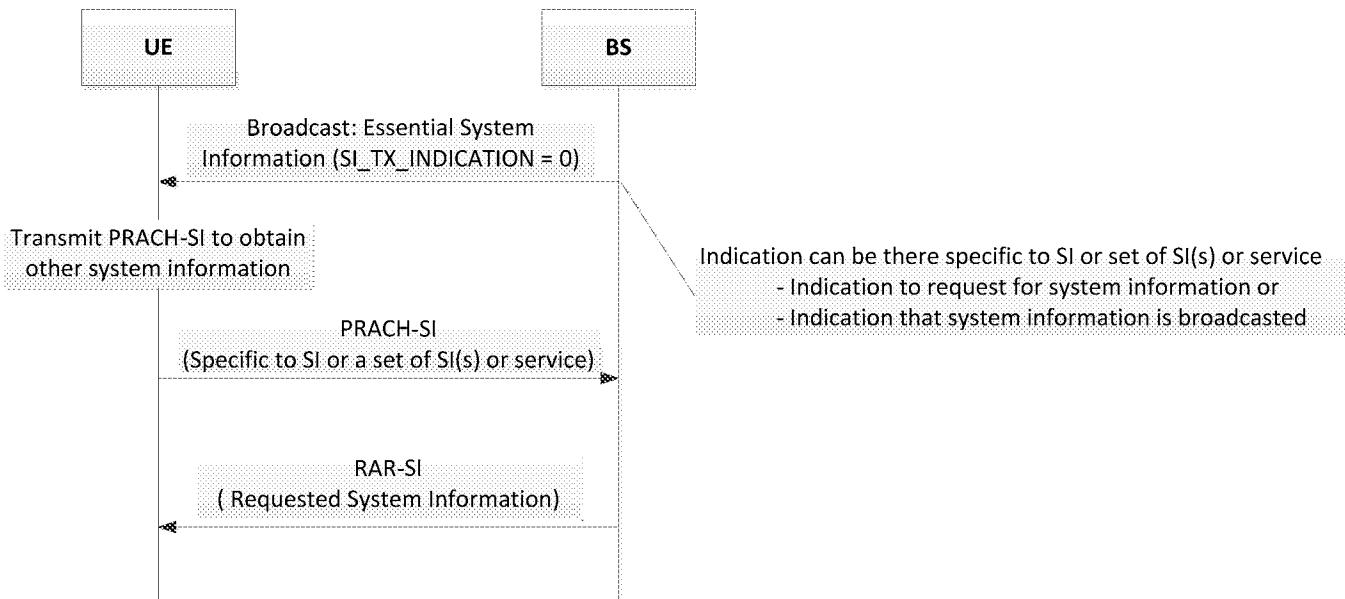


Figure 12

In another embodiment of proposed invention BS can also indicate supported SI(s) in essential system information. UE can then request one or more of the supported SIs using the method (Figure 1) explained earlier.

Method 6:

In this method of the proposed invention the UE can acquire the system information as shown in Figure 13. In this method BS broadcasts the essential system information. BS also broadcasts the scheduling information about the other system information. However, other system information is not periodically broadcasted. BS broadcasts the other system information for defined time duration on receiving a trigger (e.g. PRACH-SI) from the UE. The trigger can be specific to a system information or set of system information or service or UE type. During the time when the system information is broadcasted after receiving a trigger from UE, BS broadcasts an indication that it is broadcasting the system information. The indication can be specific to system information or a set of system information or service or UE type. This ensures that UE does not trigger PRACH-SI and reads the system information from broadcast. The trigger to broadcast can be transmitted at time slots configured by network. In one embodiment, trigger to broadcast can be transmitted at a time relative to location of particular system information.

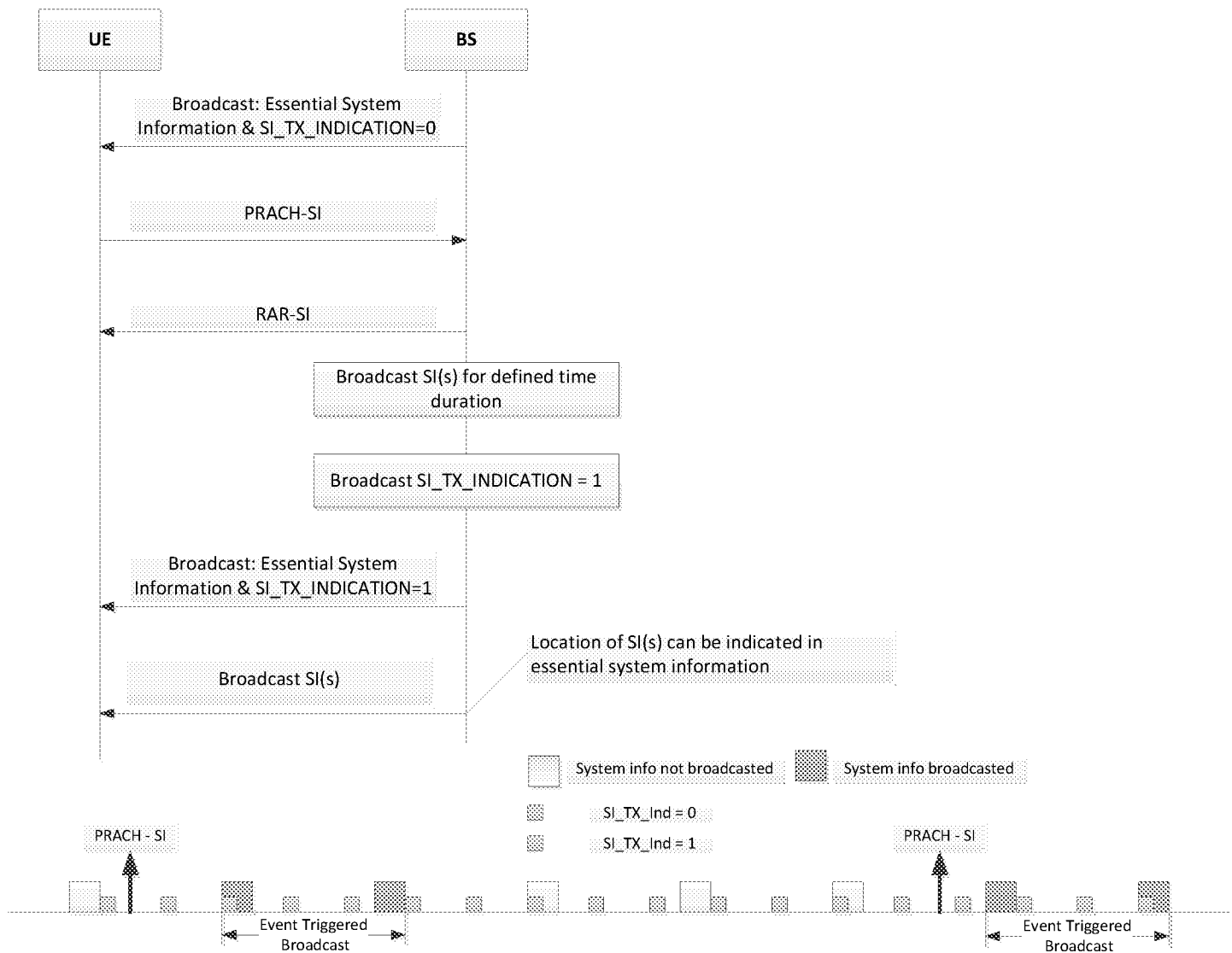


Figure 13

Method 7:

In this method of the proposed invention the UE can acquire the system information as shown in Figure 14. Essential system information is broadcasted by the BS. Other system information is obtained by UE using dedicated signaling. UE performs RRC connection setup procedure if UE is in RRC idle state. In RRC connected state UE sends SI request message. SI request message indicates one or more system information which UE needs or indicates one or more set of system information which UE needs or indicates service (e.g. eMBB, MTC, URLL, etc) for which UE needs system information or UE type. UE may transmit its UE ID (i.e. S-TMSI, C-RNTI, RA-RNTI, etc) along with SI request message. In response to SI request, ENB transmits SI-response wherein the SI-response includes the requested system information. Scheduling control information indicating the SI-response can be masked with UE's ID (e.g. C-RNTI, RA-RNTI) or a pre-defined ID (e.g. SI-RNTI). Pre-defined ID can be different for different system information or system information set or service or UE type.

UE can indicate the needed system information in SI-Request using the mechanisms explained in method 1.

In one embodiment SI request can be included in RRC connection request and SI response can be included RRC connection response. In another embodiment, BS can determine the system information needed by UE based on service supported by UE or based on service for which UE has requested connection and provide the system information to UE using dedicated signaling.

In one embodiment, eNB may provide the requested system information for one or more cells. ENB may indicate the cells for which system information provided in SI response is applicable. As a result the UE does not need to request for system information when the UE changes cell. After the cell change, if the UE does not have system information for the new cell then UE request for system information.

In one embodiment of proposed invention system information (other than essential system information) can also be broadcasted by the BS. BS may indicate in broadcasted essential system information whether other system information is broadcasted or not. If not broadcasted then UE can request using the method (Figure 14) explained earlier. If broadcasted then UE read broadcasted system information to acquire the required system information. In case of heterogeneous network comprises of macro cell and small cells, macro cell may indicate that system information is broadcasted whereas small cells may indicate that system information is not broadcasted.

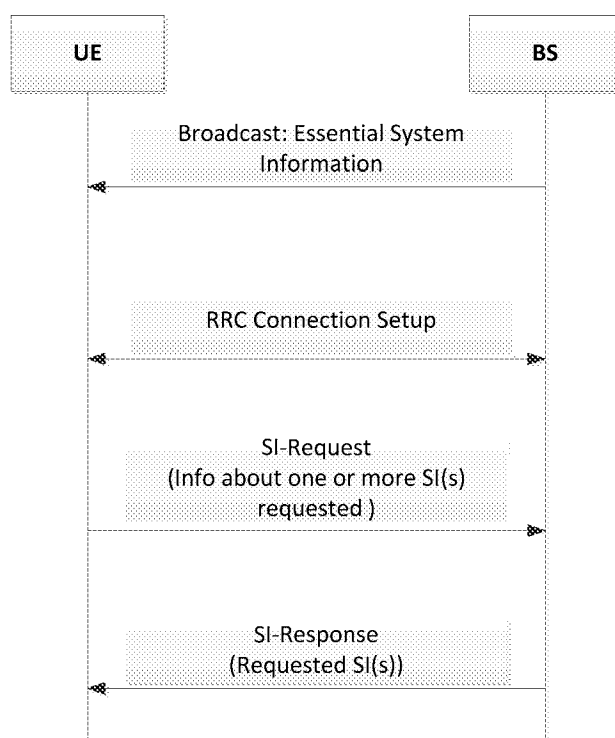


Figure 14

Method 8:

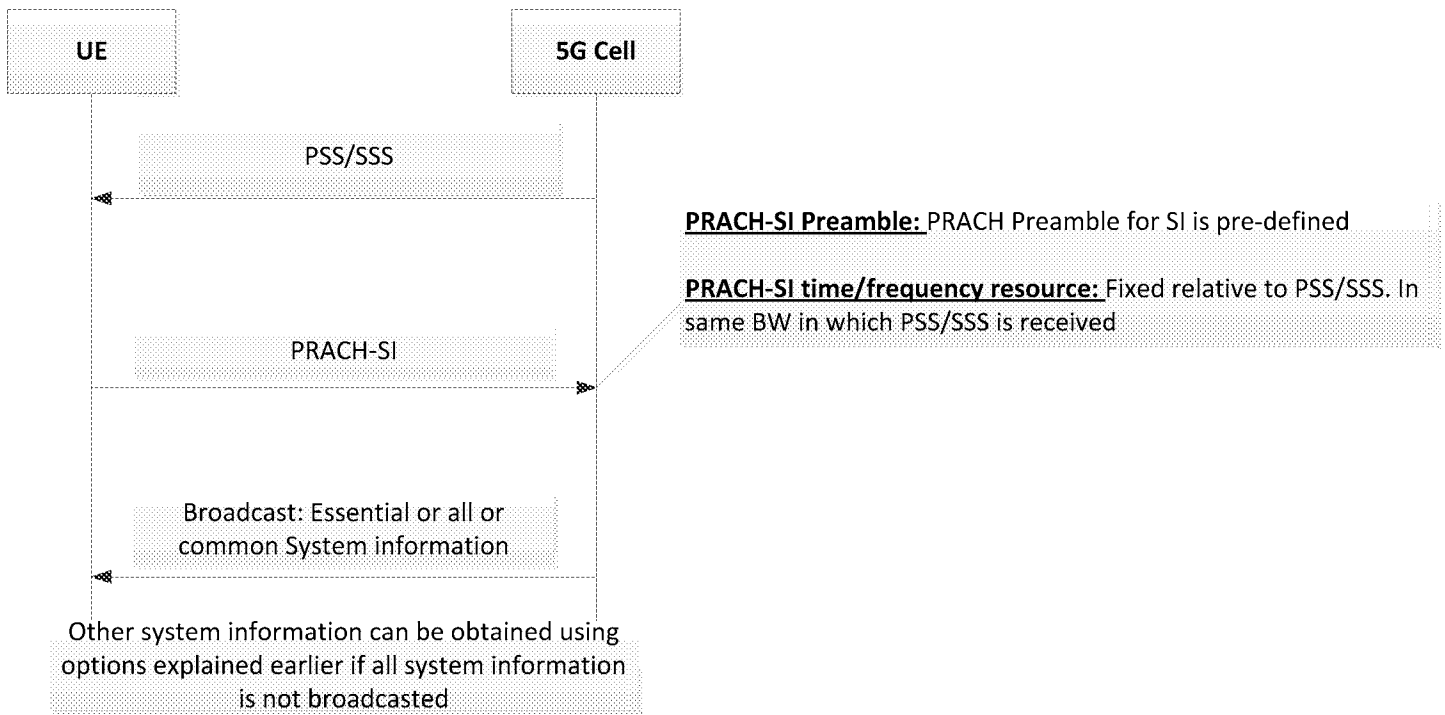


Figure 15

In the methods (Method 1 to method 8) explained earlier wherein UE requests for system information on demand, in the invention network can configure the period at which UE can request. This can reduce too many requests. If the response is broadcasted then it can be in a time window relative to time in which request is sent. In the methods (Method 1 to method 8) explained earlier wherein UE requests for system information on demand, UE may monitor broadcast transmission for a defined time duration to receive the desired system information before requesting the desired system information.

Method 9:

There can be several small cells in coverage of macro cell. Currently system information is cell specific. Currently each cell (small cell as well as macro cell) transmits their own system information.

Several system information parameters may have the same values across many cells. So in this method we propose that the system information parameters can be categorized into cell specific information and non-cell specific information. Non cell specific information i.e. system information having common values across all small cells in coverage of macro cell can be signaled using broadcasted or dedicated signaling by macro cell.

If the non-cell specific information is not same across all cells then several sets of non-cell specific information can be signaled using broadcasted or dedicated signaling by the macro cell. In one embodiment, each of these sets may be indexed in the order in which they are signaled by macro cell. Small cell may indicate (using broadcast or dedicated signaling) which non-cell specific information set amongst the multiple sets signaled by macro cell are applicable to this small cell. In alternate embodiment, macro cell may indicate list of cell ids of cells along with each set, wherein cell id identifies the cell for which this set is applicable.

Non cell specific information can be updated by cell using dedicated signaling. For example basic RACH configuration can be there in non-cell specific information. Additional RACH resources can be provided by dedicated signaling by the cell.

Cell specific system information can be obtained as follows:

- Option 1: UE obtains from Macro Cell
 - 1a: Macro cell broadcasts these information in broadcast signaling
 - 1b: Macro cell provide these information in dedicated signaling
 - Macro cell may indicate using broadcast signaling whether it provides such information
 - Macro cell may also indicate whether it provides such information in dedicated signaling if such information is not broadcasted.
 - On demand signaling as explained earlier can also be used to request information from Macro cell.
- Option 2: UE obtains directly from cell
 - If Macro cell does not provide the information then UE obtains directly from cell
 - Small cell may broadcast these information
 - On demand signaling as explained earlier can be used to request information from cell

In the methods explained earlier, the system information received on demand from a cell can be used for one or more cells. The cells for which received system information can be used can be indicated by the cell from which system information is received on demand. UE may also receive system information from multiple cells on demand. As a result the UE does not need to request for system information when the UE changes cell. After the cell change, if the UE does not have system information for the new cell then UE request for system information.

In alternate embodiment, system info area concept can be defined. System info areas refers to area covering one or more cells or transmits point or transmit/receive point wherein the system information used is same. System info area can be identified by a system inform area identifier. Cell or transmit point or transmit/receive point broadcasts the system info area identifier. Once a UE obtains the system info from a cell on demand, it requests for system info again after the cell (or transmit point or transmit/receive point) change only if the new cell (or transmit point or transmit/receive point) belongs to a different system info area.

In an embodiment eNB may support multiple configuration sets of values for system information parameters. For example let's say SI comprises of parameters P, Q and R. Let's says parameter P can have values P0, P1. Parameter Q can have values Q0, Q1, Q2. Parameter R can have values R0, R1. There can be $2*3*2=12$ possible configurations for these parameters wherein each configuration has at least one parameter's value different from other configuration. Each of these configurations is given an index. Instead of signaling (either in broadcast or dedicated signaling) all the parameters and there values, only index can be signaled. For example configuration 0: P->P0, Q->Q0, R->R0; Configuration 1: P->P0, Q->Q1, R->R0; and so on

For SI having parameters A, B and C possible configuration sets are shown in figure 16 below. In the example, Parameter A can have two possible values A0 and A1. Parameter B can have two possible values B0 and B1. Parameter C can have two possible values C0 and C1. Note that each parameter can have different number of values. Each Path from top to bottom in tree (Figure 16) is one valid configuration. These configurations can be sequentially numbered as shown in figure 16. 8 possible configurations are as follows:

Idx0: {A0, B0, C0}; Idx1: {A0, B0, C1}; Idx2: {A0, B1, C0}; Idx3: {A0, B1, C1}; Idx4: {A1, B0, C0}; Idx5: {A1, B0, C1}; Idx6: {A1, B1, C0}; Idx7: {A1, B1, C1}; idx = { index of value of parameter A * (number of values of B * number of values of C) } + {index of value of parameter B * (number of values of C) } + index of value of parameter C. In order to allow skipping of a parameter in a configuration, skipping can be considered as additional value. For example, if parameter A can be skipped then Parameter A can have three values A0, A1, skip. A0 value has index 0, A1 value has index 1 and skip value has index 2.

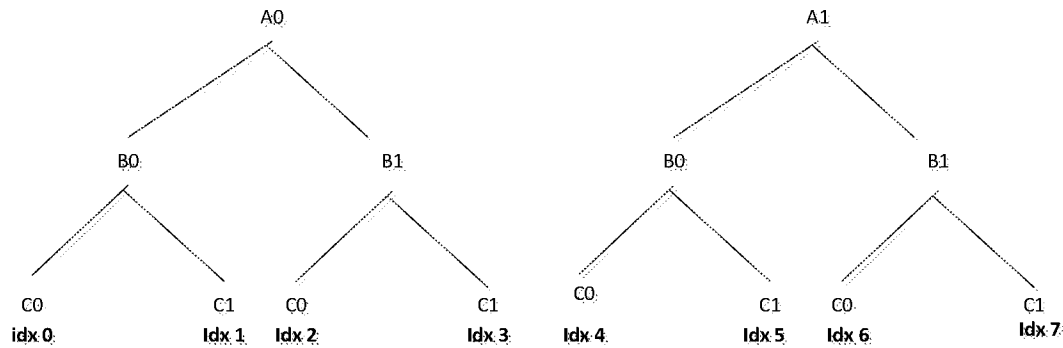


Figure 16

If possible value of each SI parameter is known, and then given the index, configuration can be known corresponding to that index. SI can be categorized into various parts/groups etc wherein each part or group has his own configuration indexes. Each SI part or SI group can have several configurations and each configuration can be indicated using index as illustrated above. For example let's say there are two SI parts, SI part 1 and SI part 2. SI part 1 has three parameters A, B, C. SI part has two parameters P, Q. SI part 1 configuration and SI part 2 configuration can be indicated independently using their own configuration indexes.

Configuration index can be broadcasted or signaled using dedicated signaling. If SI is requested on demand then configuration index can be signaled instead of full configuration in response. Alternately, configuration index for SI can be broadcasted. If UE cannot know configuration based on broadcasted index then it can request BS/eNB/TRP to provide configuration corresponding to index by sending the index in SI request. UE may not know configuration based on index if it does not know the values of parameters which are supported in Cell/BS/eNB/TRP. For example, parameter A can have values A0, A1, A2, and A3. But values A0, A1 may be supported in cell 1 whereas values A2, A3, A1 may be supported in another cell 2. If UE cannot know configuration based on broadcasted index then it can request BS/eNB/TRP to provide values of parameters of SI supported in Cell/BS/eNB/TRP in SI request. Once the values of parameters of SI supported in Cell/BS/eNB/TRP are known, UE can determine the configuration corresponding to broadcast index. SI request/response can be signaled using method 1 to 8 explained earlier.

The supported values of parameters of SI can be same throughout the network or can be specific to cell/TRP. The supported values of parameters of SI part/group can be same throughout the network and for other SI part/group it can be specific to cell/TRP.

In another embodiment instead of indexing as shown in Figure 16, network or cell/TRP/eNB can maintain several configurations for SI or SI part or SI group and assign a distinct index/identifier to each configuration. Network indicates the index/identifier in broadcast signaling for each SI or SI part/group. UE first receives the broadcast signaling and gets the index/identifier for a SI or SI part/group. If UE does not have configuration corresponding to index/identifier UE request the configuration corresponding to index/identifier using on demand signaling (method 1 to 8) explained earlier. Index/identifier is included in request. If UE has valid configuration corresponding to index/identifier then UE uses it and does not need to request. Note that in one embodiment, this

index/identifier can be valid across cells or TRPs or eNBs for an SI or SI part of SI group. In another embodiment, this index/identifier can be valid only across TRPs of same cell for an SI or SI part of SI group. Whether the index/identifier for an SI or SI part or SI group is valid across cells or TRPs or eNBs etc can be pre-defined or indicated in broadcast signaling. UE can store the configuration corresponding to an index/identifier for a defined life time.

System Information Update Procedure

UE can be notified about the system information update in one of the following ways:

Option 1

- System information is categorized into various parts/groups/sets. BS broadcasts System Information Set(s) supported. BS also broadcasts ValueTag/identifier/configuration index for each supported system information set/part/group. Change in value tag /identifier/ configuration index corresponding to a system information set indicates that system information set/group/part is updated. Additionally BS may also broadcast change notification for each system information of a service.

OR

- BS broadcasts Service(s) supported. BS also broadcasts valueTag/identifier/ configuration index for each supported service. Change in value tag/identifier/ configuration index corresponding to service indicates that system information for that service is updated. Additionally BS may also broadcast change notification for each system information of a service.

• Option 2

- Change notification for each supported system information set or service is indicated in paging message

• Option 3

- Change notification can be indicated using a SI Update message
- Each SI update message can indicate notification for a group of SI(s). RNTI specific to group can be used to schedule the SI update message.
- SI update message can be RRC message or DCI signaled in PDCCH.

▪ Obtaining Updated Information

- UE request updated system information set or service specific system information if the update indication is received using the methods explained earlier (i.e. broadcast or on demand). If the system information set changed in part of broadcasted information then UE obtains updated system information from broadcast. If the system information set changed in part of on demand system information then UE obtains updated system information using on demand signaling.
- Alt: NW may broadcast the updated information for defined time period. UE reads broadcasted information.

In one embodiment, ValueTag/identifier/ configuration index may indicate that system information set/group/part is changed. In another embodiment, ValueTag/identifier/ configuration index may identify a particular configuration of system information set/group/part. When a network signals a system information set/group/part identifier and UE does not have configuration corresponding to this identifier then UE updates the system information. In one embodiment, each of this SI Set/part/group may contain same parameters but may be valid in different area.