Self-configuration

Chapter 4

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Outline

Introduction

Auto connectivity and commissioning

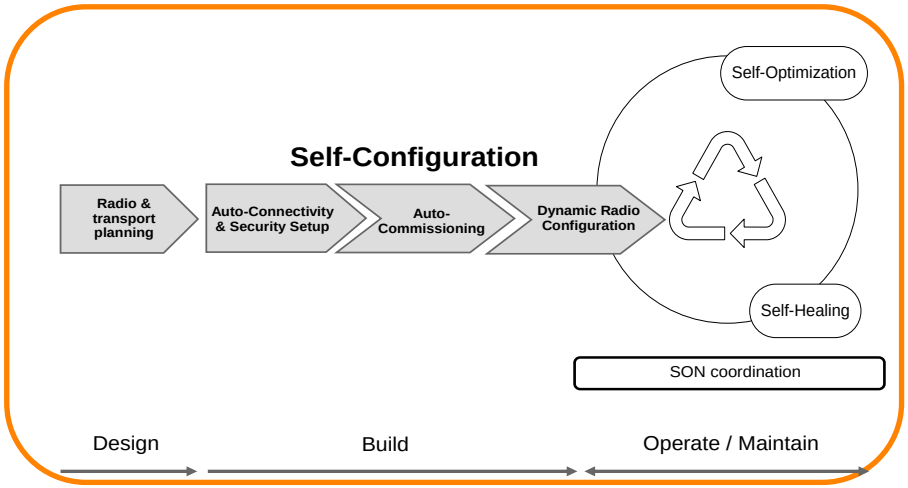
Dynamic radio configuration

Self-configuration
Auto connectivity and commissioning

Auto-connectivity with minimized manual intervention and secure setup
- Automatic setup of secure connectivity between NE and OAM system
- Site identification

Auto-commissioning for network element with off-the-shelf software and configuration
- Automatic inventory update and SW download
- Automatic CM data base preparation and download

Dynamic radio configuration during on-line
- Omitting detailed radio planning
- Reduced labor intensive planning
- More accurate parameter setting based on measurements from actual network



Plug and Play
One-Touch Base Station Deployment

Factory Assembly

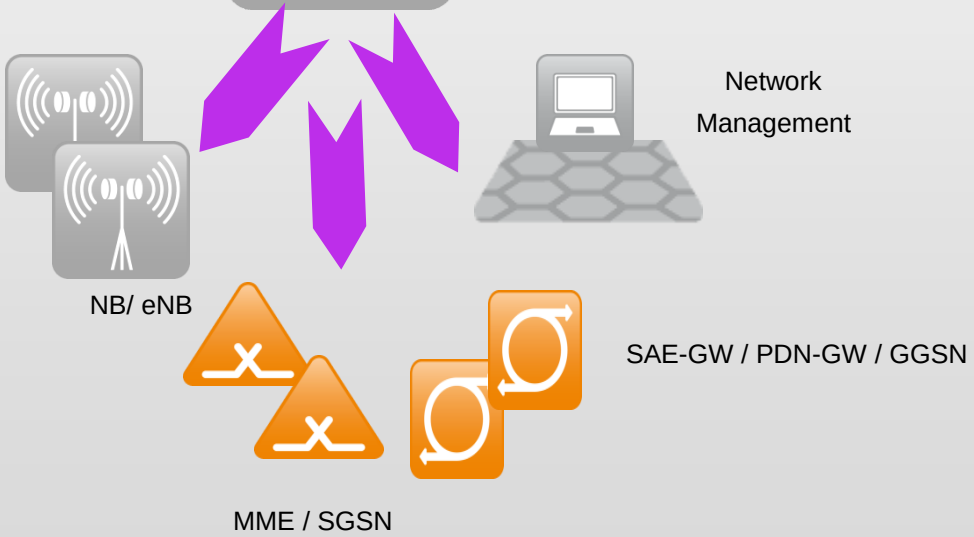
Shipping

Plug-and-play Installation

Auto connection, configuration and commissioning

Auto-connectivity with minimized manual intervention and secure setup

Auto-commissioning for network element with off-the-shelf software and configuration



Outline

Introduction

Auto connectivity and commissioning

Dynamic radio configuration

Auto connectivity and commissioning

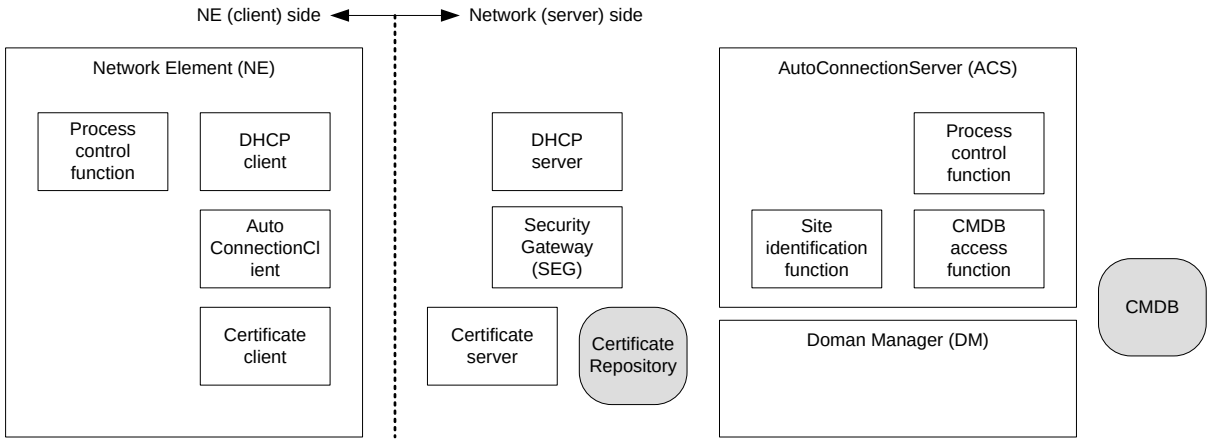
Auto-connectivity and –commissioning involves the following steps

- Setup of basic connectivity
- Initial secure connection setup
- Site identification
- Download of configuration and transport parameters
- Secure connections setup with domain manager

Auto connectivity and commissioning

Involved entities with auto-connectivity and –commissioning

- eNB
  - Process control: control of the auto-connectivity and –commissioning sequence of steps
  - DHCP client: retrieval of the initial IP configuration
  - Certificate client: retrieval/storage of the NE certificates
  - Auto-connection client: establishment of secure connectivity to the auto-connection server
- Server
  - DHCP server: supplies the initial IP configuration and IP addresses of server-side functions
  - ACS: Site identification function, Configuration Management Database (CMDB) and CMDB Access Function
  - CA Server: authenticates the NE and provides certificates
  - Certificate repository: holds the operator trust anchor and the NE certificates
  - The Security Gateway (SEG): separates the secure operator domain from the transport network domain to which the NE are physically attached



Auto-connectivity and commissioning

Preparation activities by the manufacturer

- Assigning the eNB with a serial number
- Installation of the initial software and configuration data
- Vendor key / certificate generation and installation

Preparation activities by the operator

- Transport network preparation: Configuration of transport network equipments, configuration and traffic engineering of virtual LANs and Virtual Private Networks in the aggregation and core transport networks
- DHCP server configuration: initial IP address for eNBs, addresses for ACS, CA server and SEG
- Auto-Connection Server configuration: Access to the Configuration Database is needed for retrieving auto-configuration data and updating the network topology
- SEG: installation of the operator root certificate

Auto-connectivity and commissioning

Preparation activities by the operator

- Operator preparations per eNB
  - Transport, radio and access network planning and transferring of planning data to DM
  - ACS and CA server preparation
- On-site activities by the installer
  - Hardware installation and the physical connection to the antenna, the transport network and the power feed
  - Switching on the eNB and monitoring of the auto-connectivity setup proceeding from LED indicators successfully

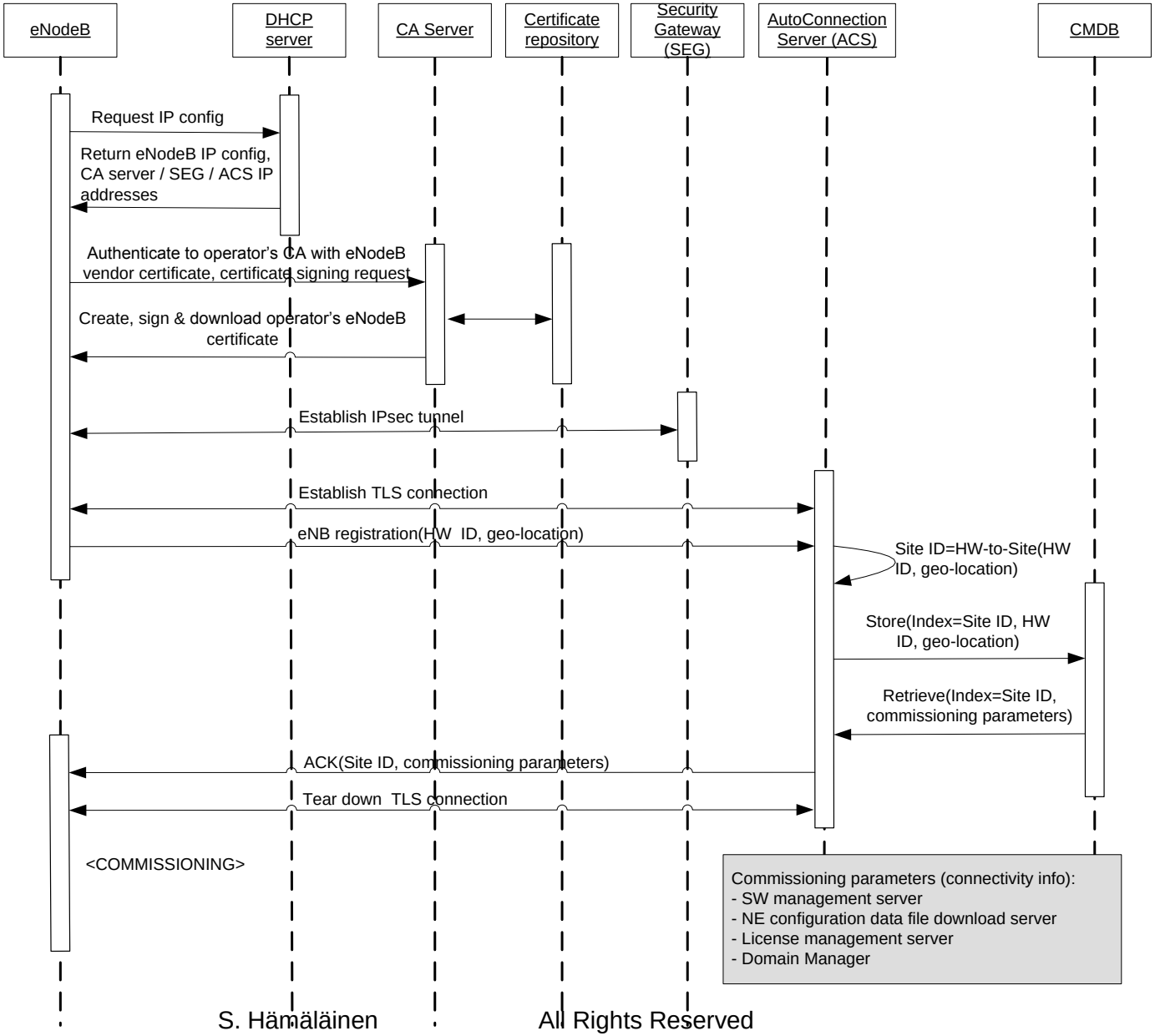
Connectivity setup

- Basic connectivity setup
  - Auto-connection process to setup L2 transport connectivity and sending DHCP request
  - DHCP server replies the eNB with its initial IP configuration, ACS, CA server and SEG addresses
- Certificate enrolment
  - eNB creates a new key pair and communicates with CA server with Certificate management protocol (CMP)
    - eNB gets the public key portion signed by a new operator certificate for this eNB
    - Download further trust anchors (operator's public key)
- Secure connection establishment/authentication
- eNB sends announcement message to ACS with HW id and GPS coordinates
- Site identification can be done with different means
  - Installer manually inserts Site-ID before self-configuration process
  - Installer informs remote commissioner about HW-ID and site ID
  - HW-ID collected on site from a bar code sticker attached to eNB
  - Installer collects GPS coordinates from a separate GPS receiver
  - Site coordinates are measured automatically by GPS receiver

TS33.310: Network Domain Security (NDS); Authentication Framework (AF)

- **Basic connectivity**
  - After switched on, the eNB performs self-test
    - DHCP to get addressess
    - DHCP server assigns an IP address from a pool
- **Authentication to Operator's CA server with vendor signed eNB certificate & key signing request**
- **Certificate enrolment**
  - Create, sign & download operator's eNB Certificate
  - Download trust anchors that can be used to authenticate other network elements
- **Establish secure connections in operator's trust domain with given operator key**
  - Setup of secure connection depends on operator's security architecture, for example
    - eNB establishes initial IPsec tunnel to SEG and /or TLS connection to TLS
    - In case both, TLS connection is tunneled within IPsec tunnel
    - SEG/ACS verity operator-signed certificate using operator trust anchors
    - eNB also verifies SEG/ACS TLS supplied certificate with operator trust anschors
- **eNB sends announcement message to ACS with HW id and GPS coordinates if available**
- **ACS matches received information to pre-configured information**
  - HW-to-Site mapping: linking HW-ID to site-ID
- **ACS communicates with configuration to update topology information**
  - Storing HW-ID in the on-line configuration DB related to the site ID
- **Site identification**
  - Bar core read with reader and site ID given manually to e.g. in an SMS message
  - Installer collects GPS coordinates from a separate GPS receiver and transfer to to eNB via e.g. Ethernet
    - GPS is expensive and needed only at the self-config

Connectivity setup



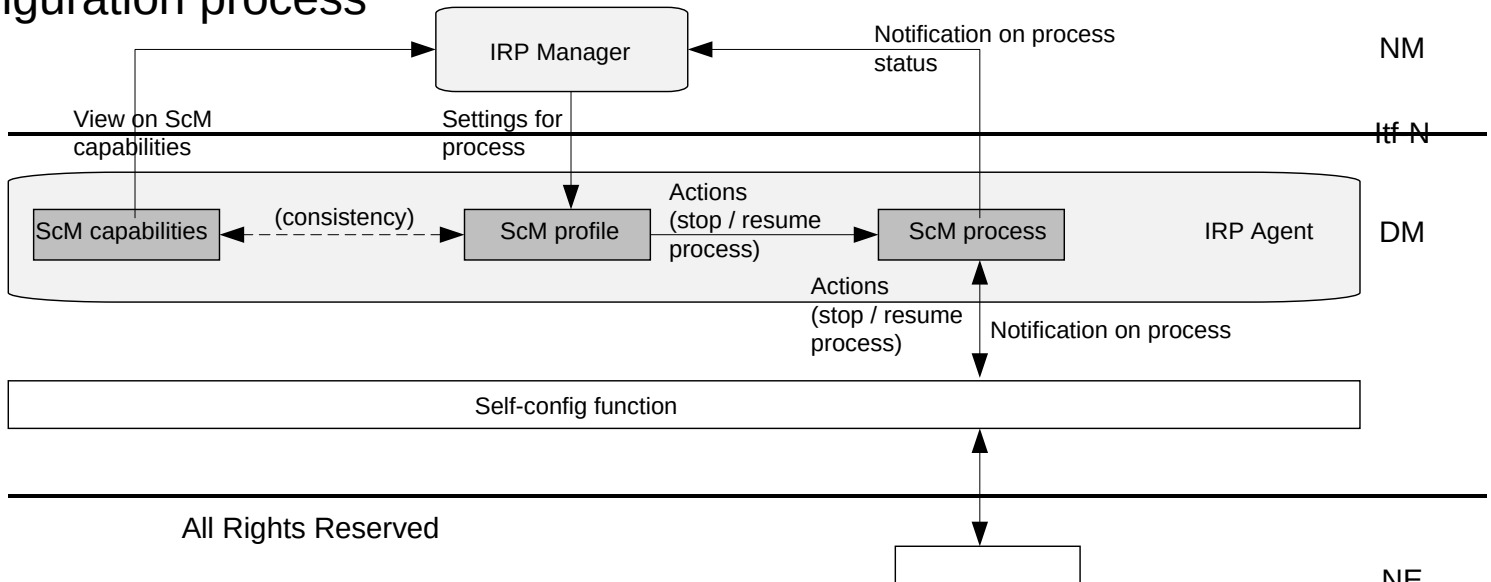
Auto-commissioning

Auto-commissioning consists of

- Automatic inventory update
  - Automatic identification of eNB components and update of CM DB
- Automatic software download
  - Validation of eNB's current software version against requiremed for the particular HW and site
  - Installation of the correct SW version
- Automatic database preparation and download
  - Downloading of the basic configuration by the eNB
    - Configuration has been created as a part of radio and transport network planning
- License management
  - After the eNB is fully installed and configured the corresponding license management procedures are performed
- Setup of call processing interfaces
- Typically pre-requisite for license management and setup of call processing interfaces is to have eNB fully configured

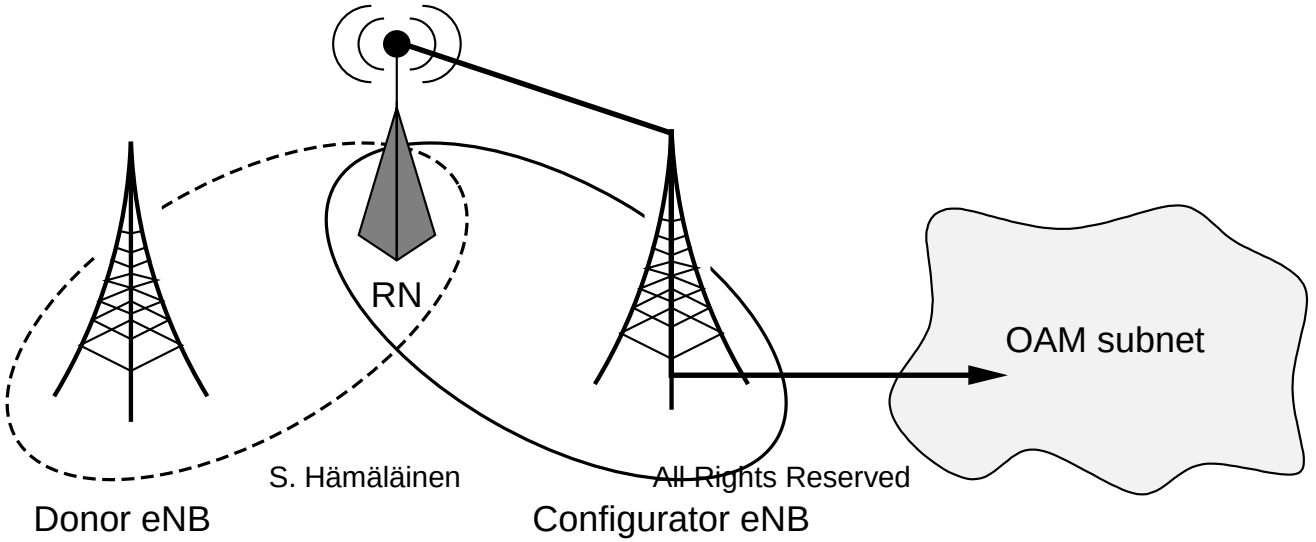
3GPP Self-Configuration and Software Management Integration Reference Point (IRP)

- Details of the individual steps for self-configuration are not standardised
- 3GPP has standardised high-level, multi-vendor-capable supervision of the self-configuration
- The objects contain the following functionality:
  - ScManagementCapability: the sequence of the steps; the possibility to select a stop points; setting of different administrative states at the end of process
  - ScManagementProfile: the “policy” of IRP manager offering possible stop points to suspend the self-configuration process
  - ScProcess: Notification to IRPManager about the progress of the self-configuration process



Relay auto-connectivity

- Relay nodes (RNs) are connected to the network through the Uu interface between UE and the serving eNB (Donor-eNB - DeNB)
  - DeNB for RN can be selected
    - Off-line by the operator during network planning
    - Dynamically during the deployment process computed in the OAM
    - During the deployment process by the RN itself
- Initial connectivity to the OAM is made through an intermediate Configurator eNB (CeNB) with RRC establishment followed by the UE Attach procedure (phase 1)
  - CeNB can be any eNB under which coverage RN resides
- Once NE becomes aware of its DeNB connection to CeNB is torn down, and connectivity to actual serving DeNB is established (phase 2)



Relay node auto-connectivity process

- During the phase 1 the RN has physical (Layer 2) connectivity to the OAM subnet, but does not have IP (Layer 3) connectivity yet
- In order to establish IP connectivity with the OAM system, the RN follows the conventional DHCP protocol procedures
- After the initial connectivity has been setup, the next steps are
  - Establish a secure connection to the OAM nodes
  - Downloading the initial parameters including a list of DeNBs
- After downloading the initial DeNB list the RN detach from CeNB and goes to phase 2
- After the OAM connection is in place, the RN can enter the operational phase

Outline

Introduction

Auto connectivity and commissioning

Dynamic radio configuration

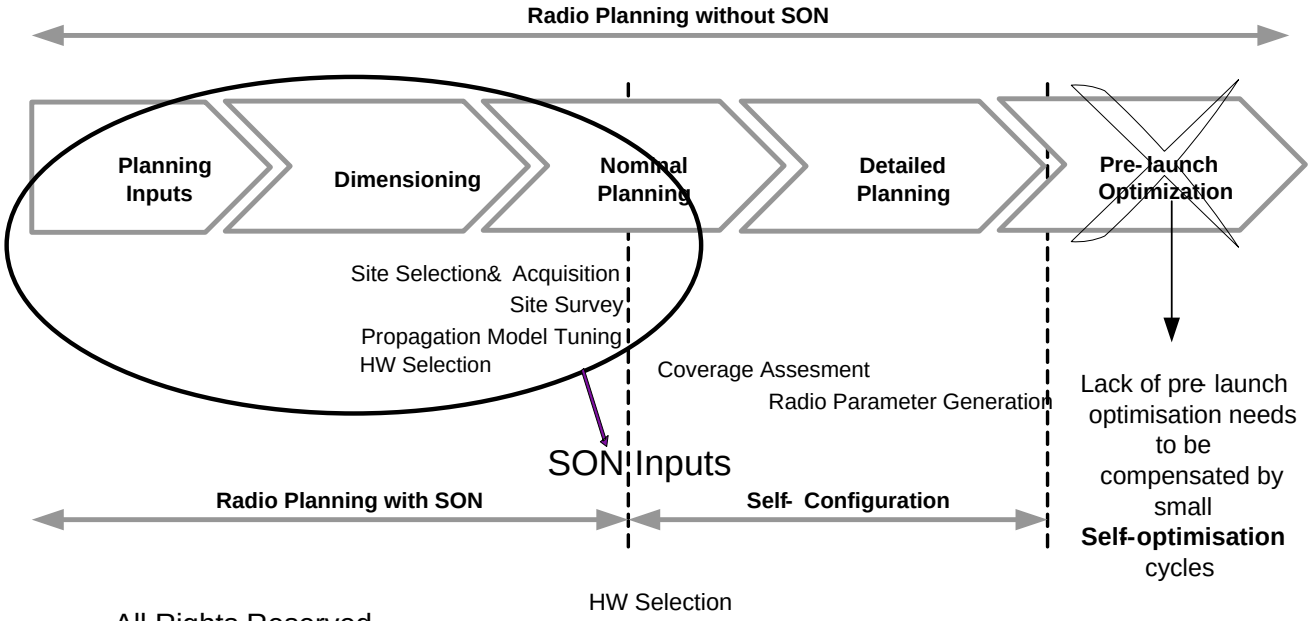
Dynamic radio configuration

Radio configuration in legacy systems is based on planning prior the installation

- Building up the network incrementally one can either perform
  - a labour intensive radio planning step every time a new NE is inserted
    - the insertion order of the base stations must proceed exactly as planned
  - periodic radio planning updates anticipating the new eNB insertions within the next time frame
    - the planning is not representative for the operational network at a certain point in time

Dynamic Radio Configuration (DRC) is adaptive to the current network topology context

- The DRC will configure the new base station / cell and its neighbours on the fly
- By using DRC the detailed radio planning can be omitted

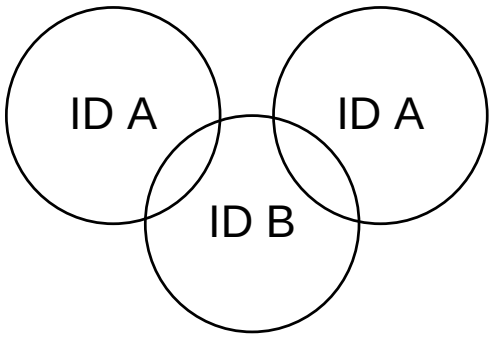


Generation of initial transmission parameters

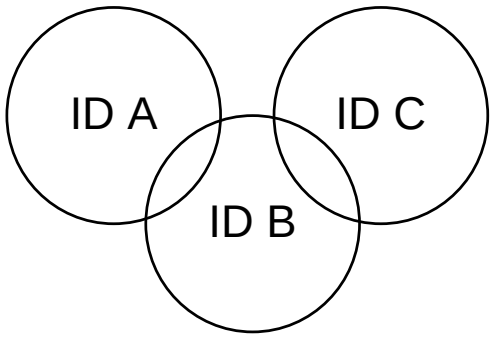
- Configuration of transmission parameters for newly installed base station
  - Maximum TX power
  - Antenna tilt
  - Antenna azimuth
- Three options to set these parameters
  - Planning prior or during installation of site
  - Using default values, that are optimized by self-optimisation during on-line
  - Determining parameters during self-configuration
- Strategies for determining transmission parameters
  - Calculation of parameters by a centralized algorithm after commissioning of the new base station, but before switching radio on
    - Moving algorithms from offline planning to self-configuration
  - Start algorithm after commissioning and base station switched on
    - Adaptation of transmission power through self-optimization

Physical cell ID allocation

- Physical Cell ID (PCI)
  - PCIs are used regionally unique identifier on the physical layer
  - 504 unique PCIs
- PCI influences to the structure if Uplink and Downlink Reference Signals of a cell
  - For the *downlink reference signals,* 6 sub-carrier groups are used leading to PCI assignment of N_{ID} *mod 6*
  - For the *uplink reference signals*, 30 sequence groups are defined leading to PCIs assignment according to N_{ID} *mod 30*
- PCIs need to reused so that their assignment is
  - Collision free
  - Confusion free



A) Confused PCI Assigment



B) Confusion-free PCI Assigment

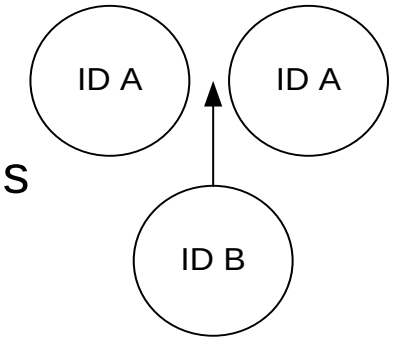
Physical cell ID allocation

Network evolution

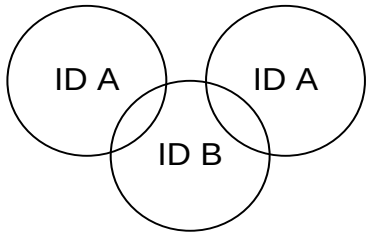
- When network evolves and cells are added by
  - adding cells to a hot spot
  - Hotspots growing and overlapping with each other
  - Overlapping macro and small cell deployment

Partitioning of ID space

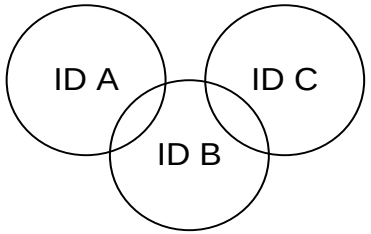
- Allocating blocks of PCIs for different types of cells – e.g. macro and small cells
  - Closed subscriber group (CSG) in case of femto cells to help to decrease the power consumption of the UEs
- Allocating blocks of PCIs for different vendor eNBs
- Allocating blocks of PCI groups for the cells located at spectrum license border locations



A) Insertion of new Cell



B) Confused PCI Assignment

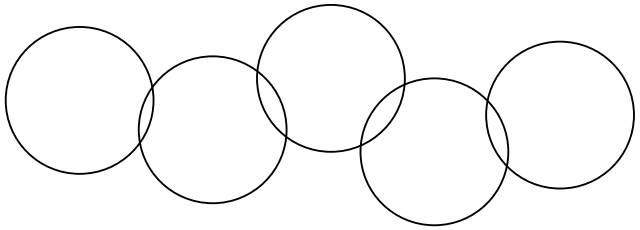


C) Resolved PCI Confusion

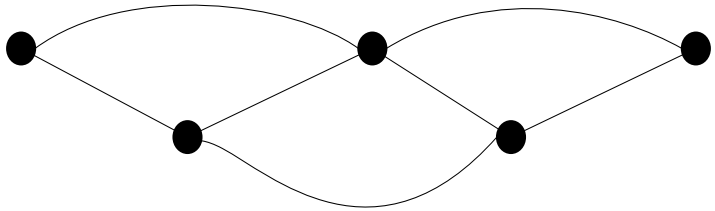
PCI assignment approaches

Graph colouring

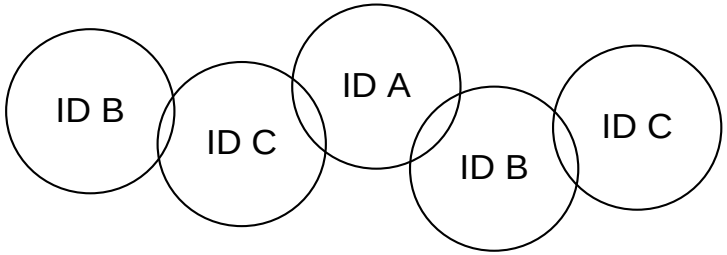
- The given cell layout with its neighbours is transferred to a graph



- For a confusion free assignment the graph has to be extended with additional edges between the nodes and all neighbours of their neighbours



- A generic graph colouring algorithm is applied to the graph which results in a collision and confusion free PCI assignment



- This approach is suitable for an initial assignment but not necessarily to assign PCIs to cells that are added during the operational phase
- Centralized and distributed approaches

PCI assignment approaches

Distributed RSRP measurement based approach

- Using UE based RSRP measurements to discover neighbours
- In case the reported PCI is not yet listed for a known neighbour
  - The serving eNB requests the UE to read ECGI
  - Neighbourship is established via an information exchange over the core network
- In case of a confusion the target eNB's NRT already contains another cell with an identical PCI
  - Confusion is resolved by reconfiguring one of the cells
- The serving cell could also be already confused
  - eNB receives a RSRP measurement report containing a PCI which is already part of the NRT
  - The serving cell will prepare for a handover to this cell, which fails
  - Such confusions can be detected by monitoring the handover success respectively the failure rates.

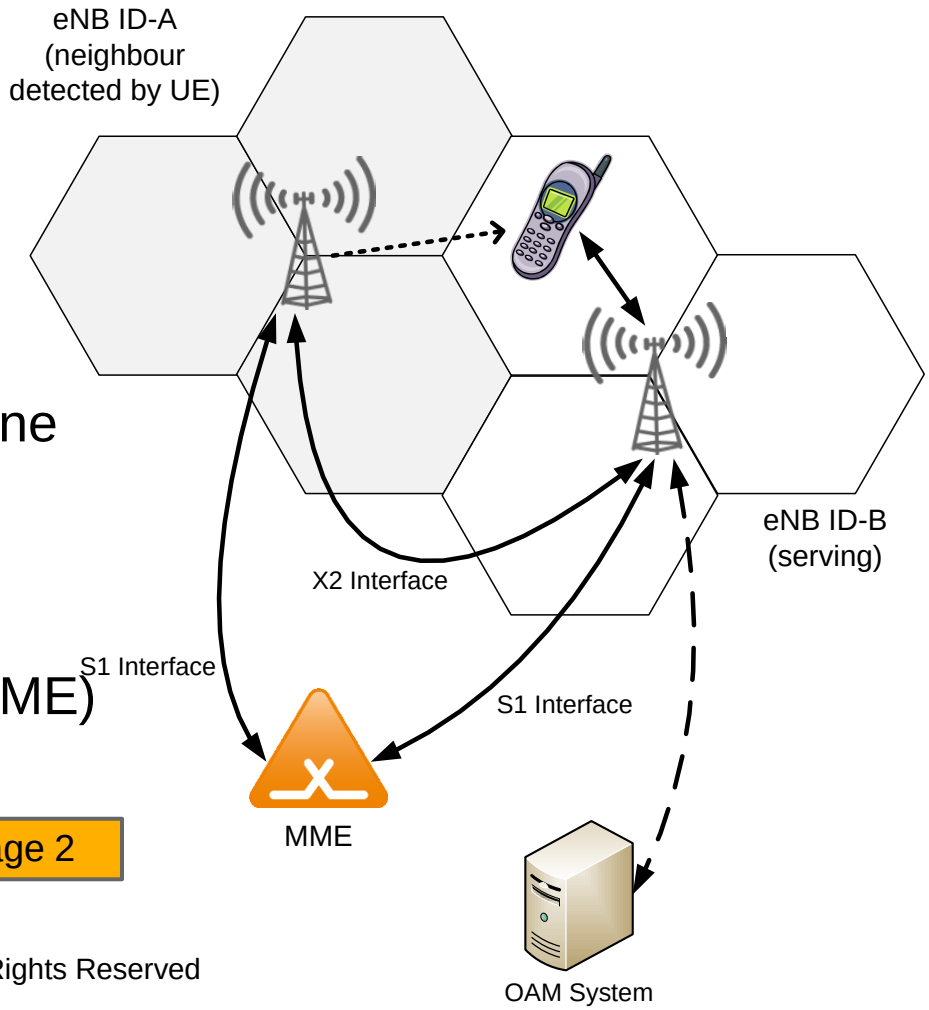
Automatic neighbour relationship setup

Pre-operational neighbour relations

- The initial neighbour relations are based on static assumptions
  - The cell planning tools calculate neighbours based on geographical proximity and direction of antennas
- The operators need to complement the planning phase with drive tests, to verify coverage datasets and identify all handover regions
- Neighbour relations may change due to changed environment

Automatic neighbour relations (ANR)

- Standardised ANR enables neighbourhood detection for
  - intra-LTE for both intra- and inter frequency
  - inter-RAT from LTE to 2G and 3G
- 2G/3G to LTE ANR is vendor specific
- ANR is based on UE reporting of PCI for detected neighbours
- PCI must be mapped to ECGI before handover. Mapping can be done
  - UE based
  - UE triggered with OAM support
- Finally ECGI is mapped into IP address with help of core network (MME)

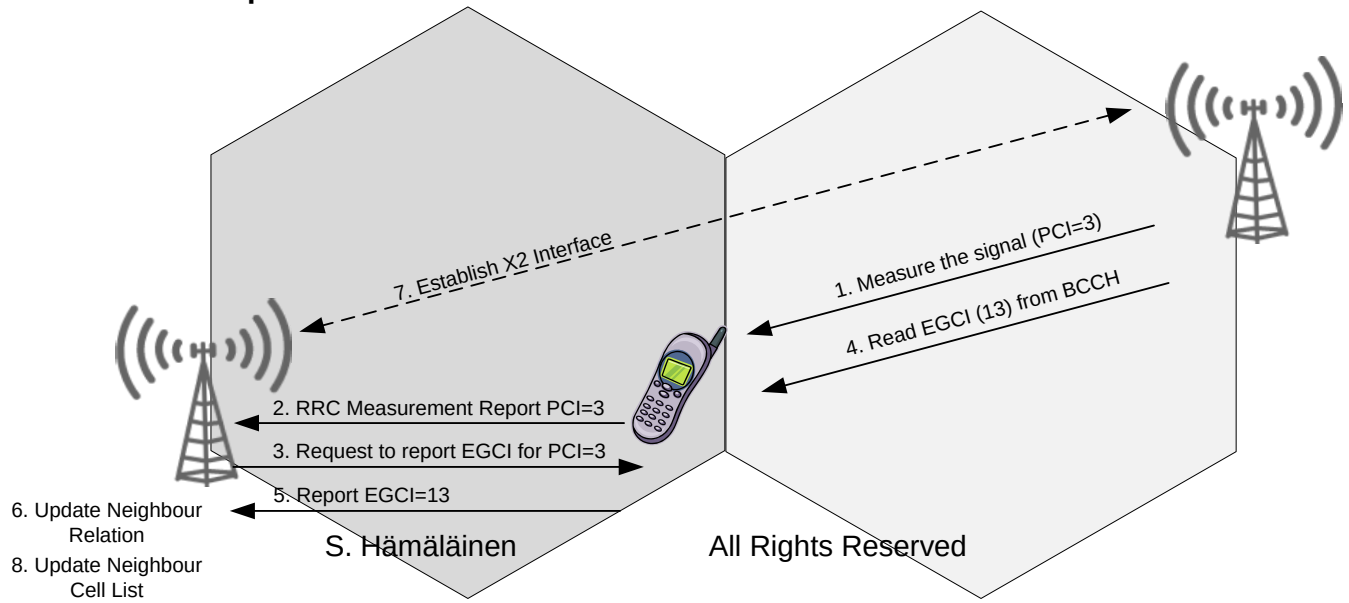


TS36.300:E-UTRA and E-UTRAN, Overall Description, Stage 2

Intra LTE – intra-frequency ANR

Neighbour cell discovery

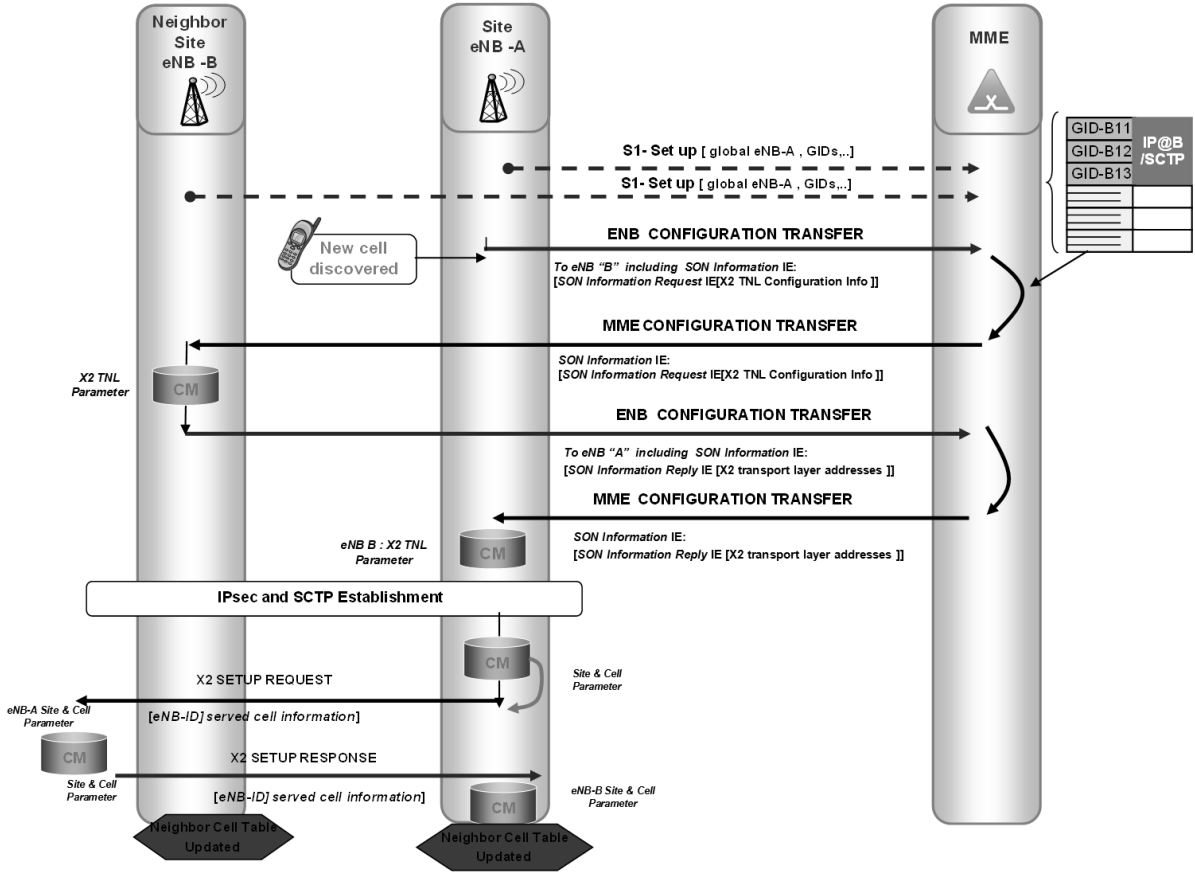
- Reporting of detected strongest cells
  - When the UE changes from idle to RRC_CONNECTED state, it is instructed via Measurement Configuration to report the detected strongest cells
  - The UE decodes the PCI and reports to eNB
  - In case of unknown PCI, eNB orders the UE to read the ECGI from the broadcast channel of the detected cell
- The network operator can configure “blacklisted” cells for ANR at the NM level
  - blacklisted cells are broadcasted in System Information Blocks 4 and 5
  - UE doesn’t report blacklisted cells



Intra LTE – intra-frequency ANR

X2 transport configuration discovery and X2 connection set-up

- Neighbour cell IP address is detected by using *Configuration Transfer Procedure*
  - The eNB requests the IP address corresponding to ECGI from the MME
- Once IP address is available, eNB updates NRT and establishes X2 with the new neighbour



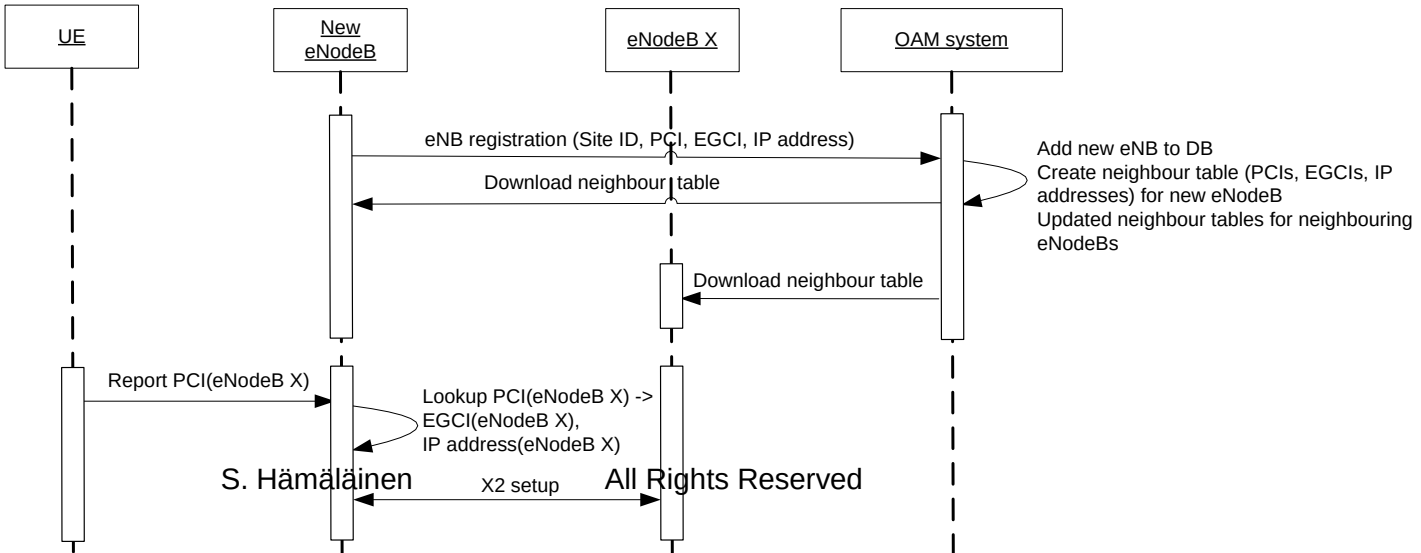
Inter-RAT ANR

Inter-RAT/inter-frequency ANR procedure is similar with intra-frequency ANR

- UE is instructed to perform measurements and report neighbours on other RATs/frequencies during connected mode
- The UE decodes the PCI of a cell that it has detected in the target RAT/frequencies and reports it to its serving eNB. The PCI is defined by
  - UTRAN FDD: the carrier frequency and the Primary Scrambling Code
  - UTRAN TDD: the carrier frequency and the Cell Parameter ID
  - GERAN: the Band Indicator + Base Station Identity Code (BSIC) + BCCH Absolute Radio Frequency Channel Number (ARFCN)
  - CDMA200: the PseudoNoise Offset
- In case of an unknown PCI, the eNB instructs the UE to read and report the neighbours'
  - GERAN: Cell Global Identifier (CGI) and the Routing Area Code (RAC)
  - UTRAN: CGI + Location Area Code (LAC) + RAC
  - CDMA2000: CGI
  - Inter-frequency LTE: ECGI, Tracking Area Code (TAC) and all available PLMN ID(s)
- The eNB updates its inter-RAT/inter-frequency Neighbour Relation Table (NRT)

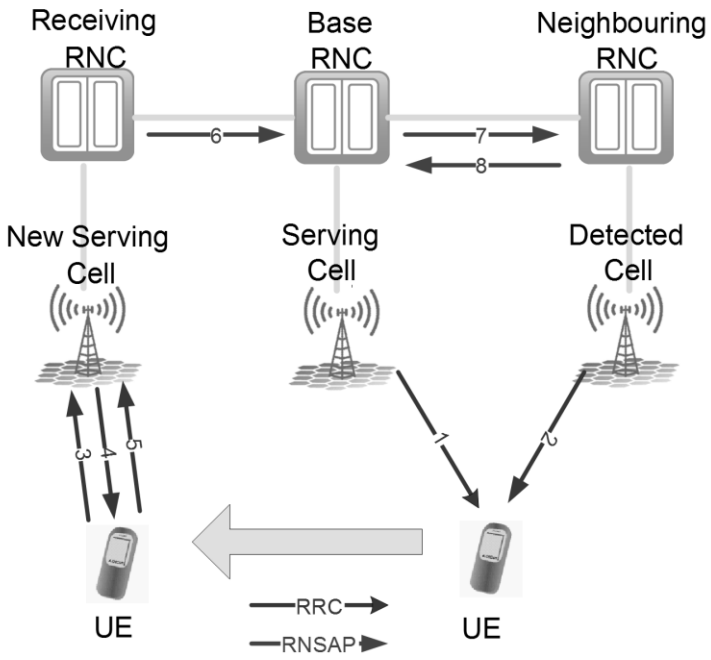
UE-triggered ANR with OAM support

- OAM system prepares and maintains a list of potential neighbour cells with related IP connectivity information (PCI-ECGI-IP address)
  - PCI / ECGI / IP address data of the current neighbours of the new eNB is created and downloaded to the new eNB
  - The tables of neighbouring eNBs for new eNB are also updated
  - Given PCI uniqueness in the relevant neighbour area, a PCI can be directly mapped to an IP address
- Neighbour cell discovery is similar to the UE-based ANR
  - The UE measures the signal of a new cell and reports the measurement
  - The UE is not instructed to read the ECGI as the neighbour information is already known
- The IP address of a neighbour eNB hosting the newly discovered cell can be derived from the mapping table
  - instead of the MME-based address resolution via the S1 interface
- The X2 connectivity setup is identical to the step in UE-based ANR

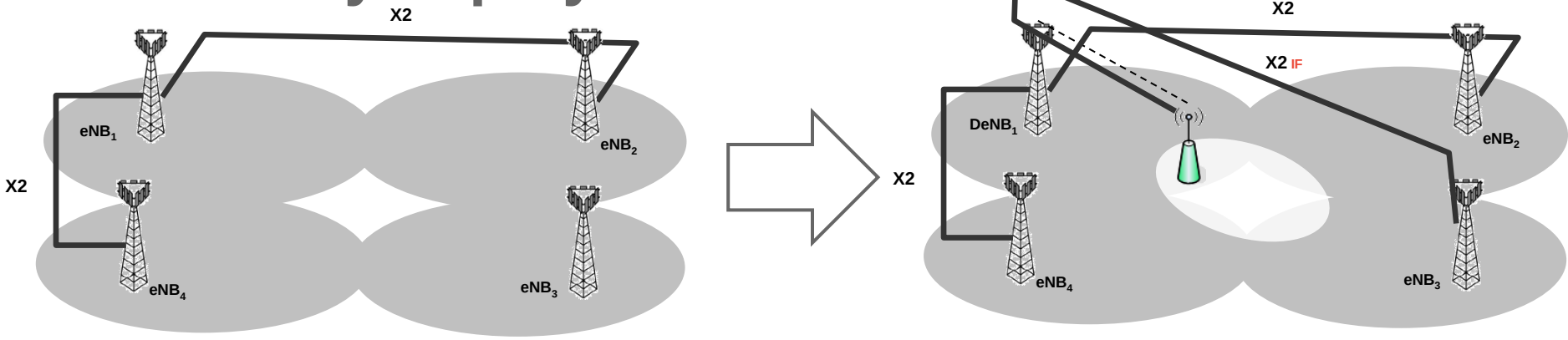


3G ANR

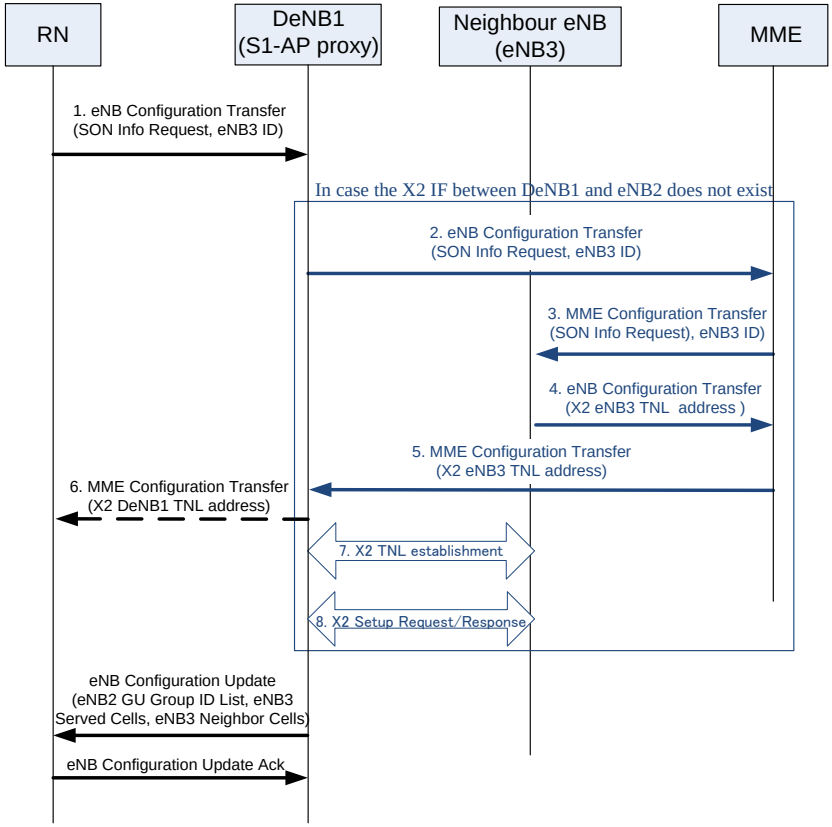
- Based on UE logged mode reporting defined for MDT
- In idle mode, in CELL_PCH and URA_PCH states
- Procedure
  1. The UE is configured with ANR measurements and parameters
  2. The UE stores the ID of the serving cell and the detected cell plus related system information in a trace log
  3. When the UE establishes an UL connection, it indicates the trace availability to the current serving cell
  4. RNC requests UE to report log
     - The receiving RNC uses RRC signalling to retrieve the ANR report
  5. The UE will send log
  6. The receiving RNC handles the ANR report and may forward the ANR report to different RNCs



ANR in relay deployment



- Newly detected neighbours are seen through RNs DeNB
- First the X2 TNL is established between $DeNB_1$ and the eNB_3
- Next the *X2 Setup procedure* between eNB_3 and $DeNB_1$ is executed
- $DeNB_1$ builds the *eNB Configuration Update* message as it was created by the eNB_3 and sends it to the RN



Quiz: Connectivity setup