LTE RAN and Services Multi-Period Planning

Dmytro Ageyev
Telecommunication Systems Department
Kharkiv National University of Radio Electronics

Kharkiv, Ukraine
dm@ageyev.net

Ali Al-Ansari
Telecommunication Systems Department
Odessa National Academy of Telecommunications
named after O.S.Popov
Odesa, Ukraine
ali_eng87@yahoo.com

Abstract— **This paper proposes an optimization model for the LTE RAN network planning that aimed to accounting of ser-vices multi-period planning. The analysis of experiments results showed that formulation of the problem, which is shown in paper and presented as a problem of MILP, allows to obtain the correct solutions from the practical point of view. Comparison of the result showed that usage of multi-period network and services planning increase the profit margin to 10% more than the proposed by us previously method.**

Keywords— LTE RAN, multi-period planning, service, optimization model

I. Introduction

The Long Term Evolution (LTE) is a step toward the 4th generation (4G) of mobile radio technologies to increase the spectral efficiency and to obtain higher throughput. During the design of telecommunications systems is necessary to ensure coherent solution of problems such as the choice of the topology, the selection channel capacity, routing and flow distribution [1]. 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 [2] refers to network design problems that span over a time horizon in terms of weeks to months, and sometimes even to several years.For realization provision of services in the network, in addition to creating a network infrastructure that provides the traffic transmission, you must also install equipment for service delivery and ensure its configuration. Services providing planning is important patch of LTE RAN creating process. In [3] we are proposed method for solving multi-period LTE RAN planning problem, but this method did not take in account services which provided in network.

This conference paper offers the modification of the proposed by us previously method [3, 4] directed to elimination these shortcomings.

II. Optimization Model Synthesis and Problem Definition

LTE RAN can be represented as set of eNodeB which transmit information to UE.

Let`s denote:

$A = \{a\}$ - set of test points (TP) [5], which covering an area of the LTE RAN.

$Z = \{z\}$ - set 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 $f \in F$.

$\varsigma = \{G_1, G_2, \ldots, G_{|\varsigma|}\}$ - 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 – network creation budget;

$c_z(k)$ – 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.*

$V = \{v\}$ - set of profiles [6, 7], $v = (\mu_v, \varphi_v)$, where

μ_v representing the SIR threshold that must be reached to ensure service coverage;

φ_v is the spectral efficiency [$\mathrm{bit}/\mathrm{s \cdot Hz}$] associated with the burst profile.

For LTE RAN multi-period network planning necessary to form step by step plan for service providing. Thereby we define next additional variables for our base optimization model [3, 4].

$S = \{s\}$ - set of services which planning for providing in our LTE network;

Each service characterized by several parameters such.

h^s - traffic arising in the network when providing service *s* in a unit volume;

e^s - revenue per a unit which operator receives when provide service in LTE network;

$q_a^s(k)$ - predicted demand (service units) from subscribers of test point a during planning period k for service s.

The total operator revenue from served test point a can be defined as

$$e_a^s(k) = e^s q_a^s(k).$$

During planning process we need to define the set of test point, which are served and set of service for each test point a during period k.

We introduce sets of Boolean variables:

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

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

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

$$x_a^s(k) = \begin{cases} 1 \text{ if service } s \in S \text{ is provided for TP } a \in A \\ \text{at planning period } k, \\ 0 \text{ otherwise.} \end{cases}$$

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

and real variable

$x_{az}^{sfv}(k)$ - traffic proportion of service $s \in S$, which is transmitted to TRX $z \in Z$ from the subscriber $a \in A$ on frequency $f \in F$ with burst profile $v \in V$ at period k.

$p_z^f(k)$ representing the power emitted by TRX $z \in Z$ on channel $f \in F$ at planning period k.

Dependence between variables can be described by next set of conditions.

TRX $z \in Z$ can be activated of any frequency f only if it has installed before.

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

where M – large constant.

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

$$\sum_{k=1}^{K} x_z(k) \le 1, \quad z \in Z. \tag{2}$$

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.

$$y_a(k) \le \sum_{z \in Z} \sum_{f \in F} \sum_{v \in V} x_{az}^{fv}(k), \quad a \in A, k = 1..K. \tag{3}$$

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.

$$x_{az}^{fv}(k) \le y_z^f(k) \quad a \in A, z \in Z, f \in F, v \in V, k = 1\ldots K. \tag{4}$$

Propagation channel model for case, when, a is served by $\beta \in Z$ on frequency f with profile v ($x_{a\beta}^{fv}(k) = 1$) can presented as inequality.

$$\gamma_{a\beta} \cdot p_\beta^f(k) - \mu_v \sum_{z \in Z \setminus \{\beta\}} \gamma_{az} \cdot p_z^f(k) + M \cdot \left(1 - x_{a\beta}^{fv}(k)\right) \ge \mu_v \cdot N, \tag{5}$$

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.

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

$$\sum_{z \in G} y_z^f(k) \le 1, \quad z \in Z, f \in F, k = 1\ldots K. \tag{6}$$

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

$$p_z^f(k) \le y_z^f(k) \cdot P_z^{\max}, \quad z \in Z, f \in F. \tag{7}$$

Expenses at each stage consists of the cost of installing new TRX and usage cost of TRX z, which activated on frequency f. Total budget $q(k)$ for the k-th stage is

$$q(k) = \sum_{z \in Z} c_z(k) x_z(k) + \sum_{f \in F} \sum_{z \in Z} c_z^f(k) y_z^f(k). \tag{8}$$

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

$$\sum_{k=1}^{K} q(k) \le Q. \tag{9}$$

Traffic, which arises in network, can be found as

$$h_a^s(k) = h^s q_a^s(k) x_a^s(k). \tag{10}$$

The service $s \in S$ is provided for test point $a \in A$ only if this test point is served at planning period k

$$\sum_{s \in S} x_a^s(k) \le M \cdot y_a(k), \; a \in A. \tag{11}$$

For traffic proportion must be true next condition

$$\sum_{s \in S} \sum_{f \in F} \sum_{v \in V} x_{az}^{sfv} = x_a^s, \quad \forall a \in A, s \in S. \tag{12}$$

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:

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

or

$$\sum_{a\in A}\sum_{v\in V}\sum_{s\in S} h^s q_a^s(k)\cdot\frac{1}{\varphi_v}\cdot x_{az}^{sfv}(k) < W\ ,$$
$$z\in Z, f\in F, k=1\ldots K\ , \qquad (14)$$

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

$$\sum_{k=1}^{K}\sum_{a\in A}\sum_{s\in S} e^s q_a^s(k) x_a^s - \sum_{k=1}^{K}\sum_{z\in Z} c_z(k) x_z(k) -$$
$$-\sum_{k=1}^{K}\sum_{z\in Z}\sum_{f\in F} c_z^f(k) y_z^f(k) \to \max\ . \qquad (15)$$

First part of (15) is operator profit, another parts are installation cost of TRX and its usage cost, which activated on some frequency.

III. Brief Analysis of the Proposed Optimization Model

Experimental investigation of the effectiveness and correctness of our optimization model was carried out on the basis of input data generated randomly. The experiment was repeated several times with different numbers of nodes in LTE RAN network.

To solve the mixed integer programming problem offered to use mathematical modeling and calculation software, such as ILOG CPLEX 12.0.

Our experiments was performed at the same values of input data. Input data related to the planning of services chosen as follows method. For basic optimization model [3] demand from subscribers of test point during period *k*. were equal to demands for the case when all services will be provided.

The analysis of experiment's results showed that modified by us optimization model for LTE RAN planning problem allows to obtain the correct solutions from the practical point of view.

TABLE I. Results comparison

Network size (sites / Test points)	Profit margin	
	LTE RAN MPP	*LTE RAN and Services MPP*
2 / 64	0 %	0 %
5 / 91	0 %	4 %
7 / 91	4 %	8 %
8 / 100	7 %	10 %
11 / 256	9 %	12 %

Comparing the values of the operator's profit values that obtained during planning based on our previous optimization model and on modified model showed that the profit margin under usage of modified optimization model is 12% higher than for basic model.

IV. Conclusion

This paper proposes an optimization model for the LTE RAN network planning that improvement of our previous method and aimed to accounting of services multi-period planning. The major physical, radio-electrical and planning parameters are identified and represented by the decision variables of a suitable mixed integer linear programming.

In order to get the optimization model with services multi-period planning it is needed to add in our previous model set of parameters that describes services, revenue and traffic characteristics; add a condition that service is provided for test point only if this test point is served, condition for traffic proportion and condition that traffic occupies part of bandwidth of channel, which not exceed the bandwidth of communication channel. We also need to modify the objective function of the optimization model to account services providing revenues.

Comparing the values of the operator's profit values that obtained during planning based on our previous optimization model and on modified model showed that the profit margin under usage of modified optimization model is 12% higher than for basic model.

References

[1] M. Resende and P. Pardalos, *Handbook of optimization in telecommunications*. New York: Spinger Science + Business Media, 2006.

[2] M. Pióro and D. Medhi, *Routing, Flow, and Capacity Design in Communication and Computer Networks*, Elsevier, 2004

[3] D.V. Ageyev and Ali Al-Anssari, "Multi-Period LTE RAN Planning with Operator Profit Maximization (Part 1: Optimization Model Synthesis)", *Sch. J. Eng. Technol*. vol. 2, no. 5B, pp. 774-779, 2014.

[4] D.V. Ageyev and Ali Al-Anssari, "Optimization Model for Multi-Time Period LTE Network Planning in *First International Scientific-Practical Conference Problems of Infocommunications. Science and Technology. PIC S&T`2014*, Kharkiv: Kharkiv National University of Radioelectronics, 2014, pp. 29-30.

[5] Yan Zhang, *WiMAX Network Planning and Optimization*. Auerbach Publications, Boston, MA, USA, 2009.

[6] J.G. Andrews, A. Ghosh and R. Muhamed *Fundamentals of WiMAX: Understanding Broadband Wireless Networking*, Prentice Hall PTR, Upper Saddle River, NJ, USA, 2007.

[7] Intel in Communications Adaptive Modulation (QPSK, QAM), Intel White Papers on Wi-MAX, http://www.intel.com/technologies/wimax, 2004.