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Research Article

Multi-Period LTE RAN Planning with Operator Profit Maximization (Part 1: Optimization Model Synthesis)

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Abstract: The LTE RAN planning is a very vital step for a wireless communication technology. The creation of a network is not an instantaneous process; it typically goes stage by stage. In this article (first part) an optimization model for the LTE RAN network planning problem is described. Parameters such as requirements, the cost of installation and usage of equipment, the specific income from providing services may change over time in the given optimization model. The analysis of experiment's results showed that formulation of the problem, which is shown above and presented as a problem of MILP, allows to obtain the correct solutions from the practical point of view. Comparison of the operator's profit during the single-period and multi-period planning showed that usage of multi-period planning increase the profit margin to 12% more than the single-period planning.
Keywords: LTE RAN, multi-period planning, test-point, Signal-Interference-Noise Rate, optimization model

INTRODUCTION

The Long Term Evolution(LTE), also known as Evolved Universal Terrestrial Radio Access (E-UTRA), is a step toward the4thgeneration(4G) of mobile radio technologies to increase the spectral efficiency and to obtain higher throughput. The main advantages with LTE are high throughput, low latency, plug and play, FDD and TDD in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs.

The combination of powerful technologies like OFDM and MIMO techniques in the same system increases spectral efficiency, and improves link reliability without additional band width or transmit power[1].

Radio network planning is a very vital step for a wireless communication technology. As standardization work of LTE is approaching the end line, it's high time to go for efficient radio network planning guideline for LTE. Designing, deploying, and managing any cellular system requires clear objectives to be identified from the outset. These include definition of the service area; the projected number of customers; their distribution, spectrum availability, growth rate, and system usage; and the network interconnect agreement, numbering, and routing policy for inter‐ network access and roaming.

In [2] coverage and capacity estimation is carried out in radio network dimensioning. Radio link budget is investigated for coverage planning. Theoretical work is later put into the development of an Excel based dimensioning tool which is designed to keep the interface simple and to set the functional parts clearly distinguishable.

It should be noted that the creation of a network is not instantaneous process. Typically, the creation of a network goes stage by stage, with a gradual increase in its capacity and territory covered. This makes the problem of multi-stage planning ensuring high economic efficiency urgent. As a criterion of efficiency in this case we can select the maximum of operator's profit.

Multi-period design [3] refers to network design problems that span over a time horizon in terms of weeks to months, and sometimes even to several years. When we consider multiple periods, there are a few important issues to consider (besides the incremental demand volume):

1) The cost structure may change over time (e.g., due to economic discounting);
2) Demand routed in one time window may have maintenance cost in a subsequent time window;
3) The capacity expansion can happen over the entire time horizon.

In [4] proposed a method of WIMAX network planning with operator's profit maximization , which can be used as a basis for the development of our method multi-period LTE RAN planning with operator profit maximization.

Our work will be divided into several parts. The first article focuses on the optimization model synthesis of multi-period LTE RAN planning with operator profit maximization. The second article will analyze the effectiveness of the proposed method and peculiarities of its application will be identified.

In this article (first part), we describe an optimization model for the LTE RAN network planning problem. To do this, the physical and radio-electrical parameters relevant to the model are first identified and described. Such parameters are then associated with binary and semicontinuous decision variables. Logical relations, coverage, and capacity requirements are represented by linear inequalities in the decision variables. Parameters such as demands, the cost of installation and usage of equipment, the specific income from providing services may change over time in our optimization model.

MODEL FOR LTE NETWORK PLANNING

A standard model, suitable for planning purposes, identifies a wireless network with a set of transmitting and receiving antennas scattered over a territory. The network design process consists in establishing locations and suitable radio-electrical parameters of the antennas.

The network planning process requires an adequate representation of the territory. Such model can be represented as set of geometrical entities, namely test points (TP). In the TP model, a grid of approximately squared cells is overlapped to the target area. Antennas are supposed to be located in the center of test points: all information about customers and QoS in a TP, such as traffic demand and received signals quality, are aggregated into single coefficients. The TP model allows for smarter representations of the territory, of the actual antennas position, of the signal strengths, and of the demand distributions. For estimation of signal quality and channel throughput can be used Signal-Interference-Noise Rate (SINR).

Required SINR is the main performance indicator for LTE RAN. Cell edge is defined according to the Required SINR for a given cell throughput. Required SINR depends up on the following factors: Modulation and Coding Schemes (MCS); Propagation Channel Model.

$$SINR = \frac{1}{LinkLost(own)} \cdot \left[\sum_{k \neq own} \frac{1}{LinkLost(k)} + + \frac{CellBW}{MaxTxPwr} \cdot ThermNoiseDens \cdot RxNoiseFig \right]^{-1} \qquad (1)$$

$$SINR \geq \text{Required}\,SINR \text{ -} \qquad (2)$$

Using Required SINR indicator we make capacity planning.

OPTIMIZATION MODEL SYNTHESIS AND PROBLEM DEFINITION

LTE RAN can be represented as set of eNodeB which transmit information to UE. For planning goal we modeling UE as TP as described above. Denote it:

$A = \{a\}$ - set of test points, corresponding to a set of equal-sized square areas covering an area of the LTE RAN.

Each eNodeB typically consisting of a pylon accommodating a number of transceivers (TRX). Every TRX is characterized by a set of radio-electrical parameters as frequency channel, which belongs to a finite set of available channels, each having a constant bandwidth; emitted power at which TRX transmits on given frequency.

Process of creating a LTE RAN is a multi period, with a known number of stages K . Denode:

$Z = \{z\}$-s

et of transmitters that can be mounted on the eNodeB`s in locations candidates;

f – frequency channel is used to organize the radio link between the UE and eNodeB to the LTE RAN.

F – finite set of available channels;
W –constant bandwidth of frequency channels;
P_z^f – emitted power at which TRX $z \in Z$ transmits on given frequency $f \in F$.

In every site and for every frequency channel, it is possible to install either a single TRX, mounting an omni directional antenna, or several TRXs, each with a directive antenna. Note that the activation of a TRX may prevent the simultaneous activation of other potential TRXs in the same site and operating on the same frequency. This is the case, for example, of TRXs with similar azimuths. Define

$\varsigma = \{G_1, G_2, \ldots, G_{|\varsigma|}\}$ - a family of sets, where $G_i \subseteq Z, i = 1, \ldots |\varsigma|$, is a set of mutually exclusive TRXs.
Creation of LTE RAN is a multistep process with a limited budget. We write
K – number of periods
Q – Determination of the required level of costs
$c_z(k)$ –represent the overall cost of installation of TRX *z* over period *k*.
$c_z^f(k)$ - represent the usage cost of TRX *z,* which activated on frequency *f* over period *k.*
Demands from subscribers defined for every test point $a \in A$ and changes during creation of LTE RAN:
$h_a(k)$ - demand from subscribers of test point $a \in A$ during period *k.*

In providing services operator receives revenue per a unit volume $E(k)$. In this case revenie from served TP $a \in A$ can be defined as: $e_a(k) = E(k) \cdot h_a(k)$. (3)

LTE supports a number of combinations of modulation schemes and forward error correction (FEC) coding schemes [5]. These combinations are referred to as burst profiles. By defining different burst profiles, different spectral efficiencies can be reached [6]. For every profile $v \in V$ two parameters $v = (\mu_v, \varphi_v)$ are also introduced, where μ_v representing the SIR threshold that must be reached to ensure service coverage; and φ_v is the spectral efficiency [$\mathrm{bit}/\mathrm{s} \cdot \mathrm{Hz}$] associated with the burst profile.

We introduce sets of Boolean variables:

$$y_a(k) = \begin{cases} 1 \text{ if TT } a \in A \text{ is served at planning period } k, \\ 0 \text{ otherwise.} \end{cases} \tag{4}$$

$$x_z(k) = \begin{cases} 1 \text{ if TRX } z \in Z \text{ installed on planning period } k, \\ 0 \text{ otherwise.} \end{cases} \tag{5}$$

$$y_z^f(k) = \begin{cases} 1 \text{ if TRX } z \in Z \text{ use frequence channel } f \text{ at planning period } k, \\ 0 \text{ otherwise.} \end{cases} \tag{6}$$

$$x_{az}^{fv}(k) = \begin{cases} 1 \text{ if TT } a \in A \text{ is served by TRX } z \in Z \text{ on frequence } f \in F \\ \quad \text{with burst profile } v \in V \text{ at planning period } k, \\ 0 \text{ otherwise.} \end{cases} \tag{7}$$

We introduce also a set of variables:
$p_z^f(k)$ representing the power emitted by TRX $z \in Z$ on channel $f \in F$ at planning period *k*.

TRX $z \in Z$ can be activated of any frequency *f* only if it has installed before. This can be expressed by the following linear constraints:

$$\sum_{f\in F}\sum_{k=1}^{K} y_z^f(k) \le M\sum_{k=1}^{K} x_z(k), \quad z\in Z, \tag{8}$$

where$M$ – large constant.

TRX $z\in Z$ can be installed only one times:

$$\sum_{k=1}^{K} x_z(k) \le 1, \quad z\in Z, \tag{9}$$

A test point $a\in A$ can be served only if there exists at least one TRX *z* serving *a* on a frequency *f* with burst profile *v*, that is at least one variable $x_{az}^{fv}(k)=1$, for $z\in Z$, $f\in F$, $v\in V$. This can be expressed by the following linear constraints:

$$y_a(k) \le \sum_{z\in Z}\sum_{f\in F}\sum_{v\in V} x_{az}^{fv}(k), \quad a\in A, k=1..K. \tag{10}$$

If $x_{az}^{fv}(k)=1$, for some $z\in Z$, $f\in F$, $v\in V$, then TRX*z* must be activated on frequency *f*:

$$x_{az}^{fv}(k) \le y_z^f(k) \quad a\in A, z\in Z, f\in F, v\in V, k=1\ldots K. \tag{11}$$

The planning process requires the adoption of a propagation channel model (1), (2). Observe that if $x_{a\beta}^{fv}(k)=1$, for some $a\in A$, $\beta\in Z$, $f\in F$, $v\in V$, then *a* is served by *β* on frequency *f* with profile v and the corresponding SIR inequality (1), (2) must be satisfied. We can easily rewrite in the following linear form:

$$\gamma_{a\beta}\cdot p_\beta^f(k) - \mu_v \sum_{z\in Z\setminus\{\beta\}} \gamma_{az}\cdot p_z^f(k) + M\cdot\left(1 - x_{a\beta}^{fv}(k)\right) \ge \mu_v\cdot N, \tag{12}$$

where γ_{az} - overall strength attenuation $\gamma_{az}\in[0,1]$ from the center of the test point accommodating transmitter $z\in Z$ to the center of each TP $a\in A$; N - is the thermal noise; M – large constant.

When TP*a*served by LTE RAN, that is to say $x_{az}^{fv}=1$, then traffic occupies part of bandwidth *W*of channel*f*. The total bandwidth required to service consumed traffic must not exceed the bandwidth of communication channel:

$$\sum_{a\in A}\sum_{v\in V} h_a(k)\cdot\frac{1}{\varphi_v}\cdot x_{az}^{fv}(k) < W \quad z\in Z, f\in F, k=1\ldots K. \tag{13}$$

To prevent the activation of mutually exclusive TRXs, we introduce the following family of constraints:

$$\sum_{z\in G} y_z^f(k) \le 1, \; z\in Z, f\in F, k=1\ldots K. \tag{14}$$

In case if TRX *z* is not activated on frequency *f* then $p_z^f=0$. This can be expressed by

$$p_z^f(k) \le y_z^f(k)\cdot P_z^{\mathbf{max}}, \quad z\in Z, f\in F. \tag{15}$$

We need to add to a optimization model that describing the problem, the constraint of the budget allocation between periods. Expenses at each stage consists of the cost of installing new TRX: $\sum_{z\in Z} c_z(k)\cdot x_z(k)$ and usage cost of TRX *z*, which activated on frequency *f* : $\sum_{z\in Z} c_z^f(k)\cdot y_z^f(k)$. Thus for the total budget $q(k)$ for the *k*-th stage can be written:

$$q(k) = \sum_{z\in Z} c_z(k)x_z(k) + \sum_{f\in F}\sum_{z\in Z} c_z^f(k)y_z^f(k). \tag{16}$$

The total cost of creating the entire network LTE RAN must not exceed the maximum value of Q:

$$\sum_{k=1}^{K} q(k) \le Q. \tag{17}$$

In the process of planning a LTE RAN is necessary to find a network configuration to ensure maximum operator profit. That can be represented as follows

$$\sum_{k=1}^{K}\sum_{a\in A}E(k)\cdot h_a(k)-\sum_{k=1}^{K}\sum_{z\in Z}c_z(k)x_z(k)+\sum_{k=1}^{K}\sum_{z\in Z}\sum_{f\in F}c_z^f(k)y_z^f(k)\to\mathbf{max} \tag{18}$$

We are finally able to summarize the overall MILP formulation

$$\sum_{k=1}^{K}\sum_{a\in A}E(k)\cdot h_a(k)-\sum_{k=1}^{K}\sum_{z\in Z}c_z(k)x_z(k)+\sum_{k=1}^{K}\sum_{z\in Z}\sum_{f\in F}c_z^f(k)y_z^f(k)\to\mathbf{max}, \tag{19}$$

s.t.

$$\gamma_{a\beta}\cdot p_\beta^f(k)-\mu_v\sum_{z\in Z\setminus\{\beta\}}\gamma_{az}\cdot p_z^f(k)+M\cdot\left(1-x_{a\beta}^{fv}(k)\right)\geq\mu_v\cdot N,\ a\in A,\ \beta\in Z,\ f\in F,\ v\in V \tag{20}$$

$$y_a(k)\leq\sum_{z\in Z}\sum_{f\in F}\sum_{v\in V}x_{az}^{fv}(k),\quad a\in A, k=1..K \tag{21}$$

$$\sum_{a\in A}\sum_{v\in V}h_a(k)\cdot\frac{1}{\varphi_v}\cdot x_{az}^{fv}(k)<W\ \ z\in Z, f\in F, k=1\ldots K; \tag{22}$$

$$\sum_{z\in G}y_z^f(k)\leq 1,\ z\in Z, f\in F, k=1\ldots K; \tag{23}$$

$$x_{az}^{fv}(k)\leq y_z^f(k)\quad a\in A, z\in Z, f\in F, v\in V, k=1\ldots K \tag{24}$$

$$\sum_{f\in F}\sum_{k=1}^{K}y_z^f(k)\leq M\sum_{k=1}^{K}x_z(k),\quad z\in Z \tag{25}$$

$$\sum_{k=1}^{K}x_z(k)\leq 1,\quad z\in Z \tag{26}$$

$$p_z^f(k)\leq y_z^f(k)\cdot P_z^{\mathbf{max}},\quad z\in Z, f\in F, k=1\ldots K, \tag{27}$$

$$\sum_{k=1}^{K}\sum_{z\in Z}[c_z(k)x_z(k)+\sum_{f\in F}c_z^f(k)y_z^f(k)]\leq Q \tag{28}$$

$$y_a(k)\in\{0,1\},\qquad a\in A, k=1\ldots K \tag{29}$$

$$x_z(k)\in\{0,1\},\qquad z\in Z, k=1\ldots K \tag{30}$$

$$y_z^f(k)\in\{0,1\},\qquad z\in Z, f\in F, k=1\ldots K \tag{31}$$

$$x_{az}^{fv}(k)\in\{0,1\},\qquad a\in A, z\in Z, f\in F, v\in V, k=1\ldots K \tag{32}$$

To solve the problem (19)-(32) of mixed integer programming offered to use mathematical modeling and calculation software, such as ILOG CPLEX 12.0.

A BRIEF ANALYSIS OF THE PROPOSED OPTIMIZATION MODEL

The analysis of experiment's results showed that formulation of the problem, which is shown above and presented as a problem of MILP, allows to obtain the correct solutions from the practical point of view.

We performed a series of experiments for comparison of optimization models of single-period [4] and multi-period planning, which is offered by us. The experiment was performed at the following values of input data:

-values of time independent parameters were the same;

-values of time-dependent parameters ($c_z(k)$, $c_z^f(k)$, $h_a(k)$) for a single-period planning were equal to the values for the last period during multi-period planning ($c_z(K)$, $c_z^f(K)$, $h_a(K)$).

Comparing the values of the operator's profit during the single-period and multi-period planning showed that the profit margin under usage of the multi-period planning is 12% higher than under the single-period planning.

CONCLUSIONS

In this article, we presented an optimization model for the LTE RAN network planning problem. The major physical and radio-electrical parameters are identified and represented by the decision variables of a suitable mixed integer linear programming.

In order to get the optimization model of multi-period planning of LTE RAN it is needed to introduce set of parameters depended on the period number (such as cost of installation and usage of equipment, requirements; parameters that reflect the current configuration of the network) into the single-period planning model; add a single-installation conditions and condition that equipment is not activated prior to its installation. Experiment's results analysis showed that formulation of the problem, which is shown above and presented as a problem of MILP, allows to obtain the correct solutions from the practical point of view. We also need to modify the objective function of the optimization model to account for changes over time in the cost parameters.

Comparing the operator's profit during the single-period and multi-period planning showed that usage of multi-period planning increase the profit margin to 12% than the single-period planning.

REFERENCES

1. Rumney M; LTE and the Evolution to 4G Wireless: Design and Measurement Challenges.Wiley, 2013:648.
2. Abdul Basit, Syed; Dimensioning of LTE Network: Description of Models and Tool, Coverage and Capacity Estimation of 3GPP Long Term Evolution radio interface. Masters Thesis submitted in Helsinki University of Technology, 2009:61.
3. MichaPióro, Deepankar Medhi; Routing, Flow, and Capacity Design in Communication and Computer Networks. Elsevier, 2004:765.
4. Yan Zhang;WiMAX Network Planning and Optimization (1st ed.).Auerbach Publications, Boston, MA, USA, 2009:451.
5. Andrews JG, Ghosh A, Muhamed R; Fundamentals of WiMAX: Understanding Broadband Wireless Networking (Prentice Hall Communications Engineering and Emerging Technologies Series).Prentice Hall PTR, Upper Saddle River, NJ, USA, 2007:496.
6. Intel in Communications Adaptive Modulation (QPSK, QAM), Intel White Papers on WiMAX, http://www.intel.com/technologies/wimax, 2004.