The evolution and principles of new RRC state for NR: Inactive state

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Agenda

- **Background**
  - What does 5G-NR require?
  - Why needs inactive state in NR?
  - What is inactive state in NR?
- Mobility issue
- State transition
- FFS issues
- Q&A

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What does 5G-NR require?

- Scenarios and Requirements for 5G-NR (New Radio Technology)
  - ITU 5G Requirements (2015 June)

Expected to reach 10 Gbit/s and support up to 20 Gbit/s

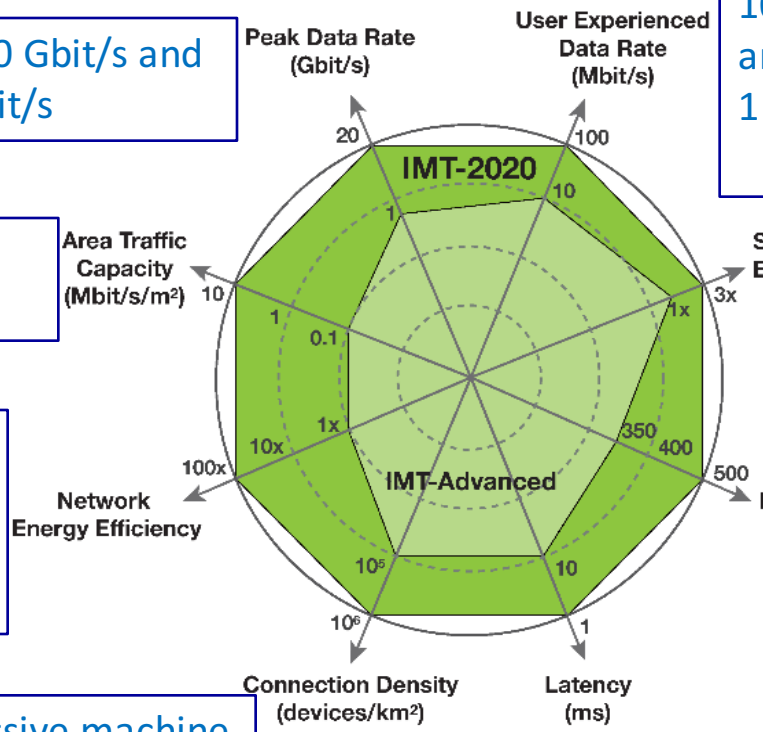
100 Mbit/s is expected in urban and suburban
1 Gbit/s can be reached in hotspot

10 Mbit/s/m^2 area traffic capacity in hotspot

3 times higher compared to IMT-Advanced
5 times subject to further research

Should not be greater than current IMT networks while delivering other enhanced capabilities

enable high mobility up to 500 km/h with acceptable QoS



Provide 1 ms over-the-air latency

up to 10^6 /km^2 in massive machine type communication scenario

*4G: IMT-Advanced

Reference: WP5D #22, June 2015

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Why needs inactive state in NR?

- **KPI (**Key performance indicators**) of NR**
  - The target for peak data rate should be 20Gbps for downlink and 10Gbps for uplink.
  - The target for peak spectral efficiency should be 30bps/Hz for downlink and 15bps/Hz for uplink.
  - **Control Plane Latency from a power efficient state to a data transmission state 10ms**
  - User Plane Latency 0.5ms for URLLC
  - User Plane Latency 4ms for eMBB
  - Latency for infrequent small packets may be 10s
  - Mobility interruption time 0ms
  - 15 years battery life with a sparse small packet traffic model
  - Mobility in the range from 0km/h to 500km/h
  - The RAN system shall have the capability to minimize the backhaul and signalling load
  - ……

One of the solution is introducing a new RRC state **"RRC_Inactive"**

Reference: TR 38.913

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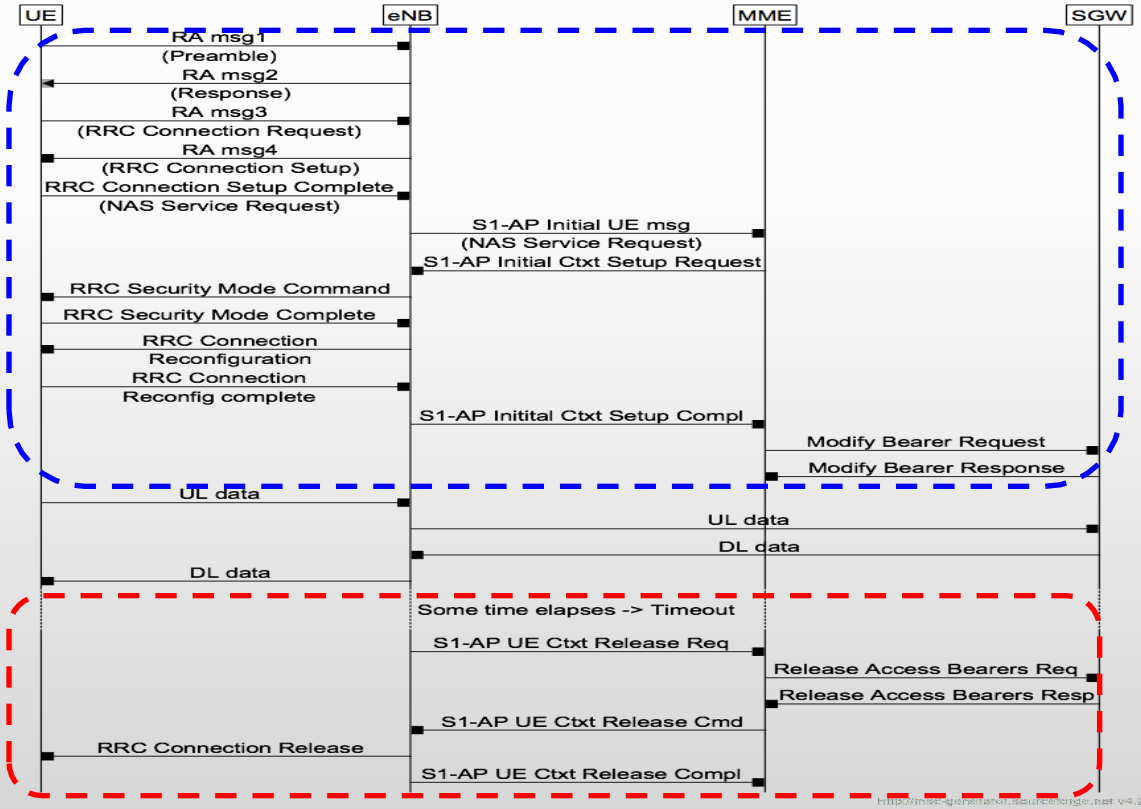
Why needs inactive state in NR?

- **UE state transition** in legacy network:



Idle Mode → Connected Mode

Connected Mode → Idle mode

Reference: R2-163998

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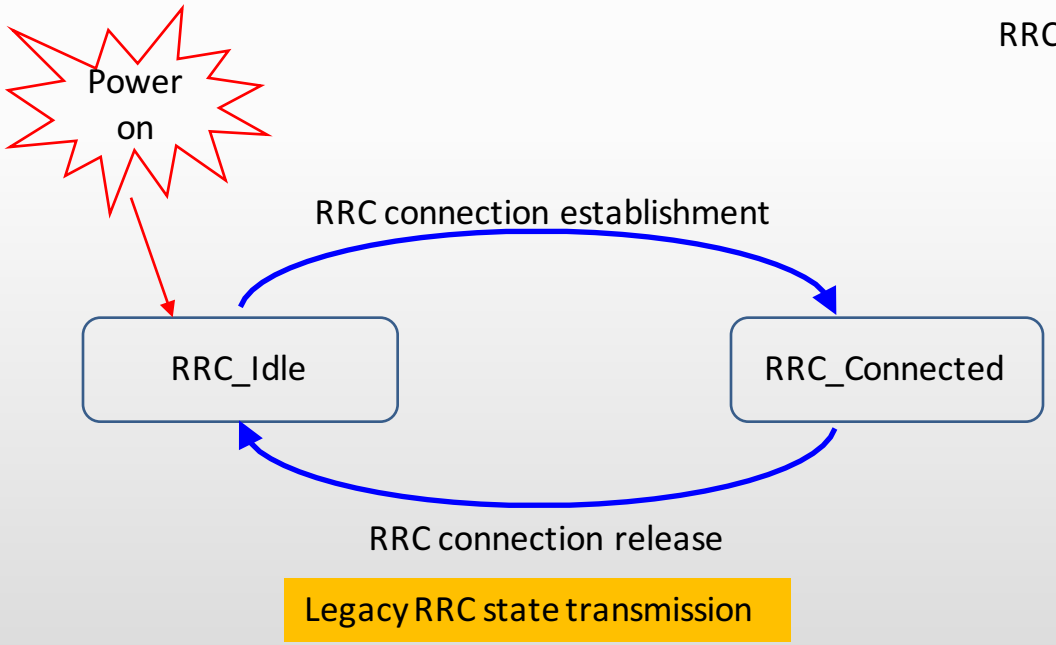
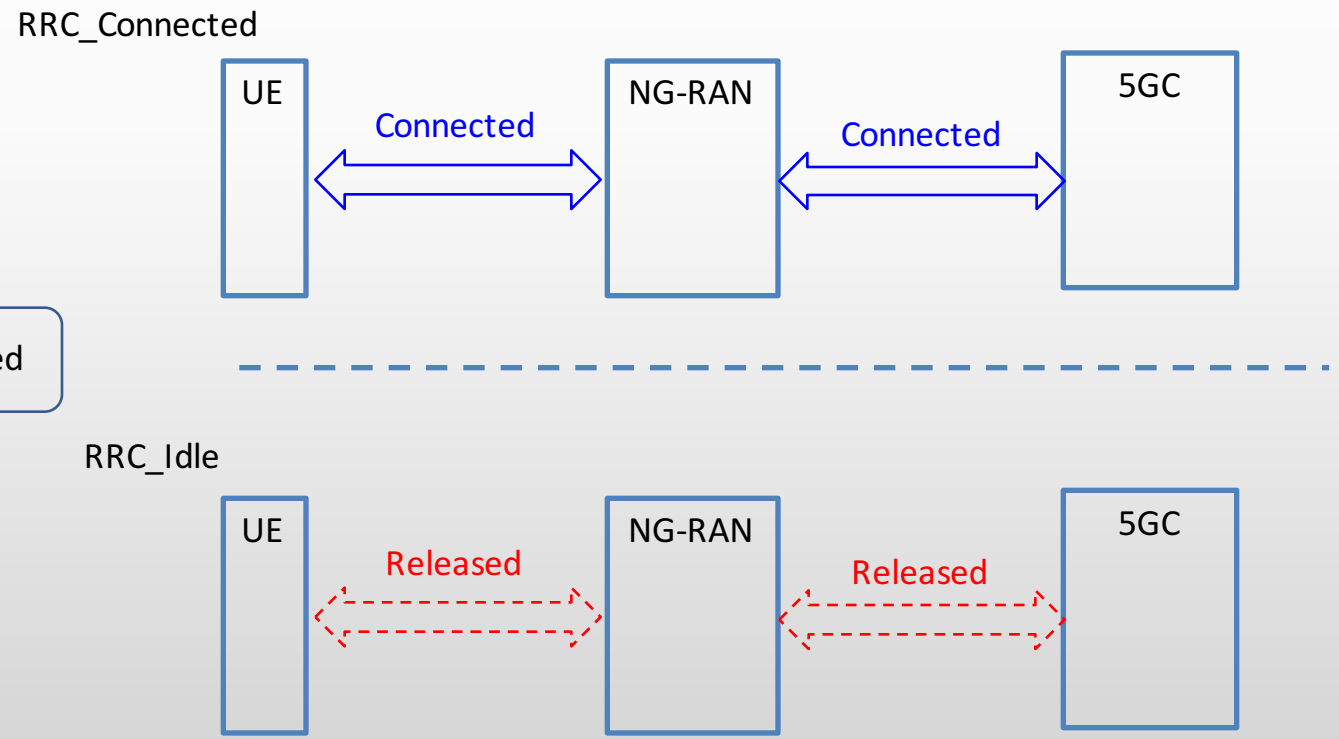
What is inactive state in NR?

- In NR, the RRC_Inactive is introduced as a new RRC state between RRC_Connected and RRC_Idle





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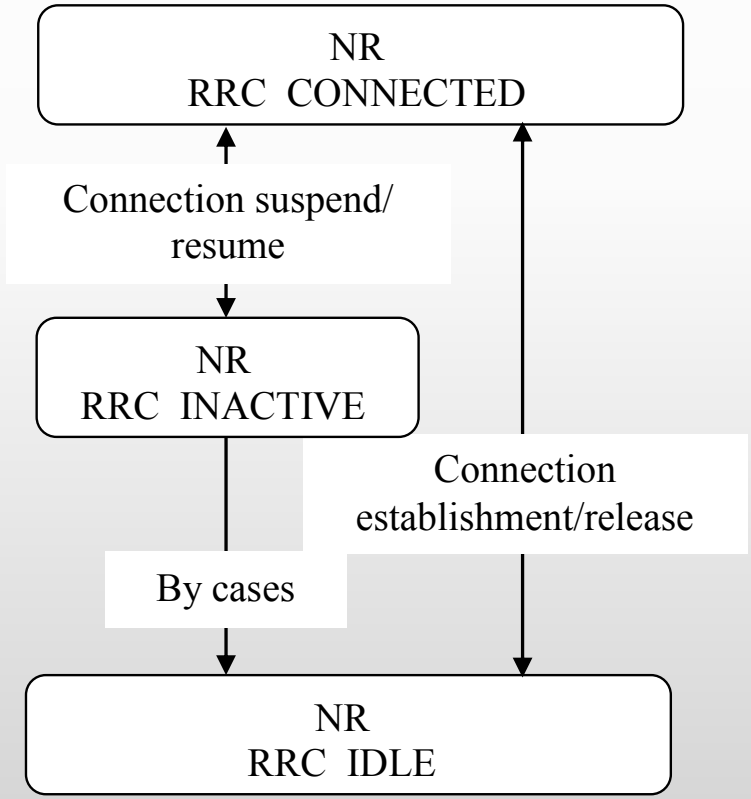

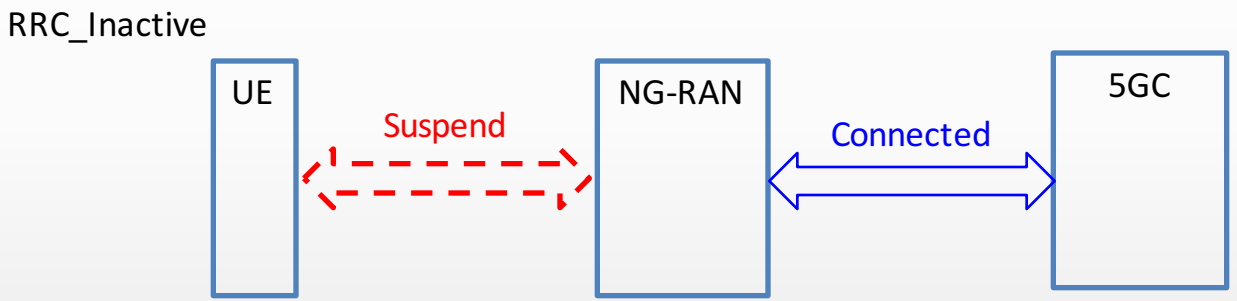

1. Suspend instead of Release
2. Core Net不需知道UE inactive or connected
   (Core Net 這邊都是 Connected)

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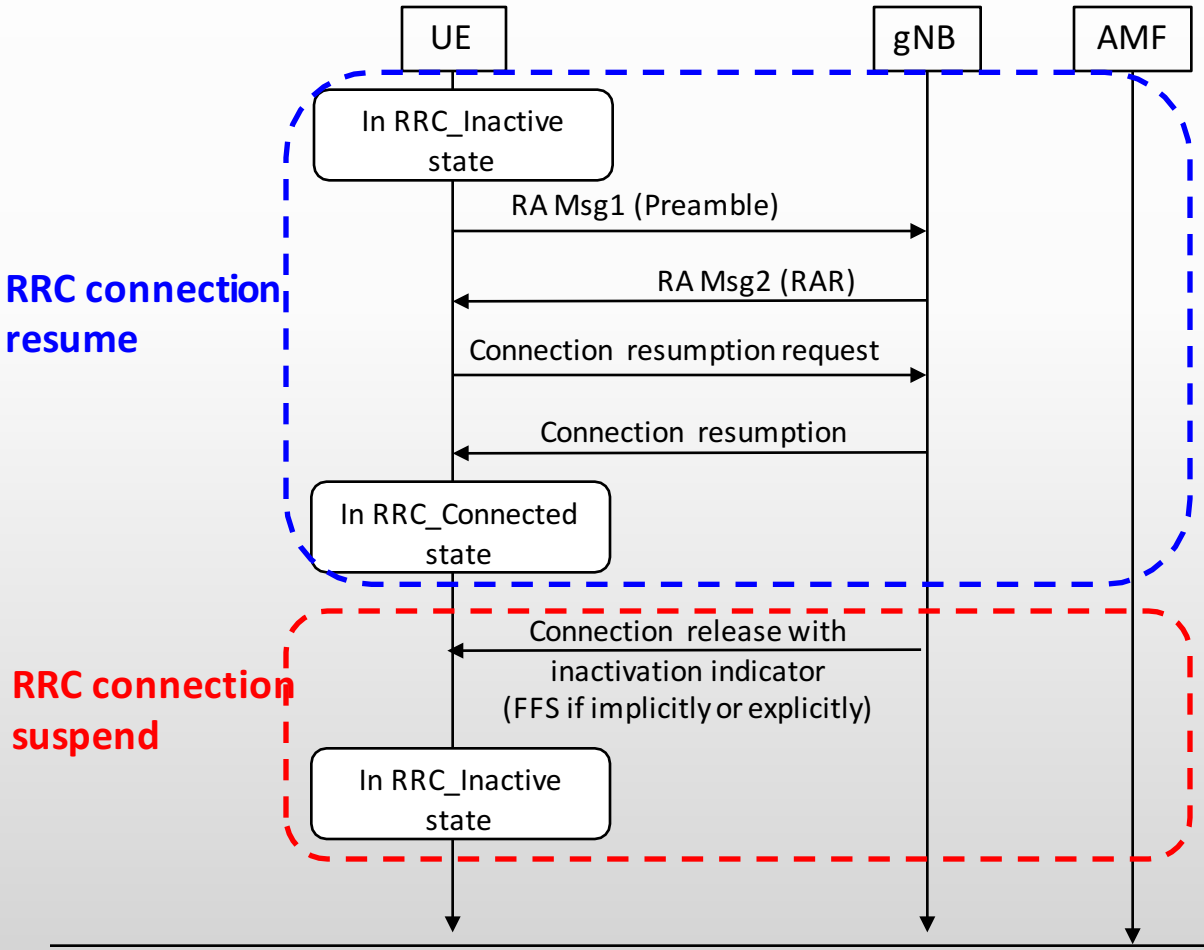
Reference: TR 38.804

What is inactive state in NR?

- State transition for RRC_Inactive



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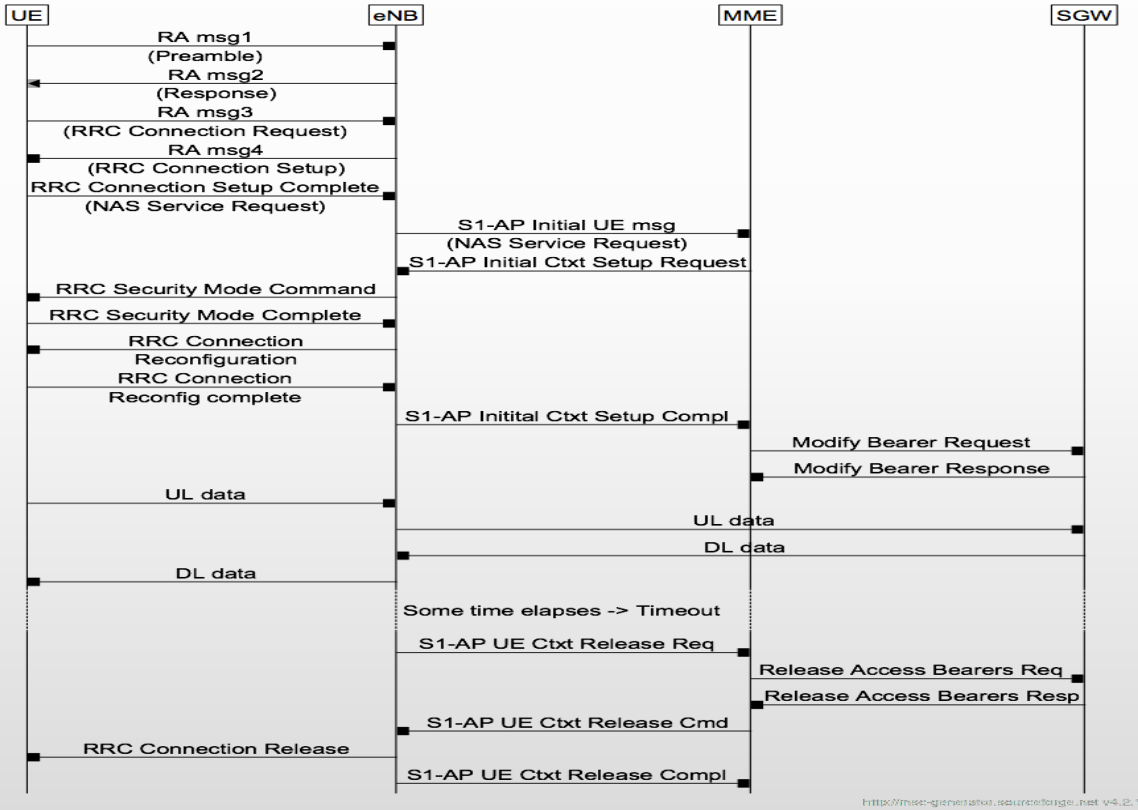

Legacy RRC state transmission

Reference: TS.38.300

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Agenda

- Background
- **Mobility issue**
  - UE reachability
    - RAN-based Notification Area (RNA)
    - RAN-based Notification Area Update (RNAU)
    - RAN paging
- State transition
- FFS issues
- Q&A

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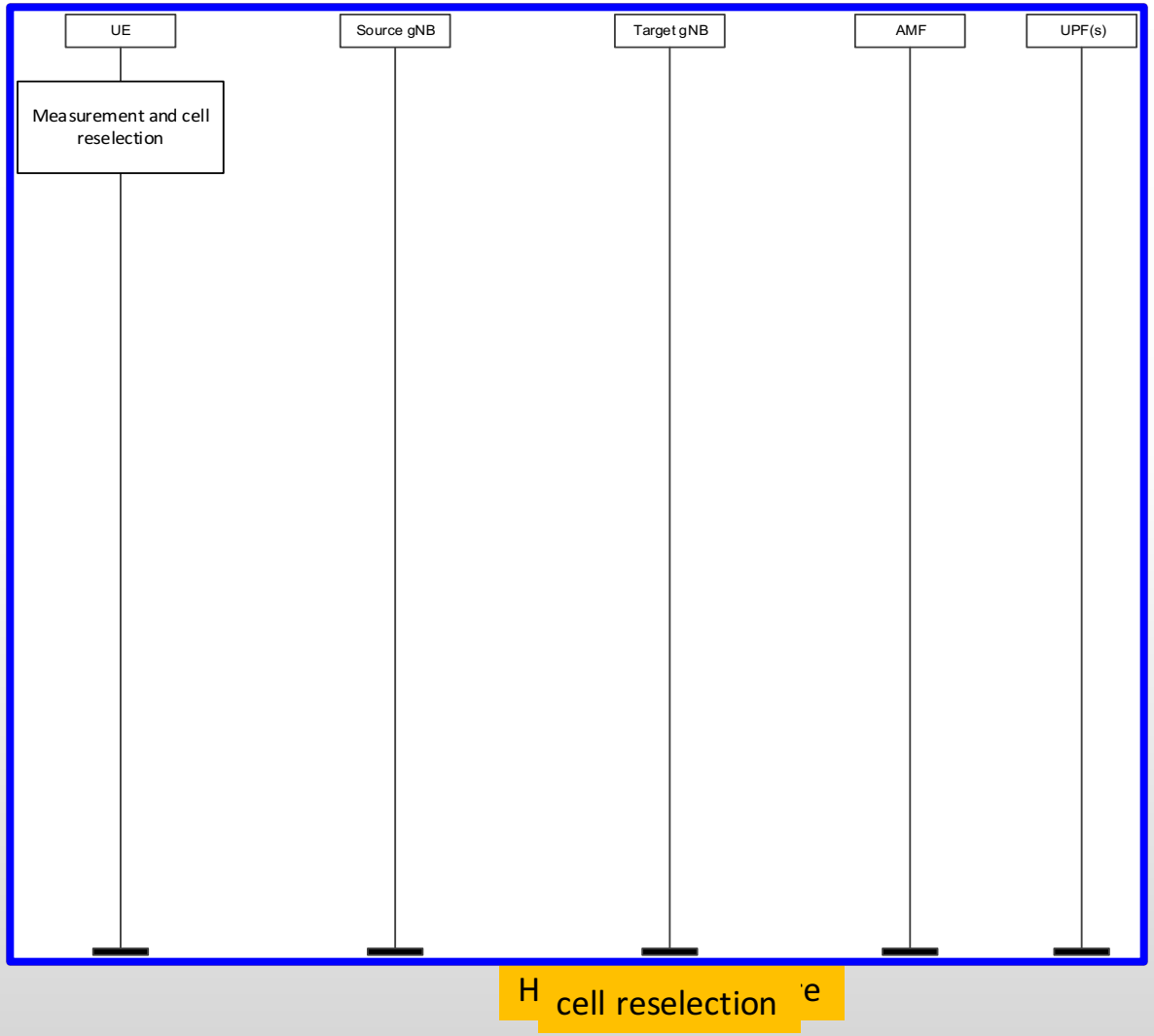
Inactive時的Handover

Mobility issue

- Mobility procedure of RRC_Connection
  - Handover procedure
- To reduce the signaling caused by RRC_Inactive mobility.
  - RRC_Inactive wil perform **UE centric mobility**, i.e. cell reselection.
- **How to reach the RRC_Inactive UE??**



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Reference: TS.38.300

Mobility issue

- Reachability of RRC_Inactive UE could be achieved by:
  - 1) RAN-based Notification Area (RNA)
  - 2) RAN-based Notification Area Update (RNAU)
  - 3) RAN paging

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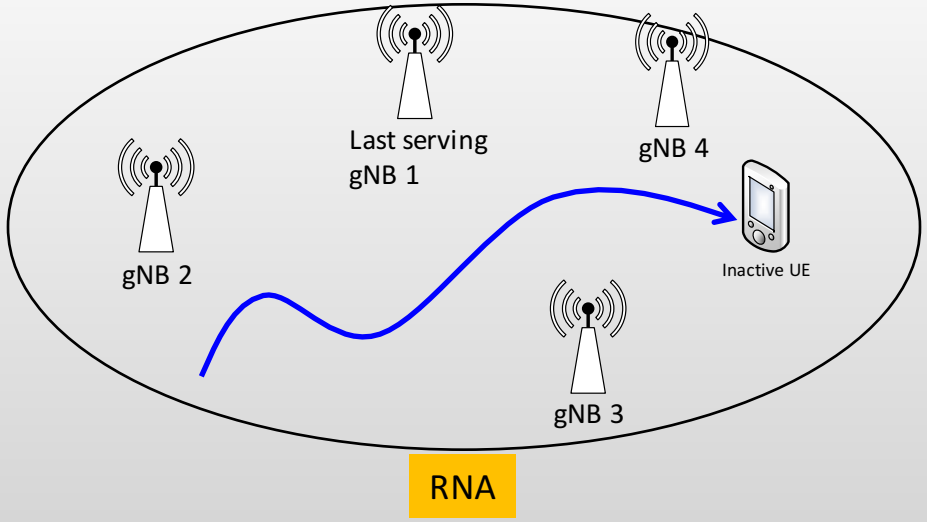
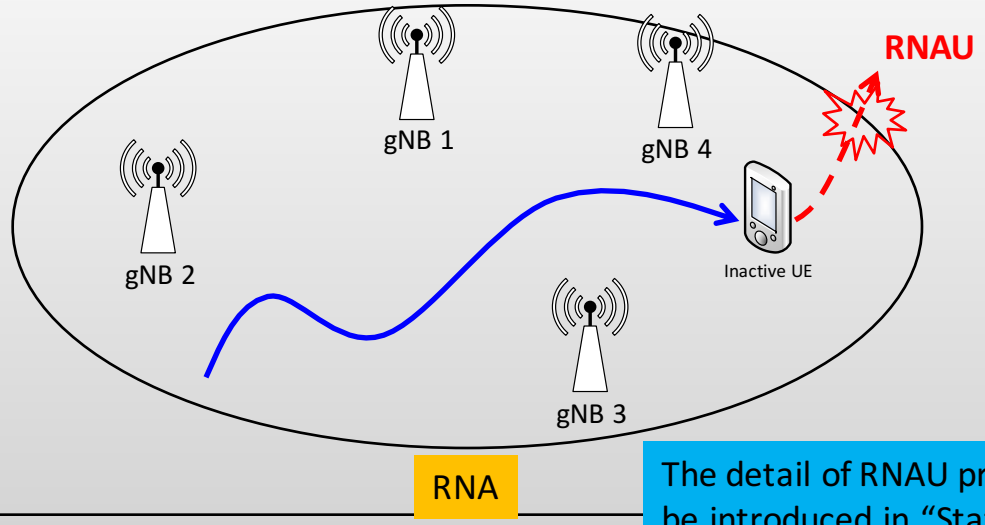
Mobility issue

- RAN-based Notification Area (RNA)
  - RRC_INACTIVE UE can move within an **RNA** configured by NG-RAN without notifying NG-RAN.
  - The RRC_INACTIVE UE notifies the network if it moves out of the configured RNA (i.e., RAN-based Notification Area Update (**RNAU**)).





The detail of RNAU procedure will be introduced in “State transition” section.

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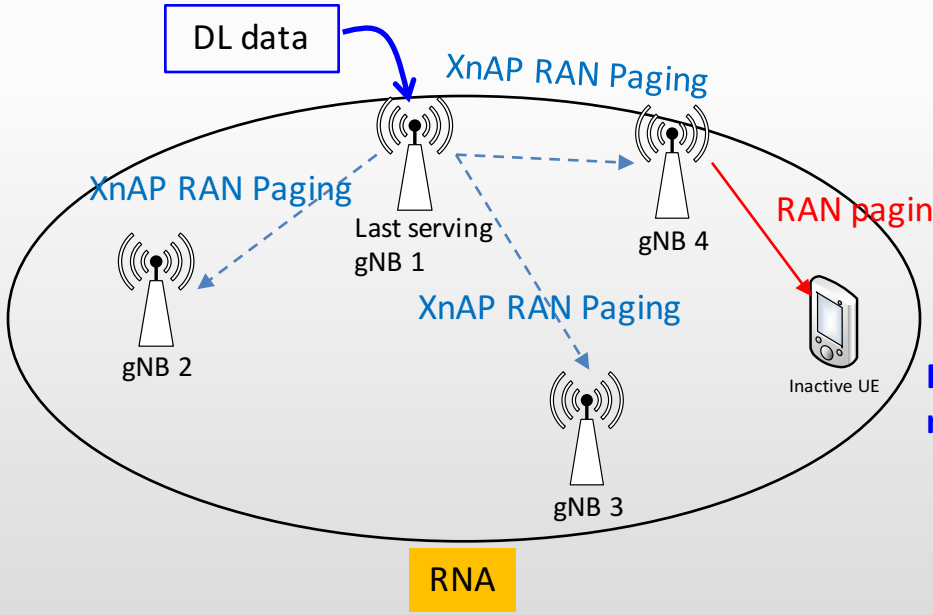
Mobility issue

- If the last serving gNB receives DL data while the UE is in RRC_INACTIVE, it pages (i.e., **RAN paging**) in the cells corresponding to the RNA.

Xn: 5G中的X2 Interface



RRC connection resume procedure

How does inactive UE perform RRC connection resume procedure and how does the DL data forward to the UE will be introduced in “State transition” section.

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Mobility issue

- A UE in the RRC_INACTIVE state can be configured with an RNA
  - the RNA can **cover a single or multiple cells**, and can be smaller than CN area
- How the RNA can be configured?
  - Alternative 1: List of cells
    - A UE is provided an explicit list of cells (one or more) that constitute the RNA.
  - Alternative 2: List of RAN areas
    - A UE is provided (at least one) RAN area ID
    - A cell broadcasts (at least one) RAN area ID in the system information

"Even though a single option is preferable in order to limit testing of multiple options, it is also recognized by RAN2 that a single option cannot handle all deployment scenarios. Thus, RAN2 concludes that all the options are technically feasible and RAN2 supports all the options." from **R2-1712006**

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Mobility issue

- The RRC_INACTIVE UE will trigger **RNAU**:
  - 1) when it moves out of the configured RNA
  - 2) periodically
- When receiving RNA update request from the UE, the receiving gNB may decide to
  - send the UE back to RRC_INACTIVE state,
  - move the UE into RRC_CONNECTED state, or
  - send the UE to RRC_IDLE.

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Mobility issue

- The UE in RRC_INACTIVE is reachable via RAN-initiated paging and 5GC-initiated paging.
  - RAN and 5GC paging occasions overlap and same paging mechanism is used.

	RAN-initiated paging	5GC-initiated paging
Trigger by	Anchor gNB	AMF
UE ID in paging	I-RNTI	S-TMSI
Paging Area	RNA	CN area
UE state after paging	Move to RRC_Connected	Enter RRC_Idle

- The UE in RRC_INACTIVE states may use DRX in order to reduce power consumption.
  - The UE monitors one paging occasion per DRX cycle for the reception of paging

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Agenda

- Background
- Mobility issue
- **State transition**
  - From RRC_CONNECTED to RRC_INACTIVE
  - From RRC_INACTIVE to RRC_CONNECTED
    - UE trigger
    - Network trigger
- FFS issues
- Q&A

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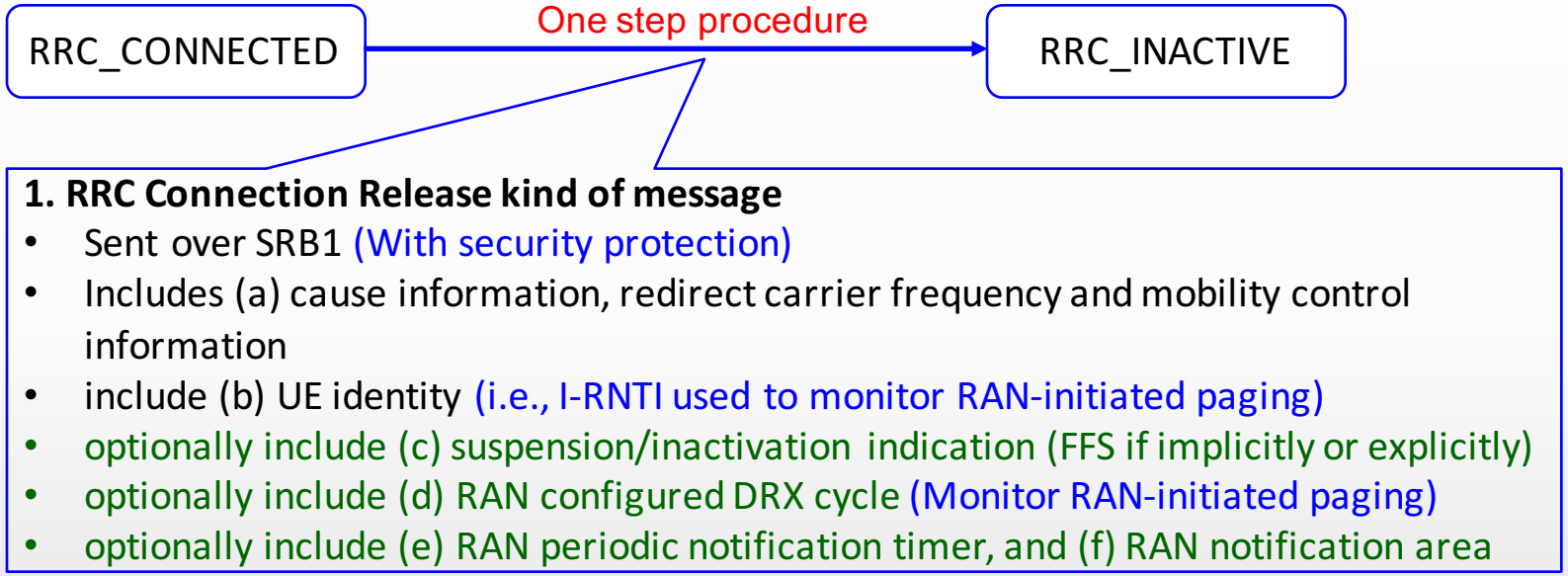
State transition

- From RRC_CONNECTED to RRC_INACTIVE



- In RRC_INACTIVE, the last serving gNB (Anchor gNB) node keeps the **UE context** and the UE-associated NG connection with the serving AMF
  - The UE context in RRC_INACTIVE includes the configuration of radio bearers, logical channels and security.

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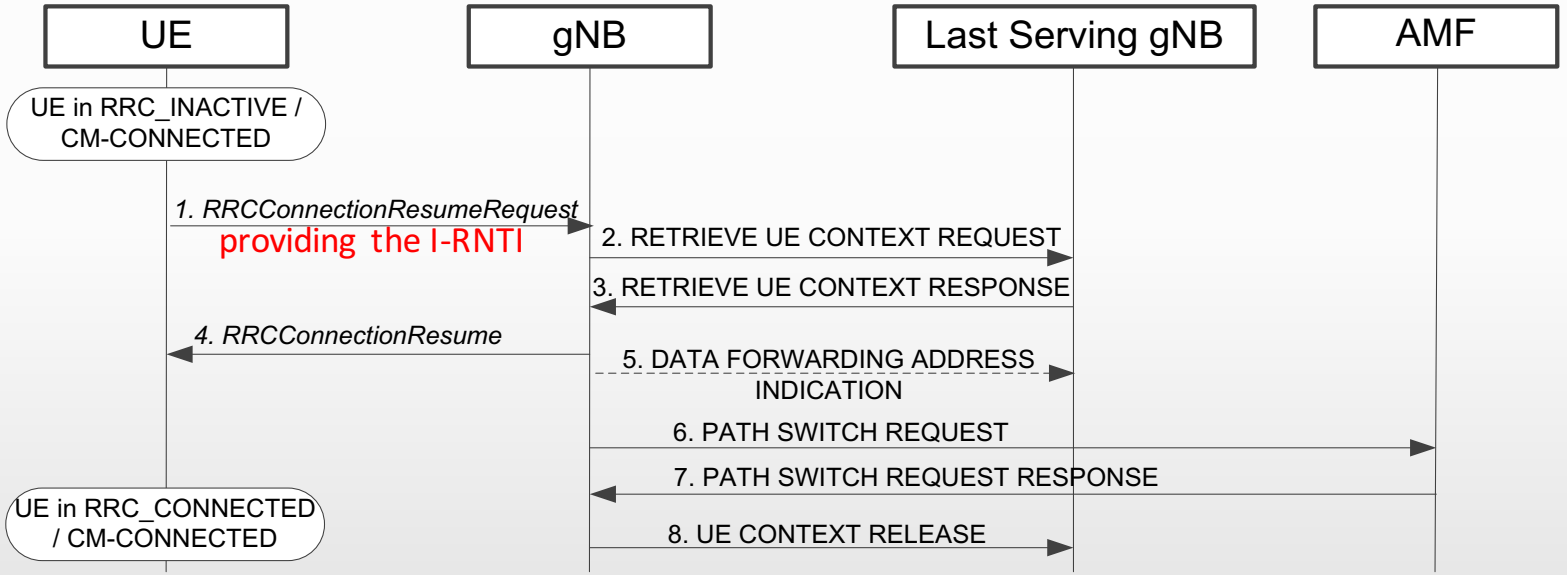
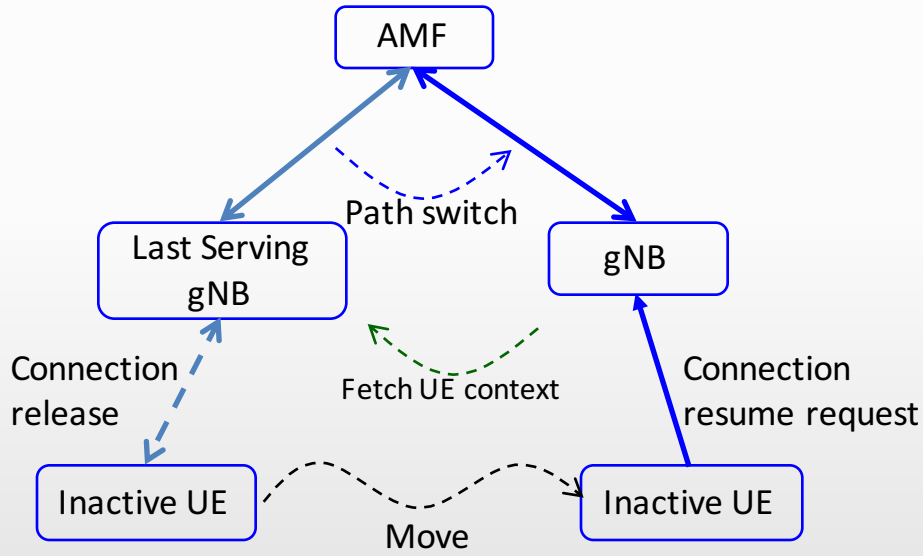
State transition

- RRC_INACTIVE UE triggered transition from RRC_INACTIVE to RRC_CONNECTED





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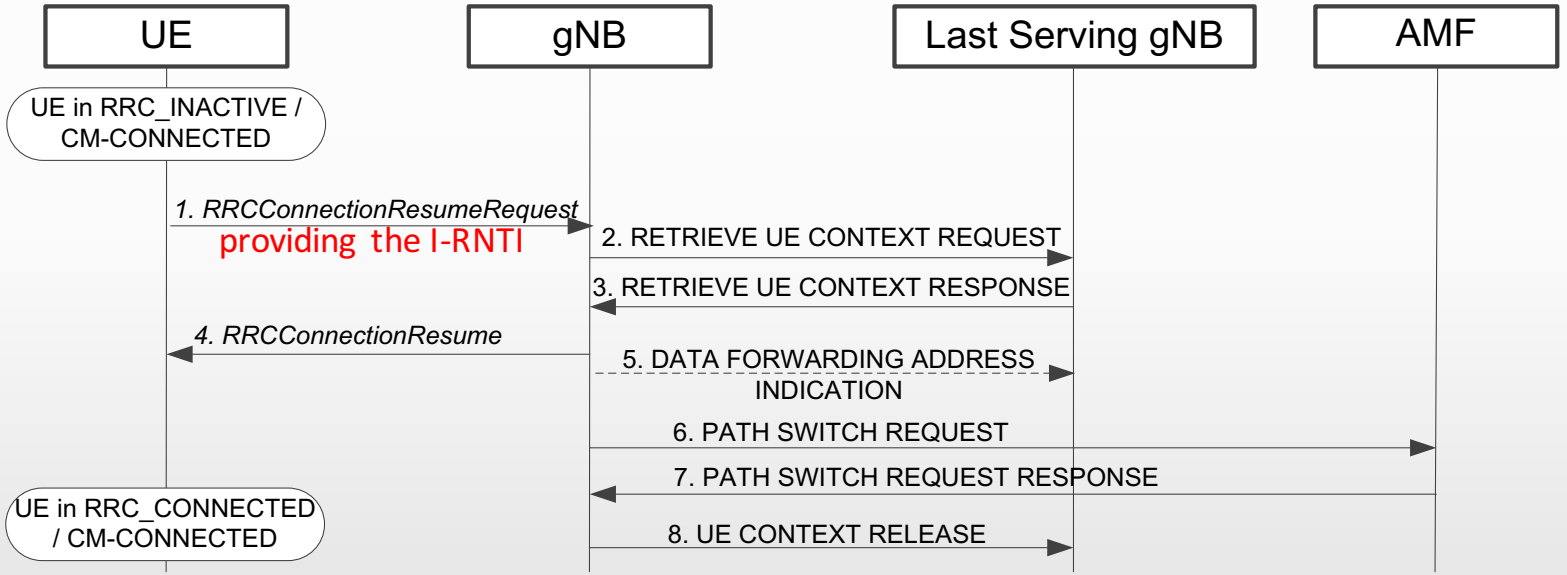
Reference: TS.38.300

State transition

- RRC_INACTIVE UE triggered transition from RRC_INACTIVE to RRC_CONNECTED



1. The UE resumes from RRC_INACTIVE, providing the I-RNTI, allocated by the last serving gNB.
2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context data.
3. The last serving gNB provides UE context data.
4. The gNB completes the resumption of the RRC connection.
5. If loss of DL user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses.

6./7. The gNB performs path switch.

8. The gNB triggers the release of the UE resources at the last serving gNB.

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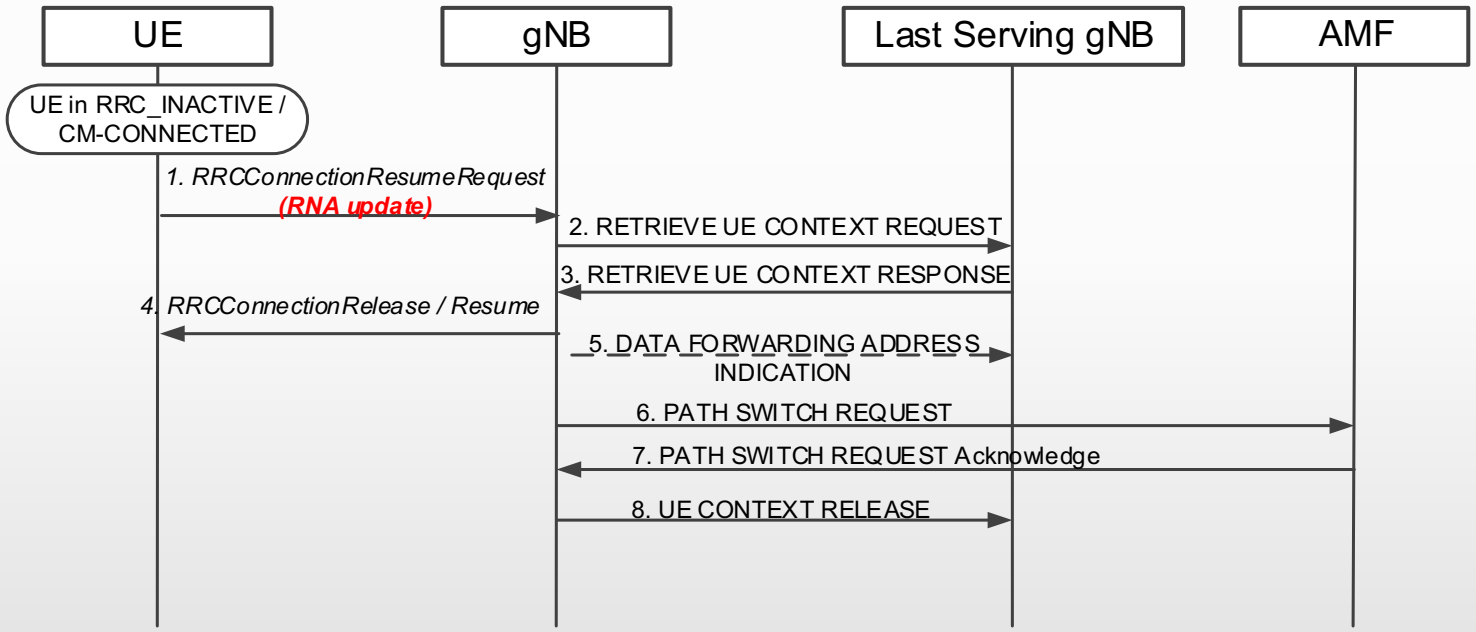
Reference: TS.38.300

State transition

- RNA update



1. The UE resumes from RRC_INACTIVE, providing the I-RNTI allocated by the last serving gNB and appropriate cause value, **e.g., RAN notification area update**.
2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context.
3. The last serving gNB provides UE context.
4. The gNB may move the UE to RRC_CONNECTED, or send the UE back to RRC_INACTIVE state or send the UE to RRC_IDLE. If the UE is sent to RRC_IDLE, the following steps are not needed.
5. If loss of DL user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses.

6./7. The gNB performs path switch.

8. The gNB triggers the release of the UE resources at the last serving gNB.

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Reference: TS.38.300

State transition

- RRC_INACTIVE UE triggered transition from RRC_INACTIVE to RRC_CONNECTED
- The gNB could
  - Option 1-1: reject the Resume Request and keep the UE in RRC_INACTIVE without any reconfiguration
    - SRB0 (without security) can be used
  - Option 1-2: reject the Resume Request and keep the UE in RRC_INACTIVE with reconfiguration
    - e.g. with a new DRX cycle or RNA
    - SRB1 (with at least integrity protection) shall be used

RNA update case

  - Option 2: setup a new RRC connection
  - Option 3: push the UE to RRC_IDLE
    - SRB1 (with at least integrity protection) shall be used
  - Option 4: Resume RRC connection

Fetch UE context failure

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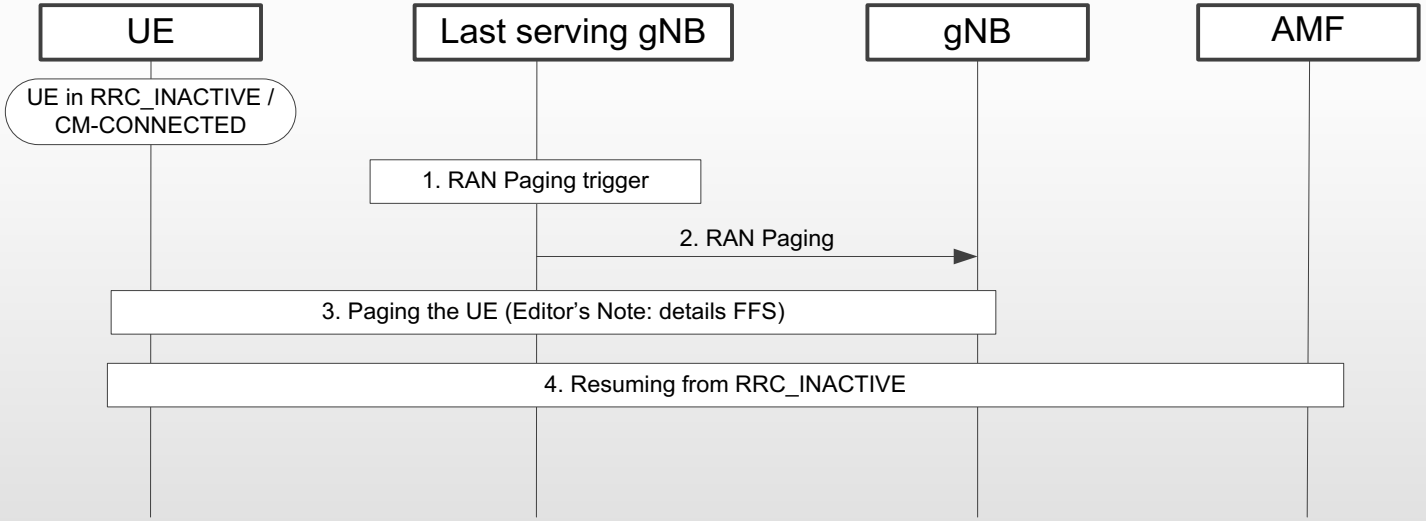
State transition

- Network triggered transition from RRC_INACTIVE to RRC_CONNECTED
  - A RAN paging trigger event occurs (incoming DL user plane, DL signalling from 5GC, etc.)



1. A RAN paging trigger event occurs (incoming DL user plane, DL signalling from 5GC, etc.)
2. RAN paging is triggered; either only in the cells controlled by the last serving gNB or also by means of Xn RAN Paging, in other gNBs, being member of the RAN Paging area the UE is registered with.
3. The UE is paged with an NG-RAN allocated UE identity.
4. If the UE has been successfully reached, it attempts to resume from RRC_INACTIVE, as described in other sections.

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Reference: TS.38.300

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- Background
- Mobility issue
- State transition
- **FFS issues**
  - Small UL data transmission in RRC_INACTIVE
- Q&A

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Small UL data transmission in RRC_INACTIVE

- Solution A (Huawei)
  - sending UL data without RRC signalling in inactive state and without UE initiating transition to connected
- Solution B (Ericsson)
  - sending UL data with RRC signalling in inactive state with/without transition to connected

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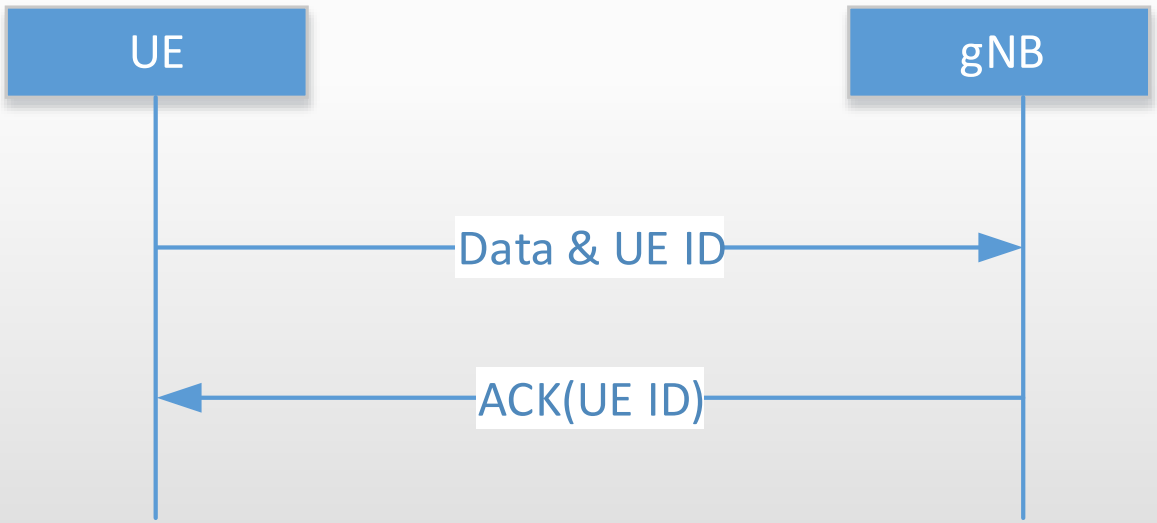

Agreed in RAN2 meeting:

1. The network should be able to send the UE into RRC_CONNECTED in response to UL data transmission if necessary
2. UE ID should be able to uniquely identify the UE context in the RAN.
3. **The UE context is maintained in an anchor gNB**.
4. The UE decides whether to use small data transmission **based on a threshold taking into account at least the amount of data in the UE's buffer.** If amount of data is above the threshold then UE initiates RRC procedure to move to connected.
5. Multiple DRBs can be maintained in RRC_INACTIVE, and data transmission takes place on the DRB associated to the concerned service.

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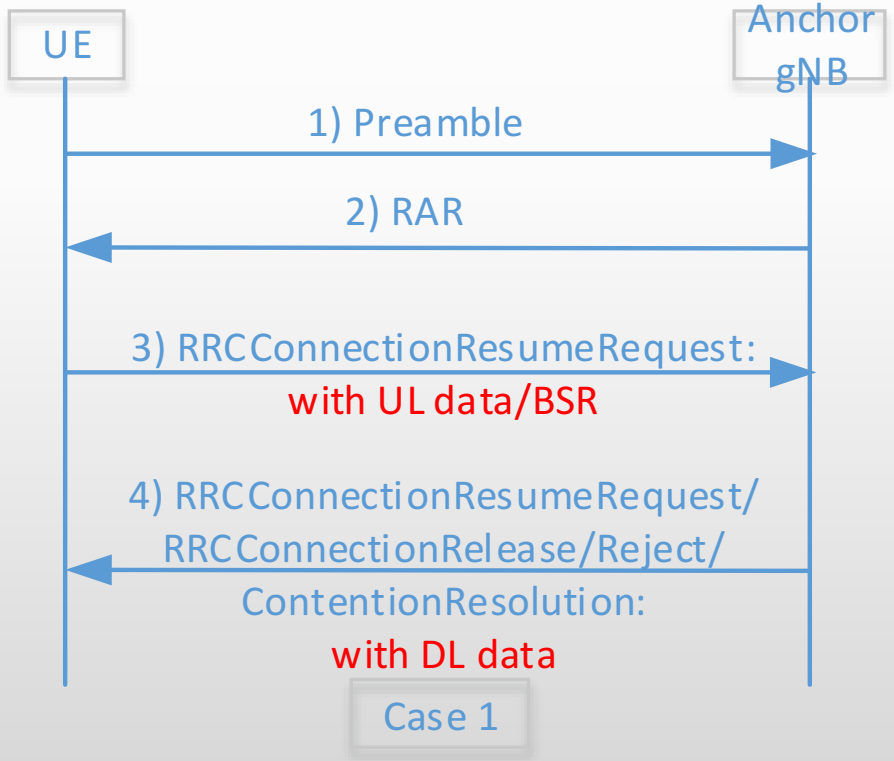
Small UL data transmission in RRC_INACTIVE

- Solution B (Ericsson)
  - sending UL data with RRC signalling in inactive state with/without transition to connected



Agreed in RAN2 meeting:

1. UE should be able to encrypt the small UL data transmission transmitted in RRC_INACTIVE.
2. Upon receiving the Msg. 4 response from the network (e.g. “RRC Connection Resume”) the UE should be able identify this is the right network, perform contention resolution and receive DL data and either remain in RRC_INACTIVE or resume its previously suspended connection i.e. moving to RRC_CONNECTED
3. UE provides information to enable the network to decide whether to leave the UE in RRC_INACTIVE or move to RRC_CONNECTED. FFS what is indicated e.g. MAC buffer related information

Reference: R2-1700351

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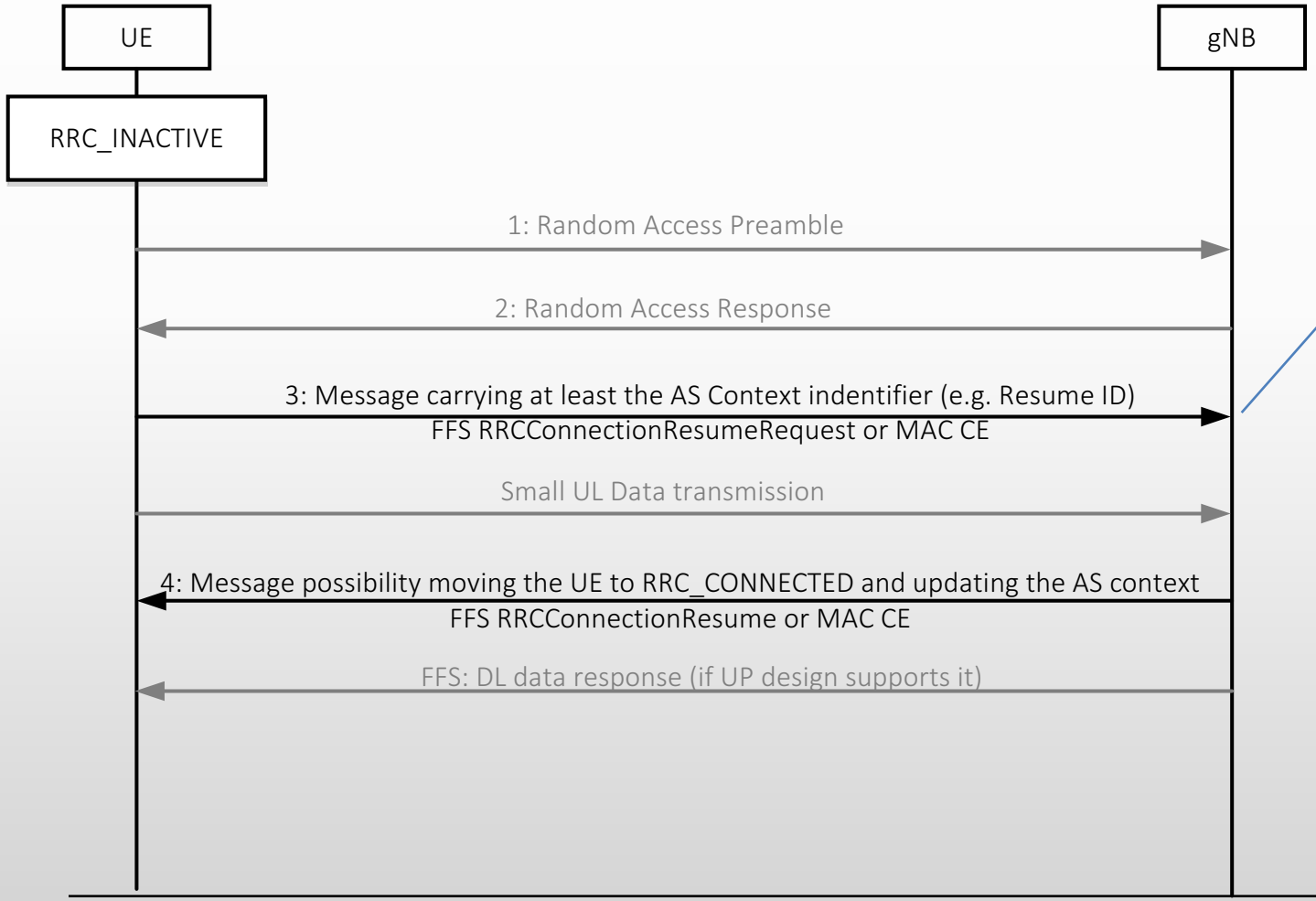
Small UL data transmission in RRC_INACTIVE



The UE sends small UL data with message 3 (FFS whether *RRCConnectionResumeRequest* or a message in a MAC CE) which contains at least an AS context identifier (e.g. resumeID) to be used for contention resolution.
This message contains all necessary information to enable the network to move the UE to RRC_CONNECTED or to enable the network to let the UE remain in RRC_INACTIVE.
It could also provide information to enable the network to apply overload control and prioritisation, if needed.

Reference: TR 38.804

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