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OPTIMIZATION MODEL FOR MULTI-PERIOD LTE RAN AND SERVICES PLANNING WITH OPERATOR PROFIT MAXIMIZATION

The LTE RAN creation of a network is not an instantaneous process; it typically goes stage by stage. 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. The proposed by us previously method did not take in account services, which provided in network. This article 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 analysis of experiments results showed that formulation of the problem, which is shown in article 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 pro-posed by us previously method.

Keywords: *LTE RAN, multi-period planning, service, optimization model.*

Introduction

Rapid development of information technologies and their wide dissemination puts high requirements to telecommunication systems. We can satisfy these high requirements for telecommunication systems not only through the development of network management methods, but through the development of design methods.

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].

The Long Term Evolution (LTE), also known as Evolved Universal Terrestrial Radio Access (E-UTRA), is a step toward the 4th generation (4G) of mobile radio technologies to increase the spectral efficiency and to obtain higher throughput.

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 article offers the modification of the proposed by us previously method [3] directed to elimination these shortcomings.

Base Optimization Model Description

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

Similarly to our previous problem [3] let`s denote:

$A = \{a\}$ – set of test points (TP) [4], 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 $f \in F$.

$\varsigma = \left\{G_1, G_2, \ldots, G_{|\varsigma|}\right\}$ – 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 [5, 6], $v = (\mu_v, \varphi_v)$, where

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

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

We introduce sets of Boolean variables:

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

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

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

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

$p_z^f(k)$ 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:

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

Base Optimization Model Modification

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].

$S = \{s\}$ – 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

$$e_a^s(k) = e^s q_a^s(k). \tag{10}$$

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 Boolean variable

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

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.

Traffic, which arises in network, can be found as

$$h_a^s(k) = h^s q_a^s(k) x_a^s(k)\,. \qquad (11)$$

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

$$\sum_{s \in S} x_a^s(k) \le M \cdot y_a(k)\,,\ a \in A\,. \qquad (12)$$

For traffic proportion must be true next condition

$$\sum_{s \in S}\sum_{f \in F}\sum_{v \in V} x_{az}^{sfv} = x_a^s, \quad \forall a \in A, s \in S\,. \qquad (13)$$

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:

$$\sum_{a \in A}\sum_{v \in V}\sum_{s \in S} h_a^s(k) \cdot \frac{1}{\varphi_v} \cdot x_{az}^{sfv}(k) < W\,,$$

$$z \in Z, f \in F, k = 1\ldots K\,, \qquad (14)$$

or

$$\sum_{a \in A}\sum_{v \in V}\sum_{s \in S} h^s q_a^s(k) \cdot \frac{1}{\varphi_v} \cdot x_{az}^{sfv}(k) < W\,,$$

$$z \in Z, f \in F, k = 1\ldots K\,. \qquad (15)$$

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

$$\sum_{k=1}^{K}\sum_{a \in A}\sum_{s \in S} e^s q_a^s(k) x_a^s - \sum_{k=1}^{K}\sum_{z \in Z} c_z(k) x_z(k) -$$

$$-\sum_{k=1}^{K}\sum_{z \in Z}\sum_{f \in F} c_z^f(k) y_z^f(k) \to \max\,. \qquad (16)$$

First part of (16) is operator profit, another parts are installation cost of TRX and its usage cost, which activated on some frequency.

Final Optimization Model and Problem Definition

We are finally able to summarize the overall MILP formulation

$$\sum_{k=1}^{K}\sum_{a \in A}\sum_{s \in S} e^s q_a^s(k) x_a^s - \sum_{k=1}^{K}\sum_{z \in Z} c_z(k) x_z(k) -$$

$$-\sum_{k=1}^{K}\sum_{z \in Z}\sum_{f \in F} c_z^f(k) y_z^f(k) \to \max\,, \qquad (17)$$

s.t.

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

$$a \in A\,,\ \beta \in Z\,,\ f \in F\,, v \in V\,, \qquad (18)$$

$$y_a(k) \le \sum_{z \in Z}\sum_{f \in F}\sum_{v \in V} x_{az}^{fv}(k), \quad a \in A, k = 1..K\,. \qquad (19)$$

$$\sum_{a \in A}\sum_{v \in V}\sum_{s \in S} h^s q_a^s(k) \cdot \frac{1}{\varphi_v} \cdot x_{az}^{sfv}(k) < W\,,$$

$$z \in Z, f \in F, k = 1\ldots K\,; \qquad (20)$$

$$\sum_{z \in G} y_z^f(k) \le 1, \quad z \in Z, f \in F, k = 1\ldots K\,; \qquad (21)$$

$$x_{az}^{fv}(k) \le y_z^f(k) \quad a \in A, z \in Z, f \in F, v \in V, k = 1\ldots K\,. \qquad (22)$$

$$\sum_{f \in F}\sum_{k=1}^{K} y_z^f(k) \le M \sum_{k=1}^{K} x_z(k), \quad z \in Z\,, \qquad (23)$$

$$\sum_{k=1}^{K} x_z(k) \le 1, \quad z \in Z\,, \qquad (24)$$

$$\sum_{s \in S} x_a^s(k) \le M \cdot y_a(k)\,, \qquad a \in A\,; \qquad (25)$$

$$\sum_{s \in S}\sum_{f \in F}\sum_{v \in V} x_{az}^{sfv} = x_a^s \qquad \forall a \in A, s \in S\,; \qquad (26)$$

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

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

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

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

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

$$x_a^s(k) \in \{0,1\}\,, \qquad a \in A, s \in S\,, k = 1\ldots K\,; \qquad (32)$$

$$x_{az}^{fv}(k) \in \{0,1\}\,, \quad a \in A, z \in Z, f \in F, v \in V\,,$$

$$k = 1\ldots K\,. \qquad (33)$$

To solve the mixed integer programming problem (17) – (33) offered to use mathematical modeling and calculation software, such as ILOG CPLEX 12.0.

A 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.

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.

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 $h_a(k)$ from subscribers of test point $a \in A$ during period k. were equal to demands for the case when all services will be provided (case when $x_a^s(k) = 1, \forall s \in S$):

$$h_a(k) = \sum_{s \in S} h^s q_a^s(k)\,.$$

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.

Conclusions

This article 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.

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.

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.

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ОПТИМІЗАЦІЙНА МОДЕЛЬ ДЛЯ РОЗВ'ЯЗАННЯ ЗАДАЧІ БАГАТОЕТАПНОГО ПЛАНУВАННЯ LTE RAN МЕРЕЖІ ТА ВПРОВАДЖЕННЯ ПОСЛУГ З МАКСИМІЗАЦІЄЮ ПРИБУТКУ ОПЕРАТОРА

Д.В. Агеєв, Алі Аль-Ансарі, Намір Касім

Створення LTE RAN мережі не є однокроковим процесом. Як правило розгортання мережі, йде поетапно. Для забезпечення реалізації послуг в мережі, на додаток до створення мережевої інфраструктури, яка забезпечує передачу трафіку, необхідно також встановити обладнання для надання послуг і провести його конфігурування. Пропонований нами раніше метод не враховував наявність в створюваної мережі безлічі послуг і необхідність складання плану їх поетапного впровадження. У цій статті пропонується синтез оптимізаційної моделі для вирішення задачі багатоетапного структурно-параметричного синтезу LTE RAN мережі, і є подальшим розвитком нашого попередніх методу за рахунок обліку безлічі послуг в мережі і складання плану їх поетапного впровадження. Аналіз результатів експериментів показав, що постановка задачі, яка представлена в статті як проблема змішаного цілочисельного лінійного програмування, дозволяє отримувати коректні рішення з практичної точки зору. Порівняння результатів показало, що використання запропонованої математичної моделі задачі дозволяє збільшити прибуток на 10% в порівнянні з базовим методом.

Ключові слова: *LTE RAN, багатоетапне планування, послуга, оптимізаційна модель.*

ОПТИМИЗАЦИОННАЯ МОДЕЛЬ ДЛЯ РЕШЕНИЯ ЗАДАЧИ МНОГОЭТАПНОГО ПЛАНИРОВАНИЯ LTE RAN СЕТИ И ВНЕДРЕНИЯ УСЛУГ С МАКСИМИЗАЦИЕЙ ПРИБЫЛИ ОПЕРАТОРА

Д.В. Агеев, Али Аль-Ансари, Намир Касим

Создание LTE RAN сети не является одношаговым процессом. Как правило развертывание сети, идет поэтапно. Для обеспечения реализации услуг в сети, в дополнение к созданию сетевой инфраструктуры, которая обеспечивает передачу трафика, необходимо также установить оборудование для оказания услуг и произвести его конфигурирование. Предлагаемый нами ранее метод не учитывал наличие в создаваемой сети множества услуг и необходимость составления плана их поэтапного внедрения. В этой статье предлагается синтез оптимизационной модели для решения задачи многоэтапного структурно-параметрического синтеза LTE RAN сети, и является дальнейшим развитием нашего предыдущих метода за счет учета множества услуг в сети и составления плана их поэтапного внедрения. Анализ результатов экспериментов показал, что постановка задачи, которая представлена в статье как проблема смешанного целочисленного линейного программирования, позволяет получать корректные решения с практической точки зрения. Сравнение результатов показало, что использование предложенной математической модели задачи позволяет увеличить прибыль на 10% в сравнении с базовым методом.

Ключевые слова: *LTE RAN, многоэтапное планирование, услуга, оптимизационная модель.*