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Overview of LTE-Advanced Mobile Network Plan Layout

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***Abstract* - Mobiles have become very essential part of our everyday life begin of voice call to internet access. As the development of 4G mobile wireless standards the operator need to know how to design and update their networks so that they can provide best services to the lowest possible cost. This paper presents topological planning problem of fourth generation (4G) cellular networks based on the Long Term Evolution Advanced (LTE-Advanced) standards. After describing the LTE-Advanced architecture, we focus on layout and the main problems faced in this planning. This paper provides a high level overview of antenna placement problem or the cell planning problem, involves locating and configuring infrastructure for LTE-Advanced mobile networks. The goal of this paper is to present and classify the different research works that have been done so that it can be used as a starting point for future research on topological design of LTE-Advanced networks.**

Keywords: network planning; cell planning and mobile network

I. INTRODUCTION

LTE stands for Long Term Evolution and it was started as a project in 2004 by telecommunication body known as the Third Generation Partnership Project (3GPP). SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution. The term LTE is typically used to represent both LTE and SAE [1]. LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved from the Global System for Mobile Communications (GSM). Even related specifications were formally known as the evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UTRAN). First version of LTE was documented in Release 8 of the 3GPP specifications.

Long Term Evolution (LTE) describes the standardization work by the Third Generation Partnership Project (3GPP) to define a new high-speed radio access method for mobile communication systems [2]. In order to successfully compete to other existing and future wireless, cellular and wire-line services, the network designers need to fully consider the technical constraints that influence the whole design process of this kind of networks. The number of combinations of network elements and parameters that can be configured (e.g. antenna tilt, azimuth, base station location, power) constitutes the solution space of the design process. The size of this space determines the degree of complexity of finding appropriate solutions. In Wireless Metropolitan Area Network (WMAN) scenarios like LTE, the number of options is high, so it is very unlikely that the optimal network configuration can be found using a manual method [3].

The main radio access design parameters of this new system include OFDM (Orthogonal Frequency Division Multiplexing) waveforms in order to avoid the inter-symbol interference that typically limits the performance of high-speed systems, and MIMO (Multiple-Input Multiple-Output) techniques to boost the data rates. At the network layer, an all-IP flat architecture supporting QoS has been defined.

Before 3GPP started working in the real 4G wireless technology, minor changes were introduced in LTE through Release 9. In particular, femtocells and dual-layer beamforming, predecessors of future LTE-Advanced technologies, have been added to the standard. The formal definition of the fourth generation wireless, known as the International Mobile Telecommunications Advanced (IMT-Advanced) project, was finally published by ITU-R through a Circular Letter in July 2008 with a call for candidate radio interface technologies (RITs) [4]. In October 2009, LTE-Advanced was submitted seeking for approval as international 4G communications standard.

LTE-Advanced LTE-A, the backward-compatible enhancement of LTE Release 8, will be fully specified in 3GPP Release 10 [5]. By backward compatibility, it is meant that it should be possible to deploy LTE-Advanced in a spectrum already occupied by LTE with no impact on the existing LTE terminals. Rel-10 started early in 2010 and was functionally frozen in March 2011 after its approval by the ITU for having met the entire requirement for IMT-Advanced.

The set of IMT-Advanced high-level requirements established by the ITU-R in [6] is as follows:

A high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost-efficient manner.

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Compatibility of services within IMT and with fixed networks.

Compatibility of internetworking with other radio access systems.

High-quality mobile devices.

User equipment suitable for worldwide use.

User-friendly applications, services, and equipment.

Worldwide roaming capability.

Enhanced peak rates to support advanced services and applications (100 Mbit/s for high mobility and 1 Gbit/s for low mobility were established as targets for research).

The remainder of this paper is organized as follows. In Section 2, we provide an overview of the network architecture that will support the LTE-A air interfaces. Then, we cover the concept of MIMO techniques in Section 3. In Section 4, we present LTE-A network planning overview. Finally, we conclude the paper with Section 5.

II. NETWORK ARCHITECTURE

The core network of the LTE-Advanced system is separated into many parts. Figure 1 shows how each component in the LTE-Advanced network is connected to one another [7-9]. NodeB in 3G system was replaced by evolved NodeB (eNB), which is a combination of NodeB and radio network controller (RNC). The eNB communicates with User Equipments (UE's) and can serve one or several cells at one time. Home eNB (HeNB) is also considered to serve a femtocell that covers a small indoor area. The evolved packet core (EPC) comprises of the following four components. The serving gateway (S-GW) is responsible for routing and forwarding packets between UE's and packet data network (PDN) and charging. In addition, it serves as a mobility anchor point for handover. The mobility management entity (MME) manages UE access and mobility, and establishes the bearer path for UE's. packet data network gateway (PDN GW) is a gateway to the PDN, and policy and charging rules function (PCRF) manages policy and charging rules[10].

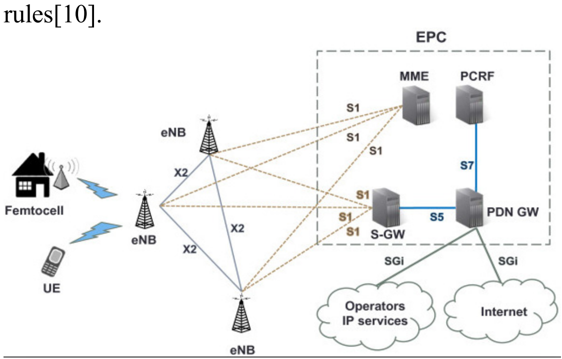

Figure 1 network architecture of LTE-Advanced

Figure 2 illustrate types of cell according to the surrounding environments.

Mobile terminal location, can be outdoor or indoor. If the mobile terminal is located inside buildings the environment is called indoor, otherwise it is outdoor.

Antenna location, it can be above or below the average rooftop level. In case, when base station antenna array is above average height of the buildings, the environment is considered to be macro-cellular and, in case, when base station antenna array is below average height of the buildings, the environment is considered to be micro-cellular. There is even smaller type of the cells than macro and micro cells, so called pico cells for which the antennas are located mainly in indoor environments if it located in shopping mall or enterprise. In Femto cells, the antennas are located mainly in indoor environments if it located in home.

Morphography type, urban, suburban, rural. These area types are determined by the variation of size and density of both manmade and natural obstacles located in surroundings of User Equipment (UE) and base station sites[11].

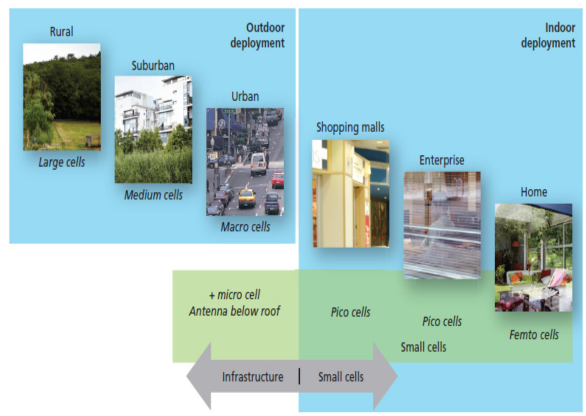

Figure 2 Radio propagation environments

A Heterogeneous Network (HetNet) is a mix of high-power macro-eNBs [12] responsible for umbrella coverage mainly for outdoor users, and low-power micro/Pico/Femto/relay BSs that are deployed for incremental capacity growth and coverage enhancement.

Macrocells: A Macrocell provides the largest area of coverage within a mobile network. Its antennas can be mounted on ground-based masts, rooftops or other structures and must be high enough to avoid obstruction. Macrocells provide radio coverage over varying distances, depending on the frequency used, the number of calls and the physical terrain. Typically they have a power output in tens of watt. Macrocells are conventional base stations with power about 20W, that use dedicated backhaul, are open to public access and range is about 1 km to 20 km.

TABLE1 COMPARISON OF SMALL CELLS

Cell type	Typical Cell Size	Data Rate Limitation
Macro	**1-30 km**	**Propagation**
Micro	**500 m-2 km**	**Capacity and propagation**
Pico	**4-200 m**	**Capacity and propagation**
Femto	**10 m**	**Broadband connection and Handset**

Microcells: Microcells provide additional coverage and capacity in areas where there are high numbers of users, for Example, urban and suburban areas. Microcells cover around10% of the area of a Macrocell. The antennas for microcells are mounted at street level, are smaller than Macrocell antennas and can often be disguised as building features so that they are less visually intrusive. Microcells have lower output powers than marocells, usually a few watts. Microcells are base stations with power between 1 to 5W, that use dedicated backhaul, are open to public access and range is about 500 m to 2 km.

Picocells: Picocells provide more localized coverage. These are generally found inside buildings where coverage is poor or where there is a dense population of users such as in airport terminals, train stations and shopping centers. Picocells are low power base stations with power ranges from 50 mW to 1W, that use dedicated backhaul connections , open to public access and range is about 200 m or less.

Femtocells: Femtocell base stations allow mobile phone users to make calls inside their homes via their Internet broadband connection. Femtocells provide small area coverage solutions operating at low transmit powers. Femtocells are consumer deployable base stations that utilize consumer's broadband connection as backhaul, may have restricted association and power is less than 100 mW.

Relay Node (RN): For efficient heterogeneous network planning, 3GPP LTE-Advanced has introduced concept of Relay Nodes (RNs). Relaying is used to improve the performance of LTE, in terms of coverage and throughput. According to 3GPP, the use of relays will allow the following improvements [13]:

- Provide coverage in new areas.
- Temporary network deployment.
- Cell-edge throughput.
- Coverage of high data rate.
- Group mobility.
- Cost reduction: The cost of a relay, by itself, should be less than the cost of an eNB, assuming that the complexity of a relay is less than the complexity of an eNB. Due to the lack of a wired backhaul, the deployment cost and time should also be reduced, compared to an eNB.
- Power consumption reduction: The single-hop distance between the eNB and the UE is divided into two distances: the distance from the eNB to the relay, and the distance from the relay to the UE.

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- Power consumption reduction: The single-hop distance between the eNB and the UE is divided into two distances: the distance from the eNB to the relay, and the distance from the relay to the UE.

In Fig. 25, the basic scheme in which relays are planned to be deployed in LTE-Advanced is depicted.

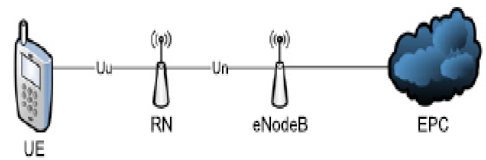

Figure 3 Relay basic scheme

III. MIMO TECHNIQUES

Multi-antenna or MIMO (Multiple Input, Multiple Output) technology is based on transmitting and receiving with multiple antennas and utilizing uncorrelated communication channels when radio signals propagate through the physical environment. If there is enough isolation between the communication channels, then multiple data transmissions can share the same frequency resources. If the multiple transmissions are for a single user, then the technology is called Single-User MIMO (SU-MIMO), for multiple users Multi-User MIMO (MU-MIMO).

The better the system can utilize these communication channels for multiple transmissions, the higher is the capacity that the system can provide.

MIMO performance is subject to a large number of parameters: the number of transmitter and receiver antennas, reference signals and algorithms for channel estimation, feedback of channel estimation data from the receiver to the transmitter and spatial encoding methods.
Consequently a comprehensive design is crucial to provide optimum system performance.

IV. LTE-A NETWORK PLANNING OVERVIEW

To be able to plan and implement a cost efficient high quality cellular mobile wireless network, very careful radio network planning procedure must be done. Thus, the planning process carried out in phases and each phase is well documented. The radio network planning procedure requires good knowledge about the coverage area, propagation environment, traffic load and required services to be able to analyses the network and to decide the optimal radio network planning strategy. The fact, that all the above mentioned aspects are not constant and vary in time, makes the radio network planning a nonstop process, which requires continuous monitoring and optimization [11].

The radio network planning is a process, which defines different steps, like measurements, planning, documentation, etc. that should be done in different phases to manage connections between coverage, capacity and interference. The coverage or capacity or QoS is not possible to maximize simultaneously, but all of them need to be optimized in order to implement a cost-efficient high quality radio network. To provide necessary coverage and, at the same time, optimize capacity and quality, the radio network planning can be divided into three main phases, illustrated in Figure 4. These phases can be used from initial deployment of the radio networks to their evolution and further development [14].

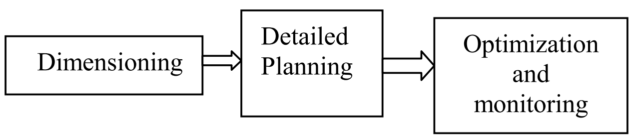

Figure 4 Radio System Planning Process Phases

During the first phase, dimensioning, the planned network configuration is analyzed and an appropriate radio network deployment strategy is defined. In second phase, detailed planning, the detailed design and actual implementation of the radio network is done. First step in detailed planning is the configuration planning, which need to be done prior to coverage and capacity planning to be able to analyses all available coverage and capacity related software and hardware features. The base station site configuration, which is different for different environments, need to be done based on both coverage and capacity requirements. Coverage specific requirements define coverage related base station elements and capacity requirements define capacity related base station elements. And finally, power budget can be calculated based on optimized base station parameters. Eventually, the configuration planning will provide total base station site configuration for different places and environments.

The configuration planning is followed by coverage planning, the aim of which is to minimize the number of base station sites by utilizing output information of the dimensioning and configuration planning. An important role in configuration planning plays surveying which helps to find out potential propagation problems and suggest base station sites locations. After that, some measurements can be done to tune propagation models for the particular areas. The tuned propagation models will give the final locations for base stations, by taking as input base station configuration parameters as well as some information about environment. The final coverage prediction and base station locations are usually defined by the use of advance planning software.

The next step is capacity planning which should be started as soon as the base station sides are selected. The capacity planning is done by the use of planning-tools, as the resource allocation mechanisms are already defined in dimensioning phase. The initial step is to define planning thresholds, after that, the main job will be done by planning-tools. The last step in the detailed planning is parameter planning, which is done immediately before the launch of the network.

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The last step in the detailed planning is parameter planning, which is done immediately before the lunch of the network. Radio performance has a direct impact on the cost of deploying the network in terms of the required number of base station sites and in terms of the transceivers required. The operator is interested in the network efficiency: how many customers can be served, how much data can be provided and how many base station sites are required. The efficiency is considered in the link budget calculations and in the capacity simulations. The end user application performance depends on the available bit rate, latency and seamless mobility. The radio performance defines what applications can be used and how these applications perform. Recent works in LTE and LTE-A network planning are divided into two directions. The first direction is solving Capacity and Coverage optimization by Self-Organizing LTE network. In [15] A novel hybrid two layer optimization framework is proposed to enhance the network capacity and coverage, where on the top layer a network entity of eCoordinator is implemented to ensure overall network coverage by optimizing the antenna tilt and capacity-coverage weight of each cell in a centralized manner, and on the bottom layer individual eNB optimizes cell-specific capacity and coverage by tuning its pilot power in a distributed manner. A heuristic algorithm is developed for the eCoordinator operation at large time granularity and the Genetic Programming (GP) approach is exploited for the eNB operation at small time granularity, for the purpose of tracking overall network performance as well as adapting to network dynamics. Results have demonstrated the usefulness of the proposed algorithms by enhancing network capacity and coverage performance under various system requirements. [16] present reinforcement learning strategies for self-organized coverage and capacity optimization through antenna down tilt adaptation. This work analyzes different learning strategies for a Fuzzy Q-Learning based solution in order to have a fully autonomous optimization process. The learning behavior of these strategies is presented in terms of their learning speed and convergence to the optimal settings. Simultaneous actions by different cells of the network have a great impact on this learning behavior. Therefore, a study for stable strategy where only one cell can take an action per network snapshot as well as a more dynamic strategy where all the cells take simultaneous actions in every snapshot, also propose a cluster based strategy that tries to combine the benefits of both. The performance is evaluated in all three different network states, i.e. deployment, normal operation and cell outage. The simulation results show that the proposed cluster based strategy is much faster to learn the optimal configuration than one-cell-per-snapshot and can also perform better than the all-cells-per-snapshot strategy due to better convergence capabilities.

From the discussion of architecture of LTE-A, we can dived the network planning of LTE-A into main type as:

- Indoor network planning
- Outdoor network planning

A. Indoor network planning

Small cells offer mobile service providers (MSPs) a cost-effective alternative to macro-only deployments for meeting growing coverage and capacity demands. That's because as small, low-cost access points, they are self-installed (home and enterprise cells) or easily installed by a single person (metro cells). Plus, as small cells are added, they offload traffic from the macro network. This increases available network capacity without the deployment of new macro sites. Owned and managed by the MSP —metro cells, small cells — are most cost effective in areas where new macro sites are required. The larger the number of macro sites, the greater the economic benefits. Metro cells cost much less than macro radio equipment and they do not require civil works that contribute heavily to macro site deployment costs. There are several factors behind the trend to smaller cells, including the perceived risks to health and visual appearance. Larger cells that transmit more radio waves sometimes spark concerns about radiation, while at the same time are held to be less aesthetically pleasing, especially in dense locations. Smaller cells also consume less power, reducing energy demands and offering potential environmental benefits. As the number of cells rises along with the demand for anywhere, anytime access, mobile service providers face a major challenge: How to define and deliver high-quality services cost-efficiently, and how to address the corresponding infrastructure and management challenges. Meeting this challenge means looking at the full set of requirements from a solutions-lifecycle perspective, beginning with architecture and finishing with deployment. Designing for small-cell environments near and in-building can be a daunting task. There is a host of legal, logistical, technological, and other issues to consider from the outset. Nonetheless, quality of design is key to creating a sustainable In-Building solution spanning time, location and mobile generations. In terms of architecture, LTE introduces new concerns and is more complex than 2G or 3G. Capacity requirements must be carefully considered, along with the impact of the macro network. Moreover, new antenna features such as MIMO and Beam Forming have to be taken into account, as well as end-to-end planning, integration and validation of IP networking and applications. Given the range and complexity of these issues, solution architects need to create an end-to-end reference architecture document detailing the necessary products and the interconnectivities among different elements and subsystems of the LTE network. The Solution Architect must also deliver a high-level design and well-documented technical interfaces. Technical deliverables must be reviewed to assure consistency with solution architecture, customer requirements, and quality goals. All of this is undertaken in keeping with the mission of the Solution Architect to mitigate delivery risk through careful scrutiny of the scope of work and clear communications [17].

Low-power base stations such as femtocells are one of the candidates for high-data-rate provisioning in local areas, such as residences, apartment complexes and business offices.

Due to the expected large number of user-deployed cells, centralized network planning becomes impractical, and new scalable alternatives must be sought [18].

In [19] novel solution is introduced and exploited . It relies on a suite of simulation tools including generation of random 3D femto-cell deployments in real environments, realistic path-loss predictions using a ray-based model and a 3D downlink performance analysis (i.e. considering all floors) of heterogeneous LTE networks in terms of coverage, macro offload and throughput. A first study demonstrates a significant macro offload and power consumption reduction in a realistic dense corporate FAP deployment. Then, a second study shows the large growth of indoor capacity enabled by dense FAP deployments but also the coverage degradation for non-subscribers when closed-access mode is used.

In [20] proposes and analyzes a new method for dynamically adjusting LTE femtocell power levels to mitigate interference to meet user selectable network performance goals. This paper proves that the proposed method converges to feasible solutions. The proposed algorithm is suitable for both distributed femtocell control and centralized policy enforcement.

Paper [21] introduce a deterministic approach for the simulation and performance evaluation of LTE networks in urban and indoor scenarios. Besides signal levels the expected MIMO capacity is evaluated. Comparisons with two measurement campaigns verify the high accuracy of the presented prediction model.

B. Outdoor Network planning

The second direction is the study of Energy and cost impacts of relay and femtocells deployments in long-term-evolution advanced [22] where presents a methodology for estimating the total energy consumption, taking into account the total operational power and embodied energy, and TCO of wireless cellular networks, and in particular provides a means to compare homogeneous and heterogeneous network (HetNets) deployments. The realistic energy models and energy metrics based on information available from mobile-network operators (MNOs) and base stations manufacturers must taking into consideration. Additionally, up-to-date operational and capital expenditure (OPEX and CAPEX) models are used to calculate TCO of candidate networks. There are two scenarios for HetNets, namely a joint macro-relay network and a joint macro–femtocell network, with different relay and femtocell deployments densities. The results obtained show that compared to macro-centric networks, joint macro-relay networks are both energy and cost efficient, whereas joint macro–femtocell networks reduce the networks TCO at the expense of increased energy-consumption. Finally, it is observed that energy and cost gains are highly sensitive to the OPEX model adopted

Paper [23] study the Impact of base station antenna eNB configurations on dual-stream Multiple-Input Multiple-Output (MIMO) performance is demonstrated by means of a real-world measurement example.

V. CONCLUSIONS

In this paper, the architectures for the LTE-A solutions have been defined by their respective standards bodies. We focus on layout and the main problems faced in the planning of LTE-Advanced. This paper provides a high level overview of antenna placement problem or the cell planning problem, involves locating and configuring infrastructure for LTE-Advanced mobile networks.

Femtocells, Pico cell provide a one-box solution: a small, low-cost, low power unit that can be self- installed to provide mobile 4G coverage to the home. Femtocells or Pico cells are not simple standalone devices. They must be integrated into the mobile operator’s network to enable seamless service and to ensure optimal performance across both femtocell and macrocell networks.

It is also expected that the use of femtocells, small cell, Pico cell, self-organizing networks, and energy management systems will drive the evolution of current and future mobile wireless networks.

In the future the efforts must be focused on improving the support of heterogeneous networks, as well as device-to-device and machine-type communications.

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