KAPITEL 2 / *CHAPTER 2* [2]
EQUIPMENT OF HOTEL AND RESTAURANT COMPLEXES WITH NETWORK EQUIPMENT

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Introduction

The exponential growth of mobile data traffic, the number of devices connected to the Internet, electromagnetic interference, new usage scenarios and user requirements are the main challenges for Wi-Fi networks. Wireless local area networks (Wi-Fi) meet the requirements for wireless connections for communication in buildings and offices. Today, around 15 billion devices are connected to Wi-Fi in the world. One of the drivers of the introduction of Wi-Fi for intra-office networks of the hotel and restaurant business was the fact that the equipment that works in these standards does not need to obtain a license. The advantages of wireless computer networks of 802.11 standards are their relatively high speed of information data exchange, easy and low network construction time, 24/7 access by network users, low cost and variety of equipment. Due to a significant number of advantages, wireless networks are widely used in the creation of WLAN in the buildings of hotel and restaurant complexes, for public Hot-Spot networks, for providing services to corporate users, etc. [1-3]

The work is devoted to increasing the efficiency of designing wireless computer networks for hotel and restaurant complexes based on an information system by reducing the levels of intra-system interference between receivers of neighboring cells and increasing the immunity of designed wireless computer networks to interference external to WLAN, which is relevant and economical justified direction of development of science and technology at the current stage. An analysis of the characteristics and principles of operation of wireless computer networks, EMC problems and methods of solving them was carried out, which made it possible to identify the "bottlenecks" of these technologies, which should be paid special attention during design: the problem of a hidden node; mutual interference between neighboring cells (intrasystem EMC); intersystem interference; providing QoS for responsible applications; wireless network expansion; the influence of the features of the area. [4-7]

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An algorithm for the operation of access mechanisms to the transmission medium has been developed; it is shown that accounting for intra-system and inter-system interference must be carried out at the early stages of designing wireless computer networks. Methods of designing wireless computer networks for hotel and restaurant complexes, which take into account EMC problems, have been developed; improved methods for calculating the total level of interference: a method that allows you to calculate the worst case in which the interfering signals add up to each other (simplified method); a method that allows you to take into account the difference in the phases of interfering signals that have arrived at the receptor. [8-12]

A calculation algorithm has been developed that allows modeling various dependencies that exist between WLAN parameters; the algorithms of the improved transmission medium reservation mechanism were developed, which allow to organize simultaneous operation in the same territory of several cells belonging to the same WLAN and using the same frequency channel. Calculation methods and algorithms have been improved, WLAN design methodology has been developed, which takes into account the influence of inter-system and intra-system interference. The proposed calculation methods and algorithms provide an opportunity to model dependencies connecting WLAN parameters and indicators of useful signals and interference in wireless network receptors. [12-15]

2.1. Analysis of the features of wireless computer networks of the 802.11 standard in the hotel and restaurant business

2.1.1. Analysis of wireless computer networks of the 802.11 standard

There are three main standardization bodies influencing the development of WLANs, the Wi-Fi Alliance, IEEE and ETSI.

The Institute of Electrical and Electronics Engineers (IEEE) is a non-profit professional association that, among other things, develops international standards such as the 802.11 standard for wireless LANs.

The Wi-Fi Alliance certifies WLAN devices manufactured according to IEEE-developed specifications for compatibility. Similarly to IEEE, the Wi-Fi Alliance is a non-profit international trade organization created by vendors and manufacturers.

The European Telecommunications Standards Institute (ETSI) is another non-profit organization established in 1988 to develop telecommunications standards for

Europe. As for the 802.11 WLAN standard, ETSI helped unite European countries around a common set of documents governing transmission. The working mechanisms and requirements for devices for wireless data transmission are described by the IEEE 802.11 standard, as well as its later extensions - IEEE 802.11a, IEEE 802.11b, IEEE 802.11g. The standard regulates frequency ranges, transmission speeds, information encoding methods and other technological characteristics of network operation. The main difference between the extensions of standards a, b and g is the physical level. The main purpose of the physical layers of the 802.11 standard is to provide wireless transmission mechanisms for the MAC sublayer, as well as support the performance of secondary functions, such as evaluating the state of the wireless transmission environment and reporting it to the MAC sublayer. The 802.11 set of standards defines a number of physical layer implementation technologies that can be used by the 802.11 MAC sublayer. The IEEE Institute is also working on the creation of new communication protocol specifications in wireless computer networks (WLAN). Due to the simultaneous use of several frequency channels, the devices of the 802.11n, ac, ax standards work several times faster (from 11 Gbit/s) than the equipment of the g and a standards. These standards are not considered in the work. [16-18]

Basic standard IEEE 802.11. The basic standard, developed in 1997, defines the protocols necessary for the organization of wireless computer networks (WLAN). It defines the MAC Medium Access Control protocol and three physical layer protocols for signaling in the physical medium corresponding to different signaling technologies. On radio channels in the 2.4 GHz range using Direct Sequence Spread Spectrum (DSSS) technology. On radio channels in the 2.4 GHz range using frequency hopping spread spectrum technology (Frequency Hopping Spread Spectrum, FHSS). Using infrared radiation.

Of the listed technologies, only the DSSS technology, which is considered in the work, will be used for the study of the construction of wireless computer networks. Depending on the modulation method used, the transmission speed is 1 Mbit/s (differential binary phase shift keying, DBPSK) and 2 Mbit/s (quadrature phase shift key, QPSK). The standard defines 14 frequency channels, of which 3 are non-overlapping, the width of each channel is 22 MHz.

Technologies of the IEEE 802.11b standard. The IEEE 802.11b standard, which appeared in 1999, regulated the rules for using high-rate DSSS (high-rate direct sequence spread spectrum, HR-DSSS) technology. It uses the 2.4 GHz ISM bands and specifies transfer rates of 5.5 and 11 Mbps. The HR-DSSS technology uses the same scheme of channel organization as in the DSSS technology - a frequency band with a width of 22 MHz, 14 channels, 3 of which are non-overlapping. The DSSS physical layer of the 802.11b standard is compatible with existing WLANs of the 802.11 standard. In this case, coding using complementary codes (complementary code keying, CSK) or binary packet convolutional coding (packet binary convolutional coding, PBCC) is used. At the same time, data is transmitted using SSK or RVSS modulation (5.5 or 11 Mbit/s), and headers using DSSS (1 Mbit/s).

Technologies of the IEEE 802.11a standard. Published in 1999, the standard provides a data transfer rate of up to 54 Mbit/s. This is the most wide-band standard from the 802.11 family of standards. 802.11a standards ensure operation in the U-NII (Unlicensed National Information Infrastructure) bands of 5.15-5.25 GHz, 5.25-5.35 GHz and 5.725-5.825 GHz. Equipment operating in the 5.725-5.825 GHz frequency range does not comply with the requirements of the standard and is mainly used to build distributed wireless networks. The 802.11a standard regulates the use of channels with a width of 20 MHz and defines four channels for each of the three bands. Orthogonal frequency division multiplexing (OFDM) was chosen as the signal modulation method. In contrast to DSSS and FHSS technologies, the OFDM method provides for the transmission of a useful signal simultaneously at several band frequencies. As a result, the bandwidth of the channel and the quality of the signal increase. The standard defines three mandatory speeds - 6, 12 and 24 Mbps and five optional - 9, 18, 36, 48 and 54 Mbps. The disadvantages of 802.11a include: high power consumption of radio transmitters for 5 GHz frequencies, as well as a shorter range. In addition, devices for 802.11a are more expensive.

Technologies of the IEEE 802.11g standard. IEEE 802.11g is a standard describing WLAN operation in the unlicensed 2.4 GHz frequency range. The maximum data transfer rate in IEEE 802.11g wireless networks can be up to 54 Mbit/s. In the standard, transmission speeds 1 are mandatory; 2; 5.5; 6; 11; 12 and 24 Mbit/s, and the transmission speed is 9; 18; 36; 48 and 54 Mbit/s - optional. The 802.11g standard is a development of and compatible with 802.11b. The advantages of 802.11g include low power consumption, range and high signal penetration, lower cost of equipment (compared to 802.11a), since low-frequency devices are easier to manufacture. The 802.11g specification fully incorporates 802.11b, allowing the use of both DSSS and OFDM modulation schemes. When developing the 802.11g standard, two competing technologies were considered: the OFDM orthogonal frequency multiplexing method, borrowed from the 802.11a standard, proposed for consideration by the Intersil company, and the RBSS binary packet convolutional coding method, optionally implemented in the 802.11b standard and proposed by the Texas Instruments company. As a result, the 802.11g standard contains a compromise solution: OFDM and SSK technologies are used as the basic ones, and the use of RVSS technology is optionally provided. If only 802.11g devices are used in the local network, the transmission is carried out at the maximum possible speed. However, if 802.11b devices are introduced into it, the header information must be transmitted at 802.11b speeds to be received by the 802.11b devices. This rate reduction must be performed for all transmissions, regardless of whether they are between 802.11g or 802.11b devices. RBSS coding technology can be used at speeds of 5.5, 11, 22 and 33 Mbps, of which 5.5 and 11 Mbps are mandatory and 22 and 33 Mbps are optional.

WLAN topologies. IEEE 802.11 networks are based on cellular architecture. The network can consist of one or more cells (cells). Each cell is controlled by a base station called an access point (AP). Access points of a multicellular network interact with each other through a distribution system (Distribution System, DS), which is the equivalent of a trunk segment of cable lines. The entire infrastructure, including access points and distribution system, forms an extended service area (Extended Service Set). The standard also provides for a single-cell version of a wireless network, which can be implemented without an access point (IBSS). At the same time, part of its functions are performed directly by workstations.

802.11 standard networks use three types of topologies:

- independent basic service areas (independent basic service sets, IBSS) - there is no access point in such a network;
- basic service areas (basic service sets, BSS) - one access point connected to the distribution system is used;
- extended service areas (extended service sets, ESS) - access points are connected through the distribution system.

A service area (service set) is a logical group of devices. The receiving station can receive signals on several frequency channels. The transmitting station first transmits the service set identifier (SSID). The receiving station uses the SSID to filter the received signals and select the one it needs.

Areas of application of WLAN

Wireless networks in the premises. Indoor WLANs are deployed when it is necessary to ensure the mobility of users within the building, for temporary networks (for example, at exhibitions and conferences) when it is difficult, expensive or impossible to lay a cable network in the house. Wireless local networks are also used if the network needs to be put into operation in a relatively short time. WLANs enable employees to have constant access to the company's information resources, even if they are not at the workplace. First of all, it is necessary for the management of the company, which often holds meetings and negotiations. In addition to management, wireless connection is convenient for employees who are often on business trips or do not have a permanent workplace (usually such employees have laptops). For large companies, the presence of a wireless network segment is also an image move. Any guest who came to them will be able to quickly connect to the Internet or corporate network. The presence of a wireless network in a store or warehouse allows you to promptly monitor the movement and quantity of goods, replenish stocks in a timely manner and keep statistics. Wireless barcode readers allow you to quickly count the product and immediately send the information to the database. Connecting POS terminals to the store's local network enables the manager to take into account and control the operation of the entire store in real time. The calculation of wireless networks inside buildings is significantly complicated due to the difficult-to-predict attenuation of the signal when passing through walls and ceilings, multiple reflections. Technologies used in such networks must be well adapted to multipath reception. Powers of transmitters, antennas and their location should be chosen in such a way that the signal passes through partitions inside the building, but does not penetrate outside the walls. That is, it did not interfere with other wireless systems. Frequencies should be distributed in such a way as to reduce or completely eliminate the system interference that wireless network nodes create for each other. Also, you need to pay attention to devices that are potentially sources of electromagnetic interference (microwave ovens, video cameras, etc.).

WLAN in public places (Hot-Spot). Such networks are now available in many public places - at train stations, airport waiting rooms, hotels, restaurants and cafes. With their help, users are provided with information services such as access to the Internet, menus, etc. Added to the problems inherent in indoor wireless networks is the much more complex EMO (for example, in airports where a large number of different radio systems operate).

Organization of a wireless connection between several houses

With the help of wireless technologies, it is possible to organize a single information space by combining networks (including telephone networks) located on the territory of one enterprise, but in different buildings. This task is solved by installing radio bridges or radio routers and directional antennas. In this case, powers, frequencies, antennas and the location of transmitters should be carefully selected to exclude mutual interference with wireless systems located in neighboring territories that do not belong to the enterprise.

Corporate networks in a limited area

The peculiarity of such networks is that all connected objects are located on the territory of one organization, and are connected between objects where there are no buildings belonging to other owners. Examples can be the network of a university campus or the territory of a factory, in the workshops of which a wireless network is organized. It is better to divide a wireless local network of this type into segments, cells. One cell is one radio channel used by several stations that have access to it. The territories of neighboring cells partially overlap, so neighboring cells must work at different frequencies. In such networks, you should also be careful about the possible occurrence of mutual interference with wireless systems located in neighboring territories that do not belong to the enterprise.

2.1.2. EMC problems and methods of solving them in WLAN

Built-in WLAN mechanisms ensure efficient simultaneous operation of a small number of computers inside a single cell. They do not allow you to allocate a guaranteed bandwidth for each user. As the density of subscribers increases, mutual interference increases, the number of collisions and retransmitted packets increases, network access time and delays in information transmission increase. That is, the problem of increasing the efficiency of access is becoming more and more urgent.

The hidden node problem. In wireless networks, the following situation is possible: two stations (A and B) are out of sight of each other. Station C can interact with both stations (A and B). Station A transmits information to station C. Station B "does not see" that the transmission medium is occupied, because station A is out of range for it, and, considering that the transmission medium is free, begins to transmit information. As a result, station C receives two signals from stations A and B at the same time, that is, a collision occurs. This situation is known as the hidden node problem.

Mutual interference between neighboring cells (intra-system EMC). In 802.11 b and g networks, there are only three non-overlapping channels. If the network consists of 1-3 cells, then the level of intrasystem interference is relatively small. In a wireless network consisting of four or more cells, MS and AR of neighboring cells operating on overlapping frequency channels, significant mutual interference is created. This leads to a deterioration in the quality of communication, a decrease in bandwidth and an increase in network access time, up to its complete inoperability.

Intersystem EMC. Mutual interference with different radio devices operating in the same area (microwave ovens, other wireless networks, Bluetooth devices) must be taken into account. Depending on the intensity of the radiation, this effect can lead to a significant deterioration of the connection or a complete inoperability of the network.

QoS provisioning for responsible applications. The QoS mechanisms of the 802.11e standard provide protection for delay-sensitive traffic (voice, video) from the traffic of other applications using the wireless transmission environment, but they do not protect against changes in the data transmission environment. An increase in the number of network users, the presence of external and internal interference leads to an uncontrolled increase in the number of collisions and retransmitted packets. This, in turn, leads to an increase in network access time and a decrease in available bandwidth. As a result, the effectiveness of QoS mechanisms decreases or their operation is completely blocked.

The influence of the characteristics of the area. Terrain, physical obstacles on the terrain (propagation path) affect the propagation of radio waves, and, therefore, the quality of the signal. These can be trees, houses, walls of houses, doors, cars, bookshelves, design objects (especially metal elements), etc. Weather also affects the propagation of radio waves. Precipitation is usually detected at frequencies above 5 GHz, but there may be situations when its influence is quite strong at frequencies above 400 MHz (for example, wet leaves of trees in a park). This problem is relevant for outdoor wireless networks and must be taken into account at the WLAN design stage.

Existing methods of solving EMC problems and their shortcomings. EMC problems (intra-system and inter-system) are solved during the design of wireless network equipment (for example, various coding methods are used that increase stability) and when designing the wireless network itself. At the same time, the capabilities embedded in the technical means determine the capabilities of the network designer.

Mechanisms of access to the transmission medium. The mechanisms of access to the transmission medium existing in 802.11 networks. WLANs use a mechanism called carrier sense multiple access with collision avoidance (CSMA/CA). CSMA/CA is a "listen before talk" (LBT) mechanism. The transmitting station checks whether the carrier signal is present in the medium and waits for its release before starting the transmission. Avoiding collisions is a key issue for wireless networks, as they have no mechanism in place to detect them. When using CSMA/CA technology, a collision is detected only when the transmitting station does not receive the expected confirmation.

Components of the CSMA/CA mechanism. IEEE 802.11 is an asynchronous technology based on random access methods for providing Internet connectivity over a wireless environment. It uses the carrier control multiple access and collision avoidance (CSMA/CA) protocol, which implies that each node discovers a channel to transmit. If the energy measured on the channel exceeds the threshold value for channel cleanliness, then the channel is determined to be busy and the transmission is delayed. Otherwise, the channel is declared free and the node proceeds to frame transmission.

Components of the CSMA/CA mechanism:

- carrier control;
- distributed coordination function (distributed coordination function, DCF);
- confirmation frames;
- reservation of the transmission environment using the mechanism "readiness to transmit/readiness to receive" (Request-to-Send / Clear-to-Send, RTS / CTS).

Additionally, two other mechanisms are specific to 802.11 media access, but not directly related to CSMA/CA:

- fragmentation of frames;
- point coordination function (point coordination function, PCF).

A station intending to transmit in a wired environment must first verify that a carrier is in use. If the carrier is busy, the transmission is delayed until the medium is freed. The station determines the state of the environment using two methods. Checking the physical level for the presence of a carrier. Using the virtual carrier control function, the network allocation vector (NAV).

The station can check the physical level and make sure that the carrier is free. But, in some cases, the transmission medium may still be occupied by another station due to the network allocation vector. This is a timer whose value is updated by frame data transmitted over the transmission medium. The station updates the value of the network distribution vector only when the received value of the duration field exceeds the one stored in its network distribution vector. The IEEE approved medium access mechanism for 802.11 networks is Distributed Coordination Function (DCF), a medium access mechanism based on the CSMA/CA method.

When working with DCF, a station that intends to transmit a frame must wait a certain amount of time after the medium becomes free. This time interval is called DCF interframc space (DIFS). After the end of the DIFS time interval, the station can participate in the competition for the right to access the transmission medium. There is a high probability that several stations will simultaneously attempt to transmit immediately after the medium is released, resulting in a collision. To avoid this situation, DCF uses a random backoff timer.

The 802.11 specification requires that the receiving station transmit an acknowledgment frame to the sending station. If the transmitting station does not receive an acknowledgment frame, it assumes that a collision has occurred in the transmission medium. The transmitting station updates its retry counter value, doubles the contention window width, and starts the process of accessing the transmission medium again.

In 802.11 wireless networks, the hidden node problem is solved using a special control frame called the RTS frame (Ready to Transmit Frame). An RTS frame containing the time needed to exchange frames is sent to the access point.

The access point receives an RTS frame from the station and responds with a CTS control frame (ready-to-receive frame). The latter also contains a duration field, the value of which is sufficient for the transmitting station to complete the exchange of frames. The exchange of frames includes the frame that the station intends to transmit, as well as the acknowledgment frame expected by it. All stations in the access point's range receive the CTS frame and update the values of their NAVs (network distribution vectors).

The initial RTS frame must pass through the DCF procedure like any other frame. But, similarly to the acknowledgment frame, the corresponding CTS frame transmitted by the access point will pass the random delay procedure and, before being transmitted, must withstand a time equal to the SIFS interval.

The station that received the frame confirms its error-free reception by sending the transmitting station an acknowledgment frame. Frames may contain acknowledgments and are allowed not to participate in the random delay process. This guarantees the receiving station the greatest chance of gaining access to the transmission medium, compared to other stations. With each unsuccessful attempt to access the environment, the station increases the value of the attempt counter. When the value of the retries counter reaches the threshold set by the network administrator, the station attempts to reserve the environment.

Frame fragmentation is a function performed at the MAC level, the purpose of which is to increase the reliability of frame transmission over a wireless environment.

Fragmentation means splitting a frame into smaller fragments and transmitting each of them separately. Receipt of each frame fragment is confirmed separately. Therefore, if any fragment is transmitted in error or collides, only that fragment will have to be retransmitted, not the entire frame. This indirectly increases throughput. Each frame fragment includes a header, and requires the transmission of a separate acknowledgment frame. As a result, the number of service signals increases and the share of transmitted useful data decreases. The size of the fragment can be set by the network administrator. Only unicast frames are subject to fragmentation. Broadcast and multicast frames are transmitted in their entirety. In addition, frame fragments are transmitted in a packet, using only one iteration of the DCF transmission medium access mechanism. [19-20]

When working with DCF, a station that intends to transmit a frame must wait a certain amount of time after the medium becomes free. This time interval is called DCF interframc space (DIFS). After the end of the DIFS time interval, the station can participate in the competition for the right to access the transmission medium. There is a high probability that several stations will simultaneously attempt to transmit immediately after the medium is released, resulting in a collision. To avoid this situation, DCF uses a random backoff timer. The 802.11 specification requires that the receiving station transmit an acknowledgment frame to the sending station. If the transmitting station does not receive an acknowledgment frame, it assumes that a collision has occurred in the transmission medium. The transmitting station updates its retry counter value, doubles the contention window width, and starts the process of accessing the transmission medium again. In 802.11 wireless networks, the hidden node problem is solved using a special control frame called the RTS frame (Ready to Transmit Frame). An RTS frame containing the time needed to exchange frames is sent to the access point.

PCF is an optional transmission medium access mechanism used in addition to the DCF mechanism. PCF operation is possible only in BSS infrastructures. The PCF mechanism allows the transmission of frames by polling, limiting free access to the transmission medium. Most manufacturers do not support the PCF mechanism in their devices, because it increases the number of transmitted service signals in the BSS.

The PCF mechanism is based on the interaction of the point coordinator (point coordinator, PC) and the stations polled by the point of coordination (CF-Pollable stations). When operating under the control of the PCF mechanism, stations can transmit data (one frame at a time) only when the coordination point polls them. The coordination point can send frames to stations, poll them for frame transmissions, acknowledge receipt of frames as required by the MAC layer, or terminate a CFP session.

The mechanism of access to the transmission medium: efficiency under the influence of interference. Carrier control mechanisms using time division ensure simultaneous operation of only one transmitter in one cell. In the presence of interference, this mechanism is ineffective because the wireless environment may be occupied by an independent third-party transmitter that interferes. The DCF and PCF coordination functions ensure bandwidth allocation between subscribers. With the help of confirmation frames, the fact of information delivery to the recipient and the need to resend packets is determined. The RTS/CTS mechanism solves the hidden node problem and provides subscriber access to the transmission medium in the loaded BSS. This mechanism works only within one cell and cannot regulate the operation of neighboring cells. By fragmenting frames, the reliability of frame transmission in wireless computer networks can be increased, because the probability of successful transmission of a smaller fragment through a wireless environment with interference is higher. At the same time, it leads to an increase in the transmitted service information. Fragmentation can be useful in a busy wireless network or in the presence of interference.

Of the considered mechanisms, only confirmation and fragmentation frames can be used to counteract radio interference (this is clearly not enough). The rest of the mechanisms are designed only to ensure communication within the cell and are vulnerable to both inter-system interference and interference from neighboring cells.Специфікація IEEE 802.11e.

The IEEE 802.11e standard is designed to provide application services with the required bandwidth with acceptable data transmission delay (Quality of Service, QoS). The difficulty of solving this problem for wireless networks is that the number of erroneous packets can reach 10-20%, and the speed of data transmission depends significantly on the location of the subscriber and can change during the connection. The device that controls the allocation of the required bandwidth remains in the dark about the available resources, since a similar neighboring device can at any time use a part of these resources for its needs.

The 802.11e specification provides for the marking of packets related to critical data with priority labels. The maximum priority is given to voice data packets (IP-telephony), as the most critical to the delay in the transmission bandwidth, streams transmit video information, which are allocated the necessary bandwidth if it is available. In BSS and ESS, data transmission goes only from the client to the access point and back. The 802.11e specification adds the ability to exchange traffic directly between two clients, which not only allows more efficient use of bandwidth, but also adds some functionality, in particular, for home wireless networks that can do without an access point at all.

The 802.11e research group has proposed two solutions implemented at the MAC level to ensure QoS in 802.11 networks. Hybrid coordination function (HCF) with operation in competition mode. Most often, this solution is called enhanced distributed coordination function (enhanced DSF, EDSF). HCF with work in alternate access mode. In the specification of the 802.11e standard, data is divided into eight classes. EDSF and HCF in alternate access mode use these eight classes, which are called traffic classes (TC), which are related to the eight classes defined in the 802.1d standard. Traffic is divided into four large categories - access categories (AC). The mechanism for classifying and marking data frames is not covered by the draft document 802.11e, but it can be assumed that the application (since it provides speech transmission and is installed in the 802.11 standard phone) should mark the priority bits of the IP datagram. The client device converts these values into traffic classes of the 802.11e standard. In the presence of classified and labeled traffic, the 802.11e standard provides a mechanism for differentiation and prioritization of transmitted traffic.

After the traffic is classified and queued, the next step is to transmit the frames. The purpose of QoS measures is to protect the traffic of high-priority applications from being affected by the traffic of background applications. If two or more stations collide, then the frame of the high-priority station has priority, and the background station will be forced to release the transmission medium and increase the width of its contention window.

The admission control mechanism monitors available network resources and allows or rejects new application communication sessions. The extended distributed coordination function (EDSF) uses an admission control scheme called distributed admission control (DAC). The DAC mechanism keeps track of the percentage of media used for each access category. The unused portion of the bandwidth of the transmission medium is called the budget (available budget) for this category. The access point informs stations about the available budget in signal frames. If the budget starts to approach zero, stations cannot initiate new data streams. This process protects existing information flows of applications from being influenced by new flows.

The operation of the HCF in the alternate access mode is similar to the operation of the PCF coordination point function. The access point contains a logical entity (logical entity) called a hybrid coordinator (hybrid coordinator), which monitors the information flows of HCF client stations and assigns polling intervals. Obtaining access through HCF polling allows a station to request the time it needs to transmit, rather than simply determining the available bandwidth as in the case of EDSF. HCF allows the hybrid coordinator to determine which wireless environment resources are available and to accept or reject application traffic information flows. HCF can operate in two modes, one coexisting with EDSF and the other using a competition-free period (CFP) similar to PCF.

The mechanism of distributed access control (DAC) does not have the necessary characteristics, because it does not perform strict control of the input. Stations can potentially carry out a transmission and thereby negatively affect already existing information flows. The effectiveness of 802.11e mechanisms quickly decreases with increasing overlap on the combined channel.

Effectiveness of IEEE 802.11e standard mechanisms under the influence of interference. Thus, IEEE 802.11e standard equipment protects high-priority wireless network traffic from low-priority traffic within the same cell. Cell-independent interfering transmitters adversely affect any type of transmitted traffic. As a result, damaged packets must be retransmitted. For low-priority traffic, the delay in packet delivery is not very critical. For high-priority traffic (for example, IR-telephony), this is unacceptable, because the mechanisms of 802.11e are precisely designed to ensure the fast delivery of high-priority data.

Additional specifications designed to reduce the impact of interference: IEEE 802.11h and IEEE 802.11k standards. The IEEE 802.11h standard complements the existing 802.11a specification with algorithms for effective frequency selection, as well as means of managing the radiated power and generating relevant reports. The protocols used in the standard provide for the dynamic response of wireless network clients to radio signal interference by switching to another channel, reducing power, or both. The solution of these tasks is based on DFS (Dynamic Frequency Selection) and TRS (Transmit Power Control) protocols. DFS technology detects other devices using the same radio channel as the WLAN access point and, if necessary, switches the BSS to another channel. DFS is responsible for the absence of interference from access point signals and other means of communication, including radar systems and "foreign" WLAN segments. When a wireless device first connects to an access point, it sends the base station a list of channels it can support. If the access point needs to switch to another radio channel, it checks the received data to determine the best one. An access point initiates a channel switch by sending a corresponding frame to all wireless devices associated with it in the session. The frame indicates: the number of the new working channel, the time before switching and the permission to transmit until the moment of switching the channel. All subscriber stations that receive a message about the switching of the working channel change their settings after the end of the specified period. The access point constantly measures channel activity to detect traffic from other systems. To do this, it sends measurement requests to the subscriber terminal or a group of terminals, specifying the channel number to be checked, the measurement start time, and the duration of the measurements. The subscriber station measures channel activity and generates a report for the access point. TRS technology is designed to reduce interference from WLAN networks to satellite and radar services by reducing radio transmission power. TRS can also be used to manage the power consumption of wireless devices, to change the working distance between access points and wireless devices. Access points limit the maximum permissible transmission power of both their own and subscriber stations that are served. The transmission power of any station, when communicating with this access point, cannot exceed the maximum value specified by the access point. As each new 802.11 terminal connects to it, it reports the required amount of signal strength. The access point accumulates data about the stations associated with it to determine the maximum power of the entire segment of the local radio network. Radio power in this segment of the WLAN is regulated to reduce interference to other systems, and sufficient power is maintained for reliable wireless network operation.

The IEEE 802.11k standard is intended for 802.11 networks and involves the exchange of various service parameters. Some of them are related to the intra-network roaming procedure and allow optimizing the distribution of traffic over the network. In a wireless environment, the client device will connect to the access point at the maximum signal level. With a certain number and location of users, it is quite possible that some access point will be overloaded, and the rest will work with a minimum load, which will lead to a decrease in the overall performance of the network. In an 802.11k wireless network, when the access point with the highest signal strength is fully loaded, client connection requests will be redirected to other devices. As a result, thanks to a more rational use of resources, the total bandwidth of the network will increase. The decision to redirect the client to another access point is made on the basis of information received from subscriber devices about all access points recognized by it, signal intensity, supported services, encryption types, etc. The IEEE 802.11k standard provides access to the parameters measured at the first and second levels of the OSI model, from higher levels. The access point may request from the client information about the level of noise in the channel, which is not related to the operation of devices of the 802.11 standard, about the download and duration of use of this channel. This information will be used when selecting a radio channel to establish a connection. To improve the quality of service, the collection of data on so-called hidden nodes is also provided. Their presence reduces the effectiveness of the collision prevention mechanism and, as a result, the overall performance of the network. The 802.11k specification requires clients to transmit information about detected hidden nodes to access points. The IEEE 802.11k standard provides for access points to receive from clients complete statistical information about network parameters and events, as well as the application of radiated power management procedures in various frequency ranges in accordance with the requirements of regulatory bodies of various countries.

Efficiency of mechanisms of IEEE 802.11h and IEEE 802.11k standards under the influence of interference. In order to organize the optimal distribution of users between access points, it is necessary to increase the overlapping areas between neighboring cells. As a result, the distance between cells operating on the same frequency channel decreases, and, accordingly, intra-system interference increases. This possibility can be used effectively in WLANs consisting of one to three cells, when there are no interferences on the overlapping channel. Automatic selection of frequency channels with the lowest level of interference. This option is useful if there are one or two cells in the network. If there are three or more cells, then the number of available frequency channels to which you can switch is extremely limited. At the same time, it may be necessary to switch the frequency channels of all cells simultaneously. This is possible only if there is a unified wireless network management system. If there are 11 frequency channels (for example, in the USA), such switching is not possible at all, because a combination of three non-overlapping channels can be obtained only when using the 1st, 6th and 11th channels. Regulation of radiation power. The access point must emit a signal that could be received even by the MS farthest from it. At the same time, it makes almost no sense to regulate the power of AR radiation. If the antennas of the access points are omnidirectional, then the APs are located in the center of the cell. At the same time, the maximum power required for data transmission from the border MS to the access point will be approximately the same for all MSs that are on the border of the cells. That is, marginal MCs, which have the greatest interfering effect on neighboring cells, will, as before, radiate with maximum power. As a result, when using omnidirectional antennas, only the average level of intrasystem interference is reduced.

Coding and modulation. Coding is a mechanism that allows high-speed data transmission over noisy channels. All transmission channels are subject to interference, which causes errors in the form of distorted bits. Encoding increases the amount of data transmitted over a noisy transmission medium by replacing sequences of bits with longer codes. This allows you to recognize and correct corrupted bits. The length of a code constraint (constraint length of a code) shows how many output elements leave the system per one input. Codes are characterized by the effective degree (or coefficient) of coding (code rate). This ratio indicates how many output bits are multiplied by one input. Codes with a higher effective degree of coding allow data to be transmitted at a higher speed, but they are more sensitive to interference. One of the main assumptions on which the coding mechanism is based is that errors occurring in the transmission of information are independent events. But most often errors in transmission occur in series. For these reasons, interleaving is used to scatter the block error bits, thus making the errors appear independent. The main purpose of interleaving is to scatter adjacent bits by placing non-adjacent bits between them. During coding, the information bit, which is represented by a rectangular pulse, is divided into a sequence of smaller pulses-chips. As a result, the spectrum of the signal is significantly expanded, since the width of the spectrum can be considered with a sufficient degree of accuracy to be inversely proportional to the duration of one chip. Such code sequences are often called noisy codes. Along with the expansion of the signal spectrum, the spectral energy density also decreases, so that the energy of the signal is smeared across the spectrum, and the resulting signal becomes noise-like in the sense that it is now difficult to distinguish from natural noise. One of the most famous such sequences is the 11-chip Barker code: 11100010010. Barker codes have the best noise-like properties among known pseudorandom sequences. Direct and inverse Barker sequences are used, respectively, to transmit single and zero message symbols. In the receiver, the received signal is multiplied by the Barker code (the correlation function of the signal is calculated), as a result of which it becomes narrow-band, and it is filtered in a narrow band of frequencies. Any narrowband interference that falls into the band of the output wideband signal, after multiplication by the Barker code, on the contrary, becomes wideband, and only a part of the interference falls into the narrow information band, the power of which is approximately 11 times smaller than the interference acting at the input receiver The main meaning of using the Barker code is to guarantee a high degree of reliability of the received information and at the same time transmit the signal almost at the interference level. Thus, at a transmission speed of 1 or 2 Mbit/s, the energy of narrowband interference is distributed over the entire signal spectrum and its level is reduced by 11 times.

The use of SSK codes allows encoding 8 bits per symbol at a speed of 11 Mbit/s and 4 bits per symbol at a speed of 5.5 Mbit/s. The code sequences themselves are 8-chip, and at a transfer rate of 11 Mbit/s, encoding 8 bits per symbol corresponds to a symbol rate of 1.375•106 symbols per second (11/8=1.385). A similar symbol rate is used at a transfer rate of 5.5 Mbit/s, since in this case only 4 bits are encoded in one symbol. In order to ensure the reliability of the received data (that is, to be able to detect and correct errors) in OFDM transmission modes, the addition of redundant information and the so-called convolutional coding are used. The essence of convolutional coding is that service bits are added to the sequence of transmitted bits, the values of which depend on several previously transmitted bits. For the same type of modulation, different transmission rates are used in the standards. With a degree of convolutional coding of 1/2, one service bit is added to each information bit (redundancy equals 2). For this reason, with a degree of convolutional coding of 1/2, the information rate is half the transmission rate. With a degree of convolutional coding of 3/4, one service bit is added for every three information bits, so in this case the useful (information) rate is 3/4 of the full rate. Accordingly, with a total transmission speed of 12 Mbit/s, the information rate for a coding ratio of 1/2 will be 12x1/2 = 6 Mbit/s. And for a coding ratio of 3/4, the information rate will be 12x3/4 = 9 Mbit/s. Binary packet convolutional coding technology is optionally used in the 802.11b standard at speeds of 5.5 Mbit/s and 11 Mbit/s. The basis of the RVSS method is the so-called convolutional coding with a rate of 1/2. Modulation types used in PBCC: BPSK for a speed of 5.5 Mbit/s and QPSK for a speed of 11 Mbit/s.

To obtain speeds of 22 and 33 Mbit/s, 8-position 8-PSK phase modulation is used in PBCC technology. The data is first sent to a convolutional encoder with a coding ratio of 1/2, and then to a punctate encoder with coding ratios of 4/3 (22 Mbit/s) and 2/1 (33 Mbit/s). A bit encoder is necessary to reduce the redundancy of the transmitted information. The resulting coding ratio will be 2/3 for a speed of 22 Mbit/s, and 1 for a speed of 33 Mbit/s.

It can be assumed that the type of modulation used sets the requirement for the signal/interference ratio, and the coding and redundancy of the transmitted data determine the gain in the signal/interference ratio during decoding depending on the degree of damage to the useful signal by interference. Ideally, the acceptable signal-to-interference ratio should be specified by the equipment manufacturer. Unfortunately, such information is usually not available for WLAN equipment. For 802.11b/g equipment, the signal-to-interference ratio at the difference between adjacent channels is 25 MHz (interference from the adjacent channel) and 35 MHz (cross-interference). Then, for equipment of the 802.11g standard using OFDM technologies, according to the spectral mask and data on permissible levels of interference, the decrease in the signal level when moving away from the carrier by 16 or more MHz will be at least 24 dB, the decrease in the signal level when moving away from the carrier by 30 and more MHz will be at least 40 dB. In the 802.11 DSSS, 802.11b and 802.11g PBCC standards, it is specified that the communication should be ensured when the level of the adjacent channel (25 MHz difference, reduction of the level of at least 30 dB) above the signal is not less than 35 dB. According to the spectral mask, the signal/interference ratio in this case will be 30-35 = -5dB. That is, the interference level can exceed the signal level by 5 dB. This number is not suitable for evaluating the permissible signal/interference ratio under the influence of interference on an overlapping channel. According to the test results, when testing the devices at the same level of packet errors (PER = 0.01) and a transmission speed of 11 Mbit/s, operation in SSK mode was possible with a signal-to-noise ratio of 8.5 dB, and the use of PBCC allowed reduce this ratio to 4.5 dB. For the DWL-900AP access point model, the manufacturer shows the requirements for the signal-to-interference ratio (except for the 33 Mbit/s mode, which is not supported by that access point). In the 33 Mbit/s RBSS mode, the sensitivity requirement is 2 dB lower than in the 22 Mbps RBSS mode. Therefore, with the same noise level of the receiver, the permissible signal / interference ratio should be 2 dB higher.

EMC provision at the WLAN design stage. The process of designing a wireless network must be carried out taking into account the parameters of the equipment used, the characteristics of the area, the influence of intersystem and intrasystem interference. Today, there are systems that allow you to plan a wireless network and carry out its monitoring and management. One of the most functional existing WLAN design and management systems - NetAlly AirMagnet Survey - allows monitoring and visualization of the internal network in real time. The main focus in this system is not on WLAN design, but on centralized wireless network management and monitoring.

When designing a WLAN, the coverage area is determined depending on the materials from which the building is constructed. There is a built-in floor plan editor. Based on the provided data, NetAlly AirMagnet Survey helps to choose the optimal location of access points and shows the expected coverage area.

2.2. Development of the methodology for designing wireless computer networks in the hotel and restaurant business that takes into account EMC

2.2.1. Determination of basic characteristics. Analysis of intrasystem interference

Determination of basic characteristics

Stage 1. Determination and analysis of WLAN requirements.

Depending on the applications with which users of the wireless network will work, the requirements for it are determined. Before planning a WLAN, it is important to formulate these requirements: bandwidth requirements (per client); program type: streaming (telephony, video) or pulsating (mail, Internet); QoS (sensitivity of applications to delays). As the density of clients increases, the total bandwidth requirements increase. In wireless networks, a fairly significant part of the bandwidth is spent on application needs. In the 802.11b standard, at a transfer rate of 11 Mbit/s, the real performance is about 6 Mbit/s. For 802.11a/g standards at a transmission speed of 54 Mbps, the actual performance is approximately 22 Mbps. Depending on the bandwidth needs of WLAN users, the number of users served by one access point is determined. The types of applications used significantly affect the amount of data transferred. The requirements of streaming-type applications, such as voice or video, are quite different from those of burst-type applications, such as HTTP or POP3. The bandwidth used by burst-type applications is volatile and unpredictable. As a result, it is very difficult to determine the number of users that a single access point should serve. The upper limit is 25 users per access point. All stations, as a rule, have the same access rights to the transmission medium. The more stations, the greater the chance of collisions and retransmissions. As a result, there are delays in data transmission. To reduce this effect, it is wise to choose a high density of placement of access points. There are two methods of placement planning: by the maximum service area of each AP and by the maximum bandwidth.

The method focused on the maximum service area is aimed at providing maximum coverage with the minimum possible number of access points. The density of users in such networks is about 25 per 1 access point. In this case, applications of the pulsating type with a low data transfer rate are usually used. Small bandwidth requirements allow you to reduce the operating speed to 1-2 Mbit/s. A similar version of WLAN is also used for temporary networks. WLANs with maximum bandwidth must provide maximum performance and packet rate for each client. They are used in the following cases. Applications that require high transfer speeds are used. The applications used are sensitive to delays. Smaller-scale subnets (or multiple subnets in one service area) are deployed. In places with a high density of users.

Cell sizes for such WLANs are smaller, and accordingly the number of used access points is larger. At the same time, each access point can serve no more than 12 users. When implementing a wireless network, it is necessary to ensure the connection of access points to the distribution system. The place (distance to the connection point) and the connection technology should be taken into account (for example, in Ethemet technology, the maximum length of the communication line is 100 m), the distance of the antennas from the AP and the length of the feeders (respectively, the losses in them), the availability of power supply, IP addressing, routing , VLAN, bandwidth, etc.

Stage 2. Study and analysis of the electromagnetic situation.

The EMO analysis determines the presence of interfering signals at the location of the network deployment. Wireless systems operating in the given area in selected frequency ranges are detected. Equipment sensitive to radio interference is identified and its characteristics are taken into account. A search is being made for radiating radio-electronic devices that are potentially interfering (microwave ovens, medical equipment, etc.).

For each detected obstacle, the signal type (modulation), power, direction and polarization of the antenna, frequency response, and detection time are recorded. For EMO research, spectrum analyzers are used, which graphically show the signal energy at different frequencies. High signal levels (eg 20 dBm or higher) can damage the analyzer. Built-in or external input attenuators are used for protection, which reduce the amplitude of signals. The signal level, center frequency and width of the frequency channel, as well as the type of modulation used, can be determined from the image received on the spectrum analyzer. The direction to the signal source is determined using a directional antenna. By rotating it in different directions, fix the direction to the signal source, which coincides with the direction in which the maximum signal level is received. By changing the polarization of the analyzer antenna (by rotation) from horizontal to vertical, it is possible to determine the polarization of the antenna that emits the signal. Signal modulation can be determined by the shape of the radiation spectrum recorded by the analyzer. The signal spectrum can change over time. In order to better analyze the signal spectrum, it is necessary to use the mode in which the analyzer records the highest values of the received radiation levels on the screen. Most of the signals detected in the 2.4 GHz band will be OFDM, DSSS, FHSS signals or their combinations (eg DSSS + OFDM). The DSSS signal is easy to determine by the width of the used spectrum (22 MHz) and the shape of the signal. In fig. 3.2 shows two strong (about -60 dBm) DSSS signals in the 2.4 GHz band. One signal is emitted on the 1st frequency channel (2412 MHz), and the other on the 6th (2437 MHz). An OFDM signal can also be determined by its spectral mask. The FHSS signal can be identified by many peaks: the signal goes from channel to channel after 1 MHz, over the entire available frequency band.

Additional information on various parameters (encryption, operating speed, traffic intensity, etc.) operating near the WLAN can be obtained using wireless protocol analyzers and sniffers. In the results of the EMO analysis, the following should be determined: the most suitable frequency ranges for the deployment of a wireless network; a list of sources of interference in these ranges, their characteristics; a list of receptors sensitive to radiation in selected ranges, their characteristics; description of the nature of the area where the wireless network will be deployed, its features from the point of view of the propagation of radio waves. It is also necessary to analyze fundamentally possible ways of reducing mutual influence with neighboring radio systems (reducing the power level, installing frequency filters, shielding, moving emitting or receiving equipment to another city).

Stage 3. Selection of access point antennas and their placement scheme.

When designing wireless computer networks, directional or omnidirectional antennas can be used in access points. Omnidirectional antennas are placed in the centers of the cells, directional ones are located at the borders of the cell. From the point of view of providing EMC (both inter-system and intra-system), it is better to use directional antennas. The AP antenna must provide reception from the MS located anywhere in the cell. The MS, accordingly, must receive a signal from the AP while also being in any part of the cell. The directional antenna of the access point has different antenna KP values depending on the direction. Regardless of the direction of the AP antenna and the distance between the MS and the AP antenna, the total loss in the signal level on these parameters should be no more than for the pair of MS-AR, the most distant from each other (the distance between them is equal to two cell radii).

Stage 4. Choosing the size of the cells.

When choosing the size of the honeycombs, the following should be taken into account: the size of the premises; user placement density; requirements for the bandwidth available to each of the users, at the average and maximum loading of the wireless network; margin for network development: increase in the number of users and bandwidth requirements: organization costs (depends on the number of access points); attenuation in the area (determine the maximum possible cell size). It is desirable that the space covered by the first AR was homogeneous (there were no walls, ceilings and other obstacles that complicate the transmission of the radio signal). That is, the boundaries of the cells coincided with the walls of the premises, if the space is heterogeneous - the losses suffered by the signal when overcoming them are marked on the map of the area (determined by measurements or by various models). The service area of one AP should be chosen in such a way that the number of mobile users belonging to this cell does not exceed the maximum determined by the network requirements. If the maximum number of users is exceeded, it is necessary to reduce the space served by one AP. In unlicensed wireless computer networks, the maximum possible cell radius can be up to 300 meters, depending on the equipment, the required data transfer rate, and the level of interference between the AP and the MS.

Stage 5. Distribution of frequencies between cells.

There are three non-overlapping channels in the 2.4 GHz band for WLAN. The 3rd and 8th combinations are of greatest interest, because in these cases the level of intra-system interference between cells is reduced. In the case of using the 3rd combination of frequencies, intra-system interference, according to spectral masks, between the second and third cells will be additionally reduced by 20 dB if DSSS technologies are used, and by 16 dB if OFDM technologies are used. In the case of using the 8th combination of frequencies, intra-system interference between the second and third cells will be additionally reduced by 20 dB (DSSS) and 16 dB (OFDM). In the 5.8 GHz band (802.11a standard), the difference between adjacent frequency channels is 20 MHz. Based on this, it can be assumed that, when using OFDM technology in the 2.4 GHz range, adjacent non-overlapping channels can be spaced by 20 MHz. In this case, there is a combination in which there are 4 non-overlapping channels: the first (2412 MHz), the fifth (2432 MHz), the ninth (2452 MHz) and the thirteenth (2472 MHz). Frequency distribution should, first of all, ensure intersystem EMC. Therefore, frequency channels should be selected taking into account intersystem interference, ensuring minimal overlap with the operating frequency ranges of other systems operating in the adjacent territories.

Stage 6. Determination of signal levels in WLAN receptors.

Signal levels in cells are determined at the access point (signal from the most distant MS) and at the boundary MS, the most distant from the AP (signal from the access point). Losses in the antenna feeder are determined by losses directly in the cable itself and in the connecting connectors. Connector losses can be assumed to be 0.5 dB per connection. The specific loss in the cable depends on the frequency and must be specified by the supplier in the cable specification. For example, a 30.48 m LMR-400 type cable has a loss of 10.5 dB at 5.3 GHz and 6.5 dB at 2.4 GHz. Losses in the feeder can be reduced in two ways: choose a cable with a lower specific attenuation and/or reduce its length. For intra-office networks, antennas are usually connected directly to the reception-transmission path. Thus, the losses in the antenna feeders are reduced to the losses at the connecting connectors. The root mean square deviation of slow fades is usually taken as 3.5-17 dB for radio paths in open space and 6-20 dB for radio paths in rooms. Wireless equipment developers, when calculating the maximum range of radio communication, take a margin for fading equal to 10 dB. The signal level at the border of the cell can be adjusted by changing antenna parameters, radiated power levels, antenna feeder parameters, etc. When using omnidirectional antennas, the access point is placed in the center of the cell. Accordingly, the distance between the AR and the boundary MC will be equal to the radius of the cell. If omnidirectional antennas are used in access points, the expressions used to calculate signal levels are simplified. When using directional antennas, the access point is usually placed on the border of the cell, the distance between the boundary MS and AP in this case will be equal to the diameter of the cell (or two radii). It should be noted that the signal level in the boundary MS when using this placement of antennas is reduced by 6 dB (losses in open space) compared to placement in the center of the cell. When transmitting information directly between MCs, the signal level (with small distances between MCs) increases slightly due to the reduction of propagation losses.

Stage 7. Determination of acceptable interference levels in WLAN receptors.

Equipment manufacturers, as a rule, do not specify a permissible signal-to-interference ratio. Therefore, it is necessary to use calculated values. The permissible level of interference for MC (direct path) and AR (return path) will differ.

Analysis of intrasystem interference

Stage 1. Determining the level of inherent noise of the receiver.

As mentioned earlier, equipment manufacturers usually indicate only the sensitivity of the receiver, which gives information about the level of the receiver's own noise and the recommended signal / interference ratio. The level of inherent noise of the receiver is determined by the characteristics of the equipment. For MS and access point, its value may differ, so when designing, it is necessary to determine the noise level of the receiver for MS and AR.

Stage 2. Evaluation of interference levels from neighboring cells.

When analyzing intrasystem interference, it is necessary to obtain dependencies to reflect the relationship between various WLAN parameters and the level of interference between cells. In the case of choosing the cell radius of the AP and MS models, the AP antennas and the method of their placement and orientation, the combination of the frequency channels used, it is possible to estimate the level of intersystem interference in the cell. The work considers the interference from the 0th and 1st circle of cells. Obstacles of the 2nd, 3rd and subsequent circles increase intra-system obstacles even more.

The components used to calculate the level of intersystem interference can be divided into two groups: the same for all cells and individual for each cell. If you take the value of the power and the amount of losses in the feeders, KP and DS of the AR antennas of all cells to be the same, then you can significantly simplify the calculation of intrasystem interference. MS parameters are initially assumed to be the same for all cells. therefore, the same MSs can move between cells. The value of the CP of the receiving antenna and the loss in the feeder of the receiving antenna depend only on the type of receptor (AP or MC) and are the same for any of the obstacles. Losses in the feeders are calculated in the same way as when calculating the signal level (see the 6th stage of the 1st design stage). The following characteristics should be included in the group of individual parameters: losses in the transmitting antenna in the direction of the receptor; losses in the receiving antennas in the direction of the obstacle; losses in free space; additional losses on the track. The characteristics of the spectral mask depend on the equipment used (minimum requirements are set by the standards). On the other hand, the reduction of the level of out-of-band radiation depends on the difference between the operating frequencies of the cells. This parameter must be taken into account when calculating interference levels from transmitters of neighboring cells operating on different frequency channels. The reduction of out-of-band radiation levels is determined by the spectral masks specified in the standards. For real equipment, the obtained values can be refined. The out-of-band emission level requirements for DSSS technology are much stricter than those for OFDM technology. This means that the level of intra-system interference when using DSSS is lower than when using OFDM. Let's make the assumption that the MS is in the center of a circle limited by area. Then the distance between the boundary MCs of different cells. located in close proximity to each other, will be determined by the distance between the centers of the circles bounded by the corresponding ones. The distance between the centers of the tangent circles is equal to the sum of their radii.

WLANs organized using omnidirectional antennas. WLANs using omnidirectional antennas are characterized by a high level of mutual interference between cells. Therefore, it is recommended to use omnidirectional antennas when the number of cells does not exceed three.

WLANs organized using directional antennas. WLANs using directional antennas are characterized by lower inter-cell interference and inter-system interference compared to omnidirectional antennas. The disadvantage of this arrangement of antennas is that the signal level (in the marginal MS and in the AP) decreases by 6 dB due to the increase in the maximum distance between them by 2 times. Some gain in the signal/interference ratio can make it possible to adjust the power of the MS radiation. When designing, you can choose other options for the placement and orientation of AR antennas and conduct an analysis according to the proposed method.

2.2.2. Analysis of the mutual influence of parameters and the selection of wireless network operating modes. Analysis of intersystem electromagnetic compatibility

At this design stage, on the basis of the obtained dependences of the signal and interference levels in the cells, it is necessary to finally select the WLAN operation modes: operation speed; working frequency channels; equipment with the necessary characteristics; power levels of AR and MS transmitters; honeycomb radius; location, landmarks and installation height of AR antennas in cells.

WLAN parameters must be selected in such a way as to ensure the maximum signal/interference ratio in WLAN receptors. To evaluate the signal/interference ratio, it is necessary to calculate the total intrasystem interference, which consists of interference from neighboring cells and the level of the receiver's own noise. The interference from the neighboring cell is considered to be the greatest interference from the AR or MS of the cell. When using the developed algorithms of the transmission medium reservation mechanism, intra-system interference between cells operating on the same frequency channel is excluded. Therefore, when calculating the total level of interference, only interference from neighboring cells operating on non-overlapping frequency channels will be effective. To reduce the drop in bandwidth due to its distribution between neighboring cells, it is necessary to achieve the minimum radiation power of mobile stations and access points. Interference levels may differ in MC and AR, and permissible interference levels will also differ. If the level of total intra-system interference (in AR or MS) exceeds the permissible level, then there will be no connection with acceptable quality between AR and marginal MS. In this case, it is necessary to evaluate the reduction of the radius of the service area.

If the total intrasystem interference is determined by the interference from neighboring cells, then the reduction of the radius of the cells means that the neighboring cells form a single collision domain, dividing the bandwidth between them. In an unloaded wireless network - this, at least, can lead to some reduction in real bandwidth. In a busy WLAN, high intra-system interference is likely to cause the network to fail completely outside the coverage area. Since the losses in the level of interference (receptor - MS) from the AP on the adjacent channel are much greater than the losses in the level of interference from the AP on the overlapping channel, the interference from the APs operating on the adjacent channels can be neglected.

The calculation of the total level of obstacles in AR is carried out similarly. Since the losses in the level of interference from APs on the adjacent channel are much greater than the losses in the level of interference from APs on the channel, the interferences from APs operating on adjacent channels can be neglected.

If the network consists of two or three cells operating on non-overlapping frequency channels, the level of intrasystem interference is calculated on the 0th circle, taking into account the reduction in the level of out-of-band radiation. A detailed analysis of intrasystem interference levels in wireless networks using directional antennas has not been performed due to the cumbersome nature of the calculations. However, with the help of the developed WLAN calculation program, various dependencies can be obtained, which help to rationally choose WLAN parameters and operating modes.

Determination of the level of interference in the receptor is based on the data obtained during the EMO analysis. It is better if the EMO analysis was carried out by a spectrum analyzer with antennas, which were then used in the organization of the network. Then the determination of the level of intersystem interference in the receptor (AP or MC) is reduced to the fact that losses in the antenna feeder of the receptor (for MC are equal to zero) and losses in the receiving antenna in the direction of the source of interference (for MC are also zero) are subtracted from the measured level of interference. If the measurements were performed with a different antenna, then they can be repeated by connecting the spectrum analyzer to the AP antenna (a larger option), or take into account the difference in the KP of the AP antenna and the antenna with which the measurements were performed. In the second case, it is additionally necessary to take into account losses due to differences in the polarization of antennas.

The reduction in interference due to bandwidth differences depends on what enters the receiver band: the main or out-of-band radiation that interferes with the transmitter. Accordingly, the level of interference in the receiver must be adjusted taking into account the spectral mask of the interfering interference used in the modulation receiver and the coding method. In general, the methods of assessing inter-system and intra-system interference are practically identical. If several external interferences act on the receptor, then it is necessary to either measure their total level, or sum up, taking into account their spectral masks, the intrasystem interferences similarly. If the level of intersystem interference in the receptor exceeds the permissible level, it is necessary either to reduce the level of intersystem interference (shielding, territorial, frequency diversity, use of frequency filters, etc.), or to increase the permissible level of interference (by reducing the radius of cells, increasing the power of MC transmitters and/ or AP, reducing the data rate, choosing a different AP antenna or equipment with a lower signal-to-interference ratio requirement, etc.).

2.2.3. Implementation of a wireless network in hotel and restaurant complexes

Implementation of a wireless network consists of two main stages: installation and configuration of equipment; testing

Stage 1. Installation and configuration of WLAN equipment. The process of installation and configuration of equipment can be divided relative to the levels of the OSI model. Physical level - installation, connection and configuration of network equipment. Logical level - IP addressing management, VLAN configuration, security systems, administration, etc. Placement of access points in the premises is carried out in places determined as optimal as a result of the research that precedes the installation. When installing outside the premises, it is important to ensure reliable sealing of the connectors. In addition, the equipment installed outdoors must work at temperatures from -50 to +50 degrees. In the case of a significant distance from the location of the antenna attachment to the premises, active equipment must also be placed on the street. In this case, either an all-weather model is selected, or the equipment is placed in a thermostatic container that provides a working temperature range. An important factor is also the organization of uninterrupted power supply in unserviced points, grounding, and lightning rods.

Stage 2. WLAN testing. Testing is a necessary step in commissioning a wireless network. Tests should ensure a reliable wireless connection. After installing the wireless network equipment, it is necessary to conduct a "tour" of the territory, check the levels of signals and interference in various points of the coverage area, the ratio of the number of corrupted packets to successfully received ones, etc. Various spectrum analyzers and/or an ordinary laptop with a wireless card and the appropriate software installed can be used as a testing tool. There are many different programs, paid and free, that allow you to check the operation of the wireless network. The program is used in this work. You can also use standard software provided by the wireless equipment manufacturer for WLAN diagnostics. Its capabilities, as a rule, are limited and provide a minimum set of information about the operation of the WLAN. To obtain more complete information about network traffic, you can additionally use sniffers and protocol analyzers, which will allow you to obtain information about data transmitted over the network.

Conclusions.

The performed analysis shows that the data provided by equipment manufacturers are insufficient for effective design. This forces us to use experimental and calculated parameter values. A WLAN design methodology has been developed that takes into account the influence of inter-system and intra-system interference. The proposed calculation methods and algorithms provide an opportunity to model dependencies connecting WLAN parameters. Within the framework of the developed methodology, results were obtained for schemes using directional antennas in access points, and requirements for DS were formulated. Considered possible combinations of frequency channels and proposed options with a minimum level of intra-system interference. Received formulas for calculating signal and interference levels in WLAN receptors.

Using the proposed method, the total level of intrasystem interference from neighboring cells in WLAN receptors was estimated. Various organizational measures and methods of their application, which allow to adjust the ratio of signal / interference in WLAN receptors, are considered. The proposed method of calculating the permissible levels of intersystem interference in WLAN receptors, which takes into account the signal level, the level of inherent noise of the receiver, and the level of intrasystem interference. With the help of the proposed method, an assessment of the permissible level of intersystem interference in WLAN receptors was carried out.

The practical value of the work is that the use of the developed method of designing wireless computer networks for hotel and restaurant complexes, taking into account EMC, will reduce the level of intra-system interference between the receivers of neighboring cells due to the rational selection of wireless local network parameters; increase resistance to interference of designed wireless computer networks due to accounting for intersystem interference at the early stages of design; reduce material and time costs for re-design by taking into account the influence of radio interference in the early stages of design.