

# Self-Organizing Networks (SON) in 3GPP Long Term Evolution

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## Introduction

As every mobile network, LTE (Long Term Evolution) system also needs to be managed. Since LTE is an evolution of UMTS, the management should also evolve from UMTS. There is a trend to simplify the management by auto-configuration and auto-optimization. However, the complexity of LTE system also place new demands on the Operations and Maintenances of the network. Self-Organizing Networks (SON) is seen as one of the promising area for an operator to save operational expenditures. SON is therefore currently discussed in 3GPP standardisation. This paper provides some background on SON principles, introduces different architectures that are considered and describes some exemplary procedures.

## Main Drivers for SON

The main drivers for SON are [1]:

1. The number and structure of network parameters have become large and complex;
2. Quick evolution of wireless networks has led to parallel operation of 2G, 3G, EPC infrastructures;
3. The rapidly expanding number of Base Stations (especially Home eNB) needs to be configured and managed with the least possible human interaction.

SON aims to configure and optimize the network automatically, so that the interaction of human can be reduced and the capacity of the network can be increased.

## Main Functionality of SON

The main functionality of SON includes: self-configuration, self-optimization and self-healing. Figure 1 shows a basic framework for SON. Refer to [2] and [3].

### • Self-configuration

Self-configuration process is defined as the process where newly deployed nodes (eNBs) are configured by automatic installation procedures to get the necessary basic configuration for system operation.

Self-configuration process works in pre-operational state, which starts from when the eNB is powered up and has backbone connectivity until the RF transmitter is switched on.

As shown in Figure 1, self-configuration includes two stages: basic setup and initial radio configuration. The whole procedure is shown in Figure 2:

1. An IP address is allocated to the new eNB and the information of the Self-configuration Subsystem of OAM (Operation and Management) is given to the eNB.
2. A GW is configured for the new eNB so that the eNB can exchange IP packets with other internet nodes.
3. The new eNB provides its information, including type, hardware and etc., to the Self-configuration Subsystem for authentication. Necessary software and configuration data are downloaded from the Self-configuration Subsystem.
4. The new eNB is configured based on the transport and radio configuration data.

5. The new eNB connects to the normal OAM subsystems for other management functions.

6. S1 and necessary X2 interfaces are established

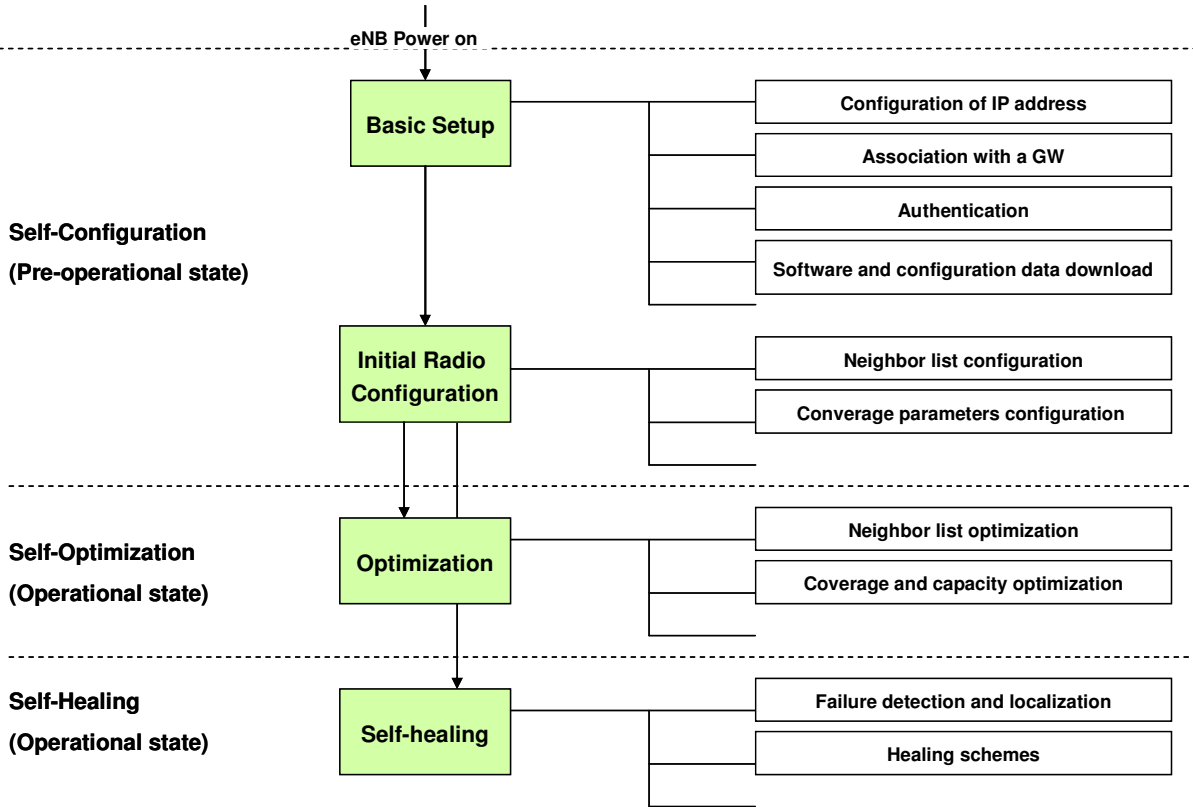


Figure 1: Framework of SON

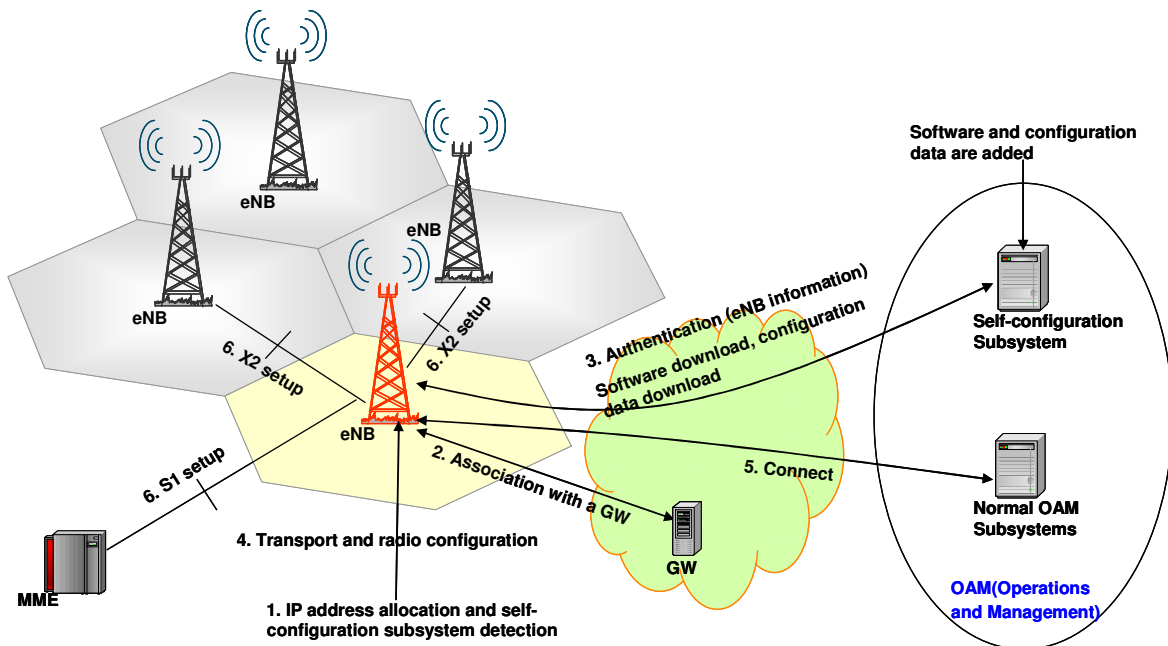


Figure 2: Self-configuration Procedure

- **Self-optimization**

Self-optimization process is defined as the process where UE & eNB measurements and performance measurements are used to auto-tune the network.

This process works in operational state, which starts when the RF interface is switched on.

The self-optimization process collects measurement information from UE and eNB and then with the help of external optimization tool, it auto-tune the configuration data to optimize the network. A typical example is neighbour list optimization.

- **Self-healing**

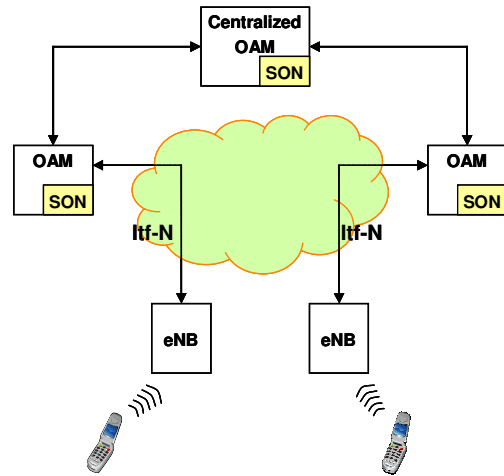
Self-healing function aims at automatic detection and localization of most of the failures and applies self-healing mechanisms to solve several failure classes, such as reducing the output power in case of temperature failure or automatic fallback to previous software version. Refer to [4].

### SON Architecture

A Self-configuration Subsystem will be created in OAM to be responsible for the self-configuration of eNB. For self-optimisation functions, they can be located in OAM or eNB or both of them. So according to the location of optimisation algorithms, SON can be divided into three classes: Centralised SON, Distributed SON and Hybrid SON.

- **Centralized SON**

In Centralized SON, optimisation algorithms are executed in the OAM System. In such solutions SON functionality resides in a small number of locations, at a high level in the architecture. Figure 3 shows an example of Centralized SON.



**Figure 3: Centralized SON Example**

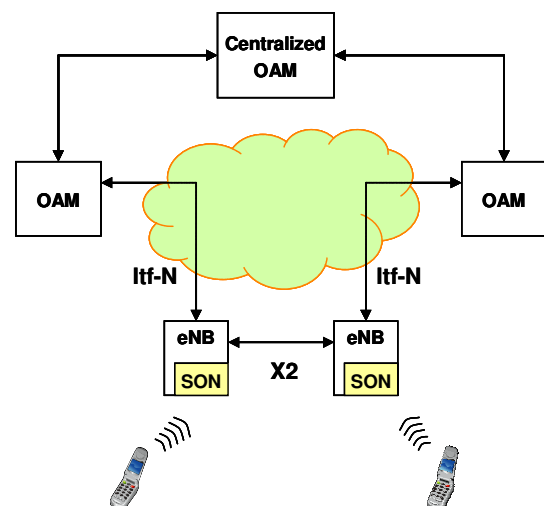
In Centralized SON, all SON functions are located in OAM systems, so it is easy to deploy them. But since different vendors have their own OAM systems, there is low support for optimization cases among different vendors. And it also does not support those simple and quick optimization cases.

To implement Centralized SON, existing Itf-N interface needs to be extended.

- **Distributed SON**

In Distributed SON, optimisation algorithms are executed in eNB. In such solutions SON functionality resides in many locations at a relatively low level in the architecture.

Figure 4 shows an example of Distributed SON.



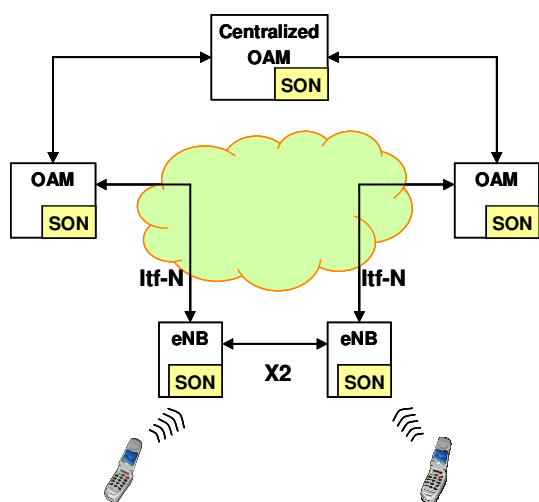
**Figure 4: Distributed SON Example**

In Distributed SON, all SON functions are located in eNB, so it causes a lot of deployment work. And it is also difficult to support complex optimization schemes, which require the coordination of lots of eNBs. But in Distributed SON it is easy to support those cases, which only concern one or two eNBs and require quick optimization responses. For Distributed SON, X2 interface needs to be extended.

- **Hybrid SON**

In Hybrid SON, part of the optimisation algorithms are executed in the OAM system, while others are executed in eNB.

Figure 5 shows an example of Hybrid SON.



**Figure 5: Hybrid SON Example**

In Hybrid SON, simple and quick optimization schemes are implemented in eNB and complex optimization schemes are implemented in OAM. So it is very flexible to support different kinds of optimization cases. And it also supports the optimization between different vendors through X2 interface. But on the other hand, it costs lots of deployment effort and interface extension work.

**SON Use Cases**

Up to April 20, 2008, there are already eight use cases approved on 3GPP meetings. Most of them are included in 3GPP TR36.902. The use cases are defined but solutions are still in discussion. Here the nine use cases will be described and possible solutions will be given.

**1. Automatic Neighbor Relation (ANR)**

In the context of LTE, it is necessary to set up the neighbour relation automatically as much as possible. Because the next generation mobile network is growing more and more complex, it will cause a lot of efforts to configure the neighbour relation relying on traditional configuration methods. ANR function aims at automatic setting of neighbour relation.

ANR function relies on UE to report the cells that it has detected but not in the neighbour list. According to the standards, the UE measures and reports the following types of cells:

- The serving cell.
- Listed cells, i.e. cells that are indicated by the E-UTRAN as part of the list of neighbouring cells (i.e. as measurement object).
- Detected cells, i.e. cells that are not indicated by the E-UTRAN but detected by the UE. However, E-UTRAN does indicate the carrier frequency.

So the detected cell can be a LTE cell within the same frequency or a LTE cell with a different frequency or even a cell belonging to another RAT. To detect inter-frequency cells or inter-RAT cells, eNB needs to instruct UE to do the measurement on that frequency.

- **ANR Procedure**

Figure 6 gives an example of intra-RAT ANR procedure.

1. UE does the measurement according to the measurement configuration set by E-UTRAN. In this example, UE detects an E-UTRAN cell with Physical ID 3.
2. UE sends the measurement report to the serving cell, using Physical ID to identify

- different E-UTRAN cells. Here, UE includes the measurements of the cell with Physical ID 3.
- eNB receives the report and instructs the UE to report Global Cell ID for the cell with Physical ID 3.
  - UE gets the Global Cell ID by reading the BCCH (Broadcast Control Channel) of the detected cell.

- UE reports the Global Cell ID to the serving cell.
- The serving eNB updates the neighbour cell list.

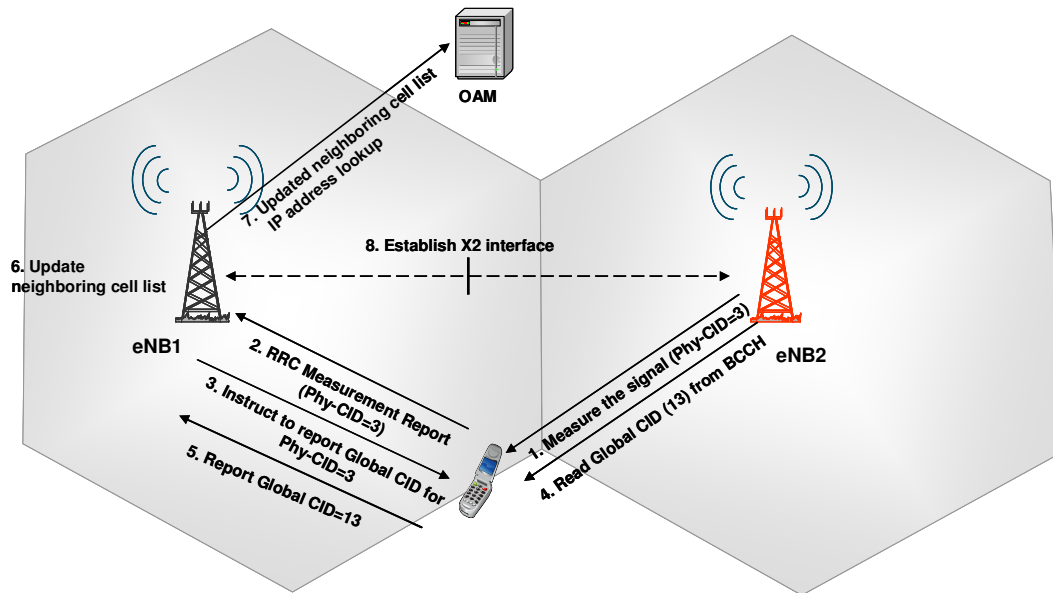


Figure 6: ANR Procedure

- The serving eNB sends the updated neighbour list to OAM and gets the IP address of the new detected cell from OAM.
- If required, the serving eNB will establish a new X2 interface with the target eNB.

• Possible ANR Architecture

The goal of ANR is to manage neighbour relation. Since OAM also has some restrictions on neighbour relation due to the requirements of operators, ANR also needs to consider the restrictions from OAM. So how to describe the neighbour relation based on the restrictions and how to manage the neighbour relation is a question of implementation.

Figure 7 gives an example of possible ANR solutions. The details can refer to [5]. Here the neighbour relation is described by

Neighbour Relation Table. The table composes of two parts. The left part is the list of Neighbour Relation according to the measurement report. The right part is the Neighbour Relation Attributes controlled by OAM. The attributes include: No Remove, No Handover and No X2. The left part will be updated according to measurement report and the right part will be updated according to OAM commands.

Within ANR, it is divided into three functions: Neighbour Removal Function, Neighbour Detection Function and Neighbour Relation Table Management Function. The first two functions decide whether to remove an existing Neighbour Relation or to add a new Neighbour Relation. The third one is responsible for updating the Neighbour Relation Table according to the input of the previous two functions and OAM.

The Neighbour Relation Detection procedure is as follows:

0. Neighbour Detection Function instructs RRC to measure the cells on some certain frequency or in another RAT.
1. RRC forwards the measurement reports to Neighbour Detection Function.
2. Neighbour Detection Function decides to add a new Neighbour Relation.

3. Neighbour Relation Table Management Function updates the Neighbour Relation Table.
4. Neighbour Relation Table Management Function sends the updated Neighbour Relation through some standard interface to OAM.
5. OAM will ask Neighbour Relation Table Management Function to update the Neighbour Relation Attributes if necessary.

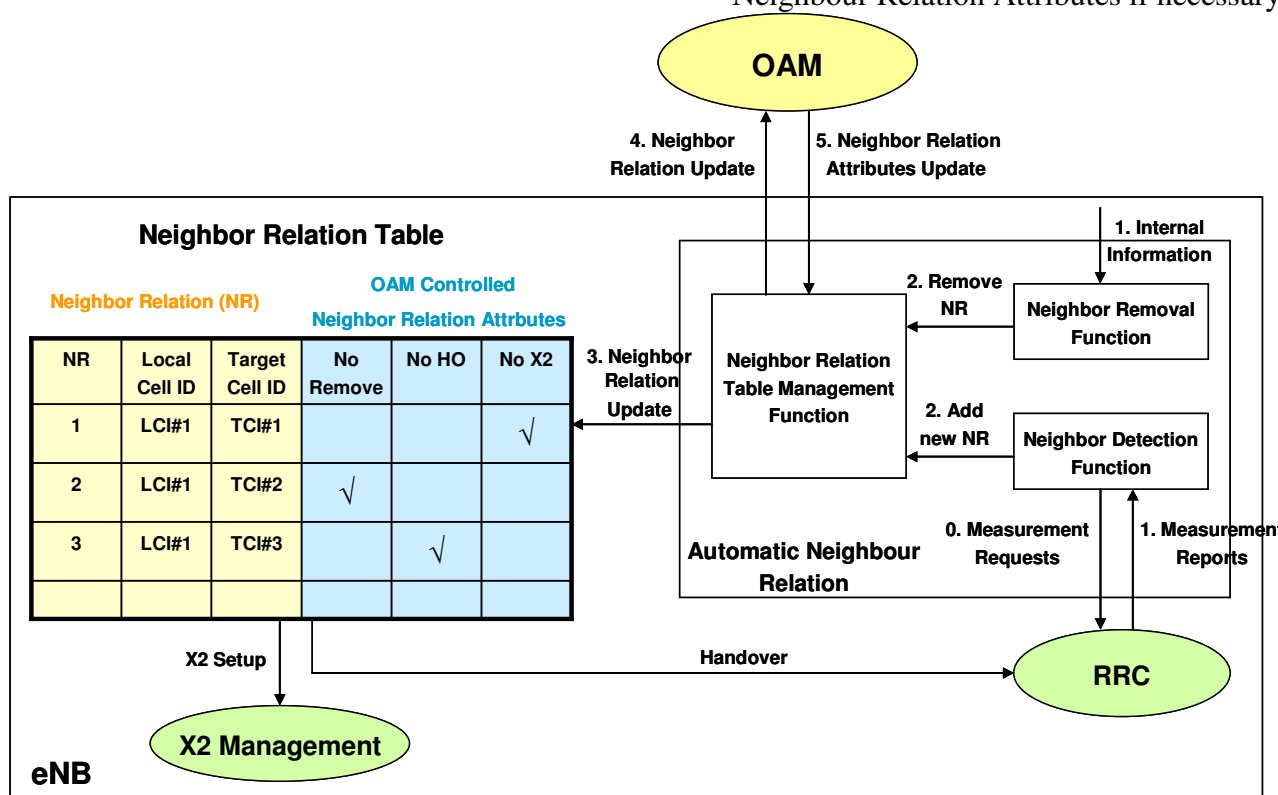


Figure 7: Possible ANR Architecture

The Neighbour Relation Removal procedure is similar:

0. Neighbour Removal Function receives internal information, such as many times of handover failure to a certain cell.
1. Neighbour Removal Function decides to remove the cell from the neighbour list.
2. The following steps are the same as the detection procedure.

The Neighbour Relation Table will be used by eNB for other functions, such as handover and X2 setup.

## 2. Coverage and Capacity Optimization

A typical operational task is to optimize the network according to coverage and capacity. The traditional way is to find the problems by drive tests and use planning tools to find possible solutions. This use case aims at discovering the coverage and capacity problems automatically through the measurements at the eNB and those reported by UEs. It minimizes the human intervention and reduces the feedback delay.

### Objective:

- Optimization of network coverage
- Maximize the system capacity

**Expected results:**

- Continuous coverage
- Increased capacity of the system
- Interference reduction
- Controlled cell edge performance
- Savings on drive tests
- Minimized human intervention in network management and optimization tasks
- Self-healing in case of equipment (e.g. eNB) failure by automatic reconfiguration of surrounding eNBs.

**Possible Solutions:**

The input of Coverage of Capacity Optimization function can be:

- UE measurements on the signal strength of current cell and its neighbours
- UE signaling/reporting
- Timing Advance (TA)
- Radio Link Failure counters
- Coverage triggered mobility counters
- Traffic load distribution measurements

The output is optimized radio configuration parameters, which may include:

- Downlink transmit power
- Downlink Reference Signal Power Offset
- Antenna tilt

The procedure can be as follows:

1. Measurements are collected from inside eNB and UE reports.

2. Problems are detected concerning the coverage and capacity.
3. Problems are described and given to Planning Tool. The Planning Tool adjusts the radio related parameters to solve the problems and optimize the coverage and capacity of the system.
4. Adjusted parameters are given to Coverage and Capacity Optimization function.
5. The Optimization function updates the parameters, which are used to deploy and operate the system.

**3. Energy Saving**

A typical critical cost for the operator is the energy expenses. Cuts on energy expenses could be realized if the capacity offered by the network would match the needed traffic demand at any point of time as close as possible.

**Objective:**

- Energy savings based on e.g. cell switch on/off.

**Expected outcome:**

- Cuts on operational expenses through energy savings.

**Possible Solutions:**

There can be many ways to save the energy. Some of the possible solutions are listed below. Refer to [6] and [7].

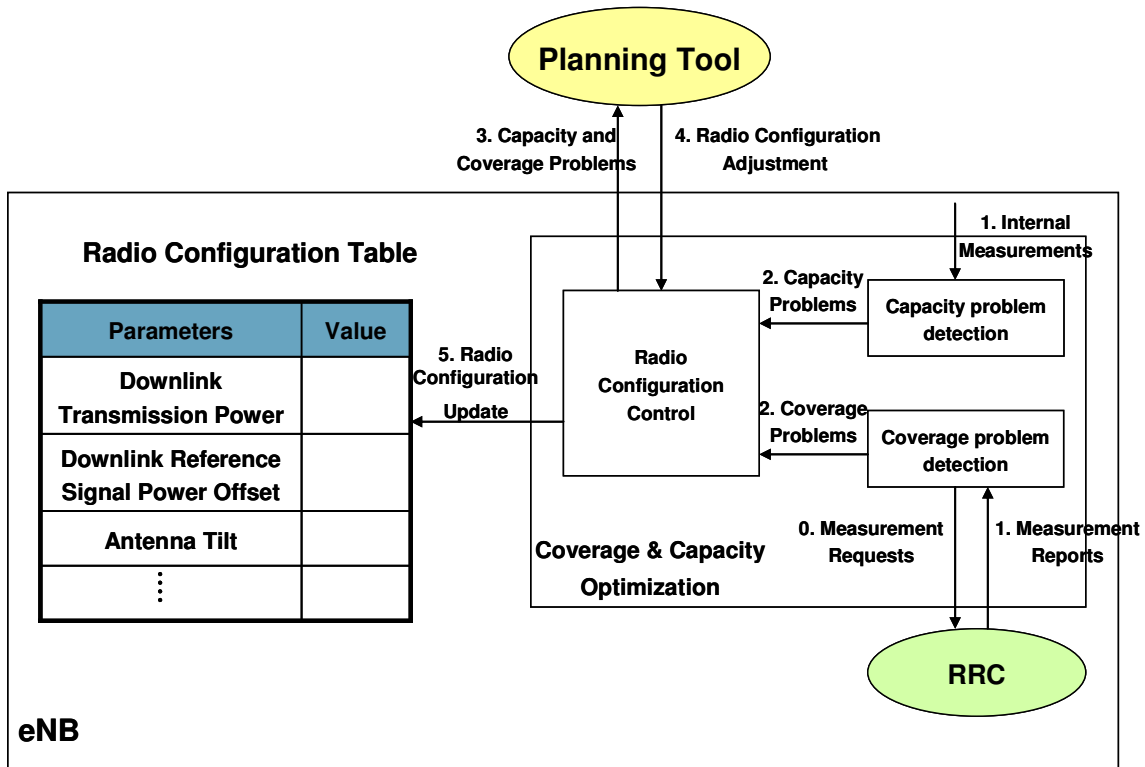


Figure 8: Possible Coverage and Capacity Optimization Architecture

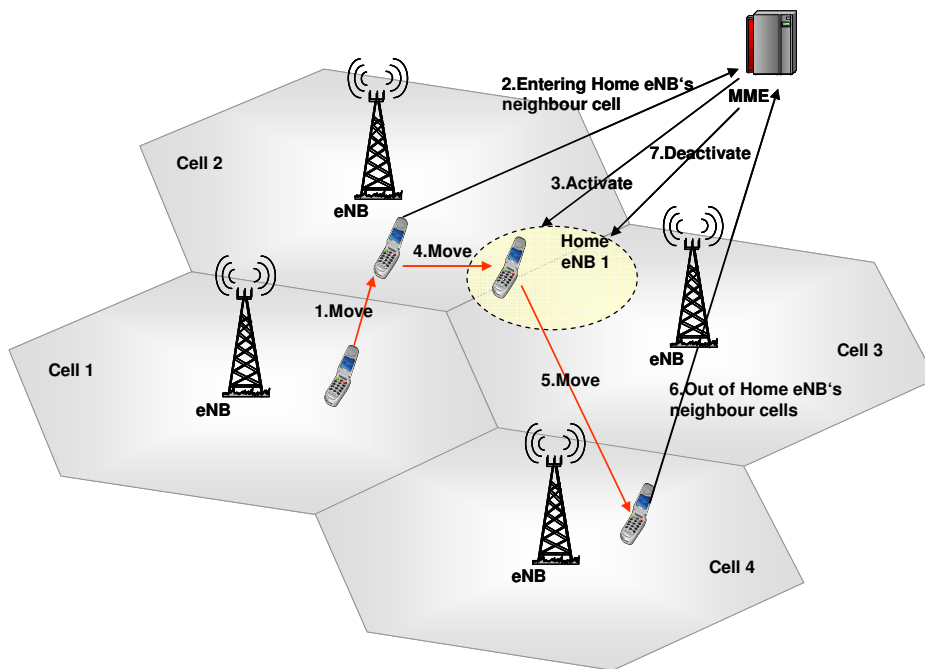


Figure 9: Home eNB Activation and Deactivation



- **Switch off cells**

With the deployment of a large number of Home eNBs, the energy consumed by Home eNBs becomes a big consideration. Since some Home eNBs are just deployed for some special time, dynamic activation and deactivation of Home eNBs are proposed.

The main issues are when to activate and deactivate the Home eNBs and how. One solution is cell based and MME involved activation and deactivation. Figure 9 illustrates the procedure. In this example, cell 2 and cell 3 are neighbour cells of the Home eNB and we assume that UE knows the neighbour cells of Home eNBs.

1. UE moves to one of the neighbour cells of Home eNB 1.
2. The UE informs MME that it has moved to the neighbour cell of Home eNB 1.
3. MME notices that Home eNB 1 is still not activated. It sends messages to activate Home eNB 1.
4. When UE moves to the range of Home eNB 1, it detects the signal from Home eNB 1 and can receive services from Home eNB 1.
5. UE moves out of the neighbour cells of Home eNB 1.
6. The UE informs MME that it has moved out of the neighbour cell of Home eNB 1.
7. MME notices that there is no UE in the neighbour cells of Home eNB 1, so MME sends messages to deactivate Home eNB 1.

When Home eNBs are activated and deactivated, the impact on the neighbour cells should be taken into account.

- **Adapt the Transmission Power**

If the transmission power is too high for the deployed area, it can also be reduced without impact on the whole capacity. The adaptation can be based on UE measurements. To assure that the adaptation does not influence the coverage, handover and load balancing, some measurements concerning handover and load balancing should also be gathered and taken into consideration.

- **Adapt the multi-antenna schemes (Single antenna, SIMO, MIMO, Beamforming)**

In the multi-antenna system, some of the antennas can be switched off to save the power. The transmission schemes can also be adapted among SIMO or MIMO or Beamforming to achieve the maximum capacity with the minimum transmission power.

#### **4. Interference Reduction**

Capacity could be improved through interference reduction by switching off those cells which are not needed for traffic at some point of time, in particular home eNBs when the user is not at home.

##### **Objective:**

- Interference reduction based on cell switch on/off.

##### **Expected outcome:**

- Increased capacity through interference reduction.
- Increased quality through interference reduction.

##### **Possible Solutions:**

The solutions for switching off cells used in energy saving case can also be used here. Automatic activation and deactivation of cells not only save the energy but also reduce the interference to surrounding cells.

#### **5. Physical Cell ID Automatic Configuration**

The goal of this use case is to automatically configure the Physical Cell ID of a newly introduced cell.

The Physical Cell ID (Ph\_ID) is an essential configuration parameter for a cell. It is contained in the SCH (Synchronization Channel) for UE to synchronize with the cell on the downlink. There are 504 unique Ph\_IDs in E-UTRAN, so the reuse of Ph\_IDs in different cells is unavoidable.

When a new eNB is established, it needs to select Ph\_IDs for all the cells it supports. The Ph\_ID of one cell should satisfy the following two criteria so that no confusion is caused.

- The Ph\_ID of one cell should not be the same as those of his neighbour cells.
- The Ph\_IDs of the neighbour cells should not be the same.

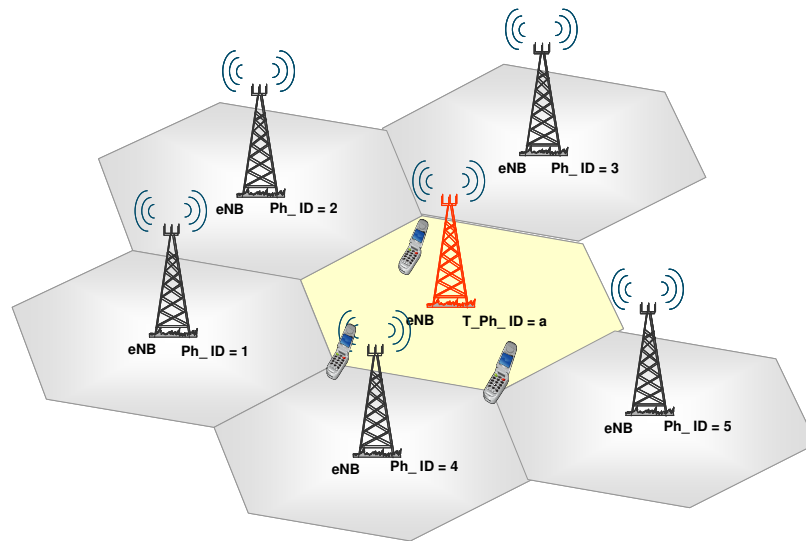
**Possible Solutions:**

The solution of Physical Cell ID automatic configuration has not been fixed in the standards. Some possible solutions are proposed. Here an example is given.

Figure 8 shows an example of Physical Cell ID deployment. Refer to [8].

In this example, the eNB with red colour is the one that is newly introduced. The automatic configuration of the Physical Cell ID for the new cell proceeds as follows:

1. When the procedure starts, the new cell starts a timer for this configuration phase.



**Figure 8: An Example of Physical Cell ID Deployment**

2. A set of Physical Cell IDs is defined as a set of temporary Physical Cell IDs. The new cell picks one temporary Physical Cell ID randomly.
3. According to ANR (Automatic Neighbour Relation) function, UE reports those detected cells with their Physical Cell IDs to its serving cell. So the cells around the new cell receives the report of the new cell and the new cell receives the report of its surrounding cells. By ANR function, they also get the Global Cell ID of those reported cells.
4. The new cell adds those reported cells to its neighbour cell list. It also looks up the IP addresses of those neighbour cells and establishes the X2 connection if necessary.
5. Those cells, which receive the report of the new cell, adds the new cell in their neighbour cell list, look up the IP address

of the new cell and establish the X2 connections if necessary. Which trigger the X2 connection setup, the new cell or the surrounding cells, depends on which one detects the neighbourhood relation first.

6. After X2 connection is set up, the surrounding cells exchange their neighbour cell lists with the new cell. As a result, the new cell also gets the neighbour relation information of its neighbour cells
7. When the timer times out, the new cell collect all the information it gets, which includes its neighbour cell list and the neighbour cell lists of its neighbour cells. Then the new cell selects one Physical Cell ID that satisfies the two criteria, which has been explained before.
8. The new cell informs its neighbour cells that it has changed its Physical Cell ID.

Those neighbour cells updates their neighbour relation table accordingly.

During the configuration phase, some collisions may also happen. For example, two new cells select the same temporary Physical Cell ID and they are neighbours. The collision will be detected during the configuration procedures and one of the configuration procedure will be restarted.

## 6. Mobility Robust Optimization

Manual setting of HO parameters in current 2G/3G systems is a time consuming task. In many cases, it is considered too costly to update the mobility parameters after the initial deployment.

For some cases, RRM in one eNB can detect problems and adjust the mobility parameters, but there are also examples where RRM in one eNB can not resolve problems:

- Identify and avoid using non-suitable neighbours.

The eNB for the source cell cannot always detect when a handover was performed to a non-suitable cell. One example of this is radio link failures occurring shortly after the UE has connected to the target cell.

- Identify problematic settings of cell selection/reselection parameters.
- Minimize handovers immediately after initial RRC connection establishment.

If the idle and active mode mobility parameters are not well aligned, this may result in a large number of handover shortly after the UE has transited from idle to active mode. For the scenarios where this behaviour is not intended, or where the number of handover exceeds an acceptable level it would be beneficial to be able to detect and control this behaviour.

### Objective:

- Automatically adjusting the mobility parameters in those cases that cannot be done by RRM.

### Expected outcome:

- Non-suitable neighbours are identified and avoided.

- Problematic settings of cell selection/reselection parameters are identified.
- Immediate handovers after initial RRC connection establishment are minimized.

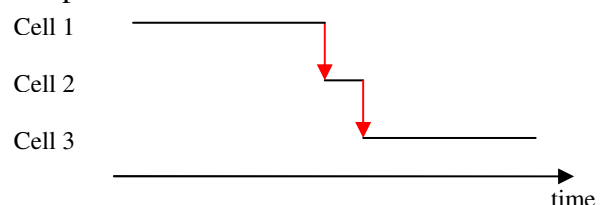
### Possible Solutions:

The main tasks of Mobility Robust Optimization are first to detect the problems and then to adjust the parameters. Refer to [9].

#### • Problem detection

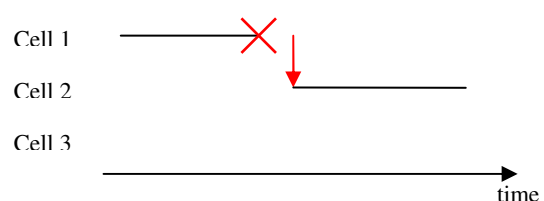
One solution to detect the mobility problems is to set two counters for each pair of cells to evaluate their pair relationship. One is called too early, which means handover occurs too early between this pair. The other is called too late, which means the handover should be performed earlier between this pair. The eNB collects the counters of each pair of cells and sends them to a centralized entity in OAM. OAM is responsible for adjusting the parameters based on the counter information. Here some scenarios are given to show how to use the two counters.

#### 1. Rapid handover between three cells



UE performs handover to cell 3 shortly after it performs handover from cell 1 to cell 2. It means that it would be better if UE performs handover directly from cell 1 to cell 3. So it indicates that the handover is:

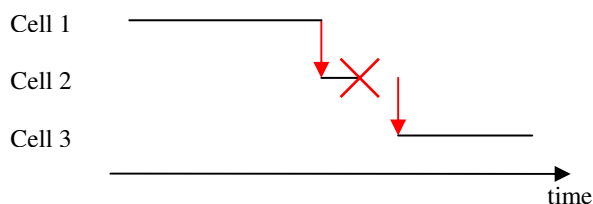
- Too early between cell 1 and cell 2
  - Too late between cell 1 and cell 3
2. Radio Link Failure shortly followed by a radio reestablishment



Shortly after the radio link failure in cell 1, UE reselects cell 2 and reestablishes a radio link. It means that the handover from cell 1 to cell 2 should be performed earlier, before radio link failure. So it indicates that the handover is:

- Too late between cell 1 and cell 2

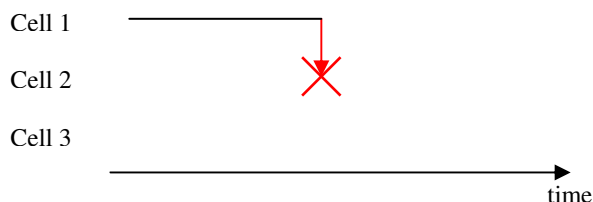
### 3. Radio Link Failure shortly after a handover



Shortly after UE performs the handover from cell 1 to cell 2, the radio link fails. Then UE reselects cell 3 and establishes a new radio link. It means that cell 3 is the perfect neighbour for cell 1. UE should perform the handover from cell 1 to cell 3. So it indicates that handover is:

- Too early between cell 1 and cell 2
- Too late between cell 1 and cell 3

### 4. Access failure



When UE performs handover from cell 1 to cell 2, it fails to access to cell 2. It means that the handover has been performed too early. So it indicates that handover is:

- Too early between cell 1 and cell 2

## 7. Mobility Load Balancing Optimization

Self-optimisation of the intra-LTE and inter-RAT mobility parameters to the current load in the cell and in the adjacent cells can improve the system capacity compared to static/non-optimised cell reselection/handover parameters and can minimize human intervention in the network management and optimization tasks.

The load balancing shall not affect the user QoS negatively in addition to what a user

would experience at normal mobility without load-balancing. Service capabilities of RATs must be taken into account, and solutions should take into account network deployments with overlay of high-capacity and low-capacity layers where high-capacity layer can have spotty coverage.

### Objective:

- Optimisation of cell reselection/handover parameters to cope with the unequal traffic load and minimize the number of handovers and redirections needed to achieve the load balancing.

### Expected outcome:

- According to the cell reselection and handover mechanisms, part of the UEs at the cell border reselect or hand over to the less congested cell;
- In the new situation the cell load is balanced.
- Increased capacity of the system.
- Minimized human intervention in network management and optimization tasks.

### Possible Solutions:

To implement Mobility Load Balancing Optimization, the following actions need to be executed:

- Load is measured for each cell in its monitoring eNB. Load information is exchanged between eNBs over X2 interface.
- An algorithm is applied to identify the need to distribute the load between two adjacent cells.
- Handover and/or cell reselection parameters are adjusted in both cells to enable the load balancing and at the same time avoid ping-pong effects.

For detailed implementation, the following questions need to be solved. Refer to [10].

### • Load definition

The definition of load here has not been decided yet. It can be radio load, transport network load or even the processing load. Even for radio load, it can be split between uplink load and downlink load or split among

different QCI. The definition of load influences the algorithm to distribute the load.

- **Algorithm for load balancing**

An algorithm needs to be defined as to when to balance the load. Due to the different possibilities of load definition, the algorithm can be based on radio load or transport network load or both of them. If the radio load is concerned as the most important factor, it should also be decided whether to differentiate among QCIs. For example, if GRB services have been overloaded but non-GRB services have not, will the load be balanced? If transport network load is also considered with the radio load, which one will have higher priority?

So the problem is how to define the overload situation.

- **Parameters to be adjusted**

According to the cell reselection criterion, UE calculates the R values for serving cell and neighbour cells, ranks the R values and selects the cell with the highest R value. The calculation is defined in 3GPP TS36.304 as follows:

$$R_s = Q_{meas,s} + Q_{hyst,s}$$

$$R_n = Q_{meas,n} - Q_{offset,s,n}$$

$Q_{meas,s}$  and  $Q_{meas,n}$  are the RSRP (Reference Signal Received Power) measured by UE for serving cell and neighbour cells respectively.  $Q_{hyst,s}$  specifies the hysteresis value for ranking criteria.  $Q_{offset,s,n}$  specifies the offset between serving cell and neighbour cell.

If  $Q_{hyst,s}$  is changed, it will influence the selection relation between serving cell and all the neighbour cells. So if only one pair of cell' relation needs to adjusted, it is better to tune  $Q_{offset,s,n}$ .

To avoid mobility problems, the  $Q_{offset,s,n}$  parameter between two cells would be tuned within a proper range. So one of the outputs of Mobility Robust Optimization may be the optimized range of  $Q_{offset,s,n}$  values.

## 8. RACH (Random Access Channel) Optimization

### Roll of RACH

In LTE, RACH (Random Access Channel) is an uplink unsynchronized channel, used for initial access or uplink synchronization. The triggers for Random Access procedure include:

- Connection setup
- Radio Link Failure
- Downlink data transmission in uplink unsynchronized state
- Uplink data transmission in uplink unsynchronized state
- Handover

So the Random Access procedure performance influences the call setup delay, handover delay, data resuming delay, call setup success rate and handover success rate.

Besides, physical resources for RACH are reserved for its special use. So the configuration for RACH influences the capacity of the whole network.

### Necessity for RACH optimization

The performance of Random Access procedure is evaluated by its delay and success rate. The performance depends on following factors:

- Population under the cell coverage;
- Call arrival rate;
- Incoming handover rate;
- Whether the cell is at the edge of a tracking area;
- Traffic pattern, as it affects the DRX (Discontinuous Reception) and uplink synchronization states, and hence the need to use RACH.

These factors are affected by network configurations, such as antenna tilt, transmission power and handover threshold, and also by the load of network. If network configurations or load is changed, the performance of Random Access procedure may change greatly, which influences the performance of other procedures, such as call setup, data resuming and handover. Therefore

the automatic optimization of RACH would be beneficial.

### **Possible RACH optimization algorithm**

The configurations of RACH include:

- RACH physical resources
- RACH preamble allocation for different sets (dedicated, random-low and random-high)
- RACH persistence level and backoff control
- RACH transmission power control

Measurements are done in eNB, recording random access delay, random access success rate and random access load. The random access load can be indicated by the number of received preambles in a cell in a time interval. It is measured per preamble range (dedicated, random-low and random-high), and averaged over the PRACHs configured in a cell.

Thresholds are set separately for random access delay and success rate. If either of the thresholds is reached, RACH optimization is triggered. First, Random access load is analyzed to check if the random access is overload in any of the three preamble ranges. If one of them is overload, RACH preambles are reallocated among these three preamble ranges. If all of them are overload, more physical resources need to be reserved for RACH. If none of them is overload, other parameters need to be adjusted, such as increasing the transmission power step and distributing the backoff time in a wider range.

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- [5] R3-080988: "Clarifications on ANR".
- [6] R3-081174: "Solution for interference reduction SON use case".
- [7] R3-081281: "Issues and Enhanced Framework for the Energy Saving Use Case".
- [8] R3-080376: "SON Use Case: Cell Phy\_ID Automated Configuration".
- [9] R3-081165: "Solutions for the Mobility Robustness use case".
- [10] R3-081163: "Principles for intra frequency load balancing".

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