UDC 621.397

THE METHOD OF OPTIMAL SYNTHESIS OF THE BROADBAND SUBSCRIBER ACCESS NETWORK

Nikityuk Lesya, Tsaryov Roman, Lavreka Kateryna, Shulakova Kateryna

O. S. Popov Odesa national academy of telecommunications,
1 Kuznechna St., Odessa, 65029, Ukraine
lesyanikityuk579@gmail.com, c4r1980@gmail.com

МЕТОД ОПТИМАЛЬНОГО СИНТЕЗУ ШИРОКОСМУГОВОЇ МЕРЕЖІ АБОНЕНТСЬКОГО ДОСТУПУ

Нікітюк Л. А., Царьов Р. Ю., Лаврека К. Д., Шулакова К. С.

Одеська національна академія зв'язку ім. О.С. Попова,
65029, Україна, м. Одеса, вул. Кузнечна, 1.
lesyanikityuk579@gmail.com, c4r1980@gmail.com

МЕТОД ОПТИМАЛЬНОГО СИНТЕЗА ШИРОКОПОЛОСНОЙ СЕТИ АБОНЕТСКОГО ДОСТУПА

Никитюк Л. А., Царёв Р. Ю., Лаврека Е. Д., Шулакова Е. С.

Одесская национальная академия связи им. А.С. Попова,
65029, Украина, г. Одесса, ул. Кузнечная, 1.
lesyanikityuk579@gmail.com, c4r1980@gmail.com

Abstract. The proposed method is actualized for the optimal synthesis of a subscriber access network during its reconstruction in order to ensure broadband availability and accessibility to new services that require high transmission rates. The task of reconstructing the subscriber access network using FTTC technology and the equipment of "active cabinets" has been set up and formalized in terms theory of graph. The method for solving the problem is proposed, which ensures the determination of the optimal number of active cabinets in and the achievement of a minimum of the total length of cable routes. The method had been tested in the framework of the all-Ukrainian project of Ukrtelecom and involves the dismantling of classic automatic telephone system (PBX/DPBX) and the organization of a network infrastructure using so-called "active cabinets" based on FTTC (Fiber-to-the-Curb) technology. From the cabinet to the subscribers copper cables can be used, and fiber-optic lines using any modern access technology (ADSL, VDSL, FTTB, FTTH, PON). As a result, the subscriber receives not only high speeds, but also access to new services (digital telephony, interactive TV, "cloud" solutions etc).

Key words: optimal synthesis of subscriber access network, reconstruction of the network, FTTC, technology, optimization of placement of "active cabinets.

Анотація. В роботі пропонується метод оптимального синтезу широкосмугової мультисервісної мережі абонентського доступу, яка надасть користувачам можливість отримати доступ до нових сучасних послуг, що висувають більш високі вимоги до швидкостей передавання даних. Метод забезпечує ефективне проведення реконструкції мереж абонентського доступу на базі концепції Fiber to the Cube (FTTC) з використанням технології «активних шаф». Поставлена задача оптимального синтезу широкосмугової мультисервісної мережі абонентського доступу формалізована у термінах теорії графів. Запропоновано метод розв'язання зазначеної задачі, який дозволяє визначати оптимальну кількість та місця розташування специфічного мережного обладнання, так званих «активних шаф», за умови мінімізації загальної довжини кабельних трас мережі та місця розташування шлюзів до транспортної мережі. Метод оптимального синтезу широкосмугової мультисервісної мережі абонентського доступу формалізовано у вигляді алгоритму. Запропонований метод було використано в Україні національним оператором електрозв'язку ПАТ «Укртелеком» під час реконструкції мереж доступу, що проводиться у межах всеукраїнського проекту B6, який передбачає демонтаж класичних АТС/РАТС та організацію мережевої інфраструктури на базі FTTC з використанням в якості точки підключення абонентів «активних шаф». Абоненти можуть підключатися до шафи за допомогою будь-якої сучасної технології доступ (ADSL, VDSL, FTTB, FTTH, PON), внаслідок чого абоненти отримують значно більші швидкості та можливість споживати нові послуги (інтерактивні сервіси, хмарні «послуги» тощо).

Ключові слова: оптимальний синтез мережі абонентського доступу, технологія FTTC, реконструкція мережі, оптимізація розташування «активних шаф», граф.модель.

Аннотация. В работе предлагается метод оптимального синтеза широкополосной мультисервисной сети доступа, которая предоставляет пользователям доступ к новым современным услугам, которые требуют более высоких скоростей передачи данных. Метод обеспечивает эффективное проведение реконструкции сетей абонентского доступа на базе концепции Fiber to the Cube (FTTC) с использованием технологи «активных шкафов». Поставленная задача оптимального синтеза широкополосной мультисервисной сети формализована в терминах теории графов. Предложено метод решения данной задачи, который позволяет определить оптимальное количество и место расположения «активных шкафов», при условии минимизации общей длины кабельных трасс сети и место расположения шлюзов к транспортной сети. Метод формализован в виде алгоритма. Предложенный метод был использован в Украине национальным оператором электросвязи ЧАО «Укртелеком» во время реконструкции, которая проводится в рамках всеукраинского проекта В6, который предусматривает демонтаж классических АТС/РАТС и организацию сетевой инфраструктуры на базе FTTC с использованием в качестве точки подключения абонентов «активных шкафов» Абоненты могут подключаться к шкафу с помощью любой современной технологии доступа (ADSL, VDSL, FTTB, FTTH , PON, в следствии этого они получают значительно более высокие скорости и возможность потреблять новые услуги (интерактивные сервисы, облачные «сервисы» и т.д.).

Ключевые слова: оптимальный синтез сети абонентского доступа, реконструкция сети, технология FTTC, оптимизация размещения «активных шкафов», граф, модель.

The modernization of telecommunications networks carried out in Ukraine within the framework of the all-Ukrainian project of Ukrtelecom involves the dismantling of classic ATS/RATS and the organization of a network infrastructure using so-called “active cabinets” based on FTTC (Fiber-to-the-Curb) technology, which allows each cabinet to be connected with an optical cable (Fig 1). From the cabinet to the subscribers copper cables can be used, and fiber-optic lines using any modern access technology (ADSL, VDSL, FTTB, FTTH, PON). As a result, the subscriber receives not only high speeds, but also access to new services (digital telephony, interactive TV, “cloud” solutions, etc).

The guarantee of ensuring the required transmission speed is in compliance with the condition that the distance from the cabinet to the subscriber does not exceed 500 m. Since only part of the objects of the area serviced earlier by one DPBX can be connected to one active cabinet, when establishing a regional broadband subscriber access network, the problem arises of finding the optimal number of cabinets for a given area.

The **task of optimal synthesis** of a broadband subscriber access network in the specified conditions of its reconstruction is as follows:

– determination of the necessary and sufficient number and location of active cabinets for connection of subscriber lines, subject to the conditions for limiting the distance from the subscriber to the cabinet and the capacity (the number of ports for connecting subscriber lines) of one cabinet;

– finding the configuration of a ring network that joins the active cabinets of a given area, subject to minimizing the total length of cable routes;

– determination of the location of the active cabinet in which it is advisable to locate a gateway that provides the interface between the optical fiber ring of the regional network of subscriber access and the city optical network.

The consecutive reconstruction of subscriber access networks in all districts of the city or region and the use of fiber optic cable on the METRO scale will provide a complete reconstruction of the telecommunications network both at the access level and at the kernel level (see Fig. 1).

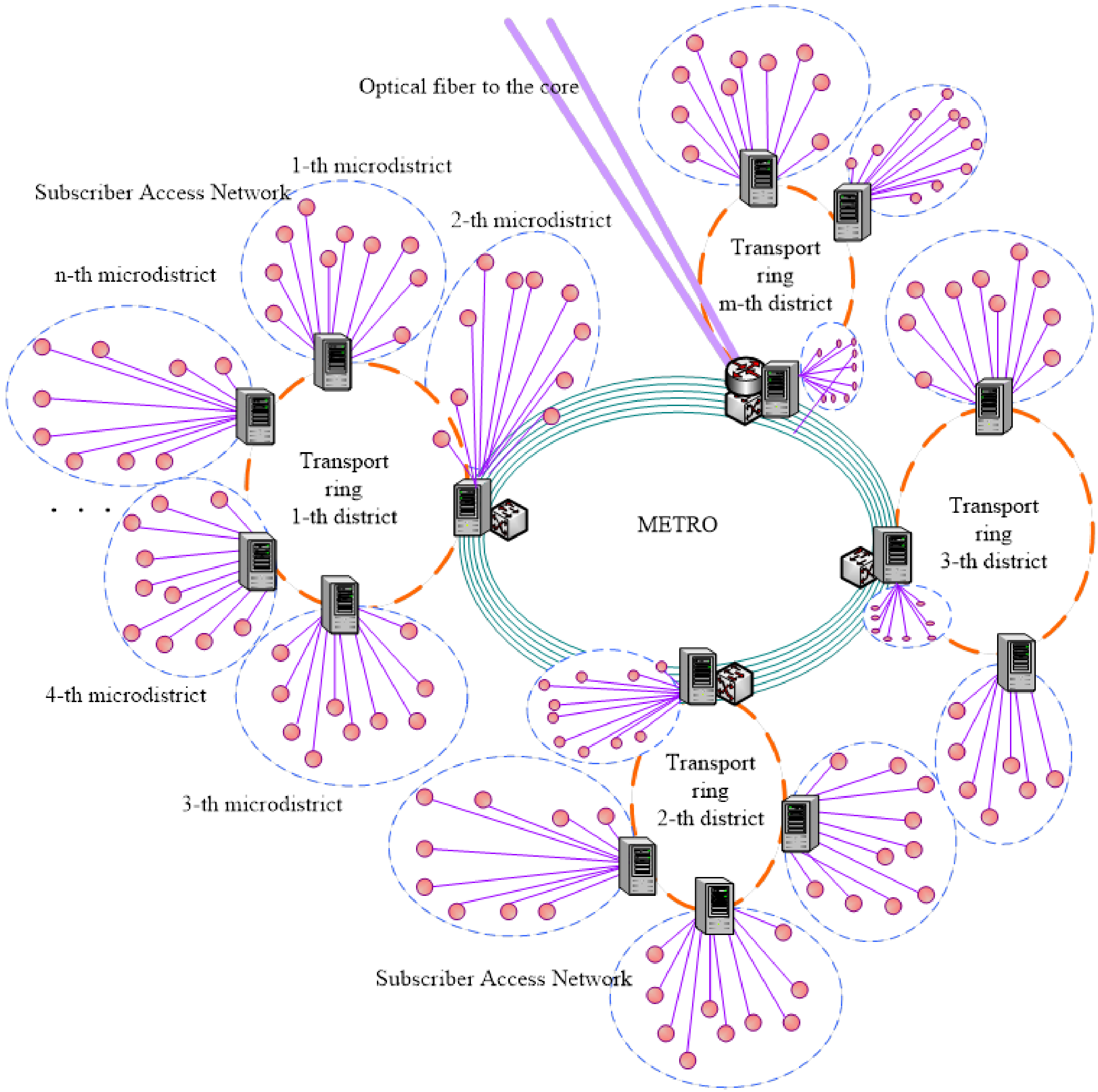

Figure 1 – Metro telecommunications network based on the concept of “active cabinets"

The **purpose of this work** is to build a mathematical model for the optimal synthesis of a broadband subscriber access network, which guarantees finding the required number of active cabinets for a given area, subject to minimization of the total length of cable lines and developing a method for solving it.

The task of optimal synthesis of a broadband subscriber access network in the above-mentioned conditions for its reconstruction can be formalized in terms of graph theory as follows [1].

Let the initial regional network be represented as a fully connected weighted undirected graph *G (N,E),* in correspondence to the variety of vertices *N,* the power *n,* of which the residential objects of the district are delivered, and the variety of edges *E* , the power of *e* - the length of the paths between the objects along which there can be laid lines of communication. As weight characteristics $\{A_i\}$ the vertices of the graph are assigned the number of subscribers in *i*-th residential object ($i \in N$, $i = 1, \ldots, n$), and as weight characteristics of the edges $\{r_{ij}\}$ the distance between the vertices of the graph along permissible lines of laying cable lines.

It is required to synthesize a network representable by the graph $G^*(N^*,E^*)$, where *of* N^*-vertices variety of power *n,* in accordance with which the residential objects of the district (points of the network) are placed, including *k* locations for the desired number of active cabinets, and E^* is the set of edges with capacity e^*, in accordance with which the required lengths of cable lines connecting the objects are delivered.

The graph G^* is a subgraph of the original graph *G,* the distinctive structural feature of which is the fact that it represents the variety of *K*, the power *k* , the subnets of subscriber connection to the active cabinets, the integrated ring network, i.e.

$$G^* \subset (G_1^*, \dots, G_i^*, \dots G_k^*) \cup G^*(K),$$

where - subnet graph of the *i*- th active cabinet (*i* = 1, 2, ..., *k*); $G^*(K)$ - subgraph of the desired network combining the desired variety of active cabinets.

When finding the desired number of *k* active cabinets for a specific district and constructing the corresponding subnets G_i^* (*i* = 1, 2, …, *k*), the following allowances and limitations are taken into account:

– the position points of active cabinets coincide with the corresponding vertices of the graph G^*. In one vertex, more than one cabinet can be located;

– the network graph combining the vertices in which the desired active cabinets are located has the configuration of a cycle of the smallest length;

– distance $L = r_{ij}$ from the subscriber to the active cabinet must not exceed the maximum allowable L_{max};

– the number of ports *D* involved in one active cabinet, determined by the total number of subscriber lines from objects to the cabinet, must not exceed the maximum allowable D_{max}.

The task of optimal synthesis of the reconstructed network of subscriber access can be formulated in the following form:

1. Find the minimum of the objective function:

$$\gamma = \sum_{i \in K} \sum_{j \in N_i^*} r_{ij} + \sum_{l,m \in K} \sum r_{lm} \rightarrow min\,, \tag{1}$$

where N_i^* is the number of vertices of the subgraph $G_i^*,\ N_i^* \subset N^*,\ \ i = 1, \dots, k$.

2. Under the following limitations:

$$D(i) = A_i + \sum A_j \le D_{max} \quad i \ne j, \quad i = 1, \dots k, \tag{2}$$

$$L = r_{ij} \le L_{max} \quad \forall (i,j) \in G^*. \tag{3}$$

The solution of this task can is provided as a result of the following step-by-step procedures [2].

Step 0. We form the matrix $R = \|r_{ij}\|,$ of dimensions ($n \times n$) whose elements correspond to the weight characteristics of the edges of the initial graph *G.* Let be a vector whose elements are the weight characteristics vertices of the graph *G.* We assume: $K = \emptyset\ ,\ N_i^* = \emptyset\ ,\ i = 1, 2 \dots;$ $L = 0;\ D(i) = 0,\ i = 1,2 \dots$.

Step 1. In the matrix *R* we find the element r_{ij} with the smallest value. We check condition (3) of the task.

If the limitation is satisfied, we assume $D(i) = A_i$ and vertex *i* becomes the location of the active cabinet, i.e. $i \in K, i \in N_i^*$. Go to step 2, otherwise - go to step 5.

Step 2. For vertex *i* we check condition:

$$D(i) = D(i) + A_j \leq D_{max}. \tag{4}$$

If the limitation is not satisfied at point *i* you can arrange two active cabinets, the value D_{max} while doubling. Go to step 3.

Step 3. We assume $i, j \in N_i^*$, edge(i, j) belongs to the graph G_i^* , and all elements *j*- th column and *j*- th row of the matrix *R* is assigned the values "∞".

Step 4. In the row *i* of the matrix *R* we search an element r_{ij} with the smallest value for which we check condition (3) of the task.

In case of non-fulfillment of the limitation (3), go to step 1.

If limitation (3) is satisfied, to the value *D* (*i*) for the vertex *i* we add the value A_j, and we check condition (4).

If condition (4) is satisfied, go to step 3, otherwise go to step 1.

Step 5. If $K \neq \emptyset$ we find the cycle of the smallest length [4] (determine the configuration of the ring network) for the variety of vertices K, which are the desired points of the location of active cabinets for in a given district. Otherwise, go to step 7.

Step 6. If $N_i^* \neq \emptyset$ and $E_i^* \neq \emptyset \;\; i = 1, \dots, k$, we calculate the total length L_1^{Σ} edges of all formed subgraphs $G_i^* i = 1, \dots, k$:

$$L_1^{\Sigma} = \sum\sum_{(i,j) \in G_1^*} r_{ij} + \sum\sum_{(i,j) \in G_2^*} r_{ij} + \dots + \sum\sum_{(i,j) \in G_k^*} r_{ij}. \tag{5}$$

Calculate the total length L_2^{Σ} edges of the cycle $G^*(K)$:

$$L_2^{\Sigma} = \sum_{i=1}^{k}\sum_{j=1}^{k} r_{ij}. \tag{6}$$

Calculate the total length of all edges of the graph G^*:

$$L^{\Sigma} = L_1^{\Sigma} + L_2^{\Sigma}. \tag{7}$$

Step 7. The end of the algorithm.

In the active cabinet, where the number of ports involved is the smallest and, consequently, a smaller amount of equipment, a gateway can be installed that allows the optical fiber ring of the regional subscriber access network to be interfaced with the urban optical network.

Fig. 2 shows the block diagram of the algorithm.

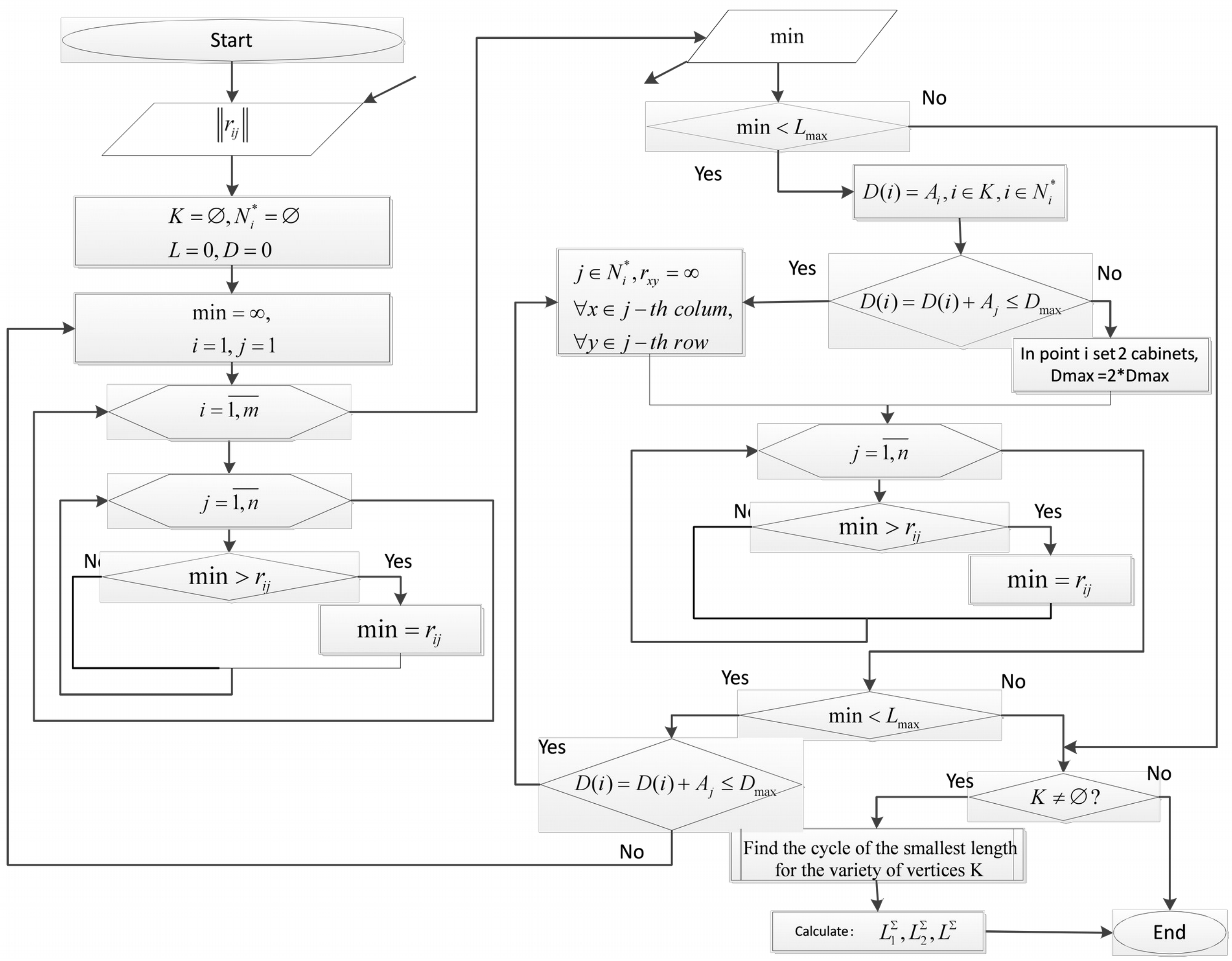

Figure 2 – Structural scheme of the algorithm

In the paper are formulated the problem of optimal synthesis of subscriber access network reconstruction and the proposed method for its solution. The solution method is formalized in the form of an algorithm and allows the determination of the necessary and sufficient number of active cabinets that need to be installed in an area serviced earlier by a single DPBX, which as a result of reconstruction is to be dismantled. In addition, there is ensured structural optimization of the synthesized network, which guarantees minimization of the total length of the fiber optic cable spent for reconstruction.

REFERENCES:

1. Diestel R.Graph Theory NY, Springer-Verlag, 2005, p. 422., electronic edition.
2. Santanu S. R.,Graph Theory with Algorithms and its Applications,in Applied Science and Technology. Springer, 2013, p. 216, in press.
3. D.Applegate, R.E. Bixby, V.Chvatal, W. Cook, The traveling salesman problem. A computational study. Princeton University Press, 2006, 593 p., in press.

ЛІТЕРАТУРА:

1. Diestel R. Graph Theory / R.Diestel – NY, Springer-Verlag. – 2005, – P. 422., – electronic edition.
2. Santanu S. R. Graph Theory with Algorithms and its Applications,in Applied Science and Technology / S. R. Santanu // Springer. – 2013. – P. 216. – In press.
3. Applegate D. The traveling salesman problem A computational study / D.Applegate, R.E. Bixby, V.Chvatal, W. Cook // Princeton University Press. – 2006. – 593 p. – In press.

DOI 10.33243/2518-7139-2018-1-2-59-64