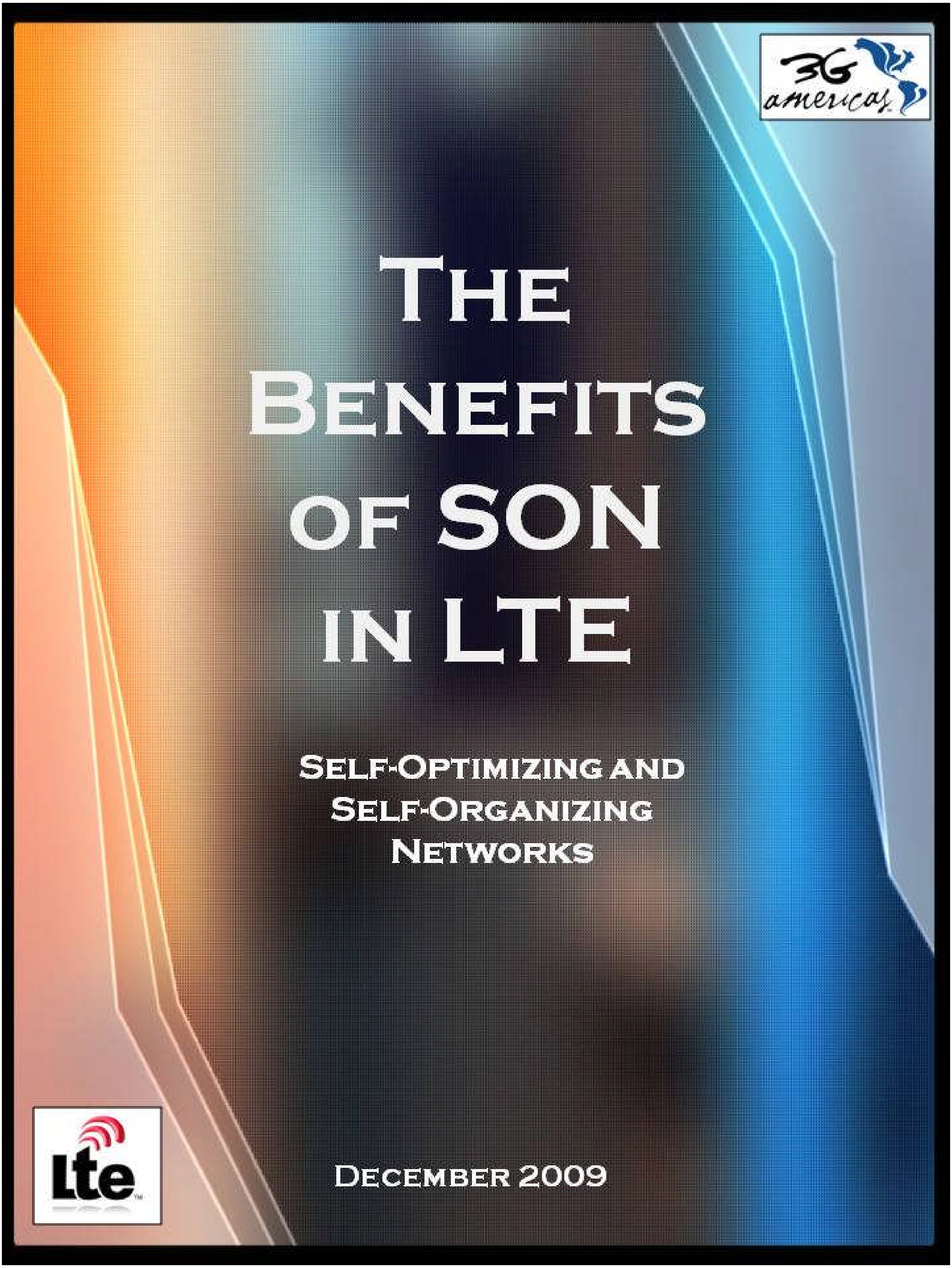

THE BENEFITS OF SON IN LTE

SELF-OPTIMIZING AND SELF-ORGANIZING NETWORKS

DECEMBER 2009

CONTENTS

1 INTRODUCTION

1.1 GOALS OF THIS WHITE PAPER

In today's 2G/3G wireless networks, many network elements and associated parameters are manually configured. Planning, commissioning, configuration, integration and management of these parameters are essential for efficient and reliable network operation; however, the associated operations costs are significant. Specialized expertise must be maintained to tune these network parameters, and the existing manual process is time-consuming and potentially error-prone. In addition, this manual tuning process inherently results in comparatively long delays in updating values in response to the often rapidly-changing network topologies and operating conditions, resulting in sub-optimal network performance.

3GPP is standardizing self-optimizing and self-organizing capabilities for LTE – in Release 8, Release 9, and beyond – that will leverage network intelligence, automation and network management features in order to automate the configuration and optimization of wireless networks, thereby lowering costs and improving network performance and flexibility. This paper will discuss, highlight and recommend the Release 8 and Release 9 Self-Organizing Network (SON) techniques and explain how these capabilities will positively impact network operations in the evolved LTE network.

1.2 TECHNOLOGY AND MARKET DRIVERS FOR SON

Reflecting upon recent wireless industry events, 3G Americas member companies observe several important trends that are driving additional network complexity and operations effort.

New and emerging classes of mobile devices (smartphones, pc datacards, USB modems, consumer devices with embedded wireless, machine-to-machine, etc) are fostering explosive growth of wireless data usage by public and enterprise users. As a result, wireless service providers have to simultaneously support a growing number of higher-bandwidth data applications and services on their networks. The list of user applications and services is quite broad in scope, and includes Internet browsing, Web 2.0, audio, video, video on demand, gaming, location-based services, social networking, peer-to-peer, advertising, etc.

On the network side, wireless service provider networks are becoming more complex and heterogeneous. Projections point to rapidly growing numbers of femto and picocells (in order to drive greater coverage and/or offload capacity from macrocells), plus increasing prevalence of multi-technology networks (2G, 3G, “4G,” plus WiFi). These trends pose potentially significant operational and network complexity regarding macro/femto and inter-technology handover, as well as management of macro/femto and macro/pico interference.

Taken together, these trends place ever-increasing demands upon service providers’ networks and their operational staff. Ensuring quality user experience requires more complex Quality of Service (QoS) and policy implementations while they simultaneously must increase network throughput in response to the rapid growth in wireless data.

Moreover, wireless data revenue measured on a per-megabit (Mb) basis is decreasing. Fortunately, spectral efficiency gains are provided by new wireless technologies, and do provide some measure of relief; however, the data throughput per user is growing (and revenue per Mb is dropping) so rapidly that spectral efficiency gains alone appear unable to keep up. Consequently, service providers – and infrastructure vendors – are increasing their focus on operational cost reductions. Reflecting upon these dramatic trends, it has become clear that traditional network management needs significant improvement for managing this growing data volume and network complexity in a cost-effective manner.

1.3 REASONS FOR AUTOMATION

Generally speaking, the reasons of SON automation can be grouped into two broad categories:

1. Previously manual processes that are automated primarily to reduce the manual intervention in network operations in order to obtain operational and/or deployment savings.

2. Processes that require automation because they are too fast, too granular, and/or too complex for manual intervention. Their automation can provide performance, quality, and/or operational benefits.

These categories need not be distinct, (e.g., a previously manual process that is growing too complex due to the above trends) may by necessity require automation in order to manage it.

It should be obvious that automation is not a new concept for wireless networks – clearly networks already critically depend on extensive use of automated processes. For instance, numerous examples abound just in the area of radio resource management (scheduling, power and/or rate control, etc.). Thus, the appearance of SON algorithms represents a continuation of the natural evolution of wireless networks, where automated processes are simply extending their scope deeper into the network.

2 3GPP EVOLUTION AND SON

2.1 LTE SON HIGH-LEVEL SCOPE AND TIMELINE

SON concepts are included in the LTE (E-UTRAN) standards starting from the first release of the technology (Release 8), and expanding in scope with subsequent releases. A key goal of 3GPP standardization is the support of SON features in multi-vendor network environments. 3GPP has defined a set of LTE SON use cases and associated SON functions.[1] The standardized SON features effectively track the expected LTE network evolution stages as a function of time. With the first commercial networks to be launched in 2010, the initial focus of Release 8 has been functionality associated with initial equipment installation and integration. The scope of the first release of SON (Release 8) includes the following 3GPP functions, covering different aspects of the eNodeB self configuration use case:

- Automatic inventory

- Automatic software download[2]
- Automatic Neighbor Relation[3]
- Automatic Physical Cell ID (PCI) assignment[4]

The next release of SON, as standardized in Release 9, will provide SON functionality addressing more maturing networks. It includes these additional use cases:

- Coverage & Capacity Optimization
- Mobility optimization
- RACH optimization
- Load Balancing optimization

Other SON related aspects that are being discussed in the framework of Release 9 include improvement on the telecom management system to increase energy savings, a new OAM interface to control home eNodeBs, UE reporting functionality to minimize the amount of drive tests, studies on self-testing and self-healing functions, and minimization of drive testing. It should be clear that SON-related functionality will continue to expand through the subsequent releases of the LTE standard.

The SON specifications have been built over the existing 3GPP network management architecture, reusing much functionality that existed prior to Release 8. These management interfaces are being defined in a generic manner to leave room for innovation on different vendor implementations.

Figure 1 provides the standardization timelines for the different 3GPP LTE releases.

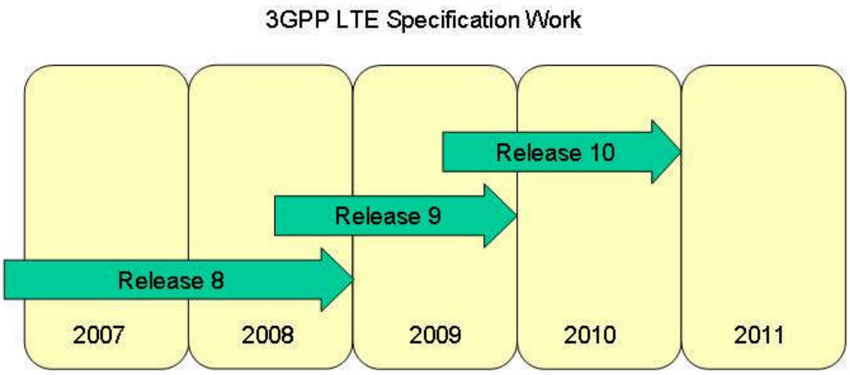

Figure 1. 3GPP LTE Specifications Timelines. Core Release 10 Specs will be Frozen in Dec 2010, ASN.1 Specs will be Complete in Early 2011.

2.2 SON DEVELOPMENT IN NGMN

An important source of LTE SON development is the industry forum NGMN (Next Generation Mobile Networks). NGMN established a set of initial requirements on Self-Organizing Networks in 2006,[5] and since then several use cases have been defined to cover multiple aspects of the network operations, including planning, deployment, optimization and maintenance.[6] The generation of SON-specific requirements by the NGMN contributed to the adoption of the SON concept by the 3GPP.[7]

These use cases have been identified by the operators as the typical tasks that will be performed by their engineers in their day-to-day operations, therefore, a better system integration and automation would result in a more efficient utilization of the operator resources, both material (spectrum, equipment, etc.) and human (engineering time). It is expected that many of these use cases will be introduced into 3GPP for subsequent standardization.

Table 1 summarizes these SON use cases/requirements:

Table 1. NGMN Use Case Definitions.

Planning
Planning of eNodeB
Planning of eNodeB Radio parameters
Planning of eNodeB Transport parameters
Planning of eNodeB data alignment

Optimization
Support of centralized optimization entity
Neighbor list optimization
Interference control
Handover parameter optimization
QoS parameter optimization
Load Balancing
Home eNodeB optimization
RACH load optimization

Deployment
Hardware installation
eNodeB/network authentication
O&M Secure tunnel setup
Automatic inventory
Automatic Software download to eNB
Transmission setup
Radio parameter setup
Self Test

Maintenance
Hardware/capacity extension
Automated NEM upgrade
Cell/Service outage detection and compensation
Real-Time Performance management
Information correlation for fault management
Subscriber and equipment trace
Outage compensation for higher level network elements
Fast recovery of unstable NEM system
Mitigation of outage of units

3 KEY LTE RELEASE 8 AND RELEASE 9 SON FEATURES

3.1 BASE STATION SELF-CONFIGURATION

The deployment of a new network technology is a major investment for any service provider. In addition to the spectrum and equipment costs, the operator faces multiple challenges related to the network planning, commissioning and integration that often result in higher costs than the infrastructure equipment itself. Today, there are a number of computer-aid design tools that an operator uses to simplify these tasks, such as propagation tools, automatic cell planning (ACP) or automatic frequency planning (AFP) tools. However, much of the process related to network element integration and configuration is still performed manually. When a new base station (i.e. eNodeB or eNB) is installed, it requires that most aspects of its configuration are provided by the engineer(s) on site, including the setup of the transport links, adding the node to the corresponding concentration node (BTS or RNC), and establishing the connectivity with the core network. This is in addition to the configuration of all the radio-related parameters such as the cable and feeder loss adjustments, antenna type and orientation, transmit power, neighbor relations, etc. All these processes are cumbersome, time-consuming, error-prone, and, in general, will require the presence of more than one expert engineer, all the above resulting in an inefficient and costly process.

The objective of the Self-Configuration SON functionality is to reduce the amount of human intervention in the overall installation process by providing “plug and play” functionality in the eNodeBs. As will be seen in later sections, the scope of self-configuration functionality is expected to expand and evolve with upcoming versions of the LTE standard.

3.1.1 BENEFITS

Self-Configuration of eNodeBs will reduce the amount of manual processes involved in the planning, integration and configuration of new eNodeBs. This will result in a faster network deployment and reduced costs for the operator in addition to a more integral inventory management system that is less prone to human error.

3.1.2 DESCRIPTION

Self-Configuration is a broad concept which involves several distinct functions that are covered through specific SON features, such as Automatic Software Management, Self Test and Automatic Neighbor Relation configuration.

The Self-Configuration algorithm should take care of all soft-configuration aspects of the eNodeB once it is commissioned and powered up for the first time. It should detect the transport link and establish a connection with the core network elements, download and upgrade the corresponding software version, setup the initial configuration parameters including neighbor relations, perform a self-test and finally set itself to operational mode.

In order to achieve these goals the eNodeB should be able to communicate with several different entities, as depicted in the figure below:

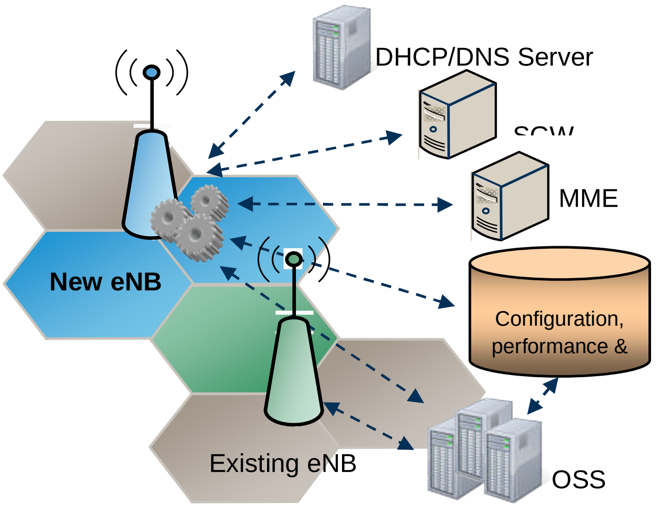

Figure 2. Self-Configuration of eNodeB in LTE.

To be able to successfully achieve all functions the following prerequisites should at least be met prior to the installation of the new node:

1. A network planning exercise for the cell should have been completed resulting in a set of RF parameters, including location, cell identities, antenna configuration (height, azimuth & type), transmit power, maximum configured capacity and initial neighbor configuration. This information should be made available in the configuration server.

2. The transport parameters for the eNB should be planned in advance, including bandwidth, VLAN partition, IP addresses, etc. The IP address range and Serving Gateway address corresponding to the node should be made available in the configuration server.

3. An updated software package download should be made available from the OSS.

The specific set of actions involved in the process will be covered in the next section.

3.1.3 SELF-CONFIGURATION ACTIONS

The Self-Configuration actions will take place after the eNB is physically installed, plugged to the power line and to the transport link. When it is powered on, the eNB will boot and perform a Self Test, followed by a set of self discovery functions, which include the detection of the transport type, Tower-Mounted Amplifier (TMA), antenna, antenna cable length and auto-adjustment of the receiver-path.

After the self-detection function, the eNB will configure the physical transport link autonomously and establish a connection with the DHCP/DNS servers, which will then provide the IP addresses for the new node and those of the relevant network nodes, including Serving Gateway, MME and configuration server. After this, the eNB will be able to establish secure tunnels for O&M, S1 and X2 links and will be ready to communicate with the configuration server in order to acquire new configuration parameters.

One of the O&M tunnels created will communicate the eNB with a dedicated management entity, which contains the software package that is required to be installed. The eNB will then download and install the corresponding version of the eNB software, together with the eNB configuration file. Such configuration file contains the pre-configured radio parameters that were previously planned.

Note that at the time of the installation most of the radio parameters will have the default vendor values. A finer parameter optimization will take place after the eNB is in operational state (self-optimization functions). The configuration of neighbor relations can optionally be performed through an automated SON functionality that is covered in a separate section of this paper, otherwise the initial setup will be done according to the output of the network planning exercise.

After the node is properly configured, it will perform a self-test that will include hardware and software functions, and will deliver a status report to the network management node. Also, the unit will be automatically updated in the inventory database that will incorporate the unique hardware identifier, as well as the current configuration and status of the node.

3.1.4 SELF-CONFIGURATION STATUS IN 3GPP

Current LTE standards incorporate functionality related to the self-configuration of eNB, including Automatic Software Management[8], Self Test[9], Automatic Neighbor Relation[10] and Automatic Inventory Management[11]. It is expected that the first versions of the eNB self-configuration functionality in the eNB will have vendor-dependent aspects, as 3GPP has not fully specified a standardized self-configuration functionality. Examples of open areas in the standards include:

- A defined interface between operator planning tools, equipment inventory and network management entities
- Configuration of transport parameters
- Specific message formats for implementing the overall process

3.2 AUTOMATIC NEIGHBOR RELATION (ANR)

One of the more labor-intense areas in existing radio technologies is the handling of neighbor relations for handover. It is a continuous activity that may be more intense during network expansion but is still a time-consuming task in mature networks. The task is multiplied with several layers of cells when having several networks to manage. With LTE, one more layer of cells is added; thus optimization of neighbor relations may be more complex. Even with the best methods at hand, due to the sheer size of large radio networks – with several hundred thousands of neighbor relations for a single operator – it is a huge undertaking to maintain the neighbor relations manually. Neighbor cell relations are therefore an obvious area for automation, and Automatic Neighbor Relation (ANR) is one of the most important features for SON. To explore its full potential, ANR must be supported between network equipment from different vendors. ANR is, therefore, one of the first SON functions to be standardized in 3GPP.[12]

3.2.1 BENEFITS

ANR will remove – or at least minimize – the manual handling of neighbor relations when establishing new eNBs and when optimizing neighbor lists. This will increase the number of successful handovers and lead to less dropped connections due to missing neighbor relations.

3.2.2 DESCRIPTION

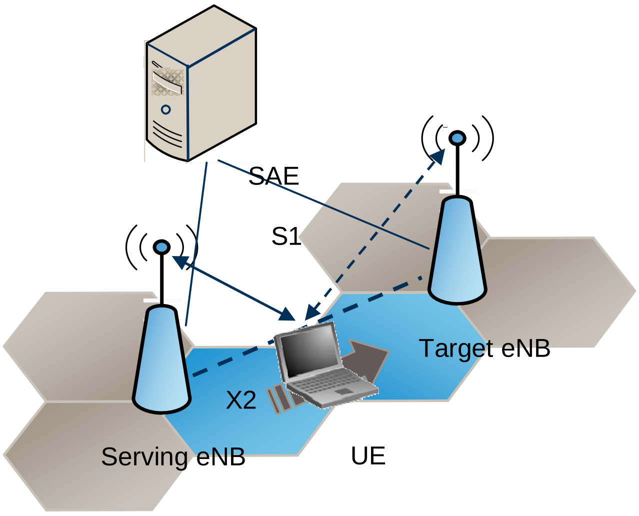

Figure 3. Automatic Neighbor Relation (ANR) in LTE.

The ANR in LTE allows automatic discovery and setup of neighbor relations when a user (UE) moves from a serving eNB to another (target) eNB. ANR also automatically sets up of the LTE unique X2 interface between eNBs, primarily used for handover.

There are two LTE distinctive functions that make ANR possible:

1. The UEs in LTE do not require a neighboring list and the reporting of unknown cells is fast enough to be used during handover preparation. It enables ANR to receive handover measurements on unknown cells that are not yet known by the serving eNB.

2. The possibility for the eNB to request the UE to make a full identification of a cell. It allows eNB to determine an unambiguous identity of a neighboring cell.

3.2.3 NEIGHBOR RELATION DISCOVERY

The UE is ordered to report measurements to the serving eNB directly after the RRC connection is set up (i.e. is attached to the cell) and continues to do so while staying in RRC connected mode. The UE reports all detected PCIs (Physical Cell Identities) – the short identity of the LTE cell – that fulfill the measurement criteria set by the eNB at RRC connection. The UE may also measure on legacy radio technologies if it supports multi-mode operation.

If there is an unknown cell included in the measurement report then ANR may begin actions to make the cell known and potentially enable handover to the cell.

3.2.4 ANR ACTIONS

If a PCI is reported by a UE that does not correspond to any of the serving eNBs' defined neighbor cells (i.e. it is not a neighbor cell), the ANR function in the serving eNB may request the UE to retrieve the Global Cell Identity (GCI) of the cell with the unknown PCI in order to identify the cell. This cell is from now called target cell (see figure 3 above). The UE reads the GCI, which is broadcast by the target cell and reports it to the serving eNB. When the serving eNB receives the GCI, it can – with help from MME, one part of SAE – retrieve the target eNB's IP address, which makes it possible for the serving eNB to contact the target eNB.

The serving and target eNBs are now in contact with each other and X2 can be setup.

The serving eNB requests X2 setup to the target eNB and includes all necessary cell data to create a neighbor relation (i.e. PCI, GCI, TAC, PLMN-id and frequency) from the target cell to the serving cell. The target cell adds the serving cell to its neighbor list and the target eNB sends the corresponding data for the target cell (PCI, GCI, TAC, PLMN-id and frequency) to the serving cell which in turn adds the target cell to its neighbor list.

With the X2 interface in place, it is possible to use X2 for all future handovers between the cells. For handover from LTE to legacy systems (i.e. GSM and WCDMA), ANR works in the same way with the exception that it only needs to setup a neighbor relation to the target cell and not the X2 since the handover to non-LTE systems is always performed over SAE.

ANR can automatically remove unused neighbor relations based on the relation usage, handover performance or a combination thereof.

When adding and removing neighbors, ANR is under control of policies set by the operator. The black listing allows the operator to decide neighbor relations that ANR may never add as neighbors. The white listing allows the operator to decide permanent neighbor relations that ANR may never remove. These policies are controlled from an Element Management System (EMS) such as OSS.

3.3 TRACKING AREA PLANNING

Wireless networks partition a typical market into non-overlapping Traffic Areas (TAs). Each TA is uniquely identified by the TA Identifier (TAI). Each and every user equipment (UE) in the Power-ON state is mapped to one (or more) TAs. TAs were constructed to facilitate the Paging procedure. Please note that whenever the switch (MME) receives a call for mobile M, it looks up the TA of mobile M – as TA(M)) – sends a page to all the eNodeBs in TA(M). Each eNodeB faithfully broadcasts the message on the Paging channel, which is received by UEs in Power-ON mode. When mobile M receives the page, it realizes that there is a terminating call (data transfer) for it, and it sends a paging response to its serving eNodeB – eNB(M). The eNB(M) responds with an affirmative to the switch, which goes on to direct the call towards eNB(M). Subsequently, call setup procedure is followed between mobile M, eNB(M), and MME/S-GW.

In order to ensure that the MME has the most recent information for each mobile in terms of its current TAI, all UEs are required to provide TAU as soon as they realize that their current serving eNodeB has a different TAI. Such an update is sent on the Random Access Channel (RACH). (Border eNodeB's are basically the eNodeBs which are on the border of a TA). Such a structure leads to a tradeoff between the RACH and paging channel. Observe that if each TA is kept small, then a moving mobile would cross through many TAs, and would need to make a random access attempt in one of the Border eNodeB of each TA. However, if the number of eNodeBs in a TA is large, then the RACH load on the Border eNodeBs would be less, but each terminating call/data transfer to a mobile M would lead to a broadcast of paging message from the MME to each eNodeB in that TA. This would certainly put additional pressure on the backhaul link. Additionally, on each of the eNodeBs, a page will also need to be sent using up the paging channel. Therefore, determining TA size and demographic is a trade off between the RACH load on the Border eNodeBs and the Paging load on the backhaul and RF of the eNodeBs. Note that the RACH load affects only one cell, but the paging load translates into a broadcast message on all the eNodeBs belonging to that TA.

3.3.1 BENEFITS

Present day wireless operators have been forced to take an offline approach due to lack of any mechanism for effective and efficient adjustment of tracking areas. Due to the cumbersome nature of such a process, most carriers hardly change the tracking areas of their cells. In other words, TAIs for each cell are decided at the time of deployment based on rules-of-thumb, anticipated traffic patterns, etc., and are only altered in the event of extreme performance degradations. SON TA feature has the ability to change that, both at the time of deployment using Tracking Area Planning (TAP) and during the subsequent network optimization using Tracking Area Optimization (TAO).

At the time of deployment, TAP algorithm prepares the initial deployment plan for the cell sites of a market in an (semi) autonomous fashion. The output of the TAP drives the choice of tracking area that an eNodeB belongs to. The corresponding TAI is delivered to each eNodeB during the initialization phase. The inputs to such a deployment plan could be market geographical data, TAI range and values, eNodeB locations, market size, etc.

Once initial deployment is complete, the TAO algorithm actively monitors the Tracking Area Updates (TAU) and the load on the radio access channel (RACH) to continuously identify the eNodeBs that are most suited for a change in their TAI. The intention is to capture some of the mobility patterns for each eNodeB. For example, if a highway passes through a cluster of eNodeBs, it might make sense to ensure that tracking area boundary cleanly intersects with the highway, and avoids a UE in the car to ping-pong between multiple TAs. TAO algorithm has the ability to identify such eNodeBs and allocate them to appropriate TA.

3.4 PCI PLANNING

In order for the UEs to uniquely identify the source of a receiving signal, each eNodeB is given a signature sequence referred to as Physical Cell ID (PCI). Based on the LTE specification of the physical layer detailed in 3GPP TS 36.211-840, there are a total of 504 unique physical layer cell identities. These physical layer cell identities are grouped into 168 unique physical layer cell identity groups, where each group contains three unique identities. The overall signature PCI is constructed from primary and secondary synchronization IDs as follows:

$$PCI = 3N_{\mathrm{ID}}^{(1)} + N_{\mathrm{ID}}^{(2)}$$

Where, $N_{\mathrm{ID}}^{(1)}$ is in the range of 0~167, representing the physical layer cell identity group, and $N_{\mathrm{ID}}^{(2)}$ is in the range of 0~2, representing the physical layer identity within the physical layer cell identity group. The hence constructed PCI is allocated to each eNodeB at the time of installation. Based on the allocated IDs, the eNodeB transmits the PCI on the downlink preamble. The UEs in its service area receive the preamble, and are able to identify the eNodeB, and the corresponding signal quality. It is possible, however, that a UE finds that there are two eNodeBs that have the same PCI. This is possible since the PCIs are reused by multiple eNodeBs. Note that there are only 504 PCIs, and a typical market might have 200 to 300 cell sites, assuming three eNodeBs per cell site leads to as many as a thousand eNodeBs in a market. Therefore, the service provider must carefully determine the PCI of each eNodeB to make sure that such conflicts do not happen, or are minimized.

Typical operators use an offline planning tool or depend on manual determination to develop a PCI deployment plan for a market. The plan uses basic information such as eNodeB location, potential neighbors, etc., to determine the PCI for each eNodeB. Such an allocation is carefully reviewed to ensure that the market does not have any PCI conflicts; hence the determined PCI values are communicated to each eNodeB during the installation using the configuration files or manually inputted by the staff. Needless to say, such a process does not lend itself to subsequent changes and is prone to human error.

3.4.1 BENEFITS

SON mechanisms enable the operator to automate this tedious process described above in section 3.4. In the SON framework, as soon as the eNodeB is powered up during the auto-configuration phase, it is allocated to a PCI (that is a primary and a secondary synchronization ID). Such a PCI is determined using a PCI Planning Tool (PPT) that not only uses the estimated coverage area information for each eNodeB, but also enforces significant margin and separation between two eNodeBs that are allocated to the same PCI. Additional considerations could also be included when determining such a plan. Nonetheless, SON ensures that each eNodeB has a PCI value at the time of installation without requiring explicit human intervention.

Subsequently, during the operational phase, each eNodeB collects the information pertaining to any PCI conflicts. Observe that PCI conflicts might happen due to errors during the initial PCI Planning phase, deployment of new eNodeBs, changes in the demographics of a market, power of eNodeBs, etc. Whenever an LTE UE receives power from two eNodeBs with the same PCI, it informs the serving eNodeB about the conflict. Such an alarm is relayed to the OSS/SON mechanism, which collects and logs the details of such conflicts. The operator can then decide on a suitable time interval for activating the PCI Optimization Tool (POT), (e.g., it might make sense to schedule such an activity during a lightly-loaded night-time period). The POT algorithm uses the collected logs, alarms and the updated coverage maps in order to identify the eNodeBs for which the PCI needs to be changed and the associated new PCI value. Furthermore, the SON algorithm ensures that the information is relayed to the correct eNodeBs. Upon reception, eNodeBs could wait for a hold period before they begin to deploy the newly allocated PCI values.

3.5 LOAD BALANCING

The term Mobility Load Balancing (MLB) is used in this section to refer specifically to the network cell (eNodeB) level only, not core entities such as the MME, gateways, etc. The goal of MLB is to spread user traffic across system radio resources in order to provide quality end-user experience and performance. This can be accomplished by one or a combination of algorithms that perform Idle or Active balancing of users. These SON algorithms for offloading traffic from one element to another can include intra-carrier, inter-carrier, or even inter-technology resources, as long as there is software intelligence to ensure radio admission and continuity of service on the target element. It is expected that Active user Load Balancing may become a favored mechanism for Load Balancing in LTE. The actual transfer of users is accomplished by modification of either cell-neighbor-pair parameters or user-specific parameters. This requires coordination with competing SON algorithms and standardized messaging with multi-vendor equipment to ensure robustness and stability.

The implementation of MLB algorithms depends upon the architecture. A case can be made for MLB algorithms to be either distributed or centralized. In general, the selected architecture has a strong dependence upon the access technology in question. LTE may be better suited to a distributed algorithm utilizing the X2 interface, while technologies with a BSC/RAN architecture and/or macro-diversity may favor a more centralized approach. The text in this section is more suited to single-link technologies such as LTE.

- **Distributed LB:** Algorithms run locally in the base stations. Load information is exchanged between base stations so that Idle/Active HO (handover) parameters may be adjusted and/or adjustments to RRM functionality can be made.

- **Centralized LB:** Algorithms run in a core OSS element. Base stations report load information to a central entity which then responds with appropriate modifications to idle/active HO parameters.

In either case (distributed or centralized), it is assumed there will be centralized Operations, Administration and Management (OA&M) control for an operator to enable/disable and configure relevant algorithm settings.

3.5.1 BENEFITS

The objective of Mobility Load Balancing is to intelligently spread user traffic across the system's radio resources as necessary in order to provide quality end-user experience and performance, while simultaneously optimizing system capacity. The automating of this minimizes human intervention in the network management and optimization tasks.

3.5.2 DESCRIPTION

Load Balancing refers to similar network elements that are intended to share traffic load. The similar network elements can be anything from packet gateways to MMEs to base stations and sectors. In LTE, MME pools are expected to share user traffic load across different MMEs as load increases, while eNBs may have RRM functions that share/offload traffic to neighboring cells in order to increase system capacity. As a result, different real-time algorithms at different nodes can simultaneously provide Load Balancing of user traffic per network element as required. Additionally, long-term traffic behavior of each node can be monitored so that traffic may be "directed" a-priori by a centralized entity in the network. For instance, this could be a desirable feature for markets where periodic or scheduled concentrations of users regularly occur (e.g. sporting events, conventions, daily commutes, etc.).

Idle mode traffic distribution has been widely used in 2G/3G deployments to balance idle traffic among carriers, but real-time modification to parameters to force cell reselection for cell-edge users within a carrier falls squarely in the SON category.

The decision to "re-balance" a cell or move, a particular user must take in to consideration the target for the user(s). It is not desirable to send a user to an alternate location (i.e. neighbor or co-located) if that user will then have a reduced QoS or lower performance than remaining in the source, or if the resulting re-balance will result in reduced system capacity/utilization.

3.5.3 DETERMINING A LOAD IMBALANCE CONDITION

Load Balancing mechanisms must work together with the scheduler and admission control. For non-GBR (Guaranteed Bit Rate) users, there is no constraint on the minimum performance those users receive except within the scope of the maximum number of users per cell (Admission Control) and perhaps a vendor-imposed minimum throughput (Scheduler). For GBR users, the scheduler is vitally important in ensuring all radio bearers are granted resources in a manner that satisfies their specific service. Therefore, a system may be considered “in balance” as long as there are no users being denied resources and all active services are being supported within the scope of their QoS needs.

Simple thresholds could be implemented where low, medium and high load conditions simply equate to a given number of active users in the cell for the non-GBR case. These can serve as triggers to modify idle mode parameters and/or to handover active users to neighbors (i.e. cell-edge intra-carrier, collocated inter-carrier or collocated inter-technology handover). However, more intelligent metering is needed for GBR users since it is possible for a small number of such users to “load” a cell depending upon their requirements.

3.5.4 IDLE BALANCING

The LTE system does not have a real-time, per-cell view of idle mode users. The only time the system becomes aware of the exact cell a user is in while in idle mode is when the Tracking Area of the user changes and a TAU message is sent by the UE. Therefore, while parameters that control how and when a UE performs cell reselection (idle handover) are modifiable, there is no direct measurement mechanism for the system to determine when there are “too many” idle users. Equally notable, this too many idle user condition, has no direct bearing on either system capacity or user experience.

The way around this is for the system to adjust cell reselection parameters for the idle users based on the current Active user condition. As real-time traffic and/or QoS demands increase in a cell, it would be possible for the cell to adjust the cell reselection parameters in order to force users nearest the cell edge to select their strongest neighbor to camp on, or to force a handover to a co-located carrier that has more resources available.

Care must be taken to coordinate such parameter adjustments between cells (i.e. utilizing the X2 interface) in order to prevent service-outage “holes” as well as to adjust active mode parameters to avoid immediate handover upon an idle to active transition.

Note, for LTE, the control of inter-carrier balancing falls within the scope of Idle Balancing. Parameters exist that control cell reselection and carrier preferences/priorities in the System Information Blocks (SIBs). In either case, the UE has the final decision of where it camps.

3.5.5 ACTIVE BALANCING

The advantage of Active Load Balancing is that the system has a direct measurement mechanism and knowledge of each user’s traffic requirements and radio conditions. Therefore, in conjunction with the scheduler and interfaces to other base stations (X2 interface), it is possible to make accurate decisions for “load-based HO.” A “load-based HO” reason code could be used during handover (HO) messaging to allow the target cell knowledge in order to avoid immediate “hand-back” to the source based on the normal HO thresholds.

It is noted that multi-vendor support of Active Balancing requires detailed standardization of available resources to be communicated between vendor equipment.

3.6 MOBILITY ROBUSTNESS / HANDOVER OPTIMIZATION

Mobility Robustness Optimization (MRO) encompasses the automated optimization of parameters affecting active mode and idle mode handovers to ensure good end-user quality and performance, while considering possible competing interactions with other SON features such as ANR and LB.

While the goal of MRO is the same regardless of radio technology (optimized end-user performance and system capacity), the specific algorithms and parameters vary with technology. The description below is for LTE Release 8 and 9, with its single-link (no macro diversity) approach and X2 interface between eNodeBs.

Whether a distributed or centralized MRO function is implemented (distributed is more applicable in the description text) it is assumed there will be centralized OA&M control for an operator to enable/disable and configure relevant algorithm settings.

3.6.1 BENEFITS

The objective of MRO is to dynamically improve the network performance of HO in order to provide improved end-user experience as well as increased network capacity. This is done by automatically adapting cell parameters to adjust handover boundaries based on feedback of performance indicators. The automating of this minimizes human intervention in the network management and optimization tasks.

3.6.2 DESCRIPTION

The scope of MRO as described here assumes a well-designed network with overlapping RF coverage of neighboring sites. The optimization of handover parameters by system operators typically involves either focused drive-testing, detailed system log collection and post-processing, or a combination of these manual and intensive tasks. Incorrect HO parameter settings can negatively affect user experience and waste network resources by causing HO ping-pongs, HO failures and Radio Link Failures (RLF). While HO failures that do not lead to RLFs are often recoverable and invisible to the user, RLFs caused by incorrect HO parameter settings have a combined impact on user experience and network resources. Therefore, the main objective of mobility robustness optimization should be reducing the number of HO-related radio link failures. Additionally, sub-optimal configuration of HO parameters may lead to degradation of service performance, even if it does not result in RLFs. An example is the incorrect setting of HO hysteresis, which may be the cause of ping-pongs or excessively delayed to a target cell. Therefore the secondary objective is the reduction of the inefficient use of network resources due to unnecessary or missed handovers.

Most problems associated with HO failures or sub-optimal behavior can ultimately be categorized as either too-early or too-late triggering of the handover, provided the required fundamental network RF coverage exists. Thus, poor HO-related performance can generally be categorized by the following events:

- Late HO triggering
- Early HO triggering
- HO to an incorrect cell
- Algorithm flow of operation
- Algorithm interaction check

3.6.3 LATE HO TRIGGERING

If the terminal mobility is faster than the HO parameter settings allow for, handover can be triggered when the signal strength of the source cell is too low – leading to a RLF. The signature of Too-Late HOs may be summarized by:

- RLF in the source cell before the HO was initiated or during HO procedure
- Terminal re-establishes in a different cell than the source

3.6.4 EARLY HO TRIGGERING

Too-early HO can be triggered when the terminal enters an island of coverage of another cell contained inside the coverage area of the serving cell. This is a typical scenario for areas where fragmented cell coverage is inherent to the radio propagation environment, such as dense urban areas. The signature of Too-Early HO may be summarized by:

- RLF occurs a short time after the HO trigger to the target cell (i.e. the HO may or may not be completely successful, depending on the over-the-air-messaging in the target cell)
- Terminal re-acquires the system in the source cell

3.6.5 HO TO AN INCORRECT CELL

It is possible if the cell-neighbor-pair parameters are set incorrectly that the handover may be directed towards a wrong cell. The signature of HO to a wrong cell may be summarized by:

- RLF occurs a short time after the HO trigger to the target cell (the HO may or may not be completely successful, depending on the over-the-air-messaging in the target cell)
- Terminal re-establishes in a different cell than the source or target

Note this event could also be a case of Rapid HO – where the terminal quickly and successfully performs handovers from cell A to B to C. This could be argued as either a Too-Early case for A-B or simply Too-Late for A-C.

3.6.6 ALGORITHM FLOW OF OPERATION

The SON HO Optimization function is an algorithm or set of algorithms designed to improve performance of HOs from one cell to another. Performance data collected from each cell is analyzed in order to correlate HO failures that may be due to improperly configured or unoptimized parameters. Adjustments can then be made to the configuration in an attempt to improve the overall HO performance of the network.

Care must be taken to provide a methodical adjustment to network configuration. Assuming certain cell-pair neighbors exhibit poor performance exceeding an operator-defined threshold (target KPIs are not met), the expected flow of operation comprises the following steps:

1. Monitor the network for a sufficient period of time in order to accurately baseline the performance of all cells with respect to traffic loading, traffic type, time-of-day, etc. This may take days or weeks depending on the amount of user traffic in the cells.

2. Output from algorithms suggests changes to the network that should provide overall increase in successful HO across the network. These changes or subset of changes are then made to the network

3. The network is monitored for a sufficient period of time in order to accurately compare the performance of the network with respect to the baseline in Step 1

4. Keep track of attempted changes and repeat this iterative process as necessary until the target KPI thresholds are met

5. Update centralized data base with “final” outputs

Possible cell or cell-neighbor-pair parameter modifications (in Step 2) include:

- Trigger Thresholds
- Time-to-Trigger
- Hysteresis (ping-pong control)
- Neighbor List Relation
- Speed-Dependent Parameters
- Antenna Remote Electrical Tilt

- Idle Mode Parameters (to avoid immediate HO trigger when transitioning from idle to active states)

Note that certain technologies may allow faster performance monitoring and a distributed approach to the MRO algorithm (i.e. the non-BSC based E-UTRAN of LTE and X2 interface messaging could allow a de-centralized MRO algorithm that operates on much faster time scales than the above text for the algorithm flow implies).

3.6.6.1 ALGORITHM INTERACTIONS

Finally, any modification of parameters must work in conjunction with other possible interacting SON algorithms (centralized or distributed). For instance, it is possible that Load Balancing or Neighbor List optimization algorithms may directly conflict with the mobility robustness outputs. Therefore, messaging and/or other forms of control between SON algorithms is required to resolve potential conflicts and ensure stability

4 SUMMARY AND CONCLUSION

New and emerging classes of mobile devices are driving significant growth of wireless data usage. Consequently, wireless service providers must now support a growing number of higher-bandwidth data applications and services on their networks, while simultaneously driving down the delivery cost per bit. This growth in wireless data demand is so rapid that it is also expected to increase Radio Access Network complexity through additions of femtocells, picocells, as well as WiFi access points in order to drive increases in coverage and capacity. These and other trends portend ever-increasing demands upon service providers in the areas of network performance and operations. It has become increasingly clear that traditional network management is inadequate for managing the growing data volume and network complexity in a cost-effective manner.

Previous 3G Americas white papers and technical studies have shown that LTE – with its wideband, highly spectrally efficient, low-latency and cost-effective technology – is ideally suited to serving these new applications.[13] A key component of the LTE advantage is SON, which is being standardized by 3GPP in Release 8, Release 9 and beyond.[14] LTE SON will leverage network intelligence, automation and network management features in order to automate the configuration and optimization of wireless networks, thereby lowering costs and improving network performance and flexibility.

This white paper has described the motivation for SON, and provided a description of the key SON features contained in LTE Releases 8 and 9. A key goal of LTE SON standardization is the support for multi-vendor network environments, which is a vitally important benefit for service providers. The LTE Release 8 and Release 9 SON features clearly provide significant operator benefits in terms of performance gains as well as operational benefits. Strong operator interest in LTE SON is clearly evident, which is demonstrably evident from the significant SON contributions coming from organizations such as the Next Generation Mobile Networks (NGMN). Finally, the scope of LTE SON functionality will clearly continue to expand and evolve with upcoming releases of the LTE standard, thereby ensuring LTE's continued success in tomorrow's wireless marketplace.

APPENDIX: SON HIGH-LEVEL SCOPE AND TIMELINE FOR OTHER TECHNOLOGIES

It seems clear that LTE will be adopted by the majority of the operator community and is thus expected to quickly establish itself as the dominant OFDM-based technology. However, it is interesting to contrast the SON capabilities of the other technology alternatives, notably WiMAX. WiMAX networks have been deployed worldwide, especially in the APAC region, with more than 400 networks being deployed worldwide covering around 450 million pops.

WiMAX is based on the 802.16 standards defined by IEEE, which has gone through several versions including 802.16-2004 (fixed WiMAX) and 802.16e (mobile WiMAX), both commercially available today. The next WiMAX release, 802.16m, aims to satisfy the IMT-Advanced criteria. Its commercial availability is presently estimated to be in the 2011-2012 timeframe, comparable to LTE Release 10.

The original version of WiMAX did not have a specific management architecture; however, this concept was introduced as part of release 802.16f, which includes new interfaces and protocols as well as detailed formats for O&M related information. The WiMAX management system was improved in 802.16g with the introduction of specific Service Access Points for control and management of the different network components, including remote management of mobile units.

As compared to LTE, WiMAX has taken a more open approach to the Network Management System, which can help develop functionality for network control. However, the WiMAX forum has not formally standardized a list of functionality for 802.16e and 802.16f SON support. Accordingly, while some WiMAX chipsets offer SON-like features such as neighborhood scan, over-the-air synchronization and plug-and-play femtocells, the equipment capabilities are proprietary and hence vendor-specific. Consequently, the 3GPP approach presents a more promising option for SON functionality.

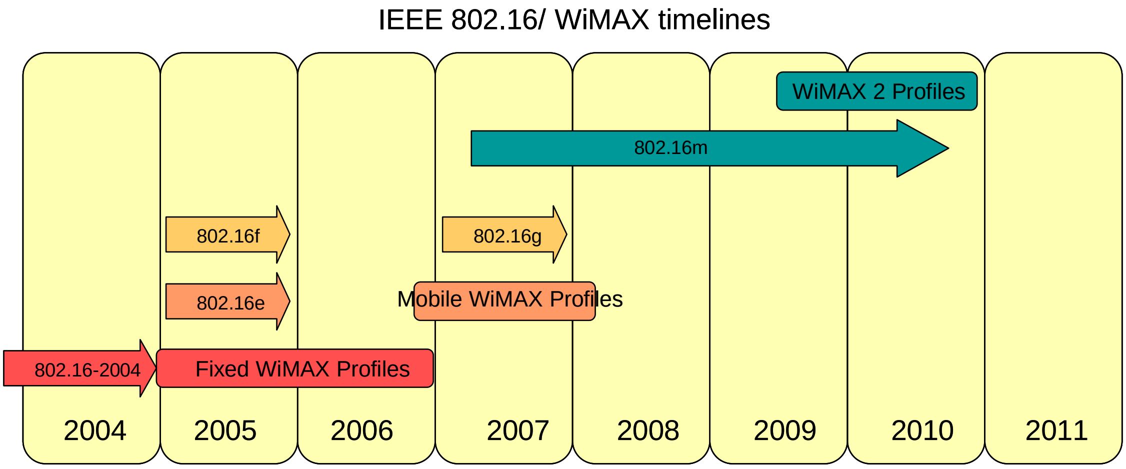

Figure A. Estimated Timelines for IEEE 802.16 Standards and WiMAX Forum Profiles.

Timelines for Associated WiMAX Forum Network Working Group (NWG) and Certification "Plugfests" Are Not Shown.

The present scope of IEEE 802.16m SON features is limited to the measurement and reporting of air interface performance metrics from base stations (BS) and mobile devices (MS), and the subsequent adjustment of BS parameters. WiMAX 16m SON functions are intended for automated BS parameter configuration and to optimize network performance, coverage and capacity. The primary 16m SON features under development in standards are:

- Coverage and Capacity Optimization
- Inter-cell interference management and optimization
- Load Balancing
- Fractional Frequency Reuse (FFR) optimization

ACKNOWLEDGEMENTS

The mission of 3G Americas is to promote, facilitate and advocate for the deployment of the GSM family of technologies including LTE throughout the Americas. Members of 3G Americas' Board of Governors include Alcatel-Lucent, América Móvil, Andrew Solutions, AT&T (USA), Cable & Wireless (West Indies), Ericsson, Gemalto, HP, Huawei, Motorola, Nokia Siemens Networks, Nortel Networks, Openwave, Research In Motion (RIM), Rogers Wireless (Canada), T-Mobile USA and Telefónica.

We would like to recognize the significant project leadership and important contributions of John Graybeal of Alcatel-Lucent as well as the other member companies from 3G Americas' Board of Governors who participated in the development of this white paper.

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