Reliable Operation of Heterogeneous Wireless Networks with SON (Self-Organizing Networks) - Self-Configuration

Henning Sanneck, Szabolcs Nováczki

Nokia Siemens Networks
- Research

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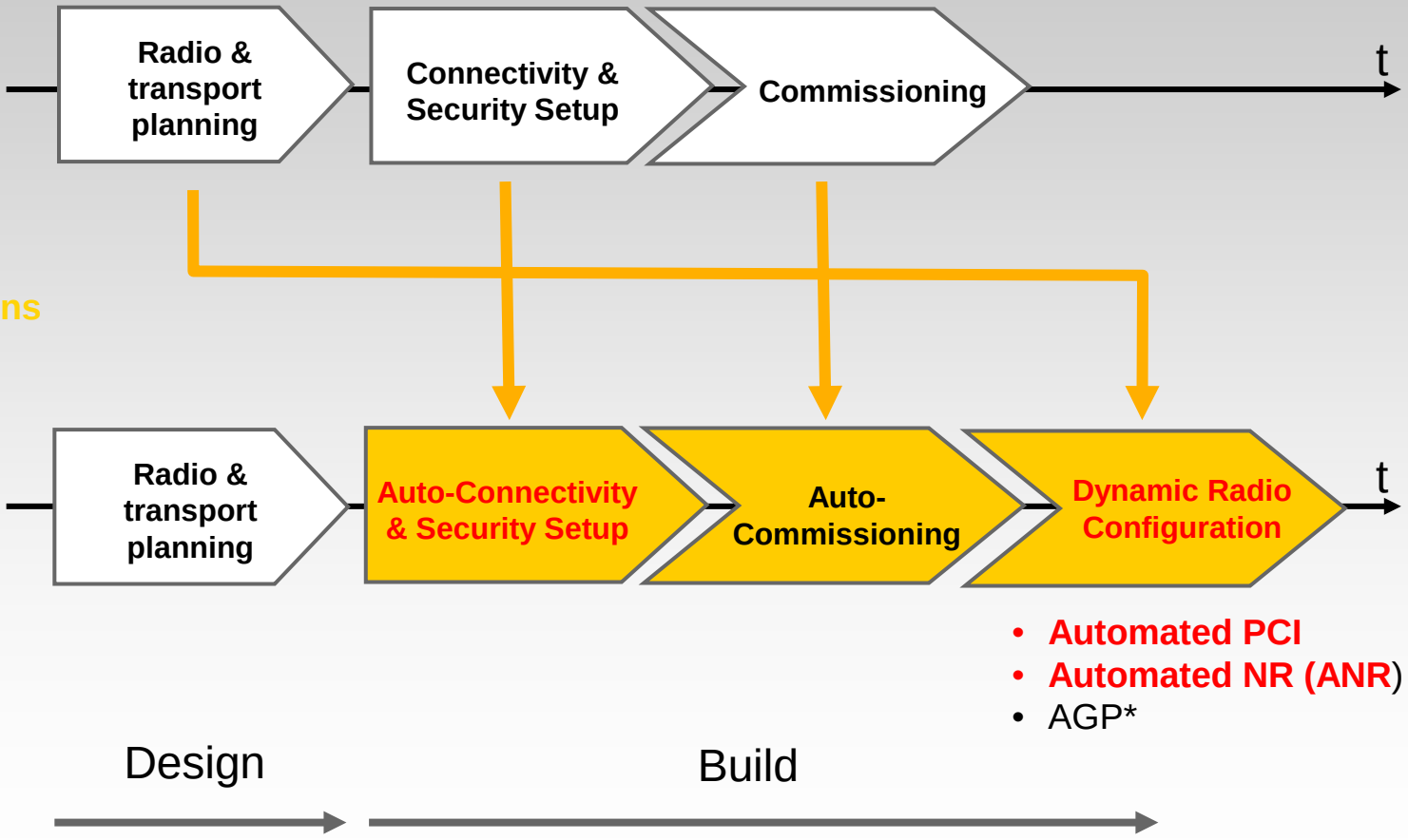
Self-Configuration
High-level process

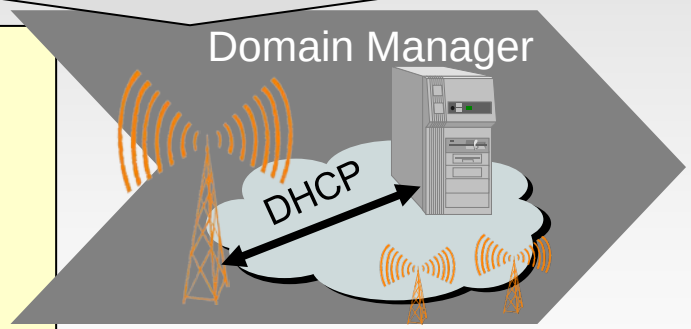
**AGP: Automatic Generation of initial power/tilt Parameters*

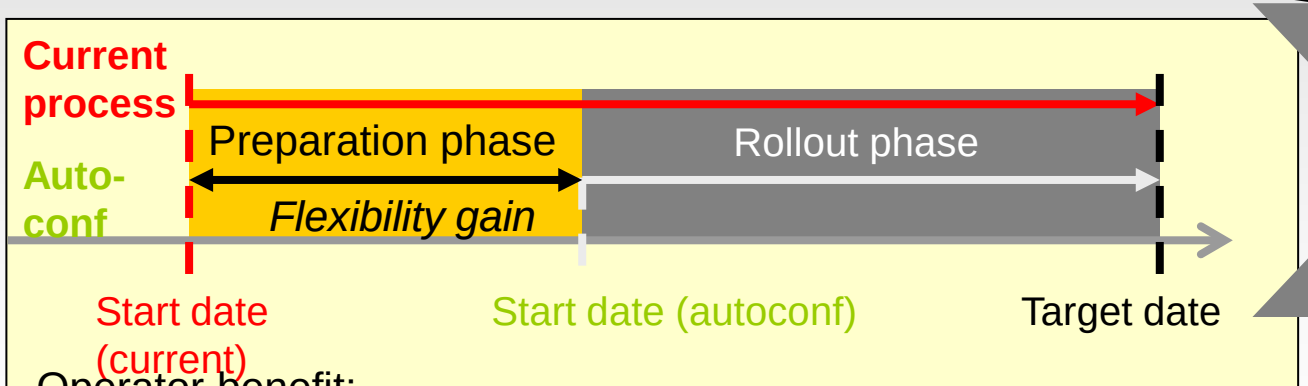
- Physical Cell ID (PCI) allocation
- Neighbour Relationship (NR) planning
- Initial TXP/Tilt setting



Auto-connectivity and -commissioning
Motivation

Self-configuration

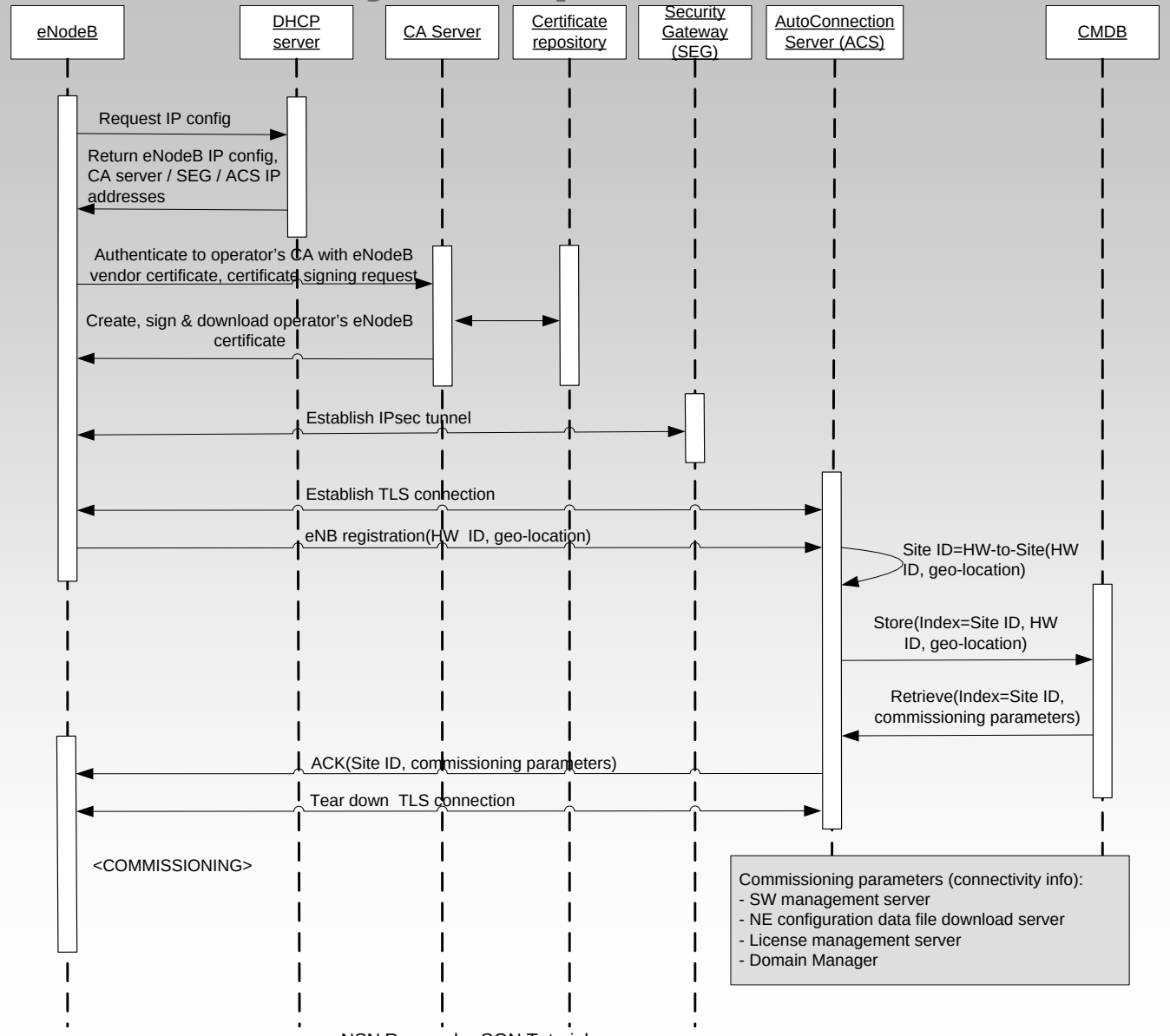




Operator benefit:
planning flexibility until roll-out of „off-the-shelf“ basestations starts

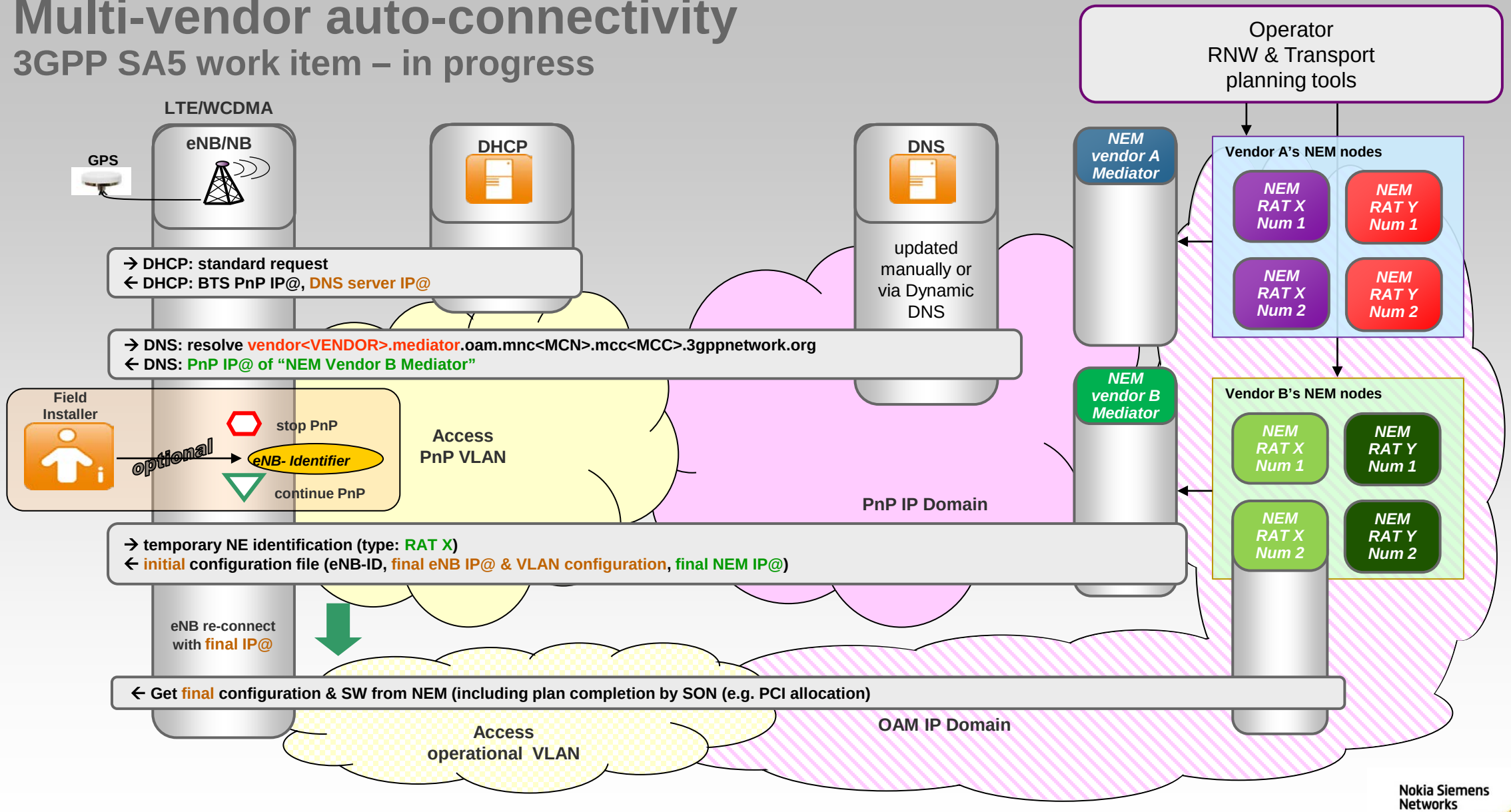
Auto-connectivity and security setup

Message flow



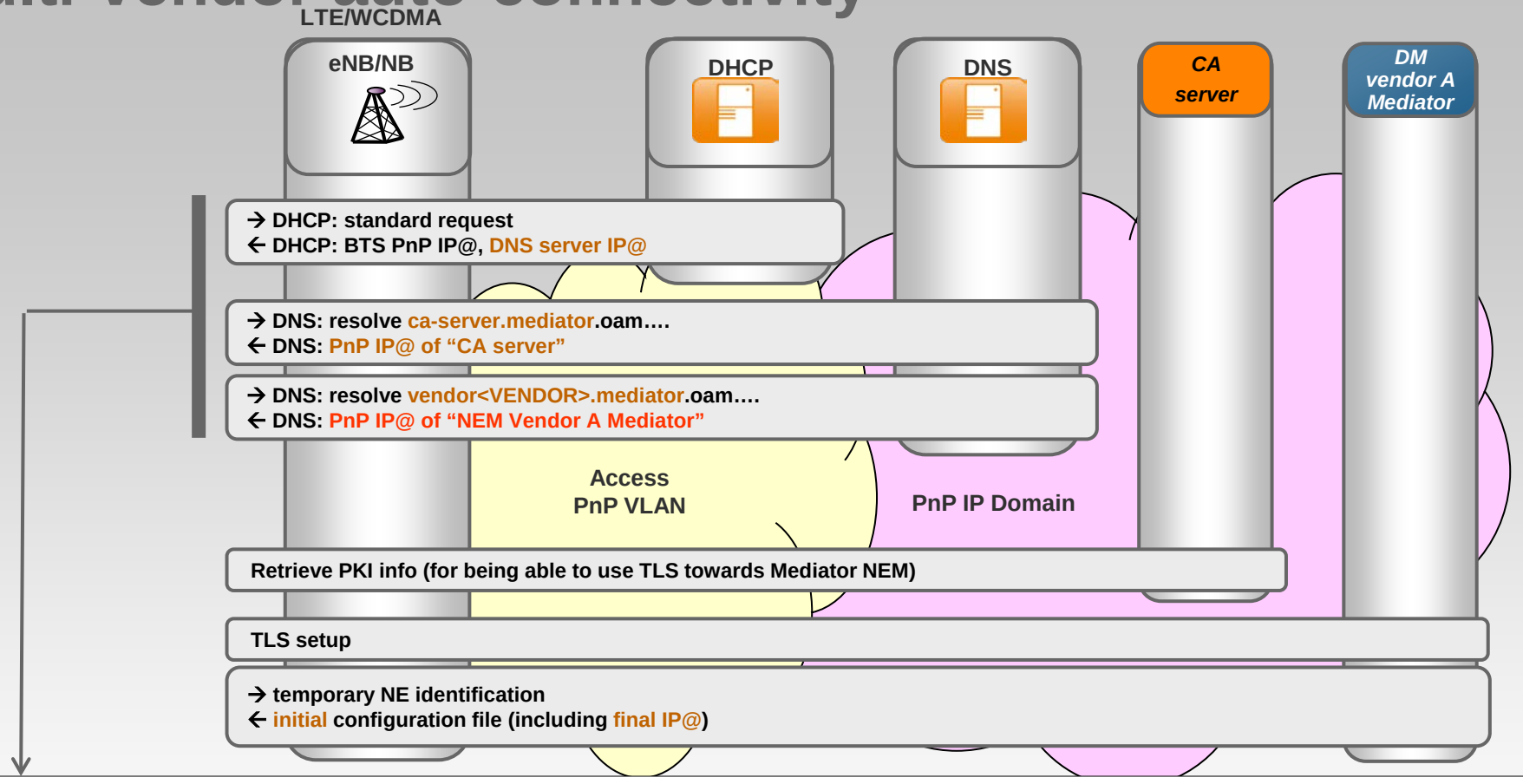
Multi-vendor auto-connectivity

3GPP SA5 work item – in progress



(security setup not shown here)

Multi-vendor auto-connectivity

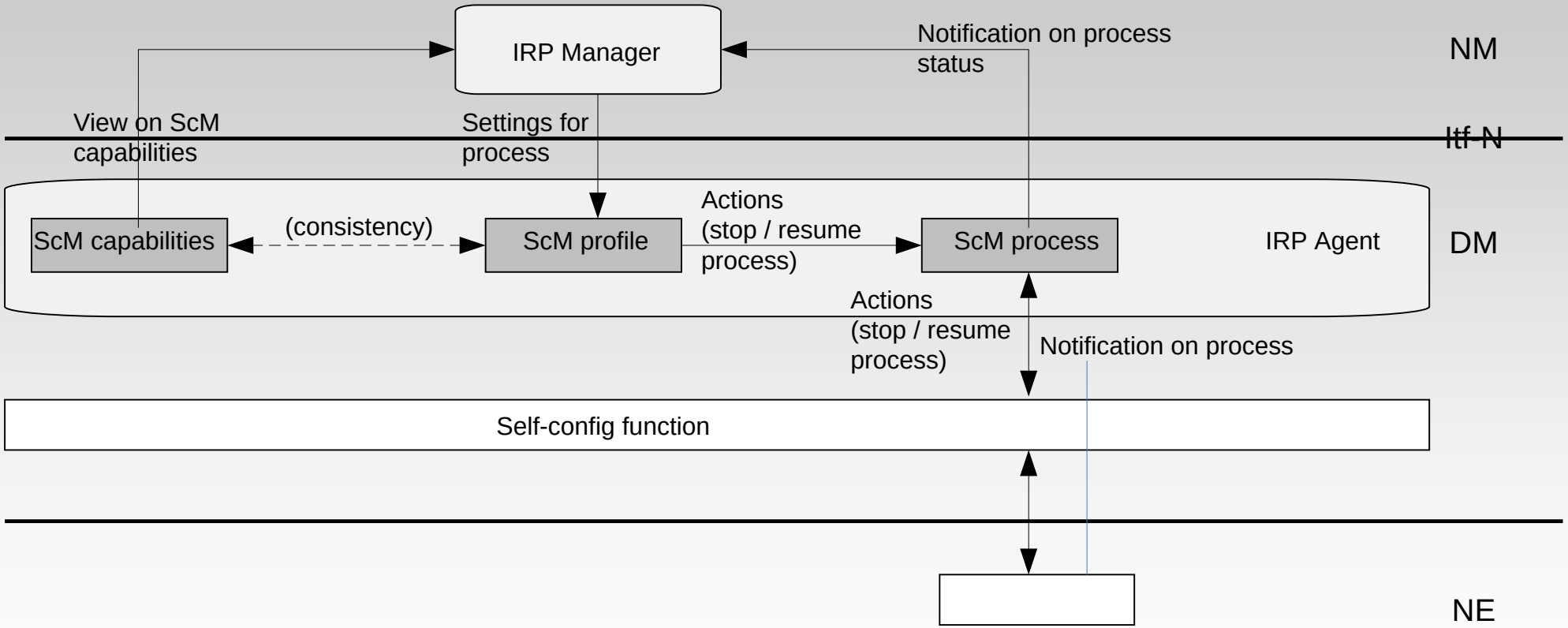


- Generic <server>.mediator.oam.mnc<MNC>.mcc<MCC>.3gppnetwork.org name is resolved via DNS to actual server IP address (for CA server, vendor-specific DM „mediator“)
  → **no pre-configuration, only basic DHCP operation required**
  → **instead of NM-level ACS, redirection to vendor-specific DM**

→Low overhead, multi-vendor solution; Work item recently accepted in 3GPP SA5

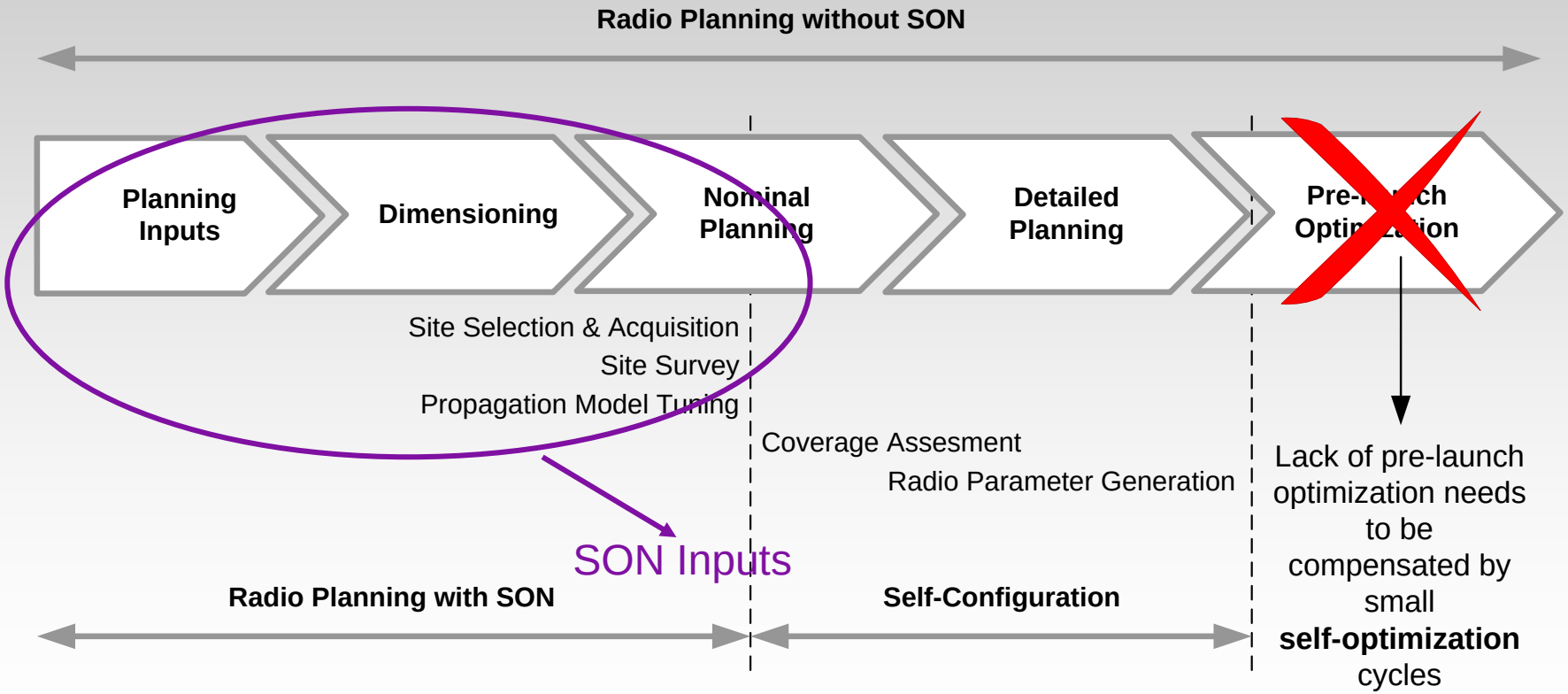
Multi-vendor Self-Configuration process control

3GPP SA5 Self-configuration Management (ScM) IRP



Dynamic Radio Configuration
Motivation

SON functions shall minimize the radio planning (but not replace it completely)



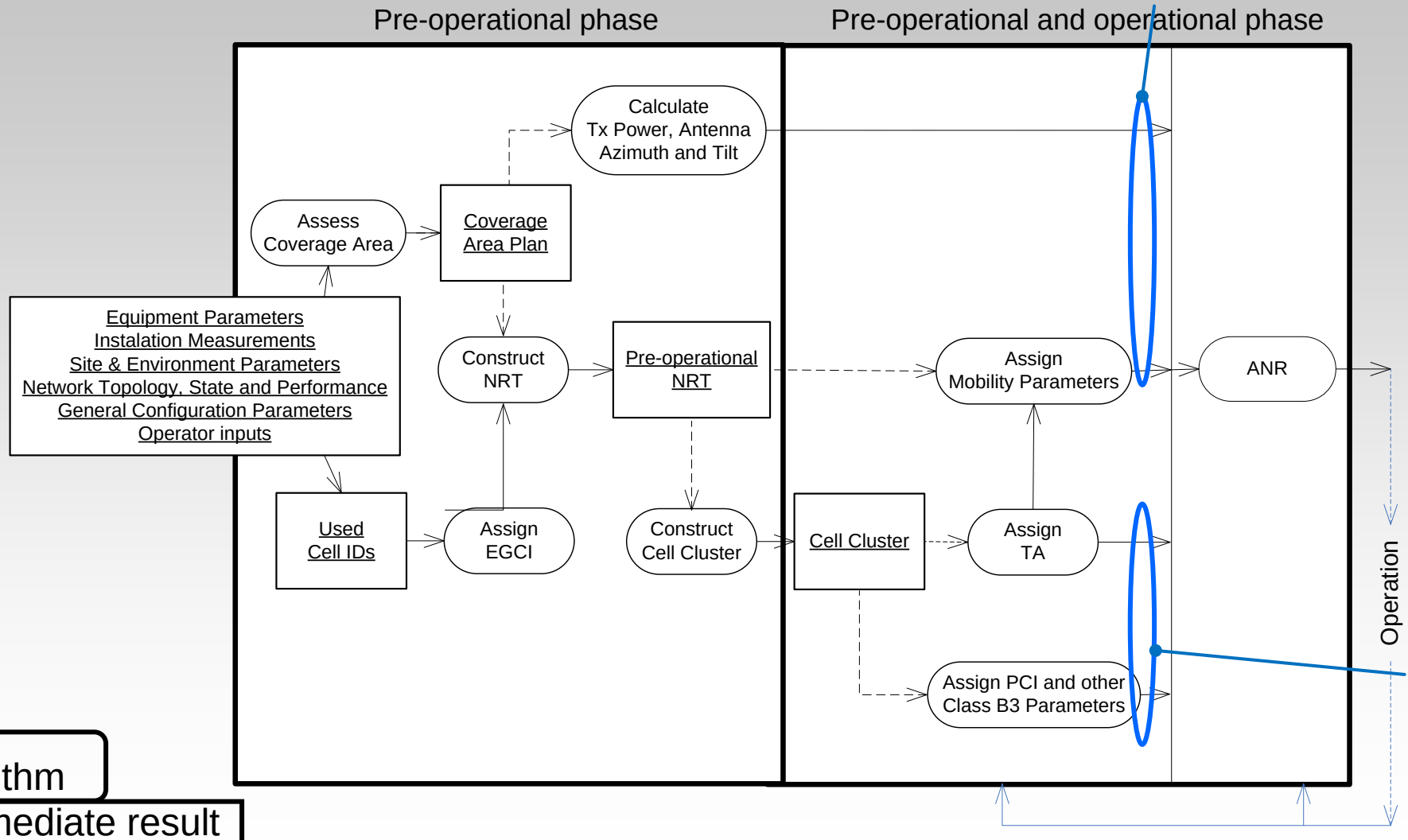
Dynamic Radio Configuration
Incremental Radio Network Build & Growth

SON functions enable an incremental radio network build and growth scenario, in which eNodeB/cells are inserted in an operational E-UTRAN one-by-one

- Without SON functions
  - Multiple network plans needed corresponding to each intermediate insertion step, in order to optimal configure the new eNodeB/cell and its neighbors
  - eNodeB/cell insertion needs to be coordinated; which eNodeB/cell is inserted first, which second, etc.
  - Drive tests needed after every insertion step
- With SON functions
  - Self-configuration → No intermediate planning needed
    - Optimal configuration for the current network topology
  - MDT / Self-optimization → Fewer drive testing needed
  - eNodeB/cells can be inserted in a (more or less) uncoordinated way

Dynamic Radio Configuration
High-level process

Computation of (continuous value) default cell parameters as baseline for self-optimization (cf. EU FP7 SOCRATES „Automatic Generation of Default Parameters“ (AGP) use case)



Computation of (discrete value) cell configuration parameters

Algorithm

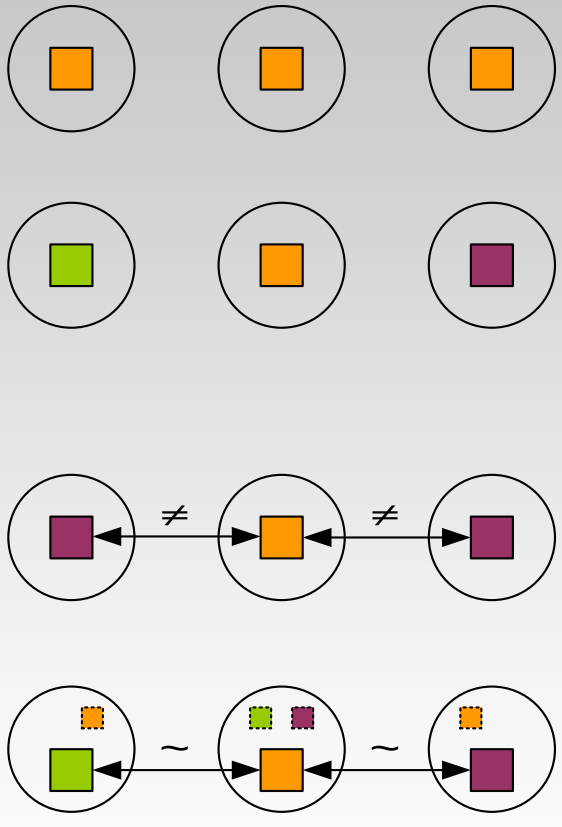
Intermediate result

Dynamic Radio Configuration
Configuration Parameter Classification

„Class A“: parameters with single cell scope, >80% of all parameters, out of DRC scope

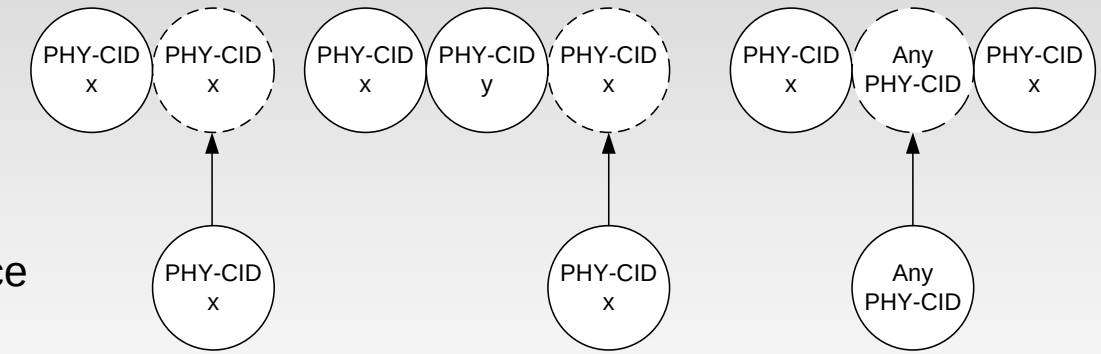
„Class B“:

B1	Uniform value • Out of scope of DRC, set by the operator • *PLMN ID, Frequency band, EARFCN, #PRB*
B2	Unique value • Straight-forward algorithms • Network wide inputs needed • *EGCI, eNodeB name*
B3	Collision free value with neighboring cell • Often additional constraints apply • *PCI, PRACH root-sequence index, RS CS*
B4	Value aligned with neighboring cell(s)
B4.1	• one-to-many relationship • *Tx Power, antenna parameters, Tracking Area*
B4.2	• one-to-one relationship • *cell specific mobility offsets*



Physical Cell ID (PCI) allocation
Overview

- PCI allows fast cell identification on layer 1; Configuration constraint: only 504 PCI available
- Avoid reconfiguration overhead in operational cells as much as possible, because this leads to a service interruption
  - Reconfiguration of an PHY-CID cannot be totally avoided in an incremental network growth scenario (cf. “gets confused case”) → algorithm should consider this pro-actively in the allocation strategy
  - If a PHY-CID reconfiguration is needed, the number of cells to be reconfigured should be kept to a minimum
- Safety margin (SM)
  - the **adjacency graph** is composed of cells as nodes and edges between neighbor cells
  - the SM specifies a range around each cell (number of hops) in the adjacency graph in which the same PCI cannot be assigned more than once
    - SM = 1: only **collision-free**
    - SM = 2: **collision- and confusion free** (minimum requirement for proper PCI allocation)
    - SM = 3, 4, etc. means an increased radius in which a PCI allocated may not be reused
  - Higher SM → higher number of required PCIs
  - Higher SM → “buffer” for the case that new adjacencies are formed later in the operational network (due to ANR discovery, additional cell deployment, etc.) → reduce required PCI reconfigurations

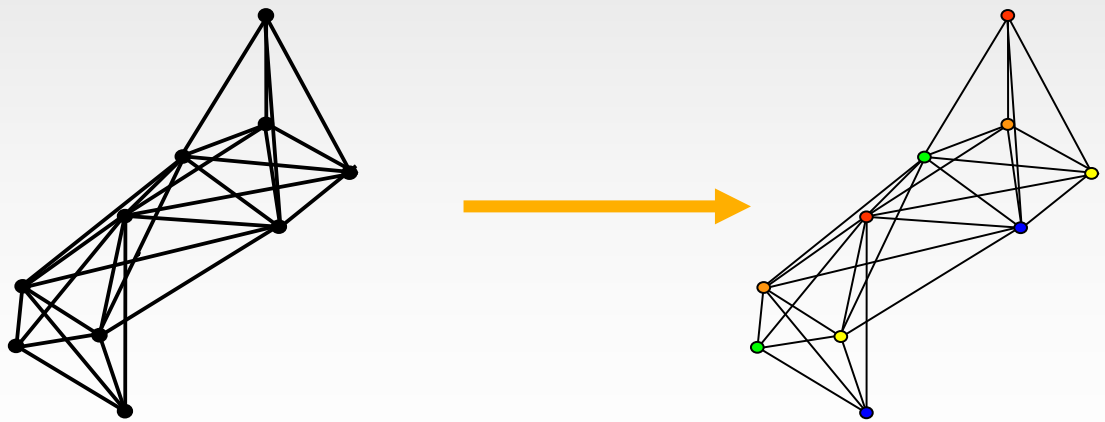


Physical Cell ID (PCI) allocation
Example algorithm: graph coloring

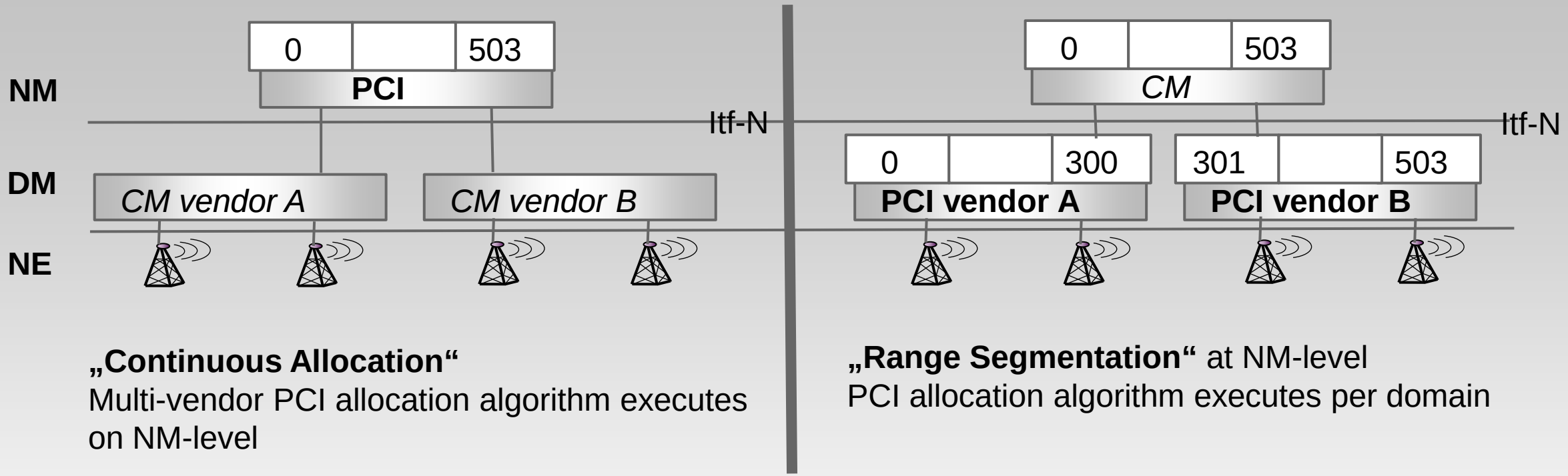
"How to assign a minimal number of colors to a graph in a way that no to neighboring nodes have the same color"

"How to assign a minimal number of PHY-CID in a cell cluster is a collision and confusion free way"

- Collision and confusion free → Construct the graph in such a way it includes the cell neighbors **and neighbors of neighbors**



Multi-vendor PCI in HetNets: solution options



„Continuous Allocation“
Multi-vendor PCI allocation algorithm executes on NM-level

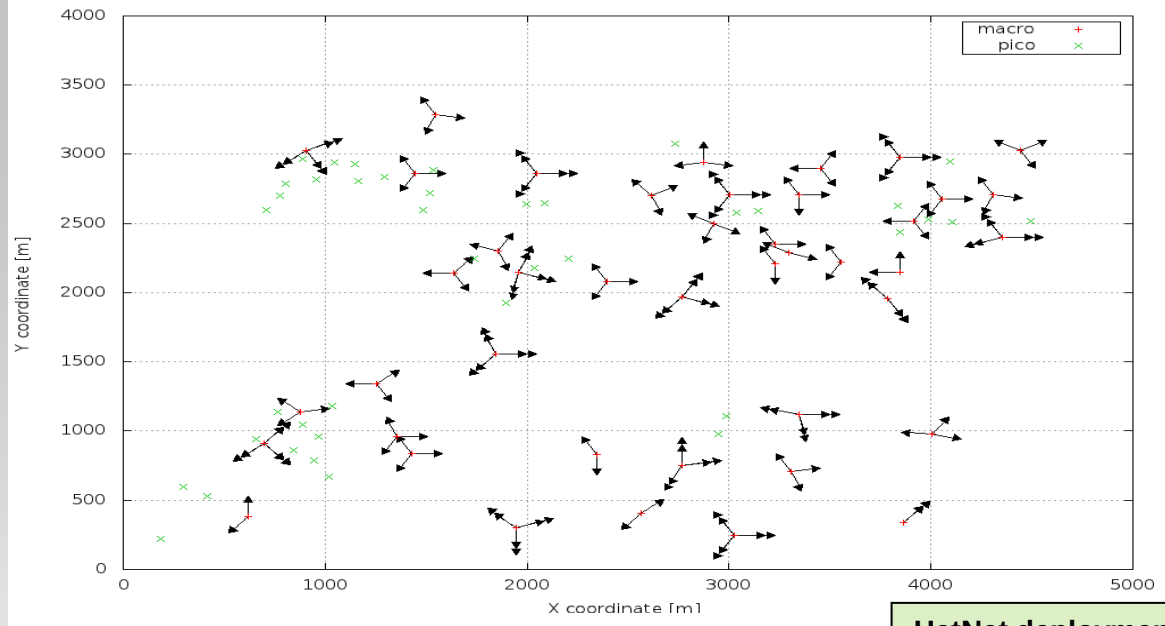
„Range Segmentation“ at NM-level
PCI allocation algorithm executes per domain

Evaluation with planned HetNet scenarios

- base station type (either macro or pico) and position
- antenna azimuth, tilt, max. TX power parameters
- conducted a simulation based on path loss model and horizontal + vertical antenna characteristics to generate adjacency graph

Itf-N standards already support both options

A1



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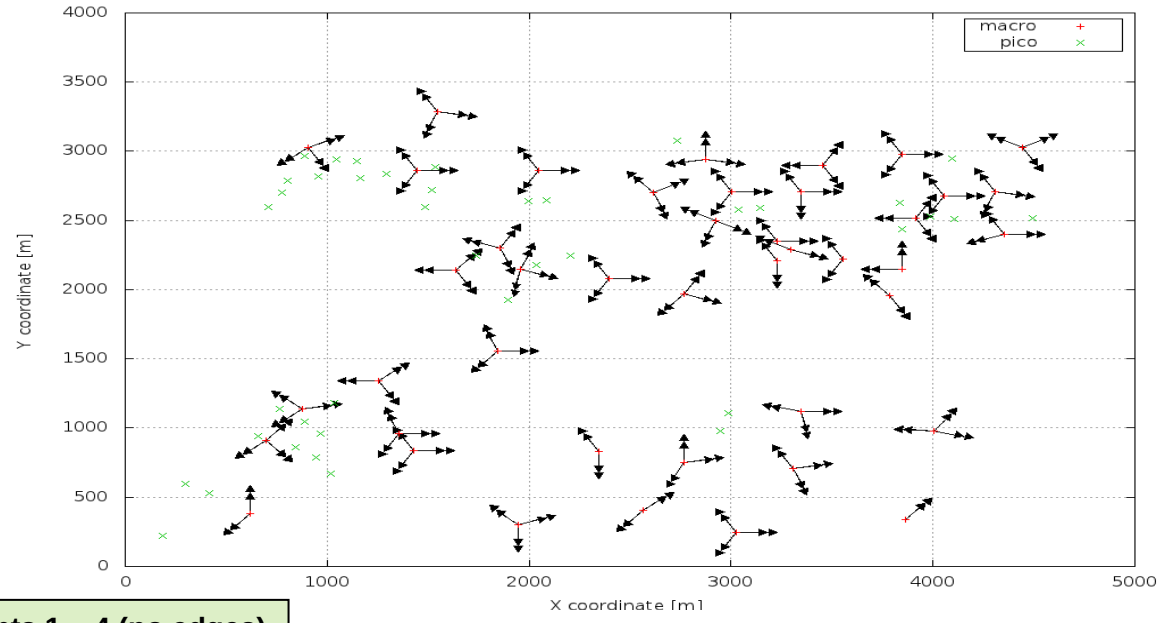
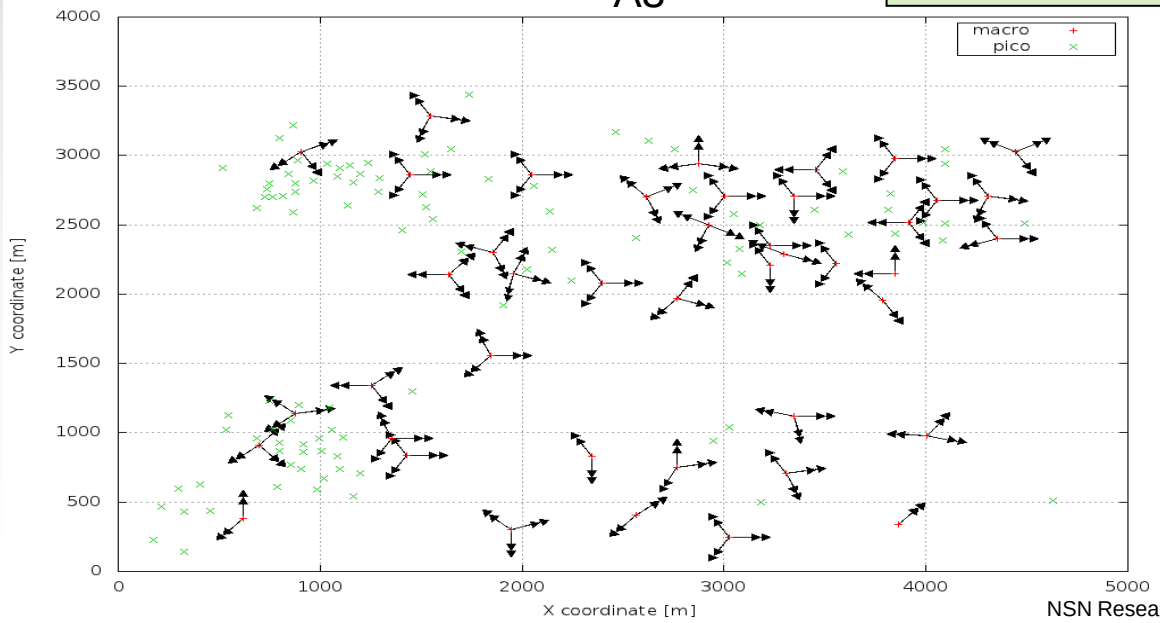


HetNet deployments 1 – 4 (no edges)

A3



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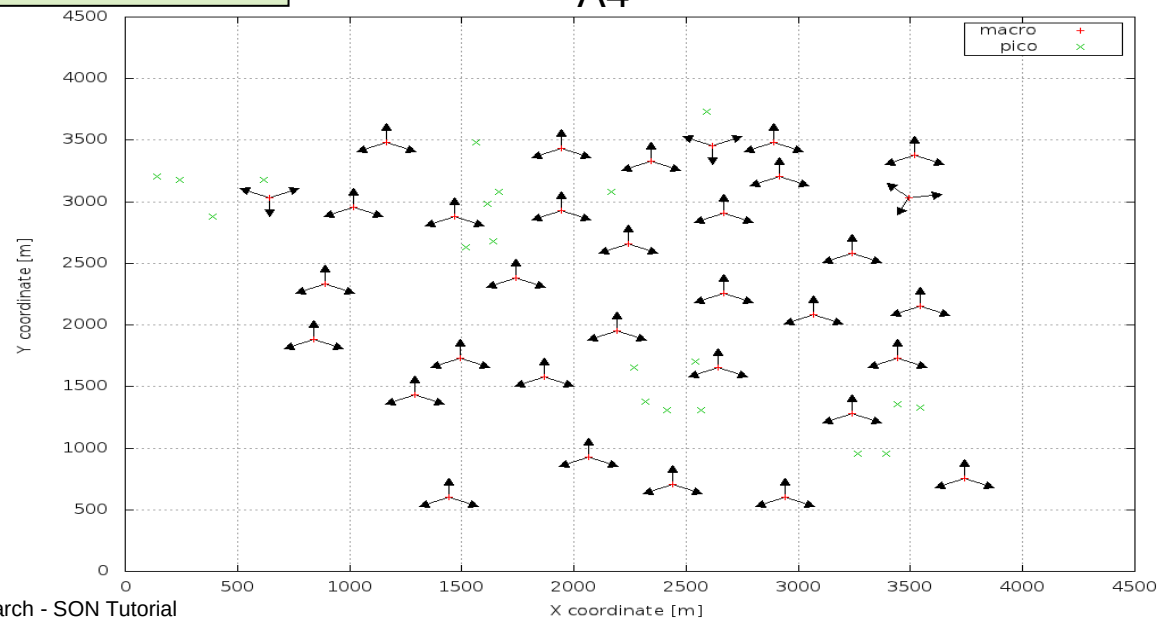
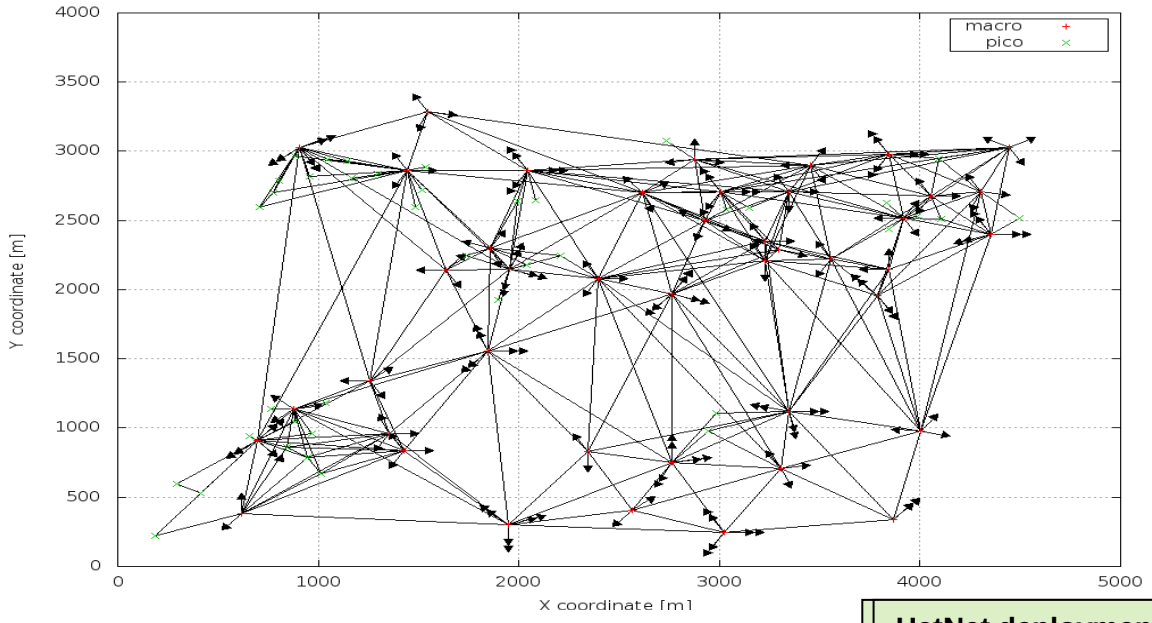


A1



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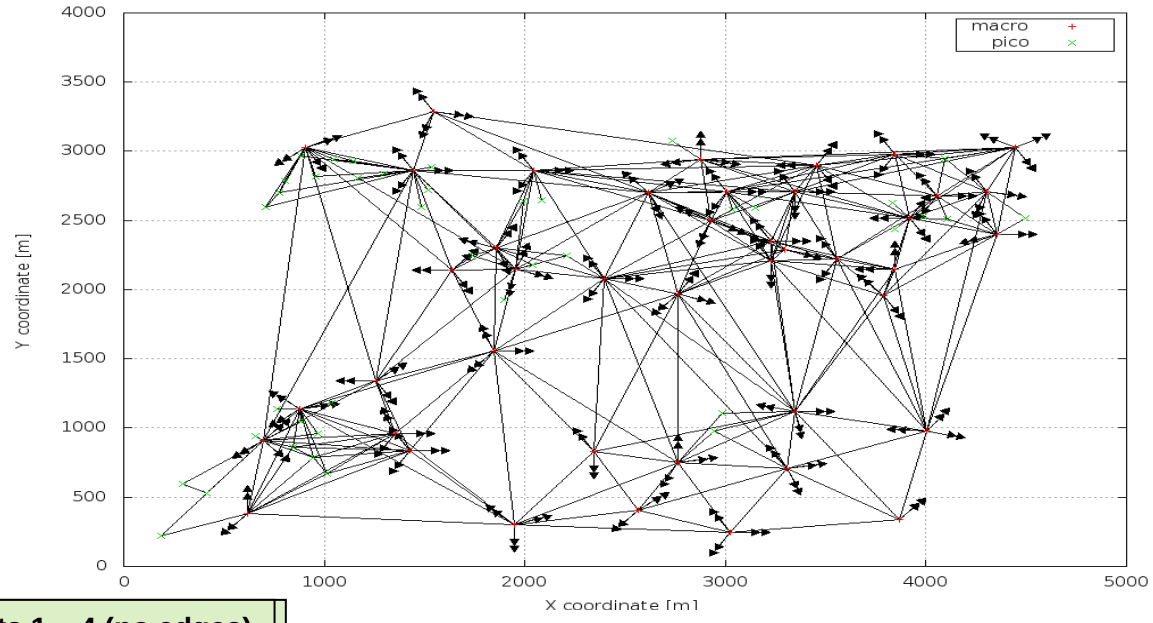
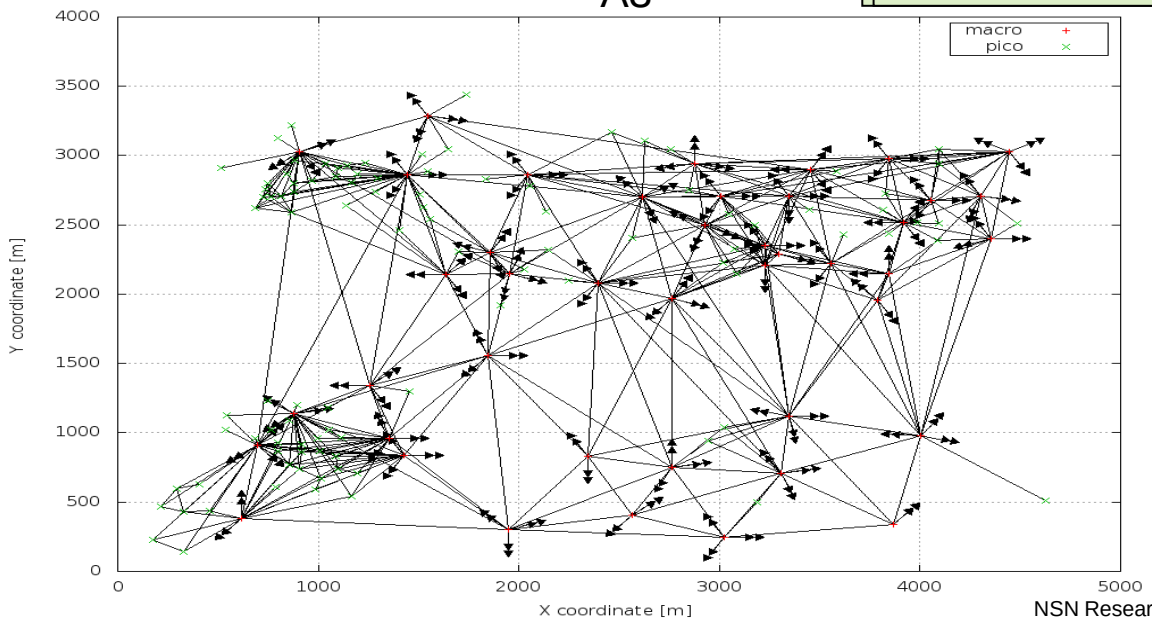
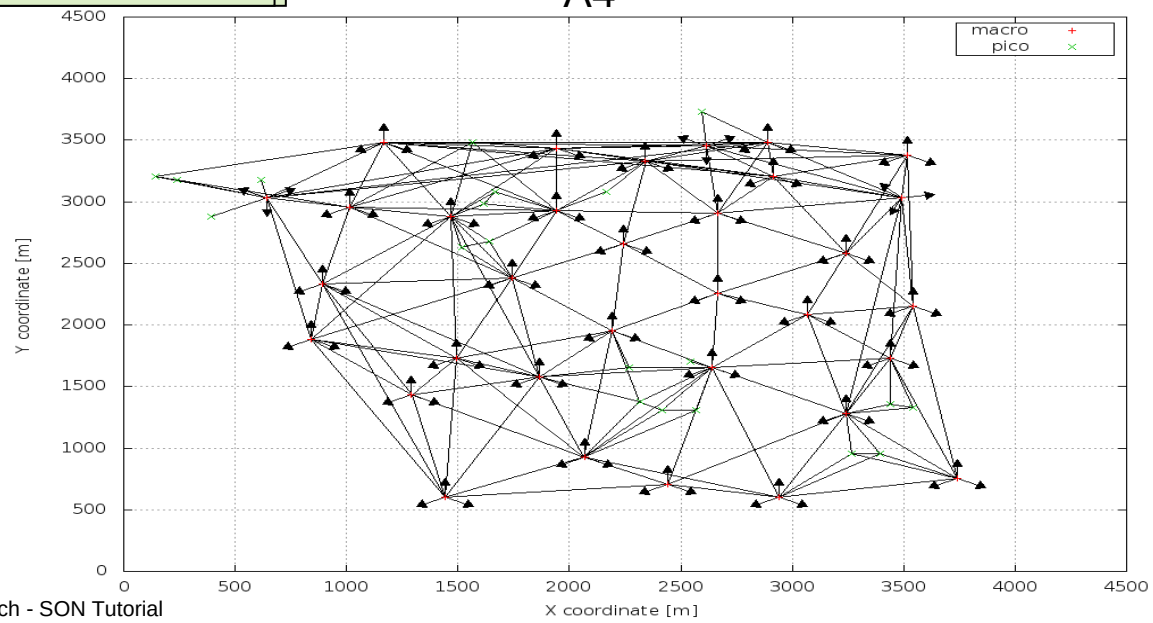


HetNet deployments 1 – 4 (no edges)

A3



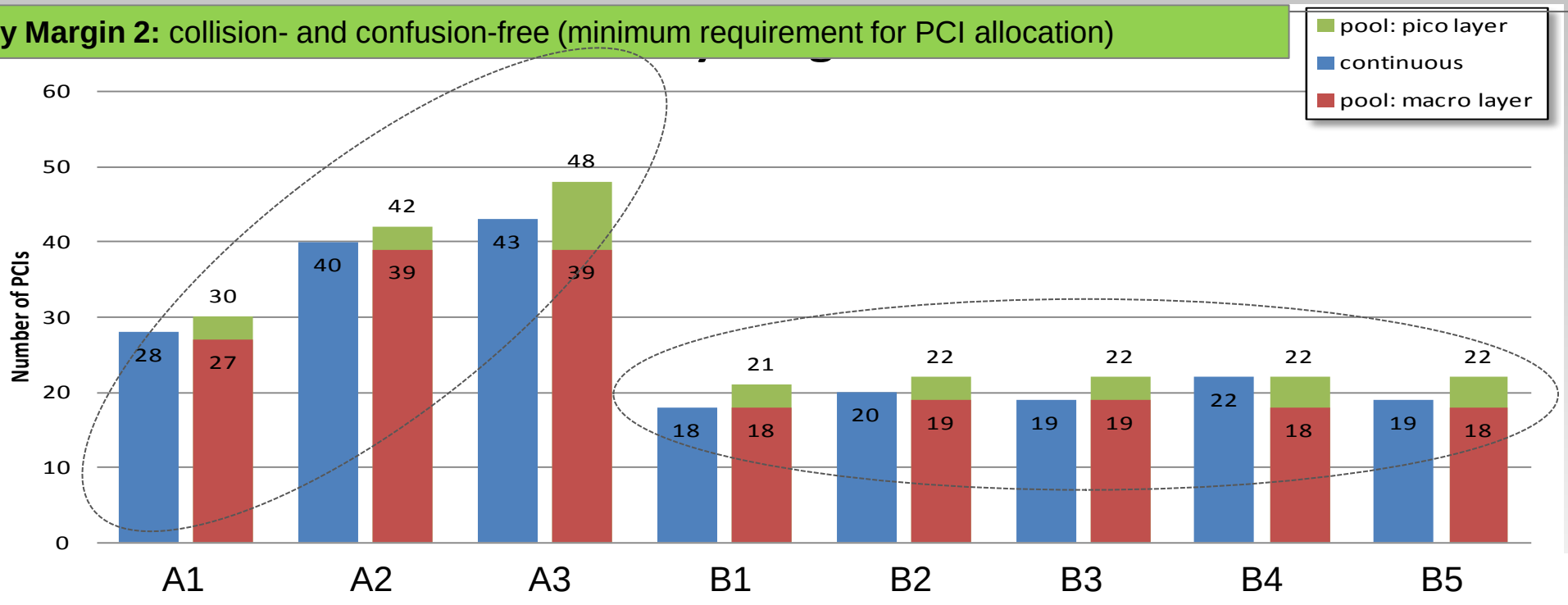
A4



Number of required PCIs in different scenarios

Continuous Allocation vs. Range Segmentation

Safety Margin 2: collision- and confusion-free (minimum requirement for PCI allocation)

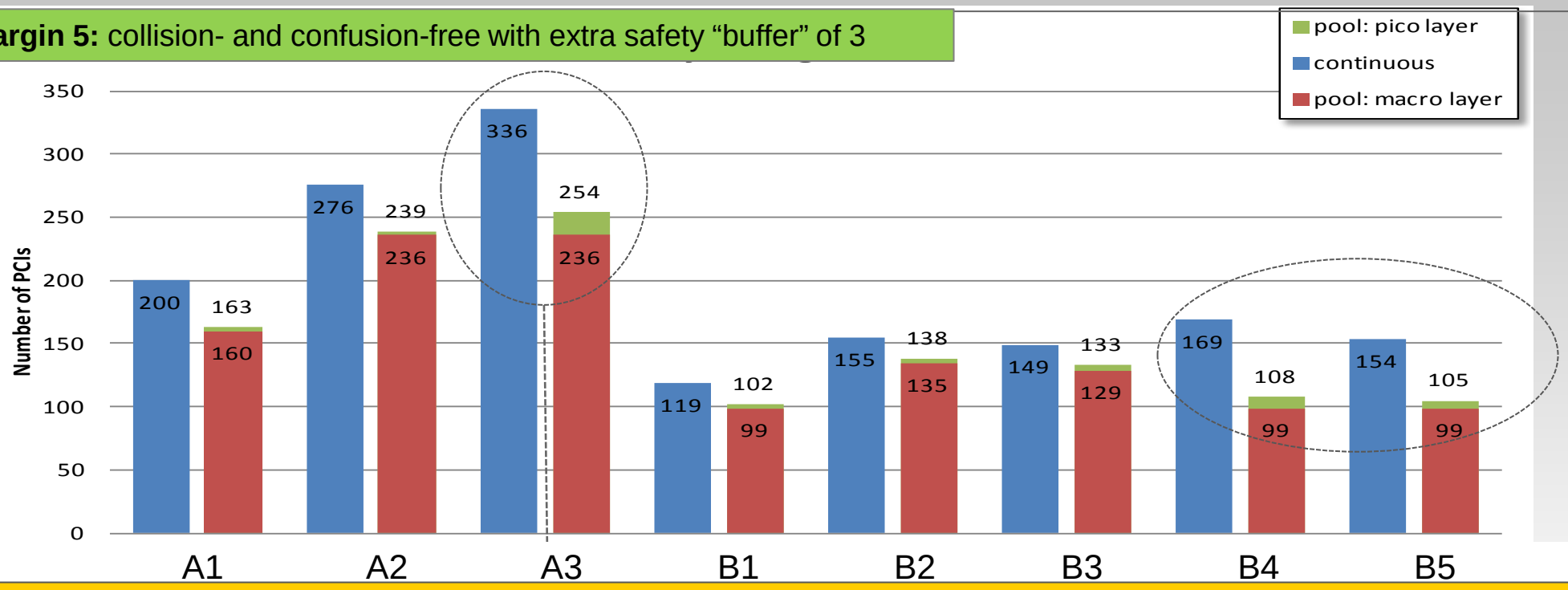


Range Segmentation:
some increase in required PCIs compared to Continuous Allocation, but not significant

Number of required PCIs in different scenarios

Continuous Allocation vs. Range Segmentation

Safety margin 5: collision- and confusion-free with extra safety "buffer" of 3



As the Safety Margin increases, Range Segmentation results in significantly lower number of required PCIs, in case there is a high number of inter-layer adjacencies (e.g., "A3" with 100 pico cells): these inter-layer adjacencies are a priori eliminated by Range Segmentation, but cause additional constraints for Continuous Allocation (pico cells connecting macro cells in the graph)

→ **PCI range segmentation** (combined with *different* per-domain PCI allocation algorithms) **is viable in multi-vendor HetNets**

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