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Algorithm of optimal technology selection of broadband access network

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Abstract

High speed applications require the access network upgrading based on new optical technologies in "last mile". At the planning stage of network modernization, special algorithms and techniques allow optimize and automate the designing process of network upgrade based on copper cables. However, these techniques are completely inapplicable if optical technologies are used to the access network modernization. Designed algorithm simplifies the throughput calculation of current access nodes and planning of new access nodes depending on subscriber's requirementstto the broadband services. Developed program based on proposed algorithm allows to determinate access nodes optimal deployment as well as the required equipment characteristics.

Keywords: access level switch, broadband access, DSLAM, multiservice traffic, optic access network

1. Introduction

With the increasing popularity of Internet, the traffic generated by domestic and small business users has been growing constantly over the last ten-twenty years. Various technologies have been deployed to provide broadband access to the network in the area known as the "last mile". "Last mile" means the technical means which interact with end user equipment. For example, the base stations of cellular network and mobile phone, copper wirelines between landine phones and local exanges, etc. Triple play services impose the higher requirements for access network throughput comparing to the legacy services like voice call [1, 2].

Throughput problem forces the operators to carefully consider the technologies of broadband access for the "last mile". Main factors determining choice of access network topology are reliability and CAPEX. Implantation of optical topologies in the access networks is the main appropriable method for fixed broadband access. WDM technologies allow transmitting data flows on every optical carrier [3-5]. Optical technologies are constantly being improved and cheapened.

Designing methods of broadband access networks are widely studied in literature [1, 6-10, 11-16]. There are special algorithms and techniques that allow optimize and automate the designing process of the access network based on copper cables at the planning stage during network modernization. However, these techniques are completely inapplicable if optical technologies are used in access network modernization. Optical access networks, except for the optical cable and associated linear devices, contain active network elements such as routers, access switches, DSLAMs, which have different performance and, accordingly, a higher price range [17-21]. Highly developed countries implant multi-fiber optic cables for "last mile" and can forget "last mile" problem for a long period [22], but remaining countries can use our method of as one way of access network upgrade with limited financing.

2. Research Method

It's known that many countries use PSTN access network for broadband access. In this case analog access network is splited in some areas such as directly connected area (a round with 1-1.5 km radius from access node) and distributed areas based on distributed box. In most cases medium (copper cables) used in directly connected area characterized by appropriable characteristics for broadband access if VDSL technology is used. It means that we do not have

to upgrade this area and keep the budget for other area modernization. We offer hybrid media for "last mile". The designed ruler set allows to automatically select the optimal technology for access providing of broadband services. When choosing broadband technologies for covering a settlement, the following ruler set is applied [23]:
- FTTC is the most profitable technology for access providing to broadband services, so if possible, FTTC should be used;
- FTTC has limitations by max data rate (5 Mbps max) and by max "access node-subscriber terminal" distance (500-1500 m). The maximum distance depends on the characteristics of the copper subscriber cables, cabling route and can not be predicted in advance. So, these two limitations are key points for the algorithm, you should specify the subscriber line characteristics in your region for the FTTC application;
- FTTB technology is implemented primarily in high-rise buildings and administrative buildings;
- FTTH technology is mainly used in the private sector;
- the radius of FTTH coverage area is about 20 km, which guarantees coverage in any locality (settlement) of the Uzbekistan Republic, or group of close located settlements which is situated nearly to one access point. You should specify this characteristic in your region for the FTTH application also.

At the stage of algorithm developing, several variants were considered for algorithm implementing, depending on the potential goal:
- calculate the maximum number of connected subscribers with different access rate profiles based on the number and characteristics of the existing access multiplexers;
- calculate the number of typical access multiplexers based on number of subscribers and its access rate requirements;
- calculate the optimal configuration of network equipment based on number of subscribers and its access rate requirements and equipment characteristics used in the Uzbekistan Republic.

Proposed algorithm based on the rules discussed above consists of three parts: data input; calculation part; data output. Algorithm architecture is listed on Figure 1.
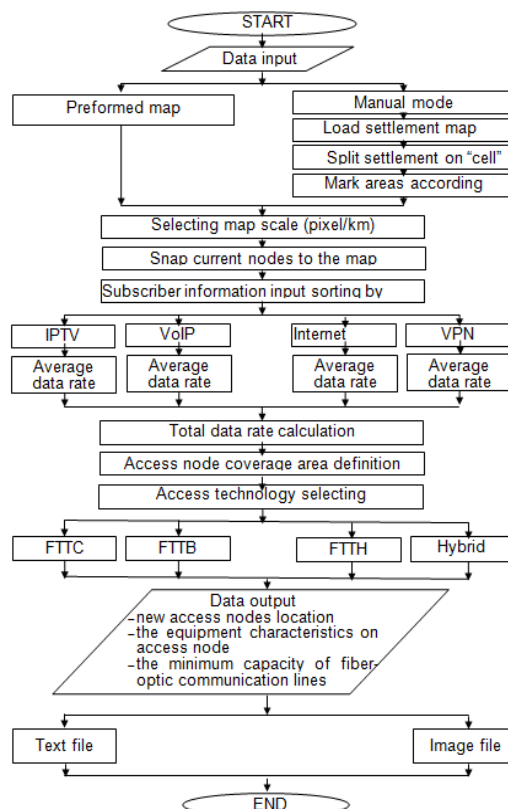

Figure 1. Algorithm of optimal technology selection of broadband access network

Data input includes following steps:
- Load settlement map.
- Split settlement into hexagons ("cells") depending on the scale.
- Mark areas ("cells") according building type non-residential area, the private sector, high-rise buildings, office buildings.
- Selecting map scale (pixel/km).
- Snap current nodes (buildings of existing exchanges, PBX, MSAN) to the map.
- Enter subscriber information differentially by required services in each "cell".
  The calculation part consists of several computations:
- Calculate the total speed in the "cell".
- Calculate the coverage area of the existing PBX considering requirements for broadband services providing. Coverage area of broadband services is reduced to compare POTS coverage area if you use copper cable lines.
- Calculate the throughput characteristics in the "cell" depending on the applied technologies and select the optimal technology as listed on Figure 2.
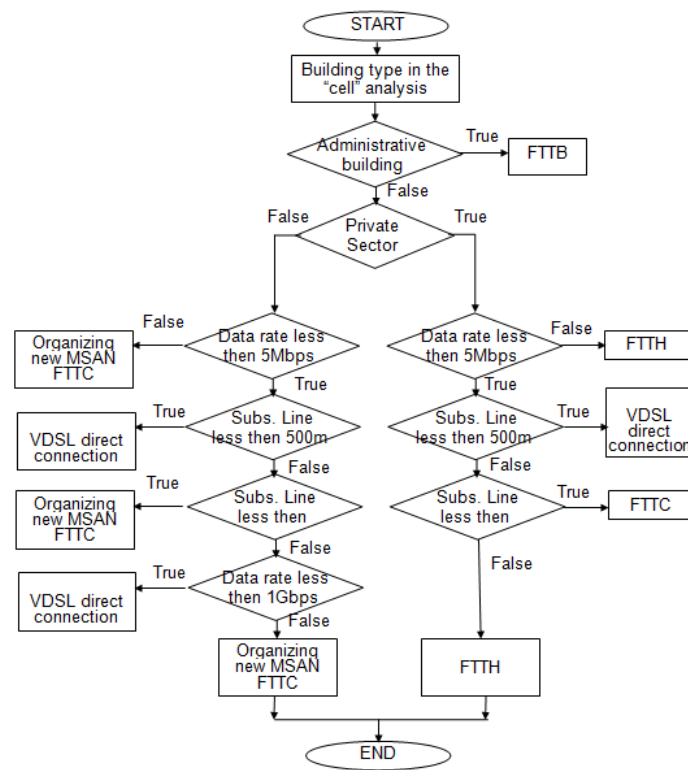

Figure 2. Access technology selection part of algorithm

We use (1) described in [11] for total data rate calculation, which is perfect for FTTC, FTTB traffic calculating and adapted to technical requirements of our national network:

$$B_1 \geq min\{\gamma + \sigma\sqrt{-2\ln(\varepsilon) - \ln(2\pi)}, Ne_1\}$$

(1)

where B_1: access switch (DSLAM) throughput;
ε: packetlossratio;
N: the number of independent IPP sources connected to the multiplexer,
μ: service rate in bps;
γ: average transfer data rate from all sources,
σ: standard deviation sum of all data rates from all sources, which is calculated by (2).

$$\sigma = R_1\sqrt{N\rho_1(1-\rho_1)} \tag{2}$$

e_1: equivalent data throughput described and defined [1, 23] as:

$$e_1 = \left\{\left[R_1\ln\frac{1}{\varepsilon} - K_d(\alpha+\beta)\right] + \left\{\left[R_1\ln\frac{1}{\varepsilon} - K_d(\alpha+\beta)\right]^2 + 4K_dR_1\beta\ln\frac{1}{\varepsilon}\right\}^{\frac{1}{2}}\right\}\left(2\ln\frac{1}{\varepsilon}\right)^{-1}$$

Therefore, as result (3):

$$e_1 = \frac{\eta_1 - K_d + \sqrt{(\eta_1-K_d)^2 + 4K_d\eta_1\rho_1}}{2\eta_1}R_1 = \tag{3}$$
$$= \frac{\frac{R_1}{\alpha+\beta}\ln\frac{1}{\varepsilon} - K_d + \sqrt{(\frac{R_1}{\alpha+\beta}\ln\frac{1}{\varepsilon} - K_d)^2 + 4K_d\times\frac{R_1}{\alpha+\beta}\ln\frac{1}{\varepsilon}\times\frac{\beta}{\alpha+\beta}}}{\frac{2R_1}{\alpha+\beta}\ln\frac{1}{\varepsilon}}R_1$$

where: $R_j = c_j$, $c_j$is data rate between j source and multiplexer, $R_j$is peak data rate of j source, and K_d is buffer size of access switch.

Based on network characteristics analysis imported to the Uzbekistan some values in (3) were defined as constant, so [23]:
- average value of active $1 / \alpha$and passive $1 / \beta$ modes of IPP source, in numerical values α=1/0.066667 seconds and β=1/0.6 seconds;
- packet loss ratio ε=10⁻⁶;
- access switch (DSLAM) buffer size $K_d = 5MB$;
- "access switch (DSLAM) aggregation switch" throughput is 1 Gbps, this value can be assigned with e_1.

You have to check and determine values to your region. When the algorithm works according to the formula, it is necessary to calculate two values of the total access rate and then choose the minimum value. As a result of the calculations, the information about the maximum number of subscribers that can be connected to the reference multiplexer (based on the entered needs of subscribers in services) is displayed. However, this figure is not final because following factors must be specified:
- subscriber's percentage which is simultaneously online in the network (typical value 25-30%);
- subscriber annual increase connected to particular multiplexer (approximately 1-2%);
- term forecasting of calculations (5-10 years).

Practice shows that a well-executed program, in addition to the output of the current value of the results, should be able to predict. The above indicators are also not constant and should be able to change in real time without the need to change the source code. The program provides for the possibility of producing the necessary results, taking into account further planning. Data output is the part of algorithm, which shows the final calculation results, namely:
- location of new access nodes;
- equipment characteristics which should be installed on each access node;
- minimal throughput of fiber-optic lines required to provide all subscribers with broadband access.

3. Results and Analysis

We designed software program based on described algorithm and run a series of simulations in our network. Program realization is described in [23]. Approbation of the program was carried out at several sites using technological cards of JSC "Uzbektelecom". To approve the program, a site was selected in the coverage area of the PSTN exchange, a pre-formed map was downloaded from the site http://GoogleEarth.com. On the map, different types of residential areas were marked with different colors.

After determining the scale, the operator made a binding to the map of the current nodes (existing PBX and MSAN). Then, the user entered data on existing subscribers and added information received from marketers. The program calculated the coverage of

the automatic telephone exchange. Technologies recommended by the program for usage in PBX areas are listed on Figure 3.

The results of the program calculations confirm the relevance of (3), but are not applicable in reality. For example, as shown in [24], the number of users connected to one DSLAM exceeds 300 subscribers. The multiplexers currently in use typically have fewer connection ports.
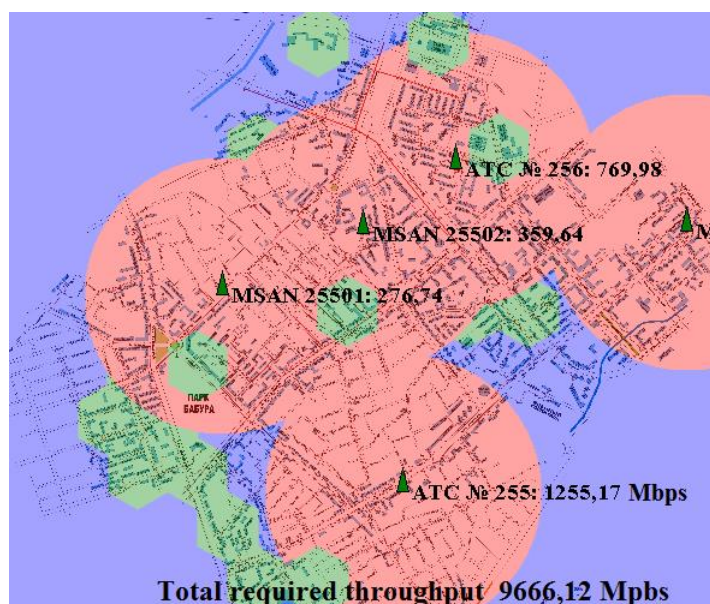

Figure 3. Simulation results (red color is assigned with FTTC technology, green is assigned with FTTB, blue color is assigned with FTTH)

4. Conclusion

Designed method allows calculating the optimal characteristics of the active network elements based on optimal throughput/optimal device price parameter. Economic effect of software realization (program's operating results) is about 40 persent after access network modernization if hybrid technology is selected to compare fully optic FTTH. Economic calculations are based on middle price per one telecommunication port implemented in the Uzbekistan Respublic.

Middle distribution values based on access technologies choising by subscribers so FTTH price 200-250 USD per port, FTTC 45 USD, FTTB 50 USD, FTTx distribution values are hybrid 40 percent, FTTH–20 percent, FTTB–40 percent. In numerical result economic effect is about 120,000-160,000 USD per 1000 subscriber lines. The considered approach is easily applicable for city-scale or town-scale areas. Although, the operators should use the different approaches based on cheaper technologies for rural areas [19, 21], e.g. WLL access (Wi-Fi, WiMAX), EoPDH [25], PLC etc. Since the "last-mile" issue is an important point for network access design and our method is not the only solution. Out further researches will focus on alternative solutions.

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