Radio Access Network Architecture and Protocols

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3GPP TSG-RAN WG2

THE Mobile Broadband Standard

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  - Overview, Carrier Aggregation, Minimisation of Drive Tests

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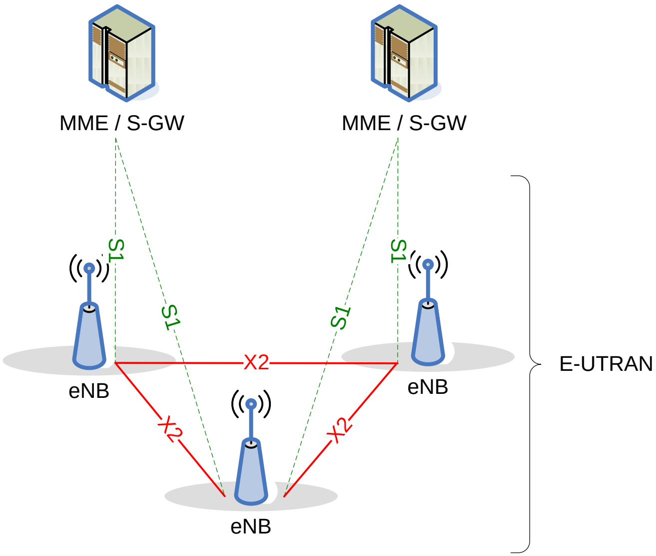
E-UTRAN Architecture and Functions

E-UTRAN Architecture

- E-UTRAN consists of eNBs
  - flat architecture (no RNC or BSC as in UTRAN and GERAN) for reduced latency and delays
- eNBs are interconnected with each other by means of the X2 interface
  - can be a logical connection via CN elements
- eNBs are also connected to the Evolved Packet Core (EPC)
  - eNBs are connected to the Mobility Management Entity (MME) via the S1-MME interface
  - eNBs are connected to the to the Serving Gateway (S-GW) by means of the S1-U interface



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E-UTRAN Functions

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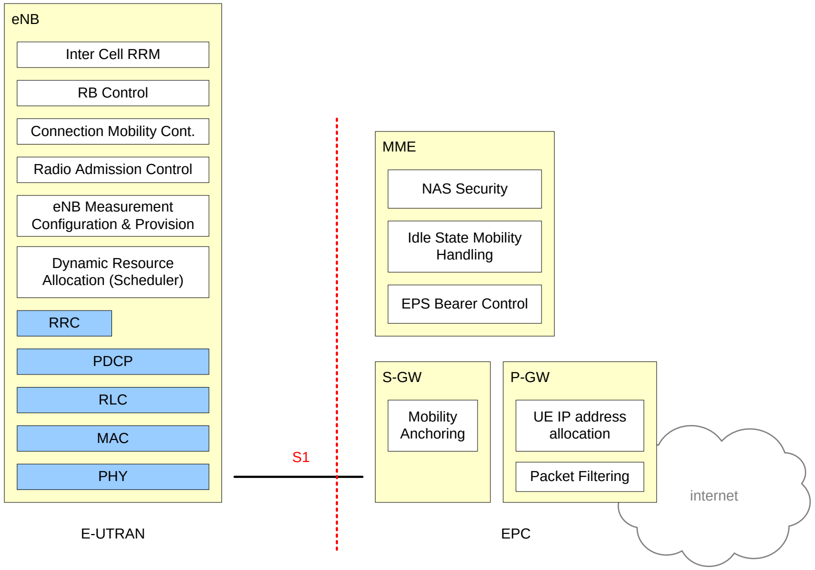
Main functions hosted by eNB include

- functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling)
- IP header compression and encryption of user data stream
- Routing of User Plane data towards Serving Gateway
- Scheduling and transmission of paging messages (originated from the MME);
- Scheduling and transmission of broadcast information (originated from the MME or O&M)



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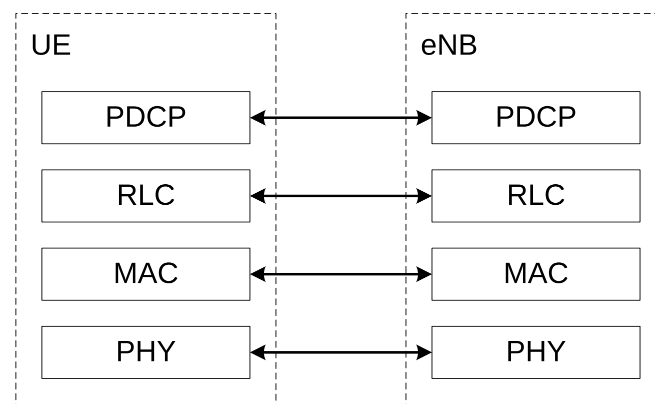
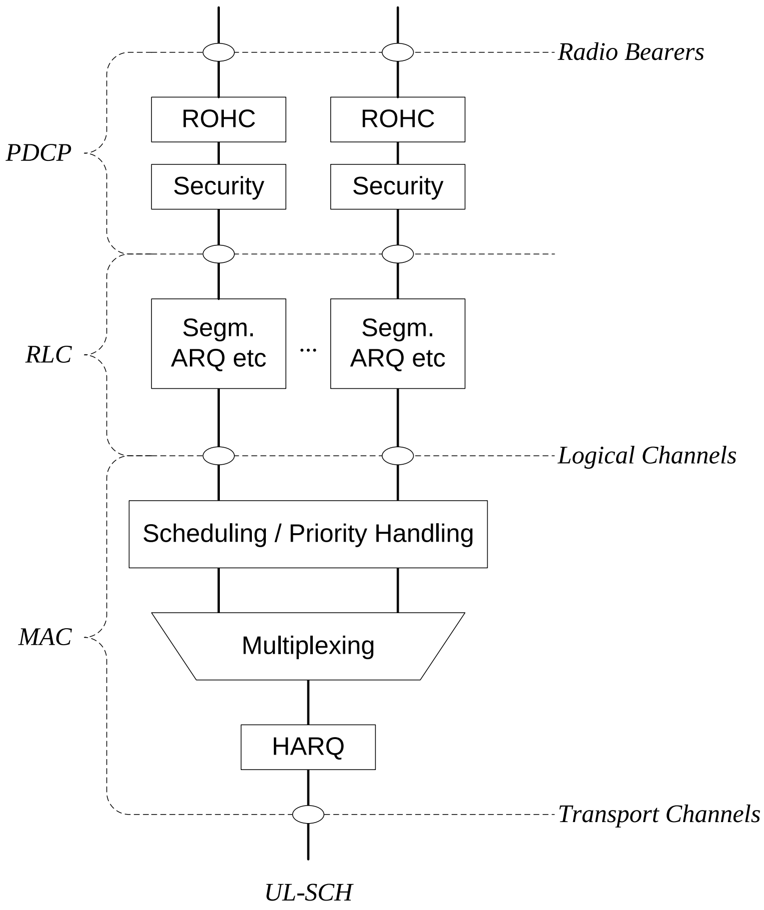
Protocol Architecture

User Plane

- PDCP (Packet Data Convergence Protocol) – 36.323
  - ciphering
  - timer-based discard and header compression using the RoHC protocol
  - in-sequence delivery, retransmission and duplicate detection of PDCP SDUs at handover
- RLC (Radio Link Control) – 36.322
  - error correction through ARQ
  - segmentation and concatenation of SDUs for the same radio bearer
  - in-sequence delivery
- MAC (Media Access Control) – 36.321
  - multiplexing/demultiplexing of RLC PDUs
  - scheduling information reporting
  - error correction through HARQ
  - logical channel prioritisation



User Plane


Radio Bearers
PDCP
ROHC
ROHC
Security
Security
RLC
Segm.
ARQ etc
...
Segm.
ARQ etc
Logical Channels
MAC
Scheduling / Priority Handling
Multiplexing
HARQ
Transport Channels
UL-SCH

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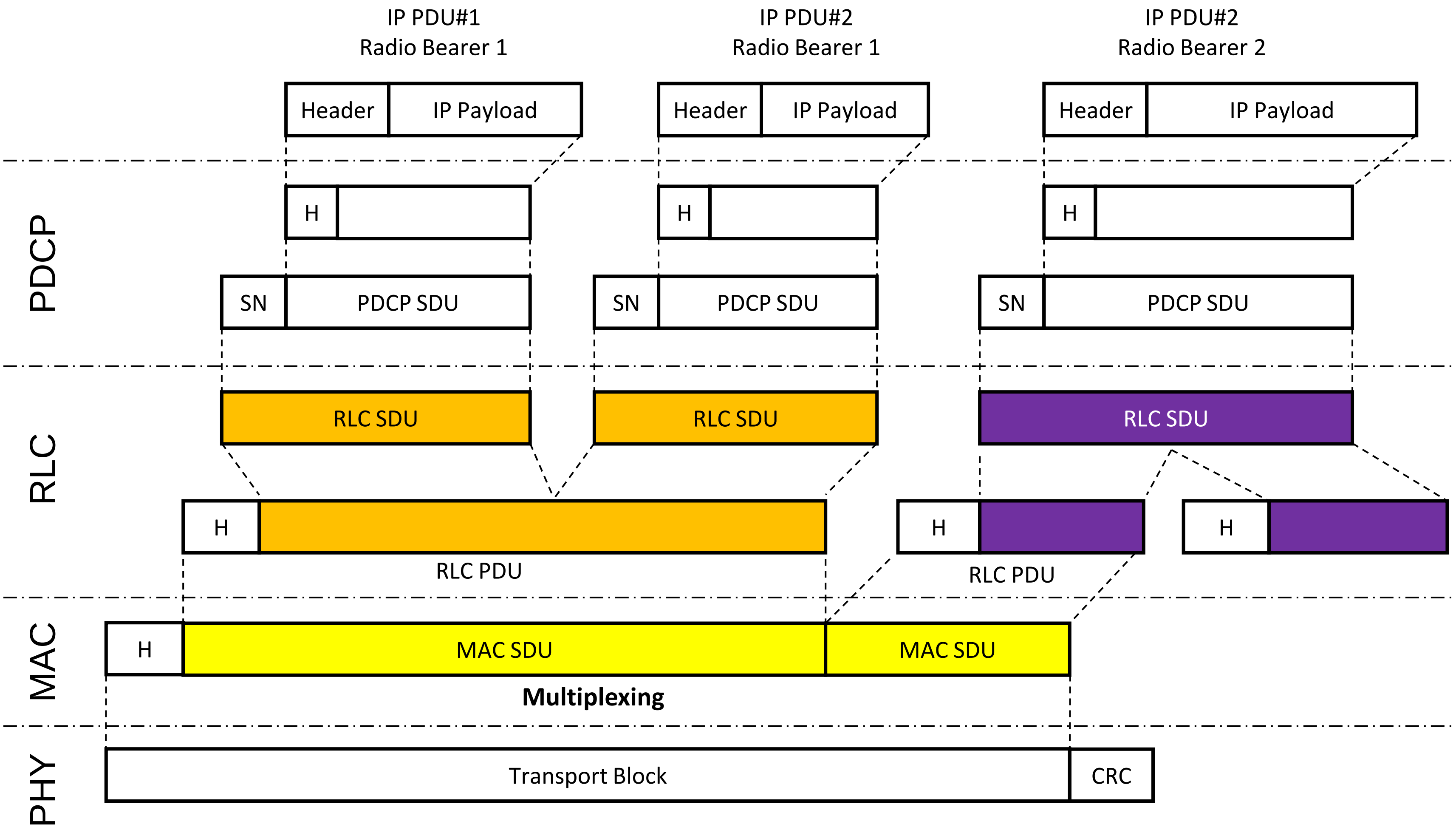
User Plane



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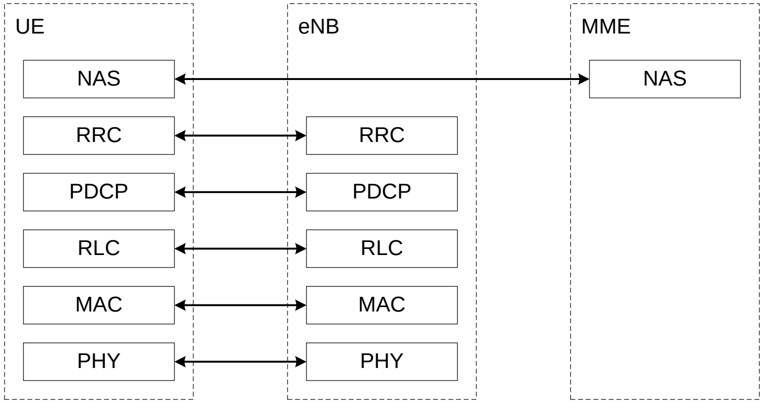
Control Plane

- RRC (Radio Resource Control) – 36.331
  - Broadcast of system information, paging, RRC connection management, RB control, mobility functions, UE measurement reporting and control
- PDCP (Packet Data Convergence Protocol) – 36.323
  - Ciphering and integrity protection
- RLC (Radio Link Control) – 36.322
  - Error Correction through ARQ, (re)-Segmentation according to the size of the TB, concatenation of SDUs for the same radio bearer, in-sequence delivery
- MAC (Media Access Control) – 36.321
  - Multiplexing/demultiplexing of RLC PDUs, error correction through HARQ, Logical Channel Prioritisation



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Control Plane

Only two RRC states

- idle and connected

Idle mode

- UE known in EPC, has an IP address and its location known on Tracking Area level
- UE-based cell-selection and tracking area update to EPC
- MME initiates paging in the whole tracking areas indicated by the UE

Connected mode

- UE known in E-UTRAN and its location known on Cell level
- Mobility is UE-assisted, network-controlled
- Discontinuous Data Reception (DRX) supported for power saving

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E-UTRAN Highlights

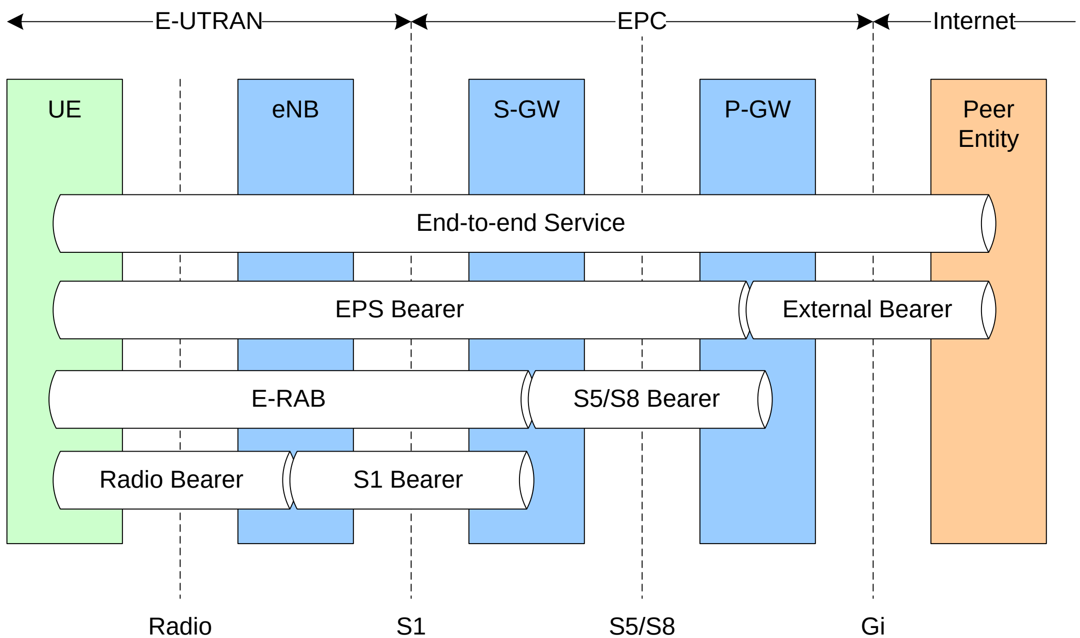
QoS

Reliability

Mobility

Latency

QoS



- E-UTRAN is responsible for Radio Bearer management and therefore ensuring QoS over the radio
  - one-to-one mapping between EPS bearer, E-RAB and Radio Bearer

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QoS

- RB establishment based on QoS parameters from MME
  - QoS Class Identifier (QCI) per bearer : scalar value which identifies a particular service in terms of resource type, priority, packet delay budget and packet error rate [23.203]
  - Guaranteed Bit Rate (GBR) and Maximum Bit Rate (MBR) per bearer
  - Aggregate Maximum Bit Rate (AMBR) per group of bearers
- RB Scheduling based on QoS parameters from MME and scheduling information from UE
  - Channel Quality Indication
  - Buffer Status Report
  - Power Headroom Report
- Scheduling for downlink is eNB implementation specific
- Scheduling for uplink is only partially specified
  - Logical channel prioritization and avoid starvation [36.321]

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Reliability

- L1 applies 24 bit CRC protection to transport blocks (MAC PDUs)
  - erroneous transport blocks are discarded on L1
- Hybrid ARQ (HARQ) protocol in MAC + ARQ protocol in RLC
  - high reliability and radio efficiency
  - HARQ feedback sent on L1/L2 control channel
    - Single, un-coded bit (low overhead)
    - Sent for each scheduled subframe (fast)
    - Retransmissions are soft-combined with previous attempt (efficient)
  - ARQ status report sent as MAC data
    - RLC Status is sent on demand (poll, timer, gap detection)
    - protected by CRC and HARQ retransmissions
- Both HARQ and ARQ protocols operate between the eNB and UE
  - fast handling of residual HARQ errors
- Ensures low latency and high reliability

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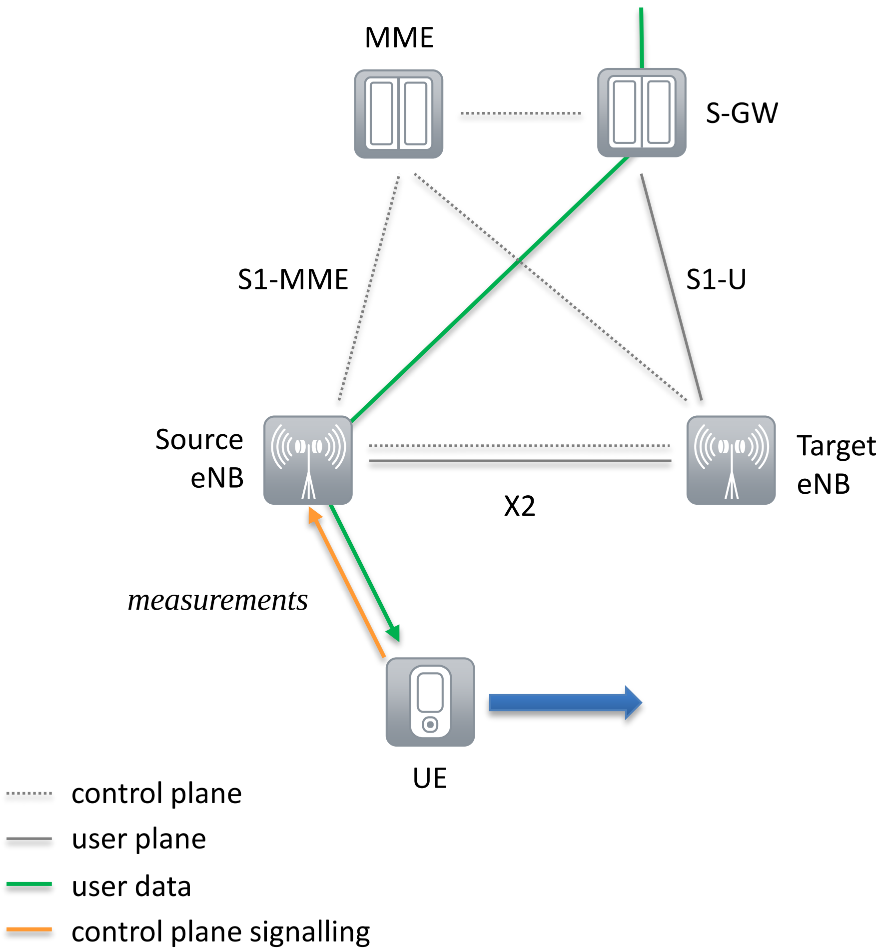
Mobility

Handover Principles

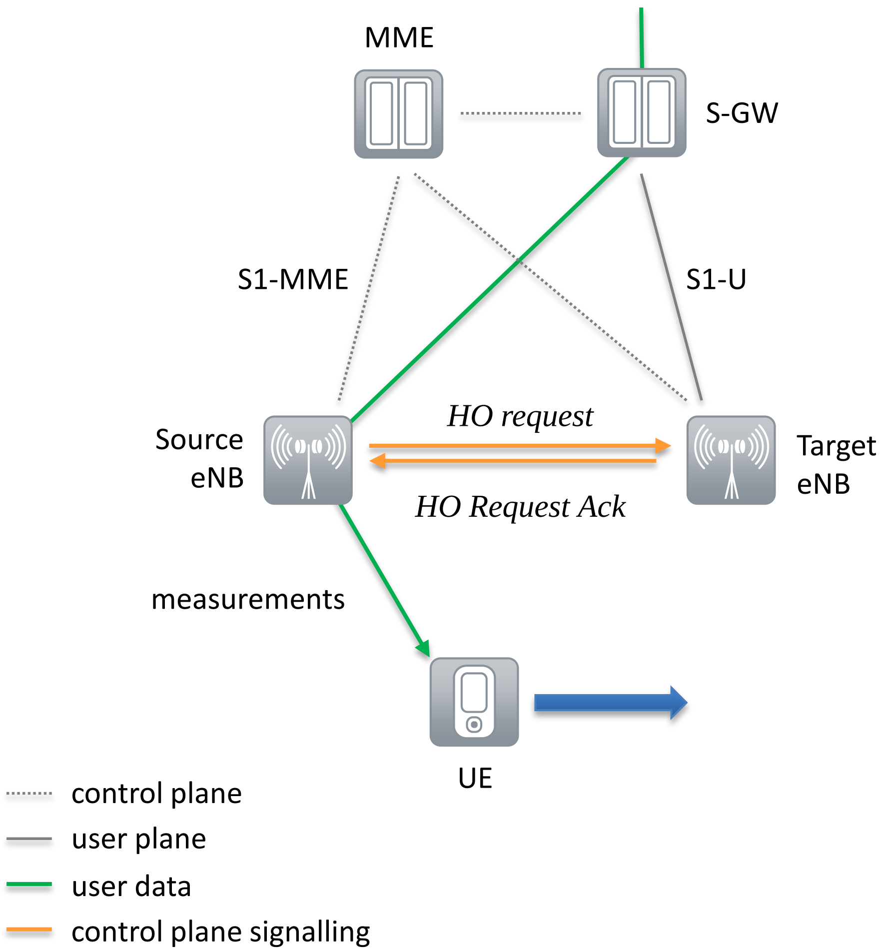
- **Lossless**: packets are forwarded from the source to the target
- **Network-controlled** : target cell is selected by the network, not by the UE and Handover control in E-UTRAN (not in packet core)
- **UE-assisted** : measurements are made and reported by the UE to the network
- **Late path switch**: only once the handover is successful, the packet core is involved

Handover



- Source eNB configures UE measurements
  - target frequency and triggers
- Source eNB receives UE measurement reports
- HO decision is made and target eNB is selected by the source eNB

Handover



- HO request sent from source eNB to target eNB
- Target eNB performs admission control and accepts the HO request
- HO Ack sent to source eNB from target eNB

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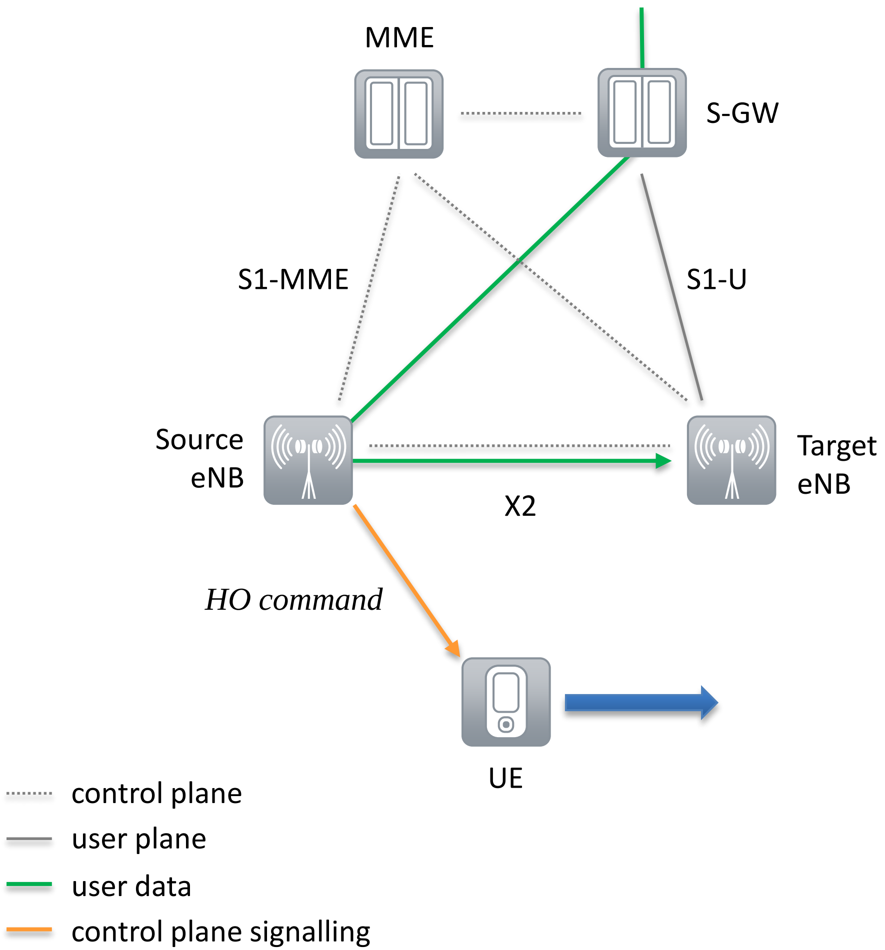
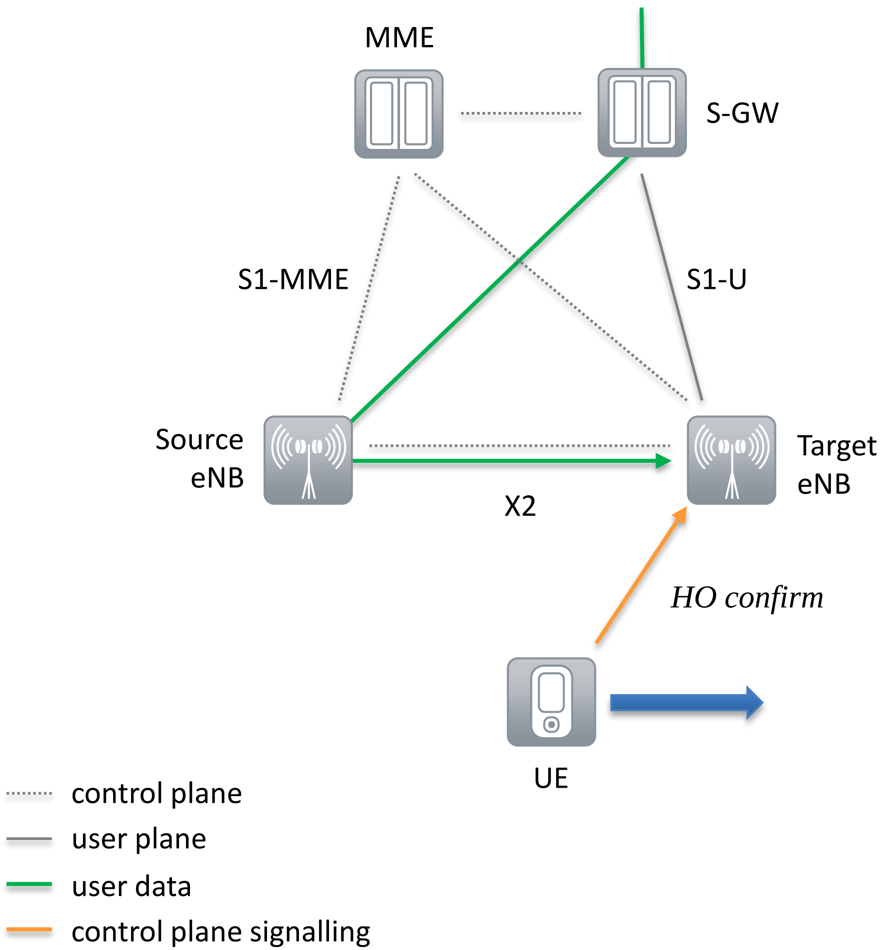
Handover



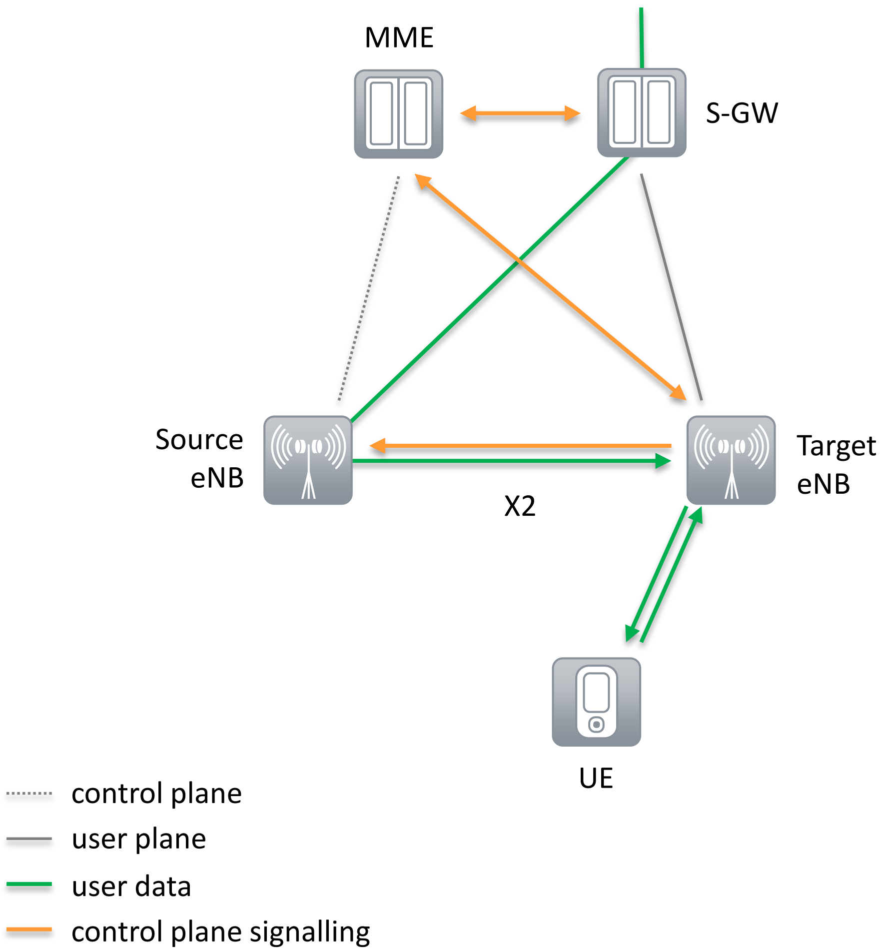
- HO command is sent to the UE
  - RRCConnectionReconfiguration including the mobilityControlInfo
- Data forwarding initiated towards the target eNB

Handover



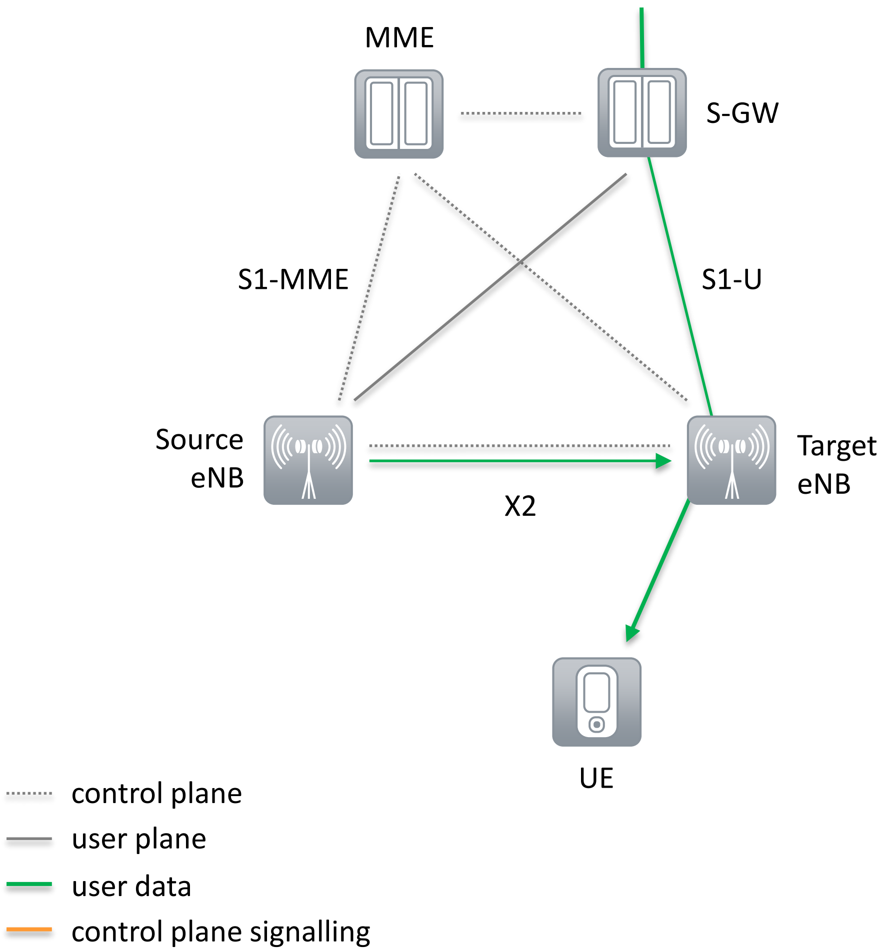
- UE accesses the target eNB and confirms the HO
  - RACH procedure is initiated
  - RRCConnectionReconfigurationComplete is sent

Handover



- Target eNB requests EPC to switch the data path
  - eNB → MME : path switch request
  - MME → S-GW : modify bearer request
  - S-GW → MME : modify bearer response
  - MME → eNB : path switch request ACK
- Target eNB notifies the source eNB that UE resources can be released

Handover



- Path is switched
- Source eNB finishes forwarding packets
  - once completed UE context can be cleared and resources freed
- HO is completed

Latency

- User Plane Latency < 10ms [36.912]
  - one way latency
  - between 5ms and 10ms depending on HARQ operating point and TDD configuration
- Control Plane Latency : 50ms
  - Transition time from Idle to Connected mode
- Handover: 12ms interruption time
  - For intra - E-UTRAN handover

Rel-10

Overview

Carrier Aggregation

Minimisation of Drive Tests

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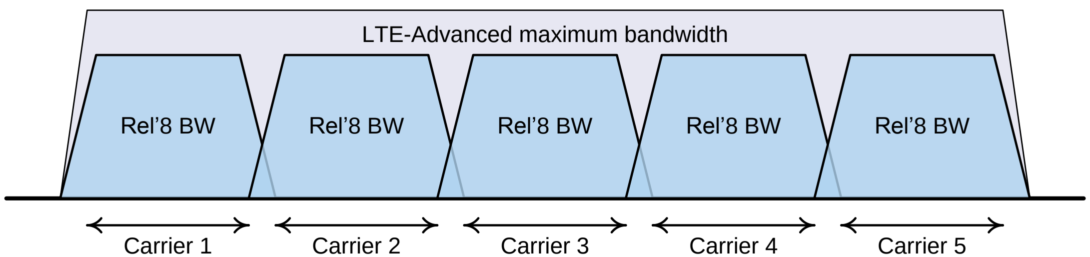
Rel-10

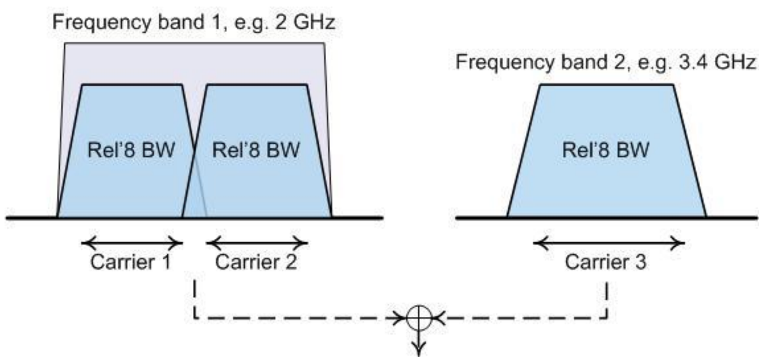
- Main goal of Rel-10 was to fulfil the **IMT-Advanced** requirements
  - up to 1Gbps in downlink and 500Mbps in uplink [36.913]
  - took 2 years of efforts in 3GPP
- Main Rel-10 Features
  - **Carrier Aggregation**: to increase the bit rate and reach IMT-A requirements [WID]
  - **eICIC**: to efficiently support highly increasingly complex network deployment scenarios with unbalanced transmit power nodes sharing the same frequency [WID]
  - **Relay Nodes**: to improve the coverage of high data rates, cell-edge throughput and ease temporary network deployments [WID]
  - **Minimisation of Drive Tests / SON Enhancements**: enhanced and combined effort to optimize the performance of the network aiming to automate the collection of UE measurements and thus minimize the need for operators to rely on manual drive-tests [WID] [WID]
  - **MBMS enhancements**: to enable the network to know the reception status of UEs receiving a given MBMS service in connected mode… [WID]
  - **Machine Type Communication**: protect the core network from signalling congestion & overload [WID]

Carrier Aggregation

- Goal of Carrier aggregation is to aggregate Rel-8 compatible carriers to increase peak data rate
  - up to 5 carriers can be aggregated in DL for a maximum BW of 100 MHz

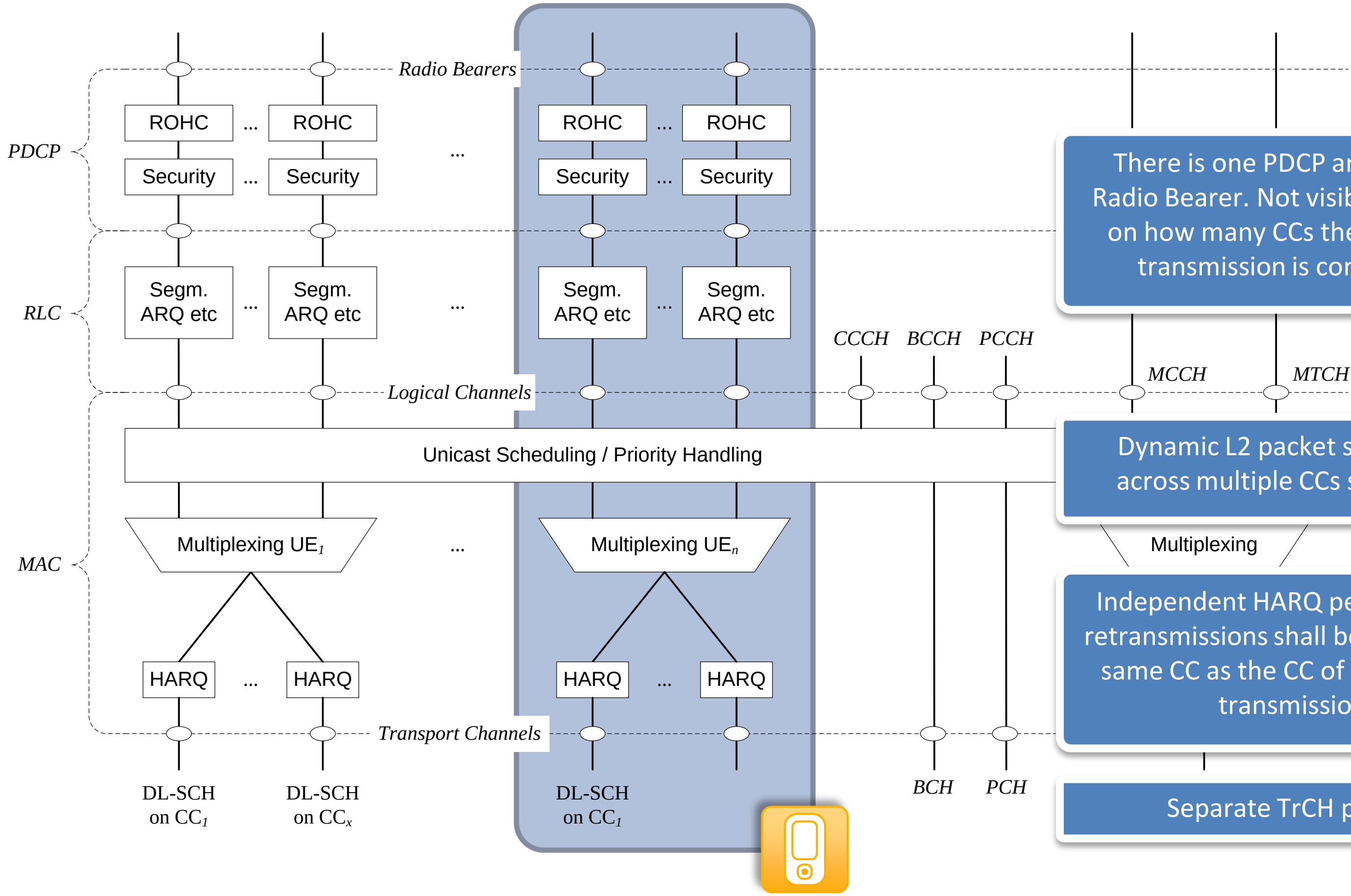


  - non-contiguous carriers can also be aggregated in DL for increased flexibility



Carrier Aggregation

Impact on L2 Architecture



There is one PDCP and RLC per Radio Bearer. Not visible from RLC on how many CCs the PHY layer transmission is conducted.

Dynamic L2 packet scheduling across multiple CCs supported

Independent HARQ per CC. HARQ retransmissions shall be sent on the same CC as the CC of the original transmission

Separate TrCH per CC

Carrier Aggregation

Basic Concept

- when CA is configured, the UE only has one RRC connection with the network
- at RRC connection establishment/re-establishment/handover, one serving cell provides the NAS mobility information (e.g. TAI), and at RRC connection re-establishment/handover, one serving cell provides the security input
- this cell is referred to as the Primary Cell (**PCell**)
- in the downlink, the carrier corresponding to the PCell is the Downlink Primary Component Carrier (DL PCC) while in the uplink it is the Uplink Primary Component Carrier (UL PCC)
- depending on UE capabilities, Secondary Cells (**SCells**) can be configured to form together with the PCell a set of serving cells
- in the downlink, the carrier corresponding to an SCell is a Downlink Secondary Component Carrier (DL SCC) while in the uplink it is an Uplink Secondary Component Carrier (UL SCC)
- the configured set of serving cells for a UE therefore always consists of one PCell and one or more SCells

Carrier Aggregation

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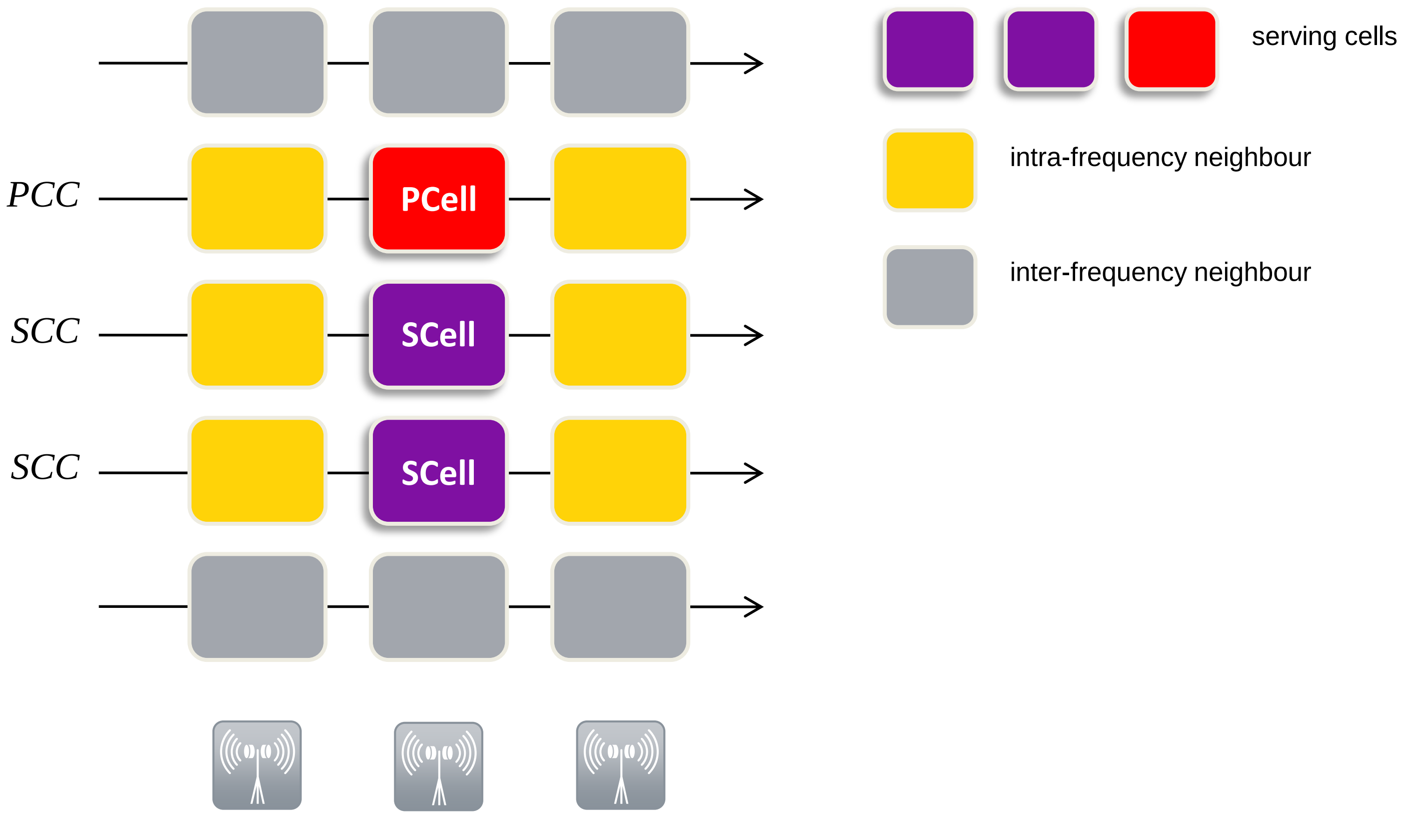
Example



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Minimisation of Drive Tests

Goal of Minimisation of Drive Tests

- replace manual drive testing that the operators have to perform currently
- automatic UE measurements and data logging in drive-tests scenarios
- provide a basis for finding coverage problems in the HSPA & LTE network

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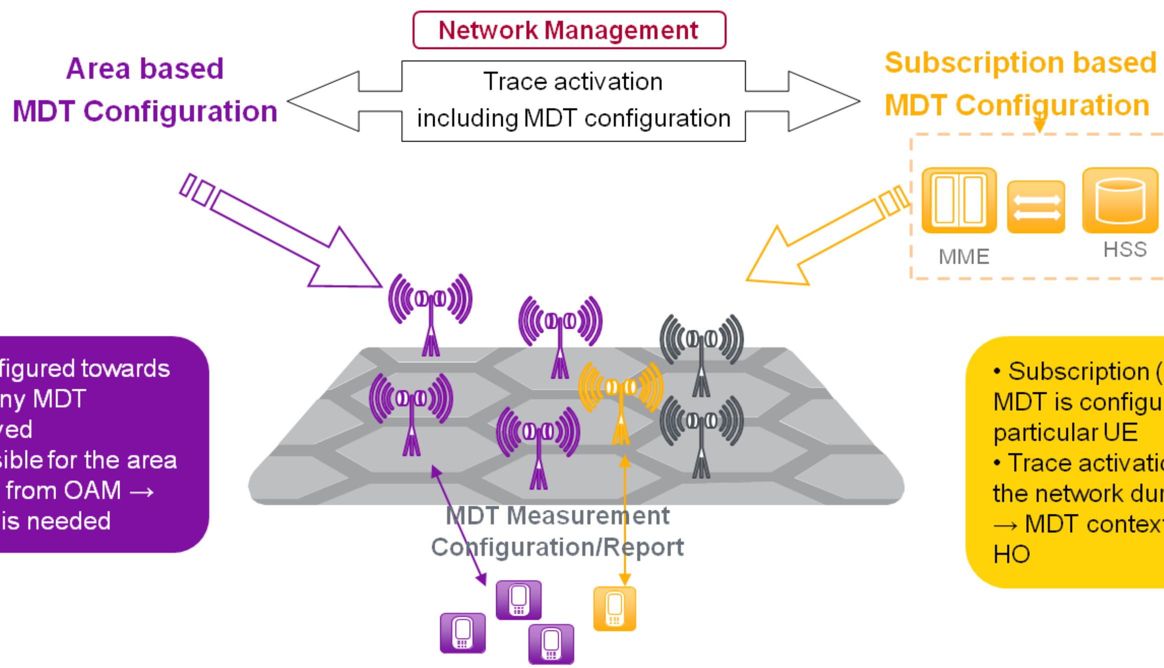
Minimisation of Drive Tests

Measurement Configuration [32.422, 37.320]

- measurements are configured to the UE by E-UTRAN/UTRAN by RRC signalling, based on Network Management systems measurement definitions configured to (E-)UTRAN



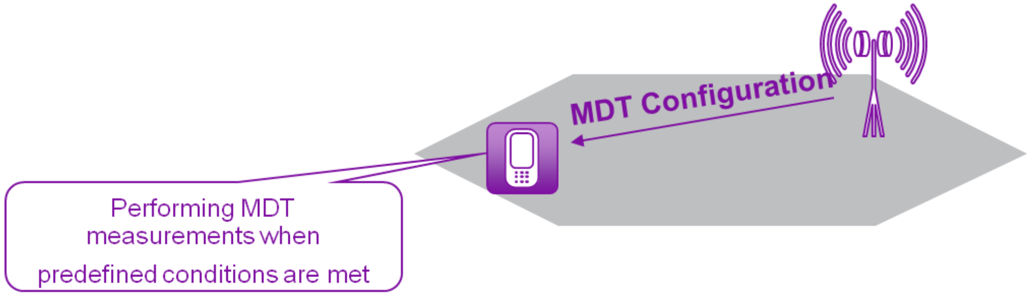
- Area based MDT is configured towards specified region, where any MDT capable UE can be involved
- All eNBs/RNCs responsible for the area are configured for tracing from OAM → No MDT context transfer is needed

- Subscription (IMEI/IMSI) based MDT is configured towads one particular UE
- Trace activation is propagated in the network during attach procedure → MDT context propagates during HO

Minimisation of Drive Tests

Measurements

- Real time (Immediate MDT) and non-real time (Logged MDT) measurements
- Measurements are configured to the UE by (E-)UTRAN by dedicated RRC signalling
- The measurements should be tagged with UE position on best effort basis
  - in the best case GNSS information can be included,
  - otherwise cell ID or RF fingerprints



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RLF Reporting

- To identify origin of radio link failures
- Content
  - Cell measurement results at the time of the failure
  - Available accurate location information
  - Cell IDs for following cells
  - E-CGI or PCI where the failure happened
  - E-CGI of the cell to which UE attempted establish the connection after the failure
  - Time between last successful HO and the failure
- Reporting
  - At RRC Connection Setup, Re-establishment or Reconfiguration
  - UE Information procedure is used
  - upon retrieval report is removed, otherwise should be maintained in the UE for 48hours

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Conclusions

Conclusions

- E-UTRAN presents a flat architecture for low latency and delays

- E-UTRAN Rel-10 introduces
  - carrier aggregation for higher bit rates and flexible spectrum usage
  - eICIC for improved support of HetNet
  - RN to increase coverage and deployment flexibility
  - MDT/SON to ease deployments and network optimisations

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Thank You

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