

MINISTRY OF SCIENCE AND EDUCATION OF THE REPUBLIC OF
KAZAKHSTAN

Non-Profit Joint Stock Company
ALMATY UNIVERSITY OF POWER ENGINEERING AND
TELECOMMUNICATIONS

Department Telecommunication systems and networks

«Admitted»

Head of the Department Baykenov A.S.
d.t.s., professor

(Surname and initials, degree, rank)

« » 20 y.
(sign)

DIPLOMA PROJECT

Theme: Projection of 5 GHz Wi-Fi network with
roaming for ICT department

Specialty: 5B071900 – Radio engineering electronics and telecommunications

Implemented by: Dyussekenova A.A. ICTe 14-9
(Student's surname and initials) group

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(sign)

Almaty 2018 y.

MINISTRY OF SCIENCE AND EDUCATION OF THE REPUBLIC OF
KAZAKHSTAN

Non-Profit Joint Stock Company
ALMATY UNIVERSITY OF POWER ENGINEERING AND
TELECOMMUNICATIONS

Institute of Space Engineering and Telecommunications (ISET)

Specialty: 5B071900 – Radio engineering electronics and telecommunications

Department: Telecommunication systems and networks

ASSIGNMENT

For diploma project implementation

Student: Dyussekeneva Anna Akhramhanovna
(name, patronymic and surname)

Theme: Projection of 5 GHz Wi-Fi network with roaming for
ICT department

Approved by Rector order № 155 of « 23 » 10 20 17 y.

Deadline of completed project: « 25 » 05 20 18 y.

Initial data for project, required parameters of designing result, object initial data:

Almaty University of Power Engineering and Telecommunications
department. Equipment ASUS RT-AC 3200 Receiver
sensitivity 82dBm. Ranges: 2,4 GHz and 5 GHz. Based on the IEEE 802.11ac
Has ASUS AiCloud 2.0

List of questions for development in diploma project or brief content:

Features of Wi-Fi communication system. Routers of next generation.
Wi-Fi topologies. Work principles. Comparing 2,4 and 5 GHz Wi-Fi
ranges. ASUS RT-AC 3200 characteristics. Strategy of building and
securing Wi-Fi network. Free Wi-Fi for everyone and everywhere.
Elon Musk and his SpaceX project. Technical parameters
solutions. Calculation of allowable losses. Calculation of sensitivity
of access point receiver. Calculation of aspiration system.
Heat map construction. Studing router functions. Fire Ball function.
Financial plan. Design part. Calculation of Fresnel zone.
Wi-Fi rapid development.


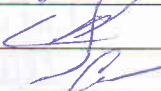
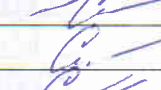
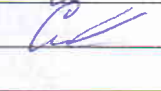

List of illustrations (with exact specifying of mandatory drawing):

- Figure 1.1 - Wi-Fi network diagram
- Figure 1.2 - IEEE 802.11a frame format
- Figure 1.3 - Division of UNII band
- Figure 1.9 - General structure of the MIMO-OFDM transmitter
- Figure 1.18 - Difference between 2.4 GHz and 5 GHz Wi-Fi network
- Figure 1.19 - Channels difference
- Figure 1.20 - Switchable dual-band router
- Figure 1.24 - Roaming topology
- Figure 2.1 - Types of access points
- Figure 3.1 - Wireless access point ASUS RT AC 3200
- Figure 3.5 - WAN functions
- Figure 3.7 - Guest network options
- Figure 3.12 - Firewall settings
- Figure 3.29 - Heatmap of 2.4 GHz Wi-Fi network
- Figure 3.30 - Heatmap of 5 GHz Wi-Fi network

Recommended main references:

1. Тухтаманкули А.Б., Бакаров У.Б., Мурод Д.Н. Технологии сети Wi-Fi-М.: БНХОМ. 2007
2. ASUS Router Information [web resource]
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<https://www.tp-link.com/ru/FAQ-229.html>
6. Networks Topology [web resource]
<https://1234g.ru/wifi/topology-networks-wifi>

Project adviser with corresponding sections specifying:

Section	Advisor	Dates	Sign
Economic part	Tuzelbayev B.I	23.05.18	
Life safety	Beginbetova A.S	20.05.18	
The main part	Semenyakin N.V.	21.05.18	
Calculation part	Semenyakin N.V.	31.05.18	
Standard compliance	Semenyakin N.V.	06.05.18	

SCHEDULE of diploma project implementation

№	Sections, list of developing questions	Dates of bringing to Scientific Supervisor	Notes
1	Study of Wi-Fi principle work	12.01.18 - 20.01.18	
2	Study of Wi-Fi standards	12.01.18 - 18.01.18	
3	Learn more about IEEE 802.11n standard	03.02.18 - 12.02.18	
4	Comparing 2.4 GHz and 5 GHz characteristics	08.02.18 - 12.02.18	
5	Choice of equipment	15.03.18 - 16.03.18	
6	Creation of 2.4 and 5 GHz Wi-Fi network	25.03.18 - 26.03.18	
7	Calculation of losses antenna-feeder	15.04.18 - 18.04.18	
8	Calculation of sensitivity of access point receiver	6.05.18 - 12.05.18	
9	Calculation of allowable interference	3.05.18 - 8.05.18	
10	Calculation of Fresnel zone	18.05.18 - 19.05.18	
11	Calculation of allowable losses	17.05.18 - 18.05.18	
12	Calculation of room lightning system	20.05.18 - 22.05.18	
13	Calculation of aspiration system	14.05.18 - 16.05.18	
14	Calculation of exploitation cost	14.05.18 - 16.05.18	
15	Calculation of income from sale of device	05.05.18 - 05.05.18	
16	Calculation of economic efficiency	07.05.18 - 07.05.18	
17	Constructing Heatmaps for 2.4 GHz and 5 GHz Wi-Fi	05.05.18 - 10.05.18	

Assignment issue date « 8 » 06 2018 y.

Head of Department: _____ (sign) _____ Baykenov A.S. (Surname and initials)

Scientific Supervisor: _____ (sign) _____ Semenyakin N.V. (Surname and initials)

Assignment submitted for implementation: _____ (sign) _____ Dyussekenova A.A. (Surname and initials)

Аңдатпа

Бұл дипломдық жобаның мақсаты Алматы қаласындағы Алматы Энергетика және Байланыс Университетінде ТКС кафедрасына 5 ГГц Wi-Fi желісін роумингпен жобалау орнату болып табылады. Сымсыз желі стандарттарының негізгі түрлері қарастырылды. Желіні жоспарлау бойынша, еңбек қорғау және өміртіршілік қауіпсіздігі бойынша және де осы технологияны университетте тиімді қолдану технологиясы анықтау мақсатында экономикалық көрсеткіштерінің есеп жұмыстары жүргізілді.

Аннотация

Целью данного дипломного проекта является проектирование 5 ГГц Wi-Fi сети с роумингом для кафедры ТКС в Алматинском Университете Энергетики и Связи. Рассмотрены основные типы стандартов беспроводных сетей. Выполнено экспериментальное исследование качества покрытия, приведены расчеты по планированию сети, расчеты по разработке мер охраны труда и безопасности жизнедеятельности, расчет экономических показателей с целью выявления эффективности использования данной технологии в кампусе университета.

Abstract

The main purpose of this diploma final project is projection 5 GHz Wi-Fi network with roaming for ICT department sets in Almaty University of Power Engineering and Telecommunications in Almaty city. There were considered main types of standards of wireless sets. Calculations were provided about planning sets, calculations about the development of labor security and life secure, also calculations of economic terms in order to define effectiveness of usage this particular technology in the university's campus.

Content

Introduction	8
1 Wi-Fi technology	10
1.1 Wi-Fi definition	10
1.2 Wi-Fi perspectives.	10
1.3 Purpose and characteristics of Wi-Fi communication system	11
1.4 Operational principle	11
1.5 Wi-Fi physical standards	12
1.5 802.11n high data rate factors	25
1.6 Comparing 802.11n and 802.11ac standards	29
1.7 Wi-Fi frequency ranges	30
1.8 Strategy of building and securing Wi-Fi network	34
1.9 Topologies of wireless Wi-Fi networks	36
1.11 Wi-Fi roaming	38
2 Wi-Fi in industry	43
2.1 Wi-Fi access points	43
2.2 Wi-Fi and cellular phones	45
2.3 Free Wi-Fi for everyone	46
3 Calculation part	48
3.1 Technical solution of the project	48
3.2 Description and characteristics of selected equipment	48
3.3 Desing part	53
3.4 Technical parameters calculations	71
4 Life safety part	77
4.1 Analysis of working conditions	77
4.2 Working conditions in department	81
4.3 Calculation of room lighting system	82
4.4 Calculation of noise and vibration.	84
4.5 Calculation of aspiration system	86
5 Economical Part	89
5.1 Business plan	89
5.2 Brief description of the project	90
5.3 Investment plan of the project	91
5.4 Financial plan	91
Conclusion	100
List of reference	101
Appendix A	Ошибка! Закладка не определена.
Introduction	3
1 Wi-Fi technology	4
1.1 Wi-Fi definition	4
1.2 Wi-Fi outlook	4
1.3 Purpose and characteristics of Wi-Fi communication system	5
1.4 Operational principle	5

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Отформатировано: По центру

1.5 Wi-Fi physical standards	6
1.5 802.11n high data rate factors	19
1.6 Wi-Fi frequency ranges	21
1.7 Strategy of building and securing Wi-Fi network	23
1.8 Topologies of wireless Wi-Fi networks	25
1.10 Wi-Fi roaming	26
2 Wi-Fi in industry	31
2.1 Wi-Fi access points	31
2.2 Wi-Fi and cellular phones	32
2.3 Free Wi-Fi for everyone	34
3 Calculation part	35
3.1 Technical solution of the project	35
3.2 Description and characteristics of selected equipment	35
3.3 Desing part	40
3.4 Technical parameters calculations	58
4 Life safety part	63
4.1 Analysis of working conditions	63
4.2 Working conditions in department	67
4.3 Calculation of room lighting system	69
4.4 Calculation of noise and vibration.	71
4.5 Calculation of aspiration system	72
5 Economical Part	76
5.1 Business plan	76
5.2 Brief description of the project	76
5.3 Investment plan of the project	77
5.4 Financial plan	78
Conclusion	86
Bibliography	87

Introduction

Worldwide, wireless connections necessity is growing rapidly, especially in business and IT. Users with wireless access to information always and everywhere can work much more efficiently. This is an attachment to a certain communications infrastructure.

At the current stage of network technologies development, wireless Wi-Fi networks is the most convenient in conditions requiring mobility, ease of installation and using. Wi-Fi (wireless fidelity) is the 802.11 standard for broadband

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wireless communication developed in 1997. Typically, Wi-Fi technology is used to organize wireless local computer networks, as well as a creation of so-called hotspots of high-speed Internet access.

Wireless networks have, in comparison with traditional wired networks, considerable advantages, the main of which, of course, is:

- ease of deployment;
- flexibility of network architecture, when it is possible to dynamically change network topology when connecting, moving and disconnecting mobile users without significant time loss;
- fast design and implementation, which is critical for stringent requirements for time of building a network;
- also, a wireless network does not need to lay cables (often requiring a crushing of the walls).

At the same time, wireless networks at present stage are not devoid of serious shortcomings. First of all, this is the dependence of connection speed and action range on presence of obstructions and on distance between receiver and transmitter. One way to increase wireless network range is to create a distributed network based on multiple wireless access points. It becomes possible to turn a building into a single wireless zone and increase connection speed regardless of walls number (barriers). Similarly, problem of network scalability is solved, and using of external directional antennas allows to effectively solve problem of obstacles that limit signal [1].

The purpose of diploma project is a design of 5_GHz Wi-Fi network with roaming for ICTCS&S department sets in Almaty university of power engineering and telecommunications. For informatization level increasing it provides modern communication services: high-speed Internet access, a computer network based on Wi-Fi technology.

Добавлено примечание ([Office1]): Необходимо добавить ссылки на работы, подтверждающие актуальность построения беспроводных сетей, в которых описываются тренды перехода на беспроводные коммуникации

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1 Wi-Fi technology

1.1 Wi-Fi definition

Wi-Fi is a technology which uses radio waves to provide network connectivity. A Wi-Fi connection is established using a wireless adapter to create hotspots - areas in the vicinity of a wireless router that are connected to the network and allow users to access internet services. Once configured, Wi-Fi provides wireless connectivity to your devices by emitting frequencies between 2.4 GHz – 5 GHz, based on the amount of data on the network [2].

Initially, it was created for cash register systems, but after some time developers realized a full benefit Wi-Fi and let it into the masses. Nowadays, Wi-Fi is one of the most commonly used Internet connections. Network diagram contains access point and as many clients as it wants to connect to this access point.

1.2 Wi-Fi outlook perspectives.

Now Wi-Fi is quickly becoming a high-tech novelty object, without which everyday life is unthinkable. Networks are actively appearing in public places. In recent years, cellular operators have begun installing Wi-Fi (so-called hot spots) in cafes, hotels, airports, train stations and other places of mass leisure. Thousands of public Wi-Fi hot spots will be opened in the near future.

People have already have Wi-Fi adapters in their mobile computers for office and home using. Most Internet service users will have one or more devices that support Wi-Fi. This technology use increasing speed method. Wireless data transmission uses several antennas for transmitter and receiver. The technology is called Multiple I/O MIMO (multiple input multiple output). Many signals are transmitted in parallel, thereby increasing a total throughput. In general, MIMO has many advantages due to simultaneous data transfer via different channels. This technology uses spatial division multiplexing (SDM). The signal is transmitted over several different frequencies, after receiving conversion into a high-speed data stream. However, in order to implement MIMO in practice, it is necessary for each data stream to use its receive/transmit antennas [3].

Also prices for Wi-Fi components are falling fast. As a result, prices for Wi-Fi devices intended for end-users have become available. A few years ago, access point device cost more expensive than nowadays, and today its price has fallen below 100\$, Price falling for Wi-Fi devices promises their ubiquitous introduction into computers and consumer electronics at present time. As a consequence of this process, many secure (private) wireless networks have already appeared in offices and in apartments. In the near future, Wi-Fi will change our perception of communications and communication services.

Prospects for Wi-Fi technology look brilliantly. ~~–This It is necessary to overcome certain inertia inherent in any mass market, and this technology became worldwide will become~~and as ubiquitous as mobile communications.

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1.3 Purpose and characteristics of Wi-Fi communication system

Wireless network technologies allow a creation of computer networks that fully accords to standards for conventional wired networks (eg, Ethernet) without cable using. Information carrier are radio waves of microwave range [4].

To organize a wireless network in a confined space, transmitters with omnidirectional antennas are used. The IEEE 802.11 standard defines two modes of network operation: ad-hoc and client-server. Ad-hoc mode (otherwise known as point-to-point) is a simple network in which communication between stations (clients) is established directly, without using a special access point. In client-server mode, a wireless network consists at least one access point connected to a wired network and a set of wireless client stations. Because most networks need to provide access to file servers, printers, and other devices connected to a wired LAN, client-server mode is most often used. Without connecting an additional antenna, stable communication for IEEE 802.11n/-ac equipment is achieved on average at the following distances: open space - 500 m, room separated by nonmetallic material - 100 m, office several rooms - 30 m. Through walls with a large content of metal fittings (in reinforced concrete buildings such are load-bearing walls) 2.4 GHz radio waves can sometimes not pass at all, therefore in rooms separated by a similar wall, access [5, p135].

1.4 Operational principle

Typically, Wi-Fi network diagram contains at least one access point (AP, from English access point) and at least one customer (Figure 1.1). Access point transmits SSID (service set identifier) using special packets called signal packets, transmitted every 100ms.

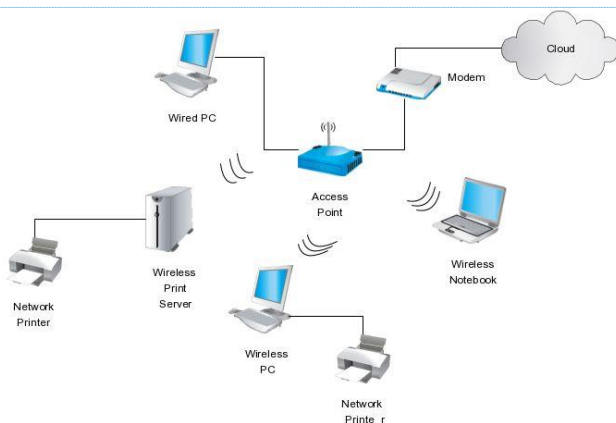


Figure 1.1 – Wi-Fi network diagram

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Отформатировано: английский (США)

Отформатировано: междустрочный, 1,5 строки

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Signal packets are transmitted at 1 Mbps and have a small size, so they do not affect to network characteristics. Since 1 Mbps is the lowest data rate for Wi-Fi, a client receiving signal packets can be sure that it will be able to connect at a speed of not less than 1 Mb/s. Knowing network parameters (that is, SSID), a client can determine whether a connection to this access point is possible. If two access points with identical SSIDs fall within coverage zone, program can choose between them based on signal level data. Standard is Wi-Fi, although it means that one of adapters can perform these actions much better than other. The latest versions of operating systems contain a function called zero configuration, which shows user all available networks, and allows you to switch between them on fly. This means that roaming will be completely controlled by operating system. Wi-Fi transmits data by air, so it has properties similar to an unswitched Ethernet network, and it can have the same problems as when working with a non-switched Ethernet network.

Like mobile phones, a Wi-Fi network makes use of radio waves to transmit information across a network. Computer should include a wireless adapter that will translate data into a radio signal. This same signal will be transmitted, via an antenna, to a decoder known as the router. Once decoded, data will be sent to the Internet through a wired Ethernet connection. A device called a wireless transmitter receives information from the internet via your broadband connection. A transmitter converts the information into a radio signal and sends it.

The whole process, meanwhile, works in reverse, with computer sending information to the wireless transmitter. It then converts them and sends them via your broadband connection. Transmitter as a mini radio station, broadcasting signals sent from the internet. The 'audience' for these transmissions is computer (or computers, as more than one can connect at the same time) which receives the radio signal via something called a wireless adapter.

As wireless network works as a two-way traffic, the data received from the internet will also pass through the router to be coded into a radio signal that will be received by the computer's wireless adapter [6].

1.5 Wi-Fi physical standards

For the first time IEEE 802.11 working group was announced in 1990 and works for 25 on wireless standards. The main trend is a constant increase of data transfer rates.

IEEE 802.11 is a set of communication standards for wireless local area network of frequency bands 0.9; 2.4; 3.6; 5 and 60 GHz.

Common name is Wi-Fi-, which proposed and promoted by Wi-Fi Alliance. It has become widespread due to development of mobile electronic computing devices: PDAs and laptops.

b /g /n/ ac are four (basic) modes of Wi-Fi 802.11 wireless network. They differ in maximum data transfer rate:

11a - 54 Mbit /s;

11b - improvements to 802.11 to support 5.5 and 11 Mbps;

11g - 54 Mbit /s, 2.4 GHz standard (backward compatibility with b);

11n - 2.4-2.5GHz (150Mbps); 5 GHz (600 Mbps). Backwards compatibility with 802;

11ac - modern standard IEEE. Data transfer rate is up to 6.77 Gb / s for devices with 8 antennas. Approved in January 2014 [7, p.60].

802.11a

The IEEE 802.11a is a standard for Wi-Fi networks. Uses a frequency range of 5 GHz U-NII. Despite that this version is not used so often due to the standardization of the IEEE 802.11b and introduction of 802.11g standard, it has also undergone changes in terms of frequency and modulation. OFDM allows data to be transmitted in parallel at multiple sub-frequencies. This allows to increase resistance to interference and since more than one data stream is sent, high throughput is realized. 802.11a can accelerate up to 54 Mb/s gross under ideal conditions. Also 802.11a standard is incompatible with 802.11b or 802.11g. The IEEE 802.11a Frame Format shown at Figure 1.2.

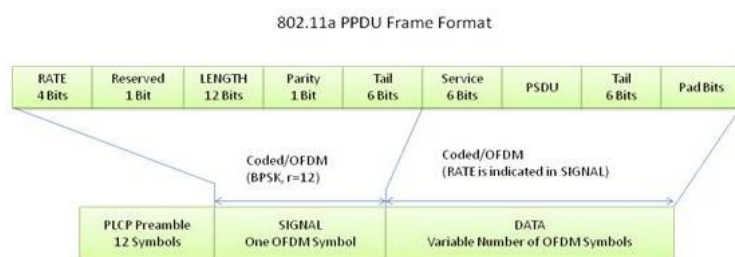


Figure 1.2 – The IEEE 802.11a Frame Format

The IEEE 802.11a standard provides data transfer rates up to 54 Mbps. As the method of signal modulation, orthogonally frequency multiplexing (OFDM) is selected, which ensures high communication stability under multipath signal conditions.

In accordance with FCC rules, UNII frequency range is divided into three 100-MHz subbands, which differ in their maximum radiation power limits. The lowest band (from 5.15 to 5.25 GHz) provides a power of only 50 mW, average (from 5.25 to 5.35 GHz) - 250 mW, and upper (from 5.725 to 5.825 GHz) - 1 W.

Using of three frequency subbands with a total width of 300 MHz makes the IEEE 802.11a standard broadband 802.11 family and allows entire frequency range to be divided into 12 channels. Each has a width of 20 MHz, eight of which lie in 200 MHz range from 5,15 to 5,35 GHz, and the remaining four channels - in 100-MHz range from 5,725 to 5,825 GHz (Figure 1.3). In this case, four upper frequency channels providing the highest transmission power are used primarily for transmitting signals outside premises.

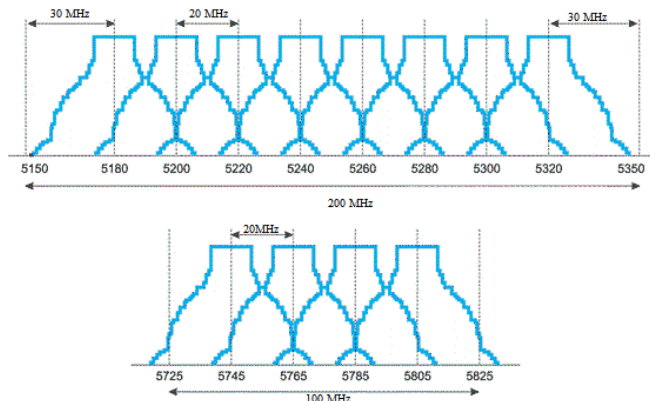


Figure 1.3 – Division of UNII band into 12 frequency subbands

The IEEE 802.11a standard is based on technique of frequency orthogonal division of channels with multiplexing (OFDM). For channel separation, an inverse Fourier transform with a window of 64 frequency subchannels is applied. Since width of each 12 channels defined in the 802.11a standard is 20 MHz, it turns out that each orthogonal frequency subchannel (subcarrier) has a width of 312.5 kHz. However, 64 orthogonal subchannels, only 52 are involved, 48 of which are used for data transmission (Data Tones), and rest for transmission of service information (Pilot Tones).

By modulation technology, 802.11a protocol differs little from 802.11g. At low bit rates, binary and quadrature phase modulations of BPSK and QPSK are used to modulate subcarriers. When using BPSK modulation, only one information bit is coded in one character. Accordingly, when using QPSK modulation, i.e., when signal phase can take four different values, two information bits are coded in one symbol. BPSK modulation is used to transmit data at speeds of 6 and 9 Mbit/s, and QPSK modulation is used at speeds of 12 and 18 Mbps.

For higher-speed transmission, the IEEE 802.11a standard uses quadrature amplitude modulation of 16-QAM and 64-QAM. In the first case, there are 16 different signal states, which allows to encode 4 bits in one symbol, and in the second - already 64 possible signal states, which allows encoding a sequence of 6 bits in one symbol. Modulation of 16-QAM is applied at speeds of 24 and 36 Mbit/s, and 64-QAM modulation is applied at speeds of 48 and 54 Mbit/s.

Modulation type and subcarriers number determines information capacity of OFDM symbol. Since 48 subcarriers are used for data transmission, OFDM symbol capacity is $48 \times N_b$, where N_b is binary logarithm modulation positions number, or, by other words, number of bits that are encoded in one symbol in one subchannel. Accordingly, OFDM symbol capacity is 48 to 288 bits [8].

Processing sequence of input data (bits) in IEEE 802.11a standard looks like input data stream is subjected to a standard scrambling operation. After that, data

stream arrives at convolutional encoder. Convolutional coding rate (in combination with puncture coding) can be 1/2, 2/3 or 3/4. Since convolutional coding rate can be different, then when using the same type of modulation, data transfer rate is different. Consider, for example, BPSK modulation, in which data transfer rate is 6 or 9 Mbit/s. Duration of one symbol together with guard interval is 4 μ s, which means that pulse repetition rate is 250 kHz. Considering that one bit is coded in each subchannel, and all such subchannels 48, we get that total data transfer rate is 250 kHz x 48 channels = 12 MHz. If convolutional encoding rate is 1/2 (one service bit is added for each information bit), information rate will be half total speed, that is, 6 Mb/s. At a convolutional encoding rate of 3/4 for each three information bits, one service one is added, so in this case useful (information) rate is 3/4 of full rate, that is, 9 Mbps. Similarly, to each type of modulation there are two different transmission rates which is shown at Table 1.1.

Table 1.1- Different transmission rates

Transmission speed, Mb/s	Modulation type	Convolutional coding rate	Number of bits in one subchannel	Total umber of bits in the symbol (48 subchannels)	Number of informati on bits in a symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Отформатированная таблица

After convolutional coding, bitstream is subjected to an interleaving operation, or interleaving. Its essence consists in changing order of bits within one OFDM-symbol. For this, sequence of input bits is divided into blocks whose length is equal to number of bits in OFDM symbol (NCBPS). Next, according to a certain algorithm, a two-stage permutation of bits in each block is performed. In the first stage, bits are rearranged in such a way that contiguous bits are transmitted on non-contiguous subcarriers in OFDM symbol transmission. Bit permutation algorithm at this stage is equivalent to the following procedure. Initially, a block bit of length NCBPS line by line (row by row) is written to a matrix containing 16 rows and NCBPS/16 rows. Further, bits are read from this matrix, but already in rows (or as

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recorded, but from transposed matrix). As a result of such an operation, initially neighboring bits will be transmitted to non-contiguous subcarriers.

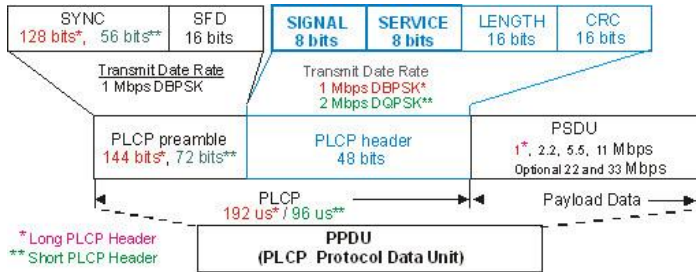
This is followed by the second bit rearrangement, purpose of which is to ensure that neighboring bits are not simultaneously in the least significant bits of the groups defining modulation symbol in signal constellation. That is, after the second stage of permutation, neighboring bits turn alternately in high and low order groups. This is done to improve noise immunity of transmitted signal.

After interleaving, bit sequence is divided into groups by number of positions of selected type of modulation and OFDM symbols are generated.

The generated OFDM symbols undergo a fast Fourier transform, resulting in output of in-phase and quadrature signals, which are then subjected to a standard processing-modulation.

802.11b

The IEEE 802.11b standard provides for using frequency range from 2.4 to 2.4835 GHz, which is intended for unlicensed using in industry, science and medicine. The main idea is to from narrowband spectrum of the signal, which arises in the usual potential coding, go to the broadband spectrum. The IEEE 802.11b frame format is shown at Figure 1.4. This is what makes it possible to significantly increase noise immunity of transmitted data.



WLAN-DSSS IEEE Std 802.11b - PPDU format

Figure 1.4 – The IEEE 802.11b frame format

802.11b has a maximum raw data rate of 11 Mbit/s and uses the same media access method defined in original standard. Due to CSMA/CA protocol overhead, in practice maximum 802.11b throughput that an application can achieve is about 5.9 Mbit/s using and 7.1 Mbit/s using UDP.

802.11b products appeared on market in mid-1999, since 802.11b is a direct extension of the (Direct-sequence spread spectrum) modulation technique defined in original standard. The Apple was the first mainstream computer sold with

optional 802.11b networking. Technically, this standard uses CSMA/CA (CCK) as its modulation technique. Dramatic increase in throughput (compared to original standard) along with simultaneous substantial price reductions led to rapid acceptance as definitive wireless LAN technology.

802.11b devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: devices, monitors and cordless telephones. Interference issues and user density problems within the 2.4 GHz band have become a major concern and frustration for users.

It is used in a configuration, wherein an access point communicates with mobile clients within access point range. Typical range depends on radio frequency environment, output power and sensitivity of the receiver. Allowable bandwidth is shared across clients in discrete channels. A directional antenna focuses output power into a smaller field which increases point-to-point range. Channels of 802.11b/g channels are shown at Figure 1.5. Designers of such installations who wish to remain within the law must however be careful about legal limitations on.

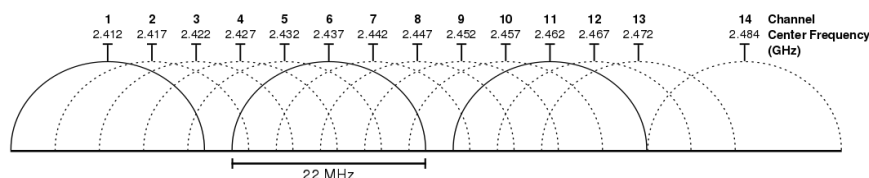


Figure 1.5 – 802.11b/g channels in the 2.4 GHz band

802.11g – high speed in the 2.4 GHz band

The 802.11g standard provides a higher data rate, supporting compatibility with 802.11b products. This standard works with DSSS modulation at speeds up to 11 Mbps, but at the same time, OFDM modulation speed higher than 11 Mbps is additionally used. Thus, equipment of 802.11b and 802.11g standards is compatible with a speed not exceeding 11 Mbit /s. If the speed in 2.4 GHz band exceeds 11 Mbps, 802.11g equipment should be used. The IEEE 802.11g Frame Format shown at Figure 1.6. It can be said that 802.11g standard combines the best 802.11b and 802.11a standards.

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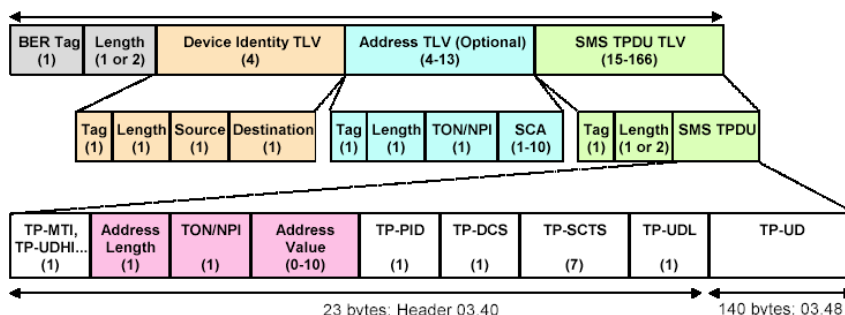


Figure 1.6 – [The](#) IEEE 802.11g Frame Format

Two competing technologies were considered in the development of the 802.11g standard: OFDM orthogonal frequency division method, borrowed from the 802.11a standard. Proposed for consideration by Intersil, and PBCC binary convolutional coding method proposed by Texas Instruments. As a result, 802.11g standard contains a compromise solution: OFDM and CCK technologies are used as the basic ones, and PBCC technology is optional.

Idea of convolutional coding (Packet Binary Convolutional Coding, PBCC) is as follows. Incoming sequence of information bits is converted in convolutional encoder in such a way that each input bit corresponds to more than one output bit. That is, convolutional encoder adds certain redundant information to original sequence. If, for example, each input bit corresponds to two output bits, then convolutional coding is said to be at a rate of 1/2. If each two input bits correspond to three output bits, then convolutional encoding rate will be already 2/3.

Any convolutional encoder is built on the basis of several sequentially connected storage cells and XOR logic elements. A number of storage cells determines number of possible encoder states. If, for example, six memory cells are used in convolutional coder, then information about the six previous signal states is stored in encoder, and taking into account value of incoming bit, we get that seven bits of input sequence are applied in such a coder. Such a convolutional encoder is called an encoder for seven states.

Output bits generated in convolutional encoder are defined by XOR operations between input values bit and bits stored in memory cells, value of each output bit generated depends not only on incoming information bit but also on several previous bits.

The main advantage of convolutional encoders is noise immunity of sequence they form. Fact is that with redundancy of coding, even in event of reception errors, original bit sequence can be accurately restored. To restore original bit sequence on receiver side, a Viterbi decoder is used.

Digit generated in convolutional encoder is used hereinafter as transmitted symbol, but previously it undergoes phase modulation. And, depending on

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transmission speed, binary, quadrature or even eight-phase phase modulation is possible.

Unlike DSSS technologies (Barker codes, CCK sequences), technology of convolutional coding does not use technology of spectral broadening due to using of noise-like sequences, but broadening of spectrum standard 22 MHz is also envisaged in this case. For this, variations of possible signal constellations QPSK and BPSK are used.

PBCC coding method considered is optionally used in 802.11b protocol at speeds of 5.5 and 11 Mb/s. Similarly, in the protocol 802.11g for transmission speeds of 5.5 and 11 Mb/s, this method is also used optionally. In general, due to compatibility of 802.11b and 802.11g protocols, encoding and speed technologies provided by 802.11b protocol are also supported in 802.11g protocol. In this plan, up to 11 Mb/s, the 802.11b and 802.11g protocols coincide with each other, except that 802.11g provides speeds that are not available in 802.11b protocol.

Optionally in 802.11g protocol, PBCC technology can be used at transmission speeds of 22 and 33 Mb/s.

For a speed of 22 Mb/s compared to PBCC scheme we have already considered, data transmission has two features. First of all, 8-position phase modulation (8-PSK) is applied, that is, phase of signal can take eight different values, which allows to encode three bits in one character. In addition, a puncture encoder (Puncture) is added to circuit, with exception of convolutional encoder.

Solution is quite simple: redundancy of a convolutional encoder equal to 2 (for each input bit there are two output ones) is sufficiently high and under certain conditions interference situation is superfluous, therefore it is possible to reduce redundancy so that, for example, each two input bits correspond to three output.

Possible to develop an appropriate convolutional encoder, but it's better to add a special punctured encoder to the circuit, which will simply destroy extra bits. Suppose a punctured encoder removes one bit from every four input bits. Then, with every four incoming bits, there will be three outgoing ones. If such an encoder is used in conjunction with a convolutional encoder at a rate of 1/2, then total coding rate will be already 2/3, that is, each three input bits will correspond to three output bits.

PBCC technology is optional in the IEEE 802.11g standard, and OFDM is mandatory. In order to understand the essence of OFDM technology, we will consider in more detail multipath interference that occurs when signals propagate in an open medium.

Effect multipath interference signals is that as a result of multiple reflections from natural obstacles, same signal can enter receiver in various ways. But different paths of propagation differ from each other in length, and therefore signal weakening will be unequal for them. Consequently, at receiving point, resulting signal is interference of many signals having different amplitudes and shifted relative to each other in time, which is equivalent to adding signals with different phases [89].

802.11n standard – next generation standard

The 802.11n standard was approved on September 11, 2009. It uses completely new technologies that increase data transfer rate and increase coverage radius. So, for example, declared data transfer rate for this standard is about 300 Mbit/s.

Modulation used by this standard is referred to as MIMO (Multiple Input Multiple Output). This modulation is based on multiple antennas using, respectively, creating a lot of information flows, which at times increases data transfer rate. Also in this standard, a new packet aggregation technology applied. This technology implies that more information will be transmitted with each packet sent (Figure 1.7). This standard works both in the 2.4 GHz band and in the 5 GHz band. This standard is compatible with all previous standards.

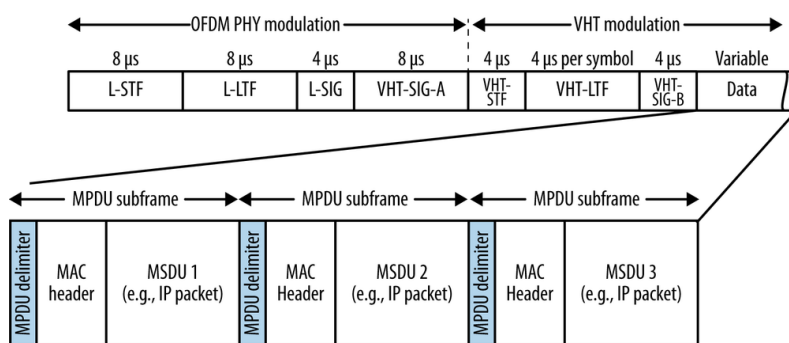


Figure 1.7 – The IEEE 802.11n Frame Format

Maximum transmission speed of standard 802.11n is about 5 times higher than performance of Wi-Fi.

The following main advantages of the 802.11n standard can be noted:

- high data transfer speed (about 300 Mbit/s);
- uniform, stable, reliable and high-quality coverage of the station's operation area, absence of uncoated sections;
- compatibility with previous versions of the standard Wi-Fi.

Disadvantages:

- high power consumption;
- two operating ranges (possible replacement of equipment);
- complicated and more comprehensive equipment.

Increase in transmission speed in the IEEE 802.11n standard is achieved, firstly, due to doubling of channel width from 20 to 40 MHz, and secondly, due to implementation of MIMO technology.

MIMO (Multiple Input Multiple Output) technology involves multiple transmit and receive antennas using. By analogy, traditional systems, that is,

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systems with one transmit and one receiving antenna, are called SISO (Single Input Single Output).

IEEE 802.11n standard is based on OFDM-MIMO technology. Many of technical details implemented in it are borrowed from the 802.11a standard, but the IEEE 802.11n standard provides for using both frequency band adopted for IEEE 802.11a standard and frequency band adopted for IEEE 802.11b/g standards. That is, devices supporting the IEEE 802.11n standard can operate in frequency range of either 5 or 2.4 GHz.

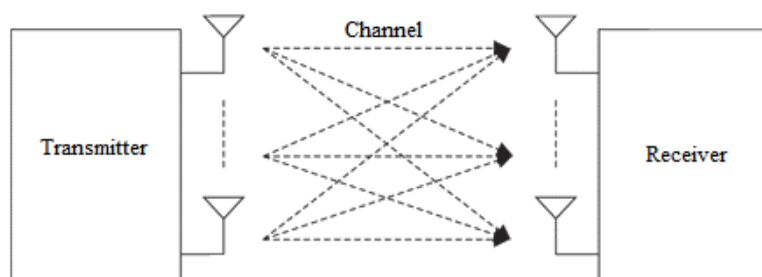


Figure 1.8 – Implementing MIMO technology principle

Transmitted sequence is divided into parallel streams, from which original signal is restored at receiving end. Here there is some complexity - each antenna receives a superposition of signals, which must be separated from each other. For this purpose, a specially developed algorithm for spatial signal detection is used at receiving ending. This algorithm is based on subcarrier allocation and it turns out to be more difficult larger number. Only drawback of using MIMO is complexity and system bulkiness and, as a result, higher power consumption. For compatibility of MIMO stations and traditional stations, three modes of operation are provided:

- inherited mode (legacy mode);
- mixed mode;
- green field mode.

Each mode of operation corresponds is own preamble structure — service field of packet, which indicates transmission beginning and serves to synchronize receiver and transmitter. Preamble contains information about length packet and its type, including modulation type, a selected encoding method, and all encoding parameters. To avoid conflicts in operation of MIMO stations and conventional (with one antenna) during exchange between MIMO stations, packet is accompanied by a special preamble and a header. Having received such information, stations operating in legacy mode postpone transmission until end session between MIMO stations. In addition, preamble structure defines some primary receiver tasks, such as estimating received signal power for automatic gain control system, detecting start packet, time offset and frequency.

Standard IEEE 802.11n allows using up to four antennas access point and wireless adapter. Mandatory mode implies support for two antennas at access point

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and one antenna and wireless adapter. It provides both standard communication channels with a width of 20 MHz, and channels with twice the width. General block diagram of the transmitter is shown in Figure 1.9. Transmitted data passes through a scrambler that inserts additional zeros or ones (so-called pseudo-random noise masking) in code to avoid long sequences of same symbols. Data is then divided into N streams and fed to an error corrected (FEC) encoder. For systems with one or two antennas $N = 1$, and if three or four transmission channels are used, then $N = 2$.

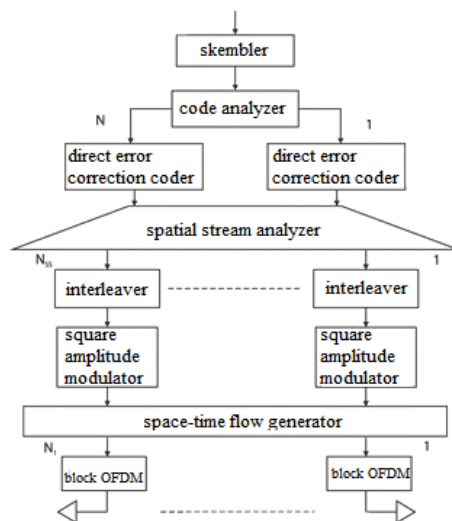


Figure 1.9 – General structure of the MIMO-OFDM transmitter

Coded sequence is divided into separate spatial streams. Bits in each thread are interleaved (to eliminate block errors), and then modulated. Next, formation of space-time flows pass through block of inverse fast Fourier transform and arrive at antennas. A number of space-time flows is equal to number of antennas. The structure of receiver is similar to structure of transmitter shown in Figure 1.10, but all actions are performed in reverse order.

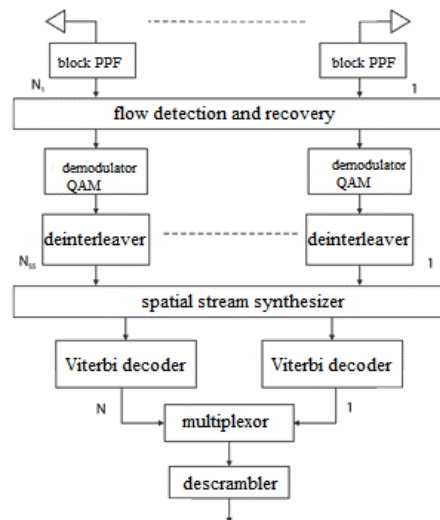


Figure 1.10 – General structure of the MIMO-OFD receiver
802.11ac standard

The IEEE 802.11ac is a wireless LAN standard operating in the 5 GHz frequency band. Backward compatible with the IEEE 802.11n.

This standard allows to significantly expand network capacity, starting from 433 Mb/s (devices with 433 Mb/s per channel) and up to 6.77 Gb/s with 8x MU-MIMO antennas. In addition to speeds, 802.11ac offers two key improvements:

Beamforming - the ability to dynamically antenna pattern changing (which is realistic for an array of 8 elements). This means that coverage area of access point is optimally adjusted to the current location of customers (Figure 1.11). It became the most significant innovation regarding the IEEE 802.11n. In addition, it is expected to reduce power consumption, will extend battery life of mobile devices.

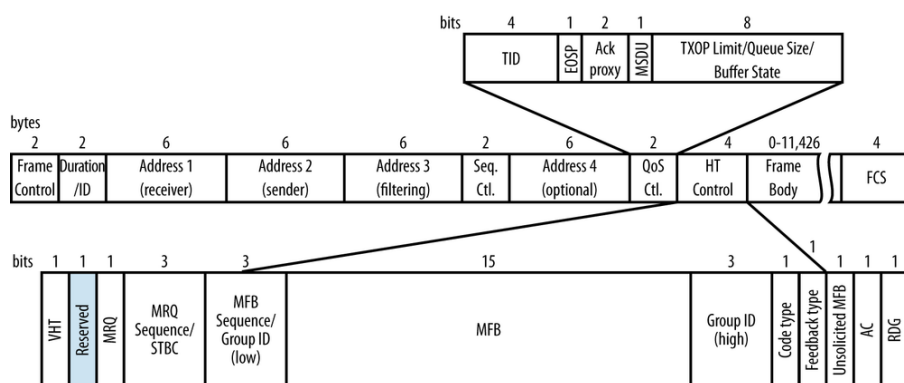


Figure 1.11 – The IEEE 802.11n Frame Format

Multi-user MIMO is an integral part of the 802.11 ac standard. But so far, there have not been devices supporting a new kind of multi-antenna technology. WLAN-routers of the standard 802.11 as former generation were designated as Wave 1 equipment. Only with Wave 2 is introduced the multi-user technology MIMO (MU-MIMO)

Since the multi-user MIMO technology transmits the signal to multiple devices simultaneously, the transmission protocol is expanded accordingly in the header part of the data blocks: instead of transmitting several spatially separated streams for one client, the MIMO multi-user technology distributes the transmission for each user individually, as well as coding-. Distribution of the frequency band and coding remain the same.

Multi User With multi-user MIMO (Multi User MIMO) support, queues from devices waiting to access WLAN-router resources are not generated. The laptop, tablet, phone and TV are provided with data simultaneously.

The WLAN network is similar to a busy highway: depending on day time, in addition to PCs and laptops, tablets, smartphones, TV and game consoles are connected to this movement. In average household, there are more than five devices connected to Internet via WLAN network, and their number is constantly growing. With speed of 11 Mbps, which is provided in basic standard of IEEE 802.11b, web surfing and data loading require a lot of patience, because router at any one time can be connected to only one device. If radio communication is used by three devices at once, then each client receives only one third of the duration of the communication session, and two-thirds of the time is spent waiting. Although the WLANs of the latest IEEE 802.11ac standard provide data transmission at speeds up to 1 Gb/s, they also have problem of speed drop due to queues. But next generation of devices (802.11ac Wave 2) promises better performance for radio networks with several active devices.

For a better understanding of essence innovations, it's need to remember what changes have occurred with WLAN networks in recent past. One of the most effective methods of increasing data transfer speed, starting with the IEEE 802.11

In order for a router to simultaneously route WLAN packets to different clients, it needs information about where clients are located. The first of all, test packets are sent to all directions. Clients respond to these packets, and base station stores signal strength data. Technology of beam formation is one of the most important assistants of MU MIMO. Although its support is already provided by the IEEE 802.11n standard, it has been improved in IEEE-802.11ac. Its essence is to establish an optimal direction for sending a radio signal to customers. The base station specifies the optimal directionality of transmitting antenna for each radio signal. For multi-user mode, finding optimal signal path is especially important, because changing location of only one client can change all transmission paths and disrupt the bandwidth of entire WLAN.

A multi-user MIMO can simultaneously serve four clients, each client can receive up to four data streams in parallel, which in total gives 16 threads. For this

multi-user MIMO, new WLAN routers are required, as there is a growing need for computing power.

Table 1.2 – Comparative table of Wi-Fi standards

Standard	802.11a	802.11b	802.11g	802.11n	802.11ac
Date of standard certification	1999	1999	2003	2009	2014
Available bandwidth	Till 300 MHz	Till 83.5 MHz	Till 83.5 MHz	Till 600 MHz	Till 3.47Gbps
Frequency of operations	5 GHz	2.4 GHz	2.4 GHz	2.4,5 GHz	5 GHz
Modulation types	OFDM	DSSS	DSSS, OFDM	OFDM	OFDM
Channel width	20 MHz/s	20 MHz/s	20 MHz/s	20-40 MHz/s	80 MHz/s
Compatibility	Wi-fi	Wi-Fi	Wi-Fi	Wi-Fi	Wi-Fi

Отформатированная таблица

1.5 802.11n high data rate factors

The 802.11n standard uses three basic mechanisms to increase data transfer rate:

- using of several transceivers and special algorithms for transmitting and receiving a radio signal, known by abbreviation

MIMO;

- increasing frequency band of signal from 20 to 40 MHz;
- optimization of network access level protocol.

Let's look at each of these mechanisms in some detail.

The first factor. With MIMO using, it is possible to simultaneously transmit several data streams in the same channel, and then use sophisticated processing algorithms to restore them at the reception ([Figure 1.12](#)).

→Drawing an analogy with roads, we can say that previously there was only 1 way connecting points A and B.

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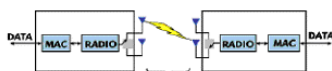
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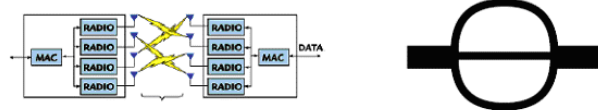
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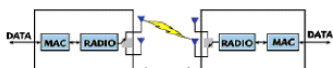
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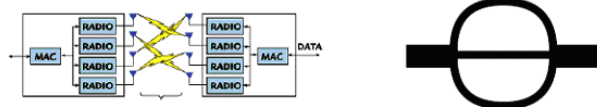
It was

ONE WAY of data transmission



Became

SEVERAL PATHS data transmission



It was

ONE WAY of data transmission



Figure 1.12 – The first factor for increasing the data rate #1

Now, there are several such paths and total system capacity has increased

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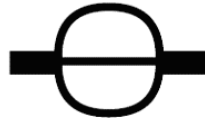
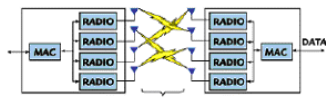
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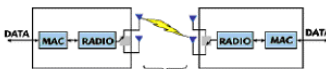
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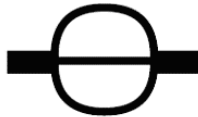
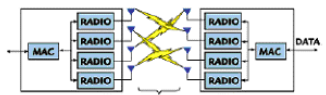


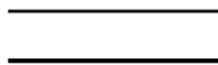
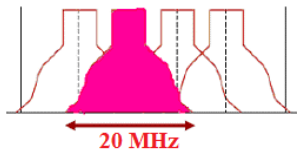
Figure 1.143 – The first factor for increasing the data rate #2

The second factor is an increase available bandwidth. Theoretically achievable throughput of a communication channel which shown at Figure 1.14 is directly depends on width of bandwidth it occupies. In new standard, it became possible to combine neighboring channels of 20 MHz and thus increase bandwidth by almost 2 times. By analogy with highways, we can assume that number of lanes available for traffic is doubled [10].

The first two factors relate to physical channel.

It was

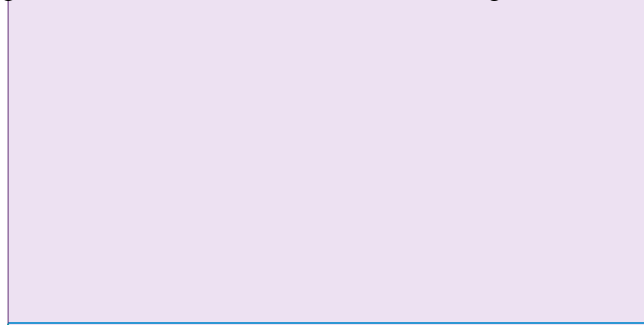
SINGLE- SIDE data transmission line



It was

SINGLE- SIDE data transmission line

Figure 1.124 – The second factor for increasing the data rate #1



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In new standard, it became possible to combine neighboring channels of 20 MHz and thus increase bandwidth by almost 2 times.

By analogy with highways, we can assume that number of lanes available for traffic is doubled.

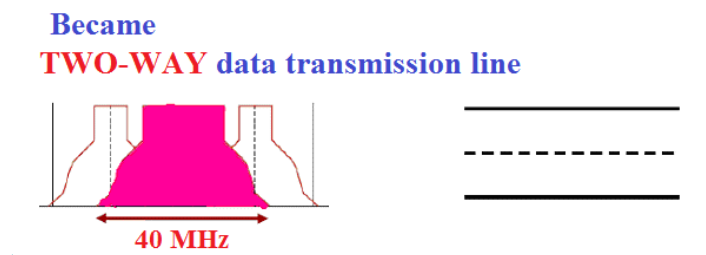


Figure 1.15 – The second factor for increasing the data rate #2

The third important factor in improving productivity is to optimize data transfer protocol at level of access to the media. In previous versions of reception (Figure 1.15), each frame is transmitted (parts of the data) was confirmed by receiving party. A new version appeared to block the confirmation. Receiver sends another confirmation of this information in several successfully received frames, which reduces overall load capacity of the channel maintenance messages. In addition, time interval between frames is reduced, which also contributed to increase in useful bandwidth. Applied to everyday life, you can compare images with containers for transport of goods. A new rules have reduced the 802.11n distance between container and allow controller to confirm each lot separately and immediately shipment.

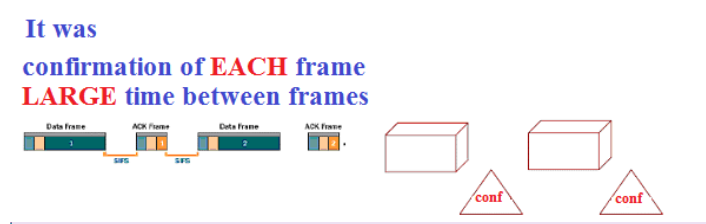


Figure 1.163 – The third factor for increasing the data transfer speed #1

A new version appeared to block the confirmation. Receiver sends another confirmation of this information in several successfully received frames, which reduces overall load capacity of the channel maintenance messages. In addition, time interval between frames is reduced, which also contributed to increase in useful bandwidth. Applied to everyday life, you can compare images with containers for transport of goods. A new rules have reduced the 802.11n distance

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between container and allow controller to confirm each lot separately and immediately shipment.

Became

confirmation of **BLOCK** frame
FEW time between frames



Figure 1.17 – The third factor for increasing the data transfer speed #2

1.6 Comparing 802.11n and 802.11ac standards

The latest generation standard is the 802.11ac standard, adopted in 2014. It introduces channels that allow it to expand network capacity, and supports up to eight data streams (spatial streams) using MU-MIMO methods in downlink channels for simultaneous transmission to multiple devices (up to four devices). These changes provide a maximum transfer rate of more than 3 Gbit/s and provide an opportunity for further increase. This standard also provides for operation exclusively in the frequency range of 5 GHz with a large bandwidth and less interference.

Earlier 802.11n technology is widely used and still serves a variety of applications. However, deployment of a new wireless infrastructure is now recommended in accordance with the 802.11ac standard. There is an opinion that in real terms, increase in bandwidth in 802.11ac networks does not correspond to declared one. And it was really true for first-generation products. But the second generation of 802.11ac devices, the so-called "second wave", offers significant advantages over 802.11n devices. Nevertheless, the most effective use of 802.11ac devices is impossible without solutions based on well thought-out wireless technologies, high-quality radio equipment and antennas.

A noticeable increase in speed in 802.11ac will be obtained due to several changes. First of all, due to doubling the width of the channel. If in 802.11n it was already increased from 20 to 40 MHz, then in 802.11ac it will be as much as 80 MHz (by default), and in some cases 160 MHz.

In earlier versions of 802.11 (up to N specification), all data was transferred to only one stream. In N, their number may be 4, although so far only 2 channels are most often used. In practice, this means that total maximum speed is calculated as product of the maximum speed of each channel by their number. For 802.11n, we get $150 \times 4 = 600$ MB/s.

In 802.11ac went further. Now the number of channels is increased to 8, and the maximum possible transmission speed in each particular case can be determined depending on their width. At 160 MHz, we get 866 Mb/s, and multiplying this

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Отформатировано: По ширине

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[figure by 8](#), we get the maximum theoretical speed that the standard can provide, that is, almost 7 Gb/s, which is 23 times faster than 802.11n.

1.76 Wi-Fi frequency ranges

The biggest difference between them is speed. Under ideal conditions, 2.4 GHz Wi-Fi will support up to 450 Mb/s or 600 Mb/s depending on router class.

The 2.4 GHz band is pretty crowded, because it is not only used for Wi-Fi. Old wireless phones, garage radio controls, children's monitors and many other devices use 2.4 GHz range. Longer wavelengths used by 2.4 GHz range are better suited for longer distances and for transmitting through walls and solid objects. Therefore, probably for better coverage, you should use them in places where many obstacles. But due to fact that many devices use this range, there are failures and a decrease in a data transfer rate.

The 5 GHz band is less loaded, so your connection will be more stable. You will also get much higher speed. However, waves in this range are short, and they overcome obstacles even worse, so 5 GHz Wi-Fi network has a significantly smaller coverage area

It is better to use the 2.4 GHz wireless band if you are going to connect over a larger distance (but unlike 5GHz, it's more likely to have network traffic). The 5 GHz band offers higher bandwidth for faster downloading, uploading and streaming videos online, but works best over shorter distances without many obstructions such as walls, etc. It shown at [Figure 1.148](#)



Figure 1.148 – Difference between 2.4 GHz and 5 GHz Wi-Fi network

Interference in 2.4 GHz is a “junk” band—it’s a frequency range that’s heavily polluted. It’s one of the most heavily used, which have broad rules to allow equipment that needs to emit a signal to work in within its confines. ISM devices aren’t used for communication, but produce electromagnetic signals as part of their operation. And those signals are interference.

The 2.4GHz band also has a host of other competing uses. 5GHz has the distinct benefit of having very little technology that makes use of the band. Reducing interference lets networks work at higher speeds and greater ranges.

A big advantage 2.4GHz has over 5GHz is range. Shorter wavelengths used in the 5GHz band cannot penetrate as well through seemingly solid objects like walls, ceilings, desks, and people. The flip side is that 5GHz has different rules about how much power a base station can use to send signals [11,10].

At 2.4 GHz frequency, 13 channels are formed and only 3 do not intersect each other. At 5 GHz frequency to 23 non-overlapping channels, which provides more choices. To use least loaded channel in area of your Wi-Fi network. Interference potential is worse at 2.4 GHz band is divided into overlapping channels. It's means that only channels 1, 6 and 11 are basically transparent when used in close proximity. In a city or residential building, you can see dozens of networks that try to use the same frequencies, and each collides with each other - Wi-Fi does not give a drop. Differences are shown at Figure 1.159

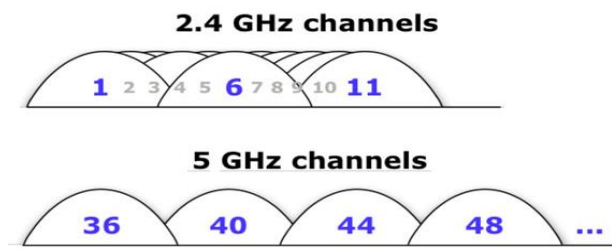


Figure 1.195 – Channels difference

The 2.4 GHz bands uses staggered, overlapping channels, which provides few clear options. The 5 GHz band reserves a full channel width without overlap.

Most modern routers act as a two or three-band router. A dual-band router is a router that broadcasts at both 2.4 GHz and 5 GHz frequencies, in effect, provides you with two Wi-Fi networks. Dual-band routers are available in two versions:

- Switchable dual-band router. Dual-band routers support 2.4 GHz and 5 GHz frequency bands (look at Figure 1.206). It's easy to select router in appropriate mode. Switched dual-band routers can work in one of these ranges, but not in both at the same time. Figure 1.4620 shows Dual-band routers with simultaneous support of both bands operate simultaneously at 2.4 GHz and 5 GHz. Usually, each frequency band is assigned a unique network name (SSID) so that the user knows to which range a particular device is connected.



Figure 1.4620 – Switchable dual-band router

- A joint dual-band router. This type of router simultaneously broadcasts both on 2.4 GHz and 5 GHz, essentially creating two Wi-Fi networks. Some routers allow you to set the same SSID for two networks, so that it looks like one. Such routers cost a bit more, but the advantages of working with different bands simultaneously outweigh this disadvantage.

Three-band router broadcasts simultaneously three networks - two signals with a frequency of 5 GHz and one signal with a frequency of 2.4 GHz. A reason for this is to relieve loading on network. Purchase of such a router is justified also it broadcasts streaming video in high definition.

Therefore, if your tablet or smartphone supports a frequency of 5 GHz, and you use it within an apartment or office, choice of router operating in two frequency bands will be a more practical option. You will be able to take full advantages of wireless high-speed continuous Internet.

1.7 Advantages and disadvantages of Wi-Fi network

For industrial use of Wi-Fi technology, a limited number of suppliers can be used. Thus, Siemens Automation drives offer Wi-Fi solutions for their SIMATIC controllers in accordance with the 802.11b IEEE standard in the 2.4 GHz ISM band and for a maximum transmission parity of 11 Mbps. These technologies are used mainly to manage moving objects in warehouse logistics, and also in those cases where for some reason, it is impossible to lay the wire through Ethernet.

Advantages of Wi-Fi:

—Absence of wires is one of the most important pluses of Wi-Fi. It is not always possible to lay a cable to a particular network device, and sometimes laying such a cable route can be very expensive and time consuming, and require reconciliation. It is much easier and much cheaper to use wireless data transmission technologies over wireless channel, which do not require cable routing.

—Fast and easy building LAN office. You do not need to design a LAN, lay wires, mount boxes under them, and this in turn provides a minimum time for building a computer network in office or production room. This is a very valuable quality for small offices and temporary events, when you need to quickly deploy, and then, also quickly dismantle computer network. Installation of a wireless Wi-Fi network in office or other premises is possible without stopping working process of company, because installation is minimized.

—Mobility and high data transfer rate. Wireless Wi-Fi network today can provide speeds up to 500 Mb/s, which corresponds to usual wired LAN. This speed is quite enough for most office applications and for working with databases.

—Wi-Fi networks do not interfere. Devices from different manufacturers can interact at the basic level of services. Different brands and types of compatible client and network devices will interact with each other. Any mobile devices supporting Wi-Fi can be connected to your network taking into account your technical requirements. Improving productivity, performance of organization using

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Wi-Fi networks ensure a more efficient use of workforce, as well as office space,

—Wi-Fi is safe for humans. The intensity of router radio emission is one hundred thousand times less than the same microwave oven in your kitchen (it works in the same range), and it can not be considered dangerous for a person in any way. If we talk about background radiation associated with operation device's chips, then it is not more dangerous than background from charging or power supply of a home radiotelephone.

—Wi-Fi networks support roaming. Client station can move in space, moving from one access point to another. You can move employees' workstations at your discretion and production need within coverage area of wireless network. Mobility of staff, opportunity to always be in touch, adherence to principle of "anyone, anywhere, anytime".

—Easy setup of Wi-Fi networks. All you need to operate a Wi-Fi network is an access point, which can be one or more dozens, depending on premises topology and software used in your company. A wireless network can be built where it is impossible or not beneficial to lay cables. Wi-Fi technology facilitates permanent or temporary installation of network.

—Wi-Fi is a set of global standards. Unlike cell phones, Wi-Fi equipment can work in different countries around the world. Extending a wireless Wi-Fi network is not an easy task: user devices can be easily integrated into network by installing wireless network adapters on them, today a large number of devices (PDAs—handhelds, smart phones, laptops and conventional computers) are equipped with wireless network adapters in stage its production by manufacturers themselves. Wi-Fi networks provide ability to move and change users' rights, new destinations, communication channels and jobs. Integration of Wi-Fi network with a wired network.

—Business reputation. Using of wireless Wi-Fi networks demonstrates your desire to evolve with times, active policy and awareness in field of IT technologies. Actively developing wireless technologies, expanding range of all kinds of compatible equipment, constantly improving standards and principles of security ensure that Wi-Fi networks are attractive for use in corporate networks of any size.

Disadvantages of Wi-Fi:

—Large environmental impact on data transmission

—The quality of connection is affected by thickness of walls and other obstacles

—Weak protection against hacking (this is only for the moment)

—High power consumption (this is terrible for battery-powered devices)

—Due to large number of Wi-Fi hotspots in house, data transmission is deteriorating. A different Wi-Fi networks interfere with each other.

—Limited range. A very big drawback is that data transfer rate depends on environment. This connection is sensitive to obstacles (walls, partitions, mirrors, furniture, etc.) and to radiation that ordinary household appliances produce.

~~Also on speed of communication depends and standardization, that is, the~~

1.88 Strategy of building and securing Wi-Fi network

The current stage of Wi-Fi technology development, this statement is incorrect. In our time, Wi-Fi technology is in great demand. Probably, each house has a wireless router, a modem or an access point. Fact is that such equipment allows you to create private groups in which users can share files, communicate, play joint games and so on. But, it is worth considering that range of one such access point is large enough. This means that not only reliable persons (friends, relatives, guests, etc.) can join the network, but also strangers, as well as intruders. It is fraught with loss of confidential data.

To prevent such consequences a security system is used. Wi-Fi network security system it is a function that allows you to set a password, as well as type of data encryption. Due to this, users can independently specify key that will be required to connect to the group. Thus, a possibility of losing important information is prevented.

In addition, encryption type can be choosen. There are several different types of authentication, but it is recommended to use one - WPA-PSK-\-WPA2-PSK mixed. The most modern and reliable kind of encoding, which provides the best protection. Such parameters are used in any wireless equipment, it can be router, a modem or some other equipment.

Conventional reflection of signal from metal cabinets with multiple overlap can lead to constructive interference with signal amplification, which easily leaves building. Hacker can use directional antennas with a large gain, which allows catching even very weak signals outside building, as well as transferring information to network, etc. All this suggests only true approach with wireless Wi-Fi solutions, as well as to build defense in depth defense. It has been known that protection of any infrastructure alone by methods of creating a perimeter is ineffective, since most often the most dangerous attacks are caused by factors inside network, for example:

- own employees

(which, incidentally, came under influence of social engineering methods, statistics shows about 90% of successful attacks were actually carried out with direct or indirect participation of employees victim companies themselves);

- embedded malicious programs (viruses, trojans, worms, programs entered into network through infected websites);

- a peer-to-peer of communication and introduction through this channel;

- quests of company who have received any access to the network, etc.

Construction of a Wi-Fi network security system should take into account all these factors in order to get as close to similar security level of wired and wireless network segments- [1111,p223].

The main components for building a wireless network security system:

- access control.

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- authentication of users.
- encryption of traffic.
- intrusion prevention system in wireless network.
- a system for detecting foreign devices and a possibility of their active suppression;
- radio interference monitoring and DoS-attacks;
- monitoring of vulnerabilities in a wireless network and ability to audit vulnerabilities;
- functions to improve security level of wireless network infrastructure, for example, device authentication (X.509, etc.), management data protection - MFP/Management Frame Protection.

The main tasks in construction of defense in depth are follows.

1. Ensuring access control

Cognition of who is members of network (authentication), what resources the user can use, application of access control policies for traffic of these users.

2. Integrity and reliability

Ensuring network is available as a resource critical to business and that emerging dangers of various kinds can be identified and found ways of circumventing them.

3. Securing privacy

Ensuring that traffic on network is not available to unauthorized users.

The starting point for creation of any Wi-Fi infrastructure with defense in depth is authentication. IP Addresses. After positive passage of authentication, which makes it possible to understand who this authenticated user is, what he can do and where he can access. 802.1x is a flexible solution, which supports a large number of authentication protocols from digital certificates to methods with a login/password. [122, p.327]. Also 802.1x supports many platforms - from cheap PDAs and smartphones to desktops and servers. Module 802.1x is built in the latest versions of Windows and MacOS, as well as in many operating systems for smartphones. You can find the 802.1x patron program (802.1x client) for almost any popular operating system.

1.99 Topologies of wireless Wi-Fi networks

802.11 networks can be built according to any of the following topologies:

- Independent basic service areas (Independent Basis Servises Sets, IBSSs);
- Basic service areas (Basis Servis Sets, BSSs);
- Extended service areas (Extended Service Sets, ESSs).

Independent Base Service Areas (IBSS)

The IBSS is a group of 802.11-based stations that communicate directly with each other. Figure 1.2147 shows how stations equipped with 802.11 wireless network interface cards (NICs) can form IBSS and communicate directly with each other.

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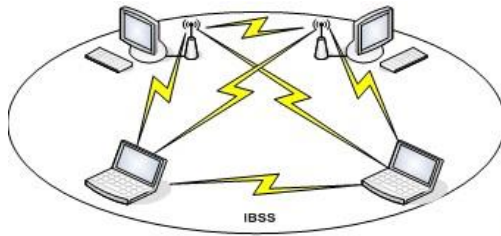


Figure 1.2147 – Ad-Hoc Network (IBSS)

A special network or an independent primary service area (IBSS) occurs when individual client devices form a self-sustaining network without using a single access point (AP-Rate point). Creation of such networks does not develop any place cards for their placement, and preliminary plans, so they are usually small and limited in length, sufficient to transfer data together if necessary- [134].

Since IBSS does not have an access point, time management (time) is decentralized. Client starts sending an interval (Beason interval) to the IBSS, a specified Beacon interval, to generate a set of transmission timing of flashing signal (target transmission time of target Beason, TBTT). After completing TBTT, each IBSS client performs the following actions:

- Pauses all the rest of the delay timer (backoff timer) compared to the previous WCDR;
- Defines a new random delay.

Basic Service Service (BSS)

BSS - the group operates on 802.11 stations, communicating with each other. The BSS technology assumes a special station, called AP (estimate point). Access point is the central point of contact for all BSS stations. Client stations are not directly connected to each other. Instead, they are associated with an access point, and it must transmit frames to the destination station. An access point can be an uplink port (an uplink port) through which the BSS is connected to a wired network (eg, an uplink Ethernet).

A wired network (eg, an uplink Ethernet channel). Therefore, BSS is sometimes called BSS infrastructure. Figure 1.4822 shows a typical BSS infrastructure.

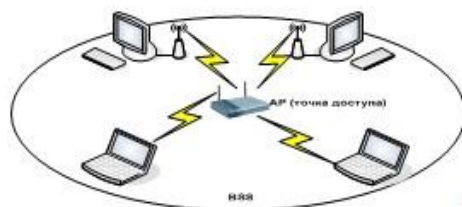


Figure 1.4822 - Local Wireless Network Infrastructure BSS

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Extended Service Set (ESS)

Several BSS infrastructures can be connected through their uplink interfaces. Where the 802.11 standard is in effect, the upstream interface connects BBS to distribution system (DS). Several BBSs connected to each other through the distribution system form an extended service area (ESS). Uplink to distribution system does not have to use a wired connection. Figure 1.2349 shows an example of practical implementation of ESS. The 802.11 specification leaves a possibility of implementing this channel as a wireless one. But more often the ascending channels to distribution system are channels of wire Ethernet technology.

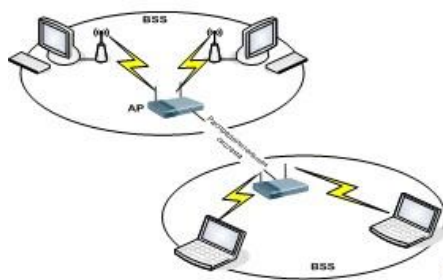


Figure 1.2349 - Extended wireless ESS coverage area

1.110 Wi-Fi roaming

Roaming refers to process of reconnecting device to a wireless network while moving it in space. A received power of radio signal weakens with distance to transmitter, as a result of which effective data rate drops, channel errors increase until a wireless connection is disconnected. If there is more than one access point in radio network with one name (SSID), moving mobile subscriber from zone of confident operation within the first access point to an area where signal from the second access point is better (higher power, higher signal-to-noise ratio) may thereis such reconnection.

A decision to re-connect always takes client device (the Wi-Fi adapter driver). Access point can only "tell" device about desirability of this action. Sometimes you can specify parameter of "aggressiveness" decision making in driver settings. However, when subscriber is initially connected, centrally managed system can "force" subscriber to connect preferred point (from the point of view of loading) and desired channel / range.

A roaming mechanism is called seamless, in which loss of data transmitted at the moment of switching from point to point is minimal or equal to zero, and TCP/IP stack of client operating system does not even notice fact of switching. Such a mechanism is important in using of delay-sensitive and loss-aware applications such as voice over the wireless network, streaming video, large amounts of data and in general all cases where TCP protocol is not able to "digest"

the temporary loss of transmission channel data. Roaming topology is shown at Figure 1.240

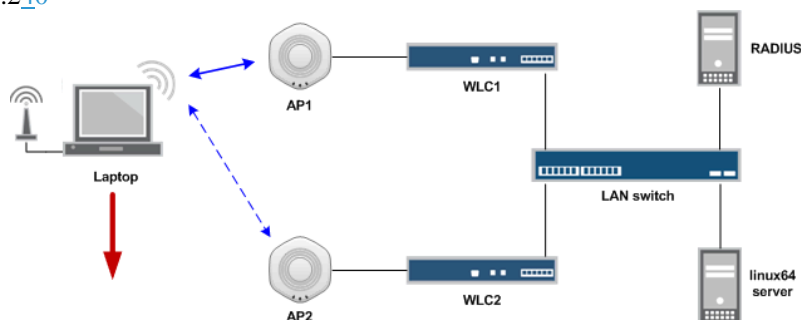


Figure 1.240 – Roaming topology

Quite often, client device instead of connecting to a neighboring point with the best signal (the Wi-Fi controller pushes it to solution), without success, tries to reconnect with a previous point. Even worse, if device tries to hook on another network from the list of saved (for example, a guest network).

But even if switching process goes according to plan, a significant amount of time takes away a repeated key exchange (EAP) and authorization on the Radius server (WPA-2 Enterprise).

To solve these problems, the Wi-Fi association developed the 802.11R protocol.

The essence of 802.11R is that the mobile device knows its own and others' points on the signal of belonging to the mobile domain (MDIE). This signal is added to the beacon signal (SSID beacon).

If your phone has seen a point from its mobile domain with the best signal/noise level, before starting the procedure for switching over an existing "thread" it performs preliminary authorization with another point of the mobile domain.

Secondly, authorization takes place in a simplified scenario - instead of long authorization on Radius server, client device communicates with Wi-Fi controller with PMK-R1 key. The original key PMK-R0 is transmitted only with primary authentication and is stored in the memory of Wi-Fi controller. (Figure 1.245)

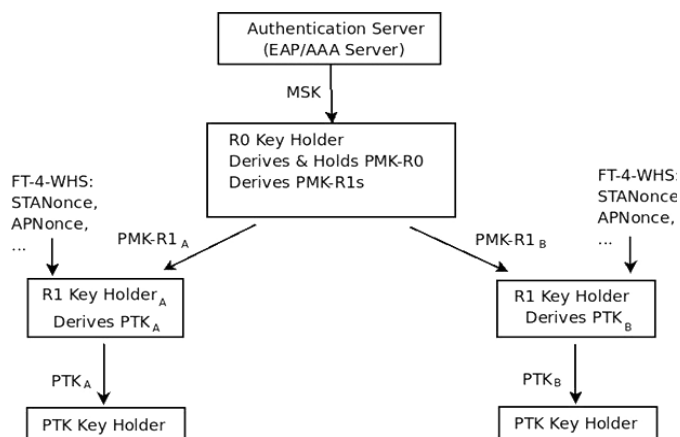


Figure 1.2+5 – Wi-Fi controller memory

At the moment when another point "retroactively" authorized device, actual handover occurs. Resetting frequency and channel in smartphone takes no more than 50 milliseconds. In most cases, it passes absolutely unnoticed for the user.

When choosing a solution for an office Wi-Fi network - pay attention to whether selected equipment supports open roaming protocol 802.11R, understandable for client devices. For example, Edimax Pro equipment fully supports this protocol, so there is no problem with roaming in most cases. However, if your device is old and does not recognize 802.11R protocol, it is possible to adjust aggressiveness of roaming based on signal lowering threshold value - as other Wi-Fi manufacturers do, giving it as an "innovative solution".

In addition to problems with roaming, often corporate users have to deal with congestion of one access point. In classic Wi-Fi implementation, all devices tend to connect to an access point with the best signal. Sometimes as a result of an incorrect location of point (error of radio planning) at one point all "inhabitants of the office" are registered and "rest".

Because of uneven load, speed of local network drops dramatically, because radio is one big "hub" where the devices "speak in turns".

To smooth out unevenness and optimal distribution of users between points working on different radio channels, 802.11K protocol was developed.

Figure 1.22 shows 802.11K works in conjunction with 802.11R (usually devices supporting "R" -standard, also support "K" -standard).

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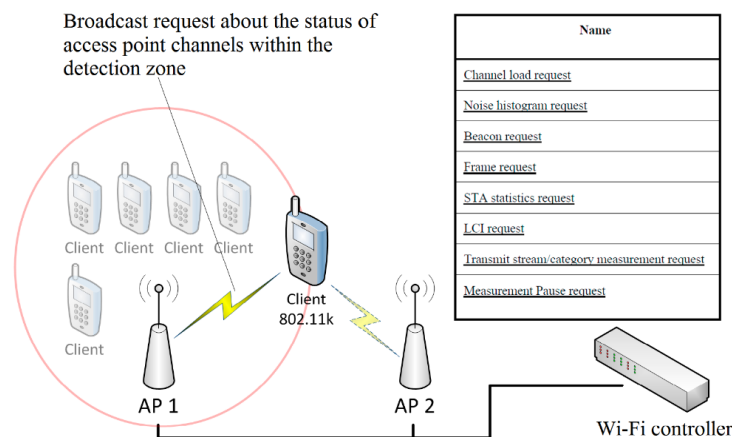


Figure 1.226 – 802.11R operational principle

If a mobile device "locates" the beacon signal from other points in the same mobile domain, the device sends a radio measurement request (RMR) frame request in which it asks for information about the current status of other access points within the scope:

- number of registered users
- average channel speed (number of packets transmitted)
- how many bytes were transmitted in a certain time interval

In extended standard specification, client's smartphone can request channel status from other mobile devices connected to a potentially interesting access point that support the 802.11K standard. Devices answer not only about real statistics, but also about the signal-to-noise state.

Thus, if your smartphone sees 2 or more points within the same mobile domain, it will choose a point not with the best signal, but a point that will provide a faster connection speed to the local network (less loaded).

Reception conditions, the number of users and load on point can change dynamically, but using 802.11K and 802.11R the devices will switch unnoticed and the load on the network will always be distributed evenly.

Many manufacturers using proprietary protocols implement similarity of 802.11K when an "overloaded" point forcibly turns off customers with worse reception conditions or limits the maximum number of simultaneously registered devices and disables registration if the number of clients exceeds the allowed limits. These proprietary protocols are not as effective, but they still do not allow the Wi-Fi network to collapse at all.

In 802.1x authentication process, access point retains pairwise key master key (PMK) for each client, idea was to transfer this key through the controller to neighboring points - thus avoiding a new access to RADIUS and simplifying exchange, significantly reducing switchover time to a new one point. It is not part of

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standard, hence all the following, but it is supported by all serious Wi-Fi iron manufacturers and some customers. Without support from client, the function is useless, for WPA2-PSK however. Some vendors forcefully try to use method, seeing stored key, even if client did not request it in the Request, sometimes works.

Radio Resource Management, an amendment of 2008, from 2012 in standard, option. Access point flag indicates in Beacon support for option, when requested by client sends it a list of neighboring points, a client does not waste time scanning all available channels and immediately switches to desired one and selects a new point. Battery is saved, in High-Load overall state of air is also improved. Together with 802.11v can make life of customers comfortable enough not to think about other technologies (after all, the client candidate still chooses himself) - unless of course you do not need VoIP and magic 50 ms for WPA2-Enterprise. Without support from client is useless.

Wireless network management (WNM) amendments were published in 2011 and in 2012 entered the standard, a large number of options. The main purpose - effective management of wireless environment - exchange of data about environment between stations, energy saving customer, improving process of roaming and balancing - client sends messages with appropriate AP, which addresses problems of point loading (Load-Balancing) and "sticky" clients with a weak signal, and some other functions. Assisted Power Saving sets maximum timeout for client without requiring him to keep frequent messages keep-alive, Direct Multicast Service allows to receive multicast frames at speed of client connection, rather than cell speed - which frees air and saves the battery (for roaming these functions do not apply).

BSS Transition is very relevant - it is a request from the client to indicate suitable points. It is important to note that these are recommendatory messages, and actions remain at the discretion of the client. Forced disconnection is possible only within framework of proprietary technologies Band/Load Steering/Balancing, and can be incorrectly worked by client, or completely ignored (it is disconnected with Disassociate frames).

Sharing 802.11k/v yields good results, and in most cases, home and small office networks are sufficient for customers, without creating problems in the operation of various devices. Next is already heavy artillery - it radically solves the main problem, but can cause side effects - it's 802.11r.

Fast Roaming/Fast BSS Transition - 802.11r is mandatory for client when using on a point, i.e. those who do not support it cannot connect - it is flag in control frames. It can also crash incorrect drivers of old client adapters - it's a matter of using FT 4-Way Handshake to distribute public key, which is what standard says: "A STA shall not use any authentication algorithm except FT authentication algorithm when using the FT Protocol".

Fast BSS Transition works with RSNA (Robust Security Network Association - WPA2) networks and completely open networks. For WPA2-PSK, meaning of fast roaming is lost; client and point are still exchanging 4 packages, there's nothing to accelerate. calculation does not take into account time to find a

suitable point, and for 5 GHz band it can be pretty - you need to scan 16 channels and find a suitable AP, so common strategy is just to use the k / v and r protocols together.

In case of use RADIUS using for authentication and want very fast roaming - you do not have a choice, only 802.11r

In addition to roaming in 802.11r, it is potentially possible to poll point about availability of resources required by client and to reserve them (QoS). Accordingly, there are two subsets of protocols - FT Protocol and FT Resource Request Protocol. Communication between client and points can occur both directly through air (Over-the-Air), and through the used point and controllers (Over-the-DS) - the second way a little longer. Query QoS from a point on clients while practically is not realized anywhere and is not used.

The most important element of the frame is MDE, Mobility Domain Element, it is necessary for successful roaming, which is possible only within one domain.

2 Wi-Fi in industry

2.1 Wi-Fi access points

All access points can be divided by method of connection: via USB port and Ethernet connection port - RJ45. The easiest way to configure and manage AP is a [increase higher transfer rate for local network](#). Access points can be indoor (in-door) and all-weather (outdoor) performance. To create a wireless network inside premises, use a room version of device. It has a lower cost and, as a rule, a great aesthetic appearance. There are such access points within one or several rooms. In open areas terrain (direct visibility) it is possible to work at a distance of up to 300 meters using standard omni-directional antennas. Access points of all-weather performance are designed to create a radio network between buildings. Depending on antennas types, such devices are capable of organizing communication channels at a distance of the order of 3-5 km: [\[164,p237\]](#). The maximum range of a wireless link increases noticeably when using amplifiers. In this case, radio channel length reaches 8-10 km. Devices such as the access point are shown in Figure 2.1.

~~Combined devices:~~

~~Of great interest, wireless access points that combine functions of other devices. For example, a high-speed wireless broadband router with an integrated Fast Ethernet switch. Router allows you to quickly and easily configure Internet sharing for a wired or wireless network or to share a broadband connection and cable/DSL modem at home or in office.~~

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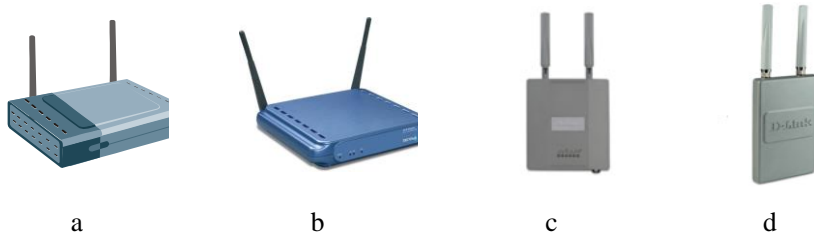


Figure 2.1 – Types of access points: a, b – internal (indoor); c, d – external (outdoor)

For connecting a wireless Wi-Fi network, it is enough to have a laptop or pocket personal computer (PDA) with connected Wi-Fi adapter.

Combined devices

Of great interest, wireless access points that combine functions of other devices. For example, a high-speed wireless broadband router with an integrated Fast Ethernet switch. Router allows you to quickly and easily configure Internet sharing for a wired or wireless network or to share a broadband connection and cable/DSL modem at home or in office.

Any wireless Wi-Fi adapter must meet several requirements:

- compatibility with standards is necessary;
- operation in the frequency range 2.4 GHz - 2.435 GHz (or 5 GHz);
- support WEP protocols and preferably WPA;
- maintain two types of point-to-point connections, and "computer server";
- support roaming function.

There are three main types of Wi-Fi adapters, distinguished by type of connection:

- connectable to computer USB port. These adapters are compact, easy to configure, and USB interface provides a "hot-plug" function;
- connectable via PCMCIA slot (CardBus) of computer. Such devices are located inside computer (laptop) and support any standards that allow transfer of information at speeds up to 108 Mbit/s;
- devices integrated directly into the computer motherboard. The most promising option. Such adapters are installed on Intel Centrino series notebooks. And, currently used on vast majority of mobile computers. All kinds of wireless adapters are shown in Figure 2.2



Figure 2.2 - Wireless adapters:

a - with USB port, b - PCMCIA format, в - built-in motherboard

2.2 Wi-Fi and cellular phones

Someone believes Wi-Fi and similar technologies can eventually replace cellular networks, such as GSM. Obstacles for such a development in near future is lack of roaming and authentication capabilities (see 802.1x, SIM cards and RADIUS), the limited frequency range and very limited range of Wi-Fi. More correct is comparison of Wi-Fi with other standards of cellular networks, such as GSM, UMTS or CDMA.

However, Wi-Fi is ideal for using VoIP in corporate networks. The first samples of equipment were available already in the early 90's, but did not enter commercial operation until 2005. Then the companies Zyxel, UT Stramsomm, Samsung, Hitachhi and many others presented VoIP VoIP phones at "reasonable prices" to market. GSM phones with integrated Wi-Fi and VoIP capabilities are being introduced to market and can potentially replace wired phones shown at Figure 2.3



Figure 2.3 – GSM phones with integrated Wi-Fi network

Phones using only Wi-Fi have a very limited range, so deploying such networks is very expensive. However, the deployment of such networks can be the

best solution for local use, for example, corporate networks. However, devices that support multiple standards can take a significant share of the market.

Commercial use of Wi-Fi

Commercial access to Wi-Fi services is provided in places such as Internet cafes, airports and cafes around the world (usually called Wi-Fi cafes), but their coverage can be considered as a point of comparison with cellular networks: Ozone Paris and France. In September 2003, Ozone began rolling out the network through the Ozone Paris The City Lights. Ultimate goal is to create a centralized Wi-Fi network that completely covers Paris. The basic principle of Ozone Pervasive Network is that it is a national scale network. WISE provides commercial access to airports, universities, and independent cafes in the United States; T-Mobile provides Starbucks hotspots in the US and the UK, as well as hot spots in 7500 in Germany; Pasifis Century SyberWorks provides access to Pasifis Soffee stores in Hong Kong; Solumbia Rural Elestris Association is trying to deploy a network- [145, p165].

2.4 GHz Wi-Fi on an area of 9,500 square kilometers located between Walla Walla and Columbia, Washington and Oregon, Yumatilla; The list of other major networks in the US also includes: Boingo, Wayport, IPASS; Sify, an Indian Internet provider, has installed 120 access points in Bangalore, hotels, galleries and government offices. Vex has a large network of hotspots located throughout Brazil. Telefonisa Fast Wi-Fi began to provide its services in a new growing network distributed throughout the State of São Paulo. BT Openzone has many hotspots in the Great Britain, working in McDonald, and has a roaming agreement with T-Mobile UK and ReadyToSurf. Commercial access to Wi-Fi services is provided in places such as Internet cafes, airports and cafes around the world (usually these places are called Wi-Fi cafes), but their coverage can be seen as a point of comparison with cellular networks: Ozone Paris and France.

An easy system to benefit from Open Wi-Fi right around the corner and as you move through Almaty: it seamlessly auto-connects your smartphone to a good Internet Hotspot in range and don't need to do anything. Due to the huge Wiman Network, consisting of users who share their Wi-Fi, can find other Costless Wireless Networks near besides the open ones. Wiman Shared Wi-Fi is definitely verified and working. In addition, it's possible to download the Free Wireless Internet map of Almaty connected to the Internet and browse it even when you're offline, when there are no Wireless Networks available nearby. Wiman leads the way and guides you through your Wi-Fi search process by upgrading your leisure experience.

2.3 Free Wi-Fi for everyone

For several years, Elon Musk talked about his plans to launch a network of Earth low-orbiting satellites, which will be able to provide high-speed Internet access around the world. And although details of this project are still kept secret, the first prototypes of satellites are already ready for using.

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The first two test satellites will be launched into near-Earth orbit already is launched. Last year, Vice President SpaceX, in charge of this direction, said that the first test devices launched in late 2017 - early 2018. But if it succeeds, SpaceX plans to launch commercial satellites next year, and by 2024, complete network of more than 11,000 satellites in low Earth orbit. The launch of test satellites means that company is still participating in race for providing Internet access. Earlier own network of satellites wanted to create Google. But then it became one of SpaceX's biggest investors when it raised 1 billion USD in investment round three years ago. Meanwhile, Japanese SoftBank and Richard Branson are supporting the European OneWeb, which hopes to provide broadband Internet access in 2019. In total, US regulators received 12 applications for testing satellites that provide Internet access. In addition, Facebook wants to provide an Internet connection in remote corners of the Earth with the help of drones.

Work on this project SpaceX began in 2014, but then focused on improving its main space rocket Falcon 9 and preparing a long-delayed launch Falcon Heavy. In the filing, SpaceX said: "The system is designed to provide a wide range of broadband and communications services for residential, commercial, institutional, government and professional users worldwide."

During the tests, SpaceX will put two small satellites into orbit and test communications with several stations on Earth, including Tesla headquarters. It is expected that one of the main applications of future 5G-networks will be high-speed data transmission to self-controlled vehicles. SpaceX plans to build a so-called mesh network from satellites, which allows information to be transmitted between them and to provide complete coverage of the Earth.

A data transmission volume via networks in near future can dramatically increase, given large number of satellite companies. "There will be insatiable demand in the future," said Cisco Systems CEO Chuck Robbins. But it is too early to predict how many competing satellite networks will support 5G, he says.

At the beginning of the century, several ambitious satellite projects were fiasco, because of inflow of investments into this industry slowed. But since then, economic attractiveness of such projects has grown significantly. "The bankruptcy of Globalstar and Iridium scared everyone away," notes Robert Twiggs, one of inventors of next generation of low-cost CubeSats, which reduced cost of space projects.

Small satellites located in low orbits have until now been used for space imagery of the Earth - for example, in agricultural and energy industries. But they were not yet used to transmit data over communication networks. Their proximity to the Earth can help avoid delays that occur in satellites in higher orbits.

This week, the SpaceX plan was personally supported by the Chairman of Federal Communications Commission, Ajit Pai. He called on other members of commission to approve company's application for a communication license. SpaceX project will provide high-speed Internet access to residents in rural areas of the United States, Pye noted. Thus, SpaceX may be the first of American companies to

obtain this license - following the European OneWeb, Space Norway and Canadian Telesat.

3 Calculation part

3.1 Technical solution of the project

~~This project is based on equipment with standard 802.11n support, received Wi-Fi certificate.~~ Wi-Fi covers whole area of department and unites all users in a single network with Internet access. Network is implemented throughout ICT department by wireless unified access points controlled by a wireless switch. ~~In diploma project I chose~~ ASUS RT-AC3200 router ~~was chosen~~ because of various configuration possibilities. ~~This project is based on equipment with standard 802.11ac support, received Wi-Fi certificate.~~ -Also I considered 3 types of Wi-Fi connections with a different bandwidths.

3.2 Description and characteristics of selected equipment

ASUS RT-AC3200 router is a ~~u~~Ultra-fast tri-band router with Wi-Fi 802.11~~aeac~~ support. It has Smart ~~c~~Connect technology, which provides a record data transfer speed in a multi-user environment. A total bandwidth of 3200 Mbit/s consists from maximum speeds addition 1300 Mbit/s in each of two channels in the 5 GHz band and 600 Mbit/s in 2.4 GHz band. This router can boast an excellent coverage area and high level of information security. Router is equipped with six external antennas supporting two channels of standard Wi-Fi 802.11~~aeac~~, three antennas per transmission and three antennas per reception. It allows to achieve maximum data transfer speed and wireless signal stability.

The 802.11n standard increases the throughput by 6 times compared to 802.11a/g networks. ASUS RT-AC3200 is backward compatible with 802.1a/b/g devices and allows 2x2 setting in both T_x/R_x directions. Multiple input multiple Output (MIMO) technology and channels with increased bandwidth increase a physical data rate 802.11n standard using. MIMO provides simultaneous transmission of multiple signals using multiple antennas instead of one. Using ASUS RT-AC3200 enterprise prepares a platform for the future generation of wireless devices and mobile applications. [16].

RT-AC3200 model operates in parallel with three data streams: it supports two channels with 5 GHz (1300 Mbit /s) and one channel with 2.4 GHz (600 Mbit/s). That option permits to optimize work of several tasks simultaneously. Example: streaming video with Ultra-HD resolution, starting online game while files are downloading. It supports a set of built-in features that allow administrators to establish a secure network and connect to any switch and router that is compatible with Ethernet devices. Advanced wireless features supported by access point include: WEP encryption, WPA/WPA2 security, MAC address filtering, load balancing between access points, QoS/WMM (Wireless Media), and detection of unauthorized access points. RT-AC3200 supports ability to locally store security

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settings. You can extend wireless connections by adding multiple access points to other 802.11a/g/n access points.

ASUS AiCloud technology can access your files from local home network and online storage services, no matter where you are. For access implementation to "cloud" exist AiCloud mobile application, available for free of charge for Android-devices and devices based on iOS. You can expand your personal "cloud" by establishing a connection to another router that supports AiCloud. AiProtection technology and Trend Micro modern network security solutions turn RT-AC3200 into one of the safest home routers on market. Due to constant monitoring of potential security threats, router guarantees complete peace of mind. External view shown at Figure 3.1



Figure 3.1 – Wireless access point ASUS RT-AC3200

It equipped with one WAN port and four LAN ports of Gigabit Ethernet standard, and supports hardware Network Address Translation (NAT). Due to this, router provides increased switching speed between external and local segments in comparison with network equipment with software implementation of NAT. For managing all functions, RT-AC3200 uses a convenient graphical interface ASUSWRT. Due to this interface, you can easily configure router’s work and connect cloud services to AiCloud 2.0. ASUSWRT is a web-based interface, so you can control the router from any mobile device with browser.

General characteristics are presented in [Appendix A. Table 3.1](#)

Table 3.1 – General characteristics of equipment ASUS RT AC3200

WLAN functions	<div>+ Up to 64 access points connected to switch</div> <div>+ Up to 256 access points per cluster</div> <div>+ Up to 2048 wireless clients (1024 users when using tunneling, 2048 users if tunneling is not used)</div>
Roaming	<div>+ Fast roaming</div> <div>+ Roaming between switches and access points connected to one switch</div>

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	<ul style="list-style-type: none"> + Inside and Inter network roaming + Tunneling between access points
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Access point functions	<ul style="list-style-type: none"> + Automatic detection of access points + Remote reboot of access points + Monitoring of access points: a list of managed access points, unauthorized and unauthenticated access points + Client monitoring: a list of clients associated with each managed access point + Ad-hoc client monitoring + Authentication of access points using a local database or an external server + Centralized management of security channels / policies + Visual tools for managing access points (Support for up to 16 jpg files) + Unified access point support: Managed / Offline mode
WLAN security functions	<ul style="list-style-type: none"> + Wireless Intrusion Detection & Prevention System (WIDS) + Minimizing unauthorized access points + Classification of unauthorized and valid access points based on MAC address + WPA Personal / Enterprise + WPA2 Personal / Enterprise + 64/128/152-bit WEP data encryption + Classification of wireless stations and access points based on the channel, MAC address, SSID, time + Encryption type support: WEP, WPA, Dynamic WEP, TKIP, AES-CCMP, EAP-FAST, EAP-TLS, EAP-TTLS, EAP-MD5, PEAP-GTC, PEAP-MS-CHAPv2, PEAP-TLS + Authentication based on MAC addresses + Station isolation

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Layer 2 functions	<ul style="list-style-type: none"> VLAN + 802.1Q VLAN Tagging + 802.1V + VLAN groups: up to 3965 records + Subnetwork based VLANs + MAC based VLAN+ GVRP + Double VLAN + Voice VLAN
Layer 3 functions	<ul style="list-style-type: none"> + IPv4 Static Routing + Routing table size: up to 128 static routes + Floating static routes+ VRRP + Proxy ARP + RIPv1/v2
Quality of Service	<ul style="list-style-type: none"> + Priority queues 802.1p (up to 8 queues per port) + CoS based on: switch port, VLAN, DSCP, TCP / UDP port, TOS, source MAC address, source IP address + Auto VoIP + Minimum bandwidth guarantee for the queue + Generate traffic to the port + Flow control based on flow
ACL (Access Control List)	<ul style="list-style-type: none"> ACL based on: switch port, MAC address, priority queues 802.1p, VLAN, Ethertype, DSCP, IP address, protocol type, TCP / UDP port number

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Отформатированная таблица

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LAN security functions	<ul style="list-style-type: none"> + Port Security function: 20 MAC addresses per port, notification in case of a function + MAC address filtering + 802.1x access control based on ports and Guest + Protection against DoS attacks + Dynamic ARP Inspection (DAI) + DHCP Snooping + Broadcast storm control: 1% step from channel speed + Protected port + DHCP filtering
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Performance	<ul style="list-style-type: none"> + Web-based interface + Switch Clustering + Account + CLI + SSH + TFTP client + SNMP v1, v2c, v3 + sFlow + Multiple configuration files + Support for two copies of software (Dual Images) + RMON v1: 4 groups (Statistics, History, Alarms, Events) + BOOTP / DHCP client + DHCP server + DHCP Relay + SYSLOG + Description of ports
Flow control	<ul style="list-style-type: none"> + Switching matrix: 88 Gbit / s + Max. Packet transfer rate: 65.47 Mb/s + Switching Method: Store and Forward + The size of the buffer of packages: 750 KB
	<ul style="list-style-type: none"> + Flow Control 802.3x in Full Duplex Mode + "Back pressure" method in half duplex mode + Prevent lock HOL

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3.3 Desing part

Отформатировано: английский (США)

The first step is to reset factory settings

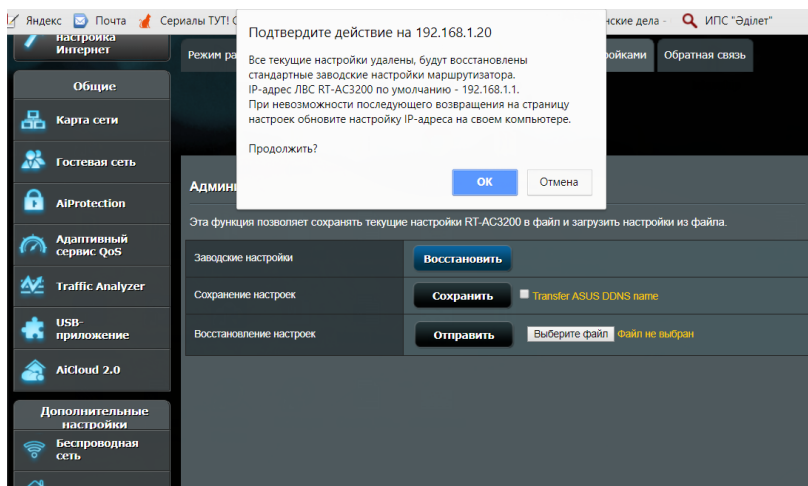


Figure 3.2 – Reset factory settings

Creation of own access point at ASUS RT-AC3200 router. An access point is a wireless base station designed to provide wireless access to an already existing network or to create an entirely new network.

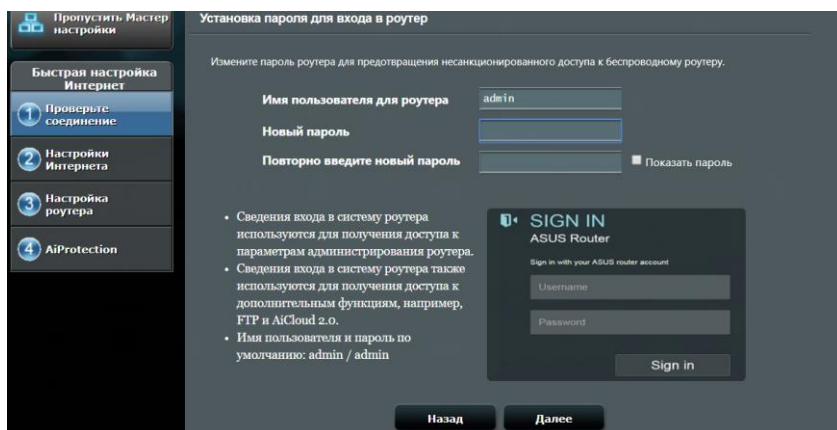
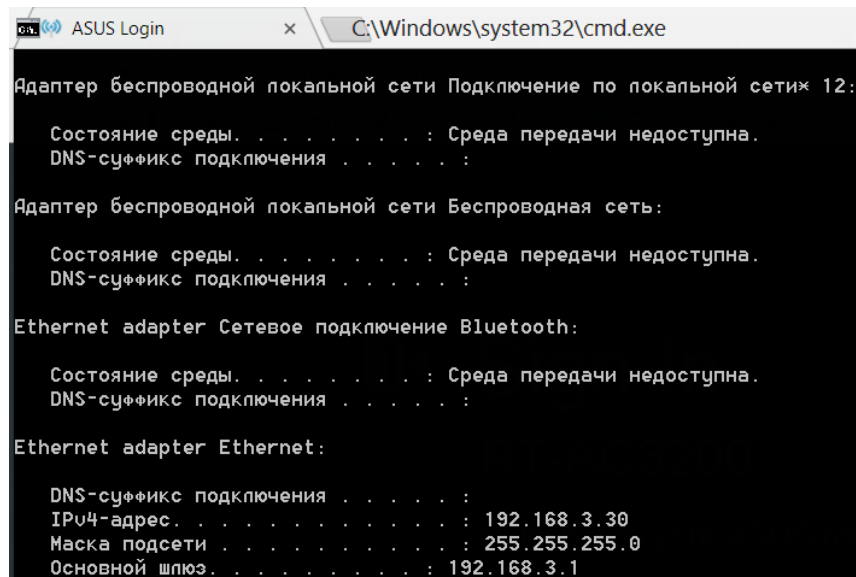


Figure 3.3 – Creation of own access point

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

With command system Ethernet statement was tested. Computer Ip address was changed.



```
ASUS Login x C:\Windows\system32\cmd.exe

Адаптер беспроводной локальной сети Подключение по локальной сети* 12:

Состояние среды. . . . . : Среда передачи недоступна.
DNS-суффикс подключения . . . . . :

Адаптер беспроводной локальной сети Беспроводная сеть:

Состояние среды. . . . . : Среда передачи недоступна.
DNS-суффикс подключения . . . . . :

Ethernet adapter Сетевое подключение Bluetooth:

Состояние среды. . . . . : Среда передачи недоступна.
DNS-суффикс подключения . . . . . :

Ethernet adapter Ethernet:

DNS-суффикс подключения . . . . . :
IPv4-адрес. . . . . : 192.168.3.30
Маска подсети . . . . . : 255.255.255.0
Основной шлюз. . . . . : 192.168.3.1
```

Figure 3.4 – Ip address was changed

Отформатировано: Отступ: Первая строка: 1,25 см, интервал Перед: 0 пт, после: 0 пт

A router's wide area network (WAN) port acts as its gateway to other networks, providing an interface for the router to send outgoing traffic over.

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

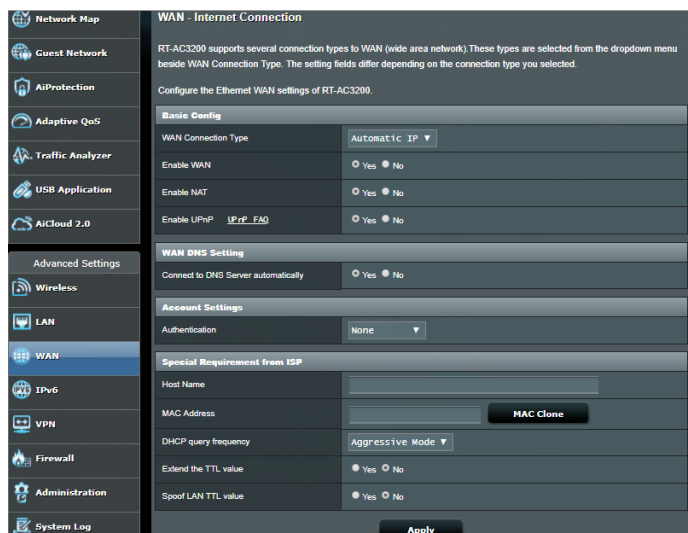


Figure 3.5 – WAN functions

ASUS RT-AC3200 router can support 2 mode of bandwidth in wireless connection. Mostly home routers use common frequency 2.4 GHz. In this frequency range it works next to household appliances like a microwave over a telephone, which can create additional noise. Because of this, there are transmission delays of data packets, especially at long distances and relatively slow speeds. At the same time, there are several key advantages:

- a strong signal can cover almost entire house.
- compatible with all modern devices.
- stable operation with indirect visibility.

The number of channels used in the range of 5 GHz - 19, due to data transmission increases significantly, and ether is much freer. As an example, number of available access points (left 5 GHz, right 2.4 GHz):

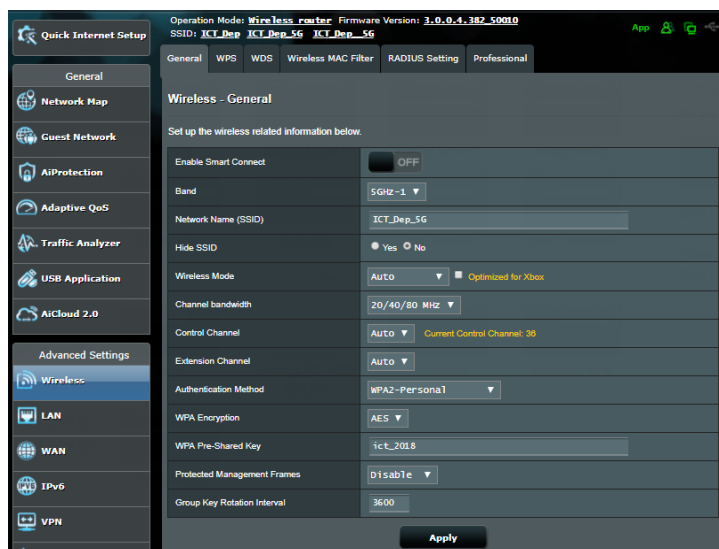


Figure 3.6 – Creation of 2.4 GHz and 5 GHz Wi-Fi network

There is option of guest network for student. Created 1 access point with 2.4 GHz and two access point with 5 GHz. Guest Network allows to connect Internet. In this case, computers connected to this wireless network will be isolated from your main local network resources. It will protect it by providing Internet access to third-party users.

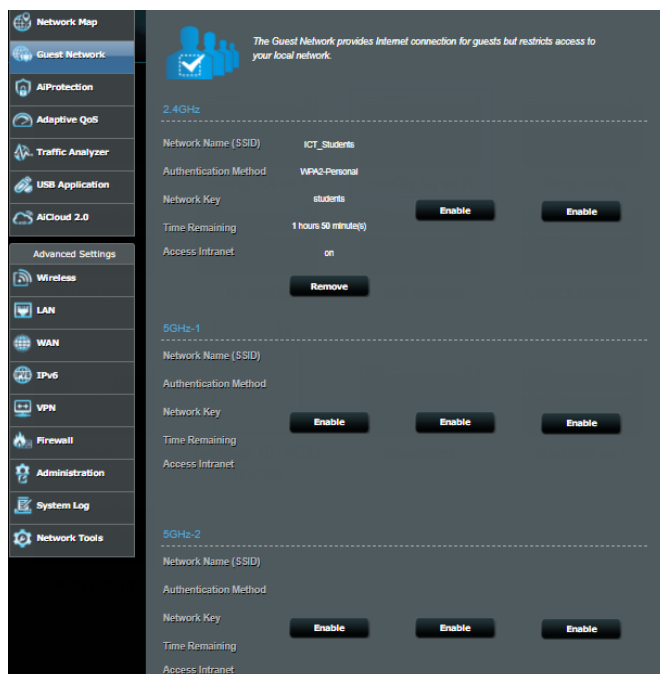


Figure 3.7 – Quest network options

There is time limitation for distribution of Internet. In our case, determined 2 hours.

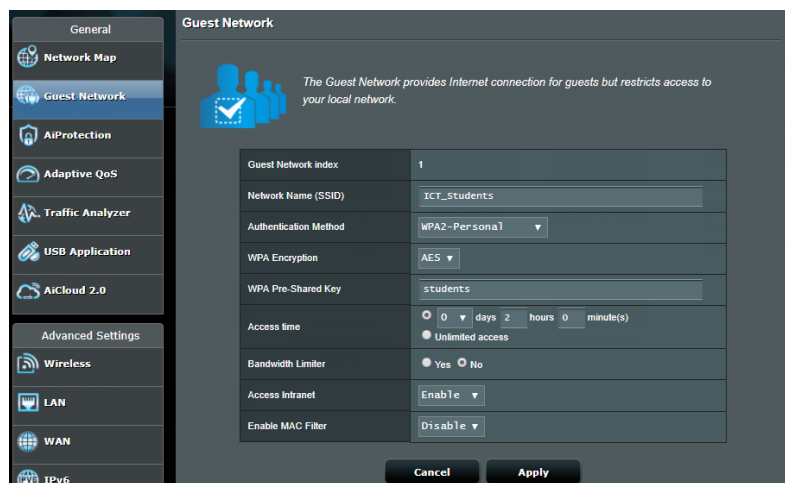


Figure 3.7 – Quest network limit time

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

The main page of ASUS RT-AC3200 settings. Created 3 networks: 1 network with 2.5 GHz bandwidth and 2 network with 5 GHz bandwidth







Figure 3.8 – The main page of settings

Different devices were connected to that access point. Tested network possibilities.






All

Interface

Wired									[Hide]
Internet	Icon	Clients Name	Client IP address	Clients MAC Address	Interface	Tx Rate (Mbps)	Rx Rate (Mbps)	Access time	
		Kurchum	192.168.3.30	DHCP F8:A0:63:75:1F:CC		-	-		
		AES-8406-19	192.168.3.149	DHCP 00:22:4D:A7:7F:59		-	-		




2.4 GHz

[Hide]

Internet	Icon	Clients Name	Client IP address	Clients MAC Address	Interface	Tx Rate (Mbps)	Rx Rate (Mbps)	Access time
		Redmi3S-Redmi	192.168.3.168	DHCP 38:A4:ED:05:12:05		19.5	1	00:03:58
		Redmi4X-Redmi	192.168.3.182	DHCP EC:1D:09:0F:63:58		19.5	6	00:09:02

5 GHz-1

[Hide]

Internet	Icon	Clients Name	Client IP address	Clients MAC Address	Interface	Tx Rate (Mbps)	Rx Rate (Mbps)	Access time
		DESKTOP-37N3595	192.168.3.219	DHCP F0:D5:8F:7D:22:83		234	866.7	00:03:02

5 GHz-2

[Hide]

Internet	Icon	Clients Name	Client IP address	Clients MAC Address	Interface	Tx Rate (Mbps)	Rx Rate (Mbps)	Access time
No data in table.								

Export

Figure 3.9 – Connected devices

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

Tested all access points from a different department places. Download possibilities also were tested



Figure 3.10 – Speed test of Wi-Fi connection

There is 3 types of mode.

Wireless Router Mode (for sharing Internet at home)

In mode, device can create access to one wired Internet connection for multiple clients and one WAN port will be used. This mode supports several types of connection, such as Dynamic IP / Static IP / PPPoE / L2TP / PPTP (Dynamic IP / Static IP / PPPoE / L2TP / PPTP). When one user can access Internet from a DSL or cable modem, use the wireless router mode to provide Internet access for more users.

Access point mode (for Internet connection in hotel)

Access point mode is intended for converting a wired connection to a wireless one. In this case, device acts as a switch. Usually it is connected behind router. If you are in an office, hotel or places where only a wired connection is available, or, for example, at a party playing network games, in a small meeting or in other conditions where you need to temporarily connect to a wireless network.

Media Bridge mode (for network connection in the office and at home)

Bridge mode uses existing wireless Internet channel and translates it using a different network name (SSID) and password. This mode allows you to create several separate networks for different groups of users, sharing one connection to Internet. For a small restaurant or bar, office or home, where access to Internet should be provided to guests without revealing password from existing network is the best choice.

Отформатировано: интервал Перед: 0 пт, после: 0 пт, междустрочный, 1,5 строки

Добавлено примечание ([Office18]): в каком еще отеле?

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

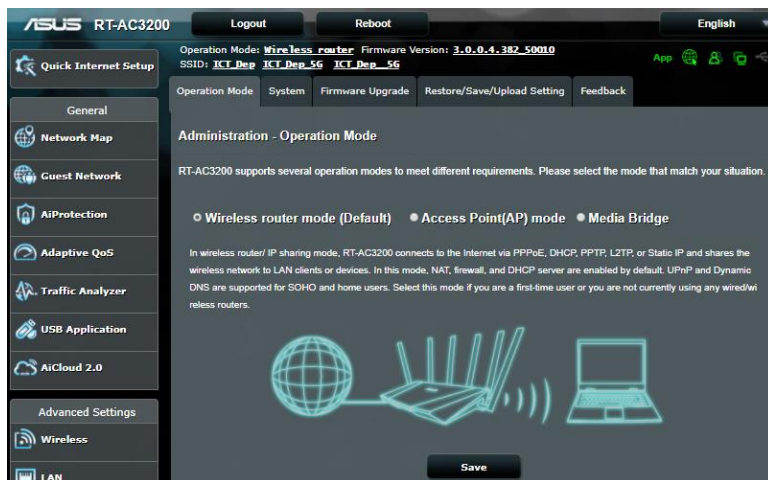


Figure 3.11 – Operation mode settings

Access to websites is controlled by a URL filter. It allows to protect user from visiting unwanted Internet resources. It be can selected both individual websites and categories of websites which access will be denied.

The content filter works according to statistical principle, that is, it counts predefined words of text and determines category to which content of the site relates.

Blocking of access to non-recommended and potentially dangerous sites is made in the following categories:

- drugs
- known sources of viruses
- foul language
- terrorism
- violence
- weapons
- sites for adults, etc.

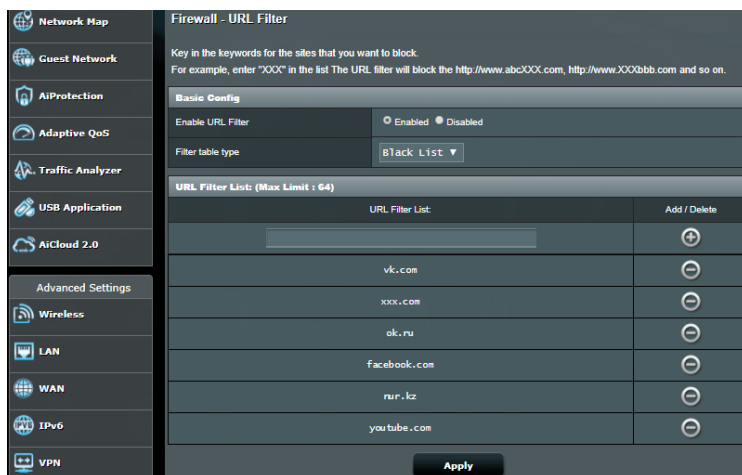


Figure 3.12 –Firewall settings

QoS (quality of service) is a technology for providing different traffic classes with different priorities in services. Also this term is a probability that communication network corresponds to the specified traffic agreement. Informal probability notation of passing a packet between two points of network.

By other words: QoS - is ability of network to provide a necessary service to a given traffic within a certain technological framework.

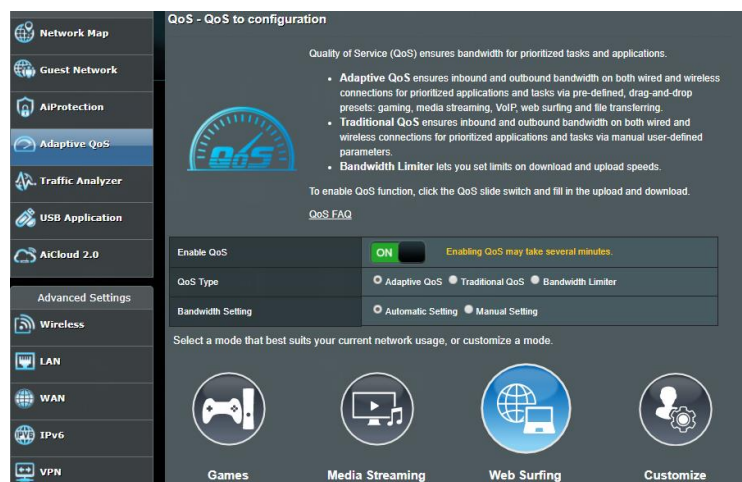


Figure 3.13 – QoS configurations

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

This software displays download and upload speed in real time in graphical and numerical forms. Bandwidth Monitor track all network connections on the computer, such as a network connection to the local network, a network connection to Internet and a VPN connection.

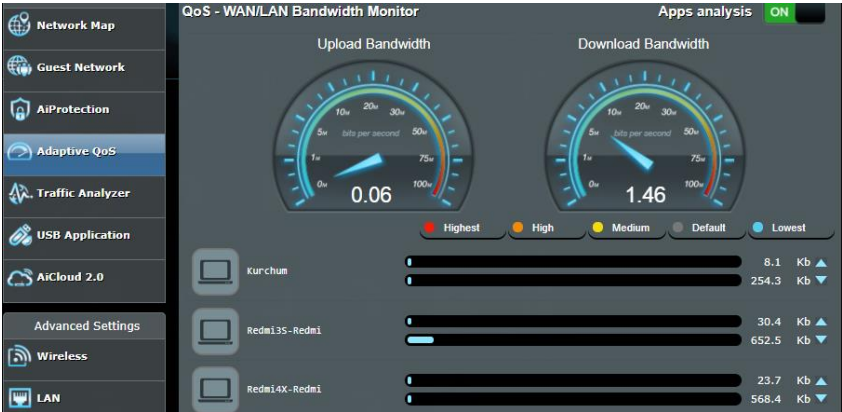


Figure 3.15 – QoS WAN/LAN Bandwidth monitor

Network Tools - function for automatic monitoring of Internet. Resources access is checked at regular intervals, in case of failure, warning will be displayed. There is an opportunity to monitor websites, servers, routers, surveillance systems and much more.

You can also specify interval and type of verification.

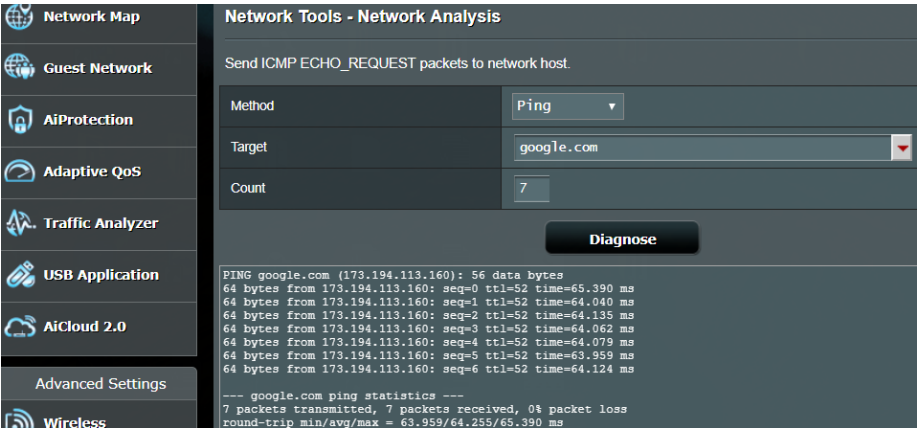


Figure 3.16 – Network tools

With this function it can track a history of browser

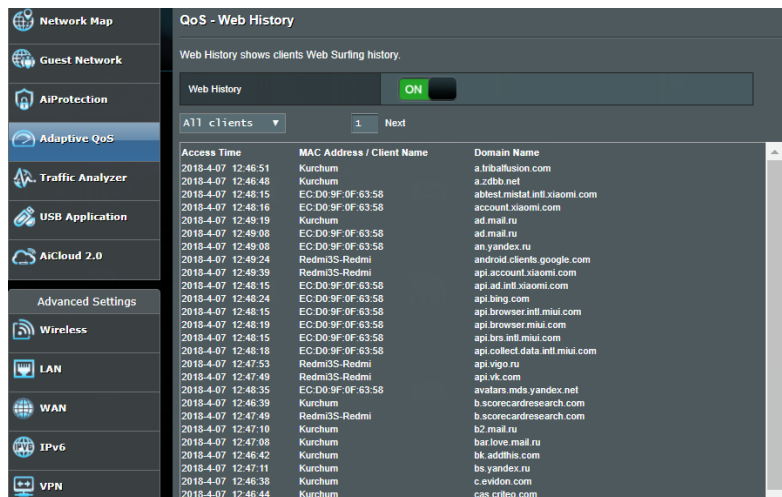


Figure 3.17 – QoS Web history

Firewall filters packet traffic coming from an external network with respect to a given local network or computer. By other words it protects your computer from all kinds of Internet scams

Purpose of Firewall - to ensure the safety: do not skip the computer viruses, spam, hackers or other evil actions. Firewall can monitor incoming and outgoing traffic and block advertising.

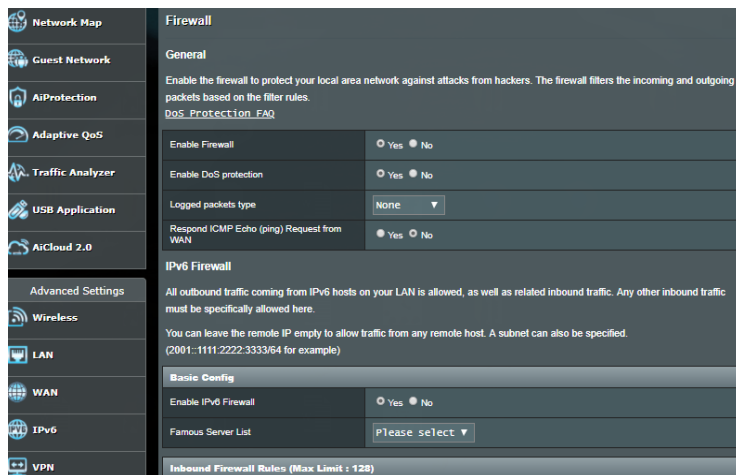


Figure 3.18 – Firewall settings

ASUS RT-AC3200 router has external USB disk. A storage device that uses flash memory as a storage and connected to a computer or other reader via USB interface. USB flash drives are usually removable and rewritable, and physically much smaller than an optical disk. USB drives are often used for the same purposes for storing, backing up data and transferring computer files. In our cause we saved setting configurations



Figure 3.19 – External USB disk status

FTP (File Transfer Protocol) - standard protocol used to transfer files over TCP networks (for example, Internet). This protocol based on a client-server architecture and uses different network connections to transfer commands and data between client and server. FTP users can be authenticated by passing username and password in open text, or if server allowed, It can connect anonymously. The main function of FTP is file transfer.

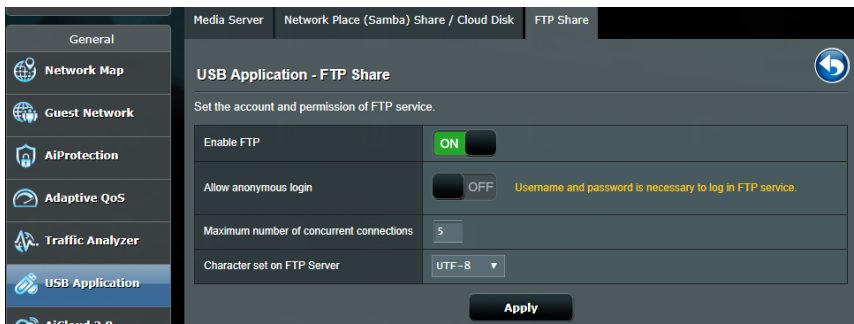


Figure 3.20 – FTP sharing settings

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания
Отформатировано: По центру

Chose labor Internship and became file transferring. [Remote file sharing connection using Windows Explorer](#)

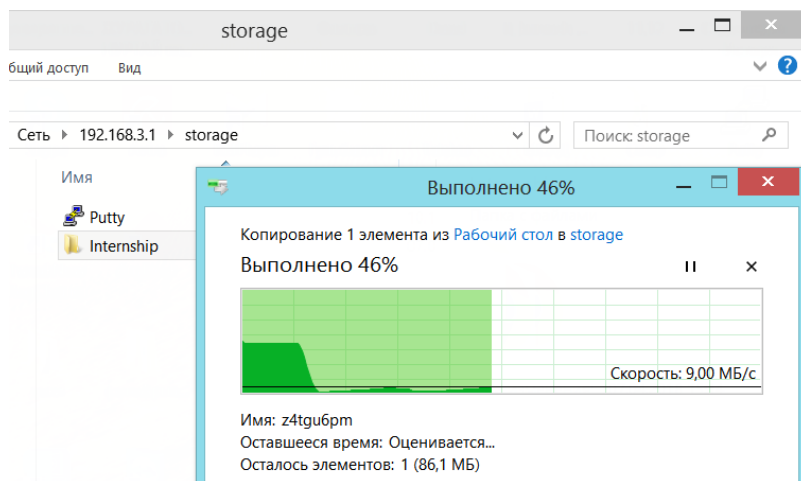


Figure 3.21 – [Remote FTP file sharing process part #1 connection](#)

For entering to server you need to fill authorization form, by other words, pass authentication. After entering user name and password is transferred to the system. If it is accepted, client will receive an invitation and work session will open.

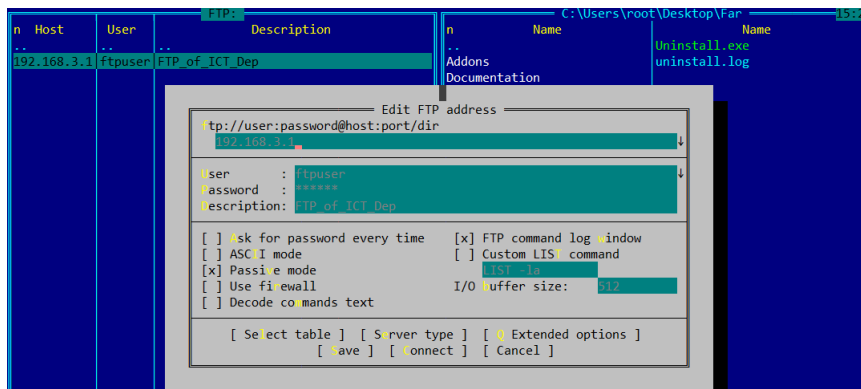


Figure 3.22 – [Remote connection via FTP process protocol part №1](#)

In addition to uploading and uploading information, various commands are available too:

- authentication is required.

Отформатировано: По центру

Отформатировано: английский (США)

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

- presence of a dedicated channel for each connection.
- support 2 modes of data transfer: text and binary (in binary system). The second option reduces time and traffic.
- control commands are sent through one and processed responses are returned. File transfer is performed at the rate of dedicated channel for each.

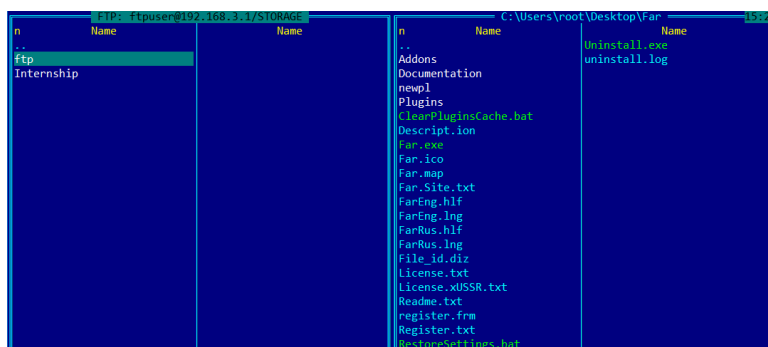
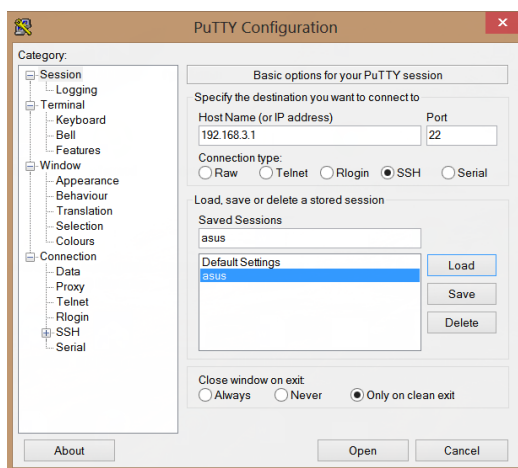


Figure 3.23 – Remote connection via FTP protocol part Remote-FTP-process-part №2

Отформатировано: английский (США)

One of configuration that also tested was remote access with SSH protocol. SSH is a network protocol that allows you to manage a remote computer through the command shell. It allows to securely transfer almost any other network protocol in an unprotected environment. Thus, can not only remotely operate with computer through the command shell, but also transmit an encrypted channel audio stream or video. PuTTY allows to connect and manage a remote host (for example, a server). Only client side of connection is implemented there.



Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

Figure 3.24 – Putty configuration

After launching Putty utility, the main window for working with program was appeared. For specify server to which we connected and named of session. Login and password for SSH access are identical to login and password for FTP. Connected to server via SSH protocol and could enter commands and interact with server. It can be used SSH protocol for secure transmission, hiding (encrypting) your login and password, as well as encrypting content

```
login as: admin
admin@192.168.3.1's password:
admin@RT-AC3200:/tmp/home/root# cd /
admin@RT-AC3200:/# ls
asus_jffs  dev      lib      opt      sbin     usr
bin        etc      media    proc     sys      var
cifs1     home     mmc      rom      sysroot  www
cifs2     jffs     mnt      root     tmp

admin@RT-AC3200:/# df -h
Filesystem      Size      Used Available Use% Mounted on
/dev/root        39.3M      39.3M      0 100% /
devtmpfs        124.6M      0      124.6M   0% /dev
tmpfs           124.7M      1.0M      123.7M   1% /tmp
/dev/mtdblock4   64.0M      2.0M      62.0M    3% /jffs

admin@RT-AC3200:/# route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.2.39    *               255.255.255.255 UH    0      0      0 eth0
192.168.3.0     *               255.255.255.0   U     0      0      0 br0
192.168.2.0     *               255.255.255.0   U     0      0      0 eth0
127.0.0.0       *               255.0.0.0       U     0      0      0 lo
default         192.168.2.39    0.0.0.0         UG    0      0      0 eth0
admin@RT-AC3200:/#
```

Figure 3.25 – Putty process part #№1

Than we peeing google.com

```
admin@RT-AC3200:/# ping google.com
PING google.com (173.194.44.67): 56 data bytes
64 bytes from 173.194.44.67: seq=0 ttl=51 time=65.472 ms
64 bytes from 173.194.44.67: seq=1 ttl=51 time=64.159 ms
64 bytes from 173.194.44.67: seq=2 ttl=51 time=64.237 ms
64 bytes from 173.194.44.67: seq=3 ttl=51 time=64.212 ms
^C
--- google.com ping statistics ---
4 packets transmitted, 4 packets received, 0% packet loss
round-trip min/avg/max = 64.159/64.520/65.472 ms

admin@RT-AC3200:/# traceroute aipet.kz
traceroute to aipet.kz (212.154.158.28), 30 hops max, 38 byte packets
 1 192.168.2.39 (192.168.2.39)  0.952 ms  0.735 ms  0.715 ms
 2 192.168.53.1 (192.168.53.1)  2.220 ms  2.266 ms  1.894 ms
 3 * * *
 4 * * *
 5 * * *
 6 * * *
 7 *
```

Figure 3.26 – Putty process part #№2

Отформатировано: английский (США)

Отформатировано: английский (США)
Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания
Отформатировано: По центру

Wi-Fi-networks inspection and a card of department coverage made by them By virtue of utility Ekahau HeatMapper made.

For HeatMapper working installed an additional protocol Ekahau NDIS Usermode I/O Protocol into network connection.

There are following advantages of this application:

- Can see Wi-Fi coverage on map
- Find all access points
- Find available networks
- Detect security settings
- Supports 802.11n,
- Works on virtually any Windows laptops
- Free of charge

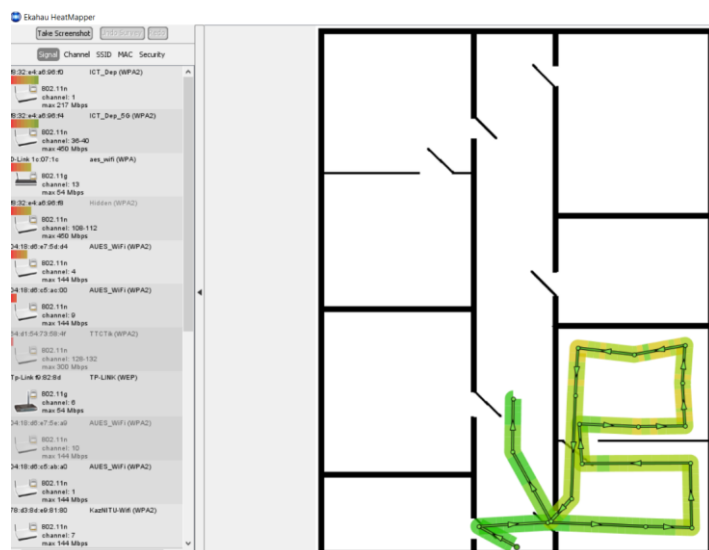


Figure 3.27 – HeatMap processing №1

Taking the laptop we slowly passed all points of department's rooms and marked them on HeatMapper plan. Each access point signal features and details displayed on the left side of program list. Signal levels were displayed in real time. Access points can be sorted by SSID name, MAC address, signal strength.

Добавлено примечание ([Office19]): эта картинка никакого отношения к putty не имеет

Отформатировано: английский (США)

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру



Figure 3.28 – HeatMap processing №2

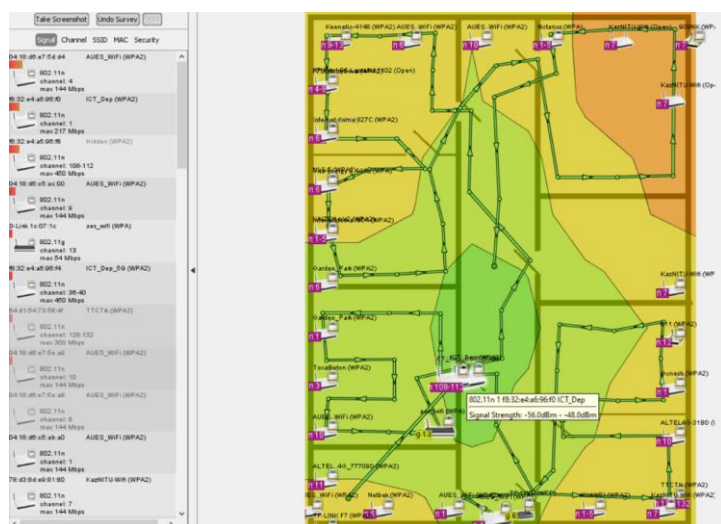
After passing perimeter, HeatMapper displayed a map of combined coverage of all Wi-Fi network access points. It can be also viewed a coverage for each access point. In addition, HeatMapper can display location of insecure network if they exist.

There we can see a coverage area of Wi-Fi with 2.4GHz bandwidth which created on ASUS RT-AC3200 router. Access point with 2.4 GHz has powerful signal.

Добавлено примечание ([Office20]): эта картинка никакого отношения к putty не имеет

Добавлено примечание ([Office21]): у вас все плохо с названиями рисунков

Отформатировано: английский (США)



Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

Figure 3.29 – Heatmap of 2.4 GHz Wi-Fi network

Difference between heat map of Wi-Fi 5GHz and heat map of Wi-Fi 5_GHz is a signal coverage area. It happened because of higher frequency of Wi-Fi network. 2.4 frequency range has more coverage area: ~~but it Wi-Fi network with 2.4 GHz has less ability passes through walls, so 5 GHz is better suited for signal transmission over long distances.~~

Добавлено примечание ([Office22]): вы все перепутали.
2.4 имеет большее покрытие



Figure 3.29 – Heatmap of 5 GHz Wi-Fi network

Wi-Fi of ICT department works only at the 2.4 GHz range. D-Link DI-524 Wireless router has 56 Mb/s speed. Compatible with 802.11g/b networks. Also it has security controls and advanced firewall. Built-in 4-Port Switch operating range of up to 99m indoors, up to 399m outdoors.

Отформатировано: Отступ: Слева: 0 см, Первая строка: 1,25 см

Добавлено примечание ([Office23]): у нас не принято измерять расстояние в футах
переведите в метры

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

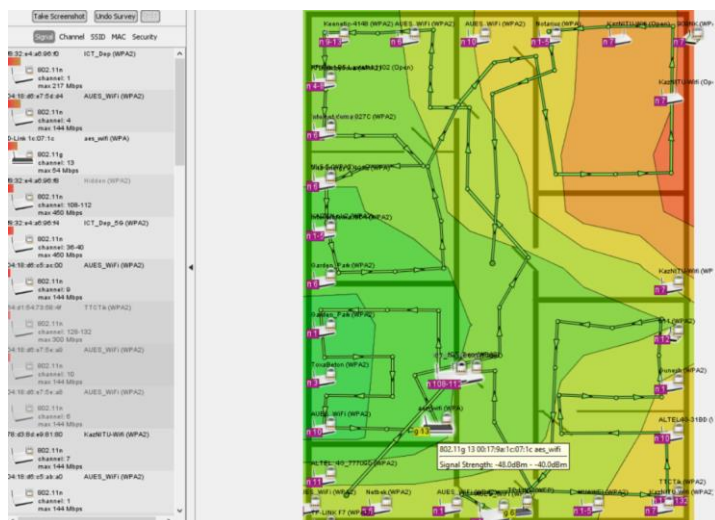


Figure 3.30 – Heatmap of AES Wi-Fi network

3.4 Technical parameters calculations

Energy calculation of Wi-Fi radio link connection (radio access points)

Interrelation of electromagnetic field parameters at receiving point and signal level in input of receiver.

Initial data:

- Receiver sensitivity - 82dB
- Radiation power - 17dBmW
- Antenna gain - 3 dB
- Operating frequency - 2.5 GHz, 5 GHz

Power of received signal is determined by the formula:

$$P_{in} = U_{in}^2 \frac{1}{R_{in}} \quad (3.1)$$

Take U_{in} as equal to the sensitivity of the receiver $U_{in} = -82$ dBm

$$U_{in} = 10^{\frac{-82}{10}} = 0,079B$$

R_{in} - Typical value of input resistance of access point, 50 Ohms

Let's substitute values in Formula 3.1

$$P_{in} = \frac{79^2 \cdot 10^{-8}}{50} = 124,8 \cdot 10^{-6} (-39,037 \text{ dBmW})$$

Отформатировано: интервал Перед: 6 пт, после: 6 пт

Отформатировано: Шрифт: не полужирный

Отформатировано: Шрифт: (по умолчанию) Times New Roman, 14 пт, Проверка правописания

Отформатировано: По центру

Losses in the antenna-feeder path

$$L_f = 0,5 \text{ dB (1,12)}$$

Power level of useful signal at output of receiving system

$$P_{\alpha} = P_{in} - L_f \quad (3.2)$$

$$P_{\alpha} = -39,037 - 0,5 = -39,537 \text{ (dBmW)}$$

Effective area of receiving antenna opening

$$S_{ef} = \frac{G_a \cdot \lambda^2}{4 \pi}, \quad (3.3)$$

where G_a is gain of antenna

$$G_a = 3 \text{ dB } G_a = 10^{\frac{3}{10}} = 1,995$$

λ is determined by Formula (3.4)

$$\lambda = \frac{c}{f} = \frac{3 \cdot 10^8}{2,45 \cdot 10^9} = 0,122 \text{ m} \quad (3.4)$$

Let's substitute value into Formula 3.3

$$S_{ef} = \frac{1,995 \cdot 0,122^2}{4 \cdot 3,14} = 0,0024 \text{ m}^2$$

Effective value of strength field at receiving point determines by Formula 3.5

$$E = \frac{P_a \cdot 480 \cdot \pi^2}{G_a \cdot \lambda^2} \quad (3.5)$$

$$E = \sqrt{\frac{125,92 \cdot 10^{-6} \cdot 480 \cdot 3,14^2}{1,995 \cdot 0,122^2}} = 4,434 \text{ W/m}$$

The current antenna height

$$h = \frac{\lambda}{2 \pi} \sqrt{\frac{G_a}{120 \cdot L_{ef}}} R_{in} \quad (3.6)$$

$$h = \frac{0,122}{6,28} \sqrt{\frac{1,995 \cdot 50}{120 \cdot 1,12}} = 0,017 \text{ m}$$

Calculation of sensitivity of access point receiver

Minimum allowable signal level at receiver input is defined as

$$P_{pr} = P_n + E_b/N_o + G_{pr} \quad (3.7)$$

where $(E_b/N_o)_{req}$ is value of E_b/N_o :

G_{pr} - gain from processing.

P_n - power of receiver's own noise.

The main parameters used in calculation:

E_b/N_o is ratio of average energy of bit spectral noise density. The required ratio E_b/N_o depends on type of service, movement speed of subscriber and radio channel.

Minimum allowable signal level at receiver input depends on required E_b/N_o ratio, user data rate, quality of analog components of receiver, interference level. Interference can be caused by different sources: subscribers from serving cell, subscribers served by other cells, as well as other sources creating operating in range used frequency channel.

Power of receiver's own noises:

$$P_n = N + K_n \quad (3.8)$$

where N – thermal noise power in receiver, dBmW

$$N = k \cdot T \cdot B, \quad (3.9)$$

where k - the Boltzmann constant ($1.38 \cdot 10^{-23}$ J/K),
 T - conductor temperature.

Power of thermal noise in receiver depends on filter bandwidth. The band of matched filter can be taken equal to 3,84 MHz.

Receiver noise factor $K_n = 6$ dB

Let's determine receiver sensitivity P_r (dBm), if conductor temperature T° , receiver noise factor K_n , (dB), receiver matched filter band B (MHz), ratio of average bit energy to noise spectral density E_b/N_o (dB), gain processing G_{pr} (dB) are known.

$T = 40^\circ$, $B = 40$ MHz, $K_n = 6$ dB, $G_{pr} = 2.8$ dB.

Accept $E_b/N_o = 14$ dB.

Substitute initial data into Formula 3.9

$$N = k \cdot T \cdot B = 1.38 \cdot 10^{-23} \cdot 313 \cdot 40 \cdot 10^6 = 1,72 \cdot 10^{-13} W.$$

Let's transform it in dBm value

$$N = 10 \cdot \log(1.72 \cdot 10^{-13} / 0.001) = -97,6 \text{ dBmW}.$$

Power of receiver's own noise:

$$P_m = -97,6 + 6 = -91,6 \text{ dB}.$$

Receiver sensitivity:

$$P_r = -92,6 + 11 - 3,8 = -85,4 \text{ dB}.$$

Which corresponds to technical specifications of access point

Maximum permissible losses:

$$L_{Maxl} = P_{EIRP} - S_{Rx} + G_{RxA} - L_{RxF} - M_{Build} - M_{int} - M_{shade} + G_{HO}, (3.10)$$

where P_{EIRP} – Effective isotropically radiated power of transmitter, dB;

S_{Rx} – receiver sensitivity, dB;

G_{RxA} – antenna gain, dBi;

L_{RxF} – feeder path loss, dB;

M_{Build} – penetration reserve, dB;

M_{int} – inter-system interference margin, dB;

M_{shade} – stock of shading, dB;

G_{HO} – gain from processing, dB.

Stock for allowable intersystem interference.

Calculation uses amount of reserve for intra-system interference, which characterizes increase in noise power at receiver input. For calculation, assumed margin for inter-system interference is:

$$M_{int} = -10 \cdot \log_{10}(1 - \eta), (3.11)$$

where η - relative cell loading in ascending or descending line.

As can be seen, margin for intra-system interference is a function of cell load, higher the allowed load in cell, larger amount of stock needs to be taken into account in calculation. If load increases to 100%, interference margin tends to infinity and cell service area decreases to zero.

Limiting power management or margin for fast fading.

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The fast power control algorithm is introduced in order to maintain desired E_b/N_0 at receiver input constant during fast fading due to multipath. Depth of fading can reach up to 30 dB. Rapid power management is especially important for subscribers with a low speed of movement, as they can not quickly change their position to compensate for deep fading. At cell border, transmitter power of mobile station is maximum, thus there is no reserve for power control to compensate for fast fading.

To calculate the maximum permissible losses of L_{MARL} in Wi-Fi network,

If transmitter EIRP is known - $P_{EIRP} = 25$ dB, receiver sensitivity $S_{RX} = -83$ dB, antenna gain $G_{RXA} = 10$ dBi, loss in the feeder path is $L_{RXF} = 0.3$ dB, penetration into room - $M_{Build} = 19$ dB, margin for shadowing - $M_{shade} = 8$ dB, gain processing - $G_{HO} = 3$ dB, zone load - $\eta = 0.7$.

Typical values of the stock of penetration:

- 22 dB in conditions of dense urban development;
- 17 dB in conditions of average urban development;
- 12 dB in conditions of rare building (in the suburbs);
- 8 dB in countryside (at open area in car).

$P_{EIRP} = 25$ dB, $S_{RX} = -97.6$ dB, $G_{RXA} = 14$ dB, $L_{RXF} = 0.3$ dB, $\eta = 0.7$, $M_{Build} = 19$ dB,

Define the margin for interference M_{int} , dB by Formula 3.11

$$M_{int} = -10 \cdot \log_{10}(1 - \eta) = -10 \lg(1 - \eta) = -10 \lg 0.3 = 5.23 \text{ dB}$$

Maximum Allowable Loss

$$L_{Maxl} = 25 + 80.4 + 14 - 0.3 - 9 - 19 - 9 + 2.9 = 85.$$

It corresponds to the technical specifications of access point

Calculation of the Fresnel zone

The radio wave propagates in space occupies a volume in the ellipsoid form of revolution with a maximum radius in middle of the span, which is called Fresnel zone Figure 3.31. Natural (earth, hills, trees) and artificial (buildings, pillars) obstacles that fall into this space weaken the signal.

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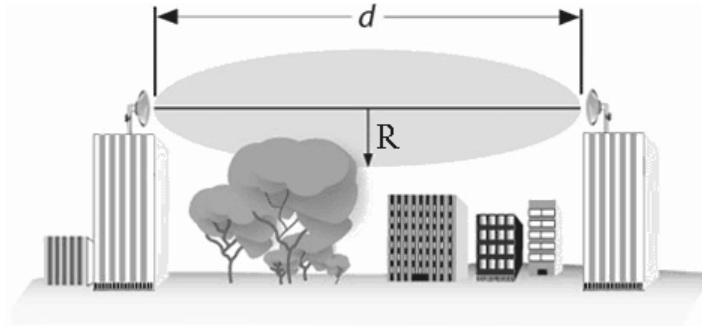


Figure 3.32 – Fresnel zone

Radius of the first Fresnel zone in widest part can be calculated using formula (3.12):

$$R = \sqrt{\frac{cSD}{f(S+D)}} \quad (3.12)$$

where R – radius of Fresnel zone (m);

S and D – a distance from the antennas to the measured area (m);

f – frequency (Hz);

c – speed of light (m/s).

For measures, let's consider a signal antenna to people user devices. The first calculation will be for Wi-Fi network with 2.4 GHz

$$R = \sqrt{\frac{3 \cdot 10^8 \cdot 6 \cdot 4}{2.4 \cdot 10^9(6 + 4)}} = 0.55m$$

The second calculation will be for Wi-Fi network with 5 GHz

$$R = \sqrt{\frac{3 \cdot 10^8 \cdot 6 \cdot 4}{5 \cdot 10^9(6 + 4)}} = 0.37m$$

Typically, blocking 20% of Fresnel zone introduces a slight attenuation into the channel. Over 40% signal attenuation will already be significant, avoid obstacles in propagation path.

This calculations is made on assumption that the earth is straight. It does not take into account curvature of the earth's surface. For extended channels, a cumulative calculation should be carried out, taking into account the terrain and

natural obstacles on the path of propagation. In case of large distances between antennas, one should try to increase the height of antenna suspension, taking into account curvature of the earth's surface.

4 Life safety part

4.1 Analysis of working conditions

This chapter describes the main harmful factors with computer working. According to sanitary and epidemiological requirements for working conditions.

At cold periods of year:

- the optimum temperature is from 22 to 24 °C, a permissible temperature is 18-26 °C;

- speed of air movement permissible and relative - 0,1 m/s;

- relative humidity from 40 to 60%, permissible humidity is 75%;

Warm periods of year

- relative humidity from 40 to 60%, and permissible humidity 55%;

- optimum temperature from 23 to 25 °C, a permissible temperature is 20-30°C;

- air speed is relative to 0,1 meters per second, and the allowable speed is 0,1-0,2 m/s.

Above stated norms of industrial microclimate correspond to the climatic conditions at workplace. Job with computer equipment can be exposed to such dangerous and harmful production factors as: electromagnetic radiation, static voltage, electric shock, insufficient illumination of workplace, air lower ionization etc. These harmful production factors can affect to health. Computer technology is a potential source of electric shock and fire hazard.

Measures to ensure fire safety with a personal computer include: a correct placement of equipment and electrical cables. At preventive measures form, it is necessary to use a hidden electrical network, reliable outlets, calculate a network load and comply with fire safety rules. You should also clean internal parts of the equipment from dust. To prevent sparking, do not disturb plugs from the sockets often. Computers' work create electrostatic fields, in action zone of the most diverse objects fall. During operation, electrified dust particles are blown outward, which settle not only on our skin, but also in the airways. Monitor screen is a store of static electricity charges. Static electricity effect on human body is poorly understood area. Most researchers believe that static electricity per person exposed a nerve endings of skin and irritated. A change of ionic composition of tissues also occurs. In case if you turn on a display on a cathode-ray tube creates a high voltage of several kilovolts. Therefore, it is forbidden to touch the back of display, wipe a computer dust.

Don't work on computer in wet clothes and wet hands. Before work starting, make sure that there are no wires which hang from table or hang under table, plugs and power wires, in a visible damage absence of equipment and working furniture or damage absence and grounding presence of a pre-screen filter. Static electricity

currents induced during computer operation at monitor, system and keyboard housings. They can lead to discharges by touching these elements. Such ranks danger for humans do not represent, but can lead to the computer failure. To reduce static electricity values, neutralizers, local and general air humidification use a floor covering with antistatic impregnation.

There are many measures against electrical shock. One of them is protective grounding. Protective grounding - deliberately electrical grounding with earth or its equivalent of metal non-conductive parts, which may be energized due to enclosure and other reasons. Measures to protect from static electricity should include: wet cleaning, additional air humidification in working rooms (relative humidity should be more than 50%), aeration of room, grounding equipment. Along with electrical hazards, there is also be electromagnetic effect of PC user. As protective measures from the electromagnetic radiation of computer, it is necessary to call systematic walks in the fresh air, airing the room, physical exercises, observance of working rules with a computer, choosing and using good technology that provides safety standards and sanitary norms.

Level of PC noise is depends on own capacity. Noise has property of causing acoustic irritation. A person subjected to systematic noise exposure quickly becomes tired irritable and forgetful. Sources of PC noise can be a system unit, cooling systems of device, processor, as well as CD or DVD-drives. It is necessary to take breaks. Light should not be bright, the best option for job with modern PC is diffuse muted light. The location of computer relative to window is important. Computer should be positioned where light from window does not fall directly to person. To avoid this, you should buy blinds or thick curtains, which will protect from direct sunlight. Also to prevent eye fatigue, it is necessary to ensure uniform illumination of workplace.

At daytime, lighting should be as natural as possible, and in dark - lights are needed to get necessary illumination. An important factor of job with computers is illumination, which is determined by network and color conditions. Luminaire projection should not be on monitor screen, for this purpose it is necessary to place screen in protective angle zone. It is recommended to place fluorescent lamps on the ceiling, in rows, which will do general lighting functions. This is one of the main safety measures for building lighting. The following types of lighting, provide a safe using of computer facilities. Fluorescent lighting, monitors are located around perimeter or at two rows along the length of the room with screens with a central location of workplaces facing in opposite directions.

Combined lighting (artificial + natural), workplaces are located in one and three rows, where a working table surface and monitor are perpendicular to the light-bearing wall. Workstations must be a row along room length with a distance 0,9 – 1,0 m from wall with open window and computer's monitors are perpendicular to this wall, is natural lighting. The main stream of natural light in such situations should be on the left. Direction of the main natural light flux behind, have to from the front side and from the right side of working computer. Addition to harmful and dangerous factors described above is that affect of the PC user during

operation, it is necessary to note other harmful factors provoked by incorrect organization of work with computer.

Workplace organization should give maximum attention, because health of user depends on this. Sitting work is harmful to humans. Long staying in one position forces muscles to work continuously without rest. Mobility lack is a major problem for PC users and programmers. With a decrease in physical activity caused by prolonged sitting, a disease risk like obesity and osteochondrosis increases. If a person works with computer sits in the wrong posture, slouches or leans forward, his back will deform and spinal discs will injure.

Psychophysiological dangerous and harmful factors described above are divided by action nature into:

- **p**Physical (static and dynamic);
- **n**Neuropsychiatric (mental overstrain, overstrain of analyzers, monotony of work and emotional overloads).

PC users and information system developers are most susceptible to an influence of static harmful factors (unchanged position of the body), overvoltage of analyzers (long time in front of computer monitor). It is necessary to properly organize a workplace, constantly computer posture and take breaks for rest and exercise. Proceeding from all the revealed harmful factors, it is necessary to allocate requirements for work organization at your computer:

- **i**n working rooms there should be both natural and artificial lighting;
- **a** room needs to be equipped with air conditioning or efficient ventilation; room should be ventilated every hour;
- **D**aily wet cleaning should be done in premises;
- **i**t is desirable to close windows with curtains or blinds, so that there are no direct hits of the sun's rays;
- **a**rtificial lighting should be general and uniform;
- **m**onitor, keyboard, computer's mouse, as well as documents, books, papers should be freely placed on the desktop;
- **c**hair should be adjustable in height and angle of inclination seat and backrest;
- **s**creen of monitor should be located at a distance at least 55 - 60 cm from your eyes, so it must be installed so that it does not reflect extraneous light. You should select the screen brightness correctly;
- **i**t is recommended to perform at least 2 times a day gymnastics for eyes;
- **a** correct hands position while working with keyboard and mouse: elbows are located parallel to the table surface and at a right angle of shoulder;
- **i**t is necessary to constantly monitor of body position at work process, that is, posture; the time of work directly behind a computer should not exceed six hours per shift;

During workday it is necessary to arrange breaks lasting 10-20 minutes, and perform exercise programs.

There is also such a measure of protection against electric shock, called grounding. Electric shock danger due to contact with accommodation and other

possible non-current metal parts of electrical equipment under tension due to closure and for other reasons can be eliminated by rapid disconnection of the damaged electrical installation from mains, at the same time, lowering a case voltage relative to the ground. This is target of grounding. Grounding is a deliberate electrical connection to the zero protective conductor of metal non-conductive parts, which may be energized. Grounding operation principle is a short circuit conversion in order to cause a high current capable of triggering protection and thereby automatically shutting down the damaged electrical installation from mains. Also there are various electrical protective devices against electric shock. Protective equipment can be conditionally divided into three groups: insulating, enclosing and protective. Isolating - isolate a person from current-carrying or grounded parts, as well as from grounding. They are divided into basic and additional.

Fire safety - is facility, in which the possibility of a fire is excluded, and in case of its occurrence, people are prevented from affecting its dangerous factors and protecting material values. Fire protection is a complex of organizational and technical measures aimed at ensuring the safety of people, preventing a fire, limiting its spread, and creating conditions for a successful fire extinguishing. Fire safety is provided by a fire prevention system and a fire protection system. All offices must have a "Plan for people evacuation in case of fire", regulating a personnel actions at an outbreak event and indicating the location of fire equipment. Fires in offices are particularly dangerous, as they involve great material losses. A characteristic feature of any office is the small areas of the premises. As is known, a fire can occur during flammable substances interaction, oxidizer and ignition sources. At the premises of department there are all three main factors necessary for fire occurrence. Ignition sources in the room can be electrical circuits from computers, appliances used for maintenance, power supply, air conditioning, where as a result of various violations formed overheated elements, electric sparks and arcs that can cause burning of combustible materials.

Modern computers have very high density arrangement of electronic circuits elements. Immediate vicinity of each other are the connecting wires, cables. An electric current flows through them, a considerable amount of heat is released. It is possible to reflow insulation. To remove computer excess heat ventilation and air conditioning systems. With constant action, these systems represent an additional fire hazard. For rooms with PC containing category has been assigned hazard B fire category.

One of the most important fire protection is building premises protection from destruction and ensuring their sufficient strength in exposure conditions to high temperatures during a fire. Considering the high cost of an electronic equipment of computer center, as well as fire danger category, buildings for computer center and building for other purposes where computer is intended for placement must be the first and second degree of fire resistance. For manufacture of building structures, as a rule, brick, reinforced concrete, glass, metal and other non-combustible materials are used. Wood using should be limited, and it must be impregnated with flame retardants. The important role is played by the workplace

planning. Workplace organizing necessary to take into account the data of human anthropometry. A person should easily access all documents, objects and devices in his work area. Furniture should be placed in such a way as to allow easy access to any part of the premises for cleaning work.

User workstation is a personal computer such as an IBM PC. Package includes:

- a system unit;
- monitor;
- keyboard;
- computer's mouse;
- printer;
- modem.

4.2 Working conditions in department

Analysis of premises:

- wWorking area is on the fourth floor;
- tType of premises: department;
- dDimensions of the room are $6 \times 4 \times 3$, respectively, length, width, height;
- Light sources: lamps - 2 pcs., in each of 2 fluorescent lamps;
- windows in the room two;
- tTo protect against excessive brightness of windows, blinds or curtains can

be used.

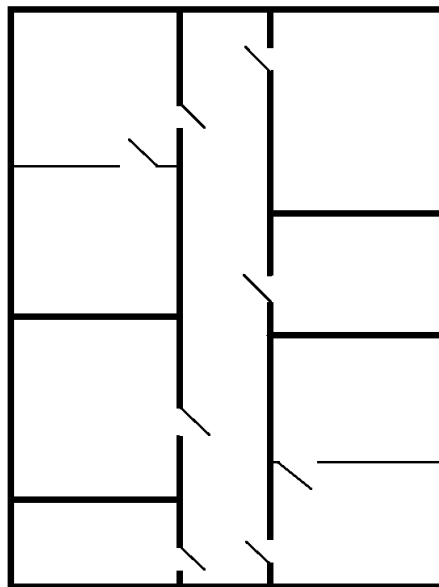


Figure 4.1- Layout of department

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Analysis of microclimate

Description of workplace:

- distance from the user's eyes to computer monitor is 50 - 60 cm;
- chair with a firm curved back, hugging a lower back;
- table for a personal computer has enough space to accommodate all necessary;
- design of table provides a necessary distance and viewing angle between display screen and eyes of person;
- room should maintain average temperature, low relative humidity. Norms of temperature, relative humidity and air speed are shown at Table 4.1;
- room size must satisfy the basic sanitary and technical requirements for location of the main equipment, and also provide for possible space for wires, passageways, maintenance and repair of equipment. One workplace should account for not less than 15 m of production volume premises and not less than 4,5 m² of area;

Norms of temperature, relative humidity and speed of air movement in the working area of the laboratory VC Ambient temperature Optimal parameters air showed at Table 4.1

Table 4.1 – Optimal parameters of air environment.

Ambient temperature	Optimal parameters of air environment at workplaces		
	Temperature, °C	Relative humidity, %	Speed of air movement, no more than m/s
Lower +10°C	20-22	40-60	0,1
Higher +10°C	22-25	40-60	0,3

4.3 Calculation of room lighting system

Calculation of daylight

One of the most important hygienic indicators of workplace is the illumination of room. Work area or workplace is illuminated to such an extent you can clearly see work process without straining your eyesight and avoid direct exposure light source to eyes. The main task of lighting calculations is to determine light holes in required area and a power consumption of artificial lighting. Daylight does not provide the necessary lighting during the whole working day due to changing of day time or weather changes, therefore, a lighting system consisting of luminaires with fluorescent lamps is provided.

Room measures: length L=6 m, width B=4 m, height H=3m. Height of working surface above floor level is $h_{ws}=0,75\text{m}$. Level of window starts $h_{lw}=0,7$

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m, height of the window $h_w = 1,5$ m. Department is located in the IV timezone - in Almaty (light climate belt - IV 50° south latitude (Almaty, Kazakhstan)).

Distance of workplace which located from outer wall of room is $l_w = 0,5$. The minimum illumination will be at a point 4 m from window opening. A total area of windows we define by formula 4.1:

$$S_o = \frac{S_n \cdot e_H \cdot \eta_o}{100 \cdot \tau_o \cdot \tau_1} \cdot k_s \cdot k_{of} \quad (4.1)$$

We express e_H from (4.1) in the new formula:

$$e_H = \frac{S_o \cdot 100 \cdot \tau_o \cdot \tau_1}{S_n \cdot k_s \cdot k_{of} \cdot \eta_o} \quad (4.2)$$

where S_n – square of the room, m^2 ;

k_s – safety factor;

$k_{of} = 1,2$ (for offices and administrative premises);

η_o – light characteristic of windows;

τ_o – a total light transmittance is calculated by formula 4.3:

$$S_n = 6 \cdot 4 = 24 \text{ m}^2$$

S_w is square of window in the room (the dimensions of window are 2,2x1,6), m^2

$$S_n = 2,2 \cdot 1,6 = 3,52 \text{ m}^2$$

Let's find τ_o

$$\tau_o = \tau_1 \cdot \tau_2 \cdot \tau_3 \cdot \tau_4 \quad (4.3)$$

where $\tau_1 = 0.5$ (hollow glass blocks);

$\tau_2 = 0,6$ (wooden double separate bindings);

$\tau_3 = 0,8$ (reinforced concrete trusses and arches);

$\tau_4 = 1$ (retractable adjustable blinds and curtains).

$$\tau_o = 0,5 \cdot 0,6 \cdot 0,8 \cdot 1 = 0,24$$

r_1 - a coefficient that takes into increase account in KEO side lighting due to light reflection from surfaces in the room and underlying layer adjacent to the building.

Average reflection coefficient in the room is $\rho_{av} = 0,5$, we take one-sided side lighting.

$$\frac{l_{pm}}{B} = \frac{0,5}{6} = 0,83 \quad (4.4)$$

Then $r_1 = 1.05$.

k_{sb} - coefficient that takes accounting for shading of windows opposing buildings.

There are no shading buildings nearby, then $k_{sb}=1$. We substitute all values in the calculation formula (4.2), we obtain:

$$e_H = \frac{2 \cdot 3,52 \cdot 100 \cdot 0,24 \cdot 1,05}{10 \cdot 1 \cdot 1,2 \cdot 30} = 0,5\%$$

A normal value of KEO is $e_H = 0.95\%$, and actual value of KEO is $e_H = 0.5\%$.

-This is mean that room does not comply with standards for lighting of work-area.

Thus, light apertures area does not provide a necessary working conditions in the workplace. In order to create the most favorable working conditions in a room with 6x4x3 parameters and to provide a normal value of KEO, $e_H = 0.95$ for the IV characterization of visual works, in conjunction with daylight, artificial lighting is used.

4.4 Calculation of noise and vibration.

Noise worsens working conditions, have a harmful effect on human body. Working in long-term exposure to noise, experiencing irritability, headaches, dizziness, memory loss, fatigue, loss of appetite, pain in the ears, etc. Such violations a variety of organs and human body systems, which can cause adverse changes in emotional state of a person before stress. Influence of noise, reduced concentration of attention, disturbed physiological functions, fatigue appears due to increased energy costs and mental stress, the speech function deteriorates. All this reduces the human performance and productivity, quality and safety of work. Prolonged exposure to intense noise (above 80 dB) per person results in partial or total hearing loss.

Table 4.2 indicates a maximum sound levels, depending on the severity category and work intensity, which are safe in terms of maintaining health and working capacity.

Table 4.2 – Limiting sound levels at workplaces, dB.

Category of labor intensity	Category of work severity			
	Lightweight	Average	Weighty	Heavyweight
Few tense	80	80	75	75
Moderately tense	70	70	65	65

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Tense	60	60	-	-
Highly tense	50	50	-	-

One of unfavorable environmental factors is the high level of noise created by printing devices, air conditioning equipment, fans, cooling systems in computers.

To eliminate it's need desirability of noise reduction and to know noise level at operator's site.

Noise arising due to several incoherent energy sources simultaneously is calculated on the basis of energy principle summation of individual radiation sources:

$$L_{\Sigma} = 10 \log \sum_{i=1}^{i=n} 10^{0,1 L_i} \quad (4.4)$$

where L_i - sound pressure level of the i-th noise source;
n- the number of noise sources.

The obtained results are compared with a permissible noise level at this workplace. If calculation results exceed the permissible noise levels, special measures should be taken to reduce the noise level. These include: facing walls and ceiling of hall with sound-absorbing materials, reducing a source noise, correct arrangement of equipment and rational organization of the operator's position.

Sound pressure levels of noise sources influent to operator at the workplace are presented in Table 4.3

Table 4.3 - Sound pressure levels in different sources

Source of noise	Noise level, dB
Hard disk	40
Fan	45
Monitor	17
Keyboard	10
Printer	45

Operator's workplace, is equipped with the following equipment: a hard disk in the system unit, a fan of PC cooling systems, a monitor, a keyboard, a printer and a scanner. Substituting sound pressure level values for each type of equipment into the formula, we get:

$$L_{\Sigma}=10 \cdot \lg(10^4 + 10^{4,5} + 10^{1,7} + 10^1 + 10^{4,5}) = 48,6 \text{ dB}$$

For different types of equipment, sound pressure level is equal to

$$L_{\Sigma} = 48,6 + \lg 2 = 51,6 \text{ dB}$$

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A received value exceeds a permissible noise level for the operator's workplace, equal to 50 dB. But if you consider that it is peripherals and printer will be used simultaneously, this figure will be lower. In addition, when printer is operating to presence of operator is not necessary, because printer is equipped with a mechanism for automatic feeding of sheets.

In accordance with State Standard 12.1.003-76, equivalent sound level does not need to exceed 50 dB. In order to achieve this noise level, it seems to use a sound-absorbing room.

Measures to reduce noise:

- lining a ceiling and walls with a sound-absorbing cloth (reduces noise on 6-8 db);
- screening of labor post (partitions setting, diaphragms);
- installation in computer rooms of equipment with generating the smallest noise;

4.5 Calculation of aspiration system

Technological conditioning systems are designed to provide air parameters (temperature, humidity and mobility) that lead a certain production requirements or technological process to maximum extent and ensure operation of radio electronic equipment, high-frequency machines, instruments, etc. Current air condition is necessary, especially a decisive condition for implementation the newest technological processes. Air conditioning importance increases year by year. Along with the food, textile and paper industries, the production of various electronic devices, precision engineering products, as well as the creation of a clean, sterile air environment with prescribed temperature and humidity conditions in the medical institutions, maintenance of special conditions for the storage of cultural and historical values, and much more.

Aspiration is designed to remove small dry particles from under the shelters of transport equipment and working area using the method of sucking them with the air flow (air is used as carrier medium) into the pipeline of the aspiration system, through which particles with air flow reach the destination (filter , a settler and collected in a container). To eliminate dust emissions, aspiration systems with a branched network of air ducts and gas cleaning equipment are used.

Installation and adjustment of aspiration units are carried out at enterprises for the storage and processing of grain products, brick factories, quarries, etc. products, brick factories, quarries, etc. Production processes are often accompanied by release of dusty elements or gases that pollute air in the room. This problem will be solved by aspiration systems. These devices remove industrial pollution by how appeared and contribute to effective air purification.

Air pollution is an inevitable part of many production processes. To maintain established sanitary standards of air purity used aspiration processes. It's possible to effectively remove dust, dirt, fibers and other similar impurities with aspiration devices. Aspiration is a suction, which is carried out by creating in the immediate vicinity of the source of contamination a region of low pressure. To create such

systems, you need serious special knowledge and practical experience. Although the work of aspiration means is closely related to ventilation systems functions, not every ventilation specialist will cope with a design and installation of this type of equipment. To achieve maximum efficiency, combined methods of ventilation and aspiration. Ventilation system production room must be supply and exhaust to ensure a constant supply of fresh air from the outside. Aspiration is widely used in such areas of industry as crushing, wood processing, manufacturing of consumer products and other processes, which are accompanied by the release of a large number of harmful substances for inhalation.

Ensuring the safety of employees with standard means of protection is not always possible, and aspiration can be the only way to establish a safe production process in shop. Removal impurities by means of this system type is carried out by means of special air ducts, which have a large inclination angle. This position prevents appearance of so-called stagnation zones.

Air conditioning system should provide favorable conditions. The equipment operation is very vulnerable to the slightest interference. It will be ineffective in conditions that do not follow at standards. These standards for air-conditioning system are prescribed in SNiP in Chapter 11-33-23 "Heating, ventilation and air conditioning" [17].

Let's calculate amount of heat released in the room during summer period. It depends on such factors as: heat generation of people in room, heat release from solar radiation, as well as artificial lighting and switching equipment. Air exchange of this apparent heat:

$$G_{ex} = \frac{Q_a}{c(t_{rt} - t_{st})} \text{ m}^3/\text{h} \quad (4.5)$$

where Q_a – a release of apparent heat, W;
 c - heat capacity of dry air;
 t_{rt} - removed air temperature from room to outside of service or working area, 20 °C;
 t_{st} - supply air temperature, 15 °C.

Calculation of the apparent heat released at using formula

$$Q_a = Q_1 + Q_2 + Q_3 + Q_4 \quad (4.6)$$

where Q_1 - heat dissipation from equipment;
 Q_2 - heat dissipation from light sources;
 Q_3 - heat dissipation from people;
 Q_4 - heat input from solar radiation through windows.

Calculate the heat dissipation from equipment:

$$Q_1 = \psi_1 \cdot (P_{pc} + P_{eq}) + \psi_2 \cdot P_{cond} = 0,9 \cdot (700 + 930) + 0,25 \cdot 1200 = 1767 \text{ W}, \quad (4.7)$$

where ψ_1 - load factor P_{pc} , P_{eq} (personal computer and equipment) is equal to 0,9;

P_{pc} - power of personal computer equal to 700 W;

P_{eq} - equipment power equal to 930 W;

P_{cond} - power of air conditioner 1200 W;

ψ_2 - load coefficient P_{cond} (conditioner) is equal to 0,25.

Then a heat dissipation from light sources:

$$Q_2 = \psi \cdot N_{pl} = 0,8 \cdot (8 \cdot 60) = 384 \text{ W} \quad (4.8)$$

where ψ - coefficient that accounting for amount of energy transferred into heat, $\psi = 0,8$;

N_{pl} - power of lighting installation of operator's room (8 lamps by 60 W each)

Heat dissipation from people:

$$Q_3 = n \cdot q = 32 \cdot 116 = 3712 \text{ W} \quad (4.9)$$

where n - a number of employees;

q - heat losses from one person, equal to 80 - 116 W.

Receipt of heat from solar radiation through the windows:

$$Q_4 = q \cdot F_{sw} \cdot m \cdot k = 3,3 \cdot 250 \cdot 2 \cdot 1,25 = 2063 \text{ W} \quad (4.10)$$

where F_{sw} - square of window, m^2 ;

m - number of windows;

k - the correction factor, $k = 1.25$;

q - heat input through 1 m^2 of window, $q = 250 \text{ W}/m^2$.

Calculation of apparent heat released. Let's substitute values to Formula(4.6):

$$Q_a = Q_1 + Q_2 + Q_3 + Q_4 = 1767 + 384 + 3712 + 2063 = 7926 \text{ W}$$

Calculate air exchange of apparent heat:

$$G_{ah} = \frac{7926}{1(20 - 15)} = 1585,2 \text{ m}^3/h$$

In summer period average temperature in Almaty is $T_{nor} = 30 \text{ }^\circ\text{C}$, this temperature is higher than temperature of room - $20 \text{ }^\circ\text{C}$. Consequently, heat loss is not observed: [18]. Despite this, there is heat input, which is release during cold

period of year. It appears from sources such as: personnel heat dissipation, heat generation equipment and artificial lighting, as well as heat from central heating batteries.

Heat stands out by the first 3 heat sources and does not change with warm period of time, calculations of heat amount are necessary, which is released only from central heating batteries.

The best option is air conditioning. Conditioner provides: air cooling; automatic maintenance of set temperature; air cleaning from dust; ventilation; removal of moisture from air; environment air exchange. For founding ventilation volume, we select air conditioner of split (cooling and heating) system with LG company model S30LH, its characteristics are given in the table

Table 4.4 - Specifications of LG S30LHP air conditioner

Air conditioner model	LG S30LHP
Power consumption, W	8900
Nominal air flow, m^3/h	1260
Serviced area, m^2	89
Overall dimensions, mm	349x1259x205

Conclusion: As a result of calculation done, we were convinced that requirements set by SNiP II-68-2005 provide all the standardized microclimate parameters in the room for telecommunications equipment.

The air conditioning and air exchanging was also calculated. Air conditioners parameters and their productivity were chosen.

In this work, we calculated daylighting and air conditioning. Illumination was calculated value of KEO $e_H = 0.5\%$. This is mean that room does not comply with standards for lighting of work area.

5 Economical Part

5.1 Business plan

In my diploma project I create 5 GHz Wi-Fi network with roaming for ICT department. At current stage of network development, Wi-Fi wireless technology is the most convenient in conditions requiring mobility. Needs for wireless connections is growing rapidly all over the world, especially in business sector. Users with wireless access to information - always and everywhere can work much more efficiently, tied to wired telephone and computer networks.

The business plan solutions considered solving such important tasks as department's office work automation with minimal expenses, significant reduction of costs for international and long distance negotiations, increase effectiveness of staff, to use information technologies for production process organizing, working with documentation and with any information in real time within geographically distributed organizational structures and working groups. [19]. Structuring the

enterprises processes in format of the proposed technologies leads to an improvement of information exchange quality with appropriate safeguards. All this ultimately can significantly increase customer loyalty and improve department's image.

5.2 Brief description of the project

The main goal of project is to choose right technological platforms and ways to implement wireless services at ICT department.

With advancement technology to boost demand for wireless communications, as it greatly increases a chances for many Internet users. WI-FI is mainly used where working on an electrical or cable plant Modern systems are expensive. In our cause we use ASUS RT-AC3200 router

Name of company ASUS came from word Pegasus (Pegasus) - so-called winged horse from ancient Greek mythology, symbolizing wisdom and knowledge, therefore ASUS brand embodies a power, spirit of creativity and purity of this being. Each new product, new heights are being conquered.

Over the past decades, Taiwanese information technology industry has experienced tremendous growth, pushing this country among leaders of the global market. They started with a motherboards manufacturer that developed a few number of employees, but now it has counted more than 17 thousand people around the world. ASUS produces products in almost all IT-related industries: computer components and peripherals, laptops, tablet computers, servers and smartphones, Wi-Fi routers.

ASUS pursues a desire for innovation. It's engaged in production:

- **P**ersonal computers, laptops, nettops, Internet tablets;
- **C**omputer components: motherboards, graphics cards, sound cards, optical drives, coolers;
- **C**omputer peripherals: monitors, external storage and optical drives, mouse;
- **m**obile phones, smartphones;
- **a** Asus routers.

Among the company's revolutionary products, it can be mentioned smartphone PadFone, which won audience at Computex 2011, as well as a hybrid mobile solutions TAICHI and Transformer Book that followed. Special place in rapid modern innovation takes development of wireless connection devices.

ASUS wireless routers provide a wide coverage of Wi-Fi network with a stable signal in every corner of house or apartment. However, this is influenced by many factors, including a layout of rooms, wall material and even furniture. By intelligently determining, it locates connected devices and router converts a weak omnidirectional signal into a strong unidirectional signal, which provides a higher data rate.

Innovation – secret of company's success among consumers, as well as among specialists who have noted ASUS products with a lot of enthusiastic reviews (4368 awards from specialized media and organizations in 2016 alone). According

to data for 2014, ASUS sells motherboards more than any other company, shipping to customers 22 million units in 2014, overtaking Gigabyte by 1 million units.

A continued development of brand is indicated by: every year ASUS increases notebook shipments, and company's revenue in 2017 amounted to 14 billion\$.

Aim purpose

- ~~i~~Improving customer service quality;
- ~~A~~ability to connect remote offices;
- ~~i~~Integration with external applications;
- ~~M~~inimization of costs for the lease of communication channels and administration;
- ~~b~~Building a highly efficient infrastructure for intra-office using;
- ~~a~~Automation of all department processes.

Project Implementation Strategy

Project implementation implies the following steps:

- ~~p~~Purchase of equipment;
- ~~i~~Installation works, adjustment and testing of equipment;
- ~~C~~ommissioning.

5.3 Investment plan of the project

Sales market

Currently, wireless communication is becoming more and more common. You can get from various wires, which at the same time expensive. In addition, it gives access for many Internet subscribers. Everyone can easily connect to network without spending a lot of time.

Wi-Fi technology is designed for short distances access and at the same time a sufficiently high speed. Among the most popular IEEE 802.11s. For data transmission, uses frequency range 2.4 to 5 GHz, the maximum speed is 11 megabits per second, while signal transmission distance is about 100 meters. Nevertheless, in open terrain you can achieve much higher values - up to 300-400 meters. This indicates that the wireless network can easily replace the normal 10 Mb of wired network.

5.4 Financial plan

Goal of this plan is to obtain maximum profit, with minimal costs and high quality of services provided, taking into account that price would be acceptable to users.

Below are calculations showing the cost of implementation, economic efficiency of use and payback period.

Capital expenditures

$$C = P + C_{tr} + C_{in} + C_{ec} \quad (5.1)$$

where P - Price for equipment purchase;

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C_{tr} - Cost of transportation to operation place;

C_{in} - Cost of device mounting;

C_{ec} - Cost of economy.

The following equipment will be needed to organize investigated wireless Wi-Fi network.

Table 5.1 – Cost of equipment

Name of equipment	Amount, pc	Cost, tg	Sum, tg
Switch GX-D1081 V2	6	90 500	543 000
AP ASUS EA-AC87	250	14 500	6 075 500
ASUS RT-AC3200 router	1	115 000	115 000
Server	1	1 450 000	1 450 000
Total			8183500

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Thus, price for equipment purchase is:

$$P = 8183500 \text{tg.}$$

Cost of transportation to operation place C_{tr} is 2% of system price:

$$= P \cdot 0,02 = 8183500 \cdot 0,02 = 163670 \text{tg.} \quad (5.2)$$

(5.2)

$$C_{tr} = P \cdot 0,02 = 8183500 \cdot 0,02 = 163670 \text{tg.}$$

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Cost of device mounting at place is 5% of system price:

$$C_m = P \cdot 0,05 = 8183500 \cdot 0,05 = 409175 \text{tg.} \quad (5.3)$$

$$= P \cdot 0,05 = 8183500 \cdot 0,05 = 409175 \text{tg.} \quad (5.2)$$

Cost of economy is 6% of system price:

$$C_{ec} = P \cdot 0,06 = 8183500 \cdot 0,06 = 491010 \text{tg.} \quad (5.4)$$

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$$= P \cdot 0,06 = 8183500 \cdot 0,06 = 491010 \text{ tg.} \quad (5.3)$$

Whence a capital costs are equal:

Let's substitute in Formula 5.1

$$C_{\text{cap}} = 8183500 + 163670 + 409175 + 491010 = 9247355 \text{ tg.}$$

Calculation of annual exploitation costs

Exploitation cost is determined by the formula

$$C_{\text{ex}} = SS + C_{\text{st}} + D + M + C_{\text{el}} + C_{\text{adm}} + C_{\text{adv}} \quad (5.54)$$

where SS - Basic and additional staff salaries.

C_{st} - Social tax;

D - Depreciation deductions;

M - Costs of materials and spare parts;

C_{el} - Electricity from production needs;

C_{adm} - Other administrative and operational costs;

C_{adv} - Cost of advertising.

For calculation of wages, we will take average monthly salaries of attendants, which we reduce to Table 5.2

Table 5.2 – Salary of attendants

Job title	Quantity, people	Monthly salary, tg	Annual salary, tg
System administrator	1	95 000	1140000
Engineer	1	75 000	900 000
Operator	1	55 000	660000
Total	3	430 000	2700000

Basic staff salary for year will be:

$$SS_{\text{bas}} = 2700000 \text{ tg.}$$

Annual wage bill includes additional wages (work on holidays, overtime, etc.) in amount of 20% of basic salary.

$$SS_{\text{add}} = SS_{\text{bas}} \cdot 0,2 = 2700000 \cdot 0,2 = 540000 \text{ tg.} \quad (5.6)$$

For calculation a wage fund, we should take into account bonuses for workers (15%):

$$W_f = SS_{\text{bas}} \cdot 0,15 = 2700000 \cdot 0,15 = 405000 \text{ tg.} \quad (5.7)$$

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Salary consists of basic and additional wages:

$$SS = SS_{\text{bas}} + SS_{\text{add}} + W_f = 2700000 + 540000 + 405000 = 3645000 \text{ tg.} \quad (5.8)$$

Social tax is 11% of total wage:

$$C_{\text{st}} = (SS - 0,1 \cdot SS) \cdot 0,11 = (3645000 - 364500) \cdot 0,11 = 360855 \text{ tg.} \quad (5.9)$$

Depreciation deductions are 15% of price:

$$D = P \cdot 0,15 = 8183500 \cdot 0,15 = 1227525 \text{ tg.} \quad (5.10)$$

Cost of materials and spare parts is 2% of switching equipment cost:

$$M = P \cdot 0,02 = 8183500 \cdot 0,02 = 163670 \text{ tg.} \quad (5.11)$$

Cost of electricity is calculated by following formula:

$$C_{\text{el}} = W \cdot T \cdot S \quad (5.12)$$

where W - Power consumption of stations, W = 3,6 kW;

T - Number of operation hours of equipment per year;

S - Cost of kilowatt-hour of electricity, S = 20,78tg / kWh.

Whence follows:

$$C_{\text{el}} = 3,6 \cdot 8760 \cdot 20,7 = 655318 \text{ tg.}$$

Cost of other expenses is 30% of annual wage fund:

$$C_{\text{adm}} = SS \cdot 0,3 = 810000 \text{ tg.} \quad (5.13)$$

Let's find Thus, exploitation cost using formula 5.5 will be:

$$= SS + D + M + C_{\text{st}} + C_{\text{el}} + C_{\text{adm}} \quad (5.6)$$

$$C_{\text{ex}} = 2700000 + 360855 + 332445 + 49746 + 655318 + 810000 = 538907 \text{ tg.}$$

Table 5.3 – Description of costs

Index	Amount, tenge	Density, %
Staff salaries	2700000	44
Social tax	1331667	21
Depreciation deductions	1227525	20
Cost of materials and spare parts	163670	2
Cost of electricity	655318	10

Cost of other expenses	810000	12
Total	5993100	100

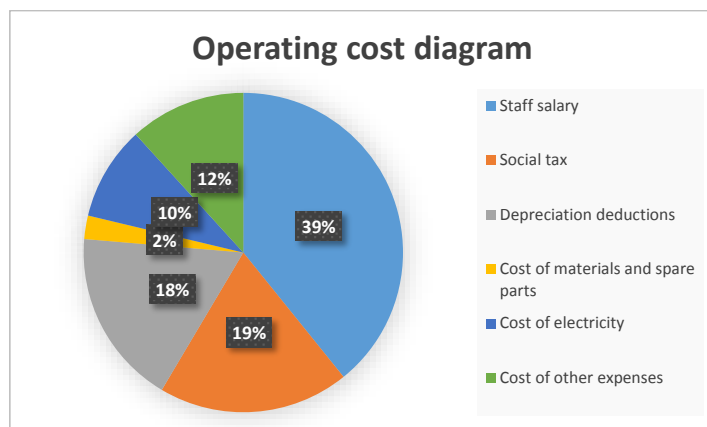


Figure 5.1 – Operating cost diagram.

Calculation of income from sale of services

This section describes a plan for obtaining funds for expansion, modernization of university and other projects. [20]

Revenue estimate will be:

- subscription fee.

Subscribers of network will be students and teachers who connect to service. Monthly fee composes 450 tenge. Subscriber numbers of campus is 20,000 people.

Suppose that 3000 people will be use a service. Monthly fee revenue will be calculated according to the formula:

$$R_f = 12 \cdot N \cdot C_{sf} \quad (5.714)$$

where N - Number of subscribers;

C_{sf} - The cost of subscription fee.

$$R = R_f = 12 \cdot 450 \cdot 3000 = 16200000 \text{ tg.}$$

Calculation of economic efficiency

Profit is a difference between proceeds from services sale and marketing service costs, a sum of operating production costs is:

$$P = P_{\text{proc}} - C_{\text{ex}} \quad (5.815)$$

Where proceed is 16200000 tg., exploitation costs are 5993100 tg.;

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$$P = 16200000 - 5993100 = 10206900 \text{ tg.}$$

Economic efficiency of production shows how much money enterprise annually returns from amount invested.

To calculate payback period, you need to know profitability value.

$$P_p = P \cdot 0,7 \quad (5.16)$$

$$P_p = 10206900 \cdot 0,7 = 7144830 \text{ tenge}$$

Accumulation fund (AF) consists of 70% of profit:

$$AF = P_p \cdot 0,7 \quad (5.179)$$

$$AF = 7144830 \cdot 0,7 = 5001381 \text{ tenge}$$

Expected net cash inflow:

$$ENCI = AF + A \quad (5.190)$$

$$ENCI = 5001381 + 332445 = 5333826 \text{ tenge}$$

Payback period is a value indicating for what time there period will be a funds return (capital investments) expended on organization of enterprise. Economic effect:

$$T_{pp} = \frac{C_{inc}}{ENCI} \quad (5.204)$$

$$T_{pp} = \frac{9247355}{5333826} = 1,7 \text{ year}$$

Thus, department invested in organization of broadband access network project for 1.7 years.

Calculation of economic efficiency, taking into account discounting

Estimated payback period is 1.7 years, in turn, is below normative payback period 5 years.

Money has a temporary value, it is necessary to take them into account in project calculations. A discount rate is $r_0 = 20\%$

The discount factor is calculated by the formula:

$$\alpha = \frac{1}{(1+r)^t} \quad (5.214)$$

where α - Discount factor;

r - Discount rate (0.20);

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t - Step number.

$$\alpha_1 = \frac{1}{(1 + 0,2)^1} = 0,83$$

$$\alpha_2 = \frac{1}{(1 + 0,2)^2} = 0,69$$

$$\alpha_3 = \frac{1}{(1 + 0,2)^3} = 0,58$$

$$\alpha_4 = \frac{1}{(1 + 0,2)^4} = 0,48$$

$$\alpha_5 = \frac{1}{(1 + 0,2)^5} = 0,40$$

Let forecast be made that investment will generate during the $t = 1, 2, \dots, n$ years, annual revenues in amount of $P_1, P_2, P_3, \dots, P_t$.
Amount of net present value (PV) is determined by the formula:

$$PV = \sum_{t=1}^{t=n} \frac{P_t}{(1+r)^t} \quad (5.4322)$$

where r - discount rate (20%)

1st year $PV = 5333826 \cdot 0,83 = 4427075$ tenge;
2nd year $PV = 5333826 \cdot 0,69 = 3680339$ tenge;
3rd year $PV = 5333826 \cdot 0,58 = 3093619$ tenge;
4th year $PV = 5333826 \cdot 0,48 = 2560236$ tenge;
5th year $PV = 5333826 \cdot 0,40 = 21335306$ tenge;

To determine economic efficiency of project, we calculate net present value of project. A net present value of project is determined by the formula:

$$NPV = \sum_{t=1}^n \frac{P_t}{(1+r)^t} - I \quad (5.4423)$$

where I - Sum of initial investment;
 r - Discount rate;
 n - A term of project (years);
 P_t - Cash flow in year t .

$$\sum_{t=1}^n \frac{P_t}{(1+r)^t} = 15894799 \text{ tenge}$$

$$NPV = 15894799 - 9247355 = 6647444 \text{ tenge}$$

$NPV > 0$, project is profitable and it should be accepted.

Profitability index is ratio of reduced effects sum to investment costs value.

Profitability index (PI) is calculated by the formula:

$$PI = \frac{\sum_{t=1}^n \frac{P_t}{(1+r)^t}}{IC} \quad (5.2415)$$

$$PI = \frac{15894799}{9247355} = 1,71$$

$$DPP = t + \frac{K - \sum_{t=1}^n PV}{PV_3} \quad (5.4625)$$

where t - A year for which capital investments will pay off;

PV_3 - Discounted income for 4 years.

In our case, instead of profit values, let's take a value of net profit taking into account discounting for two years. Given that calculation results without discounting, project will pay for 3.1 years, take $t = 2$:

$$DPP = 2 + \frac{9247355 - (4427075 + 3680339)}{3093619} = 2,36$$

It indicates it the evident why this project should be accepted, because profitability is more than one.

Table 5.4 – Estimation of economic efficiency

Indicators	Project period				
	1 year	2 year	3 year	4 year	5 year
Clean monetary flow (Pt), tenge	5333826				
Capital investments,tenge	9247355				
Rate of discount	0,20				
Discounting coefficient, α	0,83	0,69	0,58	0,48	0,40
Present value (PV), tg	4427075	3680339	3093619	2560236	21335306
NPV, tg	6647444				
Profitability index (PI)	1,7				

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Table 5.5 – Basic Design Indicators for CDMA

Name	Indicators
Capital investments, tg	9247355
Exploitation costs, tg	5993100

Отформатированная таблица

[Continuation of table 5.4.](#)

Income from activities, tg	16200000
Net income, tg	10206900
Expected net receipts, tg	5333826

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Table 5.5 – Basic Design Indicators from sale of services

Name	Indicators
Absolute economic efficiency	0,52
Payback period without discount, year	1,7
Payback period with discounting, year	2,36
NPV tenge	6647444

Отформатированная таблица

[5.4 Conclusion:](#)

Analizing calculation of economic indicators, we can say that for project implementation, a capital investment 8.35 million \$ is required. Amount of costs for year will be actual production cost or value of annual operating costs, and in our case, operating expenses amounted to 3.88 million tenge. The largest share in operating costs structure is earned wages - 59%. Net profit from introduction of network will be 5.3 million tenge. According to the calculation results, economic efficiency of project, with accounting time factor (discounting), indicates investment attractiveness of project, since the net discount for 5 years is more than zero and is 6.26 million tenge. A period of investment returning without discounting will be 1.8 years

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Conclusion

In the last decade of the twentieth century, wireless digital communications have entered a phase of rapid development, which continues to this day. The impetus for this was intensive global Internet network development and progressive methods of coding, modulation and transmission of information. Currently, wireless broadband networks are beyond competition for the speed of deployment, mobility, and possible applications breadth, only economically feasible solution, since wireless equipment of Wi-Fi mesh class has been developed.

This network is a combination of a cellular network in which nodes are located original radio routers with physical and MAC layers in accordance with the IEEE 802.11n standard and Wi-Fi access points, with equipment in accordance with the IEEE 802.11ac standard.

In my diploma project was reviewed 5 GHz Wi-Fi technology. This is a new innovation from the IEEE 802.11ac standard. It endows with a lot of advantages. The main of them are: high mobility and speed, ease of deployment equipment installation, network architecture flexibility, design and implementation. There are a lot of innovations with depend on creation and concerned with people. One of such people is Elon Musk with his project – SpaceX. In case of success in the near future our mankind will have a free access network for Internet via Wi-Fi in everywhere.

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Отформатировано: По центру

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