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A DESIGNING OF TELECOMMUNICATION NETWORK FOR THE BYDGOSZCZ CODE AREA

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Summary: In this paper an engineering approach to designing a telecommunication network over the Internet Protocol has been presented. The proposed network covers demand for telecommunication services in the Bydgoszcz code area operated by the Polish Telecommunications Co. In this network two classes of services were distinguished: Voice over the Internet Protocol (VoIP) and access to the Internet. The logical structure of the network is a superposition of two structures. First of them contains links that support VoIP and the second one contains links that provide access to the Internet. The physical structure of the network was implemented basing on the Synchronous Digital Hierarchy.

Keywords: router, link, designing

1. INTRODUCTION

This study contains engineering approach to designing of telecommunication network over Internet Protocol and can be an extension of Telecommunications Systems lecture for students of telecommunication. It contains a design of telecommunications network for assumed numeral data of Bydgoszcz code area **(former** Bydgoszcz province) **operated by the Polish Telecommunications Co** (PT Co.). National operator offers real-time services as well as the access to the Internet. The designed network should cover the demand for telecommunications services in the **Bydgoszcz** code area and interoperate with the networks of others operators. Adopted output data, i.e. the number of subscribers of the Polish Telecommunications Co. network, the number of users in the various municipalities, the number of classes of services, etc. differ significantly from the actual data and were adopted only for the project. The design includes the backbone layer of the network without the access layer. Only two classes of traffic: Voice over the Internet Protocol and access to the Internet were taken into account in output data.

The need for writing this article arose due to lack of the holistic approach to designing a network over IP platform in literature. This study was accompanied by a number of explanations and comments to increase its educational value.

Presentation of the whole scheme of network design (traffic structure, logical structure and physical structure) is a contribution of the author.

The whole study consists of six parts. The first part contains the command and output data for the project. The second part determines number of routers of the network and division of the entire area of the network into areas associated with particular routers. The third part shows the phone traffic and Internet traffic structures of the network. The fourth part contains the logical structure of the proposed network, together with accepted assumptions. The fifth part shows the physical structure of the proposed network. Part sixth contains a summary and conclusions.

Design of telecommunication network for Bydgoszcz code area **(former** Bydgoszcz province)

1. Design requirements:
   a) Logical topology:
      – determine the number o routers;
      – determine the structure of VoIP and the Internet traffic (for **exemplary router draw a flowchart of outgoing and incoming traffic);**
      – determine the logical structure of network (bandwidth of links of network and bandwidth of links at points of connection with MAN Bydgoszcz and with network of Polish Telecommunications Co. (PT Co.)
   b) Physical topology (on the basis of SDH):
      – determine course of transmission routes;
      – make the dimensioning of transmission systems (in the case of SDH there is a need to take into consideration the ring configuration);

for a telecommunication network serving traffic generated by 25000 subscribers of VoIP, assuming that 50% of subscribers will apply for access to the Internet.

2. **Design assumptions:**
   a) number of subscribers in the PT Co. network – 150000
   b) point of connection for Internet services – MAN Bydgoszcz
   c) points of connection of proposed network with PT Co. network:
      – for local traffic – local exchanges (LE): LE Chojnice, LE Inowrocław;
      – for long-distance traffic and international long-distance traffic – long-distance exchange (LDE): LDE Bydgoszcz;

It should be noticed that LDE Bydgoszcz, LE Chojnice and LE Inowrocław are located in the PT Co. network which is a circuit switched network.

3. The percentage of subscribers, depending on the size of bandwidth of access to the Internet: 10% of subscribers with bandwidth 2048 kbit/s, 20% of subscribers with bandwidth 1024 kbit/s and 70% of subscribers with bandwidth 512 kbit/s;
4. The distribution of subscribers in Bydgoszcz code area is given in Table 1. It should be noted that national operator (PT Co.) offers real-time services as well as the access to the Internet. Therefore, the numbers of subscribers in the particular communities are so small.

Table 1. The number of subscribers in the particular communities in Bydgoszcz code area

No.	Community	Subscribers	No.	Community	Subscribers
1	Bydgoszcz	5000	30	Bukowiec	100
2	Barcin	350	31	Cekcyn	250
3	Brusy	500	32	Dąbrowa	150
4	Chojnice	1500	33	Dąbrowa Biskupia	150
5	Czersk	750	34	Dąbrowa Chełmińska	100
6	Gniewkowo	350	35	Dobrcz	150
7	Inowrocław	2500	36	Dragacz	100
8	Janowiec Wielkopolski	250	37	Drzycim	100
9	Janikowo	300	38	Gąsawa	150
10	Kamień Krajeński	250	39	Gostycyn	200
11	Kcynia	400	40	Jeziora Wielkie	150
12	Koronowo	400	41	Jeżewo	100
13	Kruszwica	350	42	Kęsowo	100
14	Łabiszyn	250	43	Lniano	100
15	Mogilno	750	44	Lubiewo	200
16	Mrocza	200	45	Nowa Wieś Wielka	150
17	Nakło nad Notecią	750	46	Osie	100
18	Nowe	200	47	Osielsko	150
19	Pakość	250	48	Pruszcz	100
20	Sępólno Krajeńskie	750	49	Rogowo	250
21	Solec Kujawski	750	50	Rojewo	150
22	Strzelno	300	51	Sadki	150
23	Szubin	300	52	Sicienko	150
24	Świecie	750	53	Sośno	150
25	Trzemeszno	350	54	Śliwice	100
26	Tuchola	1250	55	Świekatowo	150
27	Więcbork	300	56	Warlubie	150
28	Żnin	750	57	Złotniki Kujawskie	150
29	Białe Błota	200			
				Sum	25000

PROJECT SOLUTION

2. NUMBER OF ROUTERS

The number of routers to some extent is related to the number of subscribers served by a single Call Manager (cluster). Call Manager is installed on the server connected to a router. Single Call Manager can handle up to 7500 subscribers, while the cluster to 30000 subscribers [5]. Assumption: number of routers equal to n.

In this project it was assumed that the entire area served by the network is divided into five equal areas in terms of the number of users: Bydgoszcz area, Chojnice area, Koronowo area, Żnin area and Inowrocław area. Each area will include 5000 users and will be served by a single Call Manager. There are also 5 routers (n = 5) in backbone layer. They are named by analogy: Bydgoszcz router, Chojnice router, Koronowo router, Żnin router and Inowrocław router (Each router is associated with appropriate area). Figure 1 shows the division of the entire area of the network into areas associated with particular routers, while Table 2 contains the allocation of communities in these areas.

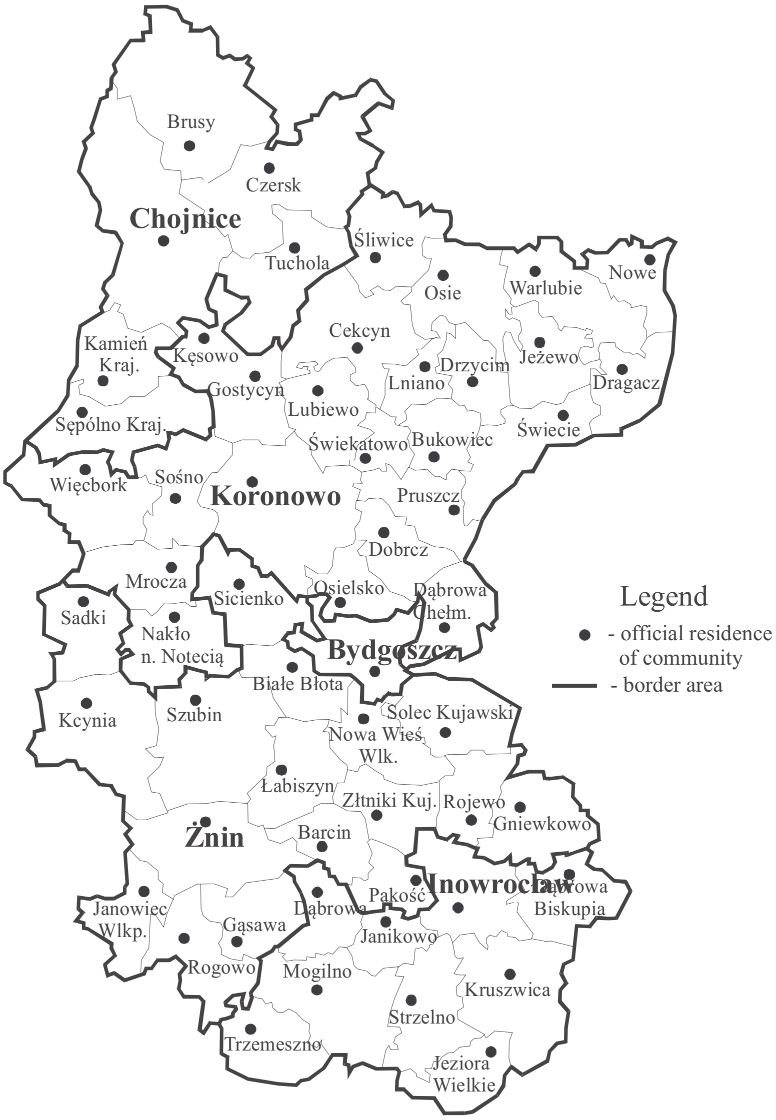

Fig. 1. The division of the entire area of the network into areas associated with particular routers

Table 2. The allocation of communities to individual areas of the network

No.	Area/Community	Users	No.	Area/Community	Users
	Bydgoszcz Area		22	Śliwice	100
1	Bydgoszcz	5000	23	Świekatowo	150
	Chojnice Area		24	Warlubie	150
1	Brusy	500		**Żnin Area**	
2	Chojnice	1500	1	Barcin	350
3	Czersk	750	2	Gniewkowo	350
4	Kamień Krajeński	250	3	Janowiec Wlkp	250
5	Tuchola	1250	4	Kcynia	400
6	Sępólno Krajeńskie	750	5	Łabiszyn	250
	Koronowo Area		6	Pakość	250
1	Koronowo	400	7	Solec Kujawski	750
2	Mrocza	200	8	Szubin	300
3	Nakło n Notecią	750	9	Żnin	750
4	Nowe	200	10	Białe Błota	200
5	Świecie	750	11	Gąsawa	150
6	Więcbork	300	12	Nowa Wieś Wielka	150
7	Bukowiec	100	13	Rogowo	250
8	Cekcyn	250	14	Rojewo	150
9	Dąbrowa Chełmińska	100	15	Sadki	150
10	Dobrcz	150	16	Sicienko	150
11	Dragacz	100	17	Złotniki Kujawskie	150
12	Drzycim	100		**Inowrocław Area**	
13	Gostycyn	200	1	Inowrocław	2500
14	Jeżewo	100	2	Janikowo	300
15	Kęsowo	100	3	Kruszwica	350
16	Lniano	100	4	Mogilno	750
17	Lubiewo	200	5	Strzelno	300
18	Osie	100	6	Trzemeszno	350
19	Osielsko	150	7	Dąbrowa	150
20	Pruszcz	100	8	Dąbrowa Biskupia	150
21	Sośno	150	9	Jeziora Wielkie	150

3. STRUCTURE OF TRAFFIC

3.1. STRUCTURE OF PHONE TRAFFIC

Assumption:
L – number of subscribers of the proposed network; $L(PT\ Co.)$ – number of subscribers of the PT Co. network, L_i – number of subscribers in area i (associated with router i), b – band for VoIP (In this paper it was assumed 32 kbit/s);
Points of connection:

a) for long-distance traffic (including international long-distance traffic) – LDE Bydgoszcz (point *A*)*;
b) for local traffic – LE Chojnice and LE Inowrocław (point *B* and point *C* respectively)*;

* – mark A, B, C are introduced to simplify formulas in the remainder of the project.

Flowchart of phone traffic in router *i*.

Assumption:

Probability of selection of the desired subscriber from the proposed network and from the PT Co. network is the same;
Probability of selection of the desired subscriber from area *i* is the same as from the other areas.

The total traffic generated in router *i*, specifically generated by the subscribers included in the access network, connected with the router *i*, is divided into long-distance traffic and local traffic. In turn, the local traffic is divided into traffic directed to PT Co. network, (through distinguished connection points B and C) and the local traffic of the network, directed to individual routers. Below Figure 2a, the flowchart of outgoing traffic of router *i* for generic numeral values, was presented. On the basis of the assumptions the contribution of individual components of traffic in the total traffic was marked on the diagram. The assumed statistical multiplexing ratio is 12:1. In turn, Figure 2b shows the corresponding flowchart of traffic for the router Bydgoszcz (in example under consideration). The numbers in circles in this diagram indicate the size of bandwidth, expressed in kbit/s, required to handle traffic. It should be noted that the shown flowchart specifies only the required bandwidth for one direction of transmission. Table 3, designated as *Tout*, shows the size of the required bandwidth, taking into account that the implementation of VoIP connection requires a symmetrical bandwidth between pairs of nodes (router *i* – router *j*, router *i* – A, router *i* – B and router *i* – C) for outgoing traffic. Assuming that the amount of traffic exchanged at the inter-network points of connection (outgoing traffic – incoming traffic) are the same, and knowing (based on analogous calculations) the amount of traffic between individual routers, the flowchart for incoming traffic can be drawn.

Table 3. *Tout*. The required size of bandwidth between pairs of nodes for outgoing traffic (kbit/s)

Router/ Router	Bydgoszcz (i = 1)	Chojnice (i = 2)	Koronowo (i = 3)	Żnin (i = 4)	Inowrocł. (i = 5)	A: LDE	B: LE Chojnice	C: LE Inowrocł.
Bydgoszcz (i = 1)	X	335	335	335	335	1600	5029	5029
Chojnice (i = 2)	335	X	335	335	335	1600	5029	5029
Koronowo (i = 3)	335	335	X	335	335	1600	5029	5029
Żnin (i = 4)	335	335	335	X	335	1600	5029	5029
Inowrocł. (i = 5)	335	335	335	335	X	1600	5029	5029
A: LDE	1600	1600	1600	1600	1600	X	X	X
B: LE Chojnice	5029	5029	5029	5029	5029	X	X	X
C: LE Inowrocł.	5029	5029	5029	5029	5029	X	X	X

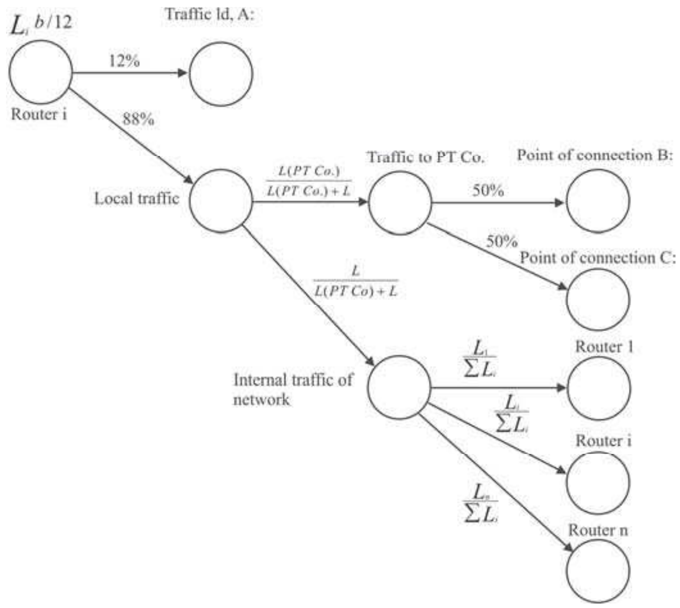

Fig. 2a. The flowchart of outgoing traffic in the router *i*

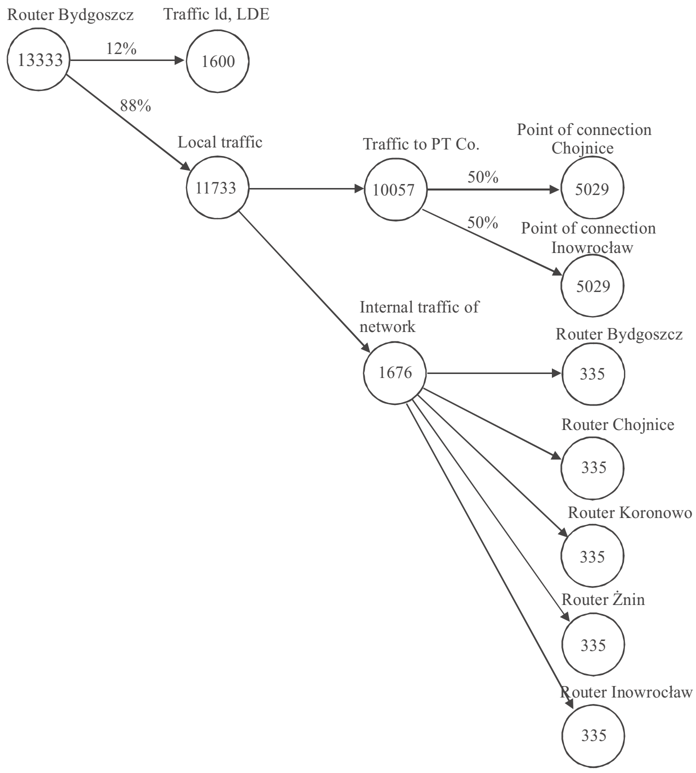

Fig. 2b. The flowchart of outgoing traffic in the router Bydgoszcz (in kbit/s)

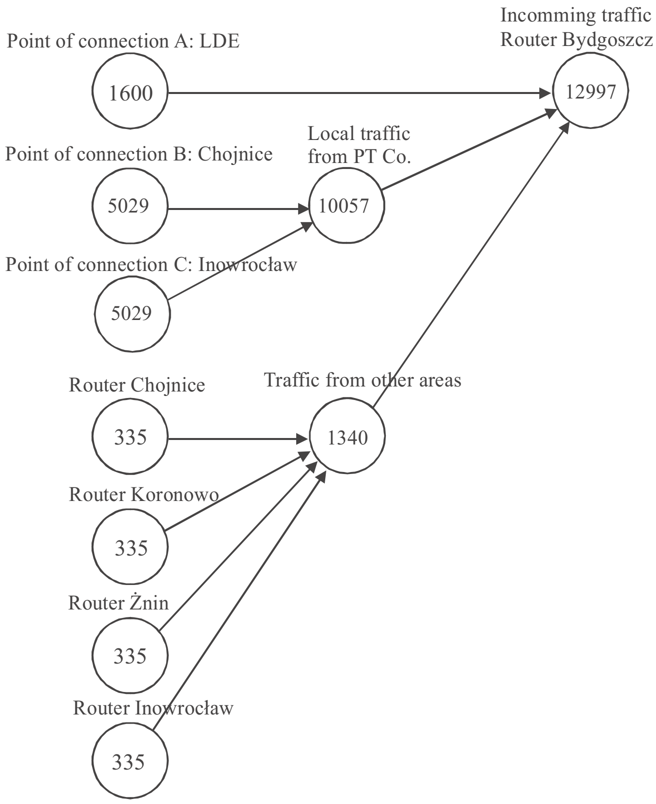

Fig. 3. The flowchart of incoming traffic in router Bydgoszcz

Table 4. *Tin*. The required size of bandwidth between pairs of nodes for incoming traffic (kbit/s)

Router/ Router	Bydgoszcz (i = 1)	Chojnice (i = 2)	Koronowo (i = 3)	Żnin (i = 4)	Inowrocł. (i = 5)	A: LDE	B: LE Chojnice	C: LE Inowrocł.
Bydgoszcz (i = 1)	X	335	335	335	335	1600	5029	5029
Chojnice (i = 2)	335	X	335	335	335	1600	5029	5029
Koronowo (i = 3)	335	335	X	335	335	1600	5029	5029
Żnin (i = 4)	335	335	335	X	335	1600	5029	5029
Inowrocł. (i = 5)	335	335	335	335	X	1600	5029	5029
A: LDE	1600	1600	1600	1600	1600	X	X	X
B: LE Chojnice	5029	5029	5029	5029	5029	X	X	X
C: LE Inowrocł.	5029	5029	5029	5029	5029	X	X	X

3.2. STRUCTURE OF INTERNET TRAFFIC

Assumptions:
L_i – number of subscribers in area *i* (associated with router *i*), P – number of subscribers (percentage) applying for access to Internet, where: x% of the bandwidth 512 kbit/s, y% of the bandwidth 1024 kbit/s and z% of the bandwidth 2048 kbit/s. The required bandwidth for incoming traffic: 256 kbit/s. Point of connection: MAN Bydgoszcz.

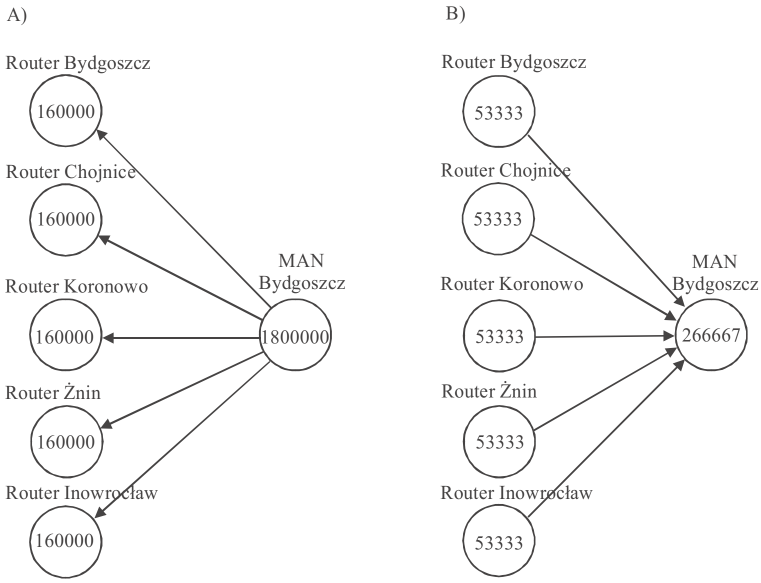

Fig. 4. The structure of Internet traffic (kbit/s): a) incoming; b) outgoing

The required size of bandwidth for the traffic $T_{MAN,i}()$ coming form the MAN Bydgoszcz to the router *i* for subscribers with bandwidth 512 kbit/s, 1024 kbit/s and 2048 kbit/s can be defined as follows:

$$\begin{aligned} T_{MAN,i}(512) &= L_i\ P\ x\ k\ 512 \\ T_{MAN,i}(1024) &= L_i\ P\ y\ k\ 1024 \\ T_{MAN,i}(2048) &= L_i\ P\ z\ k\ 2048 \end{aligned} \tag{1}$$

where:
k is the coefficient of concentration (equal to 12:1).

The total amount of bandwidth for traffic coming from the MAN Bydgoszcz to the router *i* can be defined as:

$$T_{MAN,i} = L_i\ P\ k\ (x\,512 + y\,1024 + z\,2048) \tag{2}$$

Assuming that the required bandwidth per subscriber for outgoing traffic (regardless of the size of bandwidth for incoming traffic) is 256 kbit/s, the total amount of bandwidth for outgoing traffic can be defined as:

$$T_{i,\,MAN} = L_i \; P \, k \, 256 \, (x + y + z) \tag{3}$$

For the variant under consideration: $T_{MAN,i}(512)$ = 74667 kbit/s, $T_{MAN,i}(1024)$ = = 42667 kbit/s; $T_{MAN,i}(2048)$ = 42667 kbit/s and aggregate value $T_{MAN,i}$ = 160000 kbit/s; while $T_{i,MAN}$ = 53333 kbit/s for i = 1,2,...,5. Figure 4 shows the flowchart of outgoing traffic and incoming traffic. It should be emphasized that the required bandwidth, on connections serving the Internet traffic between the router and a MAN Bydgoszcz, is asymmetric (greater value for incoming traffic).

4. LOGICAL STRUCTURE OF THE NETWORK

To determine the logical structure of the network it is necessary to specify the bandwidth of (unidirectional) links between individual pairs of nodes, i.e. between routers of the proposed network, between network routers and exchanges in the PT Co. network (exchanges A, B, C) and between the network routers and MAN Bydgoszcz. The required bandwidth (unidirectional) to serve telephone traffic (VoIP) can be determined summing appropriate elements of the Table *Tout* (describing the required bandwidth to serve outgoing traffic) with the relevant elements of the Table *Tin* (which determine the bandwidth required to serve incoming traffic). Thus, the required bandwidth between pairs of nodes (*i, j*) can be defined as:

$$T_{i,\,j} = Tout_{\,i,\,j} + Tin_{\,i,\,j} \qquad i, j = 1 \ldots n+3 \tag{4}$$

In turn, the required bandwidth to serve the Internet incoming and outgoing traffic are defined by $T_{MAN,\,i}$ and $T_{i,\,MAN}$ for $i = 1,\ldots,n$ (formulas (2) and (3)). Below, Table 5 (*T*) shows the required bandwidth in the proposed network.

Table 5. *T*. The required bandwidth in the proposed network (kbit/s)

Router/ Router	Bydgoszcz (i = 1)	Chojnice (i = 2)	Koronowo (i = 3)	Żnin (i = 4)	Inowrocł. (i = 5)	A: LDE	B: LE Chojnice	C: LE Inowrocł.	MAN
Bydgoszcz (i = 1)	X	670	670	670	670	3200	10057	10057	53333
Chojnice (i = 2)	670	X	670	670	670	3200	10057	10057	53333
Koronowo (i = 3)	670	670	X	670	670	3200	10057	10057	53333
Żnin (i = 4)	670	670	670	X	670	3200	10057	10057	53333
Inowrocł. (i = 5)	670	670	670	670	X	3200	10057	10057	53333
A: LDE	3200	3200	3200	3200	3200	X	X	X	X
B: LE Chojnice	10057	10057	10057	10057	10057	X	X	X	X
C: LE Inowrocł.	10057	10057	10057	10057	10057	X	X	X	X
MAN	160000	160000	160000	160000	160000	X	X	X	X

It should be noted that the designated bandwidth of links in Table 5 (*T*) does not include **overheads** (i.e. the increase of the volume of information transmitted) brought by the various protocols. In this project it was assumed that the data sent through the Internet links are served by Transmission Control Protocol (TCP), Internet Protocol (IP) and Ethernet protocol, while voice data (VoIP) are served by Real-time Transport Protocol (RTP), User Datagram Protocol (UDP), IP and Ethernet protocol [1]. Assuming that the length of sent/received data through the application layer (from the point of view of TCP/IP model) to/from the Internet is at an average of 1000 bytes and taking into account that the overheads brought by the individual protocols, the total percentage of the overheads brought by those protocols can be specified. The overhead brought by the TCP protocol (TCP header length) is 20 bytes, the IP overhead is 20 bytes and the overhead resulting from the structure of an Ethernet frame is 30 bytes [3]. Thus, the relative percentage of overhead for the data sent to (received from) the Internet can be described as follows:

$$\text{Overhead}_{Int} = (1000+20+20+30)*100\%/1000=107\% \tag{5}$$

In a similar way, there can be defined the total overhead for VoIP data, assuming that the length of the data after encoding is about 40 bytes [1]. RTP overhead is 12 bytes and UDP overhead (the protocol does not use confirmation during transmission) is 8 bytes and overhead Ethernet protocol is 30 bytes in relation to transmitted data (IP packets from the network layer) [3]. The percentage of the total overhead for the VoIP can be defined as before:

$$\text{Overhead}_{VoIP}=(40+12+8+20+30)*100\%/40=275\% \tag{6}$$

The bandwidth in Table 5 should be adjusted after determining the size of overhead brought by the individual protocols of TCP/IP model for VoIP and Internet connections. Table 5 elements determining the required bandwidth for VoIP $(T_{i,j},\ i,j=1,2,...,n,A,B,C,\ i\neq j)$ will be increased by 175%, while the elements that determine the bandwidth of links allowing access to Internet $(T_{i,j}, T_{j,i}\ i=MAN,\ j=1,2,...,n)$ will be increased by 7%. Table 6 shows the required bandwidth taking into account the overhead brought by the individual protocols.

Table 6. The required bandwidth taking into account the overhead brought by the individual protocols in proposed network (kbit/s)

Router/ Router	Bydgoszcz (i = 1)	Chojnice (i = 2)	Koronowo (i = 3)	Żnin (i = 4)	Inowrocł. (i = 5)	A: LDE	B: LE Chojnice	C: LE Inowrocł.	MAN
Bydgoszcz (i = 1)	X	1843	1843	1843	1843	8800	27657	27657	57067
Chojnice (i = 2)	1843	X	1843	1843	1843	8800	27657	27657	57067
Koronowo (i = 3)	1843	1843	X	1843	1843	8800	27657	27657	57067
Żnin (i = 4)	1843	1843	1843	X	1843	8800	27657	27657	57067
Inowrocł. (i = 5)	1843	1843	1843	1843	X	8800	27657	27657	57067
A: LDE	8800	8800	8800	8800	8800	X	X	X	X
B: LE Chojnice	27657	27657	27657	27657	27657	X	X	X	X
C: LE Inowrocł.	27657	27657	27657	27657	27657	X	X	X	X
MAN	171200	171200	171200	171200	171200	X	X	X	X

Figure 5 shows the logical structure of the network, taking into account also the links at the points of connection of the proposed network with the network of PT Co. and MAN Bydgoszcz. It should be noted, however, that the network of PT Co. is a circuit switched network, while the proposed network is based on packet switching, hence, there is a need to use gateways at inter-network points of connection (e.g. on the side of PT Co. network).

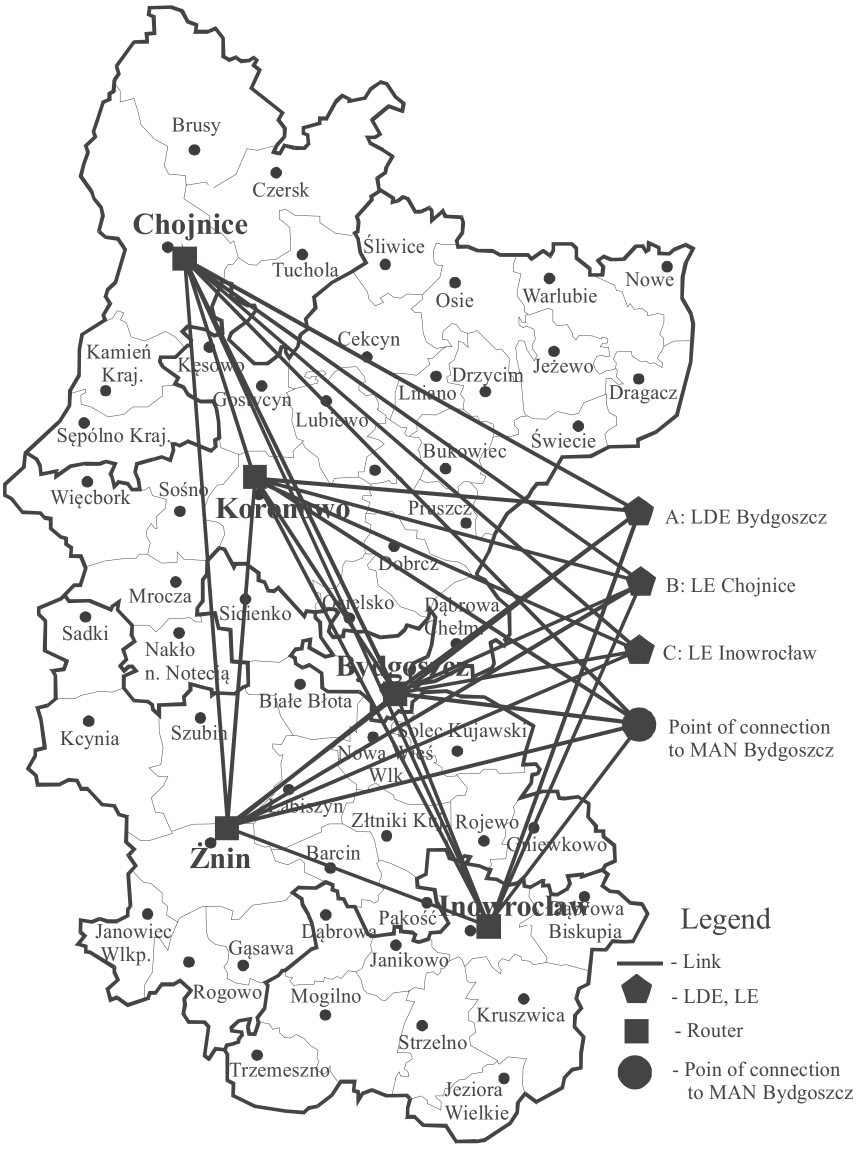

Fig. 5. The logical structure of proposed network

5. PHYSICAL STRUCTURE

Physical structure of the proposed network will be implemented basing on the bi-directional double fiber ring. After determining a bandwidth for each link, the number of virtual containers VC-12, needed to implement these links, should be estimated. For this purpose, the manual of SDH multiplexer TM-160 [2] was used. From this description it follows that the mapping of Ethernet frame 2.16 Mbps can be used in each virtual container VC-12. This means that 50 containers VC-12 (exactly 47 in case of company mapping) is sufficient for transmitting signal (Ethernet frames) of 100 Mbps bandwidth. Thus, the bandwidth determined in Table 6 can be expressed by the required number of containers VC-12.

Table 7. The required size of bandwidth expressed by the number of containers VC-12

Router/ Router	Bydgoszcz (i = 1)	Chojnice (i = 2)	Koronowo (i = 3)	Żnin (i = 4)	Inowrocł. (i = 5)	A: LDE	B: LE Chojnice	C: LE Inowrocł.	MAN
Bydgoszcz (i = 1)	X	1	1	1	1	5	14	14	29
Chojnice (i = 2)	1	X	1	1	1	5	14	14	29
Koronowo (i = 3)	1	1	X	1	1	5	14	14	29
Żnin (i = 4)	1	1	1	X	1	5	14	14	29
Inowrocł. (i = 5)	1	1	1	1	X	5	14	14	29
A: LDE	5	5	5	5	5	X	X	X	X
B: LE Chojnice	14	14	14	14	14	X	X	X	X
C: LE Inowrocł.	14	14	14	14	14	X	X	X	X
MAN	86	86	86	86	86	X	X	X	X

Table 7 shows the required number of containers VC-12 between routers and at inter-network connection points. The dimensioning of the ring can be carried out only now. This ring, as already mentioned bidirectional double fiber, should implement the link between routers (to serve network traffic) as well as links at the points of connection of networks: i.e. links between routers in the proposed network and exchanges in the PT Co. network (exchanges A, B and C) and links between routers and MAN Bydgoszcz. Dimensioning of the ring can be carried out in one of three ways. The first way consists in summing all the needs expressed by the specified number of containers VC-12 between individual pairs of nodes. Since half of the demand (or almost half in the case of odd number of containers VC-12) between a given pair of nodes is performed on one part of the ring, while the second half is performed on complementary part, hence the aggregate number of containers will be the number of containers required for the implementation of a working and backup band (more precisely upper constraint of the band) in the event of failure of the ring. Thus, in the considered example, the aggregate number of routes can be designated as:

$$\sum_{\substack{i=1,2,\ldots,n\\ j=1,2,\ldots,n\\ i>j}} T_{i,j} + \sum_{\substack{i=A,B,C\\ j=1,2,\ldots,n}} T_{i,j} + \sum_{\substack{i=MAN\\ j=1,2,\ldots,n}} T_{i,j} \le 63 \quad (252,1008) \qquad (7)$$

This formula is analogous to the formula determining dimensioning of unidirectional double fiber ring. It consists of three components: the first covers bandwidth (symmetric) between the routers, the second covers bandwidth (symmetric as well) implemented at the points of connection between routers of the proposed network and PT Co. network and the third component includes the bandwidth between the routers of the proposed networks and MAN Bydgoszcz. This bandwidth is asymmetric (Table 7, the greater part of traffic is directed from MAN Bydgoszcz to the proposed network than in the opposite direction). However, in the above formula the symmetric bandwidth was adopted. The second way consists in "manual" allocation of the required number of containers VC-12 between pairs of nodes. In this case the band at the point of connection is implemented by a dimensioned ring. The manual dimensioning can reduce the number of virtual containers required to implementing working bandwidth at the ring because it allows to "complement" residual capacity at the circuit of the ring; however, this way of dimensioning is possible only for a small number of nodes [4]. The third way of dimensioning designates the accurate solution and consists in solving a set of equations and inequalities [4]. The symmetric bandwidth at the point of connection to MAN Bydgoszcz is also adopted in the second and third way of dimensioning.

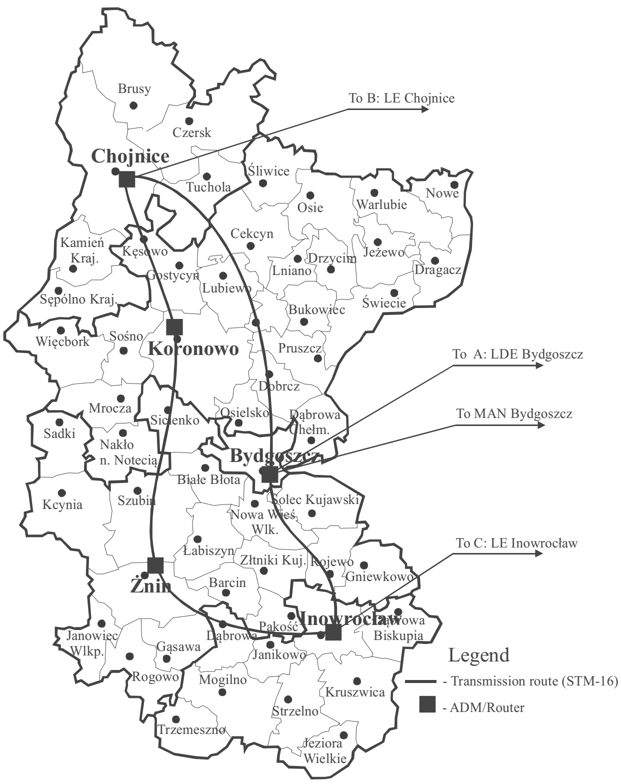

Fig. 6. The physical structure of the proposed network

For the analyzed example, the total number of containers VC-12, determined on the basis of the formula 7, is: 10+165+430 = 605 VC-12. Therefore, to implement the required bandwidth, the STM-16 transmission system should be used. STM-16 implements 1008 VC-12 containers. (The next two ways of dimensioning is left for students). Figure 6 shows the physical structure of the proposed network.

6. CONCLUSIONS

As mentioned before, the purpose of this paper is to acquaint students with the engineering approach to designing a network over IP platform. The project includes only a backbone layer of the network and omits the access layer. The output data include two classes of services: VoIP and access to the Internet. It should be noted that these services have very different impact on the structure of traffic of the proposed network. VoIP service generates the general structure of traffic that requires a bandwidth between each pair of nodes (routers). However, access to the Internet generates traffic structure of collective node, which requires a bandwidth between each network node and the point of connection to MAN Bydgoszcz. The superposition of these structures defines the logical structure of the network. The physical layer was implemented based on SDH. For the considered variant (which was adopted at the beginning of this paper) SDH ring works as bi-directional double fiber ring with a bandwidth of STM-16 (2488.32 Mbit/s) and meets the requirements concerning the bandwidth. Overhead of individual protocols of TCP/IP model was also taken into account.

Further work, related to the design of the networks will focus on analyzing additional real-time services and greater bandwidth in the access network (to the Internet). In addition, the physical structure of the network will be analyzed taking into account the different technologies: IP / WDM (DWDM) and Ethernet.

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PROJEKTOWANIE SIECI TELEKOMUNIKACYJNEJ DLA BYDGOSKIEJ STREFY NUMERACYJNEJ

Streszczenie

W artykule przedstawiono inżynierskie podejście do projektowania sieci telekomunikacyjnej na platformie IP. Projektowana sieć pokrywa żądania na usługi telekomunikacyjne, w bydgoskiej strefie numeracyjnej, na obszarze której działa Telekomunikacja Polska (TP S.A.). W projektowanej sieci wyróżniono dwie klasy usług: telefonię internetową (VoIP) oraz dostęp do Internetu. Logiczna struktura sieci jest superpozycją dwóch struktur. Pierwsza z nich zawiera łącza, które realizują telefonię internetową oraz druga, która zapewnia dostęp do Internetu. Fizyczna struktura sieci została zaprojektowana w oparciu o Synchroniczną Hierarchię Cyfrową (SDH).

Słowa kluczowe: ruter, łącze, projektowanie