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METROPOLITAN ACCESS NETWORK

ABSTRACT

The optical fibre is the highest quality transmission medium for broadband services, and therefore the new access cable network has to be realized to the greatest extent and as close as possible to the subscriber by means of the optical fibre cables, in accordance with the possibilities of the telecommunication operator. The development of digital technology in commutations, supported by the increasingly powerful systems of processor control, development of optical communications and transport technologies in the framework of SDH concepts, are reflected on the access telecommunication networks of the urban areas. Urban areas are the most profitable regions in telecommunications.

In planning of urban optical networks the fact should be taken as a guideline that only a well-organised urban network will allow high quality of service provision of the leased cables to the end points of business customers.

Business customers have greater requirements for the network reliability, flexibility and maintainability, for the sake of undisturbed telecommunication traffic.

The optical medium based technology - FITL (fiber in the loop), provides almost limitless upgrading of the system regarding the transmission bandwidths, as well as adaptation to all the future customers' requirements.

Considering the increase in the price of installing the copper cables, the prices of electronics and optical components are continuously falling. The application of the optical medium is increasing and becoming more cost-effective, and due to higher reliability of the optical transmission systems the maintenance costs are reduced.

KEY WORDS

optical network, transmission, FITL (Fiber in the Loop), SDH (Synchronous Digital Hierarchy), services, corporate subscribers, survivability, optical rings, costs

1. INTRODUCTION

In the overall care for their survival, telecom operators have to start with gradual building of the broadband infrastructure. Today, the access networks in the world have been mostly built on symmetric cables. However, the users' increasing requirements for transmission capacities result in an increased need for higher quality transmission medium, primarily the optical fibre. The reason lies in the significant fact that the price of a fibre optical cable has been gradually reduced, and in the developed telecommunication networks in the world the tendency is to bring the fibre as close to the customer as possible.

The intention is to bring the optical fibre all the way to the business building or to the office itself i.e. to the corporate customers who are technologically the most demanding ones and financially the most interesting ones, while the larger number of residential users will realise their broadband service requirements using partly also the existing copper pairs.

The result of such positive movements in the field of telecommunication technologies is the accelerated development of telecommunication equipment and the need to define a set of strategies suitable for the introduction and mass distribution of optical access technologies in the areas with an already built access telecommunication infrastructure. In the distribution part of the network there are already different concepts of optical fibre implementation according to the principle – FTTC /FTTB/FTTO (to the cabinet/near the building/to the office), and the so-called hybrid optical - coaxial network (HFC).

2. ATTITUDES OF HT d.d.

More recently, an intensive development at the local, access level of the telecommunication network can be observed regarding the Croatian telecom operator (HT d.d.). Advanced technologies are used that have already been implemented and have been relatively well developed at the national level of the network.

The general approach to the development and the construction of access networks in urban areas has been based on the fact that the price of the fibre optical cables is decreasing daily and that the optical fibre is the highest quality transmission medium for broadband services, so that the new access cable network should be realised by optical fibre cables to the greatest extent possible, and as close to the customer as possible, in accordance with the possibilities of the telecommunication operator. The realisation is possible in phases, e.g. by laying the fibre optical cable up to the access nodes located near the subscriber, gradual construction of the passive optical network and finally, as the last step, by bringing the optical fibre to the subscriber's premises themselves. The development of digital technology in switching, supported by increasingly powerful systems of processor control, development of optical communications and transport technologies within the frame of SDH concepts, have been reflected on the access telecommunication networks of urban areas. The classical loop or star-loop structures of large decentralised urban networks are being abandoned and two-layer hierarchical structure is being adopted.

The concept on which the new HT network is based:

1. SDH as close to the customer as possible,
2. Increase of capacities in receiving nodes (grooming),
3. PDH remains at the network margins.

The production line of the ALCATEL firm has been considered, called OPTINEX, which is based on the concept of Optical Multi-service Nodes.

In the OPTINEX concept, the flexibility represents a striking characteristic, since the transmission devices share the same cards, thus simplifying the maintenance and upgrading. From the aspect of upgrading, this means that the capacity can be increased very fast between two network elements.

In planning of transmission devices along optical fibres, HT network uses:

1. for PDH: OLTE-8,
2. for SDH: 1640 FOX, 1650 SMC and 1660 SM. (OPTINEX)

The OPTINEX concept does not contain only classical ADM devices (add-drop multiplexer), but also DXC (digital cross connect) devices, which may be used in different configurations (point-to-point, ring configuration, and mesh structures). [1]

The principles of forming new urban networks at HT include:

1. SDH rings are formed in layers, with completely separate routes of optical fibre cables, if possible by the existing optical infrastructure;
2. Closing of "adjacent" rings through two nodes, if possible by the current condition of the optical infrastructure;
3. Good "identification" of nodes is necessary.

In planning the metropolitan access networks the fact should be considered that only a well-organised urban network will provide high-quality services of the leased cables to the final points of corporate customers. Attention should be paid to the required level of protection and network control.

3. USERS IN THE METROPOLITAN AREA

Within the metropolitan area, different groups of users may be found:

1. Large corporate customers are concentrated in business districts of towns - requiring relatively large range of the transmission band, and they form a relative minority;
2. Small corporate customers are physically dispersed and in larger numbers;
3. Residential users form the majority of the urban network.

The large corporate customers cannot find an acceptable alternative in the conventional copper technology, so that the most logical access to such users is via the optical fibre to the building or office. Such special users have greater requirements regarding reliability, flexibility, and survivability of the network, for undisturbed telecommunication traffic.

Although for the moment, the broadband service requirements of the small corporate customers can be met by the copper network, with certain technological solutions and restrictions, the economical solution of introducing optical fibres needs to be developed in order to insure the launching of broadband services on this market as well.

The residential users' requirements for broadband transmission possibilities, that is, interactive services, will follow the requirements of large corporate customers, although, apart from the standard telephone services, their interest is oriented towards distribution services for the entertainment purposes. In case of residential users, the introduction of optical fibre transmission systems will follow gradually, and a significant role is expected by the strategy of the evolution of optical CATV network into a unique communication user network. [2]

Metropolitan access networks with the three basic groups of users are constructed in such a way that one or more optical fibres are laid up to the big buildings with large corporate customers or a greater number of residential users. The fibres are brought to the remote digital terminal which is installed in the building, and further to several optical network terminals (ONT) within the building. Each optical network terminal has a capacity of several dozens of users lines. In this way, 30% of the users in the urban area may be reached.

In mid-size buildings with 10-200 user lines, the optical fibres from the exchange or some remote terminal are connected directly to the ONT. In this way 25% of users may be reached. The residential buildings are connected by fibres from the exchange to ONT at speeds of 600 Mbit/s, and family houses may be connected to ONT by optical user line of 2-155 Mbit/s or the residential areas are connected by fibres to ONT, and from there by hybrid topology, i.e. copper medium to the user.

Well-distributed optical fibre infrastructure needs to be installed before the mass demand and requirements by the users for the new services, which will not be introduced into the network nor commercially available unless there is sufficient transmission capacity for their reaching the users. In the urban areas, the optical infrastructure needs to be realised gradually and economically, but starting from the large corporate customers. [3]

Targeted and long-term technical and technological solution for the implementation in the metropolitan access networks for residential areas, which account for about 90% of the total access capacities, is the optical fibre to the flat, i.e. to the user terminal (FTTH – fibre to the home).

However, considering the financial indicators and high investment costs, the most acceptable and actually feasible technological solution for mass implementation in the urban areas is in principle, the hybrid optical-copper network. [4]

4. TECHNICAL DESIGNS OF METROPOLITAN ACCESS NETWORKS

Metropolitan access networks may be solved by numerous, but technically very different designs - active or passive ones, different regarding cable topology and the overall architecture. [5]

Since there is a satisfactory transmission bandwidth for a certain spectrum of services, but with restricted range possibilities, many telecommunication operators are trying to use the copper infrastructure partly because of incomplete depreciation or because they want to make as much additional profit as possible from the existing network. However, longer-term prospects are not possible, since already many of the corporate customers in urban areas require transmission scopes of 100 Mbit/s and more, and the same is expected also by the residential users, since they will require higher quality of multimedia, and especially distribution services. [6]

The optical medium based technology – FITL (fibre in the loop), allows almost limitless upgrading of the system regarding transmission bandwidth, and adaptation to all the future user requirements.

The FITL concept will be of great significance and an important step in the evolution of the global broadband network, and FITL installed for telephony and CATV will turn into new highly reliable networks. Complete conversion to optical networks up to the users' premises in the developed countries may be expected by the year 2010.

Metropolitan areas provide the possibilities for various versions of FITL configurations. Every telecommunication operator will develop a scenario for the evolution of their own access network, since it is necessary to take into consideration the knowledge about the specific characteristics of the parts of the existing access network of the set objectives – groups of users that need to be included, services that will be provided, building dynamics, etc. [7]

The most commonly used FITL configurations include:

1. FTTC – fibre to the curb;
2. FTTO – fibre to the office;
3. FTTR – fibre to the remote;
4. FTTP – fibre to the pedestal (pole);
5. FTTB – fibre to the building, for very densely populated residential areas;
6. FTTZ – fibre to the zone, for mid- and low densely populated residential.

5. METROPOLITAN ACCESS NETWORK MODEL

Including different FITL versions, the target model of the metropolitan access network supporting all the communication services, but also ready to support all the future services, integrates the possibilities of the optical transmission via passive access networks (with some of the FTTX solutions), ATM transport and centralisation of specific service node point. [8]

Figure 1 shows the elements of a target model of the metropolitan access network with various specific scenarios of connecting the users.

The replacement of the existing copper network in the cities by fibre optical cables will be carried out gradually, although strategically, large corporate customers will top the priority list. By implementing a larger number of smaller UPSs (remote linesides), of the capacity of 256 connections, linked to the access exchange by optical cable transmission systems, the optical fibre, as well as the digitisation point will come closer to the users. Regarding high investment costs for the installation itself in the areas of new or reconstruction of copper networks it is necessary to start the

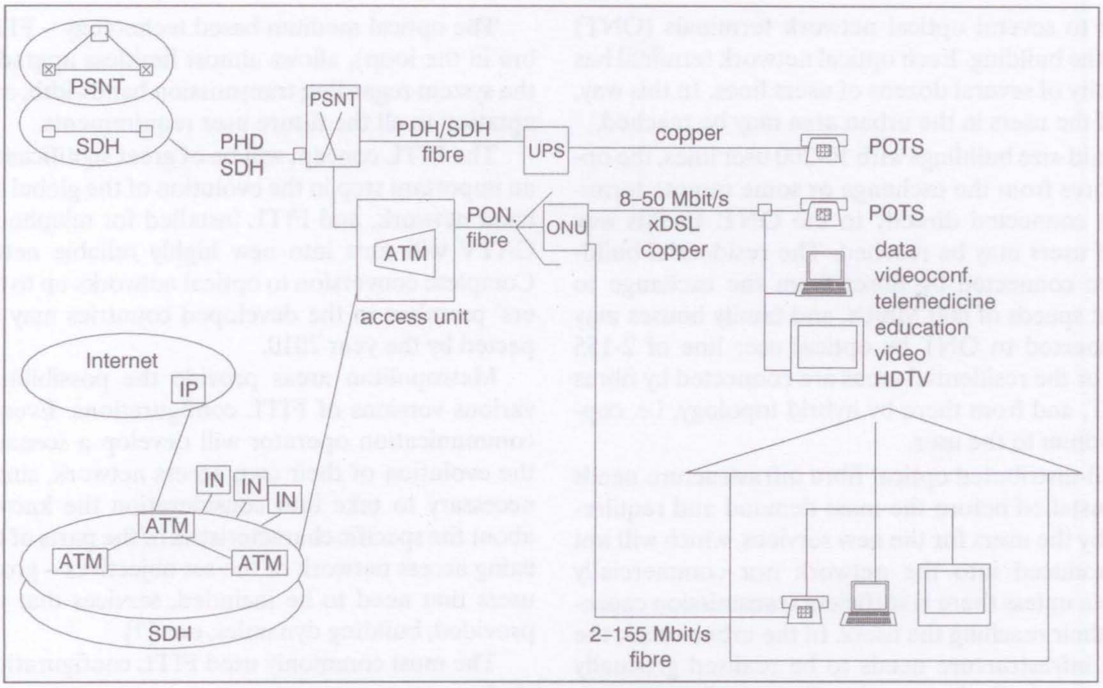

Figure 1 - Metropolitan access network target model

implementation of the optical fibre to the users. On specific places in the cities and for specific purposes that go beyond the standard needs for telephone connections, the optical network units (ONU) will be applied in metropolitan networks of different basic designs. According to their basic design, the optical networks are divided into *active* ones in case of a smaller number of ONU of greater capacity in certain parts of the network or *passive* ones, in case of a greater number of smaller ONU.

The objective is to establish the possibility of an integrated access, first of all for the corporate customers, to various networks, at different speeds. The corporate customers find such a possibility interesting, since it provides the possibility to access different services from the same place, and the services divide the access network resources in a cost-efficient manner.

6. RING CONFIGURATION

The ring structures of the self-recovery type have proven to be the best topological model of the user access networks.

Ring structures were not used in the past since the existing system of pairs and coaxial cables, of relatively low transmission capacities, did not allow it. This resulted in uneconomic rings difficult to adapt to the increasing traffic.

The properties of the optical fibres and the development of SDH networks and adequate multiplexing devices have created a basis for a wider application of ring structures.

Ring structures are sensitive to failures and require additional equipment. The development and deployment of new intelligent components - ADM (add-drop multiplexer) and DXC (digital cross connect), provide self-recovery resulting in the network survivability.

In planning of the ring access network, the objective should be to determine the minimal ring capacity which satisfies the set conditions, and this depends on the routing of requirements in the ring. Routing of re-

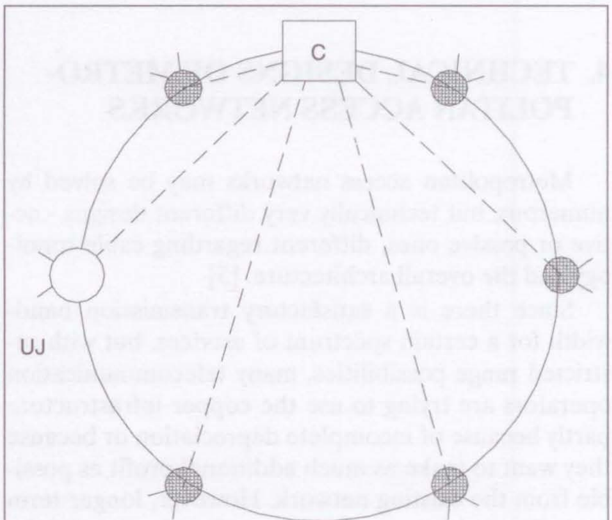

Figure 2 - Ring topology in metropolitan access network (ring physically and star logically)

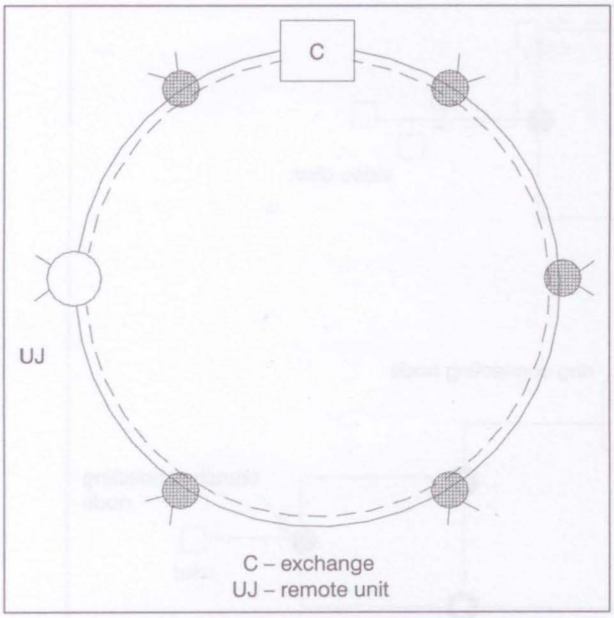

Figure 3 - Ring topology in metropolitan access network (ring physically and logically)

quirements, capacity calculations, optimisation of self-recovery networks, etc. are calculated by means of different algorithms. [9]

The most promising recovery technique in SDH/ /SONET network is the ring architecture. The recovery technique in the ring structure can be with different mechanisms:

1. One-way path recovery,
2. Two-way line recovery,
3. Configuration with two or four fibres, etc.

SDH/SONET self-holding rings (SHR) have been developed on the basis of the automatic protective switching. The architecture plans a redundant bandwidth and uses the equipment which automatically recovers the services after detecting a failure. Self-sustaining rings can recover completely from the error in the transmission link or node. Self-sustainability is the capability of network to reconfigure itself quickly and efficiently with the objective of "bypassing" the fault and allows almost 100% service accessibility.

The number of fibres to the user depends on the applied model of the user network, i.e. on its topology and the user system architecture. [10]

In order to insure completely separated transmission directions, and to realise greater possibilities in the system upgrade, it is necessary to introduce at least two optical fibres. It is preferable to install additional, non-dedicated fibres for future uses.

Cables with optical fibres are installed in cities, first of all for the needs of large corporate customers, mostly in highly sustainable ring topology, which features the following advantages:

- easier adjustment to the user requirements for very fast and/or broadband services,
- it does not require reduction in the number of fibres in the cable, which reduces the number of connections and signal losses. Besides, the distributive telecommunication channelling (DTK) in the urban areas is of a grid structure, and the possible additional costs for ring network design will be slight,
- since there are two paths between the subscriber and the telephone exchange on the same ring, one of them serves as the operating backup in case of failure of the other one, [11]
- allows deployment of adequate closed networks (MAN, CATV, connection of LANs) between buildings by the same ring of connected users. [12]

The configuration of target optical user network features the following characteristics:

1. Hierarchical configuration – access network cables are realised in the ring topology classified into the main and distributive ones.

The main ring contains switching nodes and network nodes that represent special large corporate

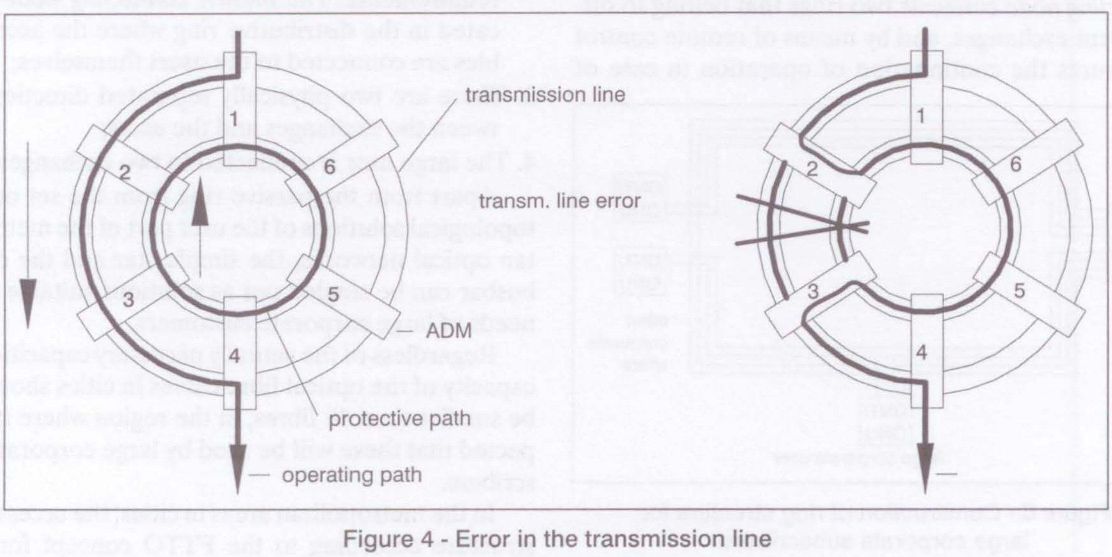

Figure 4 - Error in the transmission line

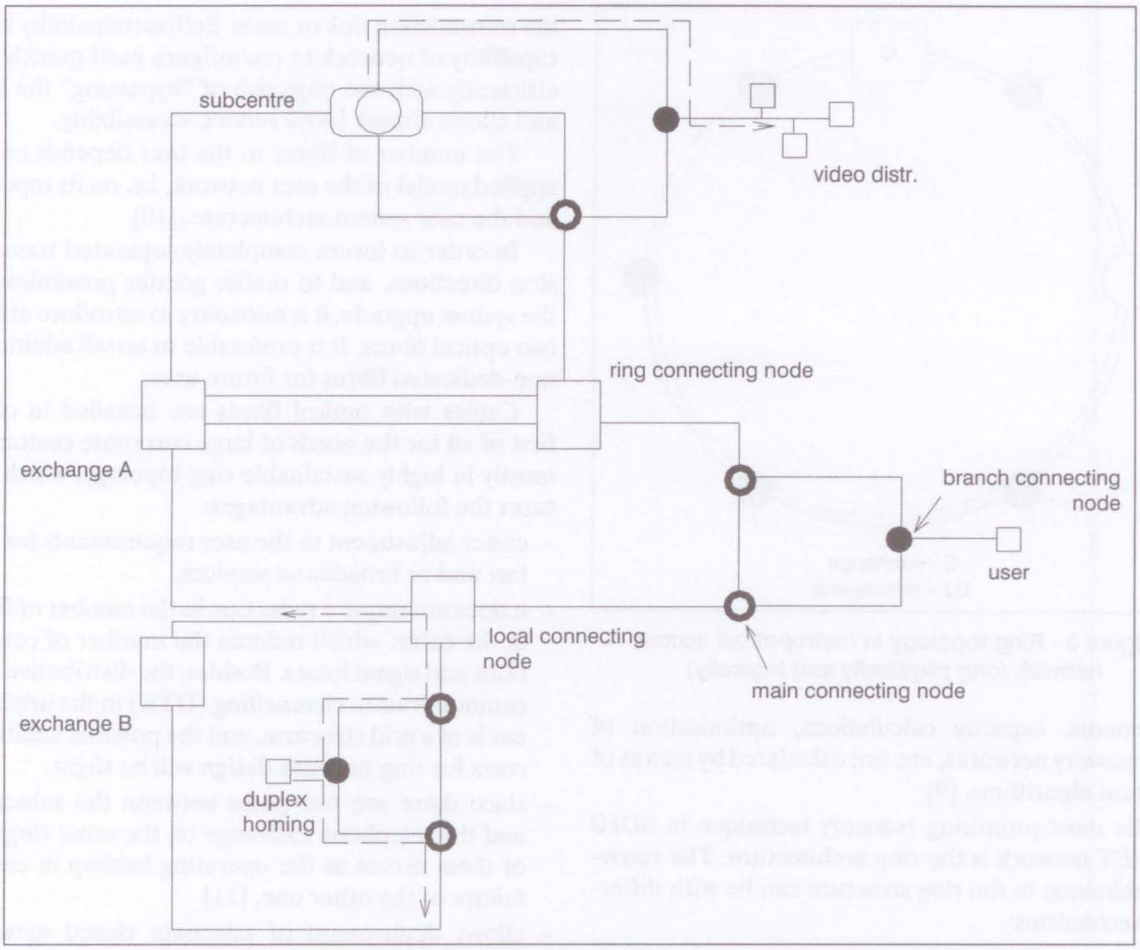

Figure 5 - Example of target configuration of sustainable user network

customers. For this ring, cables with a large number of optical fibres are used.

The distributive ring is formed as necessary, to maintain high reliability near the residential users, with cables of lower capacity optical fibres;

2. Functional assignment of optical connecting nodes for simple control of network access. *Regional connecting node* connects two rings that belong to different exchanges, and by means of remote control ensures the continuation of operation in case of exchange breakdown. *The connecting ring node* connects two rings that belong to the same exchange, and by means of remote control commutes the fibres in case of cable fault. This allows reduction of the number of backup fibres in the ring. *The main connecting node* connects the main ring with the distributive ring and allows realisation of new requirements. *The branch connecting node* is located in the distributive ring where the access cables are connected to the users themselves;

3. There are two physically separated directions between the exchanges and the users;

4. The large user is connected to two exchanges.

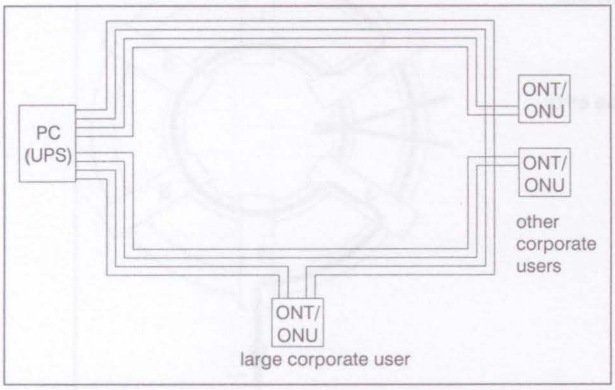

Figure 6 - Construction of ring structure for large corporate subscribers

Apart from the passive ring from the set of basic topological solutions of the user part of the metropolitan optical networks, the simple star and the double busbar can be singled out as solutions suitable to the needs of large corporate customers.

Regardless of the actually necessary capacities, the capacity of the optical fibre cables in cities should not be smaller than 48 fibres, in the region where it is expected that these will be used by large corporate subscribers.

In the metropolitan areas in cities, the access infrastructure according to the FTTO concept for large corporate customers and FTTB for other users should be realised gradually.

The architecture of the protective ring is preferable for large corporate subscribers by using several access points in the architecture.

Since new optical networks "carry" more and more critical services related to safety, medical protection support, education, etc., frequent transmission errors cannot be tolerated. It is precisely the low prices of optical fibres and their two-way feature which provide new possibilities for the development of durable, "survivable" urban networks.

7. THE COSTS OF INTRODUCING OPTICAL FIBRES INTO THE ACCESS NETWORK

Compared to the transmission capacity and the development trends, the optical medium is a very economical solution, and the basic elements of the list of costs for the introduction of the optical fibres in the telecommunication networks include:

1. optical cable is less expensive than the classical copper cable,
2. installation and connection of cables – the costs are lower compared to copper cable, since the optical cable can be inserted into the existing distributive telecommunication channel, and due to low weight per meter of length, they can be even hanged on the poles, buildings, etc.
3. optical media transmission devices – regarding price they are very similar to the respective electronic equipment for transmission via copper,
4. maintenance – the price is much lower compared to copper cables.

With a good estimate of current needs and potential possibilities predicted by the future technologies, once constructed optical network will not require adding of new fibres to the network, and therefore, the optical fibre is really a prospective and profitable investment.

One of the basic elements in reducing costs of the construction of the user optical network is the proper selection of the optical network topology.

The main criterion for network topology selection is the minimisation of costs of the optical cable, i.e. fibre.

The selection of topology means:

1. selection of optical physical connections (branches between nodes),
2. equipment that meets the requirements of the network sustainability.

The cost function includes:

1. cost for the operating and portable equipment (constant costs are for a certain network topology and selected protection procedures);
2. costs for the installation of optical fibres, i.e. cables along certain routes (these depend on the distances and actual circumstances in the observed urban environment, which due to their specific characteristics impose various limitations). The study of the quantitative relation between the costs and the sustainability on the model of Bellcare metropolitan network yields the results which show that the physical diversification of relations is sufficient (in the usual conditions) and cost-acceptable protection against the breakdown of optical cables. With the assumed costs of the technology of self-holding rings the access network costs will be reduced, and its sustainability improved. [13]

Before introducing broadband user systems, independent of the application concept (FTTO, FTTC or FTTH), it is necessary to study carefully an important factor: cost-effectiveness. This factor needs to be compared with the costs of copper cable deployment regarding comparison of costs between the optical network architectures and copper structures, and the possibilities of reducing the costs of optical systems.

In the existing copper user network the prevailing part of costs is assigned to the line section between the end of the network at the user's and the equipment in the exchange, and a small part to the user network end.

However, the picture is completely different with optical systems, since the end of the network by the user's contains the optical transmitter and receiver of the signals, and the electronics adapted to terminal and power supply. This renders much greater value to the equipment at the user's compared to the classical network, with obligatory introduction of optical transmission systems to connect the users to a certain switching, which affects significantly the overall distribution of the cost structure of the respective part of the communication network.

The costs of introducing optical cables into the network can be divided into:

1. fixed part referring to the costs of cable laying, and
2. part that is proportional to the number of optical fibres i.e. cable capacity.

The starting assumption is that all the operating costs and the costs of optical cable deployment within the cost structure are equal regarding reference unit.

Both costs show a tendency of exponential decline, and the demand for connecting of users to the optical cables will increase linearly.

According to Bellcare's cost forecasts and estimates, with an annual increase of demand for connections of 50 percent, the economical starting installation interval for main cables is 2 to 3 years, and with a demand increase of 10 percent annually it will be 4 – 6 years.

Whenever the economical characteristic is considered, the data need to be taken that serially produce components of the optical transmission system.

In order to make a more comprehensive cost comparison between copper and optical user systems, the following has to be considered:

1. labour costs,
2. management costs,
3. control costs, and
4. maintenance costs.

Rough approximation requires reduction of every one of these costs by 20 percent annually. In Bellcare, the consideration of maintenance costs range within a ratio greater than 4:1 in favour of the fibres in the distributive line. These considerations have been based on the fact that optical fibre, up to two, substitute several hundreds or thousands of copper pairs.

In developing a detailed study of costs, the Bellcare found interesting information – that already in the mid 1990 the deployment of the FITL system (FTTC concept) competed with the new copper networks. The estimate for the copper network was based on the construction of an average distributive line of 600 m between the remote multiplexer and the user.

Great variations were noticed in the cost calculations that were directly related to:

1. cost-dependent availability of a greater number (1 - 4) of speech connections per residential unit. There is an increase of interest among the users for this kind of availability.
2. the demography of the area of deployment. The density of residential units substantially affects the results of cost comparison.
3. comparison of the technological performances and economy of copper and optical loops during the whole service life (20-30 years).

FITL systems are more cost-effective than the copper systems, even at relatively small distances of about 1 km from the exchange, but provided that:

1. there is multiple connection to the digital local;
2. FITL systems are successively upgraded according to the actual needs, and not immediately to the full;
3. the price of copper rises, since world reserves of copper are getting smaller every day;
4. the prices of transmission equipment necessary for the construction of optical user systems fall.

Study and comparison of the cost structure of the optical user systems can be carried out according to:

1. different topological solutions of the network,
2. transmission technique, and
3. installed equipment.

With the increase in the distances of the users from the exchange, the optical systems have great advantage, because of the high share in the labour costs and costs of installing the cables in the copper network, since the cost of the optical transmission equipment at the exchange does not depend on the distance.

The installation costs will be increasingly dominated by the labour value, since unit prices of the optical network elements decline with the increase in scope.

The British Telecom has done a comparison of costs of applying different topologies and the architecture of the optical user systems based on them. This cost comparison showed the following results:

1. the costs of these systems are structurally different from the copper network costs. They are to a great extent determined by the price of the optical transmission systems according to the copper infrastructure, where, especially in residential areas a greater part of the costs refers to the installation of cables and the invested labour;
2. costs of realising the transmission system depend dominantly on the connection method to the exchange. The multiple port is less expensive than the individual one;
3. If broadband distribution services are transmitted along with the switching services via the same optical cable network, additional services can be achieved;
4. the cost-effectiveness of the optical user systems compared to the copper ones depends also on the distance of the considered are from the exchange.

Southern Bell Company devised a time scenario of the gradual transition to the optical user networks since technological changes are not graded functions of time, and neither are all advantages and various forms of optical technology application completely unambiguous, so that it would not be realistic to expect that telecom operators will abandon the existing copper technology not yet used to its full capabilities, and venture into high investments. By the year 2010 the Southern Bell plans to use 50-100 percent of the means for the development and construction of optical medium networks, and the reconstruction of the network based on the installation of fibres from 6 – 8 percent annually. After the year 2011, this company plans to have a fully optical transmission network, including the access level.

8. CONCLUSION

In the world, several separate options of access network architectures are being developed, based on the optical technology. However, in order to achieve mass commercial usage, the telecom operators and equipment suppliers (manufacturers) should focus on a reduced number of the existing architectures and systems of optical access networks.

The operators expect the highest revenues from the sales of telecommunication services precisely in the urban areas because of the highest concentration of the corporate customers. However, it is necessary to assure the network quality in order to focus on the diversity of services offered. The corporate subscribers have higher requirements regarding the network reliability, flexibility and maintainability, for the sake of undisturbed telecommunication traffic.

Regarding strict criteria of reliability and presence of highly reliable transmission and switching systems, the possibility of a breakdown has to be taken into consideration, and during the breakdown it is necessary to insure the protection of information flow. Regarding the increase in price of the installed copper cables, the prices of electronics and optical components are continuously falling. The deployment of optical medium is increasing and becoming more profitable, and the higher reliability of the optical transmission systems results also in the reduction of maintenance costs.

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SAŽETAK

GRADSKE OPTIČKE MREŽE

Optička nit je najkvalitetniji prijenosni medij za širokopojasne usluge, pa je stoga potrebno novu pristupnu kabelsku mrežu, u što većoj mjeri i što bliže pretplatniku, realizirati svjetlovodnim kabelima, u skladu s mogućnostima telekomunikacijskog operatera. Razvoj digitalne tehnologije u komutacijama, podržan sve moćnijim sustavima procesorskog upravljanja, razvoj optičkih komunikacija i transportnih tehnologija u okviru SDH koncepta, odražava se na pristupne telekomunikacijske mreže gradskih područja. Gradska područja su najprofitabilnija područja u telekomunikacijama.

U planiranju gradskih optičkih mreža treba se voditi činjenicom da će samo dobro organizirana gradska mreža omogućiti kvalitetno pružanje usluga iznajmljenih vodova do krajnjih točaka poslovnih korisnika.

Poslovni korisnici imaju povećane zahtjeve na pouzdanost, fleksibilnost i održivost mreže, zbog neometanog obavljanja telekomunikacijskog prometa.

Tehnologijom baziranom na optičkom mediju - FITL (fiber in the loop - svjetlovodna petlja), omogućava se gotovo neograničeno nadograđivanje sustava u pogledu prijenosne širine, te prilagodba svim budućim korisničkim zahtjevima.

U odnosu na porast cijena instaliranja bakrenih kabela cijene elektronike i optičkih komponenata kontinuirano opadaju. Primjena optičkog medija postaje sve veća i unosnija, a zbog veće pouzdanosti optičkih prijenosnih sustava reduciraju se troškovi održavanja.

KLJUČNE RIJEČI

optička mreža, prijenos, FITL, SDH, usluge, poslovni korisnici, održivost, optički prsteni, troškovi

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