Automatic Site Identification and Hardware-to-Site Mapping for Base Station Self-configuration

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***Abstract*—One of the key requirements that come with the introduction of Next Generation Mobile Networks is the automatic provisioning and configuration of new Network Elements. This targets to reduce on the one hand the time required between the installation of new hardware until it is fully functional and on the other hand the overall configuration overhead. Hardware should be setup without requiring any preconfiguration and without manual configuration after the on-site installation. A required enabler is the automatic acquisition of information about the site where a Network Element is being deployed. Only if this is possible further autoconfiguration steps can be successfully executed. Automatic site identification provides the means to assess the information required to identify a site defined by network planning.**

An analysis shows that, depending on the network setup and the deployment scenario, automatic HW-to-Site mapping shows different degrees of complexity that need to be handled. In addition to the analysis of deployment scenarios and their individual site identification and mapping solutions a combined solution that is capable to perform site identification and hardware to site mapping based on the context of the new Network Element is proposed.

I. Introduction

In a mobile network each base station (BS) is individually configured based on its capabilities and the location where it is installed. To allow a fully automatic commissioning and configuration of new Network Elements (NE), site identification and a HW-to-site-mapping are indispensable [1]. Two steps have to be performed: to identify the site a Network Element is being deployed and then subsequently to provide a mapping between hardware information and site information in the Network Management system. This combined information is the enabler for all further configuration processes. As soon as it is available the specific input to the configuration process can be provided.

The problem in site identification and HW-to-Site mapping is that a single identifier like a geo-location is often not sufficient to establish a unique mapping. Especially since it is common to have multiple sites at the same location, for example if a layered cell structure is used. Apart from the location there are more characteristics that define a site to be established.

If site identification and HW-to-Site mapping are done by a human, the acquisition of such additional information (like cell type, NE/antenna type) and the corresponding decision making is simple. However, feeding the acquired information into the configuration management process is time-consuming and error-prone. On the other hand, in an automated approach the difficulty is in the automated acquisition of the required information and the automated decision making on the site identification.

Therefore, the next Section will give an introduction into different site identification and HW-to-Site mapping methods as well a description of deployment scenarios and their challenges from the perspective of site-identification. Section IV shows the applicability of the identification methods to the deployment scenarios.

II. Site Identification and HW-to-site-mapping

Sites within mobile networks are planned long ahead of the installation of the network elements. Before a site can be used and the hardware can be installed, all the prerequisites for the operation of network equipment as for example an adequate cabinet with data an power connections has to be prepared.

As part of the planning and preparation process a unique identifier for the site is created. This identifier is put into the configuration management database together with the site characteristics and other information connected to the actual site.

The following Subsections subdivide the process into the site identification and the HW-to-Site mapping part.

A. Site Identification

In manual site identification, identification information is attached to the site as part of the preparation process, typically by attaching a sticker or something similar to the rack / cabinet, or the NE installer has a list with the identifier and additional information, street address and rack identifier within the cabinet, that allows him to identify the site.

The actual site identification is performed during the hardware setup process. An installer reads the site identification information and provides it as input to the mapping step. Site-identifiers can be long strings of characters where lots of site-specific information is encoded. The transcription of the identifier contains some sources of error, especially if it is attached to the site where it can potentially be damaged or just be hard to read.

While there is no co-location of sites the main source of errors is the transcription from the sticker to the installers task sheet. But as soon as there are multiple sites at a given location the error probability increases. In order to make the site-identification faster and more reliable it has to be automated.

1) Semi-Automated Site-Identification: Semi-automated methods can be used to improve the identification by using machine-readable identification tags. This requires that a machine-readable tag is attached to the site in a way that it is accessible by the installer and allows a distinct association of the tag with the physical site. The installer has to be equipped with a device to read the tags.

Typical tags are:

- **Bar Codes**, especially in the form of QR-Codes are becoming a common identification method. A common smartphone has the ability to read those codes and present and process the encoded information. Depending on the used encoding they can contain more or less redundancy in order to cope with partly damaged tags.
- **RFID Tags** are the electronic equivalent to bar-codes. Their main advantage is their robustness. It does not matter if the surface is damaged or polluted. Depending on the type of RFID tag they even allow to read the contained information from a larger distance without direct contact. They are widely used for logistics, so they are already integrated into respective systems and a wide range of tags and readers is available for different usage scenarios. The main challenge is to place the tags in a way that excludes the possibility of a wrong site identifier be read. This is especially challenging in compartments with co-located sites.

The usages of machine-readable identifiers solves the transcription problem but introduces complexity at other points in the process.

B. Hardware-to-Site Mapping

After the identification of the site two alternative methods can be used to provide the site identification information to the mapping mechanism as shown in Figure 1.

For the **”remote manual mapping”** shown in Figure 1, the hardware installer gathers the information on both the site and the installed hardware. The network operator’s remote commissioner updates the Configuration Management Database (CM DB) with this information. As soon as it is up to date the newly installed NE can be switched on and the configuration management system is able to respond to its configuration requests. The major advantage of this approach is that the required skills for the the on-site personnel is limited. The obvious disadvantage is the error prone manual transmission of information which increases the risk that multiple site visits are required. Additionally there is a potentially longer delay between the hardware setup and the availability of the mapped data in the CM DB caused by multiple humans in the loop for a single step of the process. This delay then increases the duration the overall configuration process.

In order to reduce this delay the **”On Site Manual”** approach can be used, c.f. Figure 1. The installer identifies the site and enters the site identification information already on site into the newly installed NE. In a first auto configuration request, the NE adds hardware information and sends this combined set of information to the CM DB, where the HW information is used to update the information of the planned site. This process is much faster and in case of an error, for example a transcription error of the Site-ID instantaneous feedback can be given to the on-site personnel.

The disadvantage of the on-site manual approach is, that it requires skilled personnel which needs to have access to the configuration interface of the network elements. It does not only counteract the target to reduce operational expenditures (OPEX) but also opens a potential on-site security hole.

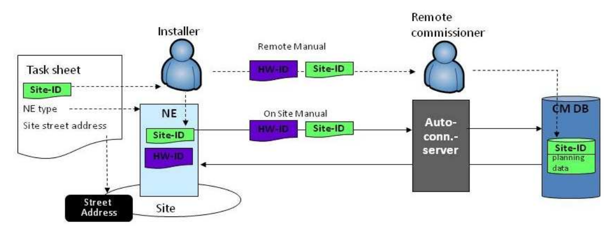

Fig. 1: Remote Manual and On-Site Manual Hardware-to-Site Mapping

C. Automated Site-Identification and Hardware-to-Site Mapping

A logical next step from a on-site manual approach is the full automation of the site-identification and the HW-to-Site mapping process, as shown in Figure 2. After the hardware is set up, it automatically acquires information that allows a successful site identification. Typically this is mainly location information but also additional information can be included. Site and hardware- specific information is then submitted to a mapping service that performs the actual site identification and the mapping and updates the CM DB. As soon as the entries in the CM DB are up to date location- and hardware-specific configuration data can be provided to the network element.

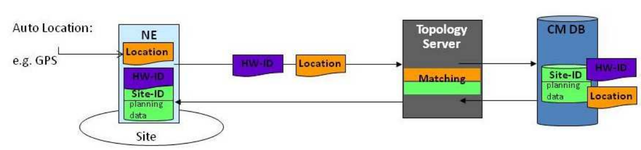

Fig. 2: Automatic Site Identification and Hardware-to-Site Mapping

III. Deployment Scenarios

Depending on the deployment of the network elements the complexity of the site identification varies. The forecast for future network deployments, especially LTE-Advanced [2] deployments, is that they will make heavy use of a layered cell structure and use a dense distribution of small cells. The following sections give a introduction to different deployment scenarios and the challenges they impose for site identification.

A. Macro deployments

”Macro” deployments are the typical scenarios in mobile networks. The sites are spread out with a rather large inter-site distance and the cells of the deployed network elements cover larger areas. Currently, site co-location for a single Radio Access Technology (RAT), with multiple sites at a single location for a single network operator is only infrequently used.

In urban areas the inter site distance is much smaller in order to satisfy higher capacity demands and cope with radio propagation limitations.

Inter RAT site-colocation will be more common in the future. With the introduction of a new RAT like LTE most of the sites will be co-located with sites for legacy RATs in order to reduce both capital and operational expenditures. NEs for all technologies are continuously updated. Automatic site-identification should therefore be applicable for all newly installed NEs not only for those of the latest RAT. In addition co-location of NEs for the same RAT will also be used as shown in Section III-C.

B. Indoor Deployments

Especially in ”Enterprise Pico” and ”Residential Femto” deployments the sites are located indoors and their characteristics differ strongly from outdoor deployments. ”Enterprise Pico” deployments are used to provide optimized coverage and capacity with small cells to a particular high value customer like a big company. Other typical scenarios for pico deployments are areas with a high demand for network capacity, like big shopping centers, trade fair areas or airports.

”Femto” deployments are targeted to individual customers which either live in an area with bad coverage or have a high demand for network capacity. The femto BS are connected to a fixed-broadband connection and provide a (private) small coverage area cell.

From a deployment point of view both scenarios show some similarities. The sites are not or only coarsely planned and show a very high density with a very small inter site distance of typically less than 100 meters. Especially for Enterprise Pico the NEs are often set up on different floors at an otherwise geographically identical location.

C. Mixed Pico and Macro Deployments

For future LTE-Advanced and ”Heterogeneous Network” deployments, mixed deployments will be often used. The 3GPP started to define possible deployment scenarios and analyze the effects they cause [2]. Mixed deployments with layered cell structures are used as a capacity improvement at places with a high number of active users. The hierarchical cell setup is used to serve stationary users and fast moving users at the same time. Such a setup combines the benefits of small cells, (high capacity for stationary users) with those of large cells, especially the reduced number of handovers for fast moving users. In case ”remote radio heads” are used even more sites will be colocated.

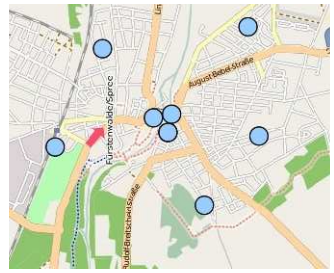

Fig. 3: Macro Deployment including three colocated sites

IV. Site-Identification Methods and their Applicability

The deployment scenarios in Section III show that automatic site identification can become a hard to accomplish task. Especially as soon as co-location or even indoor deployments have to be considered.

A. Geo-Location Based Site Identification

In order to automatically identify a site, the site’s position is the most important characteristic. Therefore identification of the location of the NE is the most important task to be performed. There are several means for position assessment:

1) Satellite based Positioning: Macro eNodeBs will come with optional GPS support used for time synchronization [3], which can also be used for positioning purposes. The assessed position typically deviates from the actual position due to restrictions for civil GPS receivers. The deviation can range from less than a meter to about 100 m, depending on the respective skyview, but usually less than 50 meters.

2) Radio Based Positioning: Within a mobile network there are several possibilities to asses a location. Both passive and active means can be used. For all methods a UE either built-in or connected to the BS is required. A major advantage compared to satellite based positioning is that it can also be used for indoor deployments, because it does not require a direct sky-view. But also for macro deployments it is useful as it does not mandate the availability of a GPS device and additional cabling and antennas.

For the passive location assessment the UE is switched on as a receiver and then scans for the identifiers of all receivable cells. This information is provided to the topology server. Based on information on the networks cell layout and possibly signal strength information a location is estimated.

The result quality depends highly on the number of received cells, if only a few cells are received the estimated position can often only be narrowed down to a still relatively large area. In case only a single cell or multiple cells with a similar coverage area are received a reasonable position estimation is almost impossible. In urban areas with many cells the position estimation is much better but it can be biased through hard to predict radio propagation effects.

A more exact radio based positioning requires an active UE at the BS. The UE is used to perform indirect NE localization. It connects to the mobile network and sends a unique identifier to a positioning service, which triggers the location assessment for this particular UE. This allows the usage of a wide range of UE localization methods [4]. The position information is provided to the UE which sends the information to the site identification service at the topology server.

Such an approach requires network coverage at the location where the new network element is deployed, therefore the usability of the method will also differ between urban and rural areas when only a single RAT is available. In developed countries there will often be several RATs available, though (for example, 2G/3G/LTE).

WIFI based positioning, well known from the smartphone world, is based on databases with the information of which wireless accesspoint is active at which position. Cells of IEEE 802.11 based wireless networks have a very small footprint. It is especially appealing for femto base stations, which are typically deployed indoors without GPS signal reception and often as a substitution for lacking macro coverage. The pre-requisite for the deployment of a femto BS is the availability of a broadband connection, which increases the probability of other wireless networks being receivable.

V. Results

An analysis of the deployment scenarios together with available site geo-location assessment methods has led to the following results.

A. Basic Assumptions and Requirements

For the assessment of the quality of the site-identification methods some basic assumptions on NE and management systems capabilities are made.

- The position assessment directly after the hardware installation has to be an integral step of the deployment.
- For Macro, Pico, Mixed and Colocation deployments the network planning database holds a wide range of information. Especially exact geographical position and at least intended cell types, radio access technology and inventory information (whether there is already active equipment installed or not). Detailed information about the setup and the structure of the network, as neighboring sites, cells and their coverage areas can be retrieved.
- For indoor Femto and Pico deployments there is somewhat less information available. For Pico deployments the site planning and preparation consists just of providing for power and data connections. Femto BS are installed by the customer., typically at a registered location, however there is no guarantee on that [5].
- The mapping service at the topology server is provided with all information sent by the network element and has access to all information in the planning DB.
- Most importantly there is no guarantee on the information accuracy. Especially location information will never be 100% accurate. Therefore the system has to be capable to reliably identify a site even with inaccurate input data.

B. Evaluation of Location based Mapping approaches

In case GPS based localization is available and there is no co-location of sites, the site identification can be easily performed. Evaluation of a network with 750 macro sites showed that even with a GPS inaccuracy of 50 meters only 2% of the sites require additional means to complete the identification.

This changes in urban areas where the inter site distance becomes smaller and satellite based positioning is not as reliable or accurate as needed due to the bad signal reception and the reduced sky view. The measured position can easily deviate from the actual position in the magnitude of dozens of meters.

Modern GPS receivers therefore usually give an estimation on the deviation of the measured position to the actual position. For a reliable mapping it is important to include the deviation twice, because in a worst case assumption this deviation has also been incorporated during the location measurement for the setup of the site.

The result is that through this safety margin instead of a specific location only some area around the actual location is used.

Radio based approaches used for geo-location assessment have some similar issues that need to be considered. The major drawbacks come from the dependency on the coverage of at least a single RAT. Results will obviously be better in urban areas and less good in areas with no or only incomplete coverage.

But even in urban areas it is not always possible to perform reliable site identification based on the assessed position. The location assessment still can strongly deviate from the actual position and the site density is much higher. In order to reduce erroneous mappings due to the positioning inaccuracy the mapping process needs a safety margin around the estimated position.

The same applies even for WIFI based positioning based on rather small cells, such services are often available only within urban areas with a high network density with an increased probability for a dense femto deployment.

The main challenge that comes from co-location and the missing accuracy for the localization methods is that no distinct mapping to a single site can be performed. Instead, the mapping only based on the location information will result in a set of potential sites.

C. Handling of Multiple Potential-Sites

In case the mapping step is not successful but reaches only reduction to a set of potential sites additional steps have to be performed. Figure 4 shows such such an example. The mapping process as been provided with a position (blue dot in the middle) and a safety margin. Within this safety margin

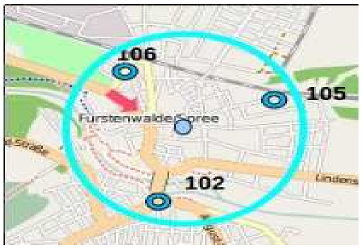

Fig. 4: Set of multiple potential sites

three potential sites are located (marked 105, 106 and 102). The proposed heuristic approach uses multiple methods and information from multiple sources to stepwise reduce the set potential sites to a single site. Additional information like hardware-type or neighboring sites is requested on demand

However, using multiple methods and acquiring more detailed information leads directly to higher operational costs. Therefore a context sensitive set of rules to determine the site is used to apply a minimal set of identification methods to speed up the identification.

D. Implementation

In a first step, the measured position is used and the set of potential sites is computed. In case no distinct mapping can immediately be made further methods are used. A subset of the available identification mechanisms and only the actually required information is dynamically chosen dependent on the deployment scenario. The means are applied one by one which reduces stepwise the set of candidate sites until a distinct selection can be made and the CM DB can be updated.

The implementation makes use of multiple identification means. For the evaluation with the given deployment scenario the following means to reduce the set of potential sites have been identified and used:

- **Remove Active** removes all sites with already active equipment
- **Remove Other Type** removes all sites which are intended for another cell type (femto / pico / macro)
- **Remove Other RAT** removes sites intended for other RATs
- **80:20** picks the closer site in case the distance ratio is better then 80:20. This method is only used if the distance is larger than a configurable lower bound.

The evaluated deployment scenario is the aforementioned set of 750 3G sites of a mobile network operator. The simulations show that choosing the right combination of identification methods allows a fast identification of the sites. Even with a strongly reduced assumed localization accuracy of a multitude of the typical GPS deviation a mapping was successful. Since there are no two fully identical sites the main task is to find the information that can be automatically assessed that allows the to differentiate the sites. The above named means were sufficient for the given deployment scenario.

E. Usage Proposals for Deployment Scenarios

The following recommendations are given with regard to which site-identification methods should be used in the respective deployment scenarios.

1) Macro Deployments: Due to the benefits of GPS based positioning, it should be used whenever available. In case it is not available Radio Network based positioning should fill the gap. This will mostly deliver a very small set of potential sites. To narrow down the remaining set hardware characteristics should be included.

2) Macro, Mixed, Co-located Deployments: For these scenarios, which will gain much more importance, the sets of potential sites after the location assessment will be larger compared to today's deployments. Therefore a set of specialized mapping methods combined with an adaptive logic for the selection of the methods should be used. Logic and mapping methods have to be adapted to concrete deployment scenarios and available data sources.

3) Enterprise Pico Deployments: Position assessment via GPS or Radio Network is not a promising approach. To compensate this, additional means as for example RFID-based site identification are suitable, as there is a low probability of multiple confusing tags in close vicinity. There will always be some preparation required for the place the NE will be installed at. The tag could be attached during this preparation process. The reader could either be built-in or be temporarily attached by the installer.

VI. Conclusions

Automatic site identification and hardware-to-site-mapping is a crucial step in the base station self-configuration process. Without it, still significant on-site and/or remote activities have to be performed by humans. Different site identification methods have been introduced and their applicability for different deployment scenarios (macro, pico, femto) has been analyzed. For macro BS deployments, which are most common today, most of the BS can be automatically identified with an available geo-positioning method. If additionally few site context data is evaluated, all BS can be identified successfully. However, for future network scenarios (dense deployments of small cells, large number of co-located sites, indoor deployments) geo-positioning may lead to ambiguities in the identification or may not be feasible at all. Hence, the acquisition and processing of site context data will become much more important for these scenarios.

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