A Framework for Cell-Association Auto Configuration of Network Functions in Cellular Networks

Stephen S. Mwanje[1](✉), Janne Ali Tolppa[1], and Tsvetko Tsvetkov[2]

[1] Nokia, Munich, Germany
{stephen.mwanje,janne.ali-tolppa}@nokia.com
[2] Department of Computer Science, Technische Universität München, Munich, Germany
tsvetko.tsvetkov@in.tum.de

Abstract. Self-Organizing Networks (SONs) introduce automation in Network Management (NM). Herein, SON functions automate the traditional NM tasks in the network. For some of these tasks, several cells must be associated together in order to achieve the intended objectives. As such, part of the process of configuring SON function is the configuration or selection of the required cell associations. For end-to-end automated NM, it is necessary that this task is also automated, especially in an environment with many SON functions.

This paper proposes an applicable auto configuration solution, called Cell Association Auto-Configuration (CAAC). First, we justify the need for the solution and describe the design of its component parts. Then, we evaluate the application of components of the approach to a real LTE network. The results, based on real network data, prove that CAAC is able to select the most appropriate associations for the SON functions, reducing the potential for run-time conflicts among the functions.

1 Introduction

Self-Organizing Networks (SONs) is an approach in managing mobile networks, which introduces automation in the typical NM tasks [1]. A set of autonomous SON functions undertake the traditionally manual NM tasks, i.e. Configuration Management (CM), network optimization or Performance Management (PM), Fault Management (FM), as well as failure detection and recovery. Each SON function is a closed control loop, which adjusts a set of Network Configuration Parameters in order to optimize a set of Key Performance Indicator (KPIs). Typical SON functions include network level function like Energy Saving (ES), Mobility Load Balancing (MLB) and others defined e.g., in [1]. In this paper, however, we use the term SON function (SF) to refer not only to the traditional SON functions but also to the other multi-cell features like Carrier Aggregation (CA) or Coordinated Multi-point Transmission (Comp), whose requirements for multi-cell operation are similar to the ones for typical SON functions.

R. Agüero et al. (Eds.): MONAMI 2015, LNICST 158, pp. 68–80, 2015.
DOI: 10.1007/978-3-319-26925-2_6

The behavior of each function can be configured by means of CM parameters, so that, depending on the CM parameter values, the function's behavior may differ at two different time or spatial instances. Consequently, we explicitly use the term "instance" for the function instances, and always use "SON function" to refer to the function type.

For many SON functions, several cells must cooperate to achieve the intended objective. For example, consider that cell 2 in Fig. 1 is to be deactivated for ES. It is necessary to ensure that another cell (e.g., cell 4) is able to guarantee coverage for the areas initially served by the deactivated cell. Similarly, before cells 1 and 2 are grouped together for CA, it needs to be confirmed that both cells support CA and if so the frequencies that are supported. For such use cases, cells must be configured to associate for the respective functions.

Generating the cell associations involves two prerequisite processes - determination of adequate overlap and detection of the requisite capabilities. In the first case, usually the coverage area of the cells must overlap in a suitable way. For example, two cells are associated for CA, when a sufficient number of users receive good coverage from both cells. Then, besides appropriate overlap, the cells must have the required capabilities which must also be communicated amongst the cells. For instance, CA requires that the supported frequencies are determined and communicated.

Moreover, it is also necessary to ensure that the selected cell associations do not conflict with each other. Consider the conflict in Fig. 1 where cell 2 is associated with cell 1 for CA but also associated with cell 4 for ES. Although cell 4 will compensate for coverage in case cell 2 is deactivated, an unexpected behavior may result for CA between cells 1 and 2 if cell 2 is deactivated without

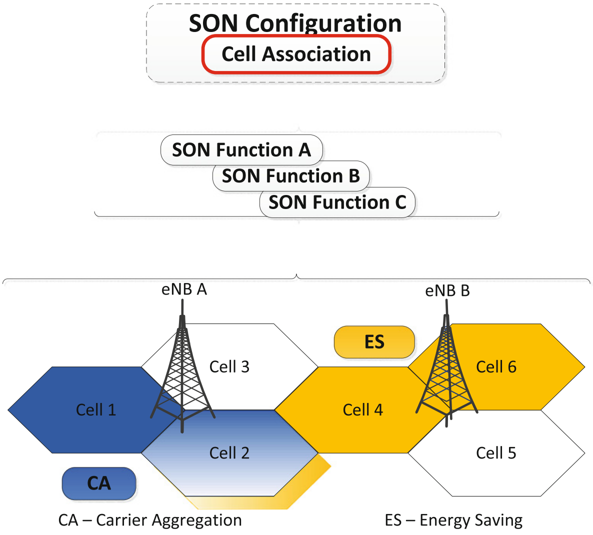


Fig. 1. Configuration of Cell Association for SON functions

consideration of this effect on CA. In that case, the cell associations need to be configured in such a way that these conflicts are eliminated or at least minimized.

It is imaginable that conflicts can be managed through runtime SON coordination and verification that have been widely studied, e.g. in [2–12]. The challenge is that as the number and complexity of SON functions increases, so does the complexity of runtime coordination. In the extreme case, this can be exponential, since the Coordinator must account for all possible combinations of the SON functions. A highly complex set of conflicting SON functions can lead to too much SON coordination and verification, which would make it difficult to undertake the necessary optimizations, as the system is in a constant state of conflict resolution. SON configuration should therefore minimize the reliance on SON coordination and verification, improving the end-to-end system performance; in effect by complementing the two processes.

In this paper, we propose a framework for the auto-configuration of cell associations. The framework implements four components that aim to automate:

1. the computation of overlap among cells
2. the detection of cell capabilities for the SON functions
3. the detection of conflicts among cell associations
4. the resolution of detected conflicts

The rest of the paper is structured as follows: Sect. 2 describes the solution and how it achieves the objectives of autonomous association of cells for SON and optimizing the associations to minimize conflicts. Then, in Sect. 3, we present results of applying the proposed approach to a real network scenario. Finally, we conclude with a summary and outlook to our expected future work in Sect. 4.

2 SON Cell Association Auto-Configuration

For the SON CAAC expected to be a part of the SON configuration task (Fig. 1), we propose the framework shown in Fig. 2. The function consists of two major components which directly relate to the CAAC objectives: (1) a Cell Association Constructor and (2) a Cell Association Optimizer. Each of the two functions is composed of two sequential sub-functions: the Cell Association Constructor having Cell Overlap Detection and the Cell Capability Detection sub-functions while the Cell Association Optimizer contains the Cell Association Conflict Detection and the Cell Association Conflict Resolution sub-functions. The following sections describe the data sources and CAAC sub-functions.

2.1 CAAC Data Sources

The CAAC function considers three data sources:

1. Network CM data: This can be read at auto-configuration execution time, and includes information about the subnetwork for which associations are to be configured. Such information includes the network topology, cells characteristics (e.g., macro or pico), as well as information on any existing cell associations.

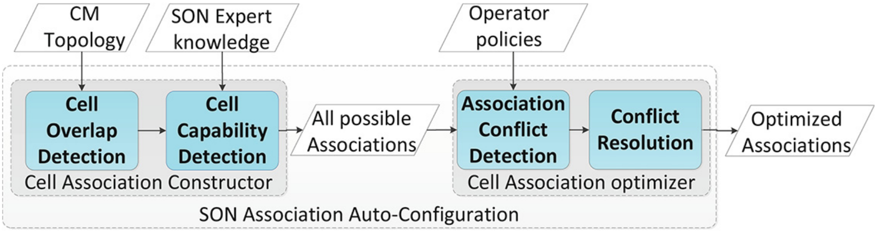


Fig. 2. Structure of the SON CAAC framework

2. SON expert knowledge: This is expected to be provided as part of the SON solution by its vendor and mainly defines two elements. First, it must define the association pre-requisites for the SON function, which are typically different for each SON function and may be different for any two vendors. In the case of CA for example, besides defining the supported frequencies, the vendor should define which particular inter-band CA combinations are supported. Secondly, expert knowledge for a given SON function should define the rules for assessing the function's likelihood and severity of runtime conflicts with other SON functions. For instance, ES is expected to conflict with CA, but its likelihood and severity, when compared say to the conflict between ES and MLB, needs to be defined.
3. Network operator's policies and targets: Defined as part of the network planning process, these are intended to optimize the conflicting objectives of the SON functions depending on the operating environment. Most critical here are priorities given to the different SON functions and the conflict threshold, which defines the acceptable level of runtime conflict (That is expected to be managed by the SON coordinator). Both the priorities and threshold may be set differently for different environments. For example, ES may be prioritized higher than CA in a rural setting and vice versa in a city business district.

2.2 Cell Overlap Detection

For two or more cells to be associated for a certain SON function, their coverage area must overlap in a suitable way. For example, two cells are associated for CA when a sufficient number of users receive good coverage from both cells. The required overlap may not be the same for all SON functions but overlap must either way be quantified. The overlap quality contains requirements on:

1. the percentage of overlap for each of the neighbor cells
2. the nature of the overlap either as intra- or inter-frequency
3. the type of the cells (e.g., macro or small cell)
4. the multiplicity defined in terms of the number of cells that overlap with the selected cell

Cell overlaps can be calculated based on the combination of radio propagation models and network planning data such as antenna coordinates, direction, angle, beam width and transmission power. Such data does not, however, necessarily reflect the real situation in the active network and so a real-time-data based solution is required. A closely related solution for determining if a number of cells overlap was introduced in [13]. In this case, the cells exchange messages, whose content relates to the user terminals within the vicinity of the cells. The concerned cell then uses the list of UEs to determine if it overlaps with the cell that originated the message. Although the solution is an automated one, it does not quantify the degree of overlap. Besides, the exchange of messages would, in a highly dynamic environment, place an extra constraint on the signaling resources.

Our proposal is an improved approach based on User Equipment (UE) measurements that are translated into an interference matrix. We note here that the cell overlap detection component aims at determining whether the concerned cells have a region of overlapping radio coverage and if this region has a sufficient number of users that the two cells should be associated for the said SON function. For example, if a cell A is a full underlay cell of another cell B (A's coverage area is a subset of B's area), the two can be associated for ES, since the smaller cell can be deactivated for ES. Alternatively, the two cells can be associated for CA.

Consider a primary cell p and an intra-frequency secondary cell s as shown in Fig. 3. The degree of overlap between p and s defines the proportion of the users served by p that lie within a region where they could also be served by s. The overlap detection component evaluates the interference C/I that users in p receive from s. This interference is defined as:

$$(C/I)_s = RSRP_s - RSRP_p, \tag{1}$$

where $RSRP_s$ and $RSRP_p$ are respectively the Reference Signal Received Power (RSRP) from cells s and p as measured by the reporting user device.

For cell p, the overlap is the proportion of users that have significant interference from s. As shown in Fig. 3, a user is considered to have "significant interference" if:

1. The neighbor cell RSRP is above a threshold `ThMIN_RSRP`, which represents the lowest possible RSRP at which a cell is able to serve a user.
2. C/I is below a threshold `ThMAX_IF`. This condition is optional and may be neglected by relying on the handover procedure to set the highest acceptable interference. The assumption in that case is that if interference from the neighbor becomes too high, then the user will initiate handover to the neighbor cell.

For the cell p and in a given time frame, we track a counter `TotalUserCount` that counts all users that have been served by p. Then for each neighbor s, we track another counter `HighIFUsers` that counts the number of users with significant interference from s. The degree of overlap between p and s is, therefore, the ratio of `HighIFUsers` to `TotalUserCount`. Note that what we quantify here is the proportion of users in the overlapping region as opposed to the percentage of geographical overlap. For many SON use cases, this overlap of users is

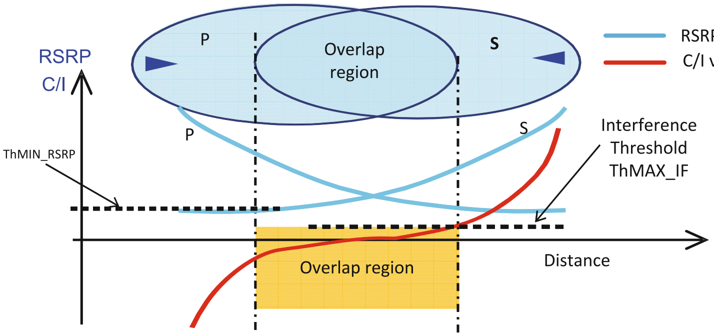


Fig. 3. Overlap detection thresholds

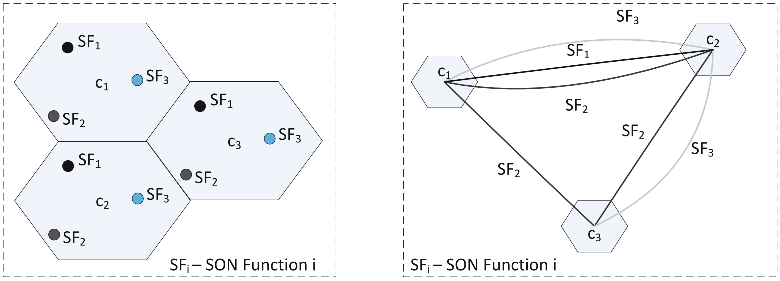
more important than the geographical overlap since the metrics rely on user experience counter statistics.

The approach as described above is also applicable for inter-frequency overlap detection. Therein, C/I is not the degree of interference between p and s but the cell coupling between the two cells. To achieve it, UEs must report RSRP measurements for the inter-frequency neighbors, which is possible when inter-frequency Automatic Neighbor Relation (ANR) [1] is activated. Meanwhile, this need for RSRP measurement (in both inter and intra-frequency scenarios) implies that the solution is only applicable during network operations. Where it may be needed to configure associations at network commissioning, planning data would have to be used as seed and the associations re-optimized on starting normal operations.

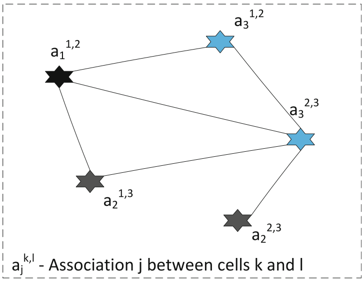
2.3 Cell Capability Detection

For a set of cells to be associated for some SON function(s), the cells or their eNBs must have the required capabilities and prerequisites for the particular SON function(s). This includes having the required features installed and enabled or disabled. Given the observed overlaps among a set of cells, the capability detection determines what each of the cells is capable of. Matching the overlapping pairs with the capabilities, it generates a list of all possible associations among the given set of cells. It then gives a score for each association depending on how well the association is suited for the particular SON function. This score defines the quality of the association and would be used, for example, if choice had to be made on retaining one of two conflicting associations.

The set of all possible associations can be represented by a cell association graph that shows the interrelations among the different cells. Consider a network topology like the example in Fig. 4a with a set of cells and a set of SON functions available to each cell. The corresponding association graph is Fig. 4b. It should be noted that capability detection is SON function and vendor specific. It heavily depends on expert knowledge as supplied by the vendor's SON experts.



a) Network scope b) Association graph



c) Coupling graph

Fig. 4. Cell Association example

Consequently, CAAC only defines an interface for the capability detection to which a plug-in implementation needs to be attached for each function to be supported by the CAAC.

2.4 Cell Association Conflict Detection

For each function, an "impact area" can be defined as the spatial scope within which the function instance modifies CM parameters, takes measurements, affects metrics after taking action or in general the set of cells it affects. Cells or functions can be considered coupled if their impact areas overlap.

The conflict detection component looks for the potentially conflicting cell associations for the considered functions and network scope. Each pair of coupled cells i.e., cells where the associations have an overlapping impact area, is given a coupling score which quantifies the expected effect of the conflict between these associations. The score is based on:

1. The likelihood and severity of a runtime conflict among the particular functions, as defined by the applicable expert knowledge.
2. The respective priorities of conflicting function instances as defined in the operator policy.
3. The quality of the respective cell association instances as determined by the capability detection.

Consider that an association $a_k^{i,j}$ is configured between cells i and j for a SON function instance k. Then, if the set of all possible cell associations is A, consider that association $a_k^{i,j}$ is coupled with another association $a_l^{m,n}$ (the association between cells m and n for SON function instance l). We define a coupling score for the effect of $a_k^{i,j}$ on $a_l^{m,n}$ as $C(a_k^{i,j}, a_l^{m,n})$ or simply $C(k,l) \in [0;100]$ for brevity. $C(k,l)$ defines the coupling score accorded to $a_k^{i,j}$ for its effect on $a_l^{m,n}$ as:

$$C(k,l) = P(k,l) \cdot imp(k,l) \cdot [w \cdot prio(l) + (1-w) \cdot q(l)] \tag{2}$$

$P(k,l)$ and $imp(k,l)$ both in the range [0-1] and defined by the SON expert knowledge, respectively give the probability of occurrence and the impact of a runtime conflict between k and l. $prio(l) \in$[0-100] is the operator-defined priority of the SON function in instance l. Such priorities can be configured to different values per sub-network or maintenance region to ensure that different SON functions are executed as priority in different parts of the network. One example could be to prefer CA in urban areas for increased capacity and ES in rural areas for reduced energy consumption. Meanwhile, $q(l) \in [0-100]$ is the quality of cell association $a_l^{m,n}$, in principle the outcome of the cell association construction. The relative significance of $prio(l)$ and $q(l)$ is controlled by the weighing factor $w \in [0-1]$. Two critical properties of $C(k,l)$ should also be noted:

1. only the priority and quality of l are considered in evaluating $C(k,l)$ since the aim is to measure the impact of association instance k on instance l.
2. $C(k,l)$ is not commutative i.e. $C(k,l) \neq C(l,k)$.

Given the definitions, any Cell association pair (k,l) for which $C(k,l) > 0$ is a potential conflict since its SON functions are coupled.

2.5 Cell Association Conflict Resolution

The Conflict-Resolution component attempts to reduce the degree of coupling, and consequently the need for run-time coordination, by eliminating those cell associations with the most coupling effects. The degree of conflict is modeled by a coupling graph that is derived from the cell association graph. Such a coupling graph is given in Fig. 4c for the network presented in Fig. 4a. In the coupling graph, each cell association is modeled as a vertex, whereas an edge is added connecting each pair of coupled associations, i.e. those for which $C(k,l) > 0$. The intention of Conflict-Resolution therefore is to decouple the graph in the best possible way (as controlled by the operator's policy).

For each function instance k (and its corresponding association), a conflict score, $S_k \in [0-100]$, is calculated as the normalized sum of $C(k,l), \forall a_l \in A$, $l \neq k$, i.e. the sum of the coupling scores of the association between k with all the other cell associations. The normalization is relative to the maximum cardinality of the set of all the SON functions, i.e.:

$$S_k = \frac{\sum\limits_{\forall l \in A, l \neq k} C(k,l)}{\max\limits_{a \in A}(|A_a|)} \tag{3}$$

where A is the set of all associations and $|A|$ is the cardinality of set A.

The operator policy sets a conflict threshold, `Th_Max_S` $\in [0 - 100]$ which defines the acceptable degree of coupling within the system, i.e. it defines the conflicts which would be coordinated at runtime. The Cell Association Conflict Resolution component then implements a simple Constraint Satisfaction Problem (CSP) solver which removes the most conflicting cell associations for which $S_k >$ `Th_Max_S`. By using this threshold, the operator can control the compromise between having as many SON functions running in the network as possible and reducing the required runtime coordination. For instance, setting `Th_Max_S` $= 0$ would mean that all coupled cell associations are removed. This will greatly reduce the need for runtime coordination, but at the same time will deactivate a high number of SON functions. Conversely, setting `Th_Max_S` $= 100$ would allow all the possible cell associations at the cost of significant runtime conflicts.

The removal of the most coupled cell associations is undertaken by removing one association at a time starting with the one having the highest S_k value. After each removal, S_k is recalculated for all k and removal continues to the next association for which $k = argmax\{S_k\}$. Once the process is finished, CAAC notifies the relevant SON functions of the changed cell associations. The SON functions then translate the associations into concrete network changes or reconfigurations of the centralized SON system.

3 Conceptual Results

In this section, we describe our results for the proposed solution when applied to data from a real LTE network topology as shown in Fig. 5. We assume that only two SON functions (ES and CA) are implemented in the SON-CAAC. The considered use case is the addition of a new cell to the network (cell 50), i.e. we assume that cell 50 has been added to the network and that associations for the two SON functions must be configured for this cell.

As described in Sect. 2.2, overlap detection requires actual UE measurements. As such, a planning-data based overlap calculation has been implemented in the experimental system to calculate the overlaps, which are used as basis for the association quality scores. We therefore do not show any results for overlap detection, and instead mainly focus on the conflict detection and resolution. We, however, pair cells for association using planning data, i.e., when cell 50 is introduced, the overlap detection component calculates the cell's overlap with all neighboring cells. These neighboring cells are also defined using planning data as opposed to being detected by the ANR SON use case.

Evaluations begin with an initially high conflict threshold, set such that all possible new associations are included. This is then later lowered to evaluate the effects of different policies. In particular, we evaluate the three scenarios:

Scenario (1) Default scenario with SON functions equally prioritized (prio=50) and the default threshold, `Th_Max_S` $= 20$.

Scenario (2) ES priority scenario which applies the default conflict threshold, but prioritizes ES higher than CA (i.e. prio(ES)=80, prio(CA)=10).

Scenario (3) Low conflict scenario where ES is again prioritized, but with a lowered conflict threshold, `Th_Max_S` = 10.

We assume a simple capability detection feature that assumes that all cells are capable of ES and CA and that the applicable prerequisites can be met in all circumstances. The overlap information is provided to the capability detection components created for CA and ES. For each SON function, based on the amount of overlap (and its directionality) between cell 50 and any neighboring cell c, the respective plug-in calculates the quality $q(l)$ of that cell association. This is then applied in computing the coupling score as defined in Eq. 2. Meanwhile, we assume also that the quality and priority of the SON functions are equally as important in calculating the coupling score, i.e. $w = 0.5$ in Eq. 2.

The result of this process, when applied to scenario 1, is the set of all the possible associations between cell 50 and the other existing cells for the ES and CA SON functions. This is depicted in Fig. 5a. Each node in the figure is a cell with the lines indicating the possible associations between the different cells. The meanings of the colour coding scheme is as follows:

- pink and green - respectively for CA and ES
- solid and dotted - respectively for existing and new asociations
- bold red - for the conflicting associations, i.e. those for which $S_k >$ `Th_Max_S`

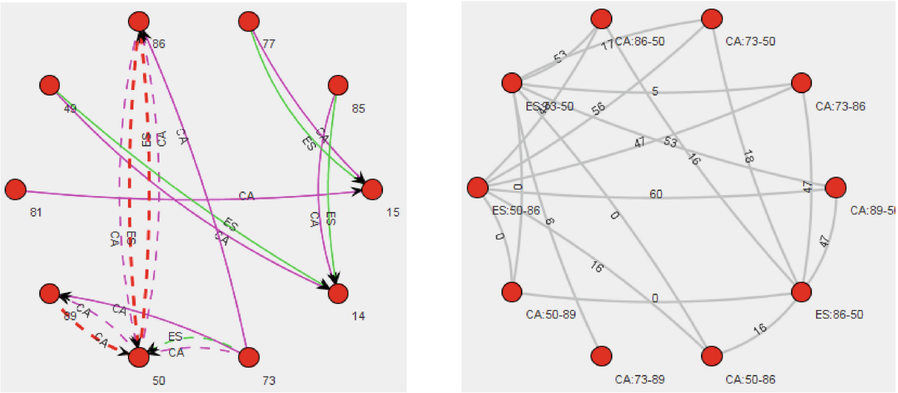
The coupling graph for the associations in Fig. 5a is the graph in Fig. 5b, which highlights all the conflicts in Fig. 5a and their corresponding coupling scores.

As seen in Fig. 5b, the ES associations between the new cell (cell 50) and cell 86 are the most conflicting and are, therefore, the recommended ones to be removed. Applying the conflict resolution removes these assoiations with the result being Fig. 5c where there is no more conclict between CA and ES.

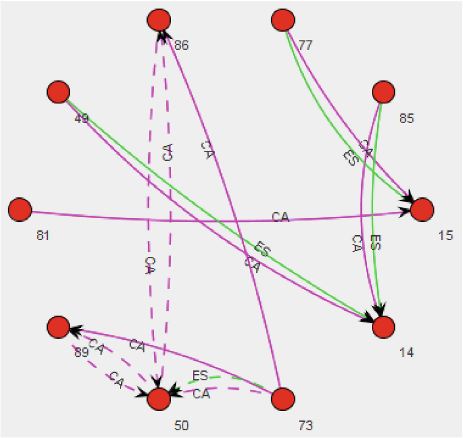
Meanwhile, we expect that the associations selected to be removed and consequently the reduction in conflict will depend on the applied threshold. To evaluate the effect of the threshold, the association graph is regenerated for the two other scenarios where ES is prioritized, i.e. $prio(ES) = 80, prio(AC) = 10$. The conflict threshold `Th_Max_S` is maintained at 20 in the first scenario, but reduced to 10 in the second. The resulting association graphs are Figs. 6 and 7 respectively.

Compared to Fig. 5a, we observe in Fig. 6a that the most conflicting SON function ceases to be ES and becomes CA. This is because the priority of ES has been raised, implying that other SON functions (CA in this case) are now penalized more for conflicting with instances of ES. The corresponding conflict resolution result is Fig. 6b, where the high conflict CA association is removed and both ES associations retained.

When `Th_Max_S` is, however, reduced as is the case in scenario 3 (in Fig. 7a), more associations are expected to exceed the threshold. From Fig. 7a, besides the CA association, the coupling scores of the two ES associations also exceed



(a) Cell association graph with conflicts (b) Coupling graph showing the conflicts

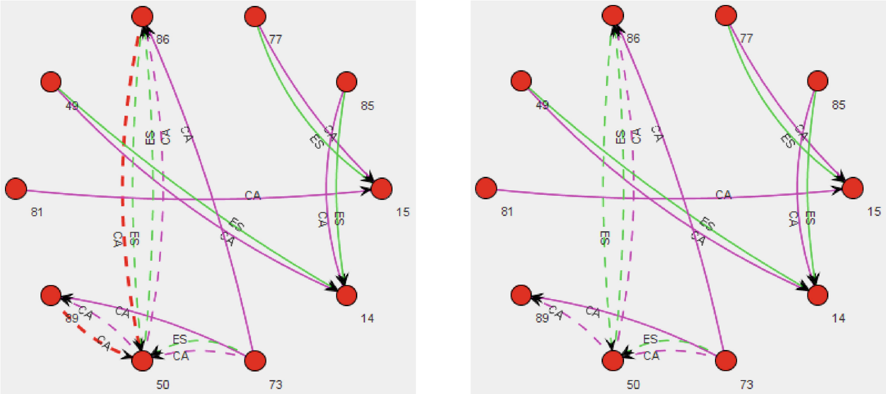


(c) Association graph after conflict resolution

Fig. 5. Conflicts resolution between ES and CA function instances

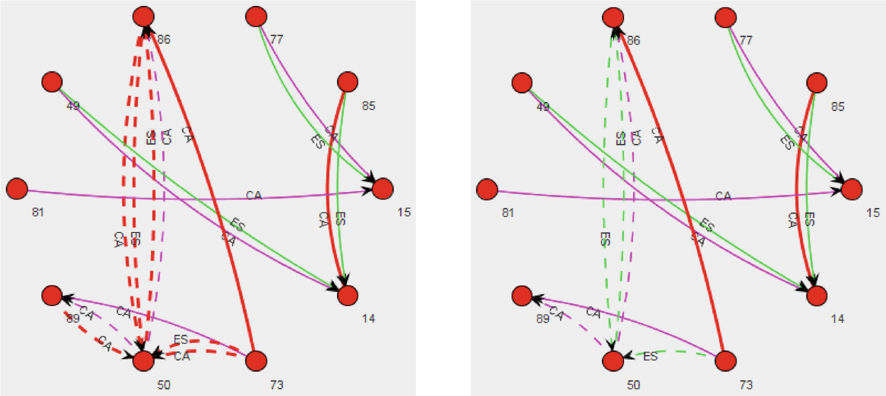
the threshold (i.e. $S_{ES} >$`Th_Max_S`), adding the two ES associations to the list of removal candidates. The ES associations are nevertheless maintained after conflict resolution, a result of the one-by-one removal process. Since the conflict scores are recalculated after removing the most conflicting association, the ES scores cease to exceed the threshold. It is then no longer necessary to remove the ES associations. Noted that with the lower conflict threshold (Fig. 7a), one of the existing CA cell associations also exceeds the threshold. This is however not removed because by default CAAC does not optimize existing associations.

These results show that given appropriate overlap detection, the CAAC is not only able to generate a set of cell associations for a given set of SON functions in consideration of the operator's objectives, but also minimizes the conflicts among the selected associations.



(a) Cell association graph (b) Association graph after conflict resolution

Fig. 6. Conflict resolution with priority for ES



(a) Cell association graph (b) Association graph after conflict resolution

Fig. 7. Conflict resolution with priority for ES and a reduced conflict threshold

4 Conclusion

Based on the observation that cells need to associate with one another for some traditional Self-Organizing Network functions as well as for multi-cell network features, this paper has proposed a framework for auto-configuration of such associations. We have justified the need for the Cell Association Auto Configuration (CAAC) solution and, proposed requirements and designs for its constituent components. We proposed automated solutions for detecting the overlap among cells with the intention of associating the cells for the SON functions. We then described a conflict detection and resolution solution through which we are able to minimize the coupling among cell associations thereby reducing their run time conflicts. Results of the trial application of the conflict resolution approach on a real network data set indicated that the solution is able to apply an operator's policies in combination with the SON-function-specific expert knowledge to reduce the conflicts. Future work will evaluate how the approach can be generalized in a multi-vendor environment with the expectation that this can then be easily applied where multiple vendors' networks are collocated.

References

1. Hämäläinen, S., Sanneck, H., Sartori, C. (eds.): LTE Self-Organising Networks (SON) - Network Management Automation for Operational Efficiency. Wiley, Hoboken (2012)
2. Jansen, T., Amirijoo, M., Turke, U., Jorguseski, L., Zetterberg, K., Nascimento, R., Schmelz, L.C., Turk, J., Balan, I.: Embedding multiple self-organisation functionalities in future radio access networks. In: 69th Vehicular Technology Conference, 2009. VTC Spring 2009, pp. 1–5. IEEE (2009)
3. Liu, Z., Hong, P., Xue, K., Peng, M.: Conflict avoidance between mobility robustness optimization and mobility load balancing. In: Global Telecommunications Conference (GLOBECOM 2010), pp. 1–5. IEEE (2010)
4. Schmelz, L.C., Amirijoo, M., Eisenblaetter, A., Litjens, R., Neuland, M., Turk, J.: A coordination framework for self-organisation in LTE networks. In: IFIP/IEEE International Symposium on Integrated Network Management (IM), pp. 193–200. IEEE (2011)
5. Bandh, T., Romeikat, R., Sanneck, H., Tang, H.: Policy-based coordination and management of SON functions. In: IFIP/IEEE International Symposium on Integrated Network Management (IM), pp. 827–840. IEEE (2011)
6. Kemptner, T.: LTE SON-function coordination concept. Netw. Archit. Serv. (NET) **NET-2013-08-1**, 101–106 (2013)
7. Iacoboaiea, O.C., Sayrac, B., Jemaa, S.B., Bianchi, P.: SON conflict resolution using reinforcement learning with state aggregation. In: Proceedings of the 4th Workshop on All Things Cellular: Operations, Applications, & Challenges, pp. 15–20. ACM (2014)
8. Mwanje, S.S., Mitschele-Thiel, A.: Minimizing handover performance degradation due to LTE self organized mobility load balancing. In: 77th Vehicular Technology Conference (VTC Spring), pp. 1–5. IEEE (2013)
9. Mwanje, S.S., Mitschele-Thiel, A.: STS: space-time scheduling for coordinating self-organization network functions in LTE. In: IFIP/IEEE International Symposium on Integrated Network Management (IM 2015), Ottawa, Canada (2015)
10. Zia, N., Mwanje, S.S., Mitschele-Thiel, A.: A policy based conflict resolution mechanism for MLB and MRO in LTE self-optimizing networks. In: IEEE Symposium on Computers and Communication (ISCC), pp. 1–6. IEEE (2014)
11. Mwanje, S.S., Mitschele-Thiel, A.: Concurrent cooperative games for coordinating SON functions in cognitive cellular networks. In: IFIP/IEEE International Symposium on Integrated Network Management (IM 2015), Ottawa, Canada (2015)
12. Vlacheas, P., Thomatos, E., Tsagkaris, K., Demestichas, P.: Operator-governed SON Coordination in downlink LTE Networks. In: Future Network & Mobile Summit (FutureNetw), pp. 1–9. IEEE (2012)
13. Ericsson Telefon Ab L M: Method of discovering overlapping cells (2010)