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TUCHOLA COUNTY BROADBAND NETWORK (TCBN)

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Abstract. In the paper the designing project (plan) of Tuchola City broadband IP optical network has been presented. The extended version of network plan constitute technical part of network Feasibility Study, that it is expected to be implemented in Tuchola and be financed from European Regional Development Funds. The network plan presented in the paper contains both topological structure of fiber optic network as well as the active equipment for the network. In the project described in the paper it has been suggested to use Modular Cable System - MCS for passive infrastructure and Metro Ethernet technology for active equipment. The presented solution provides low cost of construction (CAPEX), ease of implementation of the network and low operating cost (OPEX). Moreover the parameters of installed Metro Ethernet switches in the network guarantee the scalability of the network for at least 10 years.

1 Introduction

The total volume of traffic carried in broadband IP network is determined by the usage of different applications implemented in the network. All services offered to the users in the highest technology network impact on the one hand on the network layers realization and on the other one on income gained from network operation. Starting with 2008, Cisco has issued three successive reports [1, 2, 3] that concerns to IP traffic estimation. These reports analyze all segments of IP traffic and show the tendency of traffic changes. The reports show that the greatest increase of total traffic concerns to residential users. Moreover reports show that:

1. In 2014, the Internet will be four times larger (in traffic sense) than it was in 2009.
2. Global IP traffic will quadruple from 2009 to 2014. Overall, IP traffic will grow at a compound annual growth rate (CAGR) of 34 percent.
3. Annual global IP traffic will exceed three-quarters of a zettabyte (767 exabytes per year or 64 exabytes per month) in the year 2014.

4. Global Internet video traffic will surpass global peer-to-peer (P2P) traffic by the end of 2010, so P2P traffic will not be the largest Internet traffic type. The global online video community will surpass 1 billion users by the end of 2010.

5. Video communications traffic growth is accelerating and will increase sevenfold from 2009 to 2014.

6. Real-time video is growing in importance. By 2014, Internet TV will be over 8 percent of consumer Internet traffic, and ambient video will be an additional 5 percent of consumer Internet traffic. Live TV has gained substantial ground in the past few years. Consumer IPTV and CATV traffic will grow at a 33 percent CAGR between 2009 and 2014.

7. Globally, mobile data traffic will double every year through 2014, increasing 39 times between 2009 and 2014. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 108 percent between 2009 and 2014, reaching 3.6 exabytes per month by 2014. Almost 66 percent of the world's mobile data traffic will be video by 2014.

The expectations for total transferred volume traffic in actual broadband IP network discussed above impacts mainly on the structure of such network. Such huge volume traffic requires efficient backbone network for traffic transfer from one hand, and high bandwidth access lines from the other one. Currently, Telecomm Operators invest gigantic funds to improve backbone infrastructure, i.e. switching and transport layers of broadband IP network. Only few of them however invest money into access layer of the network, as improvement of this network layer requires investment expenses.

OECD statistics [9] for 2nd quarter of year 2010 shows that Poland broadband infrastructure seen as the penetration of broadband access lines locates Poland on one of the last places among OECD countries regarding. The average penetration of broadband access lines in Poland is 12 lines per 100 citizens where 7 ones of them are implemented in ADSL technology and 4 of them are implemented in DOCSIS technology (cable TV). In Polish network there are almost no FTTH technology access lines. It is result of very limited investments in fiber infrastructure in all layers of the network. In Fig. 1 there has been shown six years historical series of broadband access lines penetration for two most advanced counties, namely Korea and Japan, Poland for comparison with Korea and Japan, and OECD as an average of all OECD countries [10].

Currently, the broadband networks, co-financed with the European funds, are starting to be deployed in many different regions of Poland. In previous financing period, that has took place in years 2004÷2006, the only Kujawsko-Pomorskie region broadband network, has been successfully implemented [9]. In current financing period (2007÷2013) the broadband networks are intended to be implemented in some other regions of Poland. The main goal of the regional broadband networks implementation in Poland is to fulfill the gap which has appeared as a lack of investment in broadband networks infrastructure. Broadband Internet is the basis for the development of all modern networks and first of all consists a base for the construction of NGN networks.

Broadband Internet infrastructure is treated now as fundamental factor affecting on rapid development of all European countries. So, that was the reason of announcing on May 2010 special Digital Agenda where European Commission declare the policy oriented towards broadband Internet [4]. As the future economy will be a network-based knowledge economy with the internet at its centre, the actual EC policy requires additional support to improve modern Internet network - especially network infrastructure. The Europe 2020 Strategy has underlined the importance of broadband deployment to promote social inclusion and competitiveness in the EU. It restated the objective to bring basic broadband to all Europeans

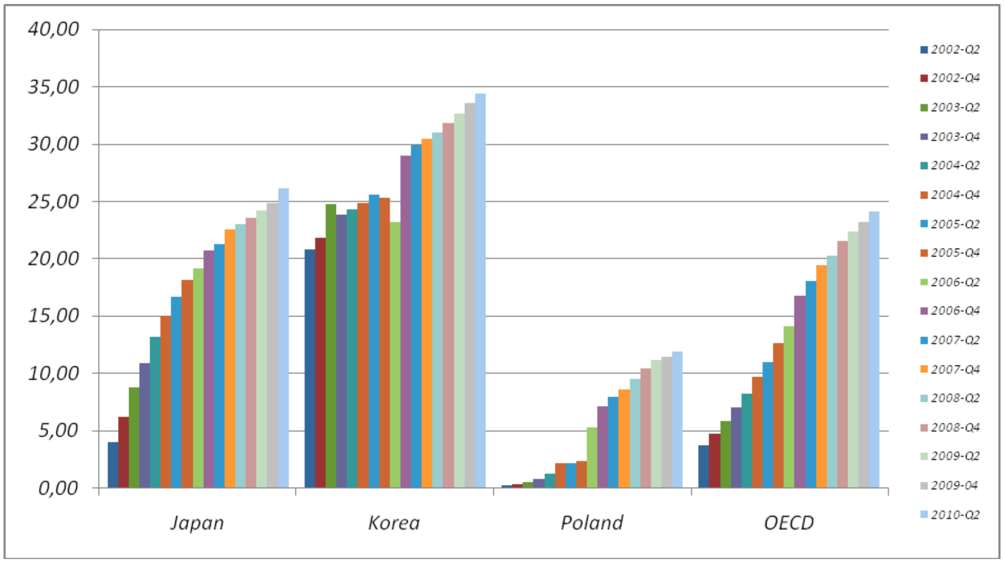

Fig. 1: Six year historical time series, broadband lines penetration (June 2010) for Japan, Korea, Poland and OECD, as an average for all OECD countries

by 2013 and seeks to en sure that, by 2020:

- all Europeans have access to much higher internet speeds of above 30 Mbps,
- 50% or more of European households subscribe to internet connections above 100 Mbps.

The only solution of 100 Mbps access line bandwidth is to built it as the optical access, i.e. to implement in access network layer FITL technology (Fiber In The Loop) and especially FTTH (Fiber To The Home) technology. Rapid deployment of FITL technology into telecom networks is currently realized in Korea and Japan (on the world) and in Sweden and Denmark on Europe [9]. However the FTTH lines penetration is usually very low in many countries (in Poland is less than 1), what is depicted in Fig. 2 [4].

From Fig. 2 it follows that the level of FTTH lines penetration is very low in Europe, putting Europe far back towards Japan and Korea. Implementation of specialize services in European networks show that some of them could not be successfully offered in wires broadband access lines (for example healthcare systems) [11]. So, many

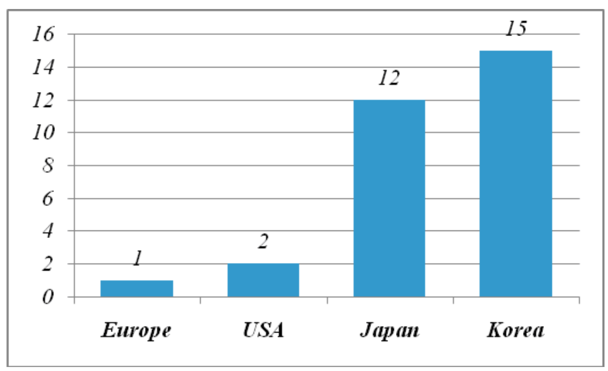

Fig. 2: Fiber to the Home (FTTH) penetration in July 2009

European countries invest or intend to invest in FTTH infrastructure improving existing telecomm operators networks. The Netherlands intends to reach 19% penetration (about 1,5 millions lines) of all homes lines with FTTH technology by 2014 [5] and the French government plans to invest 2 billion € and cover 100 % of its citizens with fiber by the year 2025 [6].

Poland is far back not only towards Korea and Japan but also towards almost all European countries. Changing this situation requires a lot of investment in existing network infrastructure, especially in access network layer. Currently, some Polish regions uses European Regional Funds (ERDF) to improve access network layer and implement FTTH technology in access layer networks. Usually, built in FTTH technology access network layers possesses functionality as the NGA.

Fiber To The Home is one of several methods for delivering Broadband to residential subscribers. With FTTH, the architectural distinctions between types of carriers disappear. All these carriers deploy virtually identical architectures once they are delivering services with FTTH, and the only remaining differences are largely due to legacy system support. As FTTH is one of the different access versions, so the others can be commonly used. Those other are as follows [7]:

- FTTB - Fiber to the Building, usually a multi-tenant building, with Digital Subscriber Line (DSL) or Ethernet delivered to each subscriber.

- FTTC - Fiber to the Curb, typically with some form of DSL connecting to the subscribers.

- FTTN - Fiber to the Node, typically with ADSL2+ or VDSL2 from an OutSide Plant (OSP) cross-connect to the subscribers.

- FTTP - Fiber to the Premises, where the premises could be a business or a residence.

The Authorities of Tuchola County decided to build the modern IP network, that cover entire Tuchola region. This network was to be financed from ERDF funds of actual financing period. Before to apply for ERDF funds the Feasibility Study should be prepared, where one of part of it was the network project. Tuchola County network project has been done by the staff of Computer Communication Division Institute of Telecommunication UTP.

2 Topology of Tuchola County Optical Network

Considering all the possible services expected by network users, i.e. Internet access, digital TV, VoD, P2P, videoconferencing, monitoring, controlling, VoIP services as well as the tendency in IP network development we decided to implement this regional network as the optical network. The network project (network plan) required to define, at the beginning topology of the network, but the network topology has been followed from Tuchola County Authorities requirements.

One of the main requirement from Tuchola County Authorities was that each node of the network should be located in the town or village in County that is the capital of commune. So the ducts with optical cables should connect all these places. The ducts has constituted the backbone layer of planned network. In order to improve network reliability, it has been assumed that backbone layer is formed from two optical fibers and operates as bi-directional ring. It has been assumed that the fibers should be ended in municipal offices located in capital of commune. The planned network should operate as aggregation/distribution layer with FTTN functionality.

During network planning process it has been decided also that optical fibers passing villages and towns situated on the route of chosen course of fibers, will be ended in the areas where the greater number of people live. The villages that belong to smaller districts called parishes should be connected to the nodes of backbone layer located in communes capital, with one link constituting star topology.

The terrains of Tuchola's County region are in majority rural and forest areas. The small business located here is mainly set on food processing activity. There is also furniture, mechanical and construction business here. The main part of this institutions is located in Tuchola. The number of small and medium enterprises, which are interested with the access to the network, has been estimated at 15% of whole enterprises.

Tourism also plays an important role for the region development. Although it has seasonal character the demand for this sector has been also included. In view of lack of information regarding exact localization of the business entities it has been assumed that they are located in community nodes, which should not have an direct impact on calculations results, as information from this type of users flow to this nodes.

For estimation of global bandwidth demands it has been assumed that the following public institutions will be connected to Tuchola County broadband information network:

- Primary schools, gymnasium, secondary schools, other educational institutions.
- Hospitals and health institutions.
- Police and municipal police.
- Fire departments.
- Commune and district offices.

It has been assumed that all educational, local government and health institutions, as well as police and fire departments, municipal and community offices are predicted to have an access to the broadband network. The topology of cable ducts for Tuchola County broadband network, both for backbone as well as for access is depicted in Fig. 3.

In Fig. 4 the connection structure for TCBN network has been depicted. Fig. 4 shows that most of lines that connects backbone nodes of TCBN network with nodes located in parishes are direct lines. Only small part of those line passes via intermediate nodes located in other parishes. Using separated fibers for each connection (this method will be discussed in detail in the next part), it is easy however to connect each parish node directly to backbone one. From Fig. 3 follows that total length of all cable ducts for TCBN is equal to 266,9 km, where:

- the length of backbone layer network is equal to 116, 9 km,
- the length of all connections to parishes is equal to 139 km,
- the length of ducts in Tuchola is equal to 11 km.

The project of the passive physical network layer (fiber optic network) involves the construction of the network using Modular Cable System (MCS) technology with the usage of one pipe equipped with three micro pipes. The assumptions about the construction of passive infrastructure are as follows:

- The fibers optical cables are done based on the MCS system.
- MCS cables (pipes) that are used for network construction are suitable for digging directly in the ground. Every pipe is equipped with 3 micro pipes. The fiber cable can be blown into each of micro pipe.
- In the first stage of project implementation to one of three micro pipes fiber cable is blown. The cable contains 96 fibers on the basis of 8 micro cables with 12 fibers in each micro cable.
- For network transmission capacity extension in the future, at each 1 km cable distance the cable bunkers are placed.

For estimation in rural area of investment cost of 1 km MCS cabling infrastructure it has been assumed that:

- Excavation for the cables - 24,0 thousands PLN.
- Cost of cable including MCS cables - 9,0 thousands PLN.
- Optical cable with 96 fibers - 11,0 thousands PLN.

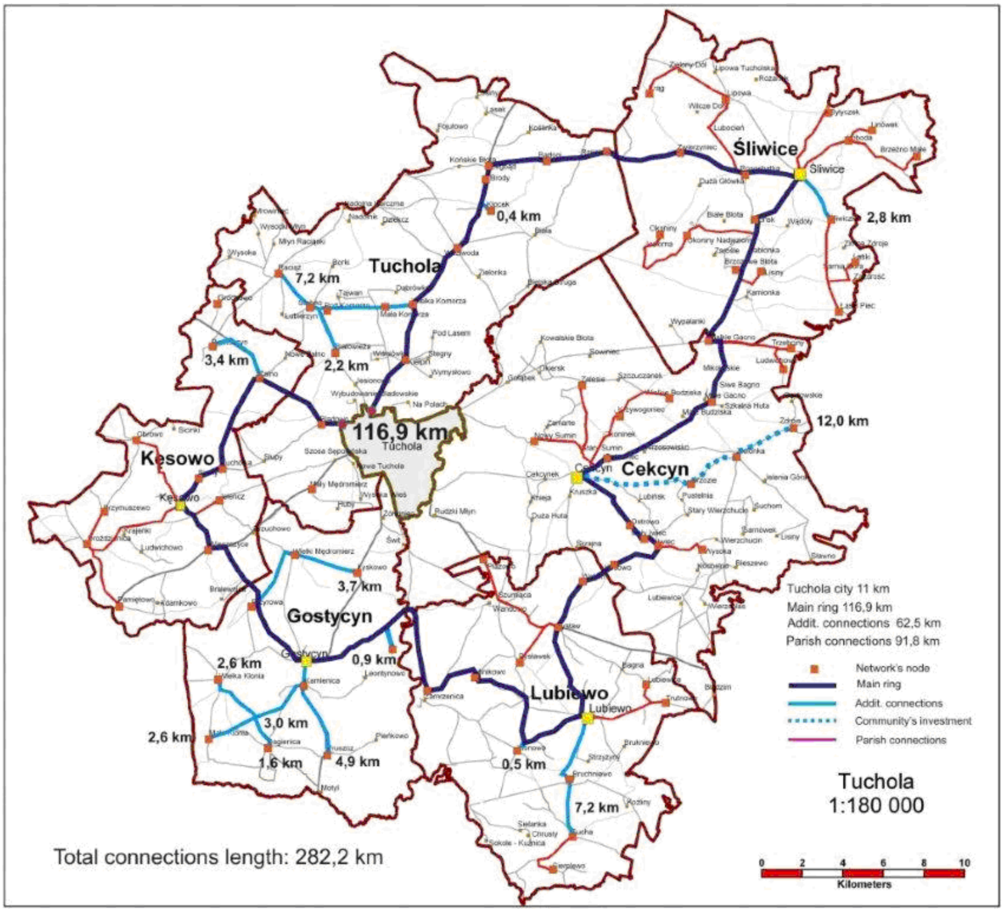

Fig. 3: Topology of cabling infrastructure for Tuchola's County Broadband Network

- Blowing the cable - 2,5 thousands PLN.
- Cabling bunkers - 2.0 thousands PLN.
- Welds - 2,5 thousands PLN.
- Measurements - 1,0 thousand PLN.
- Project - 6,5 thousands PLN.
- Fibers tray - 1,0 thousand PLN.
- Accessories - 0,5 thousand PLN.

Prices used for estimation of 1 km MCS investment cost were taken as an average of prices from different companies that build optical cabling network.

The total cost of 1 km of optical fiber in rural area was estimated on the level of 60 thousands PLN, so the total investment cost of Tuchola County Optical Network passive infrastructure has been calculated and was equal to **15.354 thousands PLN**.

3 Topology of Tuchola City Optical Network

The TCBN project contains also separate project for Tuchola City, i.e. the city that is the capital of County. As it was in the case of TCBN, the optical network in Tuchola City was designed in FTTN technology. Topological structure of Tuchola City network passive fiber optic

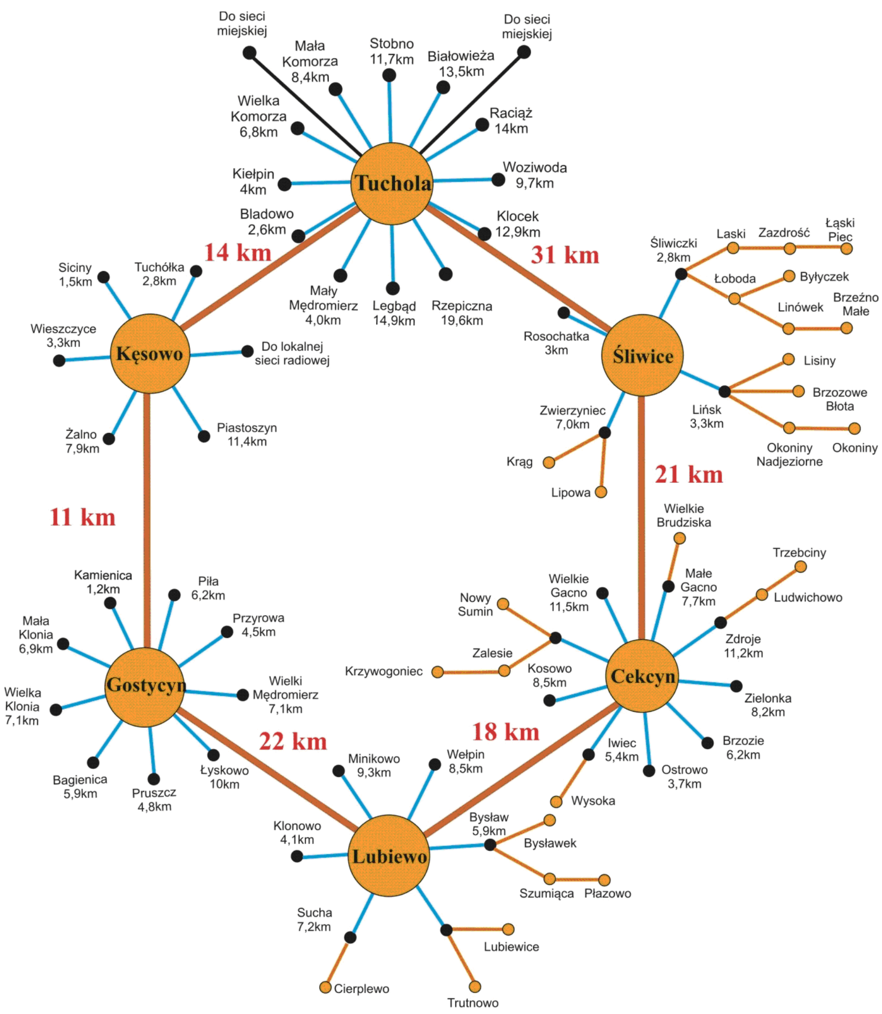

Fig. 4: The logical topology of the TBN Network

physical layer is shown in Fig. 4. This structure shows layout of all build, under the ongoing project, fiber optic cables, both for backbone and access network. In table 1, Tuchola City network node locations and characteristic of those nodes has been depicted.

In turns, Fig. 5 shows a topology structure of network nodes and links connections between the nodes depicted in Fig. 4, that was created on the basis of fibers cable physical layout. The diagram presented in Fig. 5, has been used for a mapping of physical topology depicted in Fig. 1 into logical network topology shown in Fig. 4. In planned Tuchola City IP network it has been assumed that 3 nodes (BN_1, BN_2, BN_3) function as the distribution/ aggregation nodes and the other ones as the access nodes.

Distribution/aggregation nodes of Tuchola City network plays the role of backbone layer network nodes connected together by the fiber links. The backbone layer of every network should be characterized by high level of network reliability. So, over designing process of physical topology Tuchola City network structure, it has been assumed that distribution/aggregation nodes will be connected with double fiber rings. Double ring topology structures are used very often as the topology of backbone layer, as on the one hand this topology ensures high level of network reliability but on the other one, simplifies the management process of traffic transfer in the network.

The way of increasing reliability level of traffic transfer in the ring structure it uses one of well known methods of link or path protection [8]. The main principle of protection lies in fact that all selected pairs of nodes, that communicate with each other, are connected by two disjoint routes. In double fiber optical ring, each of these paths uses single optical fiber. One path is called working path and the second one, protecting path, They are implemented with the use of disjoint rings. Traffic transmitted from any two nodes in backbone must pass through all intermediate nodes lying between those nodes. As in Tuchola City network three backbone nodes are connected without any optical system, so communication between any two nodes, in working or protecting paths, are always done via the third node (in working or protecting paths).

On the basis of fiber rings layout depicted in Fig. 4, real physical network structure of Tuchola City has been modified to "traffic oriented network" [12]. Modified Tuchola City physical network infrastructure includes two unidirectional fibers rings (or one bidirectional), that join three backbone nodes denoted as BN_1, BN_2, BN_3, and also links joining 16 access nodes to backbone ones. So, the modified physical fiber cables structure of Tuchola City IP network is implemented in the form of double fibers ring connecting distribution/aggregation nodes (backbone layer), and branches (spurs), joining backbone nodes with access ones located in the city. Thus the real structure of Tuchola City network topology, build on a physical basis of topological structure presented in Fig. 4, is shown in Fig. 5. From Fig. 5 results that two backbone nodes BN_2 and BN_3 are connected to regional (K-PSI) network via IXP. Two connections of Tuchola City network with regional network has been assumed to increase the level of reliable transfer to the global Internet via nodes A_{13} and A_{21}.

To be able to realize the topological structure of planned network the suitable usage of optical fibers is needed. The main idea of fibers usage is shown below in Fig. 6. Access nodes located on the spurs of network structure are connected with dedicated fibers to the ring, and then using dedicated ring fibers, to backbone nodes. Access nodes located in the ring has been connected to backbone nodes using fibers in the ring. Connections of access nodes located in the ring are realized out as follows: in each relation (optical cable joining neighboring nodes) one pair of fibers (let us take the pair marked with red color) is used for connection of backbone nodes. The other pairs of fibers in analyzed relation can be used for

Tab. 1: Node location and their characteristics

Node	Node Type	Location
Starostwo Powiatowe	**Backbone (BN1)**	Pocztowa st.
NZOZ Hospital	Access (A1)	Nowodworskiego st.
Marketplace	Access (A2)	Marketplace
Secondary school	Access (A3)	Pocztowa st.
Primary school num. 3	Access (A4)	Pocztowa st.
Sport and recreation	Access (A5)	Warszawska st.
Kindergartner	Access (A6)	Piastowska st.
Speciality School	**Backbone (BN2)**	Piastowska st.
Middle school	Access (A7)	Piastowska st.
Tuchola hospital	Access (A8)	Świecka st.
Przedsiębiorstwo Komunalne	Access (A9)	Świecka st.
Kindergartner num. 1	Access (A10)	Bydgoska st.
High school and techinical school	Access (A11)	Świecka st.
Primary school num. 5	Access (A12)	Świecka st.
Regional network	Access (A13)	Główna st.
KPSI	IXP	Przemysłowa st.
Fire Department	**Backbone (BN3)**	Sępoleńska st.
Police	Access (A14)	Świecka st..
Court	Access (A15)	Dworcowa st.
Promary school num. 1	Access (A16)	Szkolna st.
Medical center	Access (A17)	Świecka st.
City hall	Access (A18)	Plac Zamkowy st.
Tax office	Access (A19)	Plac Zamkowy st.
Cultural Centre	Access (A20)	Plac Zamkowy st.
Regional network	Access (A21)	Główna st.
KPSI	IXP	Przemysłowa st.

Fig. 5: The map of planned optical fiber ducts for Tuchola City network

connection of access nodes located in this relation with the nearest (and only one) backbone node. To connect each access node, the described idea requires to use separate pair of fibers. Obviously, similar situation is when connecting access nodes on spurs, as in the ring the fibers for joining spur nodes are chosen in the same way as the fibers for connection of access nodes lying in the ring.

However, to reduce the number of needed fibers, it has been assumed that the pair of fibers in the cable with the same number can be used repeatedly, however, two access nodes located in the network ring can be connected, with the same number of fibers pair, to different backbone nodes. For example, in Fig. 6 it has been shown that the pair of fiber marked with a green color (let us assume fiber pair with i-number) connects, in the same cable relation, A3 with BN1 and A6 with BN2. The described above method of fibers reuse, gives topology required minimal number of fiber pairs usage. For network presented in Fig. 5, the construction of this network requires only four pairs of fibers. In this way the logical structure of all connections is depicted in Fig. 7, where each Node (installed in access node) is join directly with one backbone node. The described method of fiber reuse has been also used in TCBN network for connecting communities and parishes

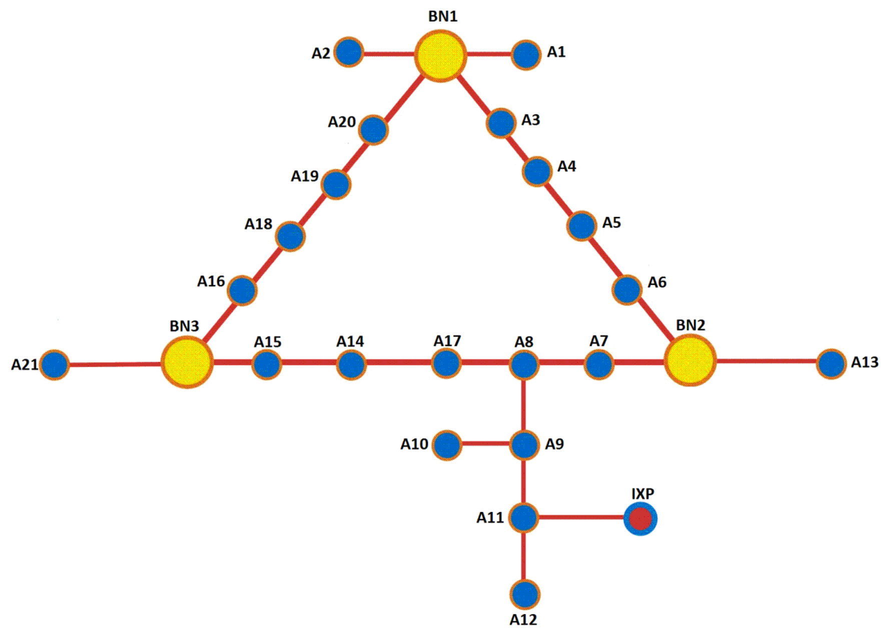

Fig. 6: Physical connection scheme following from network structure shown in Fig. 4

in Tuchola County.

Estimation of 1 km MCS cabling infrastructure investment cost in Tuchola City is based under the same assumption as for rural area, with the only difference that concerns to cost of excavation for the cables. Usually, in cities this cost is much higher than in rural area, so we have assumed that instead of 24,0 thousands PLN, this cost in Tuchola City is equal to 74 thousands PLN. Thus the average cost of 1 km fiber cable implementation in Tuchola City is around 110 thousands PLN. As the total length of fiber infrastructure in Tuchola city is about 11 km long, so the total cost of Tuchola City network passive infrastructure (fiber cabling) was calculated as 1,22 millions PLN.

Before the necessary choice of the equipment it is essential to evaluate the total volume of traffic generated in Tuchola City network. The traffic in this network has been calculated in accordance with the procedure outlined in the paper [12]. For traffic evaluation the following assumptions has been taken:

1. around 20% of all households in Tuchola city will be connected (via ISP networks) to planned Tuchola City Network. Average capacity of user access line will be 6 Mb/s;

2. around 15% of total number of SME companies (Small and Medium Enterprises) will be connected to planned network. Average capacity of business user access line will be 20 Mb/s;

3. all educational institutions, government, and local government agencies, health care, police department, fire department, municipal and county offices will be connected to designed network. Average capacity of access line for institutional users will be 10 Mb/s;

4. overbooking factor is assumed as:

   - 20 for residential users,
   - 10 for business user;

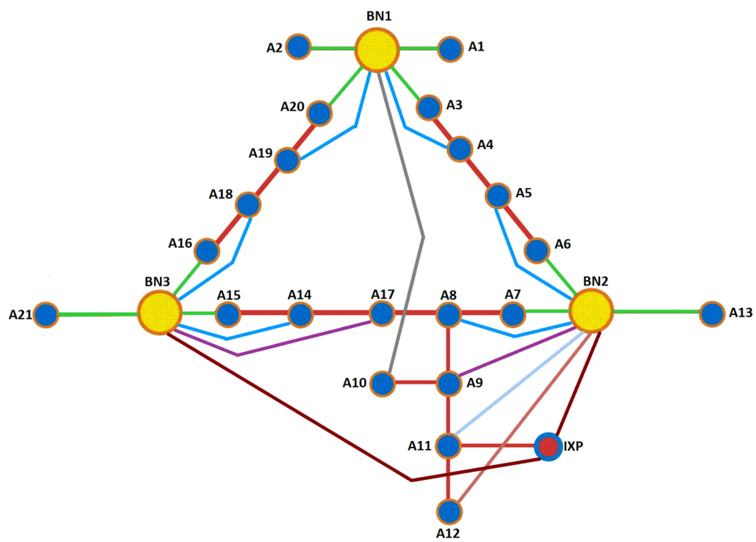

Fig. 7: Physical fibers connections for backbone and access network implementation

- 6 for institutional ones.

Taking into account the assumptions presented above, the total volume of traffic generated in Tuchola City has been estimated equal to 700 Mb/s.

4 Active infrastructure for Tuchola County Broadband Network

In TCBN network the same active equipment has been used. Before the concrete active equipment has been chosen there was made necessary calculation to evaluate equipment efficiency (performance) in the sense of total traffic volume served in the network. The total traffic volume generated in TCBN network has been made according to the procedure proposed in [12].

As an active equipment option for TCBN network, there has been chosen Metro Ethernet switches with path protection. This option is both, cost effective (allows to build the network with minimal cost) and bandwidth effective (ensures high throughput). The details requirements for Metro Ethernet switches installed in TCBN network are given below:

- Two neighboring backbone nodes connected (on double fiber rings) to the third one are using 2 optical links with capacity of 10 Gb/s. Such high capacity of backbone connections will allow to operate TCBN City, ensuring network scalability for at least 10 years and guaranteeing the appropriate level of services offered in the network. Switches ports of 10 Gb/s capacity should be equipped with optical interfaces ensuring proper transmission even on 40 km range. Every Metro Ethernet switch installed in backbone layer node additionally should support MPLS protocol, as the protection functions in the backbone are provided by MPLS protocol. MPLS protocol ensures traffic switching into protecting path in the case of working path failure.

- Each backbone node is equipped with 24 optical ports with 1 Gb/s capacity, through which these nodes are connected to lower level access nodes, located throughout the city. Similarly to the specification of backbone ports, also 1 Gb/s access ports should provide efficient transmission of up to 70 km

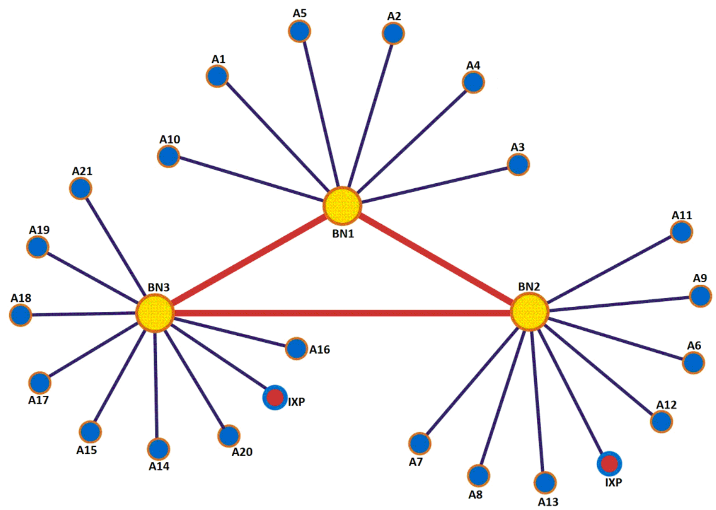

Fig. 8: Logical topological structure of Tuchola City IP network

distance.

- In access nodes the switches are equipped with one 1 Gb/s optical port (for connection with backbone node) and at least 6 wire ports (for user connection) with capacity 1 Gb/s.
- It has been assumed that active equipments of backbone nodes are installed mostly in the indoor cabinets. The cabinets are equipped with power supply unit, air condition device and UPS module. The outdoor cabinets are only located at the police station, hospital, fire department and City Hall, as there is no possibility to install indoor ones. Outdoor cabinets are also equipped with air condition devices, power supply unit as well as UPS.

In designed TCBN network the backbone nodes have been located in community capital (for rural areas) or in three main locations (District Office, Speciality School and Fire Department) for Tuchola City network. It should be noted however that described network would operate in future as Carrier of Carriers network type, where the users (both residential and business) going to be join to the network via local ISP networks. So, in the planned here network do not exist access lines connecting end users, as in fact this city network is "last mile before" network.

The switches for backbone nodes connections, both in rural area as well as in Tuchola city has been chosen on the basis of the following assumption: all backbone nodes in TCBN network, i.e. towns or villages where the commune headquarters are located, and backbone nodes in Tuchola City network are connected with through links with a capacity of 10 Gb/s. As all backbone nodes are connected physically by the double optical ring Metro Ethernet switches joining backbone nodes possesses built in functionality of increasing network reliability. Each ME switch, installed in backbone node, is equipped with two 10 GbE ports connected to two separate fibers. In the case of the fiber failure, traffic transfer among every pair of backbone node can be realized with the use of one or second fiber. 10 Gbps links capacity allows to operate the network for next couple of years with the assurance of high level of services offered by the network (high network scalability). As, in rural part of TCBN, the backbone nodes are located even several dozen kilometers each other, 10Gb/s Metro Ethernet ports have to be equipped with the inserts which allow the optical propagation of the signal at distance of 40 km. For switches installed in Tuchola City network backbone nodes the inserts allow the optical propagation of the signal at distance of 10 km.

Both for rural and city parts, the network has been planned to ensure wide scalability. It has been assumed that the main nodes of the network (backbone ones), are to be connected to each other using links with transmission capacity of 10 Gb/s, while the access nodes has been joined to the backbone nodes using links with 1 Gb/s transmission capacity. Logically, the access nodes together with backbone one, forms a star topology (the optimal topology for "traffic oriented network") with backbone nodes as the main star nodes. Functionally, both the backbone and access nodes of TCBN network meet mainly distribution (aggregation) functions, as their role is traffic transfer, to (from) main (backbone) nodes, from (to) access nodes and further to (from) regional network and thence to (from) global Internet. All access nodes lying both, on network ring or outside network ring are connected with dedicated fiber to only one backbone node. Admittedly, the star structure of access network does not guarantee high level of reliability, but it is the cheapest structure, that allow efficient traffic transfer. In fact, the damage of a fiber optic link will affect only the small group of users.

The switches installed in backbone nodes are also equipped with at least 12 ports with a total throughput of 1 Gb/s each. These ports are used to connect the parish (in rural area) or access (in city) nodes within the backbone nodes. All these 1Gb/s ports have optical interfaces that allow to traffic transfer at distance of 10 km or 70 km.

The price of the 10Gb/s equipment is estimated as follows: backbone ports - 112 thous. PLN and access ports has been calculated using the relation: n10 * 2,4 thousands PLN for the 10 km transmission or n70 * 8,6 thousands PLN for the 70 km transmission, where nx means the number of these kind of ports. It is assumed that devices in rural area the backbone nodes are installed in indoor cabinets. These cabinets are equipped with an UPS battery in case of power failure. The estimated cost of the cabinet including UPS system is 10 thousands PLN. In Tuchola City network backbone node equipment is also installed in indoor cabinets.

In parishes (in rural areas) and in access nodes (in Tuchola city) the direct access to optical network (to backbone nodes) is realized by switches equipped with 1Gb/s optical port. These switches are also equipped with at least 6 GE wire ports. The cost of the nodes in parishes (in rural area) and access nodes (in Tuchola city) include the cost of switch and transmission inserts. The cost of the switch with 6 GE ports is estimated at 3,0 thousands PLN whereas for optical 1Gb/s insert with a range of transmission at 10 km - 2,4 thousands PLN and at 70 km - 8,6 thousands PLN.

The parishes devices are installed in indoor cabinets. No UPS battery support system is predicted there. The cost of such cabinet is estimated at 3 thousands PLN. If there is no possibility to place indoor cabinets the outdoor cabinets are predicted to be used instead. The outdoor cabinets are equipped with AC and ventilation system. The cost of such cabinet is estimated at 16 thousands PLN. It has been suggested that the Tuchola County Broadband Network should be connected to the global Internet via Kuyavia-Pomerania Regional Broadband (K-PSI) network. The Internet Exchange Point with K-PSI network is installed in two backbone nodes located in a Main Power of Tuchola. The connection between TCBN and K-PSI regional network is going to be implemented for every node through two links with 1 Gb/s each (all together 4 Gb/s).

The total cost of network infrastructure (including active and passive equipment) installed in entire Tuchola County Broadband Network equals to: 13272 thousands

PLN. The total cost of network infrastructure installed in Tuchola City network has been estimated on 1914 thousands PLN.

5 Conclusions

The paper is devoted to the designing project (plan) of Tuchola County Broadband Network (TCBN). In the paper, the topological structure of fiber optic network as well as the final solution for active layer of the network has been presented. For construction of passive infrastructure the technology of Modular Cable System - MCS has been suggested. Within this technology the fairly wide range scalability and cost effective network has been provided.

For the construction of TCBN network active layer the Metro Ethernet technology is used. Metro Ethernet technology provides a low cost of construction (CAPEX), ease of implementation of the network and low operating cost (OPEX). The parameters of installed network switches (switches) Metro Ethernet guarantee the scalability of the network for at least 10 years. The project assume also, that the city network in Tuchola cooperate with the regional K-PSI network (TCBN network and K-PSI network exchange traffic via common IXP point).

Total network investment cost in Tuchola County is estimated on 15,2 million PLN.

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