

LTE SON-Function Coordination Concept

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ABSTRACT

Nowadays smartphones and tablets are used nearly everywhere at any time. The need for mobile networks with high bandwidth increases fast as all of those network elements require Internet connection for almost all applications. The radio access technologies ranging from GSM over UMTS to the currently upcoming LTE networks become more and more complex and with it the effort of controlling this complexity exceed manpower. To solve this problem Self-Organising Networks (SON) were created in order to operate, administrate and maintain these networks. This paper specifically takes a look at LTE SON.

Several SON functions were implemented so far to gain an optimisation of the networks efficiency. In order to avoid negative function interactions, so called conflicts, function coordination is necessary. This paper takes a look at a couple of severe SON conflicts and how they can be avoided by SON function coordination.

So far, SON with some of the most evolved functions have been used depending on the respective operator, but they become more and more important as complexity rises.

Keywords

SON, LTE, mobile network, 3GPP, eNodeB

1. INTRODUCTION

As mobile networks become more and more complex through new technologies like LTE and the increasing number of mobile devices, the effort to configure and maintain these networks becomes bigger and bigger. Therefore Self-Organizing Networks (SON) are introduced to manage this complexity and to save money and time. SON cover a lot of activities in mobile networks from planning to set up as well as maintenance.

In the following sections a brief overview of SON including its functionalities is given. So called SON functions like the Physical Cell ID allocation (PCI) and the Mobility Robustness Optimisation (MRO) were implemented to reduce complexity, manpower and thus costs. The problem of these functions is that if they work independently, conflicts can easily occur because other functions do not know that there is already one function running. They sometimes use or modify the same parameters of, for example, a cell at the same time. To solve or avoid these conflicts a coordination of the SON functions is necessary.

2. DEFINITION OF SON

Self-organising networks (SON) are meant to reduce the complexity of configuring parameters of network elements. Manual operation should be avoided as far as possible to save cost and time. New network elements are autonomously configured and optimised in order to provide a fast “plug and play” functionality.

The functionality of SON derive from use cases defined by the 3rd Generation Partnership Project (3GPP) and the Next Generation Mobile Network (NGMN) alliance. Therefore SON functionality is basically standardised but vendor specific functionality can also be implemented.

SON functionality is divided into three main areas that provide an overall framework (Figure 1). These areas are self-configuration, self-optimisation and self-healing which are introduced in the following sections.

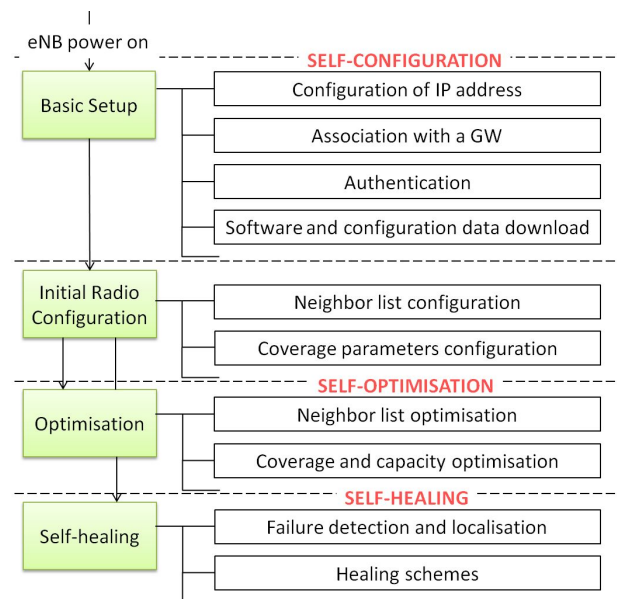


Figure 1: SON Framework [1]

2.1 Self-configuration

The goal of self-configuration is that new base stations configure and integrate themselves automatically into the network and therefore provide a “plug and play” functionality. First of all, this includes the automatic configuration of initial radio transmission parameters. Dynamic radio configu-

ration is a technique to set up initial parameters like the cell ID or the transmission power adjusted to the current radio network topology. A lot of these parameters can be derived from real time measurements and not only from the theoretical plan. For example, the neighbouring base stations (eNodeBs) communicate with each other to share information about the current situation of the network so that they can adapt accordingly.

Another important functionality is the Automatic Neighbour Relation (ANR) management. As each cell needs to know its neighbour cells, e.g. for handovers, ANR saves a lot of time when a new eNodeB (eNB) is installed. By communicating with each other all the eNBs receive the necessary information about their new neighbour and can adjust their settings like the neighbourhood relation table accordingly.

2.2 Self-Optimisation

Self-optimisation includes all use cases of the SON to operate as efficient as possible. As a lot of parameters of the environment change during the lifetime of an eNodeB and the desired traffic is never the same, self-optimisation autonomously adapts to these new circumstances. It collects information about cell loads, the usage of resources and also quality information from the mobile devices. Based on these measurements, optimising algorithms are maintained to increase the efficiency of the network.

Section 4 explains how optimisation functions like the Mobility Robustness Optimisation or the Coverage and Capacity Optimisation are implemented.

2.3 Self-Healing

A very important area in SON is self-healing. If one part of the network becomes inoperable this can lead to severe outages of the whole functionality for some users. On the one hand self-healing can detect and repair the erroneous elements a lot faster than a service team could. On the other hand during the time of outage neighbour cells can serve the affected users to give them at least the main functionality. Often a simple restart of the identified component can solve the problem, without paying a mechanic to drive to the location and repair it.

3. BUSINESS VALUE

One of the main reasons operators apply SON is to save money. This section gives a brief overview on the general economical situation of a network and how operators can benefit by using SON. The following calculations and values refer to [4].

A common way network operators use to regard their costs is to apply the concept of Total Cost of Ownership (TCO). In the context of mobile networks this concept regards one eNB as one single figure. The TCO sums up three types of expenditures including the Capital Expenditures (Capex), the Implementational Expenditures (Impex) and the Operational Expenditures (Opex) over the life-time of the equipment.

Capex includes all equipment costs an operator has to pay for. For an eNB this includes the eNB itself, the antenna and materials like cables.

The Impex contains all expenditures concerning the installation of the eNB. First of all, the equipment needs to be brought to the desired location. The physical devices need to

be mounted and established with a power supply. Furthermore costs regarding the initial configuration and planning are usually calculated to the Impex although they are sometimes called one-time Opex.

In this reflection Opex consists of site related operational costs like rent and housekeeping costs and equipment related operational costs including electricity, transmission and operation and maintenance expenditures.

As the TCO includes Capex and Impex as single expenditures at the beginning, Opex needs to be calculated over the life-time of the eNB. A realistic assumption for the life-time of the equipment is a duration of five years.

The goal of SON is to reduce all of the before mentioned expenditures. Obviously SON cannot reduce the costs for equipment like antennas and other material. But overall SON can reduce the needed equipment and therefore achieve savings of Capex. Concerning LTE networks reduction of equipment means to reduce the number of eNBs. But as Capex only accounts about 10-20% of the total costs and only a little number of eNBs can be reduced this is not the main benefit of SON.

The higher value lies in saving Operational and Implementational Expenditures.

Concerning Impex, the main benefits come from reducing the effort of planning and the actual installation. The previously mentioned self-configuration of SON is responsible for these savings. Less time and work in the planning and installation phase is needed as the network does the individual configuration by itself.

However the biggest advantage concerning business value lies in the reduction of Opex. As operation and maintenance over the life-time of an eNB is expensive and extremely time-consuming, a SON achieves big savings. The ability of self-optimisation and self-healing makes a lot human operators unnecessary who used to drive to the appropriate eNB by car to modify or fix it. Only some coordinators are needed to supervise the self-optimising processes.

Besides these operational advantages even more benefits are achieved that are not calculated within the TCO. Faster troubleshooting and higher coverage raise the image of the operator and insure higher revenues.

The following section gives an overview on concrete SON functions achieving the described benefits.

4. SON FUNCTIONS

SON functions derive from a first list of use cases published in 2007 by the Next Generation Mobile Network (NGMN). In order to make these use cases multi-vendor supportable, the 3rd Generation Partnership Project (3GPP) standardised them. There will always be differences in the implementation of those use cases for each operator, but at least they have a common base. Out of these use cases (refer to [2] and [3]) SON functions were developed and the following sections give a brief overview of some of them.

The example functions and figures refer to [4].

4.1 PCI

The Physical Cell ID (PCI) allocation is one of the most important functionalities defined in the use cases of 3GPP. Its goal is to automatically distribute unique identifiers to new cells in the network. The PCI is the reference sequence which neighbouring cells use to address each other. As this sequence should be addressed very quickly it should not be

a very large sequence. This resulted in a total number of 504 usable PCIs and thus a need to reuse PCIs as there are a lot more cells in a LTE network.

Concerning the limited number of PCIs the automated assignment to avoid conflicts is quite challenging.

There are two requirements which have to be taken into account. First of all, two neighbouring cells are not allowed to have the same identifier. This requirement is called collision-free assignment.

The second, more challenging requirement, is the confusion-free assignment shown in Figure 2. Every cell has a lot of neighbour cells and each of those needs to have a different PCI. This needs to apply to each cell in order to avoid handover failures. Otherwise, an eNB does not know which of the cells with the same PCI needs to be addressed.

A more detailed scenario of PCI conflicts is explained in section 5.1.

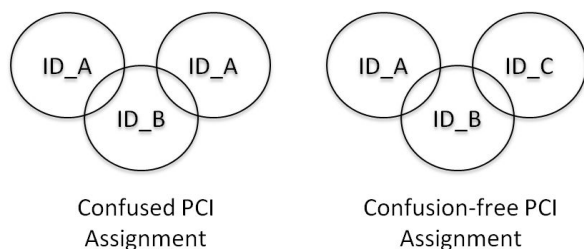


Figure 2: PCI Assignment

4.2 MRO

Mobility Robustness Optimisation (MRO) is an important function of SON in order to guarantee proper cell changes in a LTE network. As the mobile devices change their location in connected mode or idle mode it must be ensured that the handovers between cells do not cause any failures, e.g. during a call. Therefore one of the main goals of MRO is to minimise call drops as they lead directly to unhappiness of the user. Another important task of MRO is to minimise unnecessary handovers. Near the border of two cells a so called “pingpong-effect” might occur where several handovers between two cells are repeated within a short period of time. The last aim of MRO is to minimise idle mode problems. Every mobile device needs to be connected to one proper cell at any time.

4.3 MLB

The aim of Mobility Load Balancing (MLB) is to enhance the overall capacity of the network. Traffic load imbalances are detected automatically whereupon cell re-selections or handovers for some mobile devices are applied by the eNB. Within the LTE network load information can be directly exchanged over the X2 interfaces which connect two neighbouring eNBs. Inter-RAT is also possible within MLB meaning that some services like phone calls can be steered from LTE to older technologies like 3G or GSM.

Figure 3 shows how configuration parameters of the eNBs take influence on the cell size in order to balance the load. The eNB of Cell C increases for example the transmission power to enlarge its cell size, whereupon the overlapping areas with the neighbour cells A and B increase. Cell C

asks the overloaded neighbour cells A and B to handover some of the network elements in the overlapping areas to balance the load among those three cells.

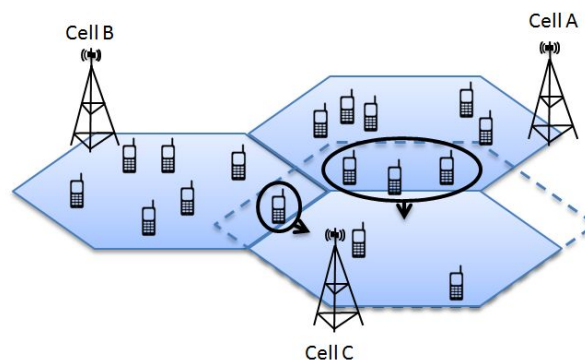


Figure 3: MLB Example

4.4 CCO

One of the main goals in mobile networks is a sufficient coverage and capacity. Coverage and Capacity Optimisation (CCO) is a SON function to achieve this automatically. As the environment in a cell changes continuously (e.g. in summer the trees have a lot more leaves than in winter or new houses are built) the cell coverage changes accordingly. CCO can adapt to these changes by changing configuration parameters like the antenna tilt or the transmission power based on long term measurements. Using this automated optimisation CCO also simplifies the planning phase of an eNB. It is no longer necessary to make a detailed plan of the cell area to configure the parameters once before roll-out. A rather rough plan can be applied to several eNBs as they configure themselves on their own after installation. This way CCO always tries to provide the best coverage and capacity for the given environment.

5. SON CONFLICTS

In the past, some of the previously described SON functions were already applied by human network operators with high expertise. They had a big knowledge on what they were doing and what were the effects of changing a configuration. In a SON enabled system it seems easy to replace the man made maintenance by the new SON functions in order to save costs and time.

But it is not that easy. SON functions are meant to interact with each other in order to optimise the overall system, but there are also negative interactions, so called conflicts.

A SON conflict is when an instance A of a SON function influences the intended behaviour of another SON function instance B. Instance B does not work anymore as it was intended to and so the overall performance of the system might have gotten worse by applying SON function A.

There are two main characteristics regarding SON conflicts. They can either occur in a spatial or a temporal scope. An example for a conflict due to a spatial characteristic is when two SON functions both apply changes to near located network elements. Each SON function may also modify nearby network elements including the one that was already modified by the other SON function. A conflict appears and has

to be solved to guarantee best performance. For the temporal characteristic the main parameter is the impact time. A SON function needs a certain amount of time until the function is applied completely and noticed by all the other network elements. The impact time consists of the execution time, enforcement time, visibility delay, protection buffer time and the relevance interval. The duration of each time segment can vary a lot depending on the SON function and can even be zero. But if a second SON function tries to apply changes to the same parameters as the currently running SON function, a temporal conflict appears (see Figure 4).

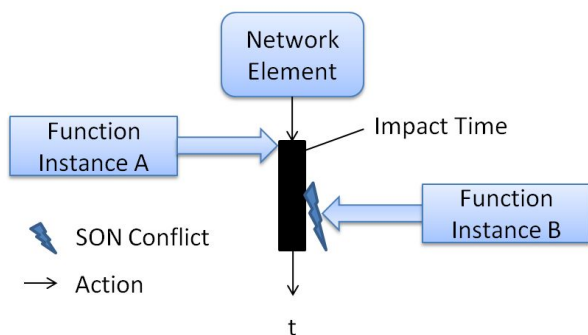


Figure 4: Temporal SON Conflict

Furthermore, not all conflicts are alike. SON conflicts are divided into different categories, called A, B and C [4]. Category A includes all conflicts due to parameter configuration. It is further divided into type A1 (input parameter conflict) and type A2 (output parameter conflict). Category B only consists of type B1 containing all measurement conflicts. Category C describes a characteristics conflict. It includes all conflicts caused by the change of a cell's characteristics. Type C1 refers to direct characteristic conflicts as C2 contains conflicts due to logical dependencies. The SON conflicts described in the following sections refer to this classification. In the following sections some of the most important SON conflicts will be explained, all referring to the previously mentioned conflict classification. Refer to [4].

5.1 PCI conflict

As described in 4.1 the PCI function section, the preconditions for a correct PCI allocation is a collision- and confusion-free assignment. With the limited number of PCIs this is not always possible without coordination at run-time. Figure 5 shows a scenario of a conflict caused by two simultaneously applied PCI allocations. In this case two eNBs are installed spatially separated but having a common neighbour cell. The PCI Instance I assigns the PCI "ID_A" to the new cell. Before the impact time of this assertion has finished, a second PCI Instance II also assigns the same PCI to the other eNB installed, because it has got notified of the other instance so far. Cell X is confused and might become inoperable or at least correct handovers are no longer possible.

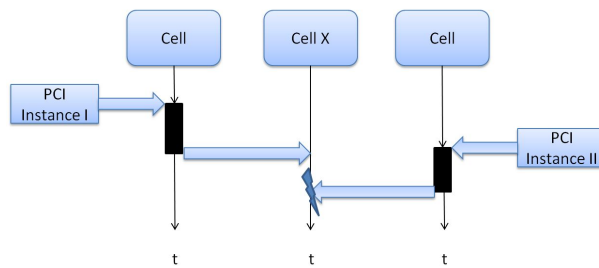


Figure 5: Conflict Between PCI Functions

Although this scenario is rather rare because new eNBs are not installed that often, the impact of the conflict would be severe. According to the conflict classification this is a type A1 input parameter conflict.

5.2 MRO-MLB conflict

Another more frequent example of a SON conflict is the conflict between a MRO function instance and a MLB function instance (Figure 6). Both functions change the handover parameters of a cell and if they try to do this at the same time, a severe conflict occurs and correct handovers can not be guaranteed anymore. The two function instances need to be coordinated so that the second function waits until the impact time of the first function is over. The conflict between a MRO function instance and a MLB function instance is classified as an A2 output parameter conflict.

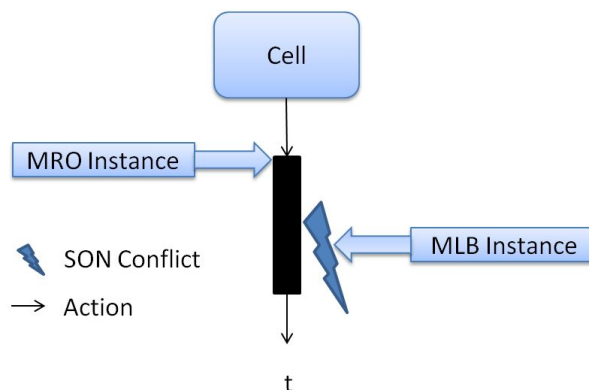


Figure 6: Conflict Between MRO and MLB Function Instance

5.3 CCO conflict

A prime example for a category C1 conflict occurs when two CCO functions change the same characteristics of a cell. Both functions modify different input parameters, as CCO (RET) changes the antenna tilt of a eNB and CCO (TXP) changes the transmission power. Even the output parameters are different but the same characteristic of the cell is modified, in this case the cell size. An uncoordinated application of both functions at the same time results in a conflict shown in Figure 7.

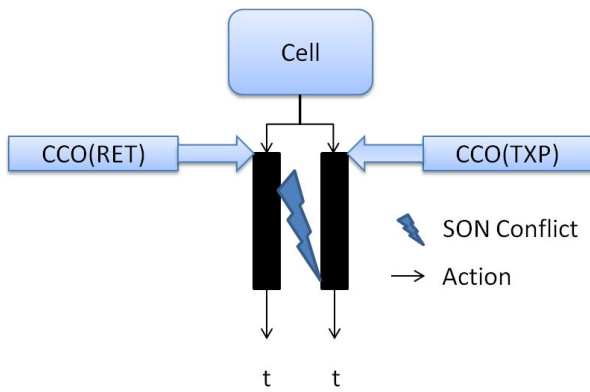


Figure 7: Conflict Between Two CCO Function Instances

Either both functions shrink or raise the original cell size twice or e.g. a down-tilt of the antenna and an increase of the transmission power might neutralize each other. Both scenarios are not voluntary as every CCO function is based on characteristics and the cell size after the completion of a former CCO function.

6. COORDINATION OF SON FUNCTIONS

In order to avoid the aforementioned SON conflicts there are two different approaches. One is the co-design of SON functions trying to reduce the dependencies of the different functions in advance. The second and main concept is the coordination of the functions. A coordination logic is built to solve and avoid conflicts at run-time.

The following sections describe both concepts in more detail. Refer to [4].

6.1 SON function co-design

As there are a lot of different SON functions in a SON network the number of potential conflicts is extremely high. One way to reduce the effort of the coordination itself is to avoid probable conflicts in the design phase. The previous sections showed that the root cause of most SON conflicts lies in the common parameters or characteristics used or changed by the SON functions. By grouping those functions in so called “function groups” coordination is just necessary within those groups. SON functions from different groups can work independently and do not need coordination anymore. Similar functions can even be merged to one new function as there is little difference and they interact with the same parameter set.

Unfortunately, co-design reaches its limit very rapidly when it goes to category C conflicts. In this case SON functions have a disjoint set of parameters, but they affect the same characteristics. A high degree of expertise is necessary when designing SON functions, as potential conflicts, regarding cell characteristics need to be taken into consideration. Those conflicts can only be prevented by function coordination at run-time.

6.2 SON function coordination

The main goal of SON function coordination is to prevent or solve conflicts at real-time. There are two basic require-

ments the coordination needs to achieve. Besides, the automatically operating low-level coordination, a gateway to human operators has to be served. Human experts still set general policy rules or thresholds as general coordination guidelines.

The low-level coordination uses these guidelines to create its own concept for best coordination. There is one instance called “coordination function” representing the coordination logic. This function decides which SON function is allowed to execute its task at what time. It can also assign priorities to several functions that try to execute at the same time. SON function instances can even be pre-empted if necessary. Like this the coordination function acts like a smart scheduler also allowing parallelisation to work efficiently.

The decision logic of the coordination function is one of the most difficult parts in the whole concept of coordination. It is mainly based on the impact area, the impact time, the input parameters, the output parameters, the used measurements and the affected measurements. All these parameters need to be taken into account in order to achieve optimal decisions.

Potential category A and B conflicts are rather easy to detect because an automatic analysis of the affected parameters shows the endangered functions. Category C conflicts can also be detected by automatic analysis, but they need a more complex data and information model as a base, originally constructed by operation experts.

Using the vendor-specific guidelines and information about the impact time and area of each SON function decision trees are used to describe the logic of the coordination function. Using this logic, an automatic coordination process can be applied.

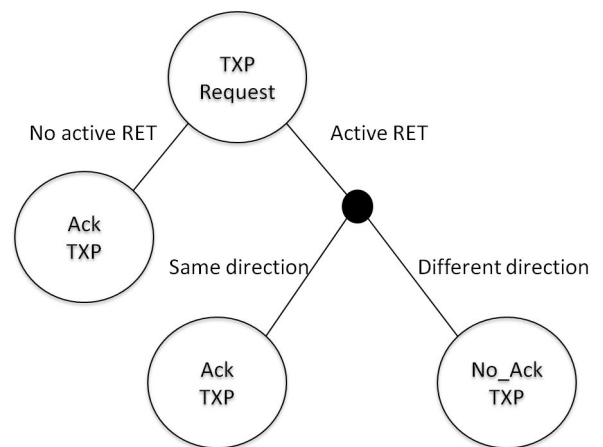


Figure 8: Decision Tree for CCO (TXP) Coordination

Figure 8 shows an example of a decision tree for a CCO coordination. The CCO function for one cell has two basic functions as described in section 5.3. CCO (RET) changes the antenna tilt and CCO (TXP) changes the transmission power. In order to avoid a CCO conflict the first step in the decision tree of a CCO (TXP) function is to check if there is an active CCO (RET) instance. If there is none, the SON function directly gets the acknowledgement by the coordination function to execute its task. If there is already

a CCO (RET) instance running, it needs to be ensured that it is into the same direction, meaning both CCO functions do not neutralize each other. If this is not the case, the CCO (TXP) function is rejected and needs to ask for permission later.

As not all SON functions are alike, SON function coordination is based on different requirements. Methods on how SON functions are coordinated are described in so called coordination schemes. Which coordination scheme is often applied depends on the impact time and area of the SON function and how it is built. SON functions can be split into three different phases whereas the coordination schemes are usually applied at the transition between the phases (see Figure 9).

In the monitoring or perception phase the network is observed and parameters and measurements indicate when the algorithm execution phase is triggered. In this phase configuration values are computed that are needed in the action execution phase. This is the phase where the real interaction with the network elements or other SON functions take place.

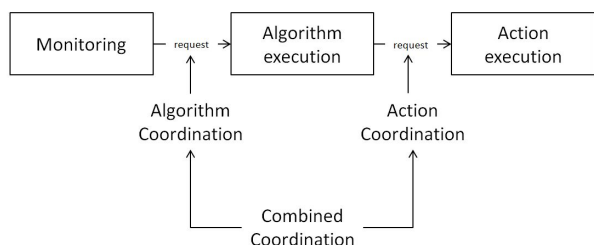


Figure 9: Interaction of Different Coordination Schemes

In between those phases there are three main types of coordination schemes that can be applied.

The most common scheme is the action coordination. As most of the conflicts occur due to simultaneous action execution the main goal is to prevent these potential conflicts. In this case the previously described coordination function is asked for permission, before the action takes place. With this method the before mentioned CCO conflict of the oscillation due to down-tilting and increasing the transmission power, can easily be detected and avoided.

A second scheme of coordinating SON functions is the algorithm coordination. This coordination takes place before the algorithm execution. As in many cases the results of the monitoring phase are already sufficient for the coordination function to reject a function request, the effort of the algorithm execution can be completely omitted.

As both schemes have their pros and cons a combination of both of them leads to the third solution. The combined algorithm and action coordination unite the benefits of both schemes to one intelligent one. If the results of monitoring are enough to reject a SON function request, no further effort needs to be accomplished. If more details are requested by the coordination function, the algorithm execution is applied before using the action coordination method.

Like this even the decision tree in Figure 8 can be simplified by dividing it into two parts. The first request can be verified by the algorithm coordination, whereas the sub-tree is coordinated by the action coordination (see Figure 10).

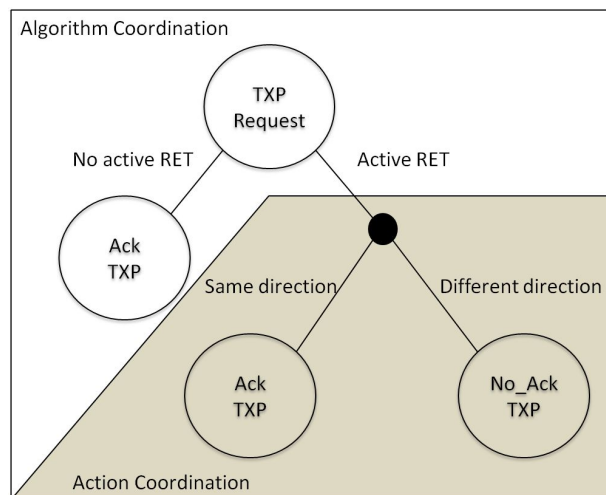


Figure 10: Separated Decision Tree for Algorithm and Action Coordination

7. CONCLUSION

Self-Organising Networks are created to reduce complexity, manpower and costs of mobile networks. Especially for the evolving LTE networks significant benefits have been achieved with SON.

As the main power of SON lies in its architecture and algorithms all vendors benefit from this framework, no matter to which degree they apply it. It is not just the saving of costs that is attractive to operators but also the increasing functionality coming along with SON. Higher coverage and capacity is enabled, the whole network becomes more robust and image damaging failures and failure times are extremely reduced. By having a coordination of SON functions not only conflicts can be avoided, the interactions between eNBs also allow load balancing between different cells. LTE is the future standard for mobile networks and with SON going along with it a new era is about to be established.

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