Reliable Operation of Heterogeneous Wireless Networks with SON (Self-Organizing Networks) - Mobility Robustness Optimization (MRO)

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- Research

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Overview

- SON Use Cases (self-configuration, self-optimization, self-healing)

- MRO
- Mobility basics, Handover
- Handover problems, detection
- Simple Algorithm
- Two examples of MRO working
- A little bit further discussion

Self-Optimization: SON Use Cases

RAN

SA 5

SON Coordination Resolution — Rel.10

Selfhealing
- Cell Outage Compensation — Rel.10

Self-optimization extensions (Rel.10/11)
- Mobility Robustness Optimization
- Mobility Load Balancing
- Energy Saving
- Coverage and Capacity Optimization

Rel.10/11

Self-optimization (Rel.9)
- Mobility Robustness Optimization
- Mobility Load Balancing
- RACH Optimization

Rel.9

Rel.10

Self-configuration (Rel.8)
- SON Plug and Play
- ANR Management
- Automatic SW Mgmt and A RC (R9)

Rel.8

Rel.10/11

Minimization of Drive Tests — Rel.10/11

Mobility Load Balancing: controlling mobility handovers to balance the load between cell-pairs

Traffic Steering:

controlling dedicated handovers to dedicated cells (other layers, other RATs)

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MRO: Mobility Robustness Optimization

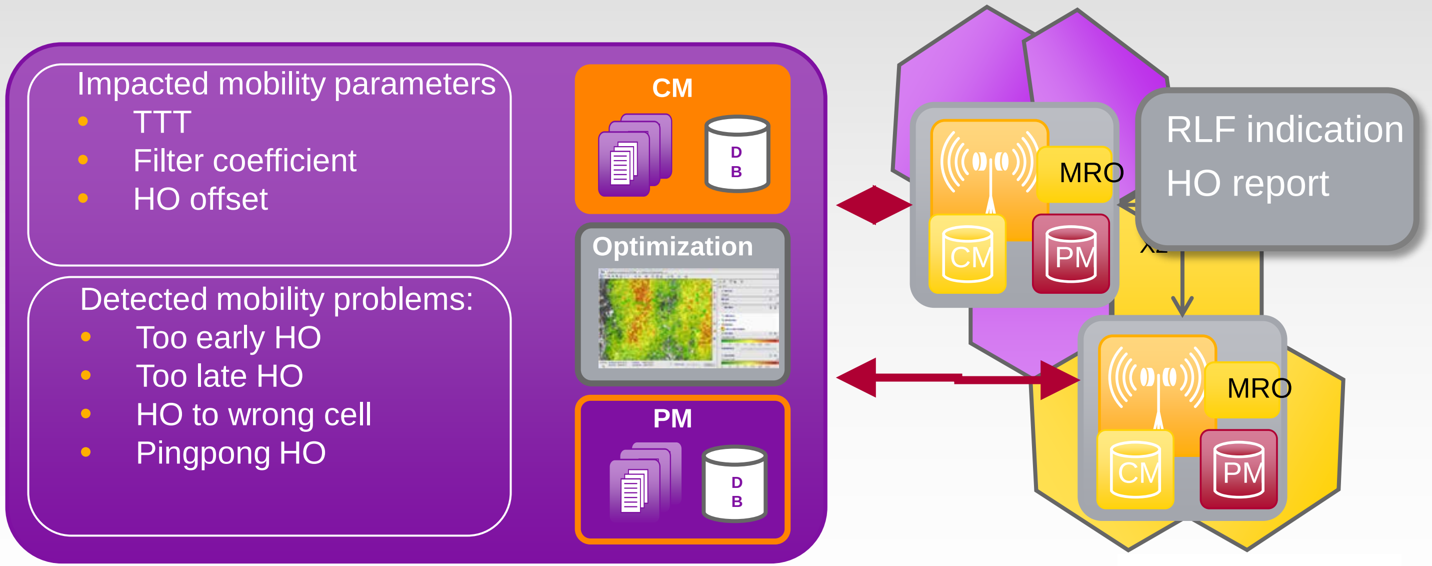
- aka: Handover Optimization
- aka: Mobility Optimization

Self-optimization of Handover Parameters to support robustness of the radio link

so working against

- Failure Cases: Radio Link Failures (RLF), Call drops
- Failure Cases: Unnecessary Handovers

Self-optimization -> Handover parameters are not part of the planning process.



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Handover Parameters?

Note:

There are no dedicated handover parameters in the 3GPP scope.

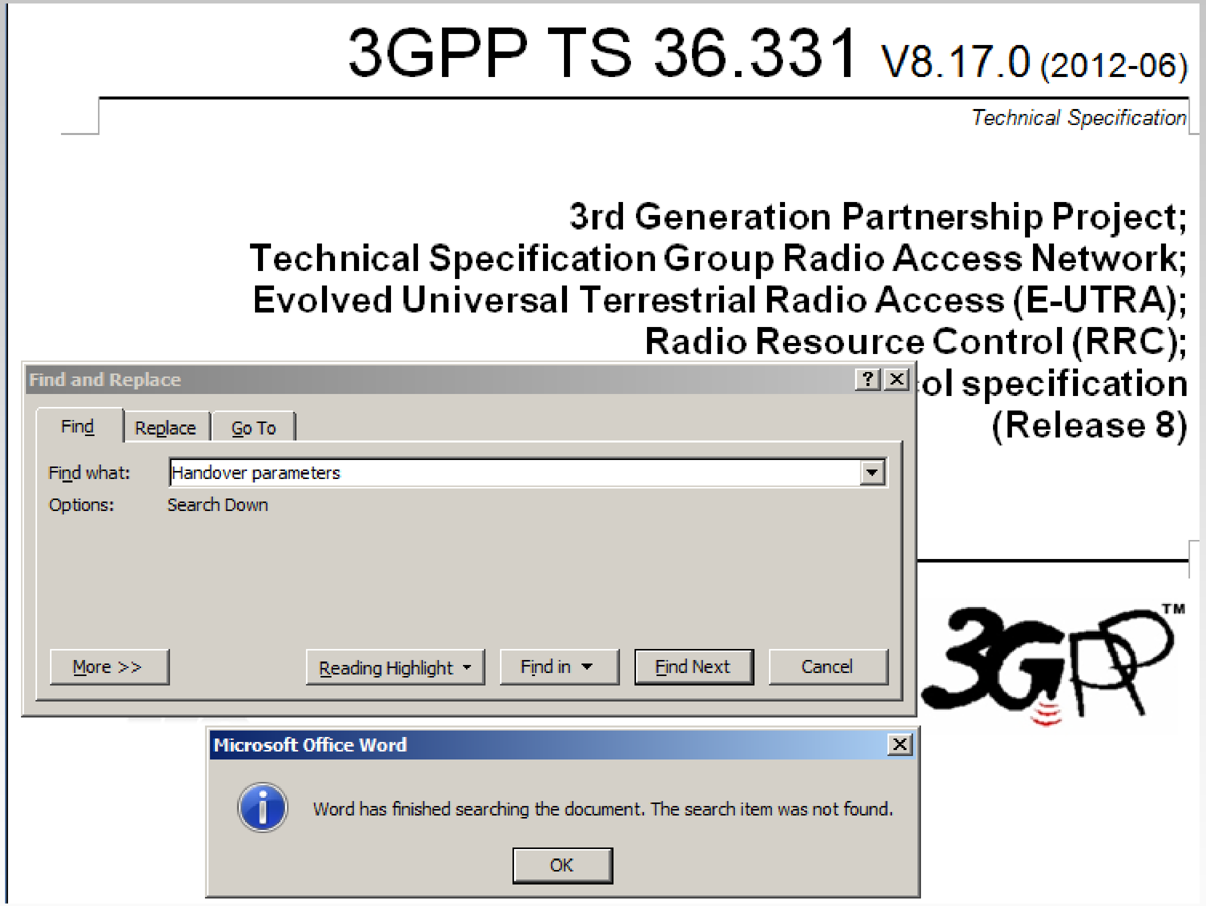
What is a handover anyway?

RRCConnectionReconfiguration on Uu

HO request on X2

S1 Handover

...



Well…

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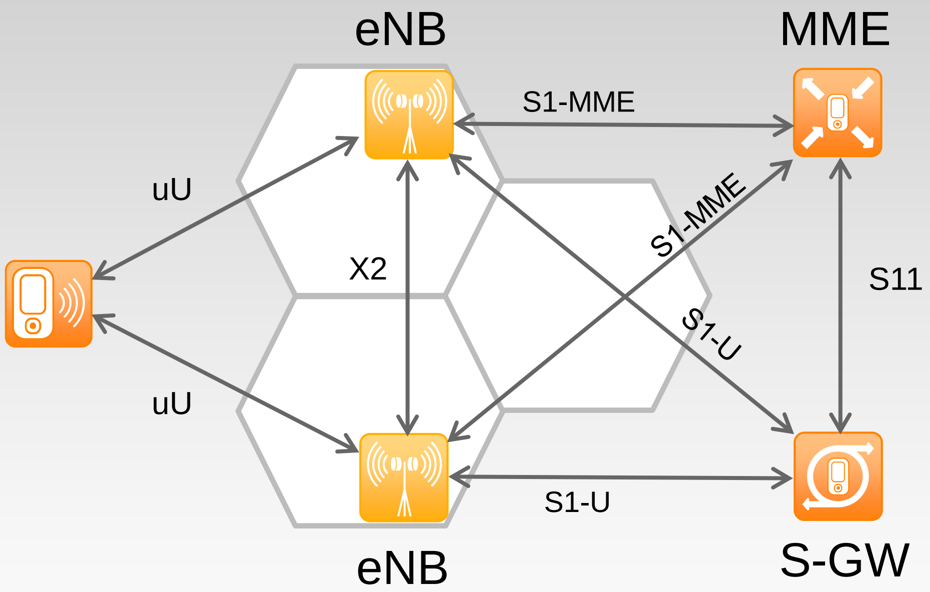
Handover Model (I), reasonable level of detail

- Two players, the network and the terminal
- Still true:
  - For 2G….4G the Handover is decided and
  - The Handover procedure is controlled by the network, eNB and MME/S-GW
  - The terminal (aka UE) has a supporting role…



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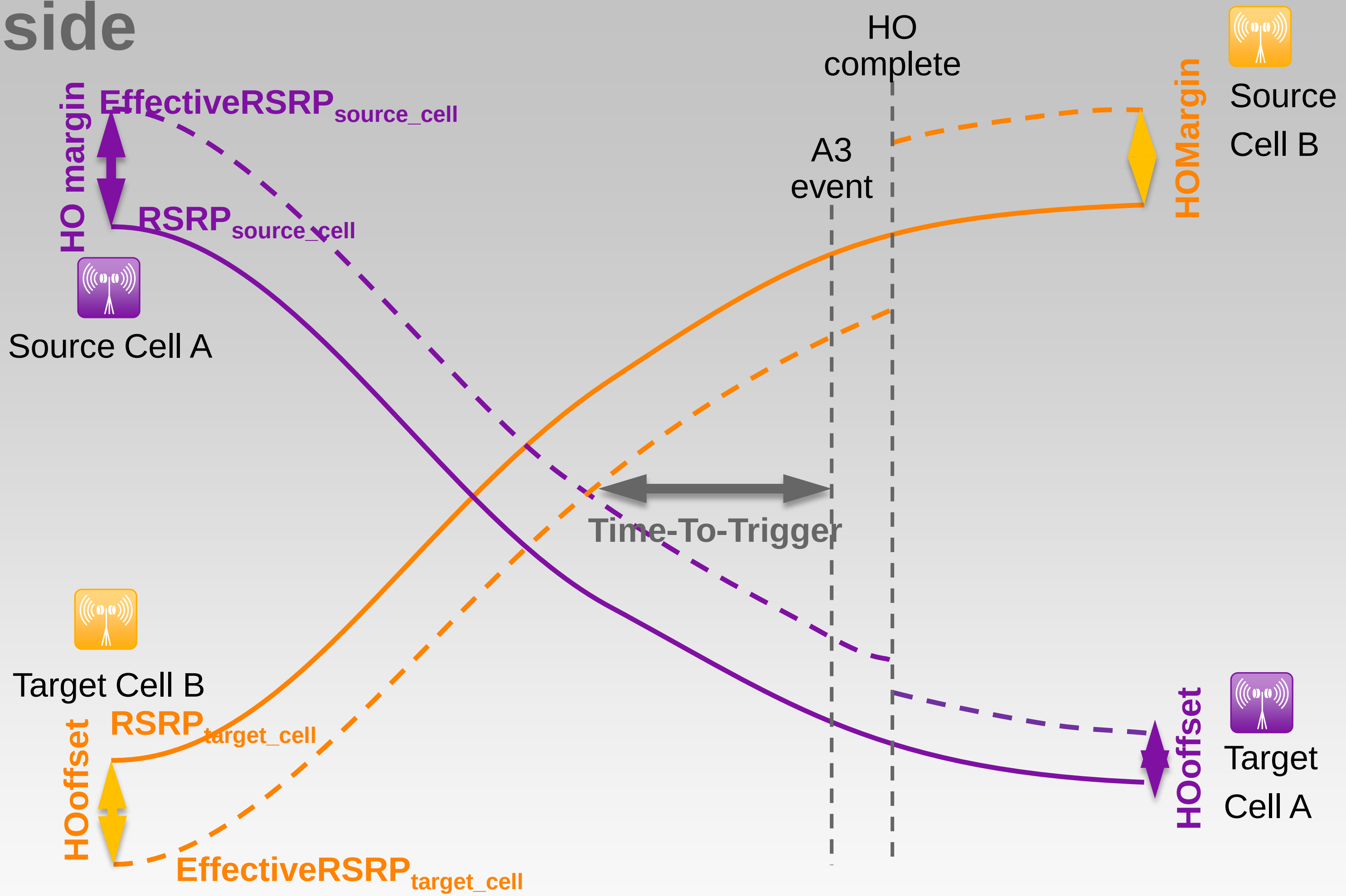
Handover Model (II), UE side

- Handover at the UE side:
- Measurement configuration
  - Items, offsets, TTT
  - Layer3 filtering
  - Measurement reporting (single, periodic)

- RRC Reconfiguration
- RACH / P-RACH
- RLF detection

- RRC reconnection/re-establishment



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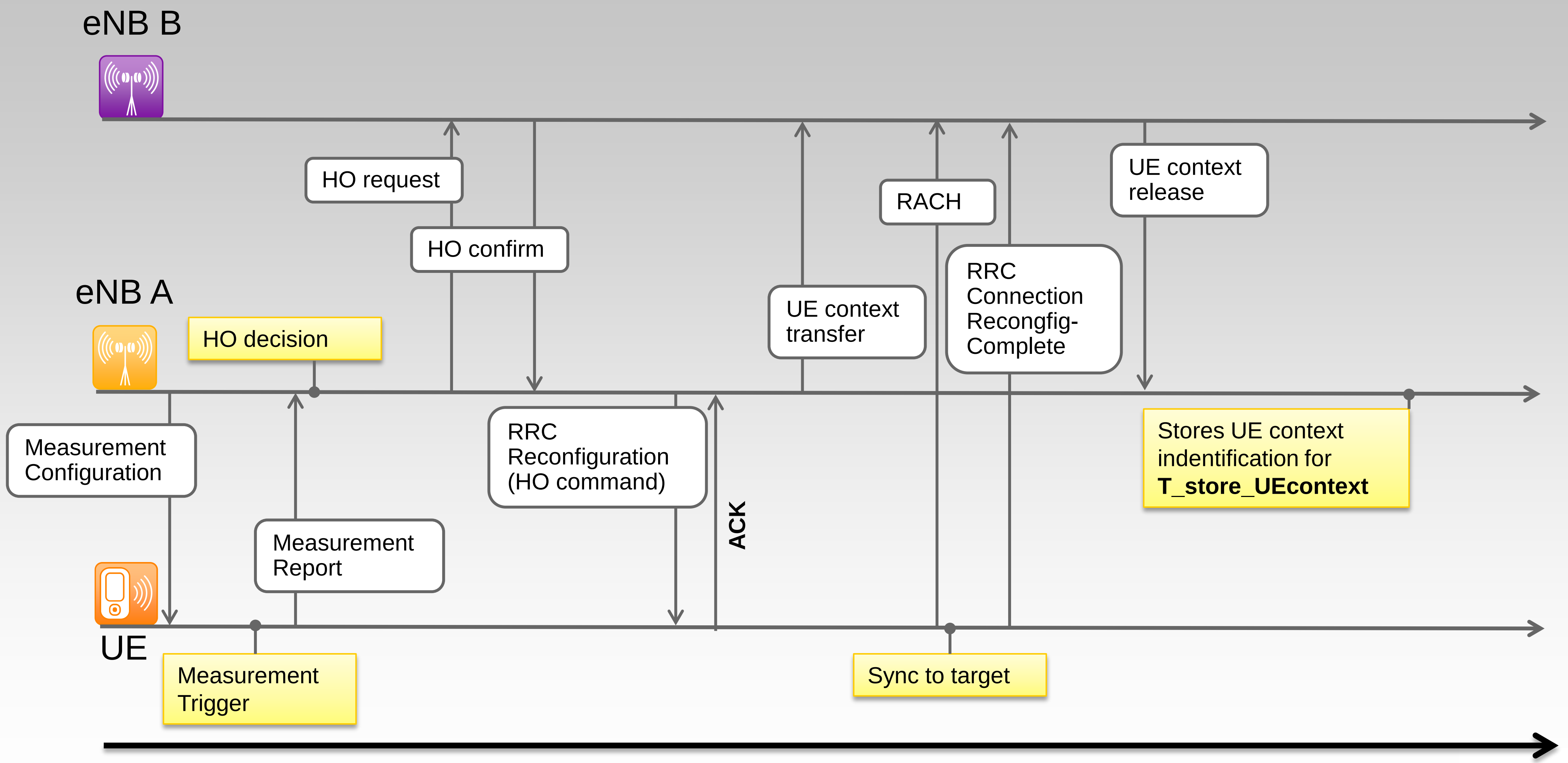
Handover Model (III), eNB side

- Radio Resource Control (RRC)
- Measurement configuration -> trigger in the UE
- Receiving Measurement Reports
- Handover decision
- MME contact/packet forwarding (source eNB)
- S1 connection
- X2 signalling

Handover model (IV), functional timeline



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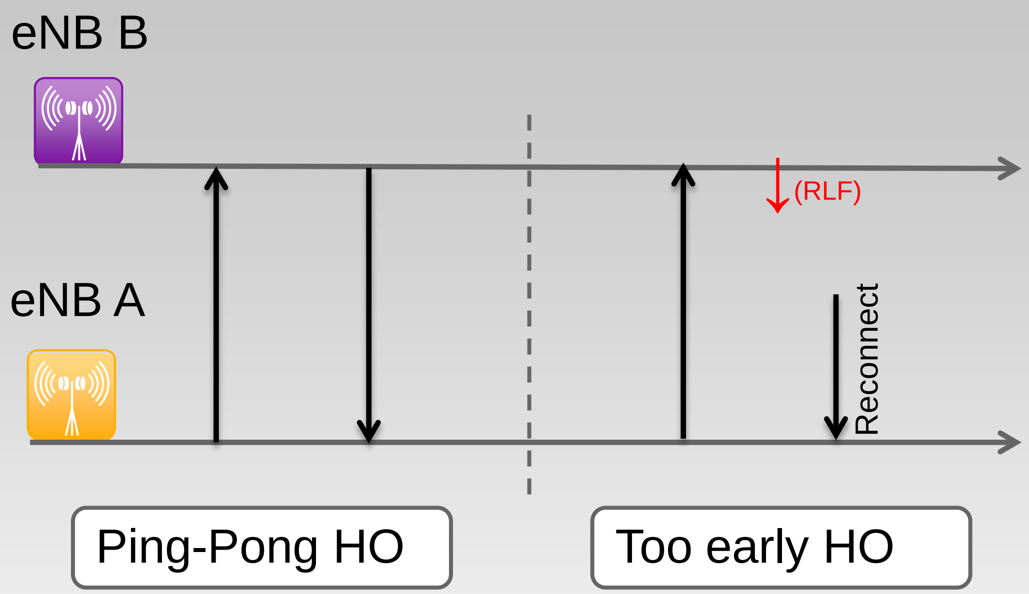
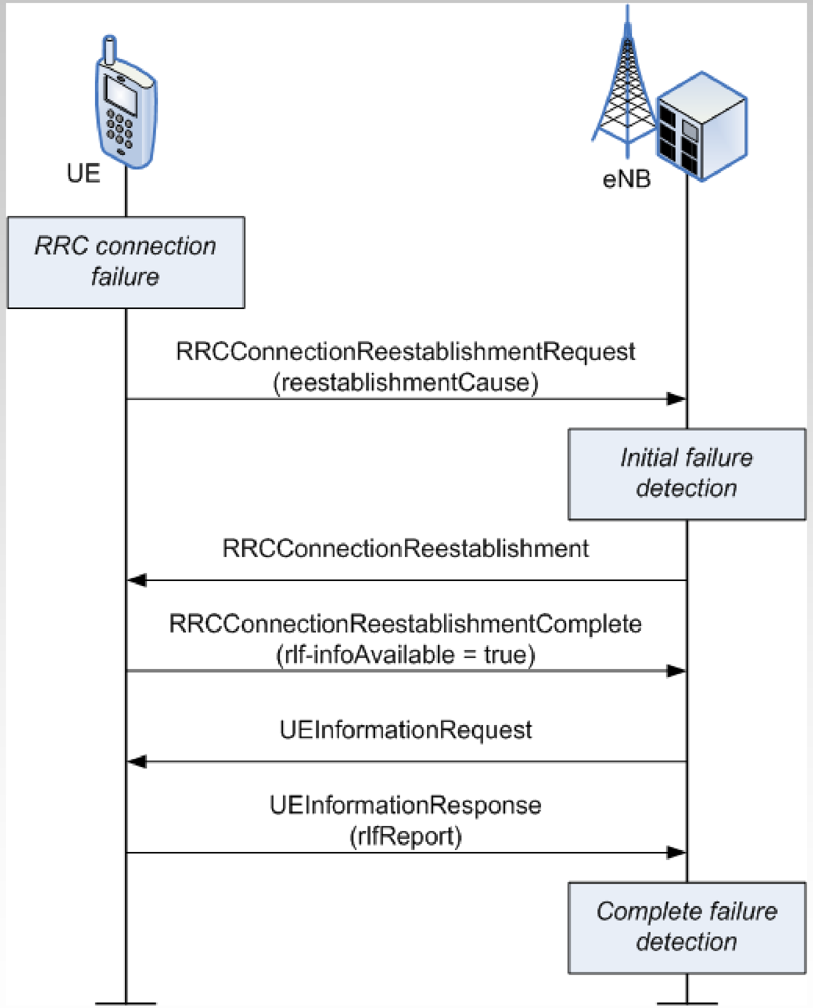
HO Problems

In general

- Handover failures direct OR
- Successful Handover followed by a second Event:
  - Ping-Pong: A B A with time in B < limit
  - Short-Stay: A B C with time in B < limit
  - Too early HO: A B, fail in B, reconnection to A
  - Too late HO: HO decision for B, fail in A
  - Handover to Wrong Cell: A B, fail in B, reconnection to C
- Ping-Pong and Short-Stays: minor cases, creating signalling effort
- TL & TE major cases, as they include a RLF (probability of call drop)



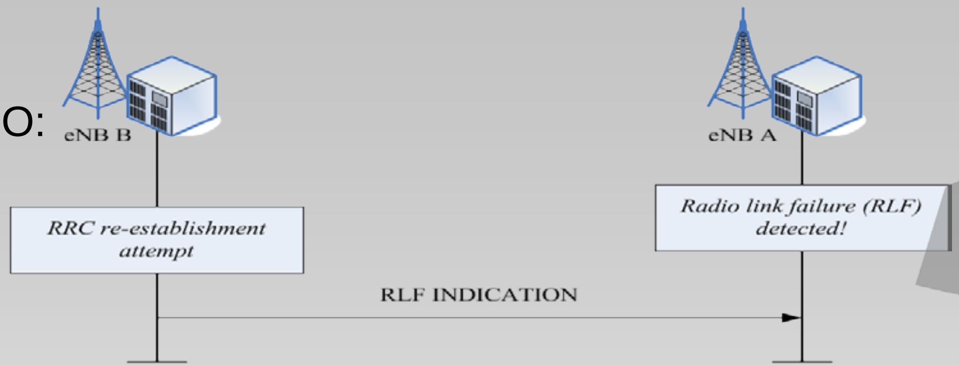
HO problem detection: RLF report, RRC re-connection and X2

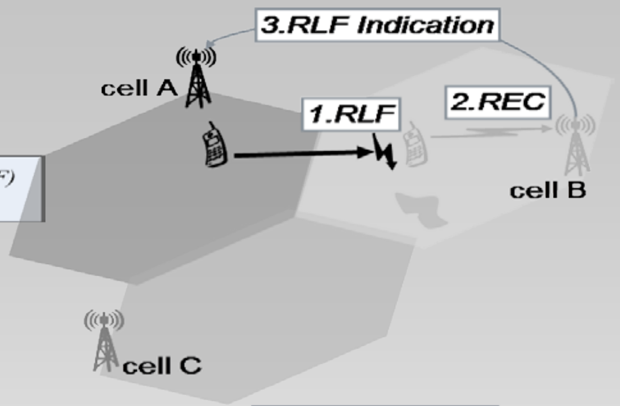


- eNB detects a connection failure after RRCConnectionReestablishmentRequest
- In order to obtain more information from the UE, the eNB must admit the connection and send a request
- The UE information is needed to derive the most probable cause of the connection failure and to decide if RLF INDICATION should be sent (the information may be included)
- If the reestablishment can not be admitted, the RLF INDICATION may be sent immediately after RRCConnectionReestablishmentRequest
- Possible causes for connection failure:
  - reconfigurationFailure
  - handoverFailure
  - otherFailure
- Reporting to the cell where the failure occurred; UE measurements may be added optionally: X2AP: RLF INDICATION
- Further clarification, if the root cause of the failure is not in the cell, where it occured : X2AP: HO REPORT

Root cause identification/analysis, X2 interface

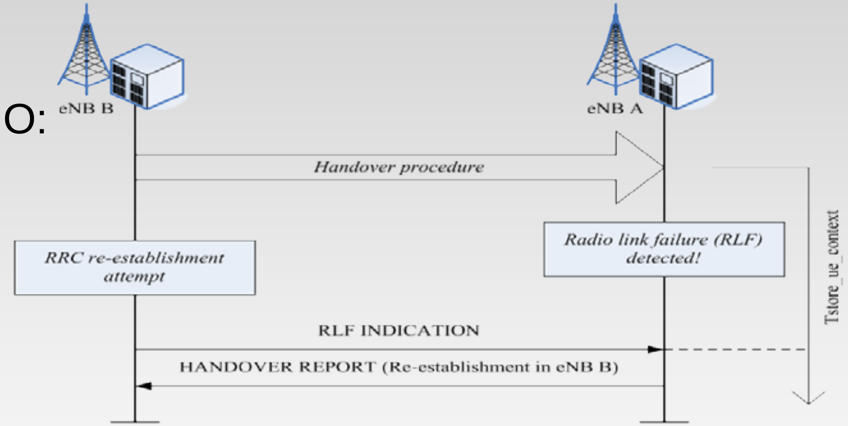
Too late HO:

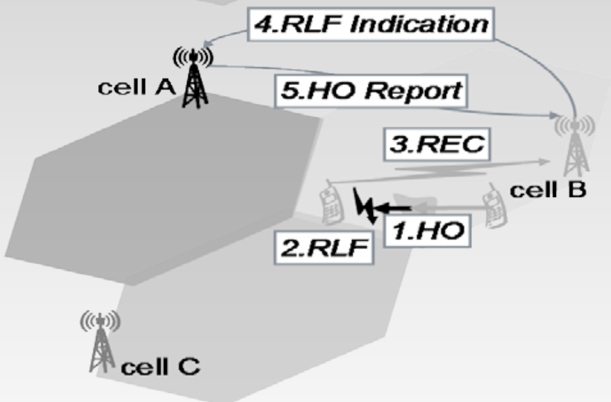




Connection failure occurs in cell **A**, connection is re-established in cell **B**: **too late HO** in **A** (i.e. cell A should have triggered a HO to B sooner), or no HO in A (i.e. cell A did not trigger the HO, though it was possible)

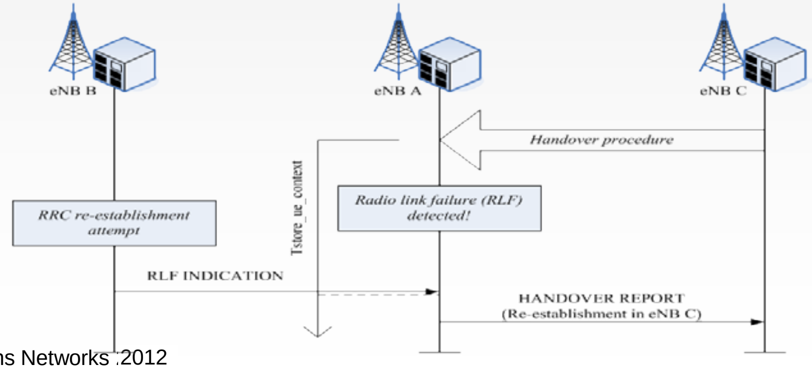
Too early HO:

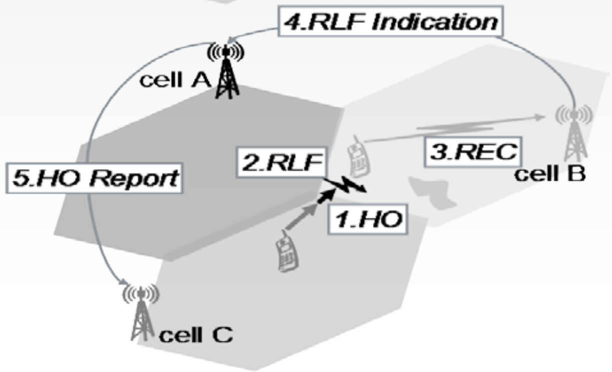




Successful HO from cell B to A, then very soon connection fails in cell A and is re-established in B: too early HO in B (i.e. cell B should not have performed the first HO to cell A)

HO to wrong cell:





Successful HO from cell B to A, then very soon connection fails in cell A and is re-established in C: **HO to wrong cell** in B (i.e. cell B should have performed the first HO to cell C, not to A)

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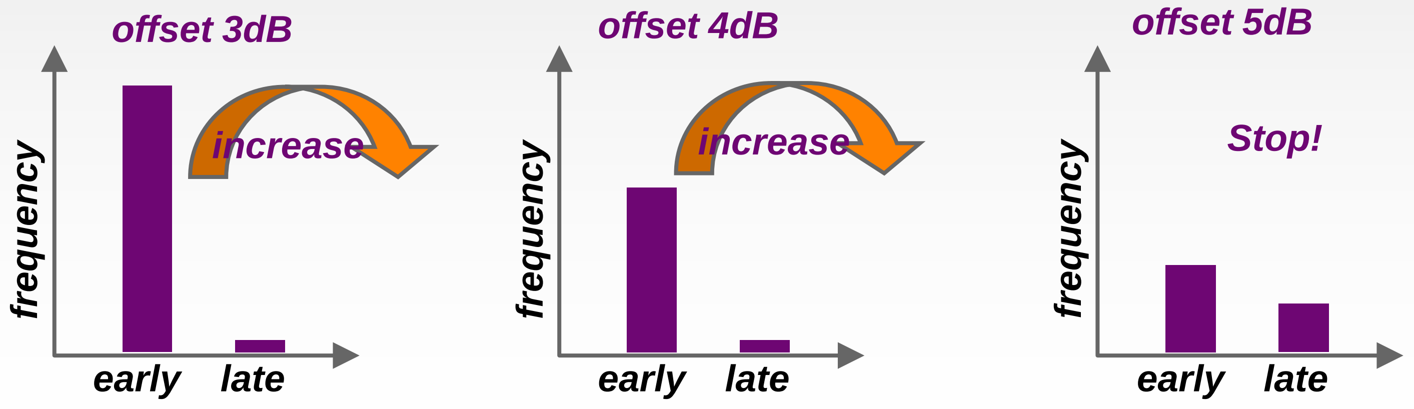
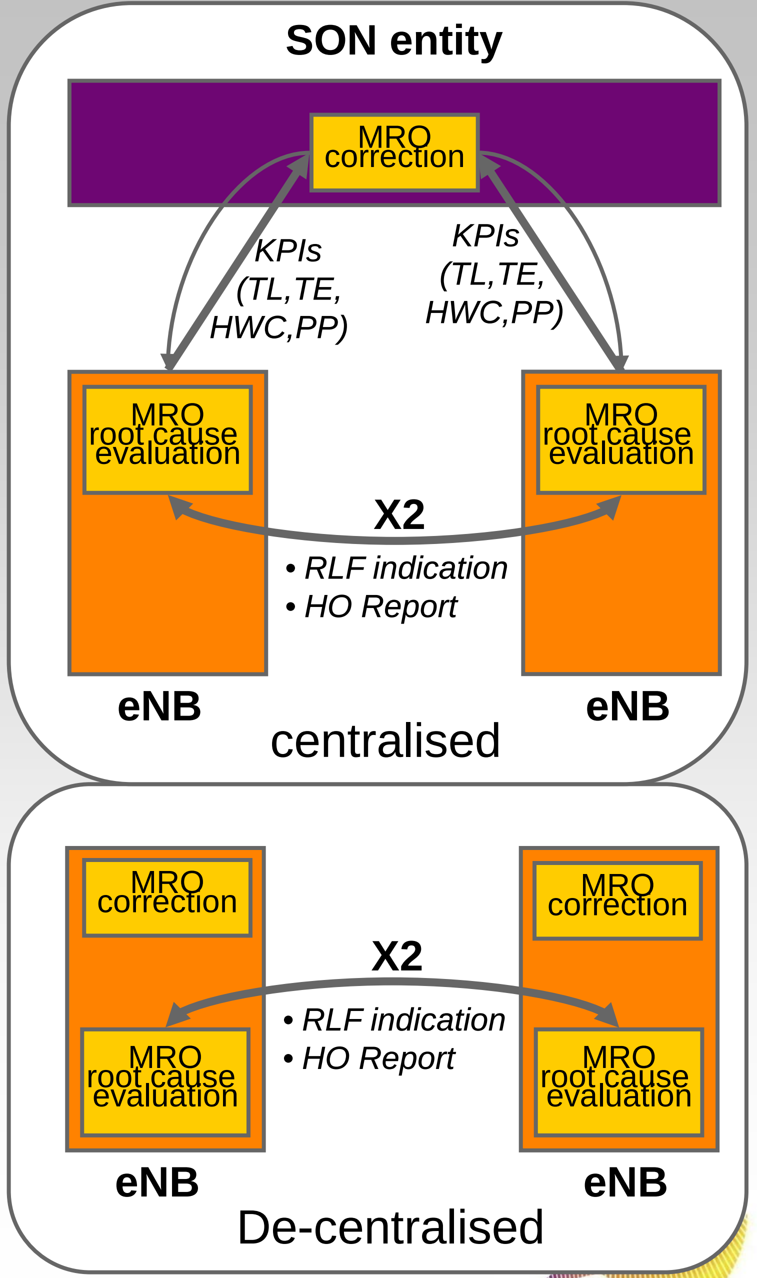
MRO key idea, simple algorithm

- Root Cause Evaluation: determine the root cause of every mobility problem
  - Too early HO, Too late HO, HO to wrong cell, PingPongs, Short -Stays …
  - Specified by 3GPP
- Corrective action -> Changing mobility parameters

  Straight forward (once root cause is clear)
  - A lot of “too late”s, few “too early”s ➔ make HOs earlier (larger CIO)
  - A lot of “too early”s, few “too late”s ➔ make HOs later (smaller CIO)
  - Similar amount of “too early”s and “too late”s ➔ bad luck





Mobility HOs, HO offsets, Cell individual offset (CIO)

Example for Measurement trigger: A3, relative to serving cell

Event is triggered when the following condition is met for a time period of time-to-trigger (TTT)

$$RSRP_{neighbour} + HOOffset_{serving \rightarrow neighbour} > RSRP_{serving} + HOMargin$$

$$\rightarrow EffectiveRSRP_{target\ cell} > EffectiveRSRP_{source\ cell}$$

$RSRP_{neighbour}$ is the L3 RSRP value of the neighbour cell

$RSRP_{serving}$ is the L3 RSRP value of the serving cell

$HOOffset_{serving \rightarrow neighbour} = Ofn + Ocn – Hys$ [TS36.331]

- *Ofn* is the frequency specific offset of the frequency of the neighbour cell
- ***Ocn*** is the cell specific offset of the neighbour cell in the serving cell, and set to zero if not configured for the neighbour cell
- ***Hys*** is the hysteresis parameter for this event

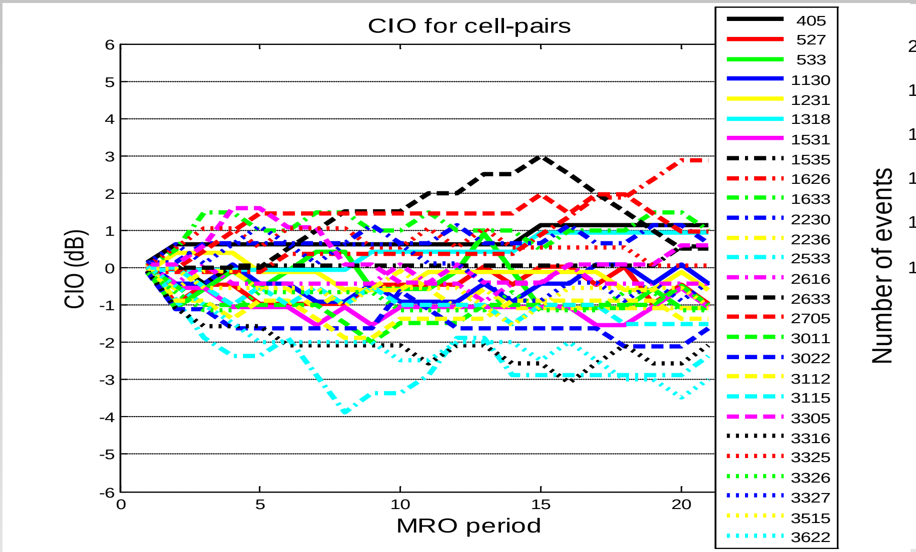
HOMargin = Ofs + Ocs + Off   *[TS36.331]*

- *Ofs* is the frequency specific offset of the serving frequency (not used)
- ***Ocs*** is the cell specific offset of the serving cell and is set to zero if not configured for the serving cell
- *Off* is the offset parameter for this event

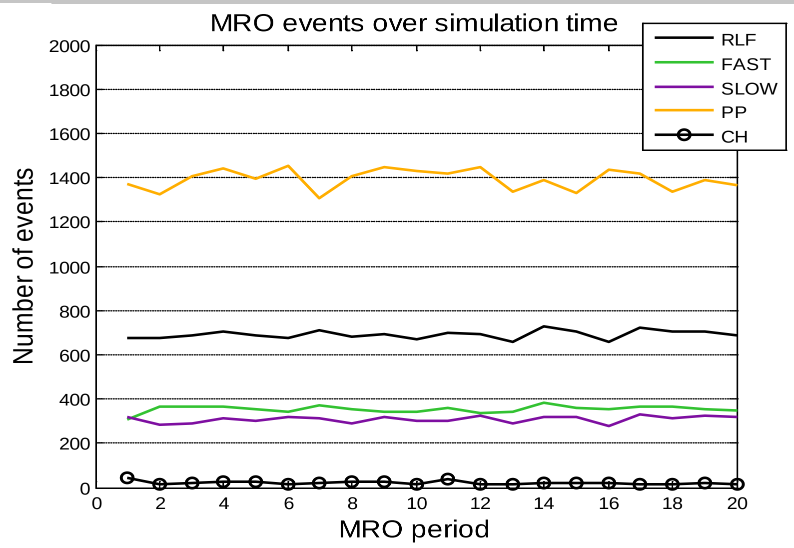
CIO = - Ocn in the simulation results. CIO is thus logically working similar to Hys

-> **bigger CIO means that HO is done later**

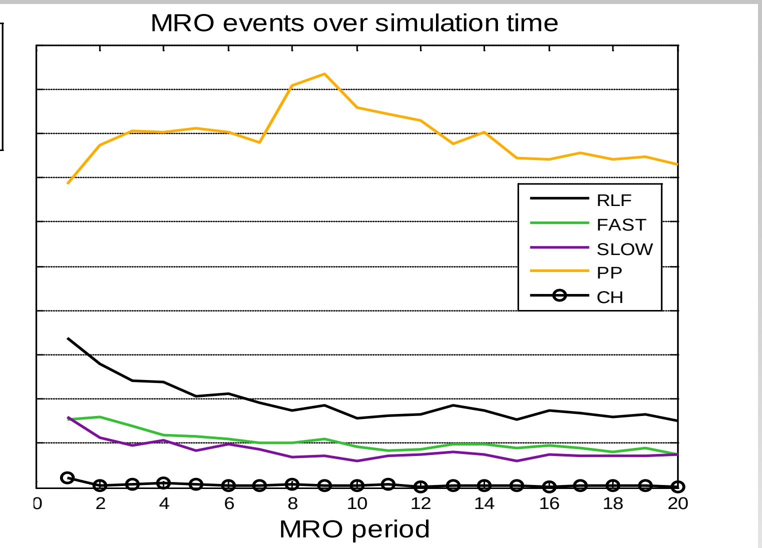
Working MRO, CIO optimization, 30 km/h UEs



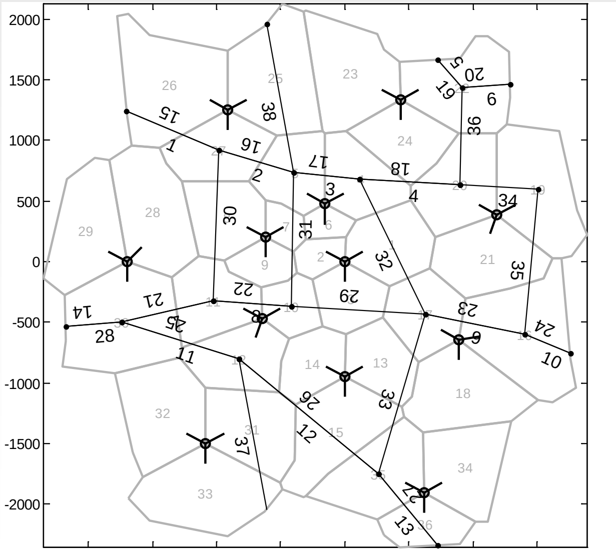
CIO for busiest cells



No MRO optimization



Distributed MRO
CIO Optimization



	All periods		Last 5 periods	
	No optimization	Distributed MRO CIO optimization	No optimization	Distributed MRO CIO optimization
HO	124413	121540	30946	29099
RLF	13817	7758	3475	1630
Fast	7081	4162	1792	856
Slow	6152	3334	1556	727
PP	27846	31750	6941	7435

KPI count sums

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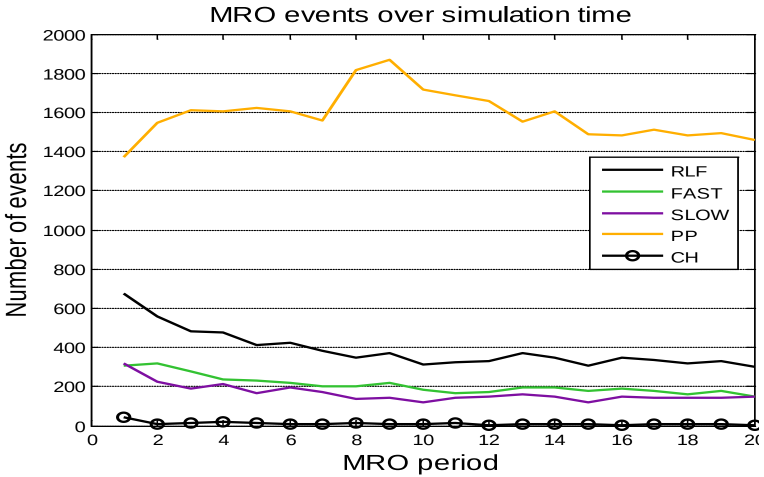
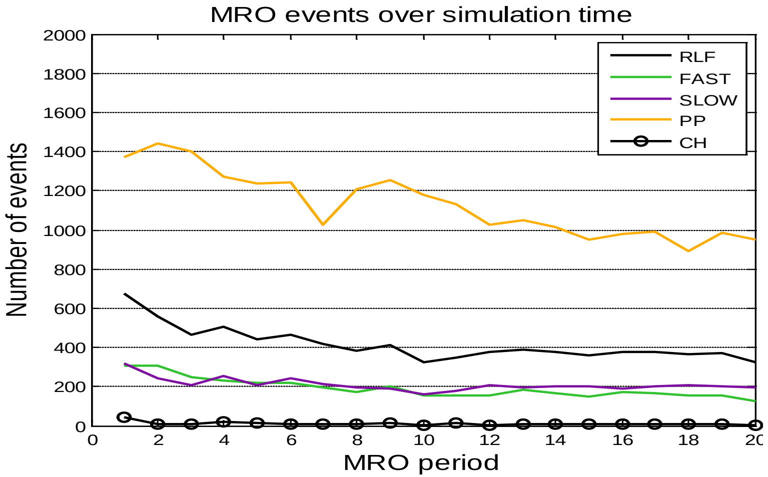
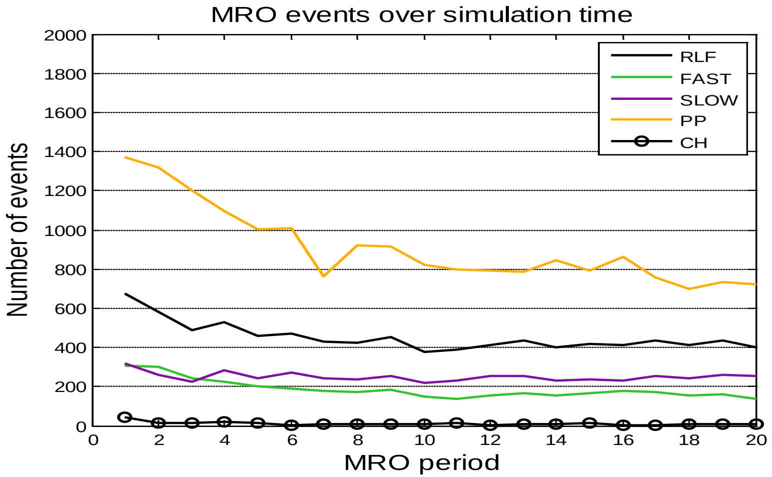
Working MRO, CIO Optimization with PP Weighting



MRO Optimization with
0 % PP weight



MRO Optimization with
10 % PP weight



MRO Optimization with
25 % PP weight

- The CIO algorithm was extended so that PPs are counted as too fast HO with given weight. Otherwise algorithm works the same
- The bigger weight PPs have the more PP are decreased. Also fast RLFs are decreased at the same time
- The PP gains come at the expense of increased RLFs compared to 0% PP case
    - I.e. slow RLFs are decreased less

	Last 5 periods			
	Non-optimized reference	Distributed MRO CIO optimization 0 % PP	Distributed MRO CIO optimization 10 % PP	Distributed MRO CIO optimization 25 % PP
HO	29243	29099	24522	22376
RLF	3033	1630	1820	2094
Fast	1576	856	774	807
Slow	977	727	995	1242
PP	8922	7435	4803	3781

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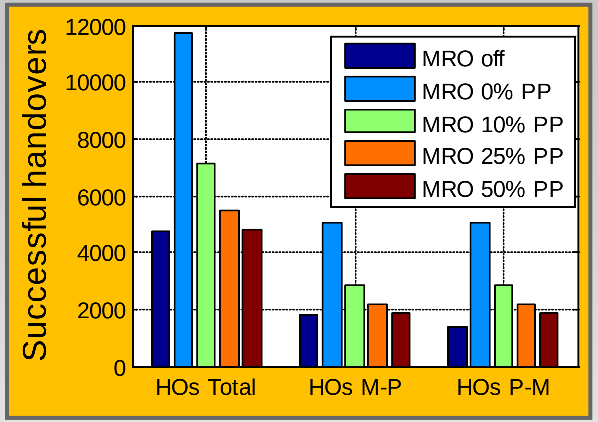
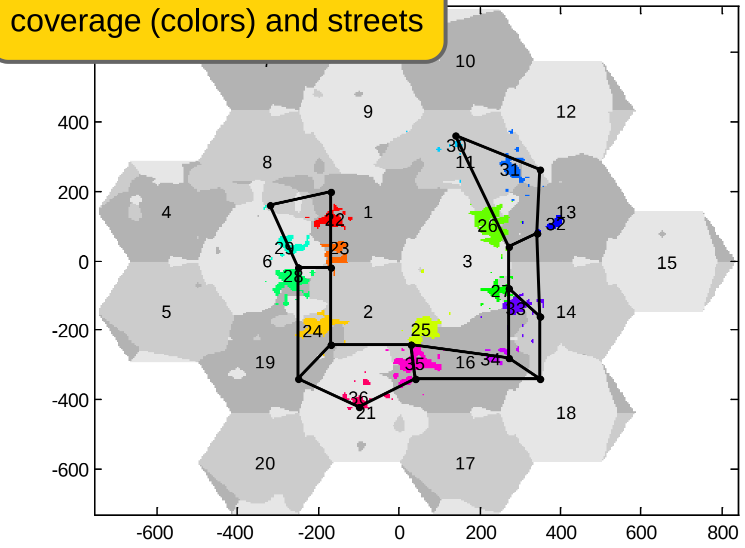
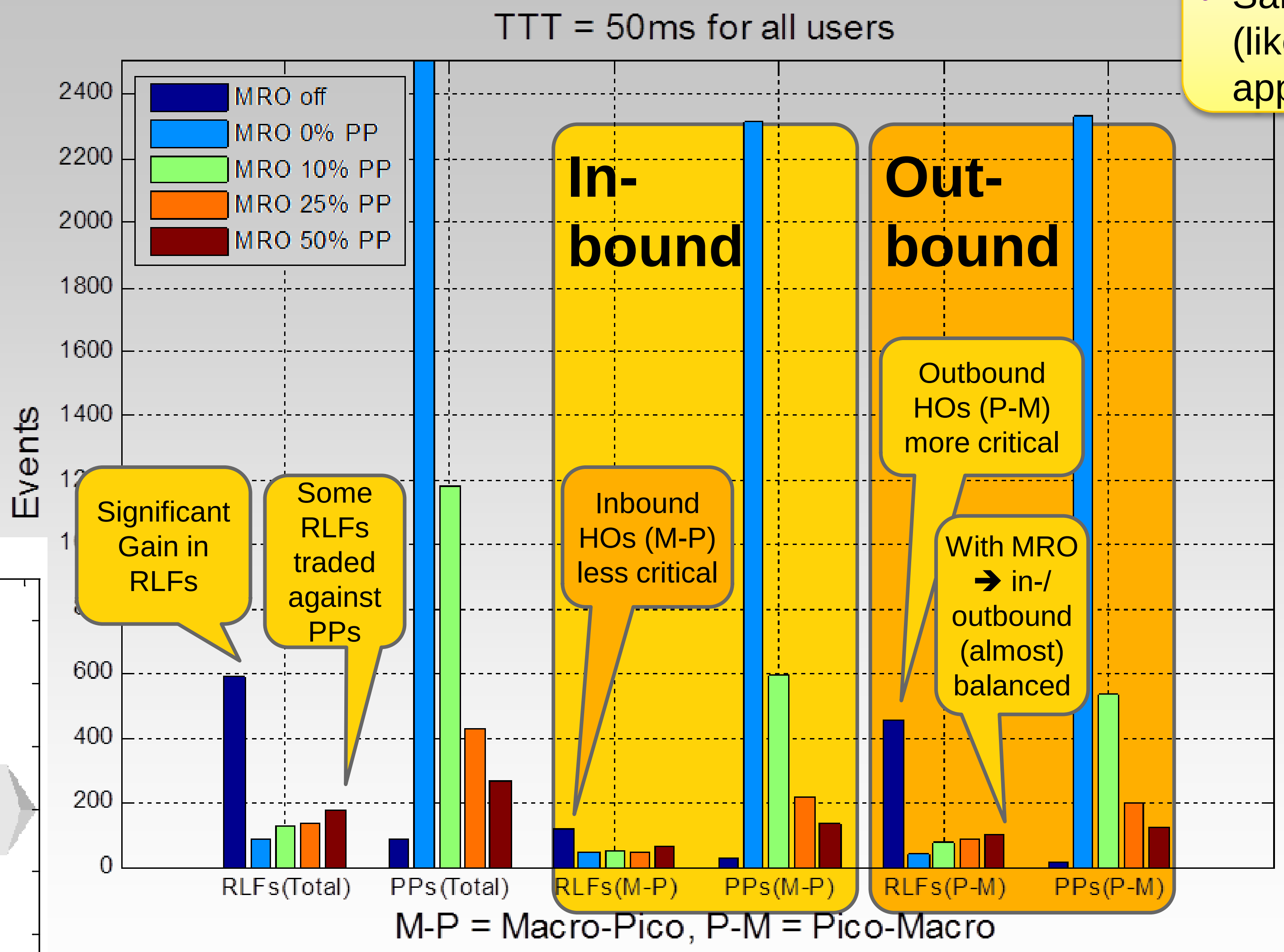
Working MRO, HetNet scenario

Note:
- Same algorithm (like macro) applies here.



Macro coverage (grey), pico coverage (colors) and streets





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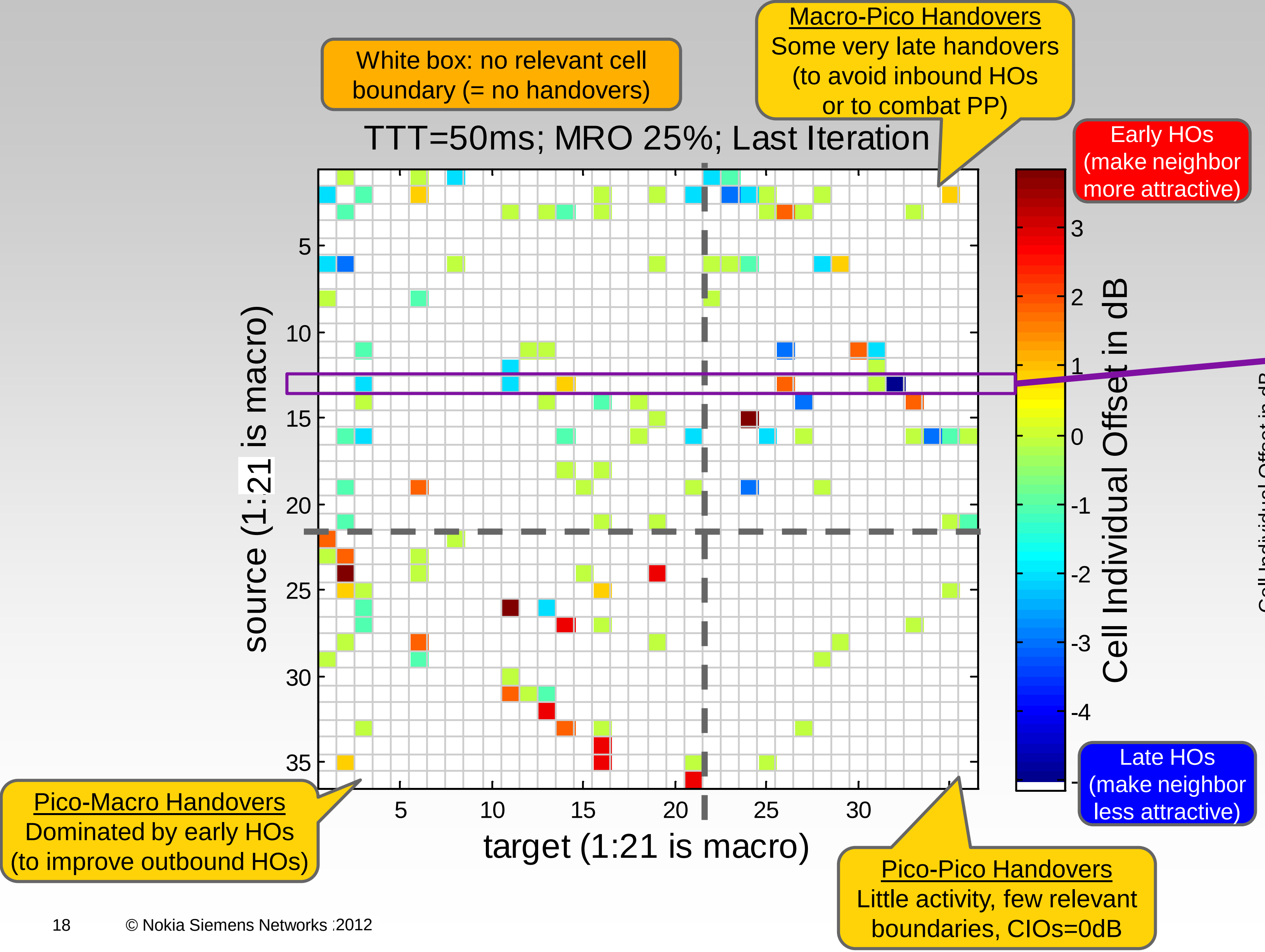
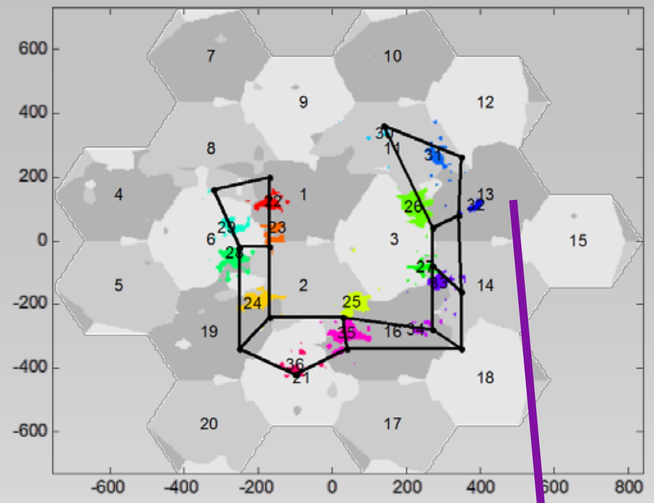
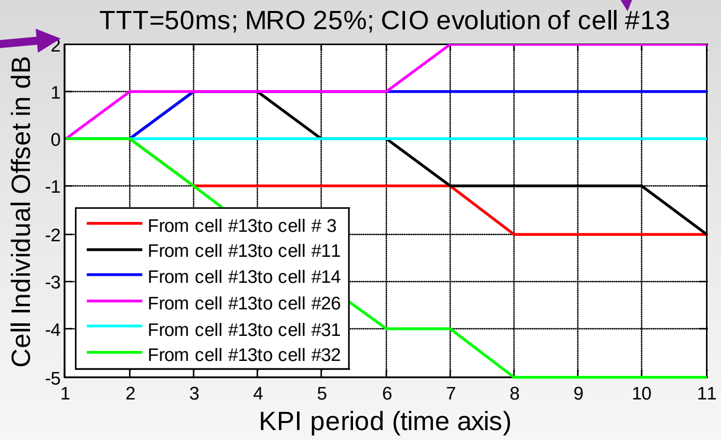
Working MRO, HetNet scenario, CIO







Note:

- Every cell has different optimal CIO
- Even single cell has different „optimal" CIOs towards different neighbors

MRO, problems

- KPIs are accounted on counters, possible problems:
  - Sufficient statistics
  - Stationarity
  - KPI periods
- System dynamics
- E.g. Fast train (group of fast moving users)
- E.g. Mobile Relay
- Higher layer SON -> policy translation

Further Extensions for MRO

- Het Net, one of the examples was already macro-pico interaction
- Multi-Layer, yes, there exists also a cell boundary or HO region between Layers, but rather not mobility based
- Multi-RAT, yes 3G / LTE is under standardisation work in 3GPP
- Other HO optimizations in parallel
- Multivendor scenarios

MRO in the Future?

- Trade-off: Effort (implementation / development) vs. Riskyness
  RLF reestablishment is pretty fast, LTE Traffic (any mobile net) will be predominatly data/IP
- MRO in Rel12: will stay

… a few wishes to the audience…

If you are with an operator

- Use SON
- Buy SON

If you are with a vendor (network or terminal)

- Use 3GPP solutions
- Implement X2 (AP)
- Enable X2 by default.

If you are in research

- Do consider the HO process as sum of parts.
- Do not assume stationarity
- Do not assume WSSUS systems
- Do explore system dynamics

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References

S. Hämäläinen, H. Sanneck, C. Sartori (eds.)
LTE Self-Organizing Networks (SON) - Network Management Automation for Operational Efficiency, Wiley, ISBN 978-1-119-97067-5, December 2011. Chapter 5, 5.1

< the 3GPP standards are here referenced in Rel11, you find the equivalent documents in Rel8 and following >

3GPP TS36.300 TSG RAN2, Evolved Universal Terrestrial Radio Access (E-UTRA); Overall description; Stage 2
Available from http://www.3gpp.org/ftp/Specs/archive/36_series/36.300/36000-b30.zip
SON: 22 Support for self-configuration and self-optimisation
MRO: 22.4.2 Support for Mobility Robustness Optimisation

3GPP TS36.331 TSG RAN2, Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC);
Available from http://www.3gpp.org/ftp/Specs/archive/36_series/36.331/36331-b10.zip
HO general: 5.3.5 RRC connection reconfiguration
HO Triggers: 5.5 Measurements
RLF: 5.3.11 Radio link failure related actions
Reconnection: 5.3.7 RRC connection re-establishment

References

3GPP TS36.420 TSG RAN3, Evolved Universal Terrestrial Radio Access (E-UTRA); X2 general aspects and principles
Available from http://www.3gpp.org/ftp/Specs/archive/36_series/36.420/36420-b001.zip

3GPP TS36.423 TSG RAN3, Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)
Available from http://www.3gpp.org/ftp/Specs/archive/36_series/36.423/36423-b20.zip
HO general: 8.2 Basic mobility procedures
RLF: 8.3.9 Radio Link Failure Indication
HO report: 8.3.10 Handover Report