Non-commercial joint-stock company

ALMATY UNIVERSITY OF POWER ENGINEERING AND TELECOMMUNICATIONS GUMARBEK DAUKEEV

Department of Telecommunication Networks and Systems

MULTI-SERVICE NETWORKS SUBSCRIBER ACCESS

Lecture notes for students of the speciality
5B071900 – Radio engineering, electronics and telecommunications

Almaty 2019

COMPILERS: Garmashova Y.M., Mukhamejanova A.D., Panchenko S.V. Multiservice networks subscriber access. Lecture notes for students of the speciality 5B071900 – Radio engineering, electronics and telecommunications. – Almaty: AUPET, 2019. - 46 p.

Here is presented eleven lecture notes for discipline «Multiservice networks subscriber access». This notes allow to understand the basic concepts, the principles of creation, functioning and operation with multiservice networks subscriber access.

Illustrations 24, table 2, bibliogr. - 13 name.

Reviewer: docent, c.e.s. Tuzelbayev B.I.

Published by the plan editions of Non-commercial joint-stock company "Almaty university of power engineering and telecommunications Gumarbek Daukeev" for 2019.

© Non-commercial joint-stock company "Almaty university of power engineering and telecommunications Gumarbek Daukeev", 2019

Introduction

The purpose of teaching of discipline is learning the basics of construction and operation of multi-service subscriber access networks.

The discipline considers the principles of construction and operation of wired and wireless multi-service networks of subscriber access, protocols and methods of transmission used in networking. Also in the discipline reflects all the technologies used in multi-service networks of subscriber access.

After reviewing the basic principles of construction and operation of multiservice networks of subscriber access, the student will be able to analyze, design and maintain multi-service subscriber access network, and to offer optimum terms of operation of technical solutions, and designing new networks.

The purpose of teaching discipline is training of students possessing the basic principles of construction and operation of multiservice networks of subscriber access necessary for the decision of tasks of telecommunication networks and their qualified maintenance.

Objectives of teaching are the students the mastery of the principles of construction and operation of multiservice networks of subscriber access, calculation of network parameters.

Lecture №1. Basic concepts of subscriber access network (SAN)

The purpose of the lecture: researching by students the basic conception of subscriber access network.

Contents:

- the basic concept of subscriber access network;
- the concept of the subscriber line (SL).

The basic concept of subscriber access network.

Subscriber access network (SAN) - this is a set of technical resources between the terminal subscriber devices that are installed in the premises of the user, and the switching equipment in the numbering plan (or addressing) which includes connected to a telecommunication system terminal [1].

Model illustrating the main options for building a subscriber network, shown in figure 1.1 [1]. This model is valid for urban telephone networks (UTN), and rural telephone networks (RTN). Moreover for UTN are shown in figure 1.1, the model is invariant to the structure of inter-office communications. It is identical to:

- unzoned networks consisting of only one telephone station;

- zoned networks, which consist of several regional ATS (DATS) connected with each other by the principle "each with each";

- zoned networks with nodes of the incoming message (NIM) or to nodes in the outgoing message (NOM) and NIM.

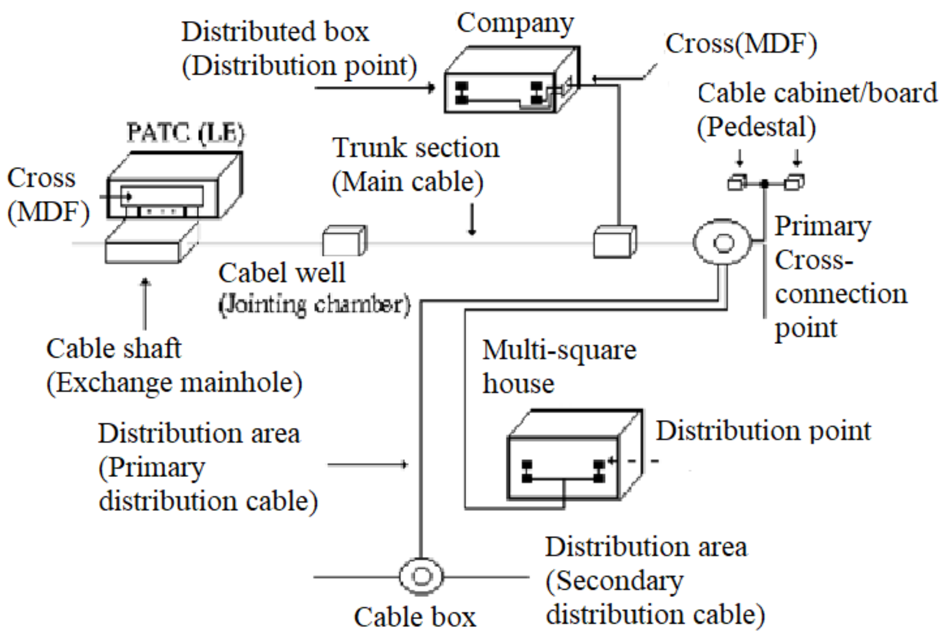


Figure 1.1 - Main options build a user's network

The model shown in figure 1.1, can be considered universal in respect of the type of switching station. In principle, it is the same as for manual telephone station, and for most modern digital systems of information distribution. Moreover this model is invariant to the form of an interactive network, such as a telephone or telegraph [1].

The main cable of SL (Direct service area) - the plot of the subscriber line from a linear part of the cross or input switching device of the local station, hub or other remote module to the control cabinet, including areas miscarry connection. The main area SL corresponds to «Long-haul zone». The main cable is also considered to be the direct power, within which to construct the subscriber network distribution cabinets are not used. The direct power occupies the territory adjacent to telephone station within a radius of approximately 500 metres.

Distribution cable SL - plot of the subscriber line from the distribution cable to subscriber's wardrobe item. This part of SL - depending on the structure of the network correspond to the terms "Primary distribution cable" and "Secondary distribution cable". And part of the area occupied distribution station, usually called "Cross-connection area".

Subscriber wiring - section of the subscriber line from the junction box to the socket enable terminal subscriber telephone device. In the English technical literature are two terms using:

- "Subscriber's lead-in" - the section from the distribution box to the premises of the subscriber;
- "Subscriber's service line" - the section from the distribution box to the telephone.

Cross, UWC - equipment junction station and line sections and trunk urban, rural and combined telephone networks. This element of the access network in the English technical literature is called "Main distribution frame"; often abbreviated MDF.

Cable distribution Cabinet (DC) - cable terminal device for installing cable boxes (with terminals, without the elements of electrical protection), which are compounds of trunk and distribution cables, subscriber lines of local telephone networks. Cable distribution cabinet conforms to the term "Cross-connection point". If subscriber line (SL) passes through the two DC in English technical literature for the second cable cabinet add the adjective «secondary». In addition, if DC is a specially equipped room, it is referred to as "Cabinet". In the case where the DC is located at the wall of a building or other similar place, he is called a "Sub-cabinet" or "Pillar ". These symbols are usually listed in parentheses after the functional purpose of "Cross - connection point". In the technical literature uses several terms more or less corresponding DC. Most common word "Curb".

Subscriber distribution box (DB) - terminal cable device designed for the implementation of the junction cable pairs that are included in the terminal junction box, with wires-pair subscriber transactions. Distribution point (DP) - similar to the term "Subscriber distribution box".

Ducts (Duct or Cable duct) - a set of underground pipelines and wells (observation devices), intended for laying, installation and maintenance of communication cables.

The well (observation device) conduit (Jointing Jointing chamber or manhole) is a device designed for laying cables in pipelines, cable ducts, installation of cables, the accommodation associated equipment and maintenance of communication cables.

Cable shaft (Exchange manhole) - construction of cable ducts placed in the basement of the telephone exchange, through which cables are introduced into the plant building and where, as a rule, linear multipair cables soldered onto terminal cables with a capacity of 100 pairs.

The concept of the subscriber line.

Subscriber line (SL) – line of the local telephone network that connects telephone terminal device with subscriber set (AK) in a terminal station, hub or other external module. In English technical literature using Subscriber line or just Line [1].

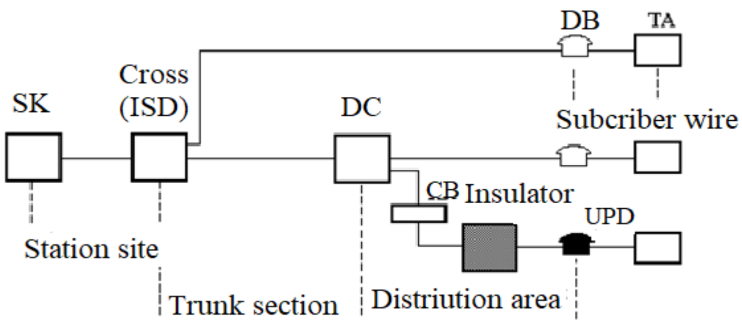
The functions of subscriber line in current telecommunication system:

- providing two-way message transfer between the user terminal and the subscriber terminal station sets;

- the exchange of signaling information necessary for establishing and tearing down connections;

- support the specified indicators of the quality of information transfer and reliability of communication of the terminal with the terminal station.

Structural scheme of the joints of the equipment of subscriber lines for the CTN and RTN is given in figure 1.2.



SS-subcriber set of the telephone exchange
ISD-Input switching devices
DC-cable distribution cabinet
DB-distribution box
C-cable box
UPD- User protection device

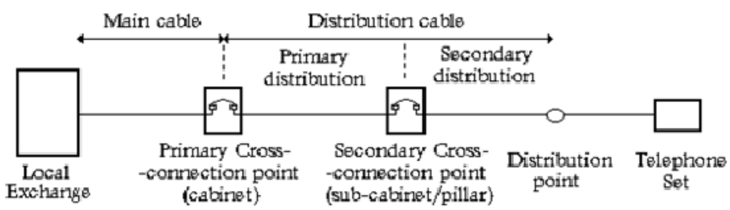


Figure 1.2 - Structural scheme of the joints of the equipment of subscriber lines for the CTN and RTN

For the structural scheme of SL (upper part of figure 1.2) presents three options for connecting the subscriber terminal to the switching station.

The upper branch of the figure shows a promising connection for TS (telephone set) without using an intermediate distribution frame equipment. The cable is pulled from the cross to the junction box where wiring is carried out through subscriber's connection TS.

On the middle branch of the figure shows the connection of TS Cabinet system, when between the cross and junction box is located intermediate equipment. In our model, the role of the designated equipment control Cabinet.

In some cases, SL can be arranged with the use of air-lines of communication (ALC). This is illustrated on the figure 1.2 on the lower branch. In such a situation on the column installed cabel box (CB) and the input-output isolators. At the location of the junction box is mounted subscriber protective device (SPD) is preventing a possible influence on the TS of dangerous currents and voltages. It should be noted that the organization of SL or its parts due to the construction of overhead lines is not recommended; but in some cases is the only variant of the organization of subscriber access.

Lecture №2. Basic concepts of multiservice network of subscriber access (MSAN)

The purpose of the lecture: students can explore the basic concepts of multiservice networks of subscriber access.

The contents:

- the basic concepts of multiservice networks of subscriber access;
- MSAN technologies;
- wired technologies.

The basic concepts of MSAN.

Under a multiservice network of subscriber access (MSAN) understand such a network which supports the transfer of mixed traffic between terminal users (systems) and transport network using a single network architecture that allows to reduce the variety of types of equipment and to apply common standards [1, 2].

Architecture and functions of MSAN should support three types of services:

- the transmission of speech (sound, telephone connection, voice mail and etc.),

- data transmission (Internet, fax, file transmission, email, electronic payments and etc.);

- transmission of video (video on demand, TV shows, video conferencing and etc.).

The concept of development of multiservice access networks includes mainly two directions:

- the intensification of use of existing subscriber lines;

- the construction of access networks with the use of new technologies.

MSAN technologies.

The technology used in the MSAN can be classified in various ways. One such method – the division of technology into two groups in accordance with the transmission environment [1, 2]:

- wired;
- wireless.

1) The wired used (totally or partially) of the physical circuit. It may be a twisted pair copper cable, coaxial cable, fiber optics, wiring of power supply networks and etc. Among them are a group of technologies that use copper-pair, which are interesting, at least from two points of view. First, they provide support of a number of new information and communication services. Second, using the traditional physical circuit, these technologies reduce the costs of upgrading the access network, even if the effective demand for new services is at a low level.

Technology on the basis of the wired funds can be distributed in the following groups [1, 2]:

- services provided to subscribers of telephone network of public use (PSTN);
- technology services access digital network with integration of services (ISDN);
- technologies of digital subscriber line – xDSL (twisted pair copper cable – symmetrical cable);
- technologies of local area networks LAN (twisted pair, coaxial cabel and fiber optic cabel);
- technologies of optical access OAN (fiber optic cabel);
- technologies of cable TV networks (CTV) (coaxial and fiber optic cabels);
- technologies of shared access networks (posting of the power circuits, wiring broadcasting networks).

In this group it is necessary to note also and technologies of wireless subscriber lines in combination with physical chains (WLLx). In this case, the transition to a two-wire physical circuits implemented at some point "x". These technologies are most often used in rural areas.

Classification of technologies in this group are presented in table 2.1.

2) Wireless - on the basis of telecommunication facilities, which complement and extend the capabilities of wired connections and allow you to implement a full range of information services: the transmission of telephone communications, data exchange, transmission of video images.

Wired technologies [1,2].

Consider in more detail the wired technology is given in table 2.1.

Telephone network of public use (PSTN) was created to provide telephony services. Customers ' access to a limited set of services the PSTN is accomplished via communication lines based on copper pairs using equipment (telephone and Fax machines and modems) operating in accordance with the algorithms of the establishment of telephone connections.

Network ISDN (Integrated Services Digital Network) – digital network integrated services - digital network communication circuit-switched. Access the

Table 2.1 - Classification of wired technologies

Wired technologies		
PSTN	telephone fax modem Data transmission leased line	
ISDN	ISDN-BRA ISDN-PRA	
LAN technologies	Ethernet family	Ethernet Fast Ethernet Gigabit Ethernet
	Tokeng Ring family	Token Ring HSTR
	FDDI family	FDDI CDDI SDDI Ethernet over VDSL (EoV)
Technologies of the xDSL family	Symmetrical	IDSL HDSL SDSL SHDSL MDSL MSDSL VDSL and etc.
	Asymmetrical	ADSL RADSL G.Lite ADSL2 ADSL2+ VDSL and etc.
Technologies of the optical access	Active networks FTTx	FTTH FTTB FTTC FTTCab and etc.
	Passive networks xPON	APON EPON BPON GPON and etc.
Technologies of the cabel TV	DOCSIS 1.0 DOCSIS 1.1 DOCSIS 2.0 Euro-DOCSIS J.112 IPCable-Com Packet-Cable	
Technologies of the shared access networks	– HPNA 1.x – HPNA 2.0 – HPNA 3.0	
	On the basis of power supply networks	Home Plug 1.0 specification
	On the basis of the cable network	EFM

ISDN network is also carried out on symmetric cable subscriber, but the services compared to PSTN is much larger.

The development of xDSL-access reflects the development of methods of signal transmission over twisted pair copper. These technologies provide access to a wide range of services in transmission of multimedia information. Standardization and promotion of xDSL technologies in the market engaged in various international organizations (ITU, ANSI, ETSI, DAVIC, ATM Forum, ADSL Forum). These technologies can be divided into sub-groups: symmetric and asymmetric xDSL access. First find application mainly in the corporate sector, the second is designed to provide services primarily to individual users.

The greatest amount of services can be provided to the user through the optical access networks, OAN (Optical Access Networks) – active (FTTH, FTTB. FTTC, FTTCab) or passive PON (Passive Optical Networks). The creation and promotion of the latest access technology, and in particular optical technologies deals the international consortium FSAN (Full Service Access Network).

Shared access networks (SAN) is designed to provide a relatively inexpensive Internet access to individual users living in apartment buildings. The idea of shared access is to use existing homes cable infrastructure (twisted pair copper cable, radiotrancetional networks, electrical wiring). In web-connected home is set to hub traffic. To connect the hub to the services node of the transport network may use different technologies (PON, FWA, satellite, etc.). Thus, the network of public access are hybrid, combining both the actual network shared access, and the network providing the transport traffic.

Cable television network (CTV) was originally designed for broadcast users of television programs for distribution networks based on coaxial cable and built in unidirectional scheme. In the early 90's, there have been many, but unsuccessful attempts to design and implement technologies needed to build interactive networks, access to multimedia services on the basis of hybrid CTV networks – Hybrid Fiber Coaxial (HFC). Mass deployment of HFC networks started after the appearance in 1997 of the standard DOCSIS (Data Over Cable Service Interface Specification).

LAN technology was developed to provide user access to resources on local networks. For user access to other resources (Internet, corporate network, etc.) modern LAN are built in hybrid technology and combine the actual LAN and the network providing the LAN connection to transport networks.

Lecture №3. Subscriber access networks ISDN

The purpose of the lecture: researching by students the subscriber access network ISDN.

The contents:

- the basic concepts of ISDN;
- subscriber signaling DSS1 in the ISDN.

The basic concepts of ISDN.

Network ISDN (Integrated Services Digital Network - ISDN) are usually created on the basis of the digital telephone network to provide transmission of information between terminal devices in digital form. In this case, the subscribers are provided with a wide range of speech and non-speech services (for example, high-quality telephony and high-speed data transmission, transmission of texts, transmission of television and video, video conferencing, etc.). Access to the ISDN services is via a defined set of standardized interfaces [3, 4].

Currently, the most prevalent mainly two types of subscriber access ISDN:

- basic (Basic Rate Interface - BRI) with the structure 2B+D, where B-64 kbps, D=16 kbit/s, group speed will be 144 kbps, in the presence of the sync channel transmission rate may be equal to 160 kbps or 192 kbps;

- primary (Primary Rate Interface - PRI) with the structure 30B+D, where B=64 kbps, D=64 kbit/s, the rate of transmission based on the synchronization signals be – 2048 kbit/s.

The basic ISDN access. Transmission of digital information via two-wire copper pair ISDN is possible at a speed of 160 kbit/s under normal conditions (cable length not more than 8 km in the cross-sectional diameter 0.6 mm, or no more than 4.2 km in the cross-sectional diameter 0.4 mm). Copper pair operating in the mode 2B+D (144 kbit/s payload) sync and data support (160 kbps General information), is part of the Uk0-interface. User ends of the copper pair network termination (network termination NT). The network translates the end of the two-wire Uk0 interface (160 kbps) in the four-wire S0 interface (192 kbps); for the case of 2B+D network ends transparent in both directions. The network operator is responsible for the connection from the station only to a network termination, and for a site from NT to the subscriber responsible for the subscriber. S0-interface is a connecting bus through which ISDN-compatible equipment can be connected to the basic ISDN station via a standard connector (figure 3.1). For institutional stations S0-interface is the point at which the office station is connected to the ISDN basic station (figure 3.2). The length of the bus S0 must not exceed one kilometer.

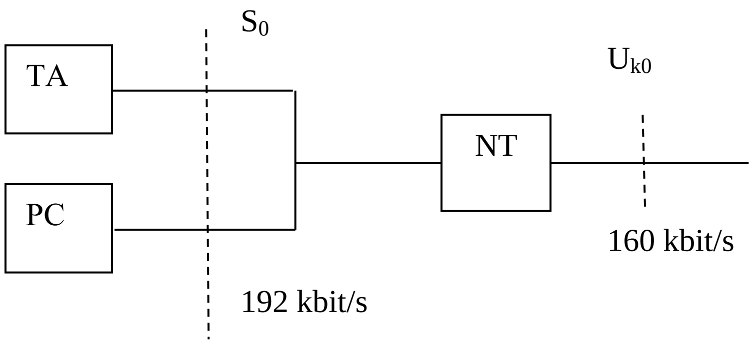


Figure 3.1 - The basic access for an individual user

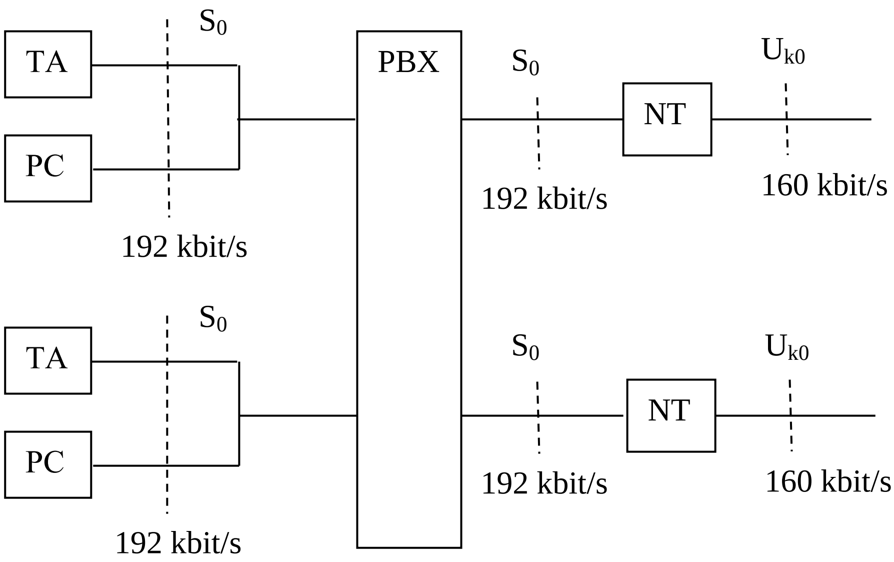


Figure 3.2 - The basic access for PBX small capacity

The primary ISDN access. Like the basic access, B-primary channels of access are used and are switched individually, and signaling information (D-channel message) is transmitted in the D channel. But unlike basic access D-channel is used only for transmission of signaling information, a packet-oriented user data must be separated from signal information in institutional station and transmitted in B channels. Link PCM working as a primary access 30B+D, is called Uk2pm interface or Uk2m interface. The end of the line on the subscriber side is designed as a network termination (NT), where the interface Uk2m changed in S2m interface. From NT to institutional station distance should not exceed one kilometer.

Institutional station is connected to the ISDN station for public use by S2pм interface. When using institutional station S0 interface acts as a bus for connection of terminal equipment (figure 3.3).

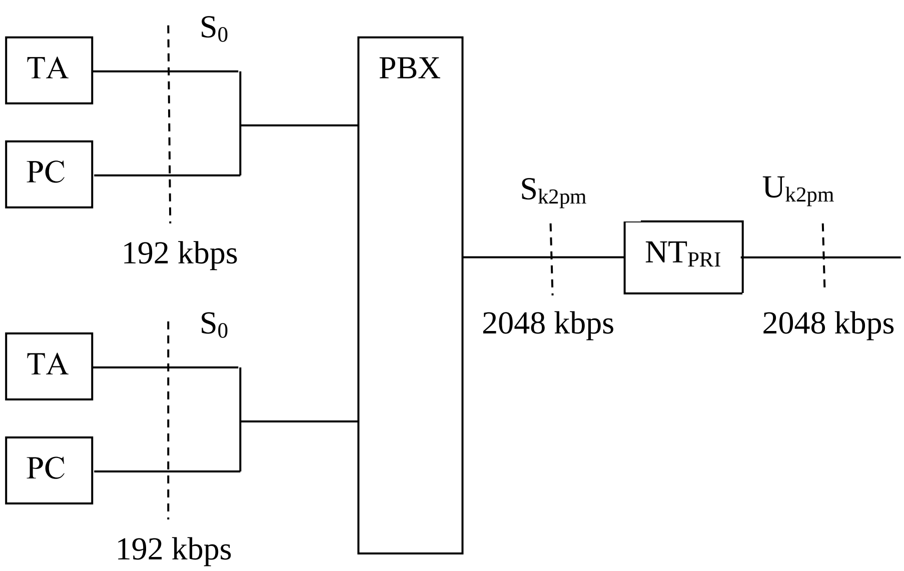


Figure 3.3 - Primary access for PBX, average and high capacity

Subscriber signalling DSS1 in ISDN.

The alarm system on the subscriber section of the network was named ISDN EDSS1 (European digital signalling system number 1) [3, 4]. This alarm system can be used for both basic and primary access.

With EDSS1 carried connection establishment and disconnection occurs, the order made by users of services, transmission of information between users.

Alarm "user - network" is within the three lower levels of the OSI, and performs the following functions:

– *data link layer* (the physical layer, layer 1) provides a synchronized network transmitting information on channels in both directions simultaneously and regulates multiple simultaneous access terminals to the shared-channel D;

– *D-protection channel* (data link layer, layer 2) provides transmission of a protected signal error information for three-level transmission of data packets and transmitted in the D - channel in both directions between the network and the user device;

– *switching level D-channel* (network layer, layer 3) ensures the establishment and management of the compound at the site "user - network The third level ends with alarm "the user - network".

Level 1 is considered on p Rimer main access (Risun to and 3. Level 1 interface S0 and Uk0 transmits signaling on the D-channel without alarm management.

The protocol used for level 2 in the D-channel when the connection establishment procedure, called the LAPD (Link Access Procedure on the D-channel). Structure of the ISDN protocol or format D-channel messages of the second level or signal packet or signal unit (figure 3. 4).

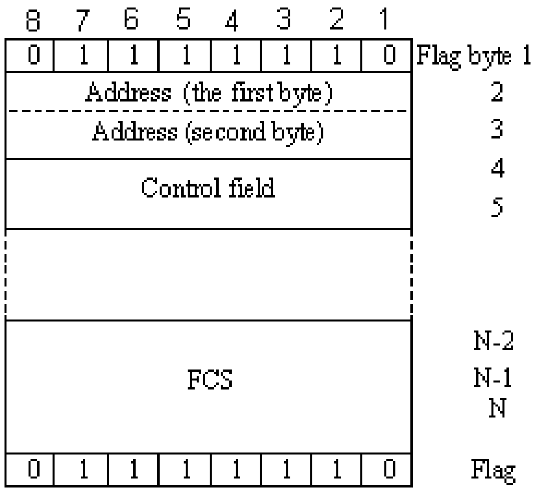


Figure 3.4 - Format D- second level channel messages

Flag: Each signal unit begins and ends with a flag, it marks the beginning of a signal unit and its end. Flag - a sequence of bits: 01111110.

Address - the address field consists of two bytes. In it is defined by the receiver control unit and the signal sent by the transmitter unit.

Control field. The control field identifies the type of D - channel messages, which can be a team, or a team response. The control field may consist of one or two bytes, its size depends on the format. There are three types of control field formats: the transmission of information about the package room (I format), supervisory functions (S format), unnumbered information and control functions (U format).

Information data field can not be presented in the package (in this case the packet does not carry the information of the third level and the second level is used, for example, control data link), if present, is behind the control box. Information field size can be up to 260 bytes.

FCS (Field control the bit-combination of screening). Since the transmission network packets may be disturbed by noise on the ground level, each of them is a field of control bits (Frame Check Sequence it consists of 16 bits and a parity check is used for error in the received packet. If a packet is received with an incorrect sequence of check bits, then it is reset.

In the level 3 is responsible for establishing and managing the connection. He prepares the messages for transmission to the second level, such information is placed in the information field of the D - channel messages. Layer 3 messages - a message sent between the user terminals and the station, and vice versa. The third level contains the procedures for call control in the mode of circuit switching, as well as procedures to be used for the implementation of ISDN calls in the packet switching mode on the D - channel.

Lecture №4. xDSL technologys

The purpose of the lecture: study of x DSL technology students.

Content:

– basic concepts xDSL;
– A technology DSL.

Concepts xDSL.

xDSL (Digital subscriber line) - a family of technologies that significantly increase the capacity of the subscriber line public telephone network through the use of efficient linear codes and adaptive methods for line distortion correction on the basis of modern methods of microelectronics and digital signal processing [3, 5].

XDSL technologies emerged in the mid-90s as an alternative to digital subscriber end of the ISDN .

Digital The acronym xDSL symbol "x" is used to refer to the first character in the name of a particular technology, and DSL stands for digital subscriber line DSL (Digital Subscriber Line, also there is another version of the name - Digital Subscriber Loop). XDSL technology transfers data at speeds far exceeding those speeds that are available, even the best analog and digital modems. These technologies support voice, high speed data and video signals, creating considerable advantages both for the subscribers as well as for providers. Many xDSL technology can combine the high-speed data and voice over the same copper pair. Existing types of xDSL technologies differ mainly in the form used by the modulation and speed of data transmission.

Technology xDSL It can be divided pouring on:

– symmetrical s;
– asymmetric.

ADSL technology.

ADSL (*Asymmetric ADSL*) - modem technology, in which the available channel bandwidth is shared between outgoing and incoming traffic asymmetrically. Since most users of the volume of incoming traffic far exceeds the volume of the outgoing, the speed of outgoing traffic is much lower [3, 5].

ADSL-based data transmission is realized through a conventional analog telephone line using a subscriber unit (DSL modem, ADSL and multiplexer access - DSL Access Module, DSLAM), or Multiplexer, DSLAM), located on the PBX to which the user connects a telephone line, with switched DSLAM to the equipment itself PBX . The result is a channel between them without any limitations inherent in the telephone network. DSLAM multiplexes a plurality of subscriber DSL lines into a single high-speed backbone network. Block ADSL connection diagram is shown in figure 4.1.

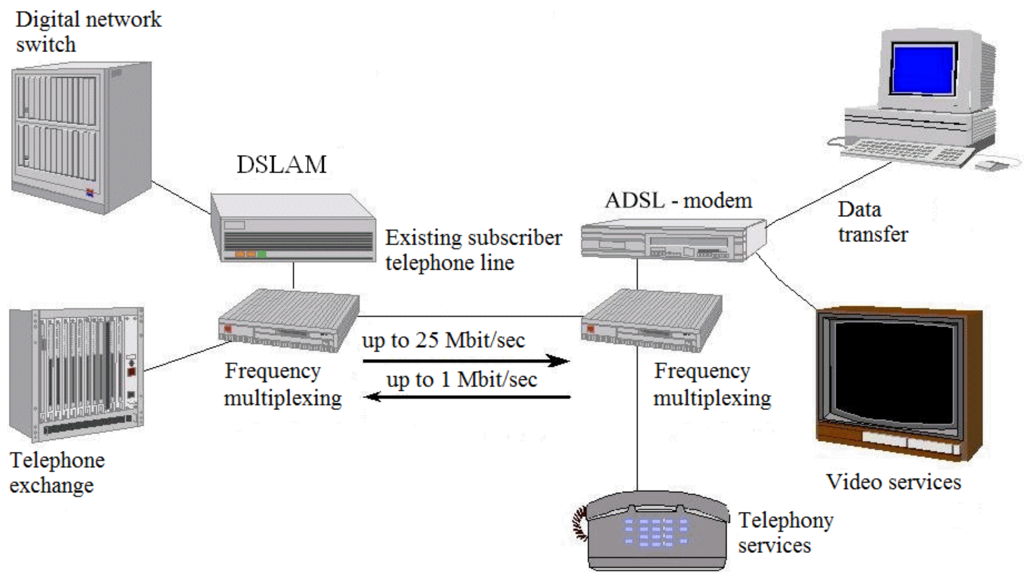


Figure 4.1 - Block diagram of the ADSL connection

They can also connect to the network ATM for PVC channels (Permanent Virtual Circuit) with Internet service providers and other networks.

It is worth noting that two of the ADSL-modem will not connect to each other, unlike the conventional dial-up-modemov.

ADSL technology is a variant of DSL, where the available bandwidth of the channel is distributed between the incoming and outgoing traffic asymmetrically, -

for most users, incoming traffic is much more significant than outgoing, so the provision for him most of the bandwidth is fully justified (exceptions to the rule are peer network , video calls , and e-mail , where the volume and speed of outgoing traffic are important). Normal telephone uses voice frequency band 0.3 ... 3.4 kHz. In order not to interfere with the use of the telephone network for its intended purpose, it is at 26 kHz in the lower limit of ADSL bandwidth. The upper limit of the basis of the requirements for data transmission speed and capacity of the telephone cable is 1.1 MHz. This band n ropuskaniya divided into two parts: the frequency of 26 kHz to 138 kHz are reserved outgoing data, and frequencies from 138 kHz to 1.1 MHz - incoming. The frequency band from 26 kHz to 1.1 MHz was chosen. In this range, the attenuation coefficient is almost independent of frequency.

Such frequency division allows you to talk on the phone without interrupting the data exchange on the same line. Of course, there are situations where a high-frequency signal to the ADSL-modem adversely affect the electronics of modern phone, or the phone because any features of its circuitry brings in line outside a high-frequency noise or strongly changes its frequency response at high frequencies; to deal with this in the telephone network directly to the subscriber's apartment set low-pass filter (frequency divider, Eng. Splitter), impermeable to ordinary phones only the low-frequency signal component and eliminating the possible impact on the phone line. These filters do not require additional power, so the voice channel is still in service outages and the electrical network in case of failure ADSL equipment.

Transfer to a subscriber is conducted at speeds up to 8 Mbit/s, while today there are devices that transmit data at speeds up to 25 Mbit/s (the VDSL), but such a standard rate is not defined. In ADSL systems with luzhebnuyu information under 25% of the total rate allocated unlike ADSL2, wherein the amount of overhead bits in a frame can vary from 5. To 25% maximum line speed depends on several factors such as the length of the line section and the specific resistance of the cable. It is also a significant contribution to the increase in speed makes the fact that it is recommended for ADSL lines, twisted pair (not TDC), with shielded, and if it is multi-pair cable, and in compliance with the directions and step helix.

When using ADSL data is transmitted on a common twisted-pair duplex form. Frequency In order to separate the transmitted and received data stream, there are two methods: frequency division multiplexing and echo (Echo Cancelation, EC) ancelation.

An ADSL-modem is a device that is based on a digital signal processor (DSP), similar to those used in conventional modems (Figure 4.2).

ADSL standards:

– ITU G.992.3 (also from the West as the G.DMT.bis or ADSL2) - standard ITU (International Telecommunication Union), extending ADSL core technology capabilities to the specified data rates below:

– towards the subscriber - up to 12 Mbit/s (all devices must support ADSL2 rate to 8 Mbit/s);

– in the direction from the subscriber - up to 3.5 Mbit/s (all devices must

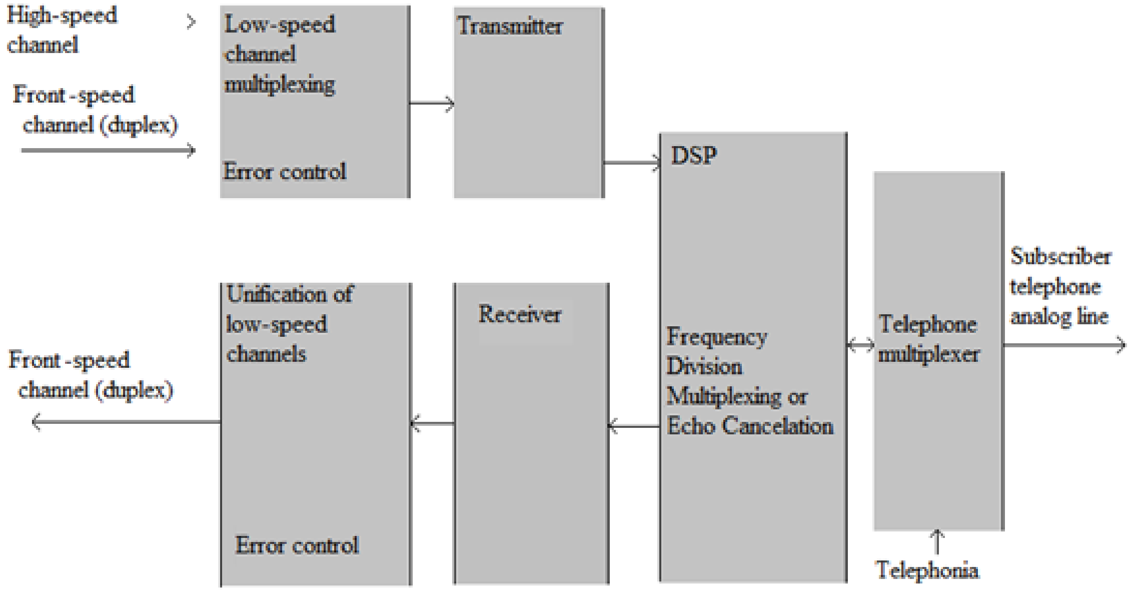


Figure 4.2 - Block diagram of transmitting unit ADSL-modem

support ADSL2 speed up to 800 kbit/s).

Actual speeds may vary depending on the quality of the line:

– ITU G.992.4 (also known as G.lite.bis) - the standard for technology ADSL2 without using the splitter. Ments speed Tre is 1 to 536 Mbit/s towards the subscriber and 512 kbit/s in the opposite direction;

– ITU G.992.5 (also known as ADSL2 +, ADSL2Plus or G.DMT.bis.plus) - standard ITU (International Telecommunication Union), extends the possibility of ADSL core technology, doubling the number of bits of the input signal to said data transmission rates below:

- bp toward the subscriber - up to 24 Mbit/s;
- n on the direction from the subscriber - up to 1.4 Mbit/s.

Actual speeds will vary depending on the quality of the line and the distance from the DSLAM to the customer's home. The standard speed prescribed for twisted pair, the rate may be much lower than when using other types of lines.

In ADSL2 + frequency is doubled with respect to ADSL2 range from 1.1 MHz to 2.2 MHz, which entails an increase in the data rate of the incoming stream of previous standard ADSL2 c 12 Mbit/s to 24 Mbit/s (figure 4.3).

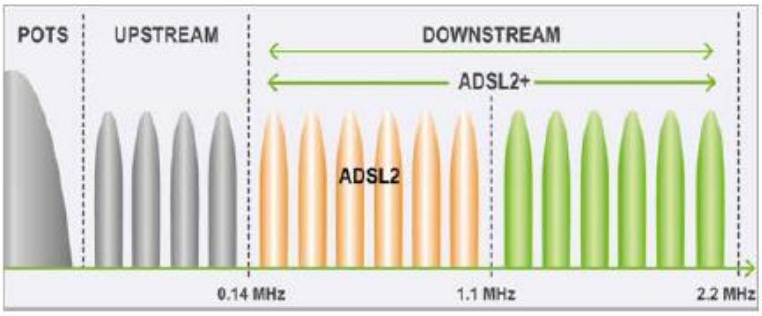


Figure 4.3 –D Range frequency ADSL and ADSL2+

Lecture №5. Wireless WIMAX technology

The purpose of the lecture: study of WiMAX technology students.

Content:

– basic concepts of WiMAX, and architecture WiMAX IEEE 802.16 networks;

– WiMAX modes.

Concepts WiMAX. The architecture of WiMAX IEEE 802.16 networks.

The WiMAX - family of standards I EEE 802.16 - a radio technology, which provides two-way access to the Internet in the far distance at speeds up to 75 Mbit/s, as well as QoS [6].

WiMAX - Worldwide Interoperability for Microwave Access, the IEEE standardized technology wireless broadband, complementing line DSL and cable technologies as an alternative solution to the problem of the "last mile" at large distances. WiMAX technology can be used to implement broadband connections "last mile", the deployment of wireless access points, high-speed communication between the organizations affiliated companies and solving other similar problems.

Base station (BS, BS - Base Station) is located in a building or on a tower, and communicates with subscriber stations **(**SS - Subscriber Station) to the scheme: Possible grid connection mode (the Mesh - Net links a point - point - the PTP), when all customers (AS) can communicate with each other directly, and antenna systems are generally non-directional. Range BS can reach 30 km (in the case of the line of sight) with a typical radius of 6-8 km network. AC may be a radio terminal or a repeater, which is used to organize the local traffic. Traffic may pass through several repeaters, before it reaches the customer. The antennas are in this case directed.

The link requires two transmission directions: uplink (AS - BS, uplink) and downlink (BS - AC, downlink). These two channels use different non-overlapping frequency ranges in frequency duplex and different time intervals in time duplex.

The simplest way to represent the architecture of WiMAX networks is their description as a set of BS, which are located on the roofs of tall buildings or towers, and client transceivers (Figure 5.1).

Radio communication between BS and SS operating in the microwave range of 2 to 11 GHz. Such a network in ideal conditions can provide technical information rate to 75 Mbit/s and does not require, to BS was located at a distance of line of sight of the user.

Frequency range 10 to 66 GHz is used for establishing a connection between adjacent base stations, provided that they are in line of sight of each other. Since in an urban environment, this condition may not be feasible, the connection between the base stations are sometimes organized through cabling.

A more detailed examination of the WiMAX network can be described as a set of wireless and base (reference) segment. The first is described in the IEEE 802.16 standard, the second is determined by the specifications of WiMAX Forum.

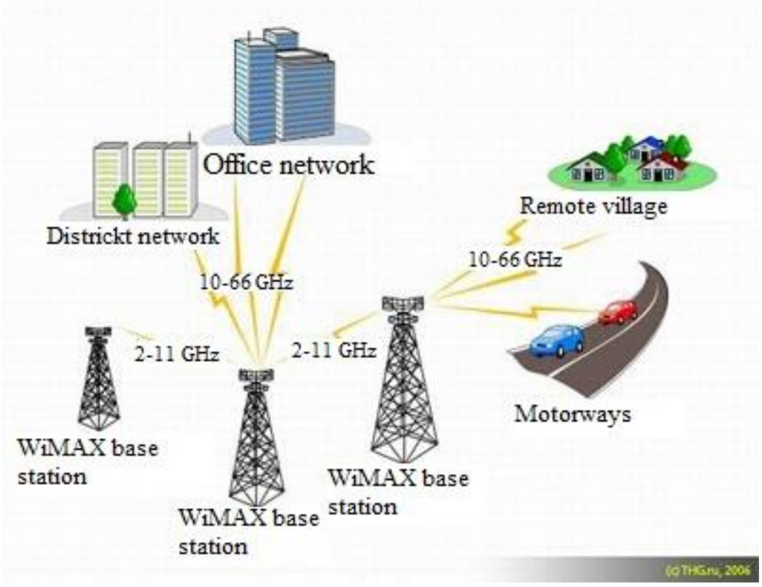


Figure 5.1 - Schematic representation of a WiMAX network

The base segment combines all aspects not related to the subscriber radio network, i.e., the connection of base stations with each other, communication with local networks (including the Internet), etc. The base segment is based on the IP protocol and the IEEE 802.3 standard -2005 (Ethernet). However, the very description of the architecture in the part not related to the wireless client network is contained in the WiMAX Forum documents, united under the common name - "Network Architecture".

In these specifications for WiMAX networks such demands as independence from the architecture and functions of the transport IP-based network structure. At the same time, must be provided with services that are based on the use of IP-Protocol (SMS over IP, MMS, WAP, and others.) As well as mobile telephony and VoIP-based multimedia services. It is obligatory condition for support of IPv4 and IPv6 architecture. WiMAX networks should be easily scalable and flexible to change and based on the principle of decomposition (based on standard logic modules are combined using standard interfaces). Properties scalability and flexibility necessary to provide for such performance characteristics as subscriber density, the geographical extent of coverage, frequency bands, topology of the network, the mobile subscriber. WiMAX network must support interaction with other wireless (3GPP, 3GPP2) or wired (DSL) networks. Of great importance is the ability to provide different QoS service quality levels.

WiMAX modes.

802.16 e standard. H and currently provides the following modes [6]:

1) FixedWiMAX - fixed access.
2) NomadicWiMAX - session access.
3) PortableWiMAX - Access navigation mode.
4) MobileWiMAX - mobile access.

FixedWiMAX. Fixed access is an alternative to wired broadband technologies (xDSL, T 1, and so on.). The standard uses a frequency range of 10 - 66 GHz. This frequency range due to the strong attenuation of short waves require line of sight between the transmitter and the signal receiver (Figure

On the other hand, the frequency range avoids one of the major problems of radio - multipath signal. The width of communication channels within this frequency range is quite large (typical value of - 25 or 28 MHz), which can achieve transmission rates up to 120 Mbit/s. Fixed mode is included in the version of the 802.16 standard d - 2004 and is already used in several countries. However, most of the companies offering services FixedWiMAX, expect a quick transition to the handheld and in the future for mobile WiMAX.

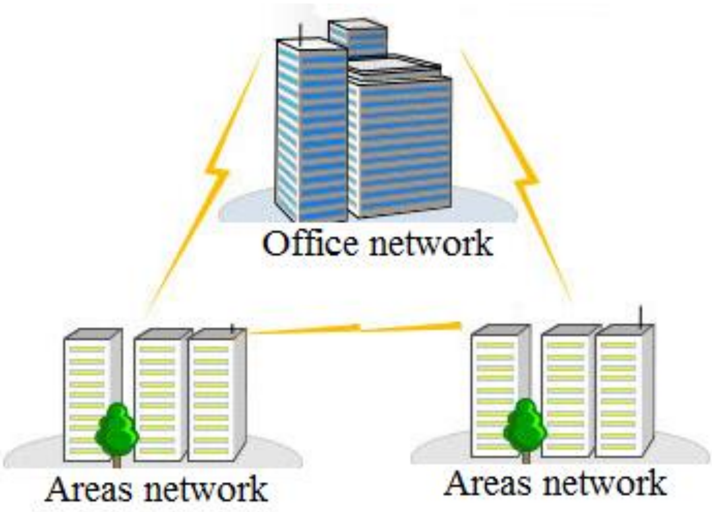


Figure 5.2 - Fixed WiMAX WiMAX

Nomadic WiMAX. Session (nomadic) added the concept of access sessions to the existing FixedWiMAX. The presence of the sessions can be moved freely between the client devices and reconnect sessions already using other towers the WiMAX, rather than those that were used during the previous session. This mode is designed primarily for portable devices such as laptops, PDAs. Introduction sessions can also reduce power consumption of the client device, which is also important for portable devices.

PortableWiMAX. For mode PortableWiMAX added the ability to automatically switch a client from one base station WiMAX to another without losing the connection. However, this mode is still limited by the speed of movement of customer equipment - 40 km / h. However, even in this form, you can use the client device on the road (in the car when driving in residential areas of the city, where the speed is limited, by bike, on foot, and so moving. D). The introduction of this regime has made appropriate use of technology WiMAX for smart phones and PDAs (Figure 5.3).

MobileWiMAX. This mode has been developed in the standard 802.16 an e - 2005 and allowed to increase the speed of the customer's equipment up to 120 km/h. The main achievements of this regime:

1) Immunity to multipath signal propagation and self-interference.

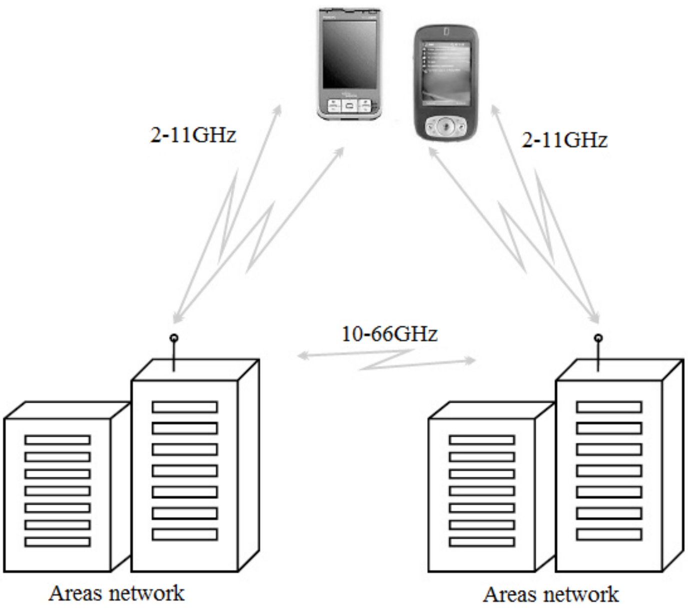


Figure 5.3 - Technology I WiM AX for smartphones and PDAs

2) Scalable channel bandwidth.

3) Technology TimeDivisionDuplex (a TDD), which allows you to effectively handle asymmetric traffic and simplifies the management of complex antenna systems at the expense of the relay transmission session between channels.

4) Technology Hybrid is - AutomaticRepeatRequest (of H - the ARQ), which allows you to keep a stable connection with the sharp change in the direction of movement of the client equipment.

5) Paspredelenie allocated frequencies and the use of sub-channels at high loading to optimize the transmission of data, taking into account the forces with Igna client equipment.

6) From the board of energy efficiency to optimize energy consumption for liaising portable mode ie standby or idle.

7) Technology the Network - OptimizedHardHandoff (the HHO), which allows up to 50 milliseconds or less to reduce the time for the client to switch between channels, and so on.

Lecture №6. Protocol V.5

The purpose of the lecture: study of students Protocol V 5.

Content:

- basic concepts;
- model V5: There servants and user ports;
- Protocol and bandwidth.

Main concepts.

Developing universal V5 protocol between the access network and PBX ETSI was launched in 1991, the first V5 specifications were published in 1993, and in

1995, ITU-T approved the recommendations for V5.1 and V5.2. Location universal interface the V5 , supporting various types of customer access, according to the recommendations I.411, is defined at the reference point V, which lies on the border between the ET and the digital access line [7, 8].

V5.1 interface can be connected to the PBX via a digital path 2048 kbit/s up to 30 analog subscriber lines or B channels without concentration. Signaling is performed over a common channel.

V5.2 interface is focused on a group of paths to 16 2048 kbit/s and maintains the concentration of, for example, by a factor of 8 in each path several signaling channels may be provided.

Model V5: There servants and user ports.

And Interface V5 is located between an access network and the tip of the second PBX (figure 6.1) [7, 8].

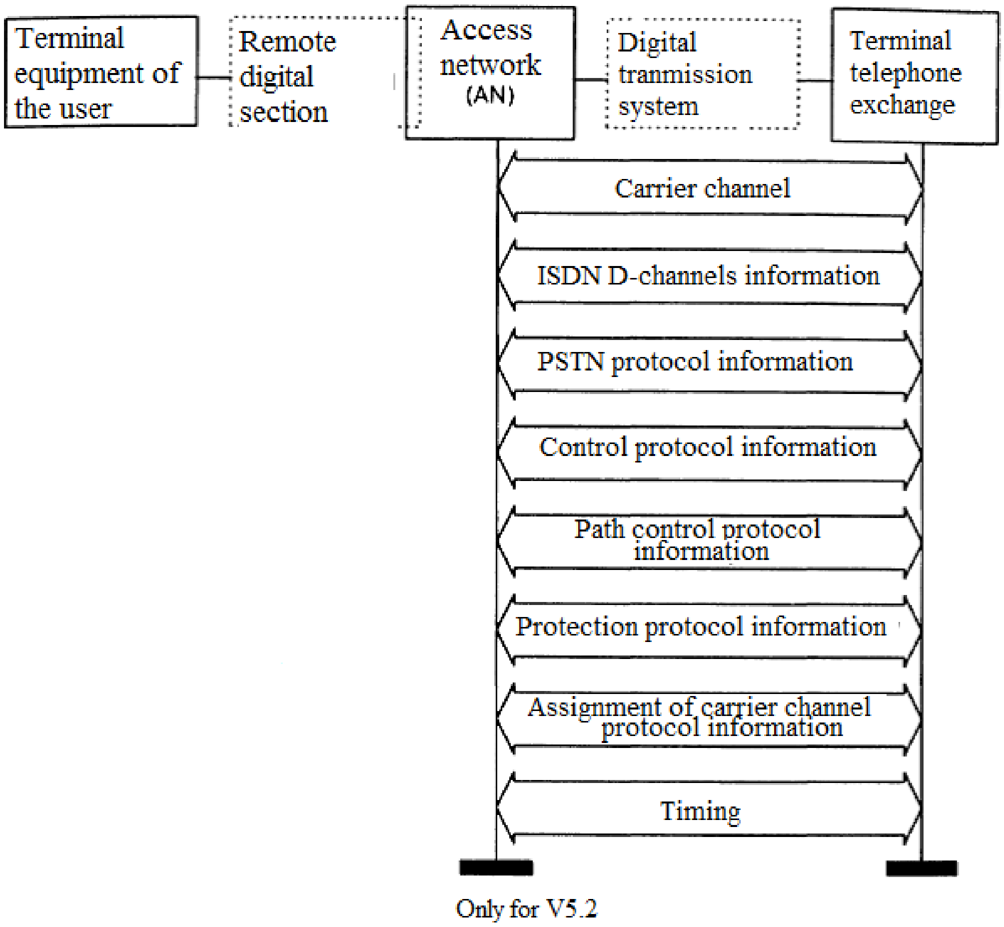


Figure 6.1 - Functional model of access through the V5 interface

To move through the user interface, signaling and service information it contains information transmission system 2048 kbit/s, which will subsequently be referred to as paths 2048 kbit/s.

The paths provide communication between the terminal PBX and user ports, both included in the access network and located outside this network. User ports associated with the V5 interface support different types of services, and the same physical ports can support different services. There are four general types of services that can support the user port associated with the V5 interface, and no more than three types of services can be supported simultaneously.

The first two types of maintenance services are available on request (on-demand services), when the connection is established when entering another PBX ISDN telephone call or a call.

The telephone call can be initiated by the subscriber PSTN having a device with pulse-dial or the DTMF, use or do not use the additional services. Phone calls can also be triggered included in the PSTN small PBX, also equipped with the means of decade dialing or DTMF and enjoying or not enjoying additional services.

ISDN call can come from the NT network termination, which is an element of the access network, or other elements relevant recommendations G.960 and G.961. It does not impose any restrictions on the use of B-channels and any additional services, as well as the transmission of packet data in the B- and D-channels.

The other two types of services - services leased line when no connection is established for each call individually, controls a given network configuration.

The first of these two types of services - services of permanent (fixed) leased line (permanent leased line). These services are implemented network of leased lines, virtually independent of the ATC and, consequently, on the V5 interface.

The second type of leased line services - services of semi-permanent leased line (semi-permanent leased line), when the load is routed through the PBX. V5 interface allows for the organization of a semi-permanent leased line or one, or two-channel ISDN basic access, or analog or digital line without a dedicated signaling channel.

User ports that are associated with the V5 interface and on the support service request to the user ports are divided PSTN and ISDN user ports. The latter can also support and leased line services.

User ports that are associated with the V5 interface and does not support on-demand services are classified as leased ports. They have to maintain a semi-permanent leased line service, or a combination of semi-permanent and permanent services of leased lines, as leased port that supports only fixed leased line service, not at all connected to the station via the V5 interface. Leased ports that require only a single bearer V5 interface are handled the same as PSTN ports. Leased ports that require more than one bearer, served as ISDN ports.

V5.1 interface comprises a path 2048 to the bit/s. Interface V5.2 contains several such paths (up to sixteen). In addition to the functions of the interface V5.1, V5.2 interface provides load concentration and dynamic assignment of timeslots. Paths 2048 to a bit/s are separated both interfaces (as usual) by 32 channel interval, and the ECC is used for frame synchronization. One V5.1 interface can support up to 30 port PSTN (or up to 15 ISDN basic access ports), while one V5.2 interface can support up to two thousand ports PSTN (or up to 1000 ports ISDN Basic Access). In both cases, the ports of PSTN and ISDN ports can use the same path V5 interface (table 6.1).

Table 6.1 - Specifications V5.1 and V5.2 interfaces

V 5.1	V 5.2
It allows you to connect to the exchange one path E1 (30-channel)	It allows you to connect to the PBX group of up to 16 paths 2048 kbit/s
Without concentration subscriber line load function. Direct correspondence between E1 timeslots tract and user terminals	Support the concentration of subscriber lines loading function. Dynamic allocation of timeslots
It does not support ISDN primary access	Supports ISDN primary access
It does not provide redundancy in case of failure function interface tract	Provides redundancy with path failure by switching to another interface path (Protection protocol)
-	paths Interface Management (Link Control protocol)
Signaling is performed in the common channel path interface	For each access (2048 kbit/s) signaling channel has several

Protocol and bandwidth.

The V5 interface acts combination of different protocols. It - ISDN basic call control protocol, call control protocol and the PSTN service protocols (management, interface management paths, carrier assignment of channels and protection). Control protocol and a PSTN operate both interfaces V5.1 and V5.2, and the remaining service protocols - only V5.2 interface [7, 8].

In ISDN Q.921 recommendations were determined for the three types of data transmitted over the D-channel, which correspond to different addresses V5 interface layer 2. Information D-channel ISDN user port comprises connection control signaling information (s-type), a broadcast data frames from user to user (f-type) and transmitted from user to user data packet (p-type). These p-type and f- usually routed to the switches packets and broadcast frames.

Implementation of each of these protocols is accompanied by a transfer across the interface V5 corresponding data type. Thus, the data transmitted through the interface V5.2:

– P-type - data ISDN D-channel SAPI = 16;
– f-type - data ISDN D-channel with SAPI = 32-64;
– Ds-type - signaling information ISDN D-channel (SAPI not equal to any of the above);
– PSTN signaling information;
– service control protocol information;
– information service paths control protocol;
– information service protocol bearers destination (BCC protocol);
– information service redundancy protocol.

Resources available in the V5 interface for one type of data is called a C-way. A group of one or more C-paths in the V5.2 interface such that each of them is different from the other C-band paths in the type of data transmitted and that is not including the C-path, transmitting reservation protocol information is a logical channel C. Channel 64 to the bit/s in the path of V5 interface adapted to transmit data P-channel logic, P-called physical channel.

C-way for the transmission of official information management protocols, in-destination channel control paths and redundancy should always be placed in the slot 16 of the first path. With the path through which data is transmitted p, f-type and Ds-ISDN port from the user, may reside in one logical channel or P-split transmission according to different C-channels. The data p, f-, and the Ds-type from a single user port should not be transmitted on different logical C-channels. Each ISDN user port for each of the three data types always uses the same timeslot V5, but may use different channel intervals V5 for different types of data. Different ISDN user ports may have different paths in C different timeslots V5 for one type of data. Link Control Protocol PSTN also uses only one timeslot, but neither he nor the C-track with ISDN D-channel data may not occupy a time slot used by official protocols to increase the resources required protocol basic call control when the number of user ports increases nafuzka or ISDN D-channel.

In the V5.1 interface, there is only one C-path for ISDN signaling data (Cs-path) with a corresponding unique channel interval that can be divided or not divided into other protocols or with other types of ISDN C-paths, such as Cp- ISDN (packet data) and Cf-ISDN paths (broadcast frames) using up to three channel intervals.

In the V5.2 interface, there are other service protocols that use the same channel spacing as the service control protocol. In the V5.2 interface, it is possible to reserve logical C-channels through which the signaling information and data of the service protocols are transmitted between the access network and the terminal station.

The protocol for controlling the paths in the V5.2 interface allows to identify the paths, block and unblock them. Locking and unlocking paths are needed to ensure normal maintenance of load flows in the interface and increase its bandwidth as the load increases.

The bearer channel connection (BER) protocol works with the V5 carrier channel slots used to transmit user information between user ports and the PBX at 64 kbit/s. These channel spans are assigned to user ports in such a way that both the access network and the station know which channel intervals are used for a particular user port. In the V5.1 interface, a static assignment of the carrier slots, which does not change from calling to the call, is provided; It can be changed by the means of the service management protocol.

In the V5.2 interface, assigning bearer slots to user ports is dynamic, performed for each call. The display of the carrier channels of the user ports on the carrier channel intervals of the V5.2 interface and is provided by the BCC protocol. The dynamic assignment of the carrier channel intervals in the V5.2 interface also provides the information load concentration. Taking into account that the concentration factor 8 is usually applied, one interface V5.2 having 16 paths can serve an access network for approximately 4000 PSTN ports.

One V5.1 interface can support only up to 30 PSTN ports, since at least one channel spacing of the path is required for signaling and one for frame synchronization.

Lecture №7. Optical Access Technologies

The aim of the lecture is to study the technologies of optical access by students.

Content:

– the basic concepts of optical access technologies;
– topology of optical access networks.

Basic concepts of optical access technologies:

The largest volume of services can be provided to the user through OAN (Optical Access Networks) - active (FTTH, FTTB, FTTC, FTTCab, etc.) or passive PON (Passive Optical Networks) networks. The international consortium FSAN (Full Service Access Network) is engaged in creation and promotion of the newest access technologies, and in particular optical technologies [2, 9].

Technology FTTx - optics up to x (Fiber-To-The-x, FTTx) - is access to a wide range of multiservice services, through optical fiber.

Types of FTTx:

– FTTA (Fiber to the Apartment) - fiber to the apartment;
– FTTB (Fiber to the Building) - fiber to the building;
– FTTC (Fiber to the Curb) - optical fiber to the switch cabinet;
– FTTCab (Fiber to the Cabinet) - fiber to the telephone cabinet/booth;
– FTTN (Fiber to the Node) - fiber to node;
– FTTE (Fiber to the Exchange) - fiber to the closest switch to the user;
– FTTH (Fiber to the Home) - fiber to the home;
– FTTMdu (Fiber to the MultiDwelling Unit) - fiber to block/block of residential buildings;
– FTTN (Fiber to the Node) - fiber to the node;
– FTTO (Fiber To The Office) - bringing the cable from the OB to the office;
– FTTOpt (Fiber To The Optimum) - bringing the cable from the OB to an optimal point, in terms of the Operator and/or the user;
– FTTP (Fiber to the Premises) - bringing the cable from the OB to the customer premises;
– FTTR (Fiber to the Remote Office) - fiber to a remote node - cable from the OB to the remote module, hub, multiplexer or PBX;
– FTTS (Fiber to the Subscriber) - fiber to the subscriber;
– FTTU (Fiber to the User) - fiber to the user.

Examples of organization of MNAC on FTTx technology are shown in figure 7.1.

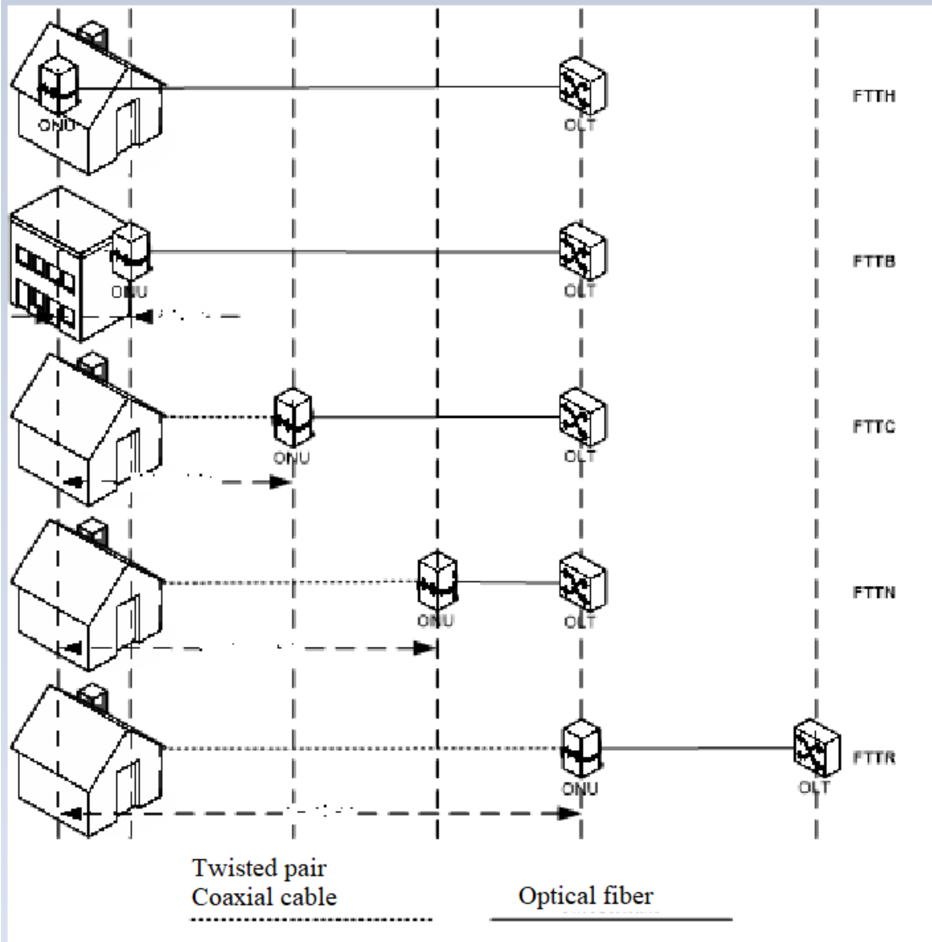


Figure 7.1 – Samples of MNAC based on FTTx technology

PON (passive optical networks) - passive optical networks: this is the most promising technology of broadband multiservice multiple access via optical fiber [2, 9].

The essence of the technology of passive optical networks is that its distribution network is built without any active components, the branching of the optical signal is carried out with the help of passive optical power splitters - splitters.

Types of PON:

– APON (ATM Passive Optical Network) - uses ATM data transport encapsulation for business applications, provides a transmission speed of 155 Mbps with a range of up to 20 km. Basic standard APON: ITU-T G.983;

– BPON (Broadband Passive Optical Network) - exceeds APON due to a number of advantages, in particular, support of the method of wavelength division multiplexing (WDM), video applications, higher transmission speed (622 Mbps and 1,2 Gbit / C). Basic standard BPON: ITU-T G.983x;

– GPON (Gigabit Passive Optical Network) - the most widespread version of PON today, providing symmetric transmission at speeds up to 2,5 Mbps, supports transport protocols Ethernet and ATM, as well as IP transport. Basic standard GPON: ITU-T G.984;

– EPON (Ethernet Passive Optical Network) - another name: "Ethernet in the First Mile" - provides symmetric transmission at speeds up to 1,25 Gbps and uses Ethernet encapsulation. The basic standard of EPON: IEEE 802.3ah;

– GEPON (Gigabit Ethernet Passive Optical Network) is one of the versions of the PON technology for passive optical networks and one of the most advanced options for building communication networks, providing high data transmission speed (up to 1,2 Gbit/s). The main advantage of GEPON technology is that it allows optimal use of the fiber optic cable resource. For example, to connect 64 subscribers within a radius of 20 km it is enough to use only one fiber optic segment;

– 10GEPON (10 Gigabit Ethernet Passive Optical Network) - a hybrid of GPON and EPON technologies with transmission speeds of up to 10 Gb/s. The basic standard is 10GEPON: IEEE 802.3av;

– TurboGEPON provides information transfer rate up to 2,5 Gbit/s downstream and up to 1,25 Gbit/s in the direction from the subscriber (upstream).

Topologies of optical access networks:

1) "Ring" - ring topology based on SDH - is used in access networks, but in access networks it is impossible to know in advance where, when and how many subscriber nodes will be installed (figure 7.2) [2, 9].

In case of casual territorial and temporary connection of users, the ring topology can turn into a severely broken ring with many branches, new subscribers are connected by breaking the ring and inserting additional segments. In practice, often these loops are combined in one cable, which leads to the appearance of rings that are more similar to a broken line - "collapsed rings", which greatly reduces the reliability of the network.

2) Point-to-Point (P2P) - the P2P topology does not impose restrictions on the network technology used (figure 7.3). P2P can be implemented for any network standard, as well as for proprietary solutions, for example, using optical modems. From the point of view of security and protection of transmitted information, when P2P is connected, the maximum security of subscriber units is ensured.

Since the optical cable must be laid individually to the subscriber, this approach is the most expensive and attractive mainly for large subscribers.

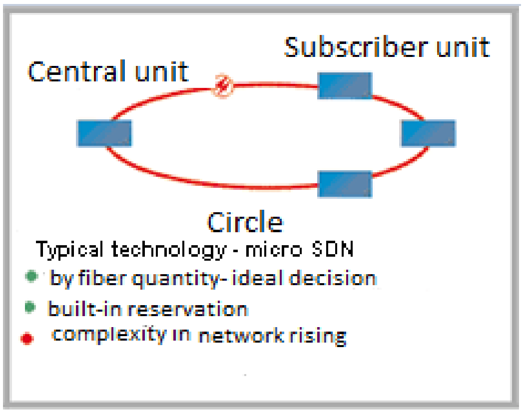


Figure 7.2 – Topology "Ring"

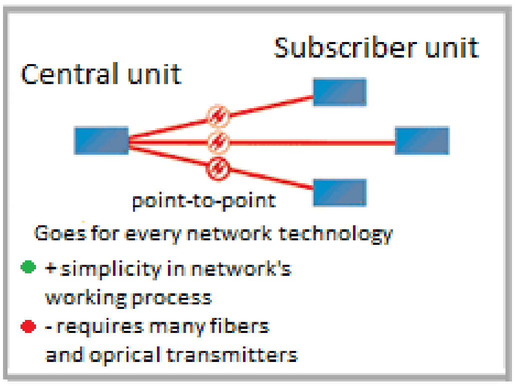


Figure 7.3 – Topology"Point-point"

3) "Tree with active nodes" is economical in terms of use of fiber solution (figure 7.4). This solution fits well with the Ethernet standard with a hierarchy in speeds from the central node to 1000/100/10 Mbit/s subscribers (1000Base-LX, 100Base-FX, 10Base-FL). However, in each node of the tree, there must be an active device (in relation to IP networks, a switch or router). Optical Ethernet access networks that primarily use this topology are relatively inexpensive. The main disadvantage is the presence on the intermediate nodes of active devices that require individual power.

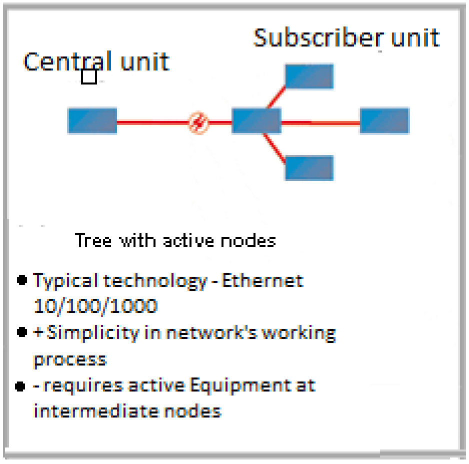


Figure 7.4 – Topology "Tree with active nodes"

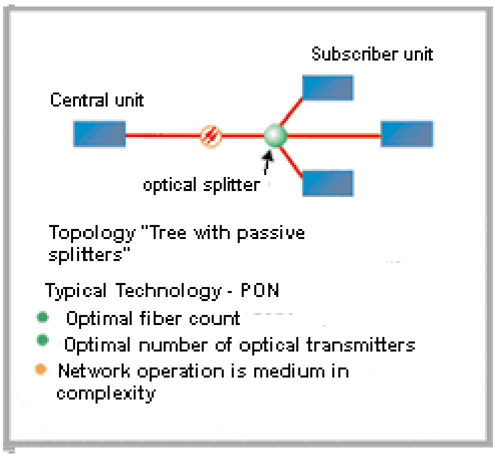


Figure 7.5 – Topology "Tree passive nodes "

4) "Tree with passive optical branching PON (P2MP)" - solutions based on PON architecture use the logical topology "point-to-multipoint" P2MP (point-to-multipoint), which is the basis of PON technology, one port of the central node can be connected A whole fiber-optic segment of a tree architecture, covering dozens of subscribers (figure 7.5). At the same time, compact, fully passive optical splitters (splitters) are installed in the intermediate nodes of the tree and do not require power and maintenance.

PON allows you to save on the cable infrastructure, due to the total length of optical fibers, because In the area from the central node to the unwinder, one fiber is used. Limitation of the number of spectators and receivers in the central node. Meanwhile, the savings on the part in some cases is even more significant.

Lecture №8. PON Technologies

The aim of the lecture is the study of PON technology by students.

Content:

– architecture PON;
– the principle of information transfer between PON devices;
– services provided by PON technology.

Architecture PON.

The basic idea of the PON architecture is to use only one transceiver module in the central node of the OLT to transmit information to and receive information from the ONU subscriber units (figure 8.1) [2, 9]:

– OLT (Optical Line Terminal) - central device, aggregates flows from terminal devices in buildings;

– ONU (Optical Network Unit) or ONT (Optical Network Terminal) - terminal device - is installed in the building, provides end users with various access ports.

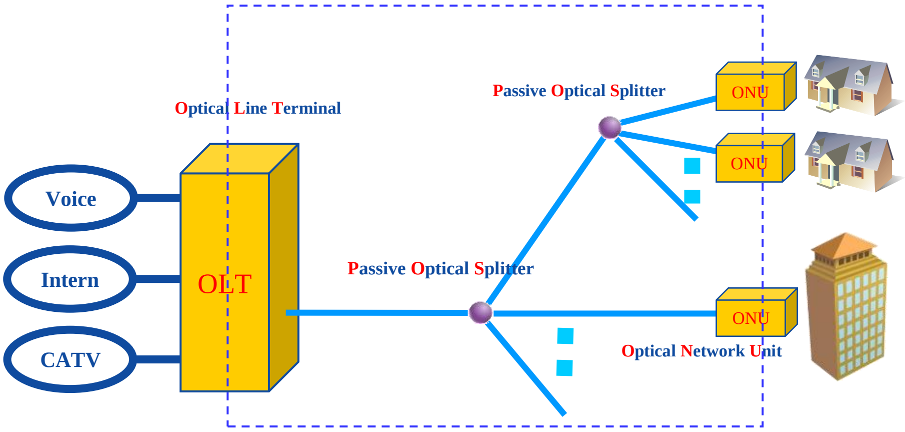


Figure 8.1 – Architecture PON

The PON network should provide transparent transport for the entire range of services - telephony, broadband access to the data network, IP-TV, cable TV. At the same time, this network should have the most economical, in terms of the volume of linear structures, fiber-optic infrastructure.

PON network properties:

– tree architecture with transmission over a single fiber at two wavelengths towards each other: 1550 nm (from the central node to subscribers, downstream) and 1310 nm (from subscribers to the central node, upstream);

– at the intermediate nodes of the tree passive optical splitters are placed;

– the use of the TDMA access method allows for flexible allocation bandwidth between subscribers;

– one fiber from the central node (OLT) can connect up to 32 subscriber nodes (ONT);

– the maximum distance is 20 km.

The main advantages of PON technology:

– low cost of building a network. The technology realizes the possibility of connecting a large number of subscriber terminals via one optical fiber, which contributes to significant fiber savings;

– low costs for operation and maintenance of the network. The advantage is due to the use of passive equipment in the distribution network;

– the possibility of a gradual build-up of the network. Entering new nodes does not affect the existing network;

– the prospect of creating a distribution infrastructure. The construction of an optical distribution network provides a good and long-term basis for the further development and provision in the future of any multimedia services with virtually unlimited bandwidth;

– reliability. The use of fewer active elements in the network ensures its reliability, and besides, it contributes to both a decrease in sensitivity to the influence of adjacent communication lines and to a decrease in the impact on them;

– high flexibility. The construction of a distribution network using PON technology requires the use of only one optical fiber, rather than a fiber bundle, as with other optical fiber technologies. Thanks to this, it is possible to build a network on a bus or tree topology, which is very advantageous from the economic point of view. The flexibility of the technology makes it possible to use it in any network configurations of the FTTx family;

– the ability to provide triple play services with the provision of video on any model: in the form of cable television services or in the form of IPTV services.

The principle of information transfer between PON devices.

The number of subscriber units connected to one OLT transceiver module can be as large as the power budget and the maximum speed of the transceiver equipment allow. To transfer the flow of information from the OLT to the ONT - the downstream, as a rule, a wavelength of 1550 nm is used.

Conversely, data streams from different subscriber nodes to the central node that together form the reverse (upstream) stream are transmitted at a wavelength of 1310 nm. In OLT and ONT, WDM multiplexers are built in to separate outgoing and incoming streams. The implementation of this principle is shown in figure 8.2 [9]. Direct stream - at the level of optical signals - is broadcast. Each subscriber node ONT, reading address fields, allocates from this shared stream the information intended only to it. In fact, we are dealing with a distributed demultiplexer.

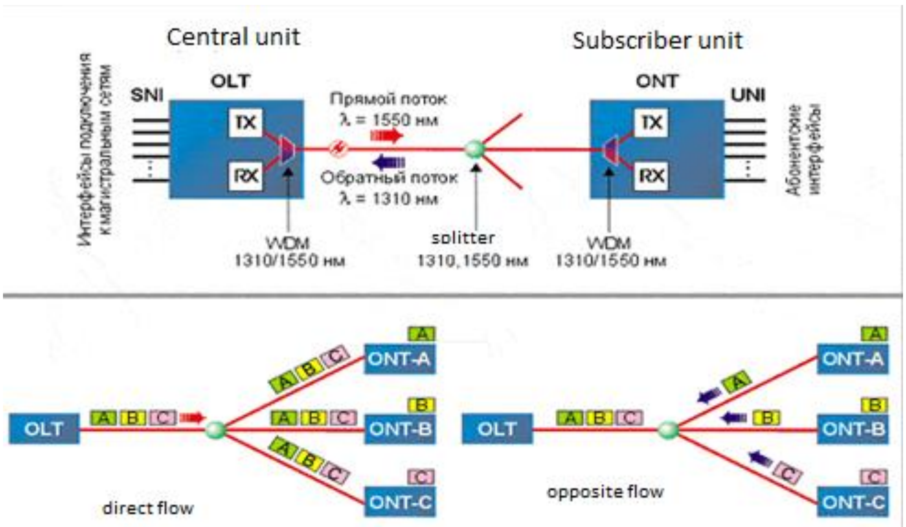


Figure 8.2 - The principle of information transfer between PON devices

Reverse flow. All ONT subscriber nodes transmit in the reverse stream at the same wavelength using the time division multiple access (TDMA) concept. In order to exclude the possibility of crossing signals from different ONTs, for each of them an individual schedule for data transmission is established, taking into account the delay correction associated with the removal of this ONT from OLT. This task is solved by the TDMA MAC protocol.

The standard PON provides for the use of a standard spectral range (C-band, conventional - 1530-1565 nm) for the transmission of DWDM traffic. So, it is permissible to use a wide-spread video at another wavelength. Using the C-band, you can organize bidirectional communication channels (figure 8.3).

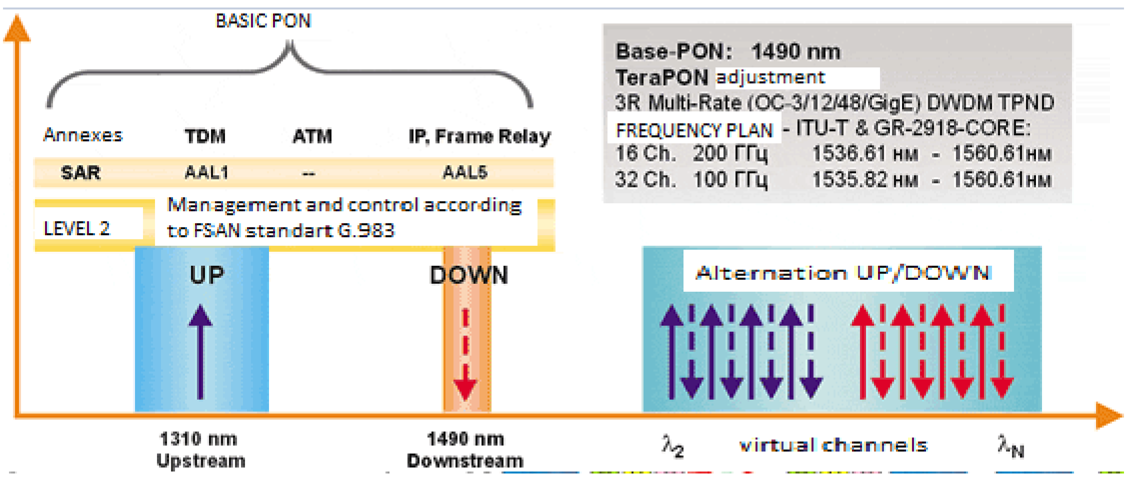


Figure 8.3 - C-band for the transmission of DWDM signals

Services provided by PON technology.

With the use of passive optical network technology, data transmission, telephony, IPTV and cable television services can be provided in the complex [9].

The possibility of providing complex services is realized using subscriber equipment.

For the organization of access to NGN network services by means of PON, a hybrid service model is used. The implementation of the logical model of access to NGN network services through PON is shown in figure 8.4.

The PPPoE session is initiated on the subscriber equipment (PC), and the ONT is configured in Bridge mode. Termination of the PPPoE session is done on BRAS. Internet traffic and data traffic of the internal network of subscribers is transmitted within a single PPPoE session. To access the Internet services of the PPPoE virtual adapter on the subscriber's equipment, a dynamic public IP address is assigned.

In order to provide access to triple play services, three service VLANs are implemented in the areas between the user equipment (ONT) and the terminating equipment (the S-VLAN-Service VLAN is implemented), within which Internet traffic, VoIP and one VLAN for traffic transmission IPTV and VoD. On ONT equipment, the physical port identifier is compared to connect the user equipment

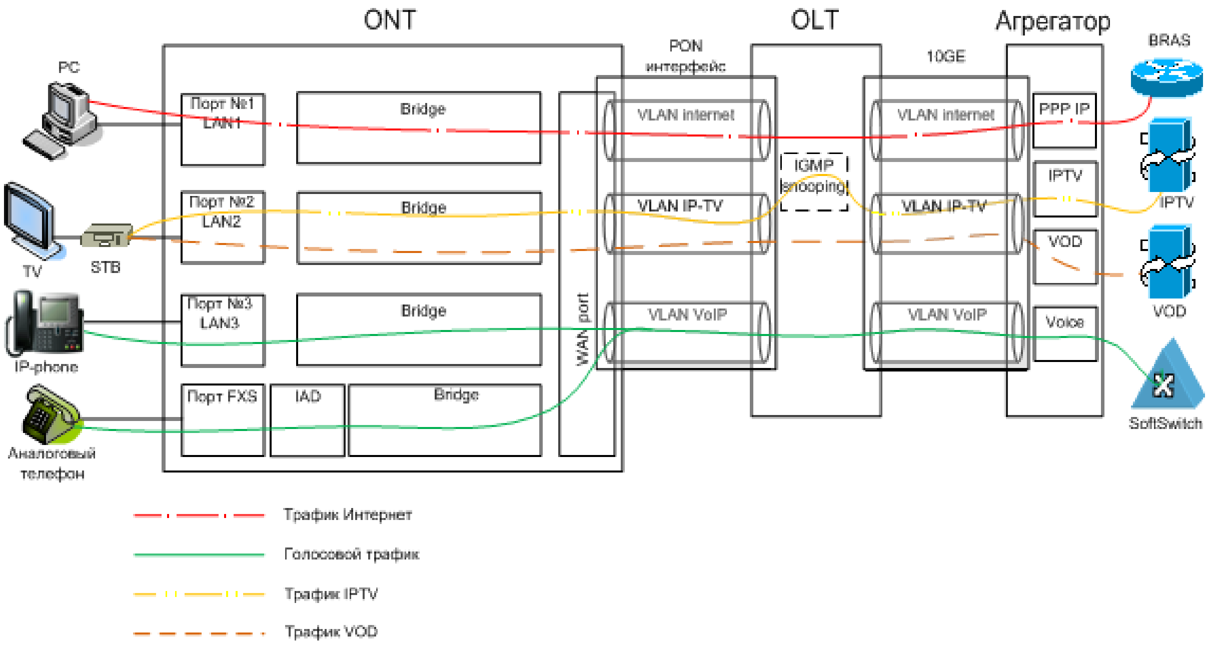


Figure 8.4 - Logical model realization

and the identifier of the corresponding service VLAN. For example:

– Port 1 - for PC connection and access to the Internet service;

– Port 2 - for connecting STB set-top box and access to IPTV and VoD services;

– Port 3 - to connect the phone and access the VoIP service.

Lecture №9. Technologies of cable television networks

The aim of the lecture is to study the technology of cable television networks by students.

Content:

– the basic concepts of cable television networks;

– hybrid optic-coaxial networks;

– realization of cable television networks on FTTB.

Basic concepts of cable television networks.

Cable television (short name from Community Antenna Television, CATV) is a model of television broadcasting (and sometimes also FM broadcasting) in which the TV signal is propagated through high-frequency signals transmitted through a cable pushed to the consumer [2, 9, 10]. Cable television is opposed to terrestrial and satellite television

For a long time the basis of cable television networks was a coaxial cable. The successful development of optical data transmission technologies led to the introduction of optical fiber in the cable television network in the form of so-called hybrid, or fiber-coaxial networks (Hybrid Fiber Coaxial - HFC), which combine coaxial and fiber-optic cables.

A modern cable television network includes a headend, main communication channels, sub-main lines and house distribution networks.

Advantages of cable television before the air:

– better signal quality;

– high noise immunity;

– no problems with signal transmission in cities with dense multi-storey buildings;

– the possibility of expanding the services provided to the subscriber and the number of channels.

Traditionally, analog cable television technology has successfully mastered digital methods of data transmission both in the direct direction to customers (DVB-C) and bilateral interactive (DVB + IP, DOCSIS).

Data Over Cable Service Interface Specifications (DOCSIS) - the standard for data transmission over a coaxial (television) cable. This standard provides data transmission to the subscriber through a cable TV network with a maximum rate of up to 42 Mbps (with a bandwidth of 6 MHz and the use of multi-position amplitude modulation of 256 QAM), and receiving data from the subscriber at a speed of up to 10.24 Mbps.

There are several versions of the DOCSIS specification:

- DOCSIS 1.0;
- DOCSIS 1.1;
- DOCSIS 2.0;
- DOCSIS 3.0;
- EuroDOCSIS.

EuroDOCSIS regulates the frequency distribution of the forward and reverse channels adopted for Europe, specifies the operation with an 8 MHz band.

The DOCSIS 1.1 standard additionally provides for special mechanisms that improve the support for IP telephony, reducing speech delays (for example, mechanisms for fragmentation and assembly of large packets, organization of virtual channels, and setting priorities).

DOCSIS has direct IP protocol support with non-fixed packet length, unlike DVR-RC, which uses ATM Cell transport to transfer IP packets (that is, the IP packet is first transferred to ATM, which is then transmitted over the cable, and the other side performs the reverse process) (table 9.1).

Top-down data transmission - to the user, or in the Downstream channel - is performed by the head equipment transmitting device, called the CMTS-Cable Modem Termination System. In other words, the entire band is divided among all users who are currently receiving data, so the band available for a specific user at any given time can "float" in a very wide range.

Upstream data transmission (in the Upstream channel) can be performed by a cable modem that meets the technical requirements of the enterprise, or is certified for compliance with the DOCSIS standard, and as an access protocol, a TDMA (Time Division Multiple Access) or CDMA (Code Division Multiple Access).

Table 9.1 – Maximum synchronization speed (Maximum using speed)

Version	DOCSIS		EuroDOCSIS	
	Direct flow (Down)	Reverse flow (Up)	Direct flow (Down)	Reverse flow (Up)
1.x	42,88 (38) Mbit/c	10,24 (9) Мбит/с	55,62 (50) Мбит/с	10,24 (9) Мбит/с
2.0	42,88 (38) Мбит/с	30,72 (27) Мбит/с	55,62 (50) Мбит/с	30,72 (27) Мбит/с
3.0 4channel	+171,52 (+152) Мбит/с	+122,88 (+108) Мбит/с	+222,48 (+200) Мбит/с	+122,88 (+108) Мбит/с
3.0 8channel	+343,04 (+304) Мбит/с	+122,88 (+108) Мбит/с	+444,96 (+400) Мбит/с	+122,88 (+108) Мбит/с

Prior to the DOCSIS 3.0 standard, the bandwidth per user in the Downstream channel was approximately 25 Mbit / s, in the Upstream channel - no more than 10 Mbit / s. This is due to the inability to allocate all time slots to one subscriber unit.

The main difference between DOCSIS 3.0 and 2.0 is that in DOCSIS 3.0 the channels on the cable modem can be combined, thereby increasing the access speed. Combine up to 16 direct and 8 reverse. Also in DOCSIS 3.0 there was support for multicast, AES encryption, etc.

Hybrid optic-coaxial networks.

Hybrid fiber-coax networks (HFC-Hybrid Fiber Coax) are built on three main technologies, often referred to as classic networks (Figure 9.1) [2, 9, 10]. HFC networks transmit both analog and digital signals. In the construction of cable television (CAT) systems, the overwhelming majority use HFC networks, they have the maximum potential broadband from all types of existing networks, both in trunk areas and in subscriber access areas.

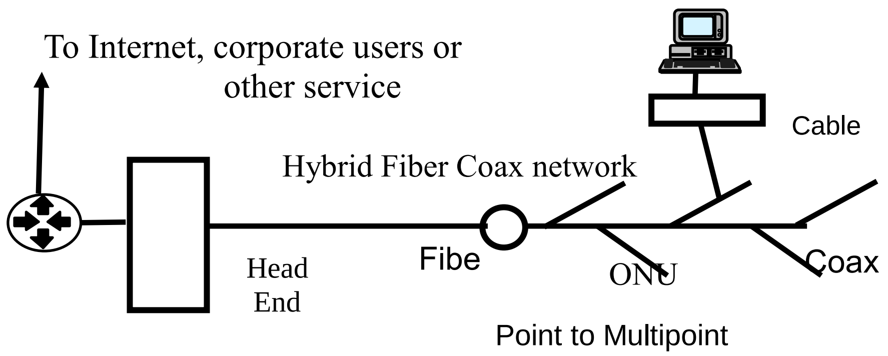


Figure 9.1 – Networks technologies of cable television

HFC networks are now becoming more and more popular due to broadband, multimedia, the simplicity of content creation, the ability to create equal information flows in both directions, access to all subscribers, high reliability and ease of maintenance.

In HFC networks, the transport network is built on optical fiber or leased, it connects the head and node stations, the topology depends on the number of hubs.

On optical highways and sub-highways the signal is fed from the headend to the optical nodes. They build a coaxial distribution network using a cable of large diameter and having small losses (not worse than 0.07 dB / 100 m). The total length of such a cable can be no more than three kilometers, as with a change in temperature, the attenuation of signals in a coaxial cable can change so much that the cable television network will be inoperable.

Realization of cable television networks on FTTB.

FTTB (Fiber To The Building) - optics to the building. Under such a technology is meant a relatively deep penetration of the optics to the subscriber, i. E. The operation of the optical node (OS) on an average of 100 ... 250 subscribers (for example, 9 ... 12-storeyed house for 4 ... 6 entrances). In this case, no more than one coaxial amplifier is usually cascaded after the op-amp (figure 9.2) [9, 10].

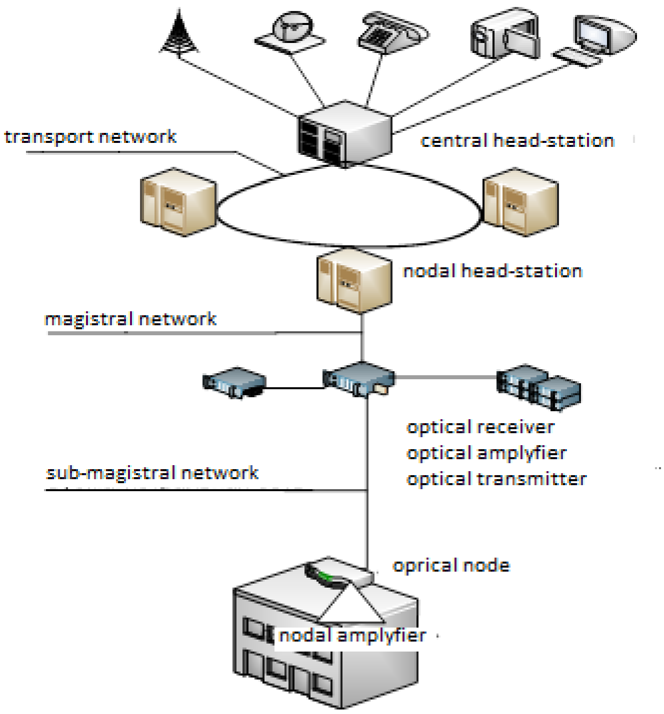


Figure 9.2 – Network of cable television based on FTTB

In a fiber-optic cable that passes to the optical node of the building, at least three active fibers are used. A pair of fibers provides a network communication channel with an Ethernet hierarchy 10/100/1000. A twisted pair of up to 200 meters in length can be connected to the subscriber for 10 Base-T or 100 Base-TX interfaces. When connecting individual subscribers, it is better to completely abandon multiplexers, and make all channels duplex. The use of switches will allow you to organize a hierarchy of speeds, introduce subscriber billing when connecting them to 10 Base-T or 100 Base-TX, and use faster channels on the main sections of the network.

One fiber can transmit a broadcast television signal to a home optical receiver, the amplifier linearly receiving this signal into an electrical signal and transferring it to a coaxial cable in a frequency band of the order of 1 GHz. When replacing HFC with FTTB, the home amplifier is removed, and the passive fragment of the coaxial cable with a 300 MHz bandwidth with digital traffic in the MPEG-2 standard above 1 MHz is retained. There is no return channel in such a network.

Unlike the traditional construction of HFC networks, where several consecutive coaxial amplifiers are installed after the optical node, only optical transmission and reception devices create intermodulation distortions in the FTTB network. For the control system, an interactive Ethernet channel is used.

Lecture №10. Collective access networks

The purpose of the lecture: Studying the networks of collective access.

Content:

– the basic concepts of collective access networks;

– communication through power lines (LEP).

Basic Concepts of Collective Access Networks.

Collective access networks (ACS) are designed to organize relatively inexpensive Internet access for individual users residing in multi-unit buildings [2, 11]. The idea of collective access consists in using the existing cable infrastructure in homes (twisted copper pair, radio transmission networks, electrical wiring). A traffic hub is installed in the house connected to the Internet.

Different technologies (PON, FWA, satellite, etc.) can be used to connect the hub to the node of transport network services. Thus, collective access networks are hybrid, combining both the actual network of collective access, and networks that provide transportation of traffic.

The main technologies of collective access are HPNA, PLC, EFM.

HPNA Standards Series.

HPNA standards are the result of the Alliance Phoneline Networking Alliance, established in 1996 to develop a technology that, based on existing in the homes of the cable network, should provide relatively inexpensive Internet access. The HPNA technology is standardized in ITU-T (Rec. G.989.1 and G.989.2).

HPNA 1.x. The HPNA 1.0 standard was created in 1998. The signal bandwidth is 4 ... 10 MHz, so HPNA systems do not affect telephone and other systems running on the same cable.

Access systems HPNA 1.0 provide a shared access to a channel with a bandwidth of 1 Mbps for a distance of up to 150 m. As a medium access method, CSMA/CD (IEEE 802.3) is used. To transmit information, DMT modulation is used. Typical network topology is "star".

The core of the network is the HPNA switch, whose ports are connected to the corresponding subscriber line. The maximum number of subscribers in the network is 32.

In the standard HPNA 1.1, the range of equipment is increased to 300 m.

HPNA 2.0. In the networks of this standard, which appeared in 2000, the bandwidth of the collective channel is increased to 10 Mbit/s with a range of up to 350 m. The typical topology of the network is the "bus". The operation of such a network does not require the use of switches and other active

Devices.

HPNA 3.0 Currently, there is a development of a new standard HPNA 3.0, which it’s bandwidth of the home network should reach 100 Mbit/s.

PLC technology.

The development of standards for the technology of PLC (Power Line Communications), implemented on the basis of power supply network infrastructure, is being carried out by various international organizations such as the PLC Forum, Powerline World and Home Plug Powerline Alliance. The last of them accepted in 2001 the Single Standard HomePlug 1.0 specification, which defines data rates up to 14 Mbit/s, methods of access to the CSMA/CD or CSMA/CA transmission medium and OFDM modulation. The standardization of PLC technology is also leaded in ETSI (TS 101 867, TS 101 896, TR 102 049).

EFM technology.

EFM (Ethernet in the First Mile) technology requires the creation of an infrastructure in the house based on fiber optic cable or a twisted copper pair of category 3 and higher. EFM was developed by the IEEE802.3ah working group, in which it is preferred to use the expression "first mile" to determine the access network, instead of the generally accepted term "last mile". Requirements were developed for the functions of a network of collective user access based on Ethernet. The standard presents various network architectures, it is envisaged to use different media for information transfer.

Communication via power lines.

PLC (Power line communication) is a term describing several different systems for the use of power lines (LEPs) for the transmission of voice information or data [11]. The network can transmit voice and data by imposing an analog signal over a standard 50 Hz or 60 Hz alternating current. The PLC includes BPL (Broadband over Power Lines), providing data transfer rates of more than 1 Mbit/s, and NPL (Narrowband over Power Lines) with significantly lower data rates.

With the development of energy networks, the question arose about the transfer of dispatching information from one energy node to another. The use of telephone and telegraph lines parallel to power lines for these purposes were considered to be irrational, therefore already at the beginning of the 20th century, DC transmission in the United States used the transmission of telegraph signals directly over the power line wires. Later, with the development of radio communications, a similar technique became applicable for AC networks.

Transmission of control information over the wires of power lines is widely used as one of the main types of communication. The transceiver is connected to the power line through an attachment filter, formed from a capacitor of small capacity (4700 - 6800 picofarads) and a high-frequency transformer (autotransformer).

Similar system allows to transmit both voice information and telemetry and telecontrol data.

The technology of PLC is based on the use of power grids for high-speed information exchange. Experiments on the transmission of data over the power grid have been conducted for a long time, but the low transmission speed and weak noise immunity resistance was restricted of this technology. But the appearance of more powerful DSP-processors (digital signal processors) made it possible to use more sophisticated signal modulation methods, such as OFDM modulation, which allowed to significantly advance in the implementation of PLC technology.

In 2000, several major telecommunications market leaders joined the HomePlug Powerline Alliance to jointly conduct research and practical tests, and to accept a single standard for data transmission over power systems. The PowerLine's prototype is the Intellon PowerPacket technology, which is the basis for the creation of a single standard HomePlug1.0 (accepted by the HomePlug Alliance on June 26, 2001), in which the transfer rate is determined to be up to 14 Mb / s.

The foundation of PowerLine technology is the use of frequency division of the signal, in which a high-speed data stream is disassembled into several relatively low-speed streams, each of which is transmitted at a separate subcarrier frequency, and then combined into one signal. In fact, PowerLine technology uses 84 subcarriers in the frequency range 4 - 21 MHz.

By transmitting signals through the household power, large attenuation can occur in the transmitting function at certain frequencies, which can lead to data loss. PowerLine technology provides a special method for solving this problem - dynamically turning on and off data-carrying signals. The point of this method is that the device constantly monitors the transmission channel in order to detect a portion of the spectrum exceeding a certain threshold attenuation value. If this fact is detected, the use of these frequencies stops for a while until the normal attenuation value is restored.

There is also the problem of the occurrence of impulse noise (up to 1 microsecond), the sources of which can be halogen lamps, as well as turning on and off powerful domestic electrical appliances equipped with electric motors.

Application of PLC technology:

1) Internet connection. Currently, the vast majority of final connections are carried out by laying a cable from the high-speed line to the apartment or office of the user. This is the cheapest and most reliable solution, but if cable laying is not possible, you can take advantage of the system of power electrical communications available in each building. At the same time, any electrical outlet in the building can become a point of access to the Internet. From the user only the presence of PowerLine modem is required to communicate with a similar device installed, as a rule, in an electrical building and connected to a high-speed channel. However, you need to be prepared for instability and low quality of the network.

2) Small office (SOHO). PowerLine technology can be used to create a local network in small offices (up to 10 computers), where the main requirements for the network are ease of implementation, device mobility and easy extensibility. At the

same time, both the entire office network and its individual segments can be built using PowerLine adapters. Frequently there is a situation where it is necessary to include a remote computer or a network printer located in another room or at the other end of the building into an already existing network. This problem can easily be solved with PowerLine adapters.

3) Home communications. PowerLine technology can be used to realize the idea of "smart home", where all consumer electronics are connected in a single information network with the possibility of centralized management.

Advantages:

1) Ease of use.
2) Single cable is not required.

Disadvantages:

1) Extremely vulnerable from radio transmitting devices in the short-wave range.
2) The network capacity for wiring is divided among all its units.
3) Specific compatible network filters and UPS are required. Through the usual does not work.
4) Radio reception is broken, especially on medium and short waves.
5) The quality of communication is adversely affected by energy-saving lamps, switching power supplies, chargers, light switches, etc. Etc. (reduction in speed is about 5 to 50%).
6) The quality and speed of communication is adversely affected by the performance / topology / quality of the wiring, the type / mode / power of household electrical appliances and devices, the presence of twists (slowing down to complete failure).
7) Installation requires live operation. Since the standard intersects with the short-wave frequency range, interference is created for communication and broadcasting equipment. The widespread distribution of the standard makes it impossible to receive shortwave transmissions at distances from hundreds of meters to kilometers from buildings and near power lines where this technology is used.

Lecture №11. Example of a multiservice subscriber access node

The purpose of the lecture: Studying of a multiservice subscriber access node by students.

Content:

- the main characteristics of the multiservice subscriber access node;
- types of accesses of the multiservice subscriber access node.

The main characteristics of a multiservice subscriber access node.

SI3000 Multi Service Access Node (SI3000 MSAN) - a multiservice subscriber access node SI3000 - is a universal subscriber access of company Iskratel. It provides any combination of delivery of high-speed, multimedia or voice services over fixed and wireless connections [12, 13].

The SI3000 MSAN node provides the implementation of multimedia services, voice and data services using various user interfaces. It is the optimal solution for the smooth introduction of Triple Play services or expanding their range for residential subscribers and business subscribers.

The SI3000 MSAN is compatible with various network configurations. It can work with traditional PSTN systems as well as with IP networks oriented to NGN / IMS. It can be used as:

- TDM-access node with the ability to connect to TDM networks;
- a node with broadband access functions over DSL and FTTx;
- a node with wireless access functions with the ability to connect to an IP network.

When designing urban and suburban access networks with high capacity on the basis of SI3000 MSAN, Ethernet technology, fiber-optic, copper and wireless transmission channels are used.

Unified control system provides a complete set of remote control and monitoring functions for each Iskratel network element. It reduces the cost of configuration and monitoring through comprehensive management of failover, configuration, charging, performance and security.

Types of user connections:

– POTS;
– VDSL2, ADSL2 + and SHDSL;
– combined IVD-transmission;
– POTS / ADSL2 +);
– WiMAX for fixed and mobile communication;
– FTTH, FTTx.

Types of network connections:

– 10 GE;
– Gigabit Ethernet;
– E1 (V5.2).

Types of accesses of the multiservice subscriber access node [12, 13].

DSL access is designed to deliver end-to-end triple-play carrier-class services on a packet-only basis. It integrates IP DSLAM with various integrated broadband DSL technologies into a single broadband access platform. Broadband unlimited access provides several Gigabit Ethernet interfaces to connect to the transport network.

To provide high quality multimedia services, broadband access supports built-in QoS functions, multilevel multicast functions, and advanced security features.

SI3000 MSAN is implemented on the basis of IP-technology. Its design allows the connected DSL subscriber to receive up to 3 IPTV streams simultaneously on one port.

Subscriber broadband interfaces are implemented on the basis of VDSL2, ADSL2 + and SHDSL technologies. These options provide the ability to provide broadband access to users located at a distance of several hundred meters to 5 km or more. Copper pairs are used to connect users. With the use of DSL technologies it is possible to simultaneously provide classic narrowband POTS and ISDN services for the same copper pair.

POTS access provides flexible and cost-effective methods of supporting traditional voice services and provides reliable options for switching to packet-based networks. POTS access, integrated into the SI3000 MSAN, is the ideal solution that allows operators to upgrade their core networks to the next-generation IP network and at the same time preserve the existing infrastructure.

POTS access can be divided into two separate components: the access gateway board and the POTS board (analogue of subscriber lines board).

On the network side, the access gateway board is connected to a local TDM station equipped with a standard V5.2 interface, and subscribers connect to the POTS card using a standard analog interface. The internal interconnection of the cards is implemented on the basis of promising IP / Ethernet technology, which allows the Iskratel software switch, called the SI3000 Call Server (SI3000 CS), or third-party software switches, to operate the POTS card; Using the protocols MGCP, H.248 / MEGACO or SIP.

WiMAX access. WiMAX access solution is suitable for servicing fixed and mobile subscribers. The introduction of the 802.16e mobile communication standard allows the use of mobile communication in compliance with infrastructure requirements.

WiMAX technology is designed to provide E1-level bandwidth for corporate users and equivalent access based on cable connections / DSL for home users.

Advantages:

1) Full coverage. The product is based on high-end technologies such as OFDM modulation. This ensures the performance of the system when deployed in line of sight (LOS) and non-line-of-sight (NLOS).

2) Addition to a wired connection. Thanks to its architecture, interfaces and easy integration with the network, the SI3000 WiMAX Access solution can be used to provide high-quality voice and high-speed Internet access, including streaming services.

3) Flexibility the SI3000 WiMAX access solution is designed for a variety of applications, including the "last mile" broadband access, Wi-Fi access point and cellular traffic.

The architecture of the SI3000 WiMAX system consists of the following components:

– SI3000 WiMAX BS base station;

– unit SI3000 WiMAX ODU, intended for outdoor installation. The SI3000 WiMAX system supports two models of ODUs used with WiMAX cards:

1) SI3000 WiMAX BS8100 (1Tx 1Rx) with a power of 30 dBm (802.16d);

2) SI3000 WiMAX BSM8200 (2Tx 2Rx) with a power of 36 dBm or 40 dBm (802.16e);

– subscriber devices SI3000 WiMAX SS. Subscriber devices are located in the user's premises and provide connections for data transmission through the base station. Subscriber devices are an important component of the WiMAX solution and are divided into devices:

a) for indoor use only;
b) for operation partially inside the premises;
c) for outdoor use;

– subscriber devices SI3000 WiMAX series SSM3100 / SSM32100 (802.16e - for mobile communication);

– gateway SI3000 WiMAX ASN. The ASN "lightweight" version is a SI3000 WiMAX ASN gateway for WiMAX-based mobile networks. The gateway provides extensive support for the functions defined by the WiMAX NWG Forum, as well as full support for roaming and interoperability functions. In addition, the gateway supports interfaces defined by the reference ASN model for communication with mobile stations, base stations, CSN networks and neighbor ASN gateways.

Optical fiber access, due to higher transmission speeds and the ability to combine multiple service flows in a single connection, provides many advantages. Unified next-generation service delivery is a good alternative to dedicated connections for the transportation of services. Such a combination of services provides significant cost savings and makes it possible to significantly simplify the structure of networks.

It offers three options for deploying fiber optic access: bringing the optical line directly to the user (FTTC) and bringing the optical line to a cable cabinet or building (FTTB).

FTTC provides for the combined use of optical connections with existing communication capabilities over wired lines based on DSL technologies. The use of shelter-type outdoor enclosures (ODU-M) allows the SI3000 MSAN to be located in densely populated surrounding areas and to connect fiber lines as close as possible to subscribers. The FTTC benefits from the high performance of fiber optic lines and the low cost of existing copper lines.

The FTTB option provides cost-optimized delivery of high-speed services for entire buildings. Deployment of Fast- and Gigabit Ethernet connections for end users is performed using unshielded twisted-pair (UTP). In the case of existing copper lines, VDSL2 or ADSL2 + technology is used in this solution, thus ensuring comparable connection bandwidth.

In the FTTB variant, a "shelter" housing (IDU-M) with a power supply and management interfaces is used to achieve the optimum performance of the access node.

List of letters

1 Sokolov N.A. Subscriber access networks. Principles of construction. – Published ZAO IG «Enter-Profi», 1999. - 254 p.

2 Systems of access to information networks. Textbook. Manual for the discipline "Access systems to computer and telecommunication networks" for students of specialties "Radio communication, broadcasting and television systems", "Multichannel telecommunication systems" for day, evening and correspondence forms of training / N.V. Tarchenko, P.V. Tishkov. - Mn .: BSUIR, 2005. - 80 p.

3 OM. Denisyeva, D.G. Miroshnikov. Means of communication for the last mile. - M .: Eko-Trens-NTC NATEKS, 1999. - 140 p.

4 Bitner V.I. Access to the resources of the digital integrated services network: Proc. Manual for higher education institutions / MVO of the Russian Federation for communication and informatiz. Sib.gos.un-t telecom. And informatics. Interregional Studies. Reef Center. Specialists. - Novosibirsk, 2000. - 84 p.

5 Baklanov I.G. Technologies ADSL / ADSL2 + theory and practice of application. - M .: Metroteck, 2007.

6 Rasic A.V. WiMAX Wireless Access Networks: Textbook. Allowance / Rashich AV- SPb .: Publishing house of Polytechnic. University, 2011. - 179 with.

7 Apostolova NA, Goldstein BS, Kadykov VB Universal interface V5 of the subscriber access network. A manual on the course of SAD. - St. Petersburg, SGUT, 2005.

8 Goldstein B.S. Access network protocols - M .: Radio and Communication, 1998.

9 Uryadov VN, Tarchenko N.V., Tishkov P.V. Modern technologies of means and systems of telecommunications. Lecture notes for students of specialties I-45 01 01 Multichannel telecommunication systems. Minsk: BSUIR, 2008. - 198 p.

10 Volkov, S.V. Cable TV networks. - Moscow: Hot Line-Telecom, 2004. - 616 p.

11 A.N. Nikiforov. PLC technology - telecommunications over power networks // "Networks and communication systems". - 2002. - № 5.

12 http://www.iskrauraltel.ru

13 http://www.si3000.ru

Content

Consolidated plan 2019, positions 258

Yuliya Mikhailovna Garmashova
Almira Dulelkhanovna Mukhamedzhanova
Sergey Vladimirovich Panchenko

MULTISERVICE NETWORKS OF SUBSCRIBER ACCESS

Lecture notes
For students of the specialty 5V071900 –
Radio engineering, electronics and telecommunications

Editor M.D. Kurmanbekova
Standardization Specialist G.I. Mukhametsariyeva

Signed in print Format
Circulation 30 copies
The volume of 2,9 ed.-pub. lic

Format 60x84 1/16
Paper typographical №1
Order ___ Price 1500 KZT

Copying Office
Non-commercial joint-stock company
" Almaty university of power engineering and telecommunications Gumarbek Daukeev"
050013, Almaty, Baytursynova, 126/1