





IM 2007 Application Session

Network Element Auto-configuration in a Managed Network

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Network Element (NE) Auto-configuration in a Managed Network



Outline

Introduction

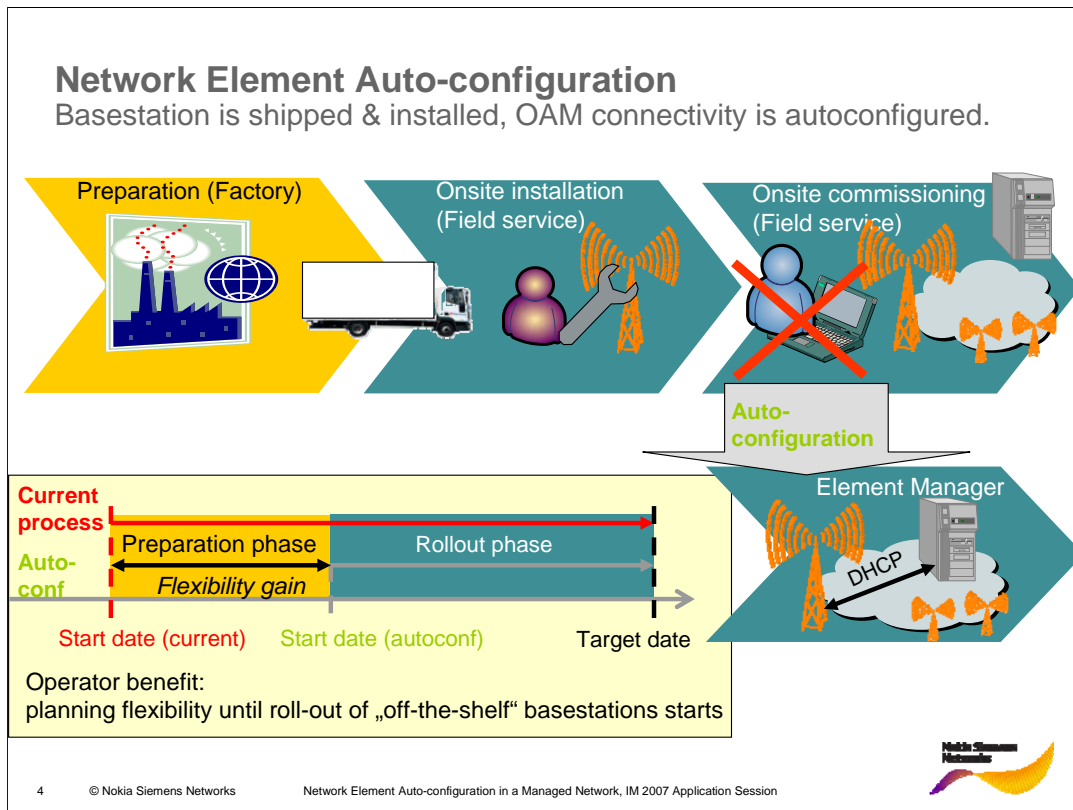
Current NE Rollout Procedure

Auto-configuration Solution:

- Characteristics
- Functional Architecture

Geo-location-based Auto-configuration

Solution Benefits



In (Mobile) Telecommunication Networks, new network elements (NEs) such as wireless base stations or access points

- are deployed in large numbers

- should be “low cost” in terms of deployed software / hardware and service costs

- typically have a rather dynamic roll-out process (i.e., various changes of planning and configuration data during roll-out)

The introduction of these NEs into the network causes considerable overhead in installation preparation, installation and commissioning:

- extensive data exchange between manufacturer and operator

- manual on-site installation and configuration / commissioning activities

In the future, due to higher complexity and heterogeneity of networks and network architectures (2G, 3G, 3G LTE / NGMN, WLAN, WiMAX), and the increasing dynamic of configuration (more frequent changes), the simplicity and rapidity of NE introduction becomes much more important.

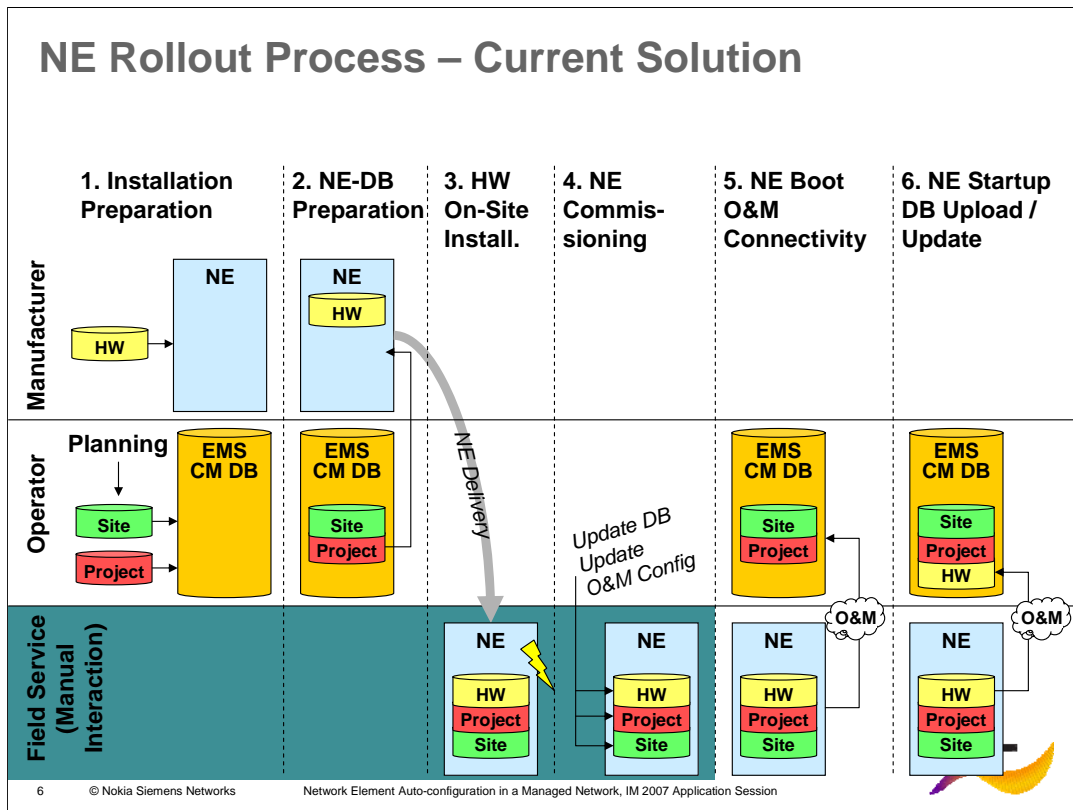
NE Rollout – Framework Conditions

Prior to installation every NE has to be equipped with the appropriate software and “database”^[1] (DB). The DB typically consists of three different parts:

- “HW” (NE hardware specific), provided by the manufacturer
- “site” (location-specific) where the NE should be set up, provided by the operator; a subset thereof is the basic O&M connectivity configuration which is required to render the NE “manageable”, i.e., that the NE can be reached and controlled from an element management system (EMS)
- “project” (operator-specific) to which the NE belongs, provided by the operator

To guarantee a proper functioning and manageability of the NE it has to be ensured that the DB at the NE and the equivalent DB in the element management system (EMS) configuration management database (CM DB) contain the same information with the same version.

[1] Note that the term “database” refers to the set of configuration data of the NE (e.g., stored in a file) rather than an actual relational or object-oriented database.



The slide shows an overview of the NE introduction process. The following steps have to be performed:

1. At the factory, every NE has to be equipped with its HW DB.
2. The operator has to supply that information which goes into the “site”- and “project”-specific parts of the DB to the manufacturer. The NE DB has to be tailored to the network operator requirements before delivery.
3. HW installation on site by field service.
4. Commissioning of the installed HW on site. The O&M communication parameters have to be entered by the field service. If additional DB information (“site”, “project”) has changed since NE delivery (last minute changes are rather rule than exception, especially if NEs are installed at a location different from the planned one), the field service has to verify the up-to-dateness of the pre-installed SW and DB and provide and configure the updates. The mapping of a specific hardware (NE) to the site (and thus to a specific DB) is done manually on site.
5. The NE is physically connected to the O&M network.
6. When the O&M connectivity has been established the (potentially updated) NE DB is uploaded to the EMS and added to the configuration management database (CM DB).

Approach – Auto-configuration of NEs (1)

To simplify and accelerate NE integration it is necessary to achieve

- Less process steps for NE integration
- The reduction of the required manual interaction
- The decoupling of manufacturer, operator, and field service tasks and processes.

➤ **Automation of configuration processes for NE introduction**

➤ **Site- and project-specific commissioning of NEs as last step of NE introduction**

Approach – Auto-configuration of NEs (2)

The solution has to work in a managed network: the network configuration is centrally governed by EMS / network planning

- Co-ordination with existing functionality for configuration management
- Mapping of physical new NE with planned NE in EMS CM DB

➤ **Automated transfer and installation of pre-configured data and software rather than dynamic configuration of the NE**

Available technologies:

- DHCP / PXE [1] → usable for basic communication and boot parameters
- Jini, UPnP → mainly intended for local configuration of end user systems / user services
- No tailored solutions available for software and data installation
- UUID as identifier, since no unique MAC address may be available

Auto-configuration of NEs: Key Characteristics (1)

NE HW delivered with a generic initial SW and database

- Minimal OS, including
 - Script executor
 - Network protocol clients and/or servers for remote downloading and monitoring
- Node Auto-configuration SW
 - DHCP client (enhanced)
 - Generic auto-configuration scripts and/or programs

NE auto-configuration in 3 stages:

- Stage 1: provisioning of IP-connectivity and auto-configuration parameters
 - IP-parameters, ATM-PVC parameters in case of IP-over-ATM, server URLs
 - Carried out on each NE boot
- Stage 2: download & installation of target SW
 - SW archived in a SW repository
- Stage 3: download & installation of NE proper configuration data
 - EMS WEB application returns URL of (in real-time generated) NE configuration data



Auto-configuration of NEs: Key Characteristics (2)

A "lifelong" NE Identifier: **Universally Unique Identifier (UUID)**

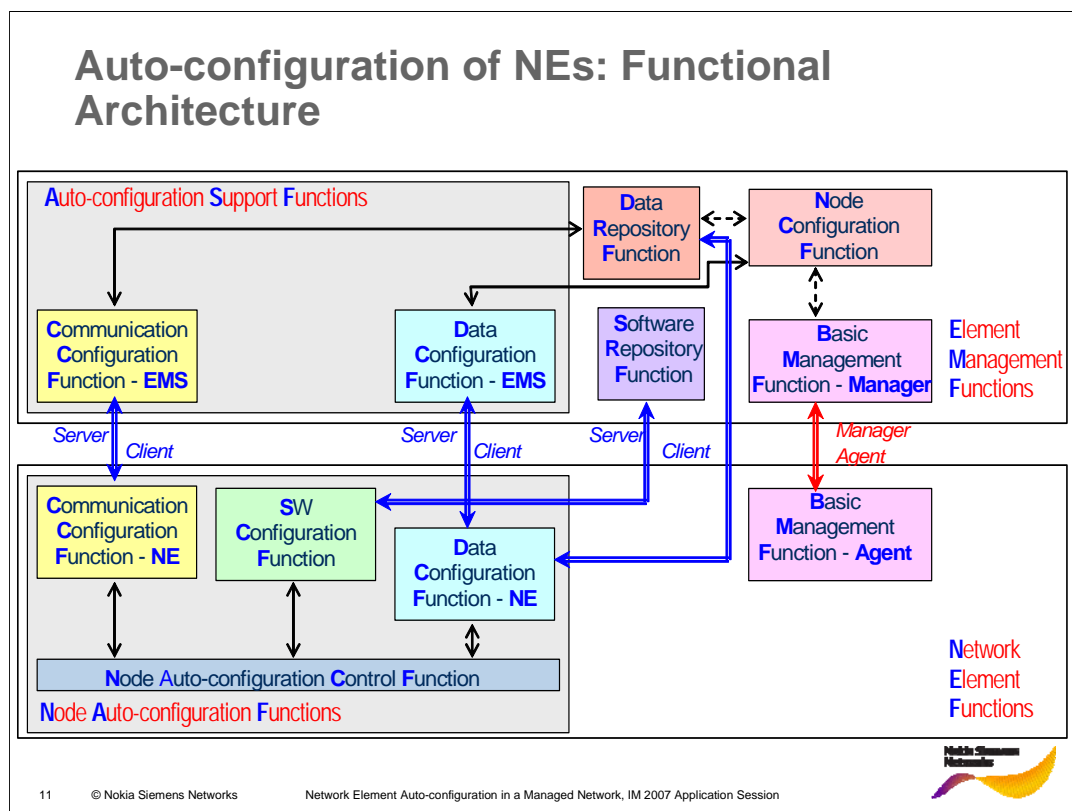
- persistently stored in the NE (CM-ROM)
- included in DHCP messages (client identifier)

"Last Known Good" parameters persistently stored at the NE

- Decision criterion for triggering auto-configuration:
 - No successful previous auto-configuration, or
 - IP- or ATM-connectivity parameters have changed

O&M-Network-based Auto-configuration Support System (ASS)

- Supports an automated configuration of the NE
- Functionally separated from, but interacts with the EMS
- Needs to be configured from EMS
 - Consistency between ASS & EMS supplied information to be guaranteed



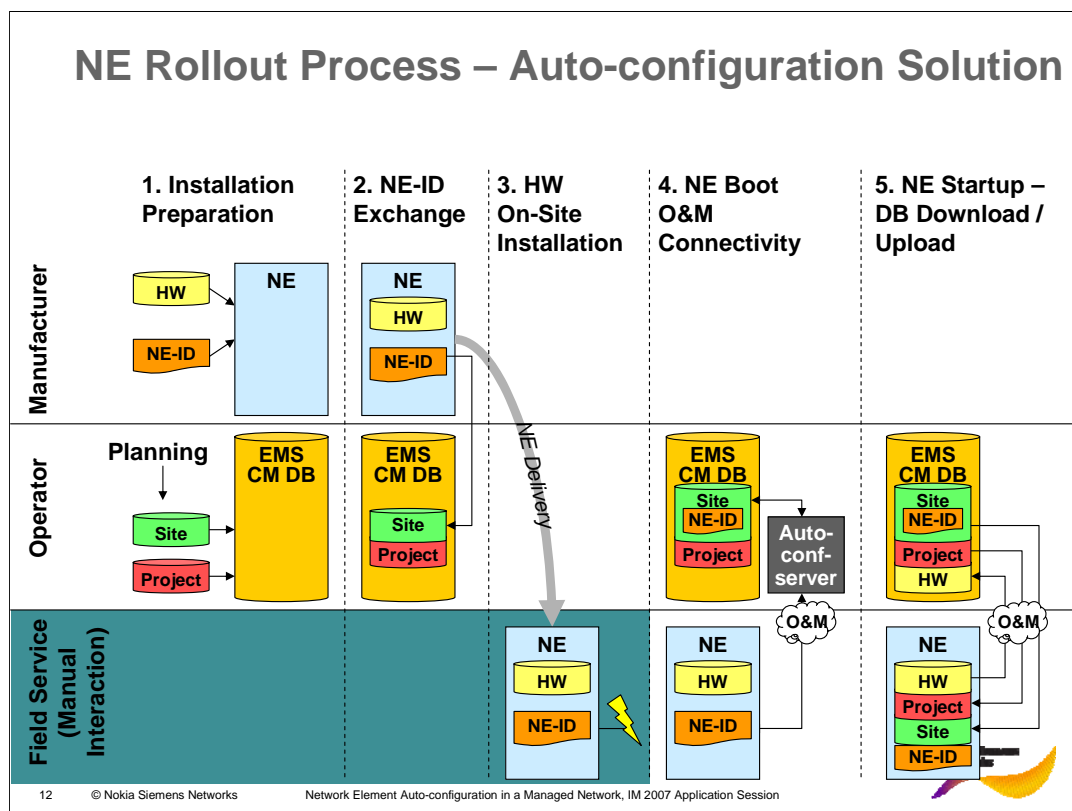
The functional architecture describes the functional blocks and the relationship and dependencies between these functional blocks. The slide shows the functions of the network element (Network Element Functions – NEF) and the element management system (Element Management Functions – EMF). Both contain generic functions and auto-configuration specific functions: Auto-configuration Support Functions (ASF) at EMS side, and Node Auto-configuration Functions (NAF) at NE side.

Network Element Functions:

- Basic Management Function – Agent (BMF-Agent): allows the NE to be managed online locally and remotely by means of basic management instructions (classical OAM agent).
- Node Auto-configuration Control Function (NACF): controls and co-ordinates the execution of the auto-configuration activities pertaining to an NE.
- Software Configuration Function (SCF): provides on initial NE startup the capability to install and activate the proper (Core) software version on the NE.
- Communication Configuration Function – NE (CCF-NE): ensures that an NE is supplied with the proper communication parameters (e.g. IP plus ATM, if necessary), and the configuration of the auto-configuration support functions themselves.
- Data Configuration Function – NE (DCF-NE): provides on initial NE startup the capability to invoke the generation of the proper database for the NE, download it to the NE and activate it.

Element Management Functions:

- Basic Management Function – Manager (BMF-Manager): classical OAM manager
- Node Configuration Function (NCF): allows to manage validated network configurations including vendor-specific parameters, and derive necessary bulk NE database updates or scripts for the BMF-Manager (cf. above). This function is already available with classical OAM functions (for configuration management) but needs to be enhanced towards auto-configuration functionality
- Data Repository Function (DRF): stores data configurations pertaining to NEs
- Software Repository Function (SRF): stores software versions pertaining to NEs
- Communication Configuration Function – EMS (CCF-EMS): EMS part of CCF (cf. description above)
- Data Configuration Function – EMS (DCF-EMS): EMS part of DCF (cf. description above)



The proposed solution as far as possible decouples manufacturing, operator and field service processes with regard to NE software and configuration data. The slide shows an overview of the proposed solution for the NE introduction process. The following steps have to be performed:

1. At the factory, each NE is equipped and tested with a default SW and configuration database. The operator has to prepare information which goes into the “site”- and “project”-specific parts of the EMS CM DB. In case “site”- or “project”-specific information changes prior to NE Boot, the EMS CM DB just has to be updated. Part of the “site”-specific information are the O&M connectivity parameters (e.g. O&M IP address, ATM settings etc.).
2. The manufacturer delivers the unique NE hardware identifier to the operator. If an NE with hardware different from the planned hardware is finally installed, the NE hardware identifier of the new NE has to be adjusted in the corresponding O&M connectivity parameters of the EMS CM DB.
3. When the NE is installed at its target location, the field service only installs the HW according to the installation procedure and checks the physical connectivity of the NE components and interfaces.
4. After physical connection to the O&M network the provisioning of the correct NE SW and database (as well as the basic O&M connectivity configuration to enable that provisioning) is achieved by means of auto-configuration mechanisms.
5. When the O&M connectivity has been established the NE DB (incl. HW DB) is uploaded to the EMS and added to the EMS CM DB.

Shortcomings of the HW-ID-based Auto-configuration Solution

The NE identifier in the EMS CM DB may have to be updated, e.g. because

- A specific NE HW is delivered to another site as originally planned
- Another NE HW should be delivered to a specific site as originally planned

The change of the HW-to-site-mapping needs to be communicated, therefore using a hardware identifier for NE identification suffers from:

- Administrative overhead for the network installation staff, because it is not possible to install any node of a particular type at a particular location
- Administrative overhead for the network operator, since he has to plan at a level of detail that he does not really care about (particular NE hardware at particular location, but only function is interesting)

→ Enter a Site-Identifier into the NE when it is deployed to map the specific NE HW to the network plan in an automated way

→ The geo-location information could be employed as a Site-Identifier generated on-site

Approach – Geo-location-based Auto-configuration

The NE HW identifier (e.g. MAC-address, UUID) has to be replaced by geographic coordinates in the EMS CM DB.

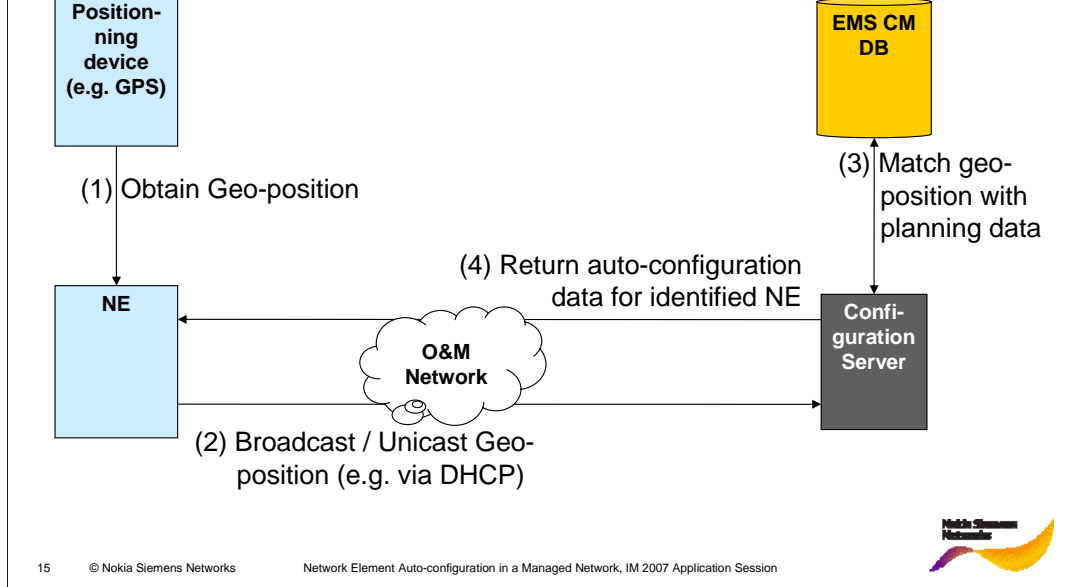
At NE side, geo-location information can be derived by at least two different procedures during installation:

- A navigation device (e.g. GPS / GLONASS / GALILEO device) provides the geographic coordinates
- A mobile terminal of an already deployed mobile network is used to determine the position, e.g. through triangulation (available services e.g. for emergency terminal detection)

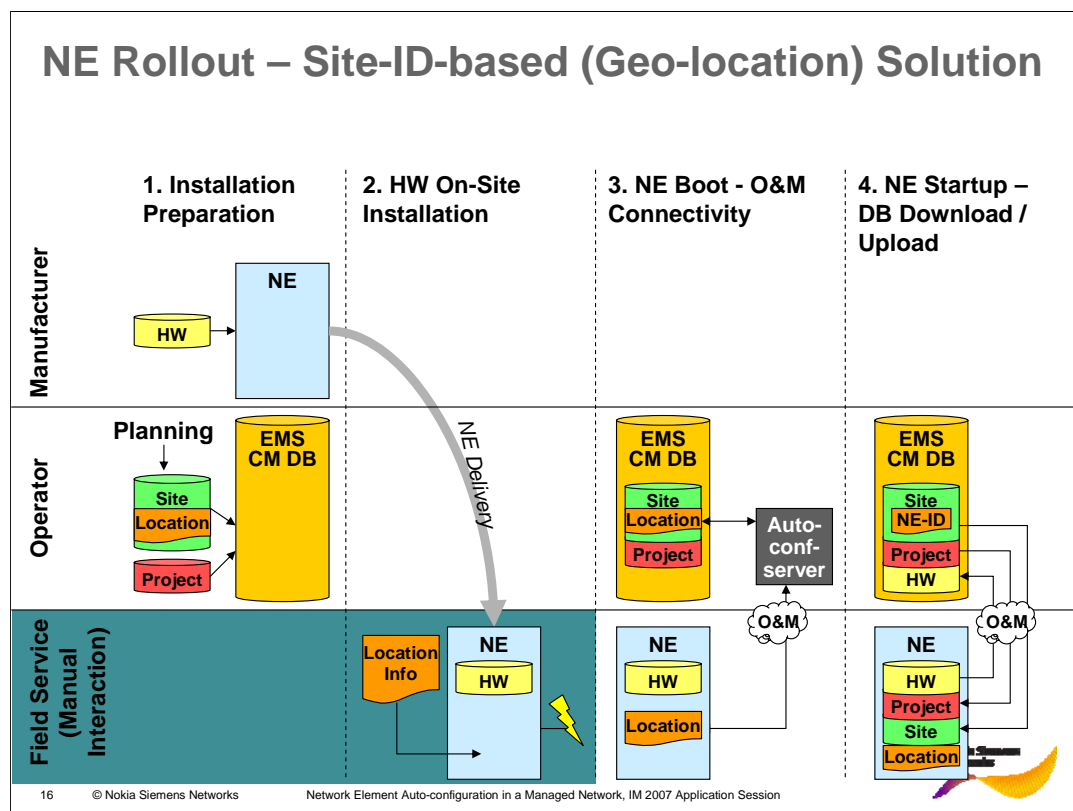
(The location information can be entered to the NE CM DB either manually by field service staff or automatically by connecting the corresponding device to the NE.)

At the EMS, the geo-location information generated on-site is matched against the planned location (site-ID).

Geo-location-based Auto-configuration solution Direct Determination of Location Coordinates



1. The network node determines its geographical coordinates, by means of the positioning device (in the exceptional case an automated positioning is not possible, the position data can also be entered manually by the installer). Note that it is sufficient to determine this position once, if the location of the node is not changed thereafter.
2. The network node contacts a configuration server, which contains the planned configuration or relevant parts thereof, either by sending a broadcast message or a directed one, if the address is already known. This message contains the geographical coordinates.
3. The configuration server matches the geographical coordinates to the planned nodes' geographical locations. If a sufficiently good match can be made, the server determines the sending node to be the planned node. It may update its data with details gained from the message, e.g. to store the hardware identification of the new node.
4. The configuration server returns a response to the network node, containing all or parts of the configuration data stored in the network plan for the matching planned node. The network node updates its configuration with the data received in the response.



This slide shows the NE integration with the geo-location solution. In comparison with the NE-identifier-based solution (see slide 12) the step to exchange the NE identifier (step 2 in slide 12) can be left out. Thus, the following steps have to be performed:

1. At the factory, each NE is equipped and tested with a default SW and configuration database. The operator has to prepare information which goes into the “site”- and “project”-specific parts of the EMS CM DB. The operator furthermore adds a Location identifier to the “site” information and the corresponding O&M connectivity parameters. In case “site”- or “project”-specific information changes prior to NE Boot, the EMS CM DB just has to be updated. Part of the “site”-specific information are the O&M connectivity parameters (e.g. O&M IP address, ATM settings etc.).
2. When the NE is installed at its target location, the field service only installs the HW according to the installation procedure and checks the physical connectivity of the NE components and interfaces. The field service furthermore provides the site’s location information to the NE CM DB by one of the previously described methods.
3. After physical connection to the O&M network the provisioning of the correct NE SW and database (as well as the basic O&M connectivity configuration to enable that provisioning) is achieved by means of auto-configuration mechanisms.
4. When the O&M connectivity has been established the NE DB (incl. HW DB) is uploaded to the EMS and added to the EMS CM DB.

Benefits / Requirements of the Auto-configuration Solution for the Operator and Manufacturer

Shift of complexity from the field service and factory to the O&M system → better decoupling of manufacturer and operator processes (fewer interfaces)

- Manufacturer: simpler initial NE installation / configuration („off-the-shelf“-product) and deployment (field service)
- Operator: more control over the deployment process, less dependency on the manufacturer
- Operator: slightly increased complexity of the O&M system, but in the long run, less personnel needed to deploy / operate a network (automation)

OPEX

OPEX

An additional sub-system for auto-configuration is required

- Manufacturer:
 - additional development necessary (for auto-configuration control / reliability, concurrent operation of auto-config. / EMS)
 - but: extensive re-use of existing SW possible, e.g., DHCP; new business opportunities e.g. for providing support tools
- Operator: additional expenses required (but outweighed by OPEX savings)

CAPEX

CAPEX

An important aspect of the auto-configuration solution is its relative independence of the existing / emerging management environment and its coexistence with conventional management mechanisms. The solution shifts the complexity of deployment away from the field service and manufacturing to the O&M system, resulting in an exchange of OPEX for CAPEX. The OPEX savings however are expected to clearly outweigh the CAPEX expenditures when large amounts of NE are handled.

The following benefits can be summarized:

NE manufacturer:

- Without autoconfiguration, each NE is equipped with a SW and configuration that is specific for this entity, with respect to operator, SW version, element manager type and version. OPEX savings occur at the HW/SW manufacturing as a generic, common SW and configuration is installed and tested (no deployment-specific SW/configuration). Provisioning procedures are simplified at the HW/SW manufacturing – hence less error prone - as no project specific information is to be supplied. Ultimately, the NE may become an “off-the-shelf” product.
- Field service activities are simplified and reduced, as the provisioning of the correct NE SW and configuration has become an operator task that is enabled by the (pre-) installed NE SW (hence field service OPEX savings occur)

NE manufacturer and the operator:

- The procedures regarding SW and configuration data provisioning pertaining to the manufacturer / field service on the one hand, and the operator on the other hand are decoupled. The responsibilities are clearly delimited and interactions between them are reduced to a minimum: a default SW and database is provided by the Siemens HW/SW manufacturing, the field service engineer installs the HW according to the installation procedure and checks the physical connectivity of the NE to the O&M network, the operator configures the O&M network and the ASS in order to install the proper basic SW and configuration onto the NE. Clearly, this contributes to a better NE provisioning.

Operator

- OPEX savings occur as NE SW and configuration deployment becomes an operator internal matter (i.e. a preliminary NE configuration does not need to be supplied to or synchronized with the manufacturer)

The described benefits can already be realized with a “conventional” DHCP solution where the HW identifier is used as a key identifier. However, more appropriate in a “managed network” is the usage of geo-coordinates, because no exact planning which hardware is to be installed at which location is needed, but only the type of hardware that is required must be known. Furthermore, it is not required to manually enter this information during installation. The geo-coordinates of network nodes are already included in the planning data, and can be used for this method.

Especially advantageous is the usage of a portable positioning device, such as a GPS receiver, which needs to be connected only during the installation so that the network node may determine its position once and use it thereafter as long as the position does not change. The positioning device, which may be too expensive to build into the network node, can be reused in subsequent installations.

Alternatively, equipment that is anyway part of a network node, such as its own air interface, or a wireless module attached to serve as a backup communication link, may serve as positioning device. Of course, a mobile phone carried by the installer could be used in conjunction with a mobile network positioning method to determine the position of the node.

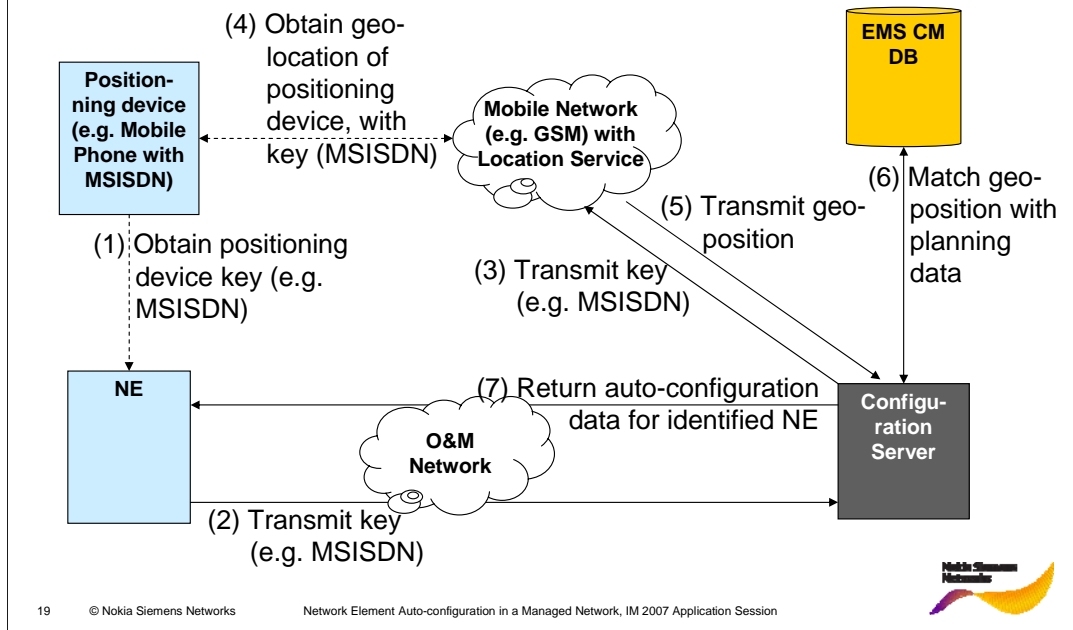
The described method is cost-efficient, effective and user-friendly. It allows a complete automatic configuration of network nodes while allowing the substitution of arbitrary equivalent hardware equipments.

The logo for Nokia Siemens Networks, featuring the text "Nokia Siemens Networks" in a bold, black, sans-serif font. Below the text is a stylized graphic element consisting of a series of vertical lines that form a wavy, ribbon-like shape, transitioning in color from purple on the left to yellow on the right.

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BACKUP

Geo-location-based Auto-configuration solution Indirect Determination of Location Coordinates



The determination of the coordinates may also be indirect (previous slide). In this case information is transmitted that allows determining the geographic location, rather than the coordinates themselves. In this case, additional steps may be required.

The network node contacts a configuration server, which contains the planned configuration or relevant parts thereof, either by sending a broadcast message or a directed one, if the address is already known. This message contains a key suitable for feeding into a geo-positioning method, e.g. one of the positioning methods offered by mobile networks themselves, such as triangulation. In the case of using a mobile network's positioning capability, the key may be a mobile station international subscriber identification number (MSISDN).

The configuration server feeds the key into the suitable geo-positioning method and retrieves the corresponding geo-coordinates.

Acknowledgements

Thanks

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References

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- S. Alexander, R. Droms, DHCP options and BOOTP vendor extensions, RFC 2132, IETF, March 1997
- Intel Corporation, Preboot Execution Environment (PXE) specification