


IR.3504 Convergent Services and Technologies

Mobile Network Architectures

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Summary

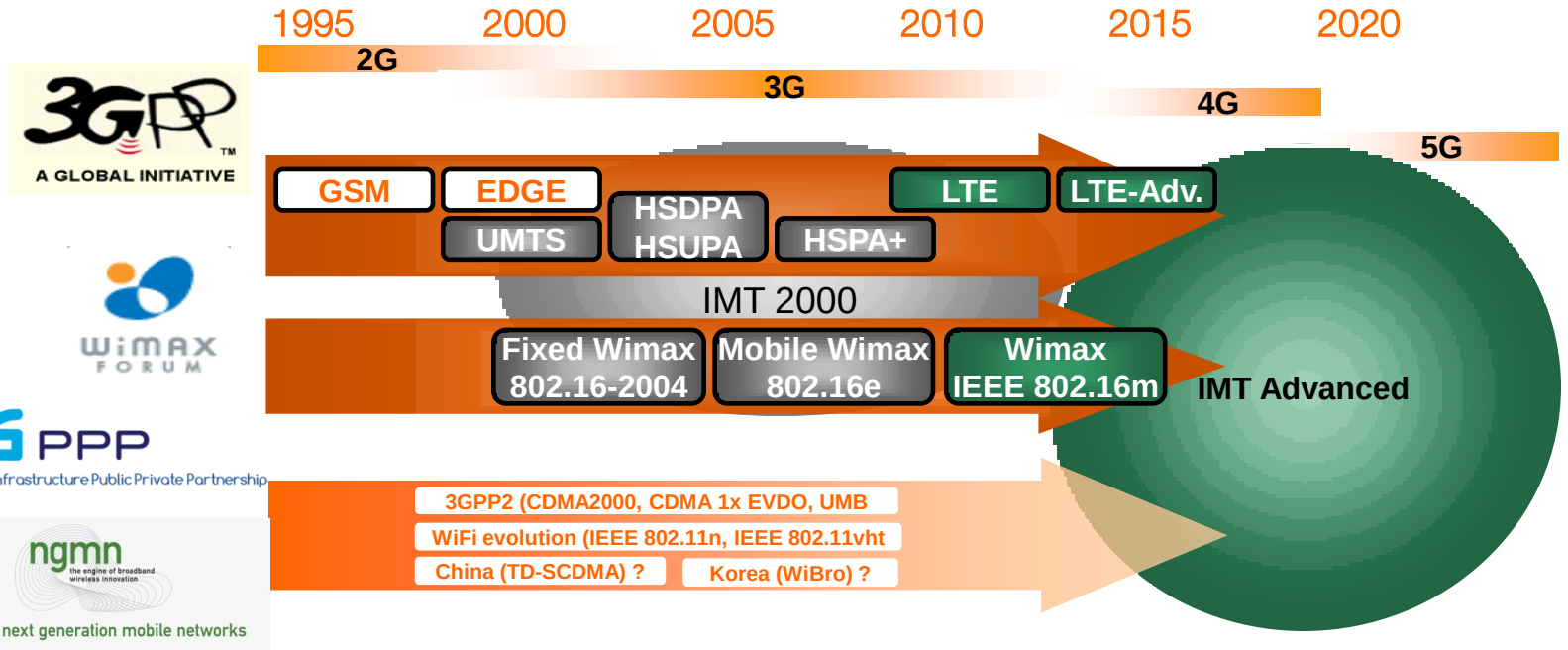
At the end of this talk, you should be able to answer the following questions:

- What are the technical names for 2G, 3G, 3G+, 4G networks?
- What are the main entities in the GSM architecture ?
- What is a handover ? How does it work in 3G ?
- What does LTE stand for ? How does it simplify 3G's core network ? Is it capable of handling voice calls ?
- To whom is the Femtocell offer targeted ?
- How does Virtualization and software impact 5G architecture ?

Summary

1. Introduction to mobile networks architecture
2. GSM – EDGE Radio Access Network (GERAN) Architecture
3. UMTS Terrestrial Radio Access Network (UTRAN) Architecture
4. Mobility Procedures in GERAN / UTRAN
5. Fundamental Mobile Network Procedures
6. LTE Architecture
7. Femto Cells / Small Cells
8. 5G and Virtualization
9. Conclusion

Technology and standards landscape

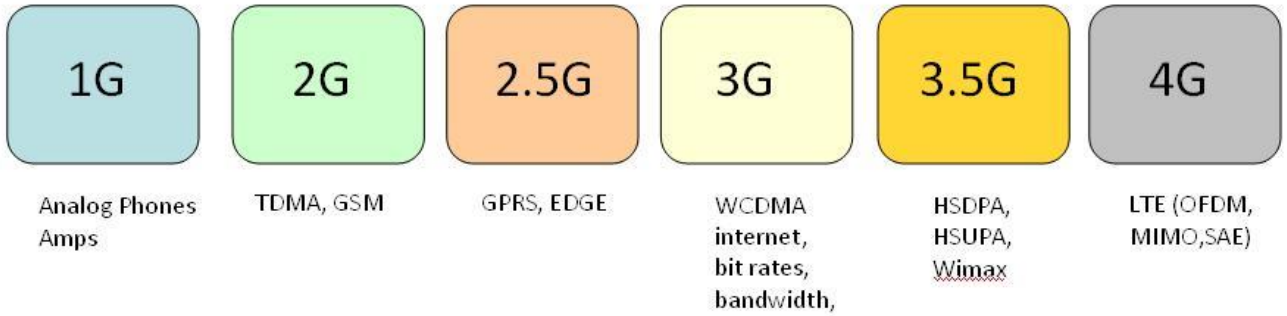


Standards

1. 3GPP (3rd Generation Partnership Project)
   - Covers GSM, UMTS and the Evolved Packet System (LTE and EPC)
   - Strength of 3GPP is the large scope ranging from CORE network aspects down to terminal tests.
   - HSPA+ covers evolution of WCDMA in both downlink and uplink
   - LTE (Long Term Evolution) is a new radio interface to be released in 2008.
   - LTE-A is the further evolution of LTE towards IMT advanced (sometimes called 4G) and will be backward compatible to LTE.
2. WiMAX Forum / IEEE 802.16
   - IEEE 802.16 covers mainly physical and MAC layer specifications (large number of options are kept).
   - WiMAX forum ensures interoperability, product certification and lobbying.
   - WiMAX does not consider CORE network aspects. Has to rely e.g. on the EPC from 3GPP.
   - IEEE802.16m is the equivalent of LTE advanced in the WiMAX world.
3. 5GPPP and NGMN for 5G

Radio frequencies and coverage

1. The Cellular technology is made from the **radio frequency,** the **network architecture** and the **communication protocol**



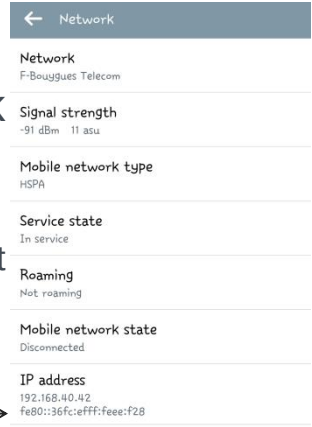
2. The Frequency used **<u>and</u>** the transmission power **<u>decide</u>** of the coverage
   - Each frequency has a different rate of energy decay, **higher frequencies decaying faster**
   - This explains why the 700MHz frequency for LTE is called “the golden frequency” → better obstacle penetration and wider coverage

Some terminology

1. Radio Access Network: the radio transmission part (includes the User Equipment and the Antenna/Base station)
   - Responsible for radio resource management
1. Core Network: the control and routing part in the operator domain
   - Responsible for user management (authentication), session management (voice and data setup), and mobility management (registration, location/routing area update)

3. User Equipment: anything the user can use to connect to the network (phone, tablet, IoT device…)
   - Responsible for authenticating the user, handling the voice/data sessions establishment and termination, measuring the signal strength and reporting it, and part of the handover

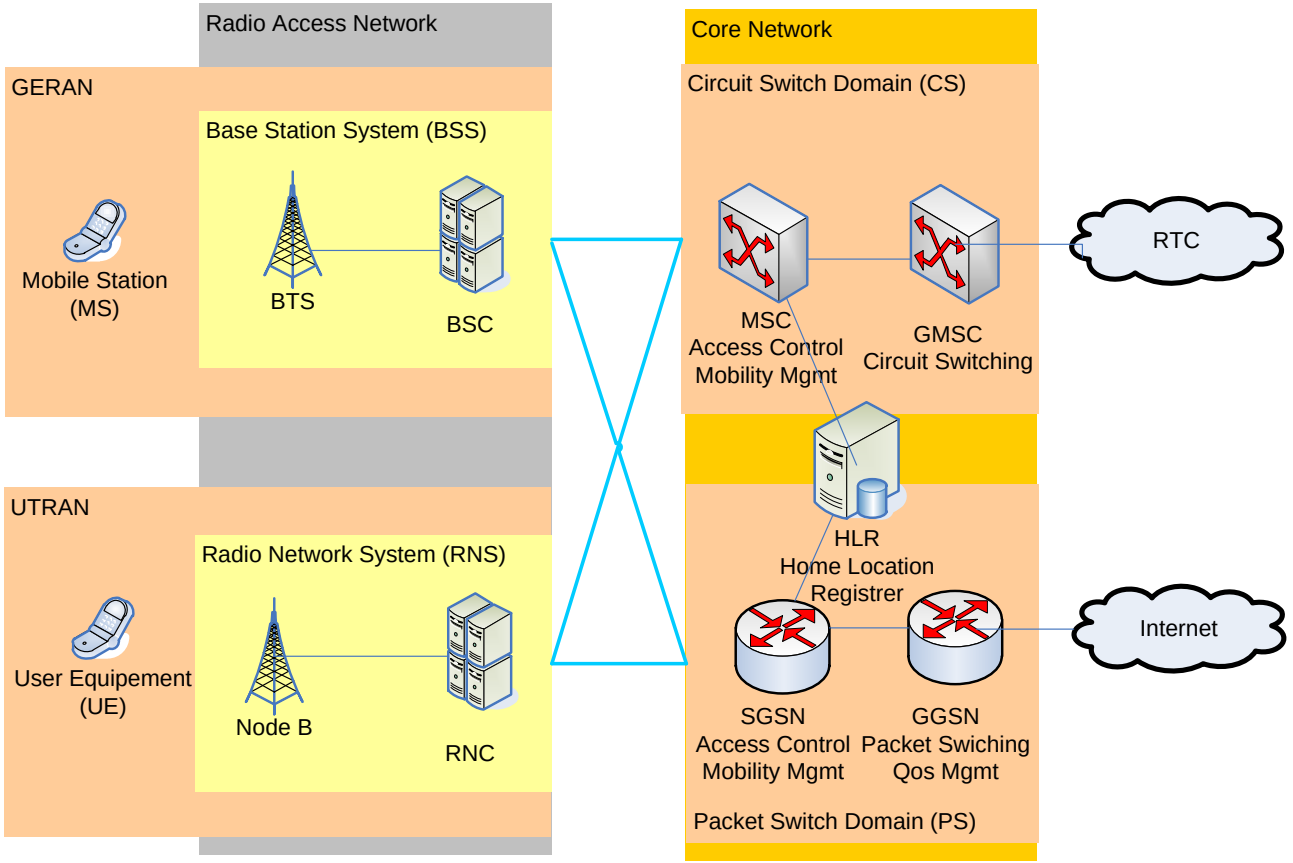
How it looks like on Android



Access and Core networks in 2G and 3G

GERAN (GSM Edge Radio Access Network) is the 2G Radio Access Network

UTRAN (Universal Terrestrial Radio Access Network) is the 3G Radio Access Network



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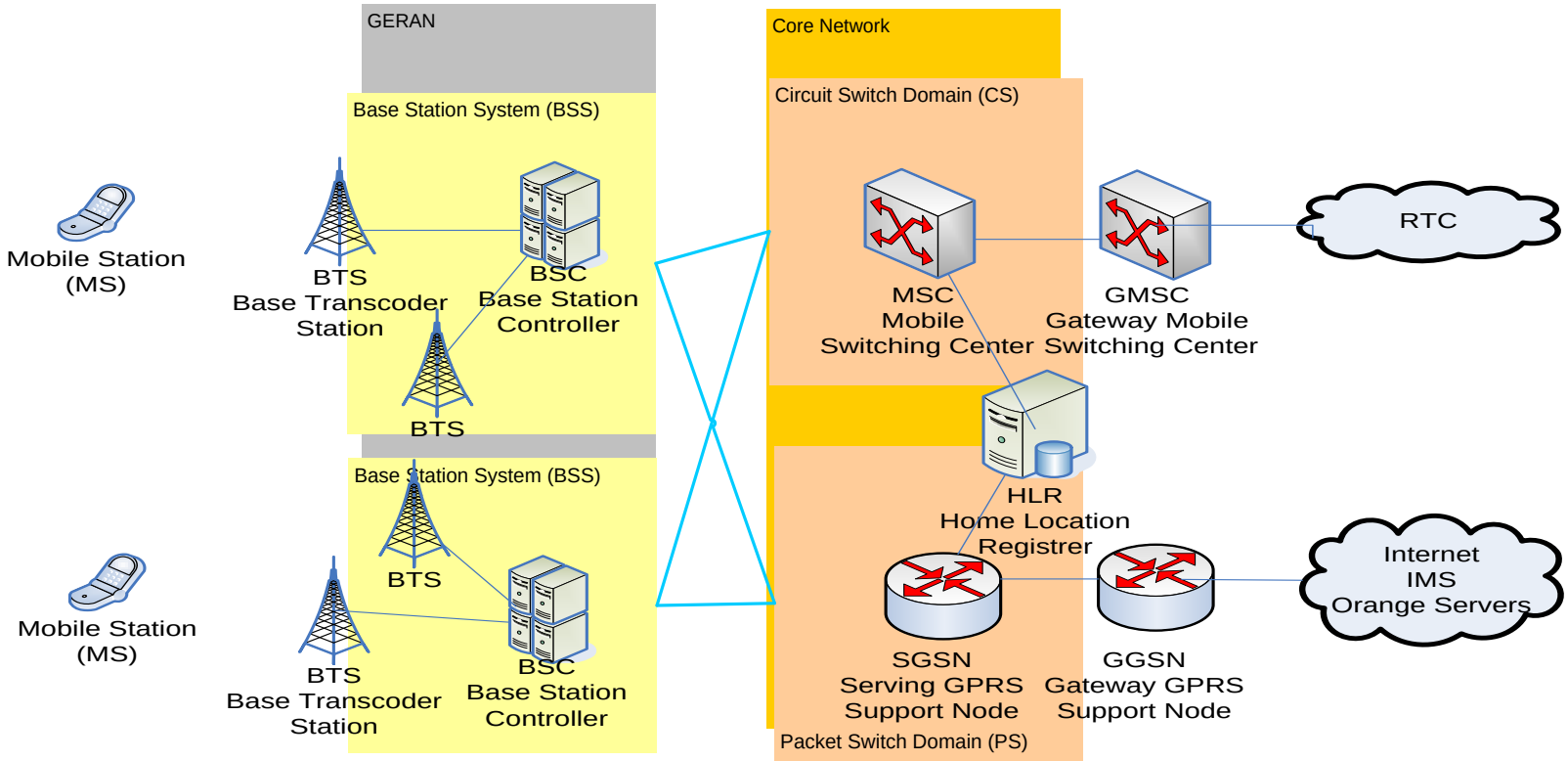
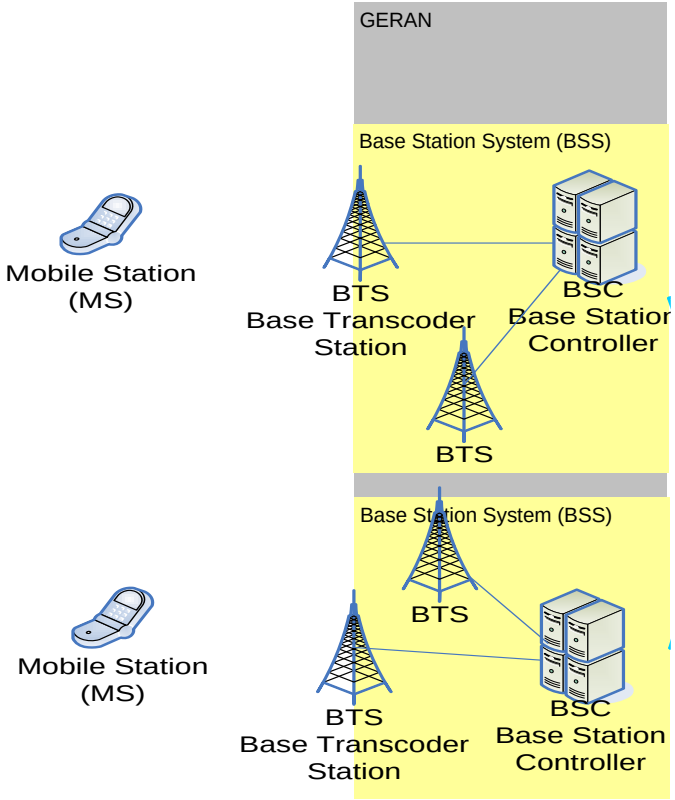
Architecture overview



Access Network Functions (GERAN)



Base Station System (BTS)

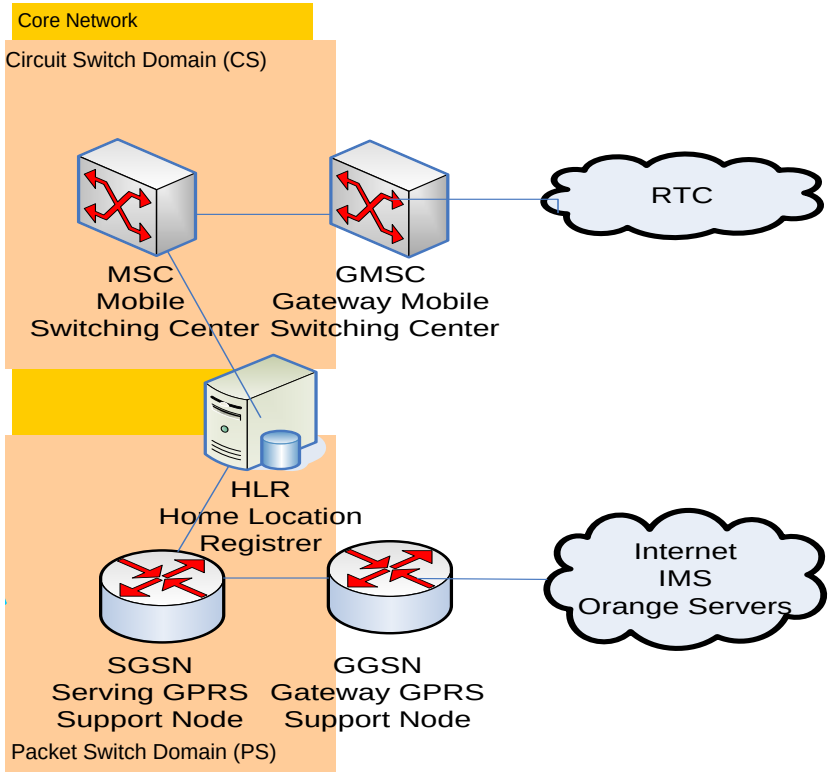
- management of the physical layer (reception / transmission; modulation, coding, etc)
- measurements triggering and measurements transmission towards the BSC
- data transmission between the BTS and the BSC

Base Station Controller (BSC)

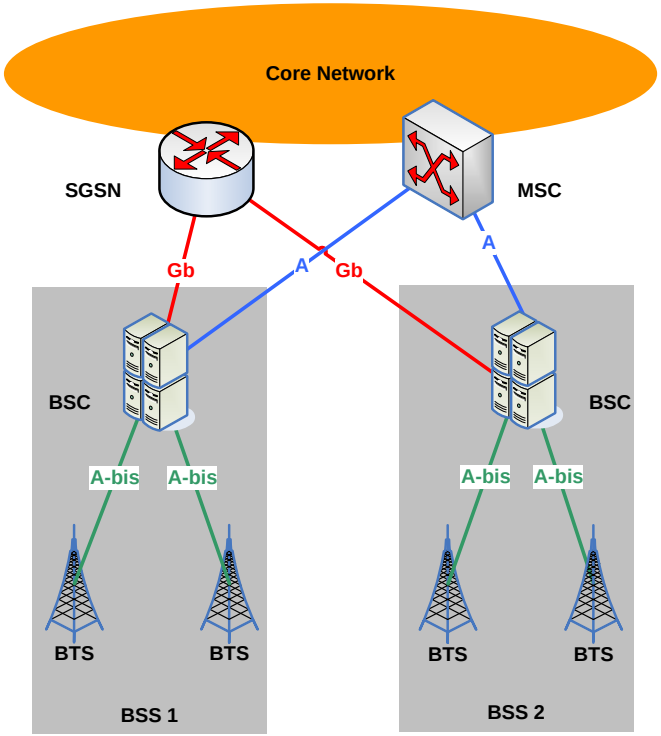
- management of the radio resources (access control resources allocation)
- uses the measurements reports for , e.g. MS and BTS power control
- takes the handover decision

Core Network Functions

1. Mobile Switching Center MSC / VLR
   - call management -voice call setup (MSC)
   - mobility management - location area updates (MSC)
   - access control according to user's profile (MSC and VLR)
   - stores subscriber information for the users registered in the Location Area managed by the MSC.
2. Home Location Register (HLR)
   - subscriber profile database - stores the subscriber information (IMSI, MSISDN, QoS profile; services subscription, etc.)
   - localization database - for each user stores the number of the last VLR the user has registered with
3. Serving GPRS Support Node (SGSN)
   - see UMTS nodes functions slide
4. Gateway GPRS Support Node (GGSN)
   - see UMTS nodes functions slide



Interfaces In the GERAN Architecture



An interface is a control plane (a management protocol)

1. The A-bis interface connects the BTS to its BSC
2. The A interface connects the BSC (Base Station Subsystem) to the CS Core Network Domain
3. The Gb interface connects the BSC (Base Station Subsystem) to the PS Core Network Domain

GERAN Application Protocols

1. BSS Management Application Part (BSSMAP)
   - used between MSC and BSC over the A interface
   - Allow radio resources management
   - Main procedure : Assignment Request
2. Direct Transfer Application Part (DTAP)
   - used between MSC and MS : DTAP messages are not interpreted by the BSS
   - The Mobility Management (MM) layer supports the mobility of user terminals
   - The Connection Management (CM) layer is divided in 3 sub-layers : CC (Call Control), SS (Supplementary Services) and SMS (Short Message Service)
3. BSSGP - Base Station System GPRS Protocol
   - used between SGSN and BSS over the Gb interface

Evolutions to GERAN

1. EDGE - Enhanced Data rates for Global Evolution (2.5G)
   - use the same spectrum as GSM 900, 1800 and 1900
   - through 3X times higher then in GPRS
   - using the 8PSK modulation instead of GMSL modulation
2. Evolved EDGE (EGPRS2)
   - further increase of user throughput
   - latency reduction, RxDiV, dual carriers, etc
3. EDGE and Evolved EDGE does not impact the GERAN architecture. Only the techniques used on the radio interface are improved

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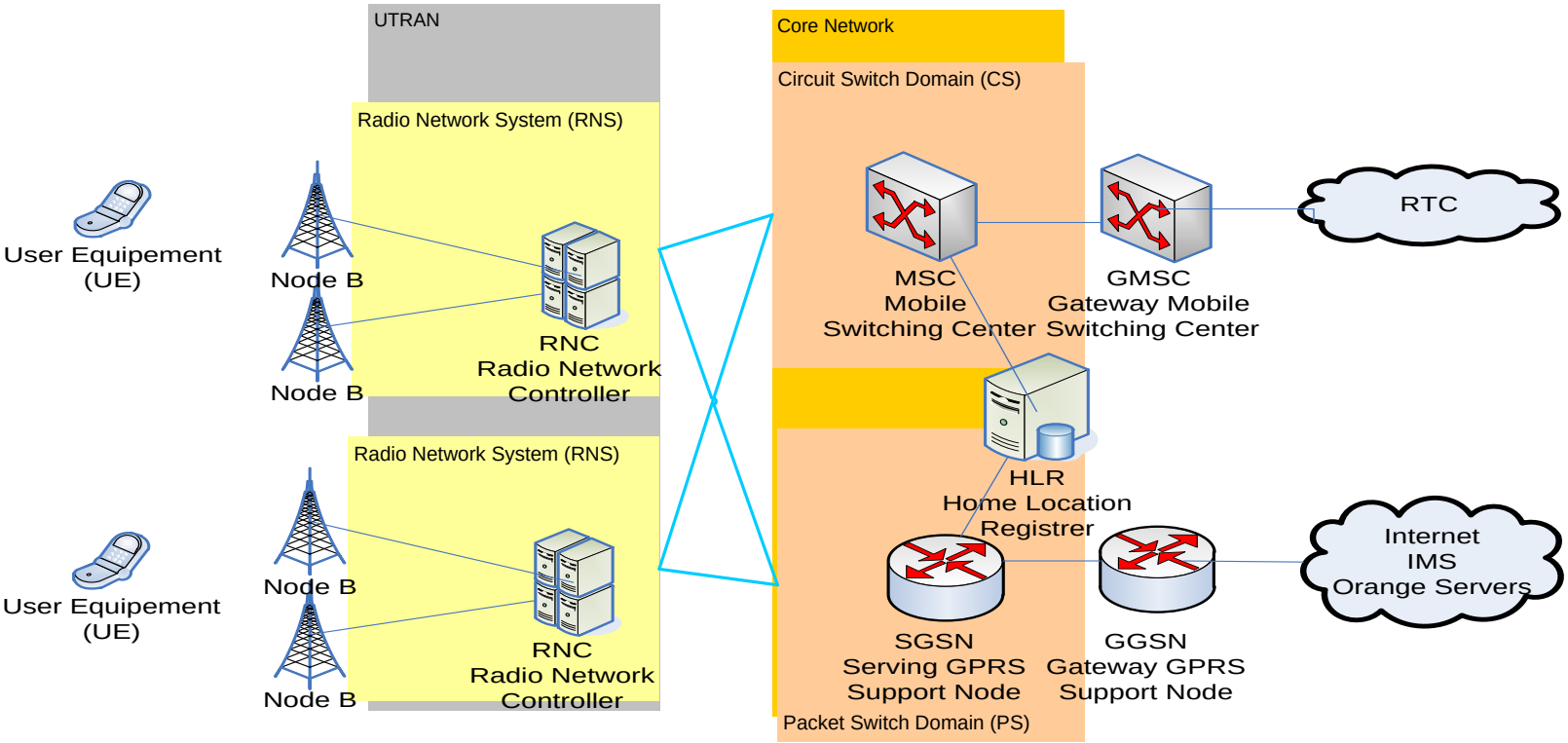
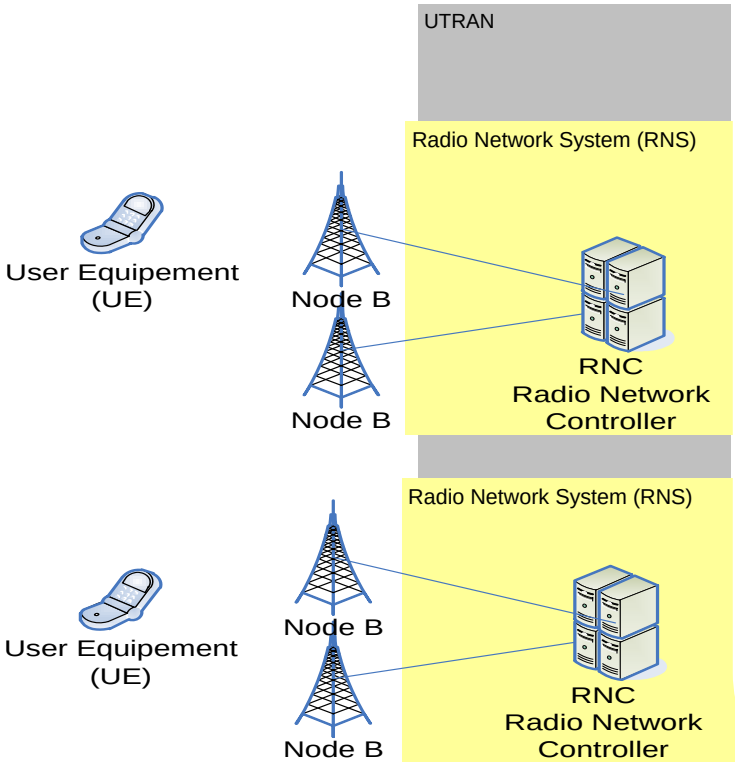


Access Network Functions (UTRAN)



1. Node B
   - physical layer management
   - inner loop power control

2. RNC
   - controls the radio resources in UTRAN

3. Controlling RNC (CRNC)
   - controls the Node B (cells) radio resources
   - admission control, resources allocation

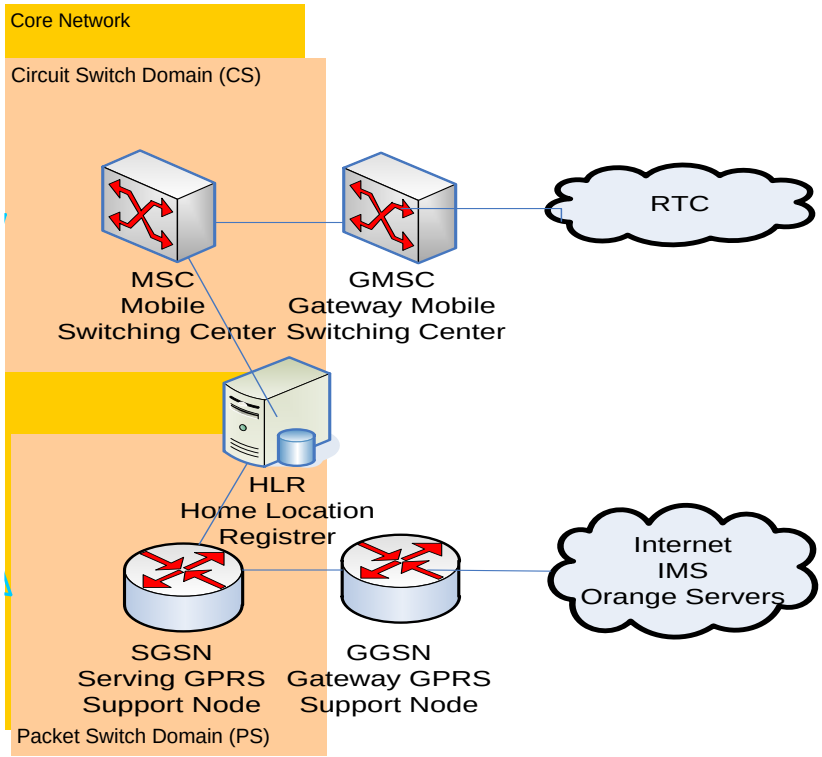
4. Serving RNC (SRNC)
   - terminates the Iu connection for a given UE (control plane and user plane)
   - terminates the RRC protocol for an UE (handover decision, outer loop power control)

5. Drift RNC (DRNC)
   - any RNC which is not the SrNC and controls cells used by the

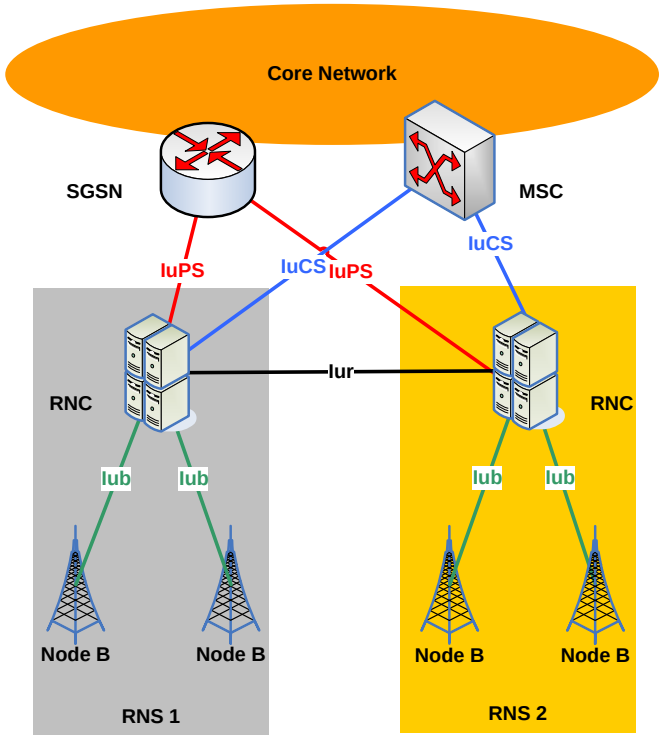
Core Network Functions

1. MSC / VLR
2. HLR

1. SGSN / VLR
   - session management - packet data session establishment
   - mobility management – routing area updates
   - access control according to user's profile (SGSN and VLR)
   - stores subscriber information for the users registered in the Routing Area managed by the SGSN (VLR)
2. GGSN
   - interconnects the PLMN to other Packet Data Networks
   - manages UEs PDP contexts (IP adrress allocation)



Interfaces in the UTRAN architecture



1. The Iub interface connects the Node B to its RNC
2. The Iur interface interconnects two RNC (or two Radio Network Subsystems)
   - Basic Mobility Procedures Module
   - Inter-RNS mobility handling
3. The Iu interface connects the RNC (or the Radio Network Subsystem) to the Core Network
   - Paging, UE-CN Signalling transfer, Location Reporting
   - Security Mode Control

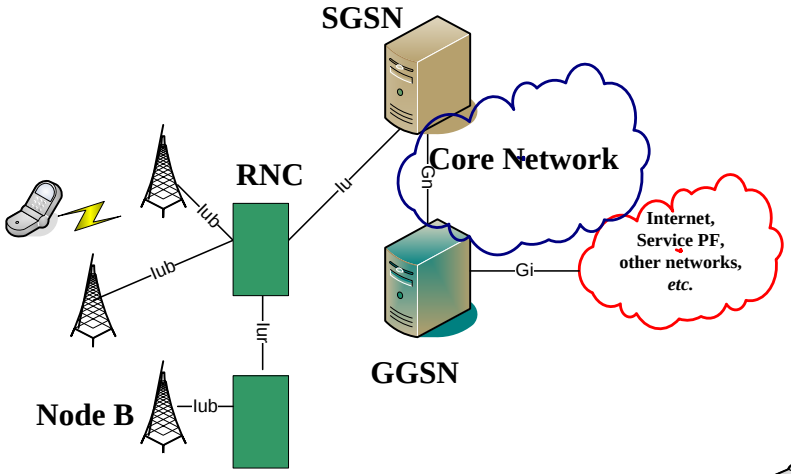
Evolutions to UTRAN

1. All IP UTRAN (3GPP Release 5)
2. HSPA – High Speed Packet Access
   - Improve user throughput and system capacity using new techniques on the radio interface
   - HSDPA – High Speed Downlink Packet Access (3GPP Release 5)
     - shared channel, fast radio dependent scheduling in the Node B, short TTI, fast retransmission, fast link adaptation
   - HSUPA – High Speed Uplink Packet Access (3GPP Release 6)
     - Node B controlled scheduling - Under the supervision of the RNC, fast retransmission, shorter TTI
   - Depending of vendors' products HSPA comes as a HW and / or SW upgrades to the Node B and RNC, and not as a feature impacting the UTRAN architecture
3. HSPA+ (3GPP Release 7)
   - introduces an optional all-IP architecture for the network, where base stations (Node B+) are directly connected to IP based backhaul and then to GGSNs.

What is HSPA+ ?

1. Main goals
   - Improve current HSDPA/HSUPA performance
   - Keep backwards compatibility to earlier releases.
   - Support of "Always on" and VoIP
   - Higher peak rates annd lower latencies
2. Physical layer peak rate improvements
   - MIMO (28 Mbit/s), 64 QAM downlink (21 Mbit/s), 16 QAM uplink (11.5 Mbit/s)
   - Combination of MIMO and 64 QAM (not R7, 42 Mbit/s)
   - Always on concept and VoIP improvements
   - UL-DTX, HS-SCCH less operation, UL DPCCH slot format 4
3. Layer 2 improvements
   - Enhanced F-DPCH, other L2 enhancements
4. Architecture improvements
   - Enable "flat" architecture via an integration of the RNC in the nodeB.

HSPA+ Architectures

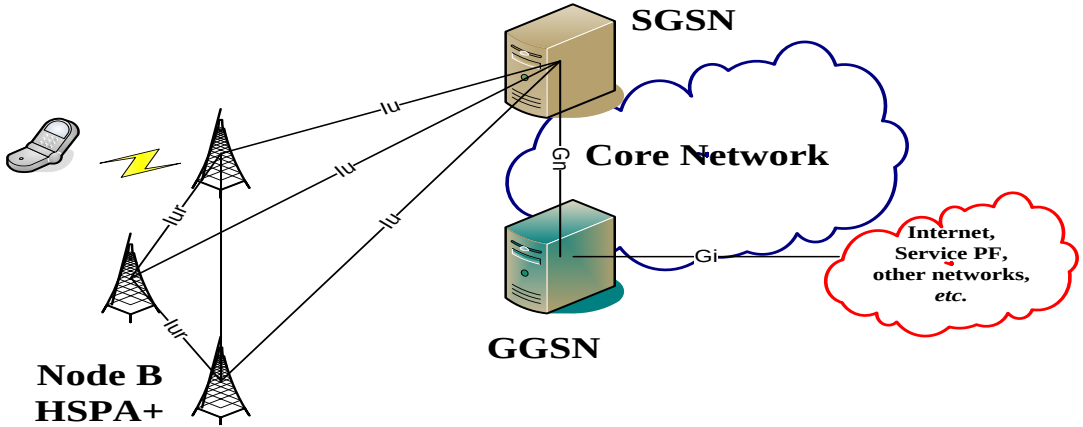


⇨HSPA+

⇨Same centralized architecture as for UMTS

⇨Flat HSPA+

⇨RNC & NodeB are collapsed



Flat HSPA+ Architecture

1. Benefits of flat HSPA+ architecture
   - Lower latency
   - Single-level access network: base stations (BS) only
   - Most functions distributed in BS, closer to air interface
   - Partially meshed BS
   - PS-only
2. Nevertheless…
   - Complexities to make Access Network evolve with as little impact as possible on Core Network and UE
   - Need for connection to legacy RNC for CS calls

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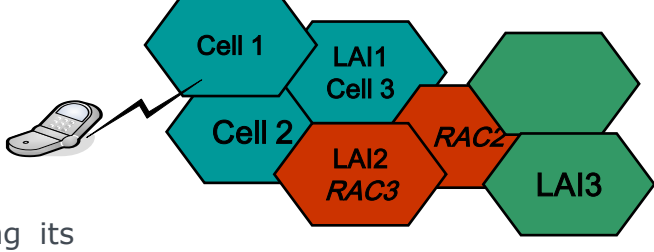
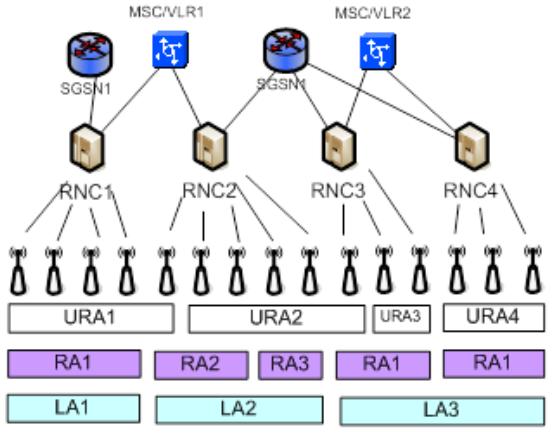
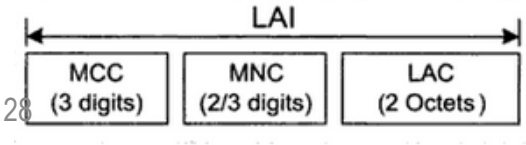
Mobile Networks Topology

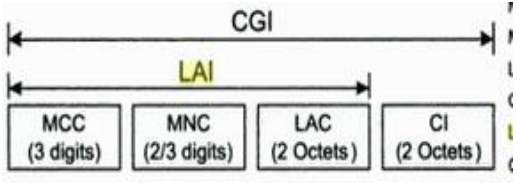


1. Location Area: The area where the MS can move freely without updating its current location at the VLR
   - If the MS moves outside the LA, it must inform the VLR by doing a Location Update
   - An LA is uniquely identified by an LAI={MCC,MNC,LAC}
2. Routing Area: it is for GPRS what LA is for GSM. It is the area where MS can move without updating the SGSN
   - If the MS moves outside the RA, it must do a Location Update towards SGSN
   - An RA is identified by an RAI={LAI,RAC}
   - The RAC (8bits) uniquely identifies an RA in an LA
3. One important difference between RA and LA is that an RA is always contained within an LA. Or, one LA may contain one or more RA.
4. Cell Global Identity: any Cell has an Identifier within GSM/GPRS realm (the CI). The CI is unique within an LA. Hence: CGI={MCC,MNC,LAC,CI}

MCC: Mobile Country Code
MNC: Mobile Network Code
LAC: Location Area Code
RAI: Routing Area Identity
LAI: Location Area Identity
CGI: Cell Global Identity
LA: Location Area
RA: Routing Area





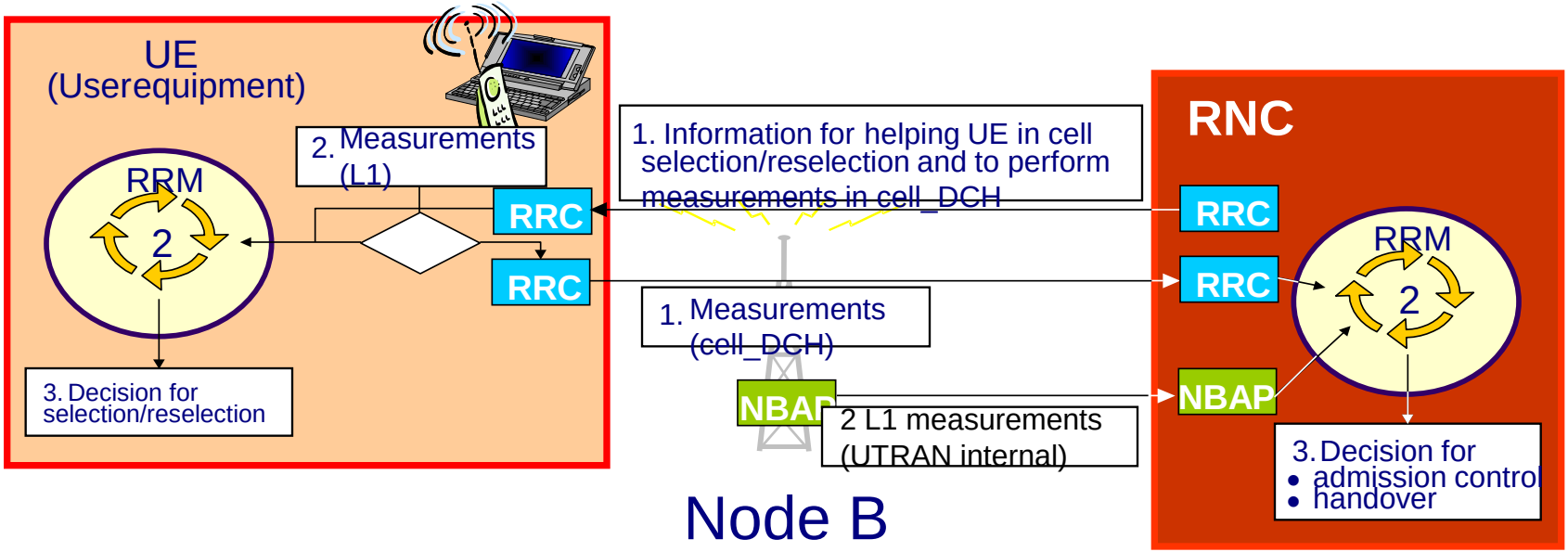


UE state and mobility scheme

1. GSM
   - MS is in Idle Mode (Camping on a GSM cell)
     - Mobility is controlled by the MS and governed by the Cell Selection / Reselection Procedures
   - MS in Connected Mode
     - Mobility is controlled by the Network and governed by the Handover Procedures

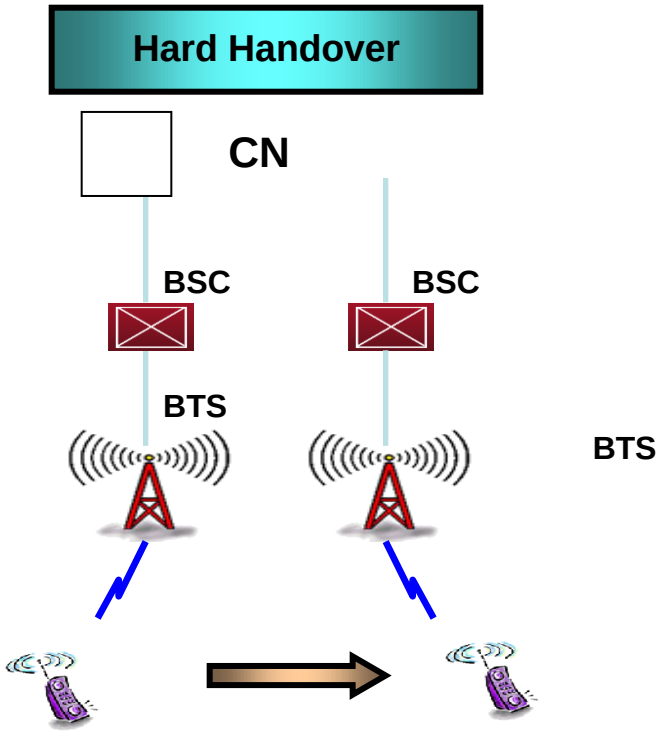
2. UMTS
   - UE is in idle mode
     - No UE-UTRAN connection (RRC idle) and no UE-CN connection (MM/GMM idle)
     - The UE mobility is governed by cell reselection principles and location updating procedures
   - UE uses shared resources on the cell (cell_FACH, cell_PCH, URA_PCH)
     - UE mobility is governed by UE measurements and cell reselection principles (like in idle mode) but UE informs UTRAN after a cell/URA change
   - UE has dedicated resources allocated (cell_DCH state)
     - A RRC connection is active and possibly a RAB and a Radio Bearer are setup (for a call)
     - UE mobility is controlled by the Network and governed by the Handover Procedures

Radio Ressources Management

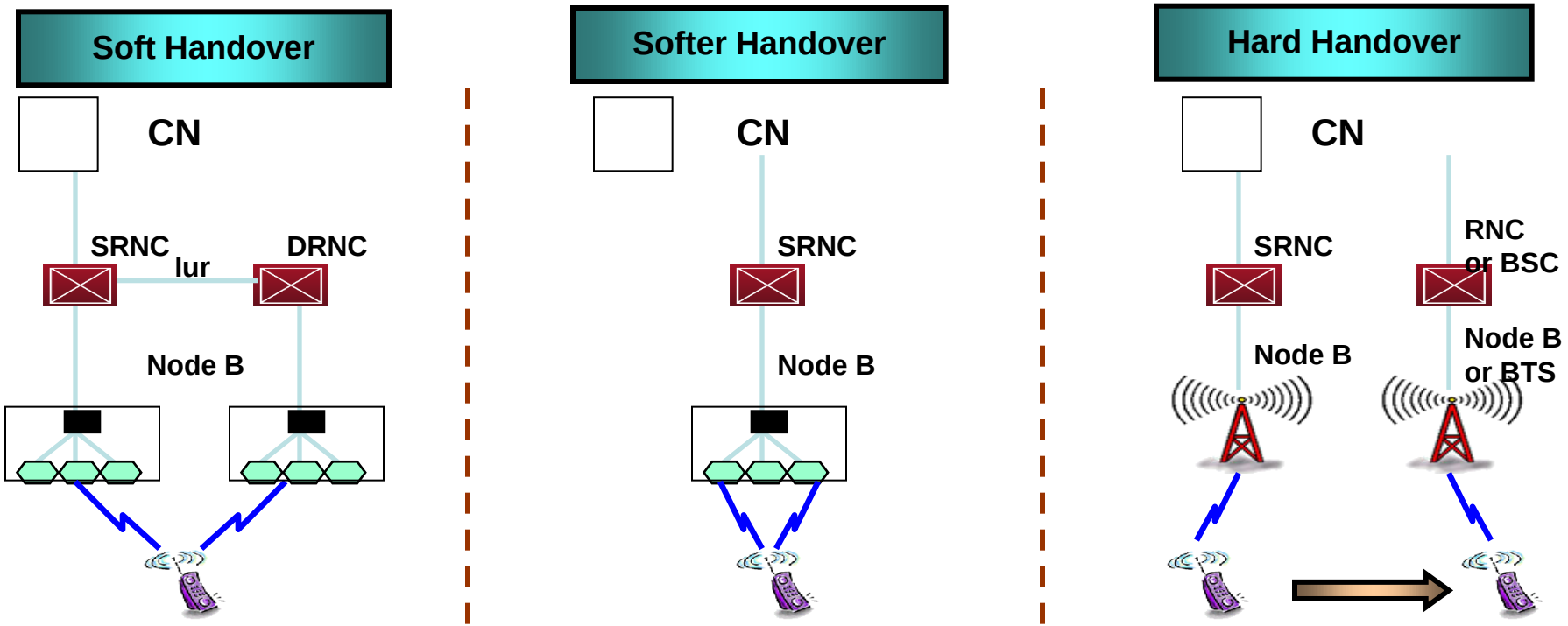


Handover in GSM

1. MS constantly monitors the quality of the radio signal received from the neighbour cells
2. Based on the measurements reported periodically by the MS the source BSC decided when the quality of the radio signal received by the MS from a neighbour cell becomes better than the quality of the radio signal of the serving cell - > HO decision is taken
3. The Target BSC performs the Access Control and informs the Source BSC if it can accept the UE
4. The source BSC gives the MS the HO command
5. The MS switches from the Source BTs to the Target BTS

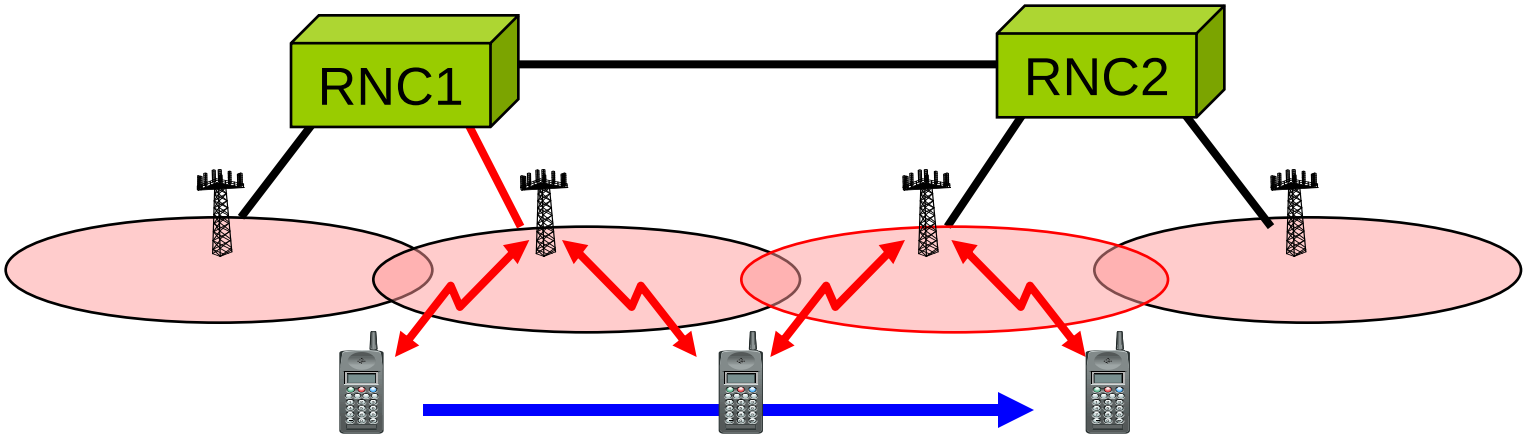


Different types of handover in UMTS



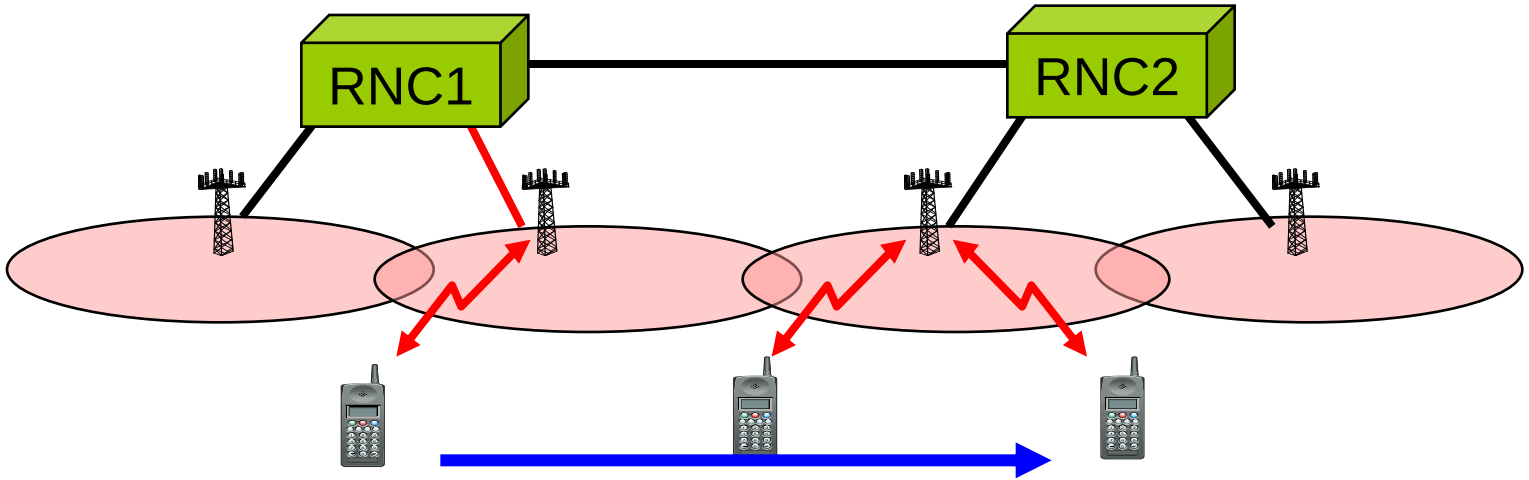
Soft/softer Handover

1. Principle : add a new radio link between UE and UTRAN when the new cell is "good", remove the old one when the old cell gets poor
   - "Make before Break" principle (in GSM, "break before make")
2. "Soft" transition between 2 cells
   - Initiated by SRNC (SRNC = Serving RNC = RNC1 here)
3. Not applicable to shared transport channels (e.g. HSDPA)



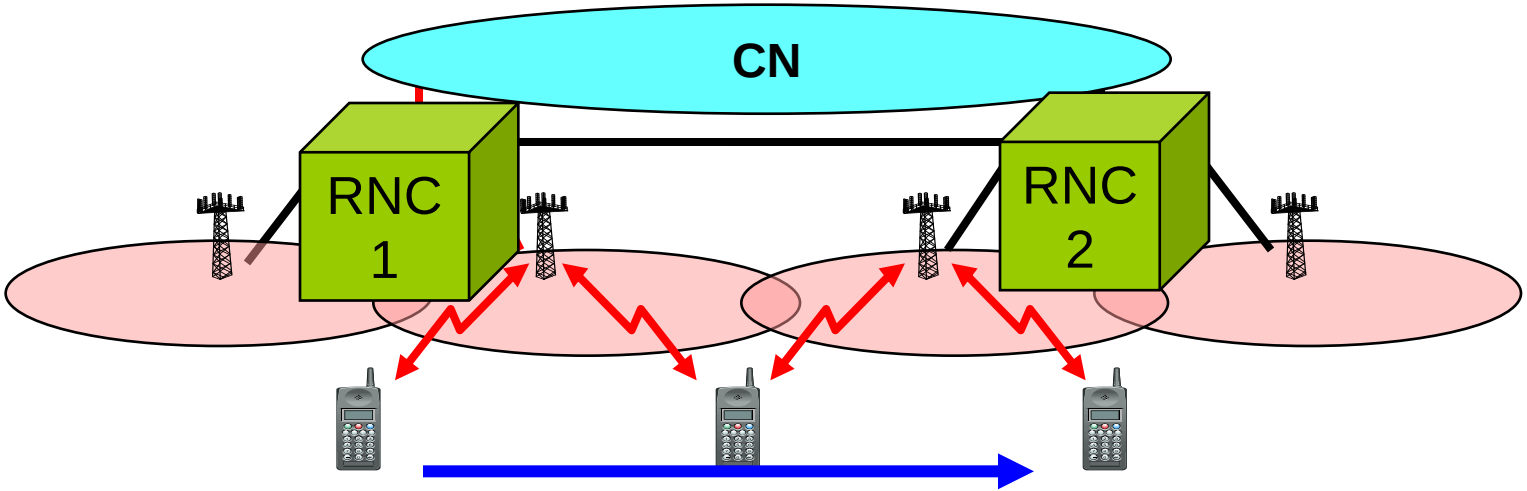
Hard Handover

1. Principle: radio link is prepared on a new cell (or several cells), but the UE switches from old cell to new cell(s)
2. "Hard" transition between 2 cells (or more)
3. Initiated by Serving RNC (RNC which has the Iu connection to the CN)
4. Applicable to both shared and dedicated transport channels



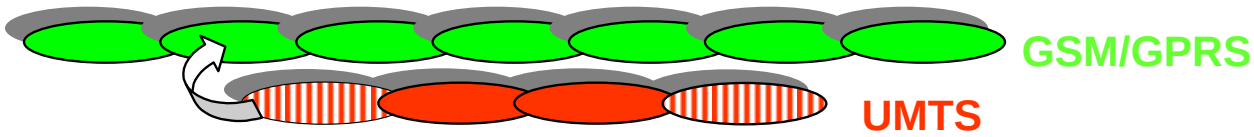
SRNS relocation

1. Principle: change the Serving RNC (DRNC becomes Serving) i.e. transfer the Iu interface to this RNC and possibly release Iur
2. Can be transparent to the UE (e.g. if no RA change)
3. Initiated by SRNC and typically triggered when all radio links are managed by Drift RNC



Inter-system handover

1. Principle: transfer a radio link between UMTS and GSM i.e. the Radio Access Technology (RAT) is changed, while the Core Network can remain the same
2. UMTS > GSM handover for a CS voice call
3. UMTS > GPRS handover for a PS data session (e.g. TV)



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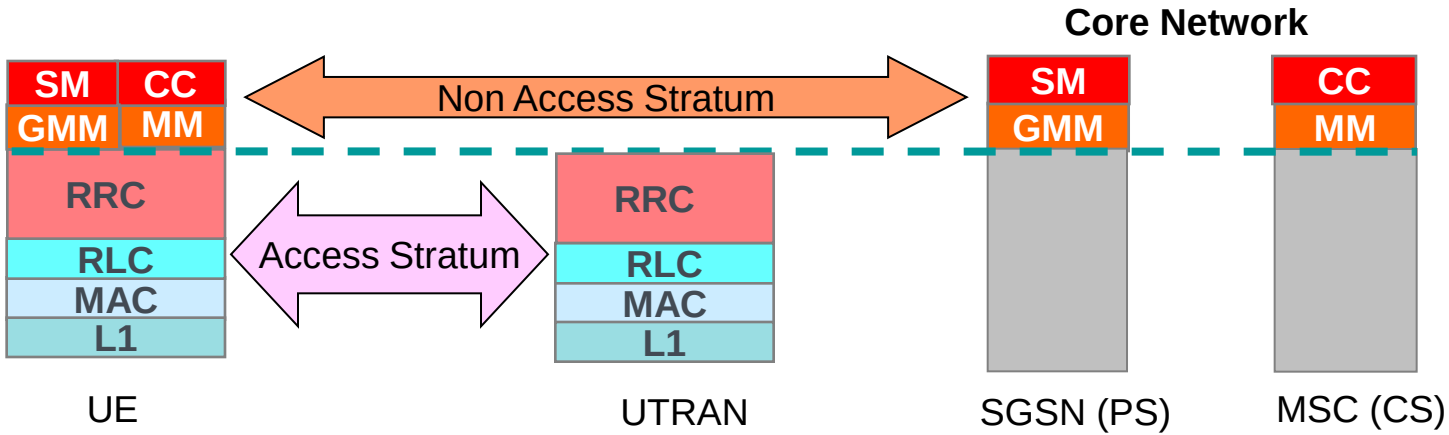
Access Stratum and Non Access Stratum

1. 3GPP protocols supported by UE are divided within
   - Access Stratum (AS): terminated in UTRAN (L1, MAC, RLC, RRC)
   - Non Access Stratum (NAS): terminated in Core Network
2. GPRS Mobility Management (GMM)/ Mobility Management (MM) procedures
3. Session Management (SM) / Call Control (CC) procedures
4. Control Plane



NAS Main Procedures

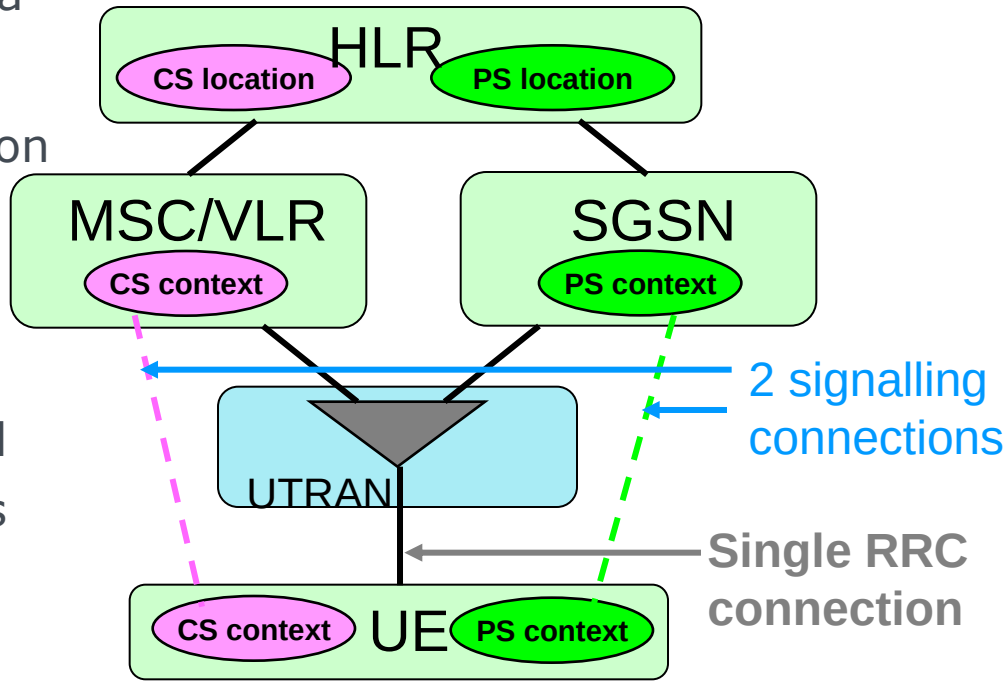
1. GPRS Mobility Management / Mobility Management (GMM / MM)
   - PLMN Registration
   - LA / RA Update
2. Call Control (CC)
   - Voice / Video telephony call setup / tearoff
3. Session Management
   - PDP Context Activation (Session initiation)
   - PDP Context Deactivation (Session deactivation)
   - PDP Context Modification (Network/UTRAN or MS initiated)

Location updating triggers

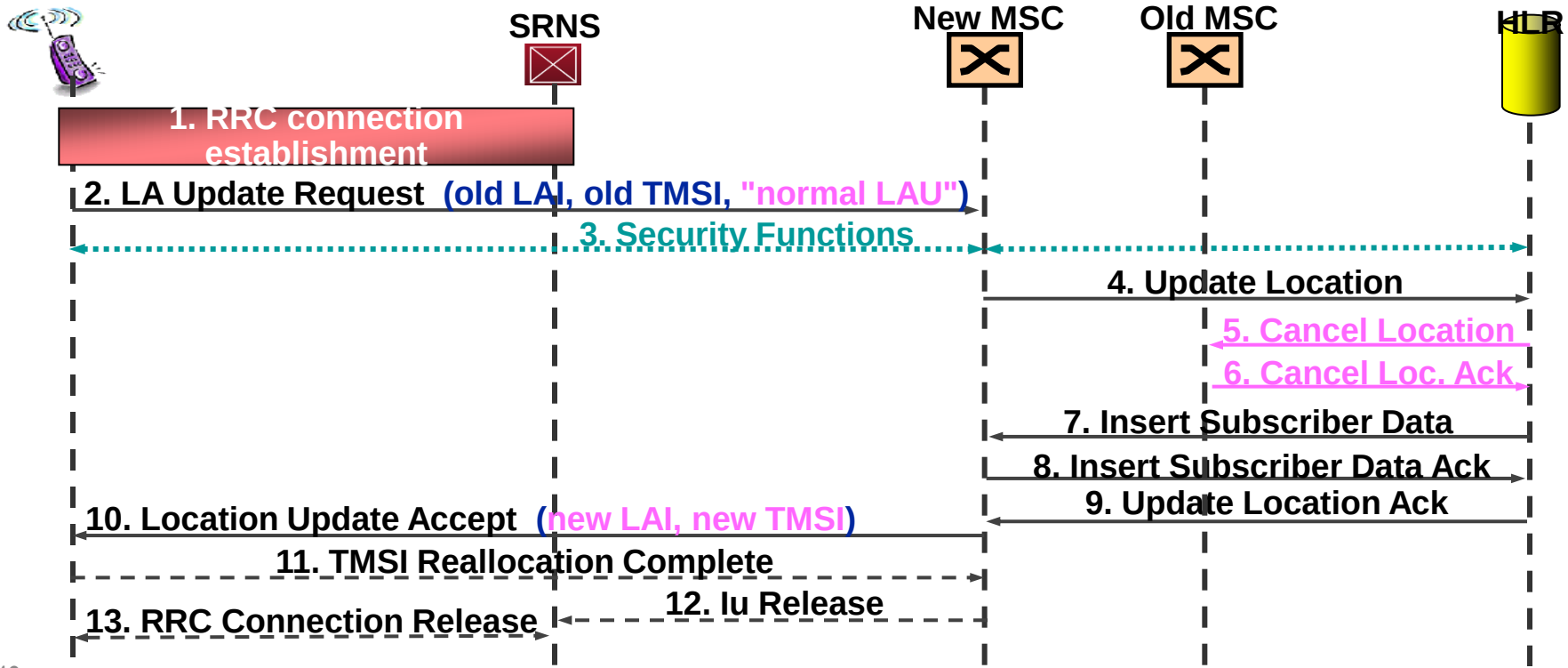
1. Change of LA/RA:
   - In RRC-idle, UE receives the System Information broadcast on the cell (BCH)
   - When a new cell is selected, the UE checks if the cell belongs to the same LA/RA as the previous cell
   - If not, it initiates an RA Update procedure (possibly together with LA Update)
2. Timer expiry (periodic update)
   - 2 different timers are used for CS and PS domains
   - Each timer is started after successful attach or location update
   - At timer expiry, UE initiates a location update procedure, indicating the type as "periodic"
   - For these periodic updates, security might not be used

Location updating main steps

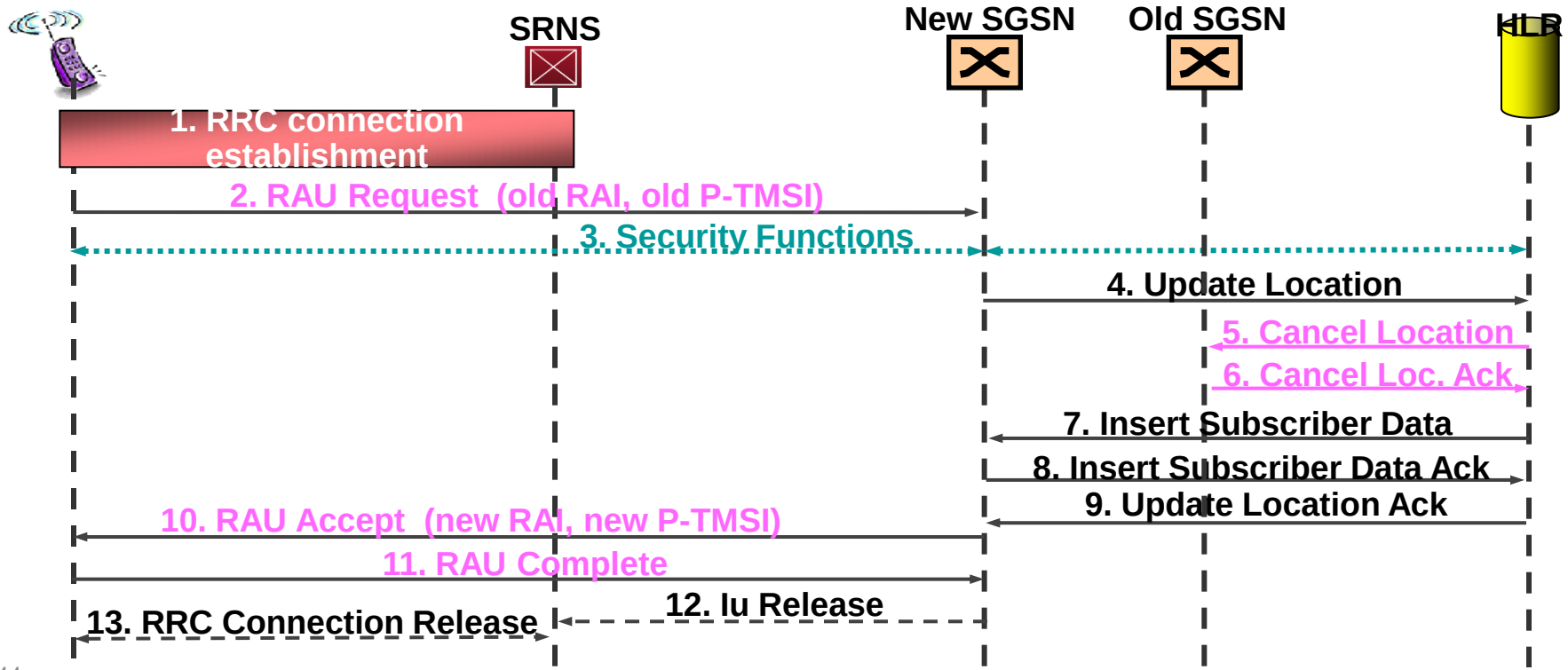
1. While in RRC-idle state, UE reselects a cell which belongs to a new LA/RA
2. When reading the new LAC/RAC on System Information of the new cell, UE decides to inform the network
3. It sets up an RRC connection and sends appropriate NAS messages to both CS and PS domains



Location Area Update (CS domain)



Routing Area update (PS domain)



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8. 5G and Virtualization
9. Conclusion

Drivers for LTE and HSPA+

1. Operators main choice for mobile system evolution is based on 3GPP
   - Easier migration from existing UMTS architecture and interoperability with existing network
   - Huge stakes in the 3GPP operator and vendor community
   - WiMAX is considered as an alternative mainly for fixed access and in regions where UMTS is not already deployed.
2. HSPA+ brings performance and capacity in existing UMTS spectrum
   - Backward compatible evolution supporting legacy terminals
   - Good performance improvements in 5 MHz spectrum allocations.
3. LTE will address new spectrum assets with improved performance
   - High flexibility for allocations ranging from 1.4 up to 20 MHz
   - FDD and TDD spectrum is addressed with essentially the same air interface
   - LTE will be deployed together with the migration of the Core Network to EPC.
   - LTE should allow for lower cost per bit thanks to lower IPR cost, flat architecture and hopefully lower operational costs.

What is LTE?

1. LTE (Long Term Evolution)
   - Evolution of UMTS Access Network (E-UTRAN)
2. Standardization mainly in 3GPP R8
   - main specifications completed in End 2008 / Beg 2009
   - Followed by 3GPP R9
   - Enhancements in R10 (March 2011) with LTE-Advanced
3. LTE ready for deployment from 2010-2011
4. EPC (Evolved Packet Core)
   - Evolution of the Core Network
   - Previously called SAE (System Architecture Evolution)
   - E-UTRAN+EPC = EPS (Evolved Packet System)
   - EPC can handle LTE as well as other 3GPP and non-3GPP access networks

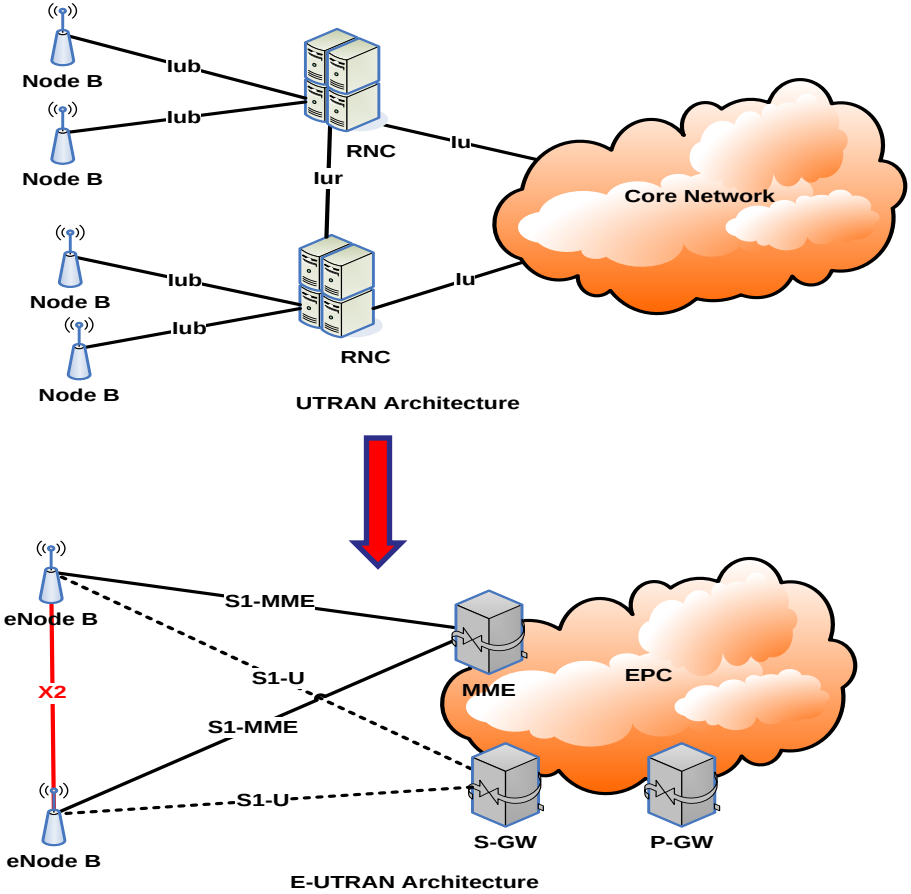
LTE performance estimations and promises

Expected performance (based on analysis and simulations)			
Peak rate (Downlink) (in 20 MHz, FDD)	144 Mbit/s	2 Tx and 2 Rx antennas, 64 QAM modulation, code rate 5/6	10x HSDPA
Peak rate (Uplink) (in 20 MHz, FDD)	56 Mbit/s (71 Mbit/s for 64QAM)	1 Tx antenna, 2 Rx antennas 16 QAM modulation, code rate 5/6	5x HSUPA
Average cell spectrum efficiency (downlink)	1.72 b/s/Hz/cell (8.6 Mbit/s in 5 MHz)	2 Tx and 2 Rx antennas MIMO transmission with linear receiver	3x HSDPA
Average cell spectrum efficiency (uplink)	0.7 b/s/Hz/cell (3.5 Mbit/s in 5 MHz)	2 Tx and 2 Rx antennas No Multi-user - MIMO	2x HSUPA
User plane latency (two way radio delay)	~ 10 ms	Assumptions: FDD, 30% retransmissions	1/5x HSUPA
Connection setup latency	< 50 msecs (dormant->active) < 100 msecs (idle ->active)		

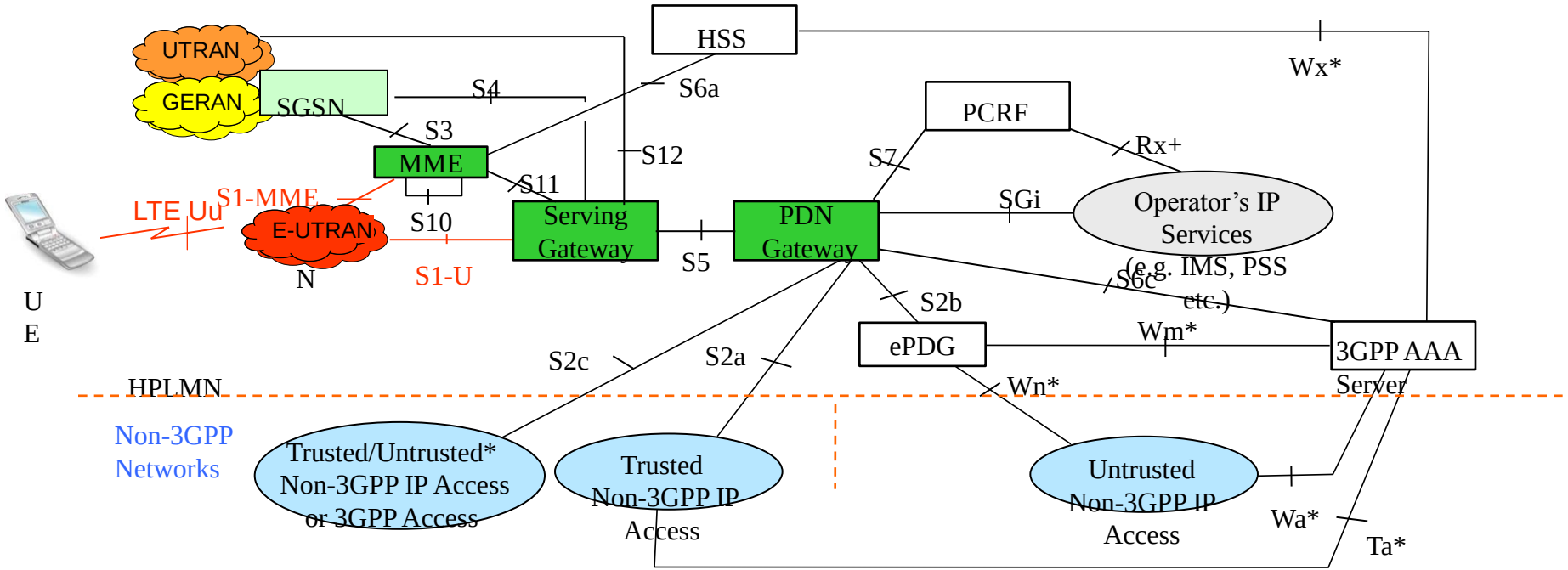
FDD: Frequency Division Duplex
TDD: Time Division Duplex
QAM: Quadrature Amplitude Modulation
MIMO: Multiple In Multiple Out

From UMTS to LTE Architecture

1. What's new in LTE?
   - RNC removal - Flat architecture
   - X2 interface
2. EPC
   - No more Circuit Switch domain
   - MME (Mobility Management Entity)
     - Control Plane handling
   - S-GW (Serving Gateway)
     - Data Plane handling
   - PDN-GW (Packet Data Network)
     - Provides IP connectivity to the UE and gives access to the PDN

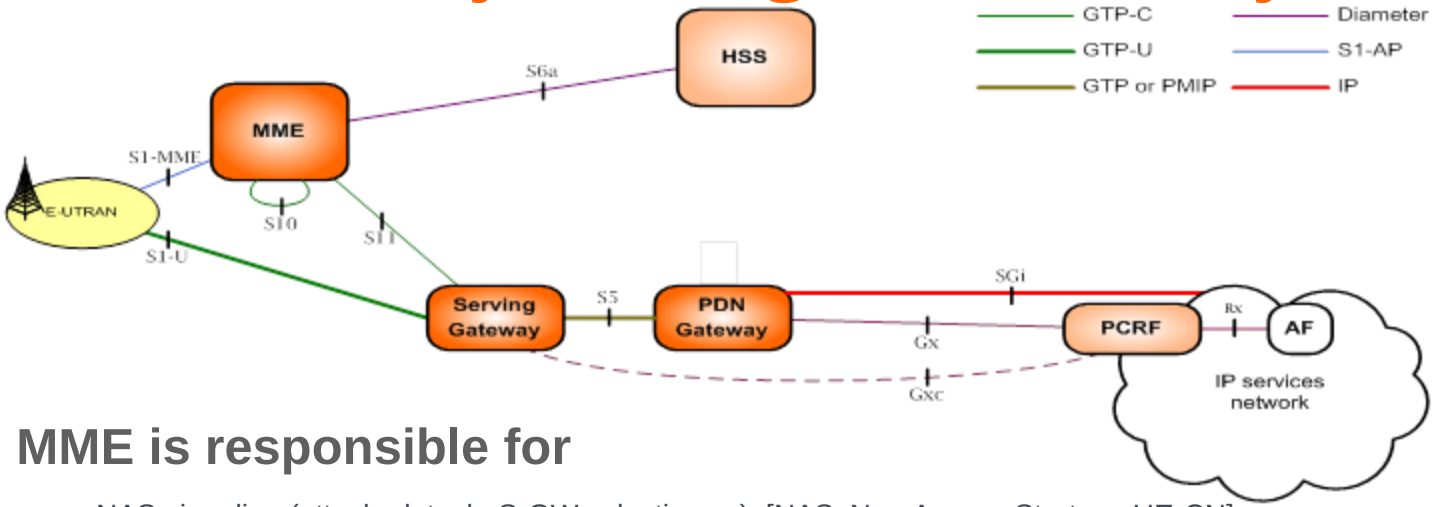


Systems overview



* Untrusted non-3GPP access requires ePDG in the data path

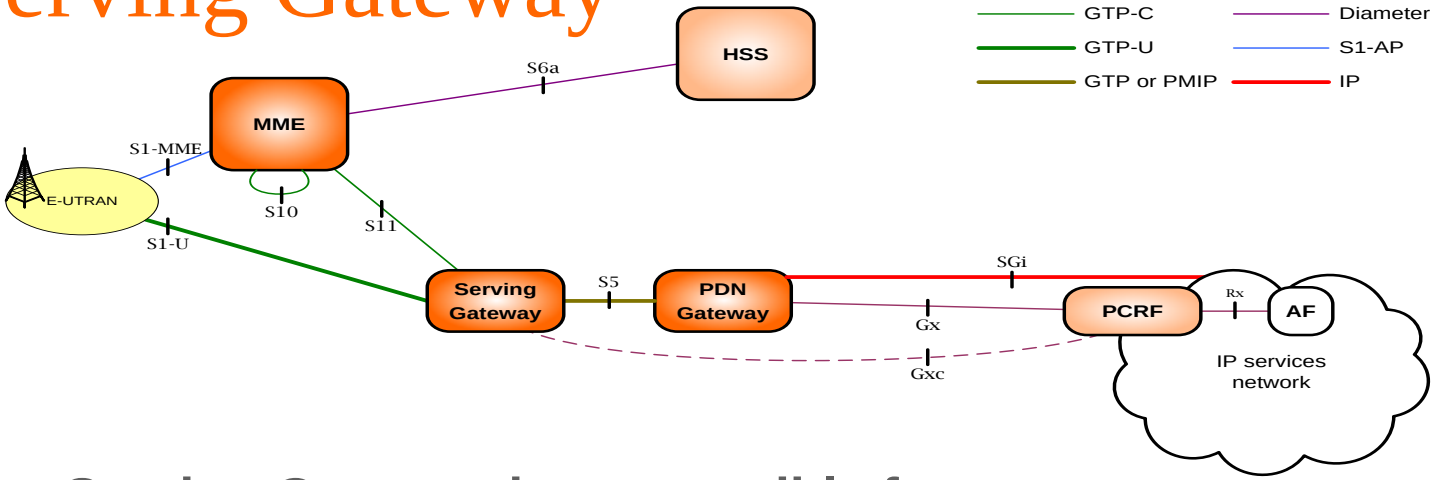
MME: Mobility Management Entity



1. MME is responsible for

- NAS signaling (attach, detach, S-GW selection,…) [NAS: Non Access Stratum, UE-CN]
- NAS signaling security (authentication, etc.)
- Inter CN node signaling for mobility between 3GPP access networks (terminating S3 [MME-SGSN])
- Idle mode UE Tracking and Reachability (including control and execution of paging retransmission)
- Roaming (S6a towards home HSS)
- Bearer management functions including dedicated bearer establishment.

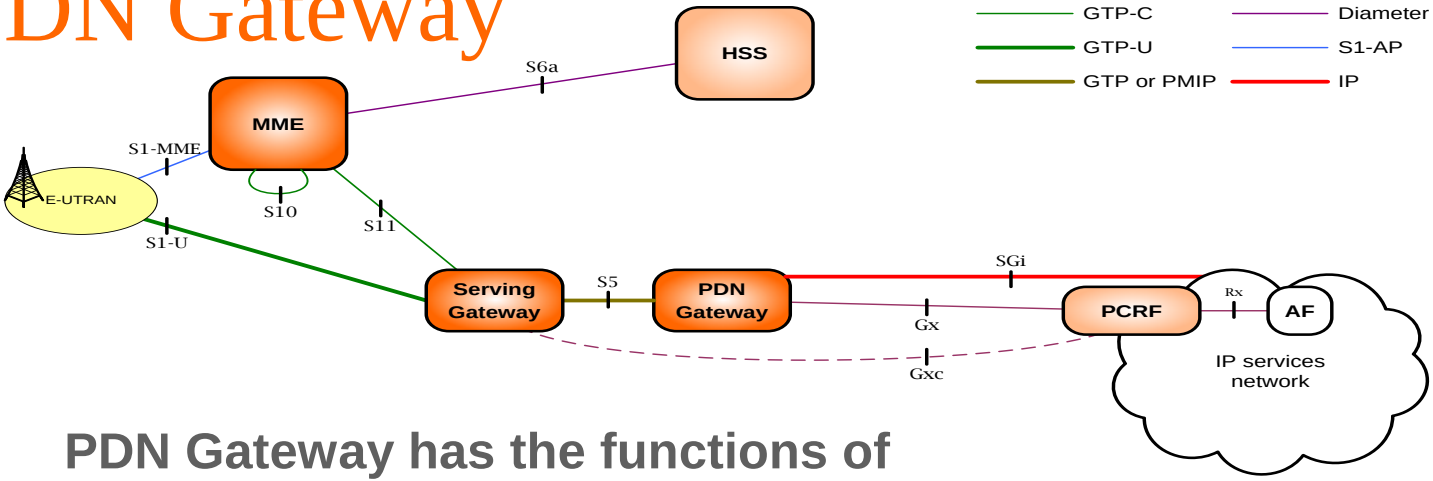
Serving Gateway



1. Serving Gateway is responsible for

- the local Mobility Anchor point for inter-eNodeB handover
- Mobility anchoring for inter-3GPP mobility
- E-UTRAN idle mode downlink packet buffering and initiation of network triggered service request procedure
- Lawful Interception
- Packet routing and forwarding

PDN Gateway



1. PDN Gateway has the functions of

- IP address allocation
- Policy Enforcement
- Per-user based packet filtering (by e.g. deep packet inspection)
- Charging Support
- Lawful Interception
- User plane anchor for mobility between 3GPP access and non-3GPP access

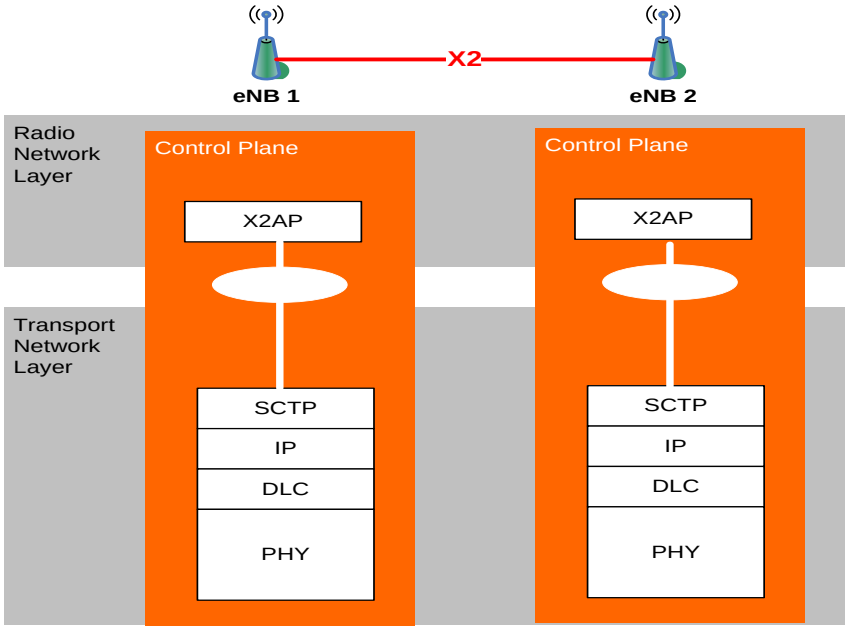
Summary

At the end of this talk, you should be able to answer the following questions:

- ❑ What are the technical names for 2G, 3G, 3G+, 4G networks?
- ❑ What are the main entities in the GSM architecture ?
- ❑ What is a handover ? How does it work in 3G ?
- ❑ What does LTE stand for ? How does it simplify 3G's core network ? Is it capable of handling voice calls ?
- ❑ To whom is the Femtocell offer targeted ?
- ❑ How does Virtualization and software impact 5G architecture ?

X2 Interface

1. Interconnects two neighbour eNBs
2. Peer to Peer Interface
3. User Plane is used only for user's data forwarding between neighbour eNBs
4. In the Control Plane the X2 Application Protocol (X2AP) is used for communication between neighbour eNBs
5. The SCTP protocol is used in the TNL to increase the reliability for signalling bearers

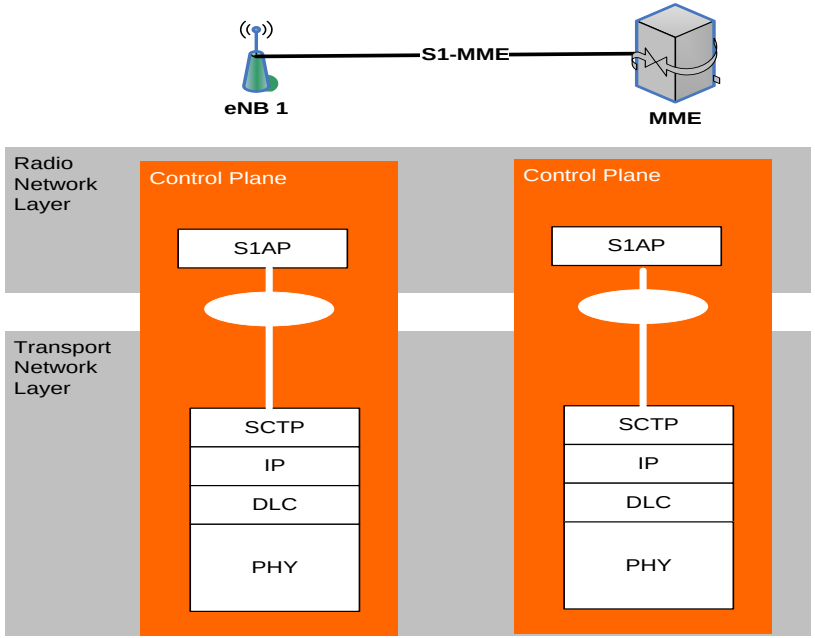


X2 Application Protocol Functions

1. Mobility Management
   - This function allows the eNB to move the responsibility of a certain UE to another eNB. Forwarding of user plane data, Status Transfer and UE Context Release function are parts of the mobility management.
2. Load Management
   - This function is used by eNBs to indicate resource status, overload and traffic load to each other.
3. Setting up and Resetting the X2 interface
4. eNB Configuration Update.
   - This function allows updating of application level data needed for two eNBs to interoperate correctly over the X2 interface.
5. Mobility Parameters Management
   - This function allows the eNB to coordinate adaptation of mobility parameter settings with a peer eNB

S1-MME (S1 control plane)

1. Connects the eNB to the Mobility Management Entity
2. The S1AP is the control plane protocol for communication between the eNB and the MME
3. The SCTP protocol is used in the TNL to increase the reliability for signalling bearers

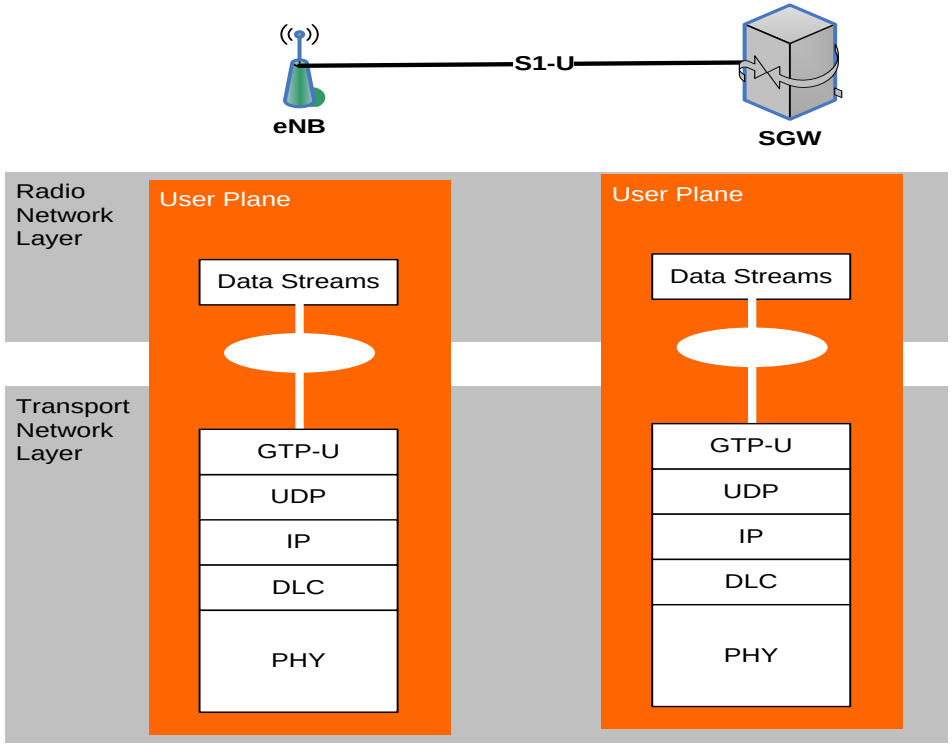


S1 Application Protocol Functions

1. Initial Context Transfer
   - establish a S1UE context in the eNB
2. UE context management
   - S1 UE context modification
   - S1 UE context release in the eNB and the MME
3. E-RAB management
   - set up, modify and release of E-RABs
4. NAS Signalling transport between the UE and the MME
5. Paging
6. Mobility Functions for UEs in LTE_ACTIVE
   - S1 Handover
7. S1 management functions

S1- U (S1 user plane)

1. Transports UEs data streams between the eNB and the Serving Gateway
2. The GPRS Tunnelling Protocol is used to protect user's data streams



LTE States / Modes

LTE Idle State

1. Mobility: Cell Reselection
2. Location Registration: UE position known at Tracking Area Level In the MME
3. Identity: IMSI + TA I
4. S1 connection: none
5. Radio Resources: none (UE listen to BCCH and PCH)
6. NAS context stored in the MME / S-GW

LTE Active State

1. Mobility: eNB controlled HO based on UE measurements
2. Location Registration: eNB address known in the CN, LA updates, Cell Level in E-UTRAN
3. Identity: IMSI + TA I, C-RNTI
4. S1-C connection towards the MME, and possible several S1-U connection towards the S-GW
5. Radio Resources: Dedicated Channels

EPC States / Modes

EPS: Evolved Packet System (basically EPC)
EMM: EPS Mobility Management
ECM: EPS Connexion Management
RRC: Radio Resource Control

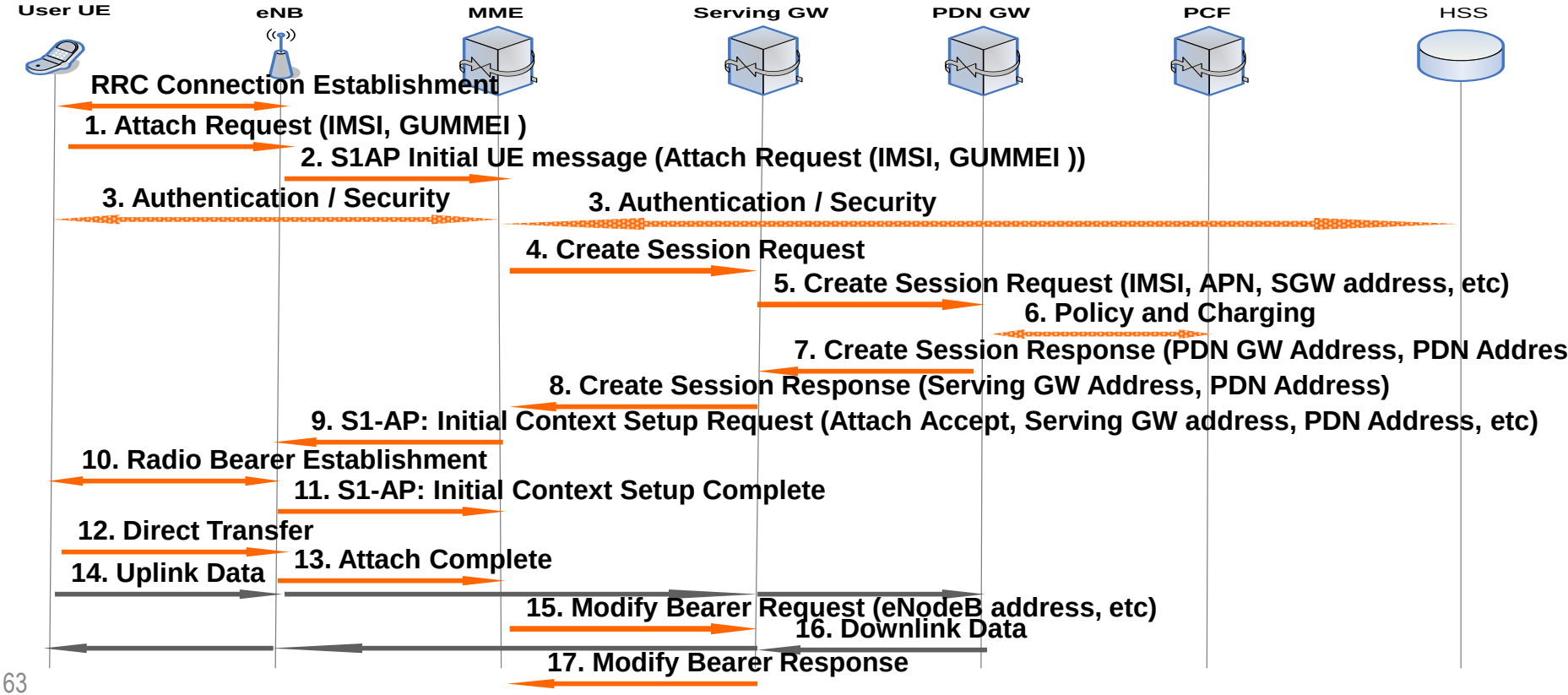
Layer	State	Entity	Description
EMM	EMM-Deregistered	UE, MME	UE is not attached to any LTE network. MME does not know the current location of the UE, but may have tracking area (TA) information last reported by the UE.
	EMM-Registered	UE, MME	UE has been attached to the LTE network and an IP address has been assigned to the UE. An EPS bearer has been established. The MME knows the current location of the UE with an accuracy of a cell or, at least, a tracking area.
ECM	ECM-Idle	UE, MME	No NAS signalling connection (ECM connection) established yet. UE has not been assigned physical resources, i.e. radio resources (SRB/DBR) and network resources (S1 bearer/S1 signalling connection) yet.
	ECM-Connected	UE, MME	NAS signalling connection (ECM connection) is established. UE has been assigned physical resources, i.e. radio resources (SRB/DRB) and network resources (S1 bearer/S1 signalling connection).
RRC	RRC-Idle	UE, eNB	No RRC connection is established yet.
	RRC-Connected	UE, eNB	RRC connection has been established.

Mobility Procedures

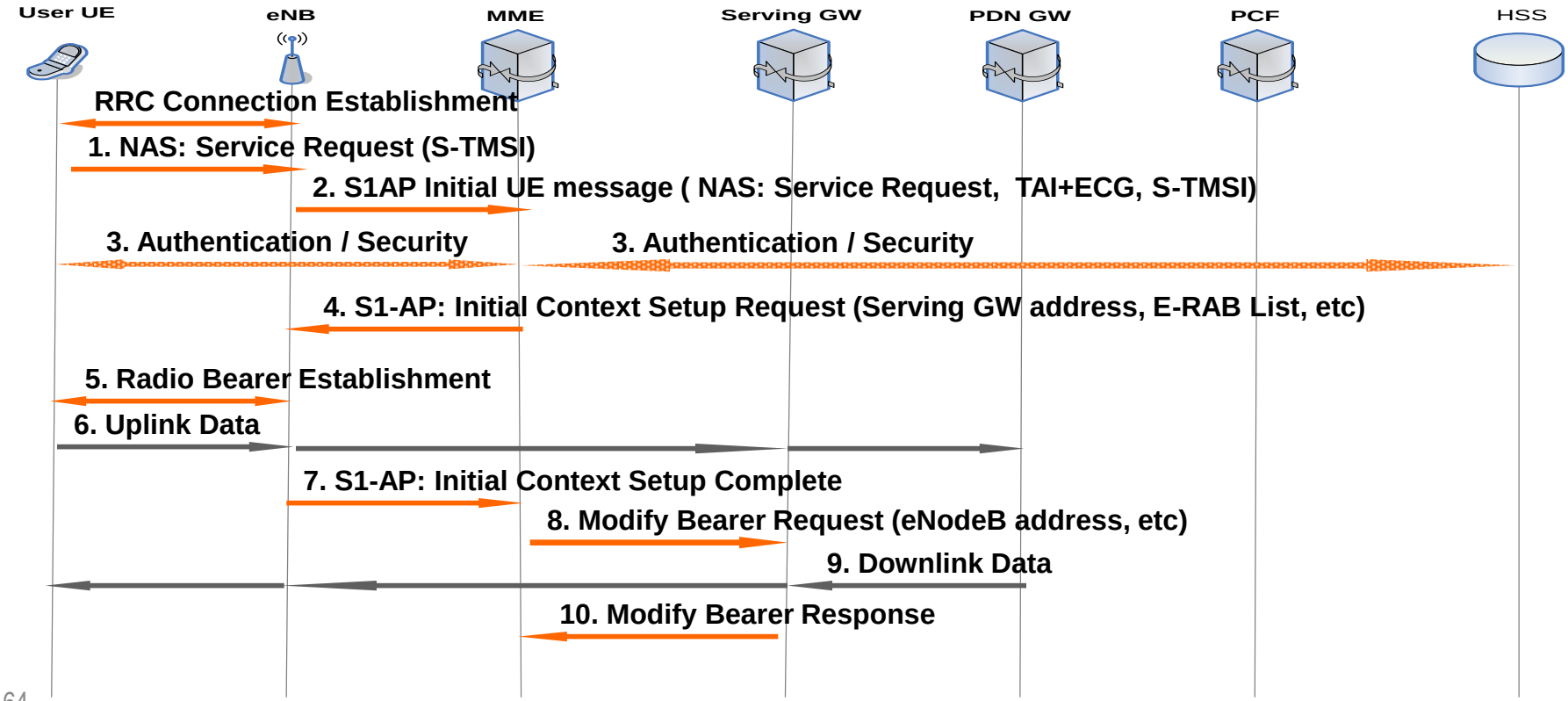
1. In LTE IDLE state, UE mobility is performed by Cell Selection / Cell Reselection Procedure

2. In LTE ACTIVE state, UE mobility is performed by Handover Procedures

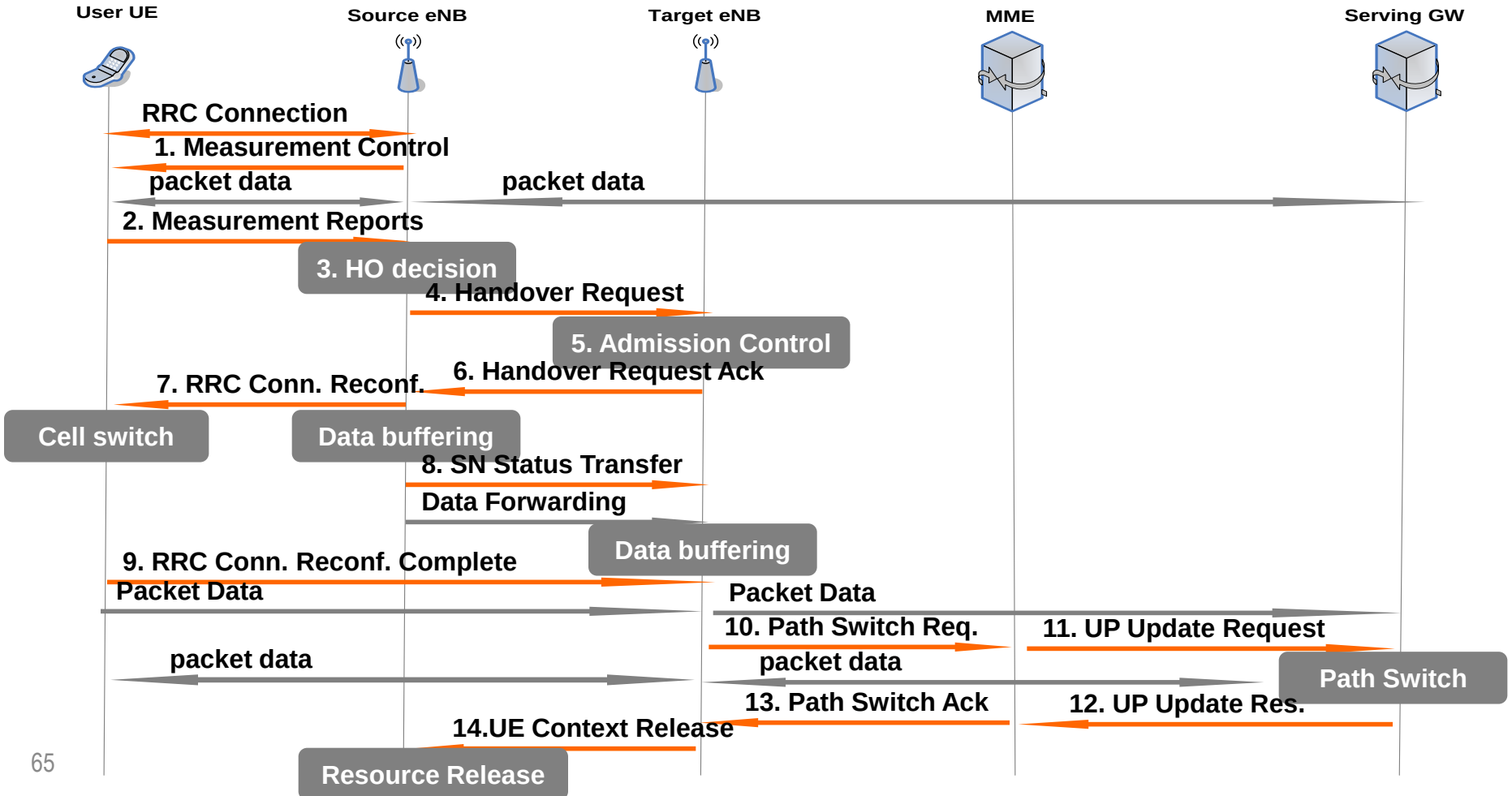
LTE Initial attach – Call Flow



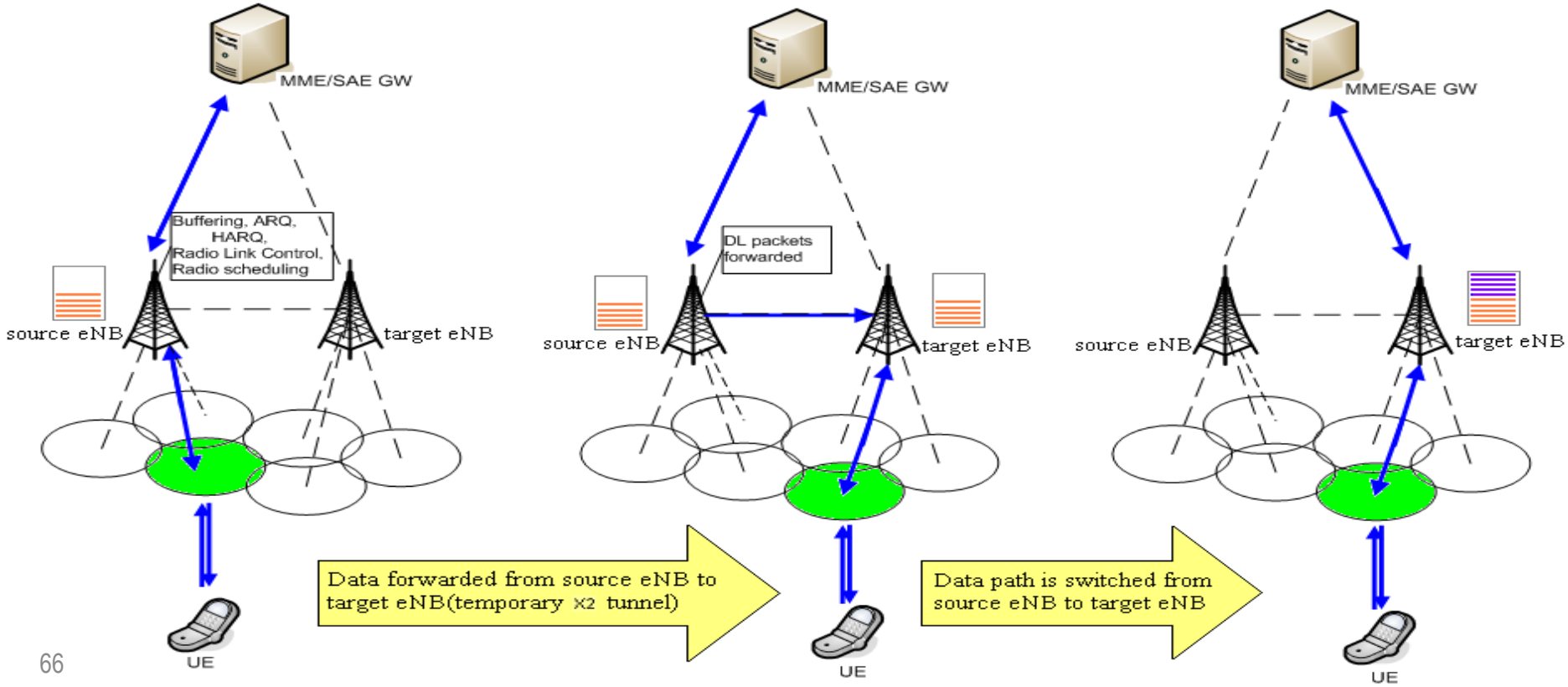
Service Request – Call Flow



Handover Intra MME/SGW



LTE Handover



LTE Handover

1. New mobile procedure due to flat architecture
2. Most mobility functions located in eNBs
   - Mobility decision in eNB
   - Buffering in eNB
   - Data forwarding on X2
3. No involvement of CN until successful HO
   - Path switch
4. Consequences
   - (-) frequent transfer of UE context between eNBs
   - (-) interruption time (hard handover)
   - (-) data forwarding : reordering by target eNB
   - (+) very reactive

Multimedia Broadcast Multicast

1. Solution for delivering a common content to several users, at the same time, with a view to optimizing resources

2. Well adapted for TV broadcast
   - Similar usages as DVB-H
   - Event based streaming (*e.g.* live football)
   - Not adapted for video on demand

3. Specified in 3GPP R9 and enhanced in R10.
   - Architecture: Need of new entities to ensure MBSFN synchronization

4. Unicast and MBMS share the same telecom infrastructure (BS, CN)

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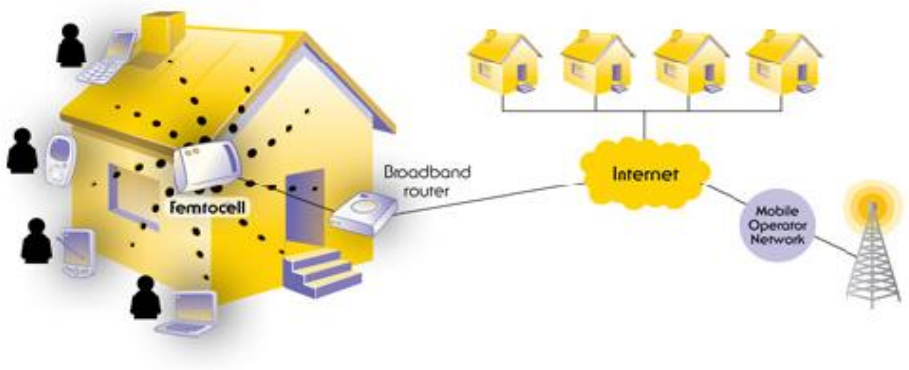
Definitions



- Femtocells are reliable solution for indoor communications enhancements
- Femtocells are small low-cost low-power wireless access points
- Femtocells operate in licensed spectrum to connect standard mobile devices to a mobile operator's network using residential DSL or cable broadband connections
- From 3GPP point of view femtocells are residential base stations: Home (e)NodeBs or H(e)NBs

1. User benefits
   - Increased indoor coverage
   - Different charging models
   - Improved quality of service, higher rates data services.
   - Better battery life
2. Operator benefits
   - Indoor coverage extension
   - Reduce load and cost on the macro network
   - Reuse of fixed-line network for transport network
3. Operators challenges
   - Low cost implementation
   - Network architecture harmonization
   - Manage the Interference between femto and macro networks

Femto Cells Standardisation

1. 3GPP is the main standardisation group for
   - Generic Access Network (GAN)
   - Wireless Local Area Network (WLAN) interworking (I-WLAN)
   - Femto UMTS and LTE
2. Femto Forum
   - Femto Forum is a not-for-profit membership organisation founded in 2007 for the promotion of femtocell deployment worldwide.

Femto Access Control

1. Access Control
   - enables restricting the access to a Femto cell to a well defined group of users called **Closed Subscriber Group** identified by the **CSG ID**.
2. CSG Cell
   - A Femto cell that implements access restrictions is also called **CSG Cell**. The CSG ID of the group of users allowed to access the cell is broadcasted in the cell.

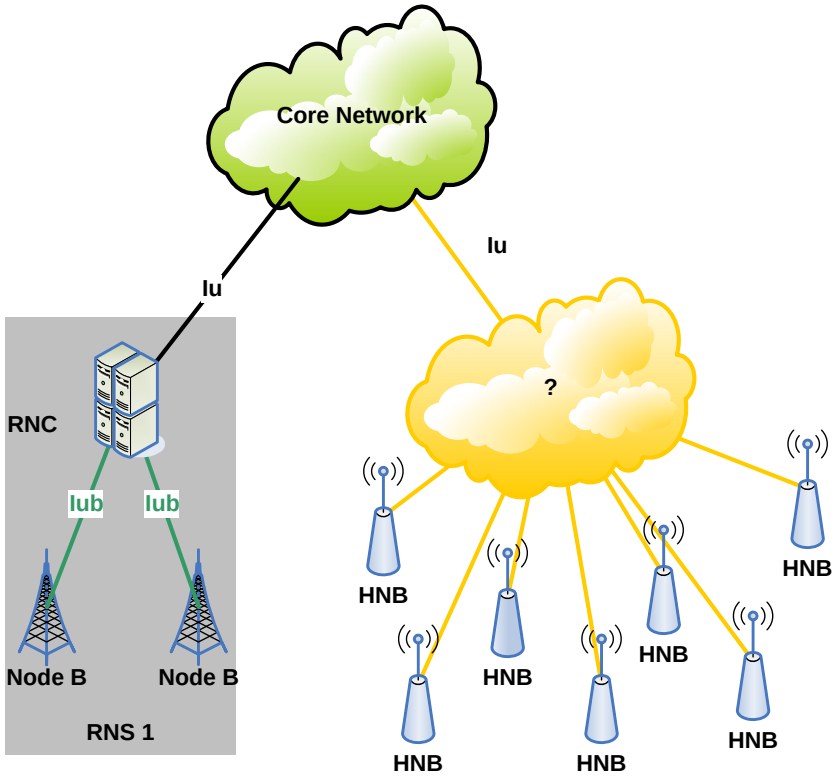
1. Access Mode
   - **Closed**: a closed CSG cell only allow restricted access to the UEs belonging to the CSG
   - **Open**: all the UEs can access the open cell. There is no access control.
   - **Hybrid**: a hybrid HeNB operates like a CSG cell but at the same time authorizes non CSG members to access it
2. White List
   - is a list stored in the UE containing all the CSG ID of the CSG the UE is a member and therefore allowed to access the corresponding CSG Cell

Femto Mobility

1. Mobility Procedures
   - If the UE is in connected / active mode the mobility is preformed by the handover procedures
   - If the UE is in Idle mode the mobility is preformed by the cell selection / cell reselection procedures
2. CSG selection / reselection
   - UE is camping idle mode on a macro cell and then select / reselects a CSG cell

1. Inbound Handover
   - UE performs a handover from a macro cell to a femto cell
2. Outbound Handover
   - UE performs a handover from a femto cell to a macro cell
3. Intra / Inter CSG Handover
   - UE performs a handover between two CSG cells broadcasting the same / different CSG IDs

Architecture Requirements for Femto Cells



1. **Scalability**
   - A H(e)NB serves only a few users (e.g.. the members of a family)
   - Potentially, the number of H(e)NBs that have to be deployed in the network may be extremely high
2. **Self configuration**
   - Not all the users are 3G network planning experts – H(e)NB must have self configuration capabilities
3. **Security**
   - Prevent unauthorized H(e)NB to connect to Core Network
4. **Interconnection with the existing Core Network**
   - H(e)NBs have to be connected to the Core Network via the existing RNS interfaces

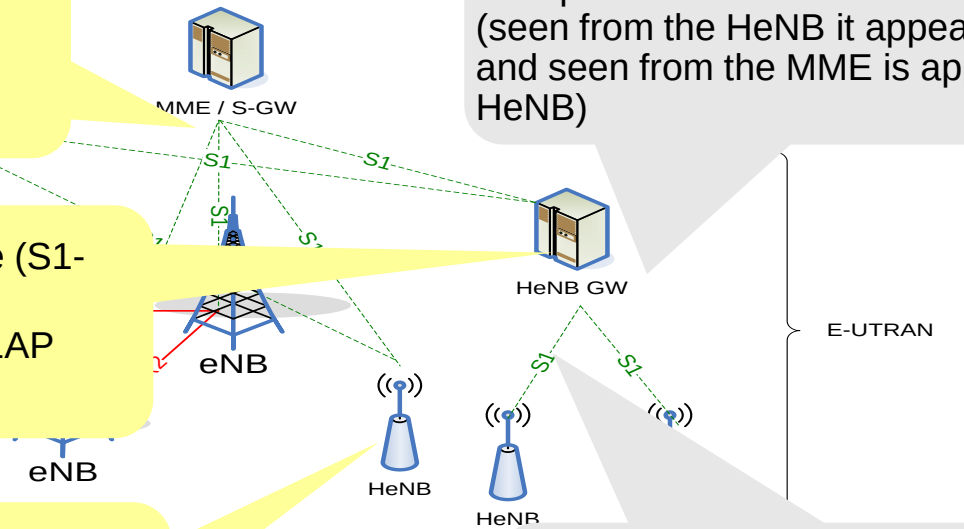
LTE Home eNodeB Architecture

MME (EPC)
Performs CSG access control

HeNB GW
Concentrator for the S1 Control Plane (S1-MME)
Terminates the non UE associated S1AP procedures

HeNB
Provides CSG coverage
Discovery of the HeNB GW

HeNB Gateway (HeNB GW) is optional and transparent node
(seen from the HeNB it appears as an MME and seen from the MME is appears as an HeNB)



No specific interface is defined for the HeNB..
S1 Interface is used to connect the HeNB either to the EPC or to the HeNB GW
SI Flex is not supported when the HeNB is connected trough the HeNB GW.

Femto Cells Evolutions

1. In 2012 Femto Forum becomes Small Cells forum
2. Small Cells becomes synonym of Femto, Pico and Micto base station
3. The architecture chosen for the small cells shapes the telecommunication industry.

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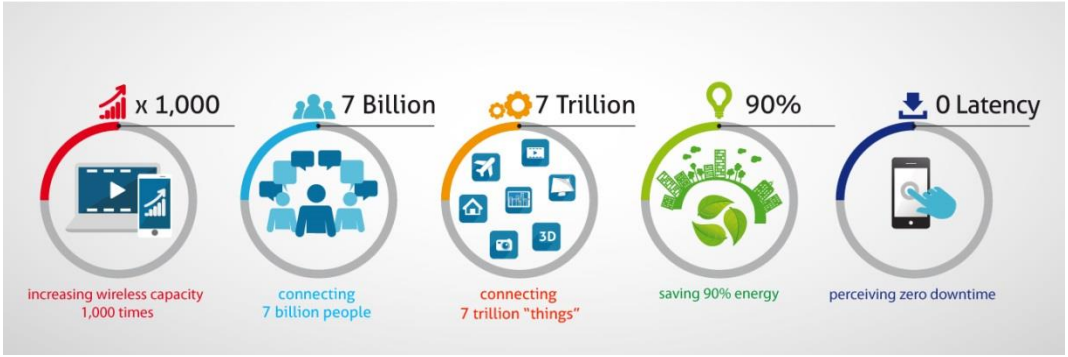
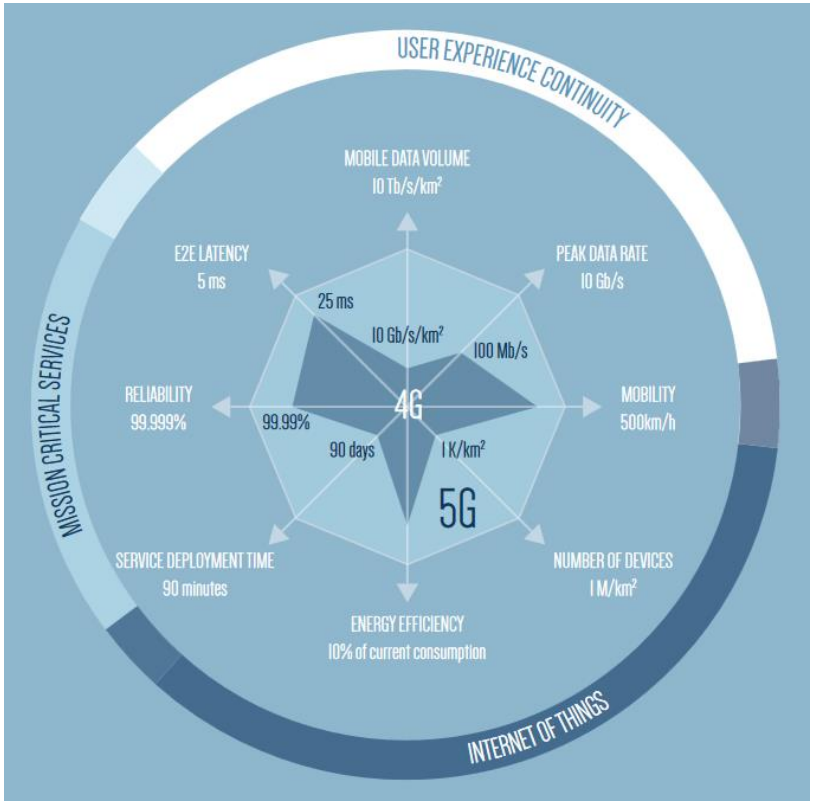
5G promises and context



Notable new standardization bodies and consortiums

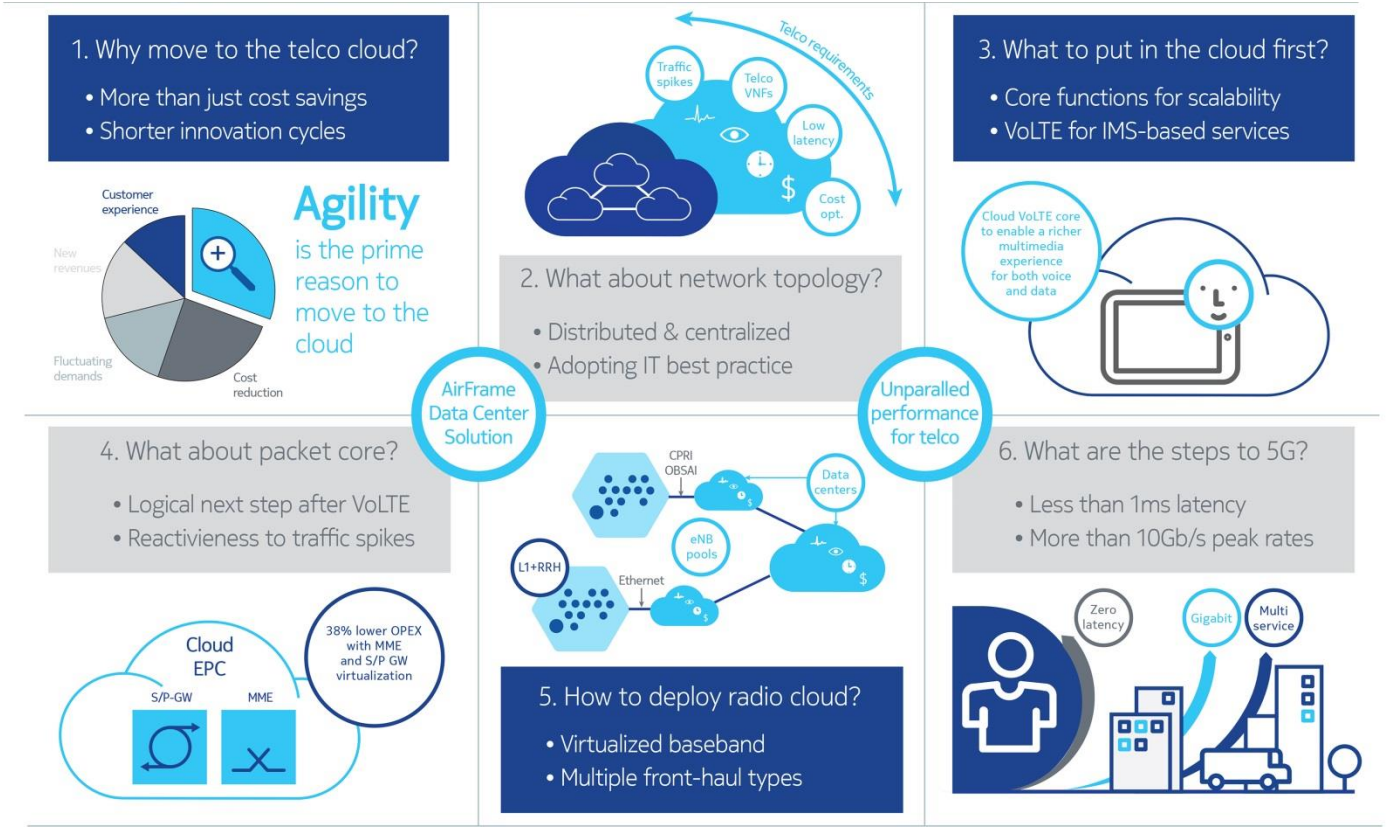
5G PPP
The 5G Infrastructure Public Private Partnership

ngmn
the engine of broadband wireless innovation
ngmn - next generation mobile networks



Radar diagram of 5G's disruptive capabilities
(5G-Vision-Brochure-v1.pdf)

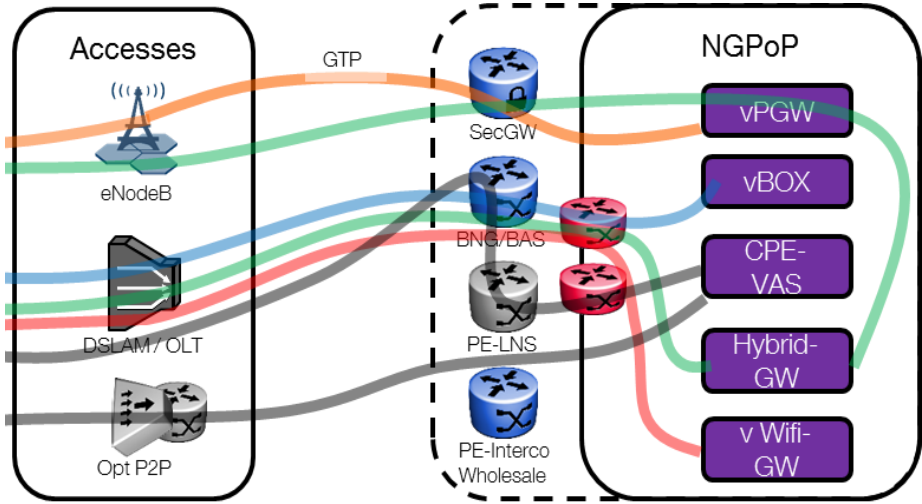
5G and the cloud



Source: Nokia networks

Host VNFs in regional PoPs

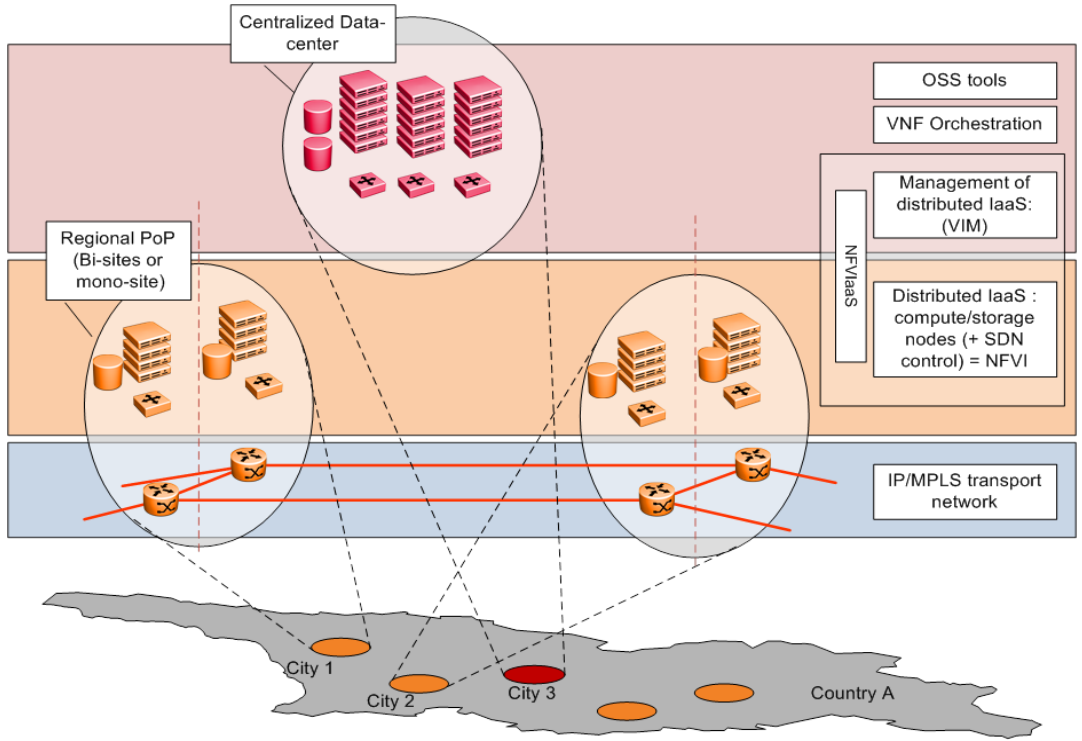
- Next generation points of presence must be capable of hosting IT components
- Solutions for Infrastructure virtualization are considered closely: Opensatck, Docker
- Other opensource projects can be considered for VNFs: openairinterface, Gnu Radio and more



How to adapt to virtualization on a country level

- Operators must rationalize of capital expenses and embrace the 5G challenges:

Solution: Leverage on existing physical infrastructures (sites, transport networks), progressively rationalize and adapt them to host IT infrastructures



What about other aspects of 5G ?

- The radio frequency/spectrum is not decided yet
- The infratructure and inter-operability is not decided yet
- The use case are numerous: they must be refined
- The costs of it all are unclear
- Some of these questions should clear up by first deployments:
  - South Korea Telecom should be the first by 2018, closely working with Samsung and Ericsson
  - Others may follow by 2019 or 2020
- For the time being, a lot of research and collaborations

Orange, Ericsson hit 17Gbps in first outdoor 5G test in Spain

Monday 25 September 2017 | 15:10 CET | News

Orange and Ericsson have conducted the first test of 5G technology in real outdoor surroundings in Spain, reaching speeds of 12 to 17Gbps at street level, reports EFE. The trial was conducted outside Ericsson's Spanish headquarters on calle Retama in central Madrid, with the companies using a 5G base station weighing 300 kilograms as well as Multi-User MIMO (MU-MIMO) and complex beamforming technology to simulate customer experience at street level. Average

Ericsson to explore 5G for smart manufacturing with Comau

Tuesday 28 February 2017 | 16:54 CET | News

Ericsson has partnered with Comau, a specialist in industrial automation products, systems and solutions, to explore the potential of 5G for smart manufacturing. The companies will explore using advanced Internet of Things (IoT) systems for industrial automation and harness existing and future 5G network technologies, IoT platforms, cloud and Big Data solutions, to develop smart manufacturing, maintenance and quality control. The collaboration also aims to establish a

Ericsson launches cross-industry 5G for Europe programme

Thursday 17 September 2015 | 12:09 CET | News

Ericsson has announced the launch of a multi-partner 5G research and development (R&D) programme that brings together major industrial players, the public sector and leading universities across Europe. The company said the 5G for Europe programme will focus on delivering research, innovation and industrial pilots that use next-generation 5G networks as an enabler. The ultimate aim is to initiate cross-industry research collaborations focused on the

Summary

At the end of this talk, you should be able to answer the following questions:

- What are the technical names for 2G, 3G, 3G+, 4G networks?
- What are the main entities in the GSM architecture ?
- What is a handover ? How does it work in 3G ?
- What does LTE stand for ? How does it simplify 3G's core network ? Is it capable of handling voice calls ?
- To whom is the Femtocell offer targeted ?
- How does Virtualization and software impact 5G architecture ?

Summary

1. Introduction to mobile networks architecture
2. GSM – EDGE Radio Access Network (GERAN) Architecture
3. UMTS Terrestrial Radio Access Network (UTRAN) Architecture
4. Mobility Procedures in GERAN / UTRAN
5. Fundamental Mobile Network Procedures
6. LTE Architecture
7. Femto Cells / Small Cells
8. 5G and Virualization
9. Conclusion

Conclusion

1. UTRAN architecture is an evolution of the GERAN architecture
   - Introduction of the Iur interface
   - Support of new mobility scheme
2. When evolving from 2G to 3G the complexity of the Node B / BTS increases.
   - RMM functions are moved closer to the radio interface (from BSC/RNC to Node B / BTS)
3. To better cope with data services UTRAN enables the transport over IP in the radio access network
4. LTE is a “revolution” compared to UMTS
5. 5G has a lot of potential and promises but is still heavily under development