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DESIGN AND SIMULATION OF VIRTUAL LOCAL AREA NETWORK USING CISCO PACKET TRACER

Abstract. Modern local networks consist of several subscriber devices located inside the same building. Computers on the local network are interconnected using network equipment - switches. By default, all devices connected to the ports of the same switch can communicate by exchanging network packets.

Computer networks of data transmission are the result of the information revolution and in the future will be able to form the main means of communication. The worldwide trend towards the integration of computers in the network is due to a number of important reasons, such as the acceleration of the transmission of information messages, the ability to quickly exchange information between users, receiving and transmitting messages (faxes, E-mail letters, electronic conferences, etc.) without leaving the workplace, the ability to instantly receive any information from anywhere in the world, as well as the exchange of information between computers of different manufacturers working under different software.

A large number of broadcast packets sent by devices leads to a decrease in network performance, because instead of useful operations, the switches are busy processing data addressed to everyone at once. The situation forces us to divide such large networks into autonomous subnets; as a result, the logical structures of the network are different from the physical topologies. This article discusses VLAN technology (Virtual Local Area Network - VLAN), which allows you to divide one local network into separate segments.

Key words: Computer Networks, IP Addresses, Cisco Packet Tracer, Ping Test, Virtual Trunking Protocol, Subnetting, VLAN.

Introduction. Today in the world there are more than 130 million computers and more than 80% of them are united in various information and computer networks - from small local networks in offices to global networks. Computer networks - a set of personal computers (PC) distributed over a territory and interconnected to share resources (data, software and hardware components).

Basic requirements for modern computer networks:

1) Easy operation and user access to the network;

2) Openness – the ability to connect different types of devices;

3) Development – the ability to increase network resources and subscribers;

4) Autonomy – the user's work on his personal computer (PC) should not be limited to the fact that the PC is included in the network;

5) Integrality – the possibility of processing and transmitting information of various kinds: symbolic, graphical, etc.;

6) Security – the ability to prevent unauthorized access to the network.

The purpose of a computer network is to provide users with a network service. The organization of network service is carried out by network services. Network service provides the user with the ability to perform the following basic functions, which are based on remote access to network resources:
    – work with files distributed over the network (transfer, storage, receiving, playback);
    – multi-user access to files, allowing you to have one instance of the data and organize the collaboration of users in a single information space;
    – work with geographically distributed databases;
    – distributed computing;
    – reception, transmission of e-mail;
    – remote maintenance, network administration.
    The existing networks are currently divided primarily on a territorial basis [1]:
    1. Locate Area Network (LAN), this network covers a small area with a distance between individual computers. Typically, such a network operates within the same institution.
    2. Wide Area Network (WAN), this network usually covers large areas (the territory of a country or several countries). Computers are located at a distance of tens of thousands of kilometers from each other.
    3. Regional networks, such networks exist within the city, district. Currently, each such network is part of a global network and a special specificity in relation to the global network is not different.
    4. Virtual Local Area Network (VLAN) is a feature in routers and switches that allows you to create multiple virtual LANs on a single physical network interface (Ethernet, Wi-Fi interface). VLANs are used to create a logical network topology that is independent of the physical topology.
    Materials and methods. Virtual LAN technology is used in the design of internal networks of universities, organizations and enterprise networks. VLAN is a data link layer technology for building multiple logical networks on the top of physical network. The LAN network is divided into different logical segments called broadcast domains. The workstation division is based on the functions, platforms and teams [2]. Virtual LAN is nothing but a group of devices that are connected virtually but may or may not physically connected [3]. Virtual LAN or VLAN allows network engineers and network administrators to make logical network from physical network. This technology is used to segment a complex network into smaller networks for better manageability, improved performance and security [4].
    Types of VLAN:
    - Port-based VLAN (Port - based VLAN) - each switch port is assigned to a specific VLAN and any network device connected to that port will be in the assigned virtual network;
    - MAC-based VLAN (MAC-based VLAN) - VLAN membership is based on the MAC address of the workstation. In this case, you must bind the MAC addresses of all devices to the VLAN on the switch;
    - Port-based VLAN and IEEE 802.1 v protocols - the Protocol type is used to determine VLAN membership;
    - VLAN based on IEEE 802.1 Q - field VLAN accessories, integrated into the Ethernet frame structure, which allows you to transfer this information over the network. The advantage is the flexibility of configuration, use not only on one switch, but also within the entire switched network; the ability to use equipment from different manufacturers in the organization of the network [5].
    There are two methods for assigning a port to a specific VLAN:
    - static assignment - when the VLAN port ownership is set by the administrator during the configuration process;
    - dynamic assignment - when the port VLAN membership is determined during the operation of the switch by using the procedures described in special standards, such as IEEE 802.1 x When using IEEE 802.1 X to gain access to a switch port a user is authenticated on the RADIUS server. According to the results of authentication the switch port is placed in a particular VLAN [6].
    X.Sun et al. [7] adopted the *K-means clustering algorithm* to partition VLANs for each user group based on a broadcast traffic cost model. The broadcast traffic cost model is defined as

$$B = H * A * W \qquad (1)$$

    Here, H denotes the number of hosts of a VLAN, A denotes the average broadcast traffic (in packets per second, *pkt/s*) generated by a host, W denotes the sum of links of the spanning tree, and B denotes the total broadcast traffic cost of the VLAN. Fuliang Li et al. [5] extend the model as shown in:

$$B_+ = H * A * C \tag{2}$$

Here, H and A have the same meaning as Sung's model, and we assume that broadcast traffic is generated at 2.12 *pkt/s* per source, that is, $A = 2.12$. C denotes the total link cost of a VLAN. B_+ denotes the weighted (i.e. taking into consideration the link cost) broadcast traffic of the VLAN.

K.He et al. [8] proposed the GreenVLAN approach, An energy-efficient approach for VLAN design, developed a practical equations to solve the proposed model and the complexity of the algorithm is analysed:

$$\min \sum_{l \in L} E_l \tag{3}$$

$$s.t. E_l = \psi_l(F_l) \tag{4}$$

$$\sum_{j=1}^{h} x_{ij} \leq N, \forall i \in H \tag{5}$$

$$\sum_{j=1}^{h}\left(1 - x_{ij}\right) \leq M, \forall i \in H \tag{6}$$

$$x_{ij}\left(1 - Q(ij)\right) = 0, \forall i,j \in H \tag{7}$$

$$x_{ij}x_{jk} - x_{ik} = 0, \forall i,j,k \ (i < j < k) \in H \tag{8}$$

$$B\left(v(i)\right) = \sum_{j=1}^{h} x_{ij} * A\left(v(i)\right) * W\left(v(i)\right) \leq Th, \forall i \in H \tag{9}$$

Equation 3 computes the total energy consumption in the network. Equation 4 calculates the energy usage of link l. Equation 5 and Equation 6 guarantee that the produced grouping solution should satisfy the *feasibility criteria*, that is, the number of host per VLAN should not exceed the upper bound N and the number of VLANs created should not exceed the upper bound M. Equation 7 means the produced grouping solution should guarantee the *correctness criteria*, in other words, hosts grouped into the same VLAN must belong to the same logical category. Equation 8 means that if $x_{ij} = 1$ and $x_{jk} = 1$, then x_{ik} must also equals to 1 ($i < j < k$), this equation guarantees the correctness of the solution. Equation 9 makes sure that for each created VLAN, the broadcast traffic will not overflow the threshold Th, which might be determined by the network operator.

The structure of a real network is formed using structure-forming equipment (switches, routers), to which network nodes are connected, and a multi-level (often three-level) network is created [9]. This approach is used when creating a corporate network based on VLAN technology. At the same time, groups of the first level of the information structure are virtual local networks. The second and third levels of the information structure are designed to connect these networks to each other. The number of switches used to connect nodes of the technical structure of the corporate network when creating first-level groups (first-level switches) is determined by the features of the real set, the technical capabilities of the switches. Let's denote this number K_1^*, $K_1^* \geq K_1 \geq 1$. Number of switches to connect first-level switches and create second- level groups (second -level switches) K_2^*, $K_2^* \geq K_2 \geq 1$. The number of switches of the third level to connect the switches of the second level - $K_3^* \geq 0$.

The technical structure of the network is defined by a set of **ST** elements: $Y_1^* = \left\| y_{1ij}^* \right\|$, $(i = 1,2, \dots, M; j = 1,2, \dots K_1^*)$ matrix of connections of technical network nodes (workstations, servers) with first-level switches; $Y_2^* = \left\| y_{2ij}^* \right\|$, $(i = 1,2, \dots, K_1^*; j = 1,2, \dots K_2^*)$ matrix of connections of first-level switches with second-level switches; $Y_3^* = \left\| y_{3ij}^* \right\|$, $(i = 1,2, \dots, K_2^*; j = 1,2, \dots K_3^*)$ matrix of connections between third-level switches and second-level switches; $X_1^* = \left\| x_{1ij}^* \right\|$, $(i,j = 1,2, \dots K_1^*)$ matrix of connections for first-level switches. $X_2^* = \left\| x_{2ij}^* \right\|$, $(i,j = 1,2, \dots K_2^*)$ matrix of connections for second-level switches; $X_3^* = \left\| x_{3ij}^* \right\|$, $(i,j = 1,2, \dots K_3^*)$ matrix of connections of third-level switches. For each level, the following parameters are set matrices that specify the bandwidth of the communication channels used when building networks: $C_1^*(Y_1^*), C_2^*(Y_2^*), C_3^*(Y_3^*), C_1^*(X_1^*), C_2^*(X_2^*), C_3^*(X_3^*)$.

Since routing is used in large-size corporate networks, it is necessary to use appropriate routing algorithms on graphs to calculate flow parameters. For this purpose the matrix of the graph of connections between switches is constructed Ω and it is presented in the following form:

$$\Omega = \begin{pmatrix} X_1^* & Y_1^* & 0 \\ (Y_2^*)^T & X_2^* & Y_3^* \\ 0 & (Y_3^*)^T & X_3^* \end{pmatrix} \tag{10}$$

Thus, the parameters of data flows in the network for a given technical structure are defined by a set of:

$$PST(ST) = \{A_1^*(Y_1^*), A_2^*(Y_2^*), A_3^*(Y_3^*), \lambda_1^*, \lambda_2^*, \lambda_3^*, \gamma_1^*, \Omega\} \qquad (11)$$

Any terminal node of the network has a single connection to the transport subsystem that implements full- duplex mode of information exchange (simplex mode and half duplex only take place in special segments of the corporate network). Therefore, from the point of view of the load on the transport subsystem, any host in the network can be considered as a queuing system with one input and one output. Assuming a Poisson flow of service requests and an arbitrary distribution of their service time (the Kendall notation *M/G/1* system), the analytical model is described following relation:

$$A = \frac{1}{2}\left[1 + \left(\frac{\sigma_{Ts}}{T_s}\right)^2\right], \rho = \lambda \cdot T_s,$$

$$\omega = \frac{\rho^2 A}{1-\rho}, T_\omega = \frac{\rho T_s A}{1-\rho},$$

$$r = \rho + \frac{\rho^2 A}{1-\rho}, T_r = T_s + \frac{\rho T_s A}{1-\rho} \qquad (12)$$

where, σ_{Ts} - the standard deviation of the average maintenance time T_s; λ – the rate of receipt, i.e. the average number of requests received per second; ω – average number of requests waiting for service; T_ω – average waiting time; r – average number of requests in the system, waiting and served; T_r – the average time that a query spends in the system.

The Poisson flow of requests assumption is valid in client-server technologies if we consider the flow of requests from multiple clients to the server.

From the above data, it follows that it is conceptually natural to imagine the corporate network management process as a two-level management process, where a set of basic parameters is formed at the first level, and at the second, with fixed basic parameters, variable parameters are managed.

The decomposition of a management task involves the decomposition of a corporate network into a set of private networks (subnets) and managing the solution of a group of similar private tasks. This is largely consistent with VLAN management principles.

The Experimental Results and Model Network. Cisco Packet Tracer (CPT) is virtual networking simulation software developed by Cisco, to learn and understand various concepts in computer networks. CPT is a powerful network simulation program that allows students to experiment with network behavior and ask "what if" questions. As an integral part of the Networking Academy comprehensive learning experience, Packet Tracer provides simulation, visualization, authoring, assessment, and collaboration capabilities and facilitates the teaching and learning of complex technology concepts. Like any simulation, Packet Tracer relies on a simplified model of networking devices and protocols. It provides a simulated environment where processes between various networking devices, such as routers, switches, wireless access points, computers, links and applications are visible with animations and easy explanatory descriptions [10].

CPT is able to model a large number of devices for various purposes, as well as many different types of connections, which allows you to design networks of any size at a high level of complexity. There are a lot of researches by using VLAN in Packet Tracer [11,12].

The article considers the location of the network topology of three departments of the *IT - TECHNOLOGY, AUTOMATION AND MECHANIZATION OF AGRO-INDUSTRIAL COMPLEX* faculty of the Kazakh National Agrarian University as an example. The scheme of information flows between departments is shown in figure 1.
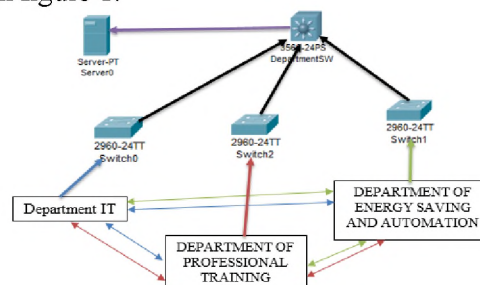

Figure 1 – The scheme of information flows between departments

For experimental work, we created the following topology in Packet Tracer: *Department of Information technology (IT), Department of Professional Training (PT), Department of Energy Saving and Automation (EA)* (figure 2).
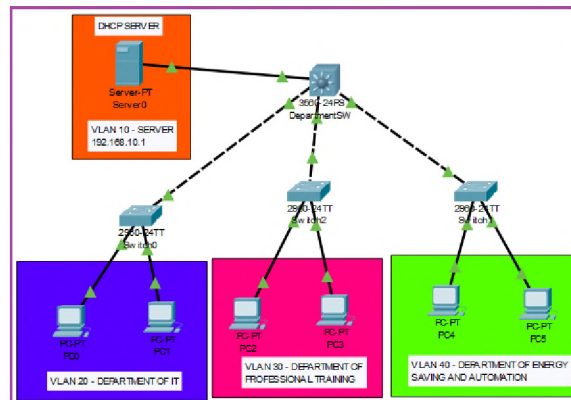

Figure 2 – Topology in Packet Tracer (with VLAN)

Show vlan command description (figure 3):

1 column is the VLAN number. There is initially number 1 here - this is the standard VLAN that is initially available on each switch. Numbers from 1002-1005 for other channel environments. You cannot delete them;

2 column is the name of the VLAN. When creating a VLAN, you can choose meaningful names for them to identify them later. By default there is default, fddi-default, token-ring-default, fddinet-default, trnet-default;

3 column - status. It shows what state the VLAN is in. At the moment, VLAN 1 or default is active, and the next 4 are act / unsup;

4 column - ports. This shows which VLANs the ports belong to. By default, they are in default.

Figure 3 – Show Vlan commands

Virtual Trunking Protocol (VTP) has some issues but not much research has been done for complexities arise in VTP based configuration. In this paper, we focus strongly on various security aspects of VLAN design using with VTP to reduce the much administrative work apart from optimal Inter-VLAN routing design.

Using VTP makes it easier to manage (create, delete, rename) VLANs in the network. In the case of VTP, the change (VLAN information) can be made centrally on one switch, and these changes are propagated to other switches in the network (figure 4). If you don't use VTP, you need to make changes on each switch.

Figure 4 – Configure VPT and Trunk – Port

The Dynamic Host Configuration Protocol (DHCP) allows automatic configuration of network devices. Setting up a DHCP server on the router is beneficial in that it allows for maximum use working router by hanging on it the maximum amount of functionality (Internet, NAT, DHCP, etc.) (fig.5). DHCP allows the router to automatically configure the following basic parameters [1,5]:

- IP address;
- Default gateway;
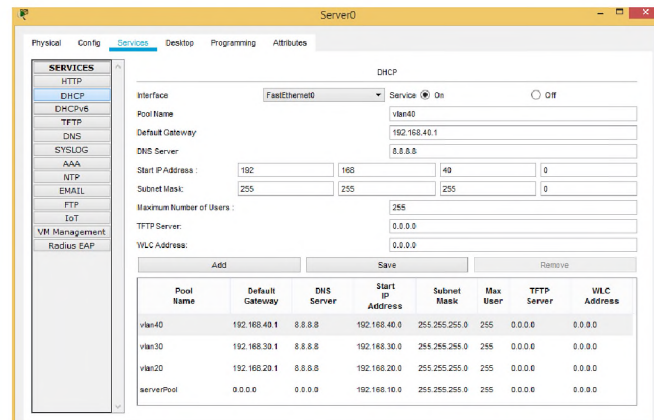- Subnet mask;
- DNS server;
- Domain name.

Figure 5 – Enable DHCP Server

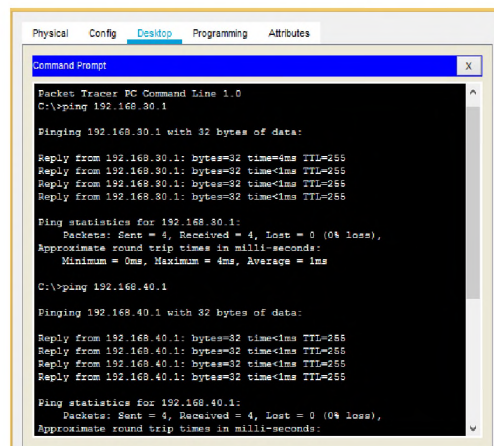Using the ping command, we can see the results of sending packets over the Vlan (figure 6):

Figure 6 – Ping results

Conclusion. In conclusion, we showed the most popular application of VLANs. Also, regardless of physical location, it is possible to logically combine nodes into groups, thereby isolating them from others. This topology is very convenient when employees physically work in different places, but must be combined. And of course, from a security point of view, VLANs are not interchangeable. The main thing is that a limited circle of people have access to network devices.

As a result of the work the following advantages were identified when using Vlan networks between departments:

- facilitates moving, adding devices, and changing their connections to each other;
- a large degree of administrative control is achieved due to the presence of a device that performs routing between VLAN networks on the 3rd level;
- bandwidth consumption is reduced compared to the situation of a single broadcast domain;
- prevention of broadcast storms and the prevention of loops.

The proposed approach to analysing the technical structure of the corporate network and the results obtained allow the network administrator and developer to evaluate the load of communication channels and network equipment with a known information structure. The proposed results can be applied to networks built using VLAN technology.

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CISCO PACKET TRACER АРҚЫЛЫ ВИРТУАЛДЫ ЖЕРГІЛІКТІ ЖЕЛІНІ ЖОБАЛАУ ЖӘНЕ МОДЕЛЬДЕУ

Аннотация. Қазіргі заманғы жергілікті желілер бір ғимаратта орналасқан бірнеше абоненттік құрылғы-дан тұрады. Жергілікті желідегі компьютерлер желілік жабдық-коммутаторлар арқылы қосылған. Бір комму-татор портына қосылған құрылғылар желілік пакеттермен алмасуы мүмкін.

Компьютерлік желілер негізінде деректерді тарату ақпараттық революцияның нәтижесі саналады және болашақта байланыстың негізгі құралдары бола алады. Компьютерлердің желіге кірігуінің жалпы әлемдік үрдісі ақпараттық хабарламаларды таратуды жеделдету, пайдаланушылар арасында жылдам ақпарат алмасу мүмкіндігі, хабарламаларды (факс, электрондық хат, электрондық конференция және т.б.) қабылдау және жіберу сияқты бірқатар маңызды себептерге негізделген, сондай-ақ түрлі бағдарламалық жасақтама арқылы жұмыс атқаратын өндіруші компьютерлері арасында ақпарат алмасады.

Қазіргі кездегі желілер мынадай топтарға бөлінеді: жергілікті желі (LAN); ауқымды желі (WAN); аймақ-тық желілер; виртуалды жергілікті желі (VLAN). Таратылатын домен көлемін шектеу арқылы VLAN жерг-ілікті желілердің қауіпсіздігі мен өнімділігін қамтамасыз етеді.

Виртуалды LAN технологиясы университет, ұйым және корпоративтік желілердің ішкі желісін жобалауда кеңінен қолданылады.

Хаттамалар желіде бірнеше ішкі желілерді бағдарламалауға мүмкіндік береді, олардың әрқайсысы тра-фикті бір-бірінен оқшаулайтын жеке VLAN-ға қосылған. Ethernet коммутаторлары орнатылған жылдамдық-ты шектеу мүмкіндіктерін қолдана отырып, физикалық интерфейстер арқылы ағын жылдамдығын шектей алады.

Қазіргі Ethernet коммутаторларындағы осы құрылымдық механизмдердің көпшілігі SNMP, HTTP неме-се командалық жол интерфейсі арқылы қолжетімді келеді. Басқару хаттамалары негізінде VLAN және соған байланысты желілерді, өзге де интерфейс жылдамдығының шектеуін бағдарламалық деңгейде бақылай аламыз. Сондай-ақ, қашықтықтан сәтсіздік қосқышын бақылап отыруға болады және соған орай түрлі әре-кеттер басталуы мүмкін.

Мақалада Қазақ ұлттық аграрлық университетінің (ҚазҰАУ) «IT - технологиялар, агроөнеркәсіптік кешенді автоматтандыру және механикаландыру» факультетінің үш кафедрасының желілік топологиясының орналасу жағдайы мысал ретінде қарастырылады.

Эксперименттік жұмысқа арнайы Cisco Packet Tracer-де келесі топологияны құрдық: «IT және автомат-тандыру» кафедрасы, «Кәсіптік оқыту» кафедрасы, «Энергияны үнемдеу және автоматика» кафедрасы.

Жұмыста жұмысшы объектілерді орналасқан жеріне қарамастан белгілі бір топтарға, бір-бірінен оқшаулай отырып біріктіруге болатындығы көрсетілді. Бұл топология қызметкерлер әртүрлі аймақтарда бірге жұмыс атқарғанда өте ыңғайлы. Қауіпсіздік тұрғысынан VLAN бір-бірін алмастыра алмайтыны белгілі. Ең бастысы, қызметкерлердің шектеулі тобы желілік құрылғыларға қол жеткізеді.

Жұмыс нәтижесінде Vlan желілерін кафедралар арасында пайдалануда келесі артықшылықтар анықталды:

– орын алмастыру, құрылғыларды қосу және олардың бір-бірімен байланысын өзгертуді жеңілдетеді;
– 3-деңгейлік VLAN құрылғысының желі арасында байланысты жүзеге асыруына байланысты әкімшілік бақылаудың жылдамдығы артады;
– ақпаратты тарату қабілеттілігі орталық тарату доменімен салыстырғанда төмендеді.

Топология факультеттің жергілікті желісін 3 жеке сегментке бөлуге мүмкіндік берді, бұл желілік жүкте-ме трафигін едәуір азайтты. Тұрғызылған топология ҚазҰАУ желілік әкімшілігіне енгізу үшін ұсынылды.

Түйін сөздер: компьютерлік желілер, IP-адрестер, Cisco Packet Tracer, Ping Test, виртуалды транкингтік хаттама, ішкі желілер, VLAN.

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ПРОЕКТИРОВАНИЕ И МОДЕЛИРОВАНИЕ ВИРТУАЛЬНОЙ ЛОКАЛЬНОЙ СЕТИ С ИСПОЛЬЗОВАНИЕМ CISCO PACKET TRACER

Аннотация. Современные локальные сети состоят из нескольких абонентских устройств, расположенных внутри одного здания. Компьютеры в локальной сети соединены между собой с помощью сетевого оборудования - коммутаторов. По умолчанию все устройства, подключенные к портам одного коммутатора, могут обмениваться сетевыми пакетами.

Компьютерные сети передачи данных являются результатом информационной революции и в будущем смогут стать основными средствами связи.

Существующие сети в настоящее время разделены в основном по территориальному признаку: Локальная сеть (LAN); Глобальная сеть (WAN); Региональные сети (Regional networks); Виртуальная локальная сеть (VLAN). VLAN помогает безопасности и производительности локальных сетей, ограничивая размер широковещательных доменов.

Технология виртуальной локальной сети используется при проектировании внутренних сетей университетов, организаций и корпоративных сетей.

Протоколы позволяют программировать в сети несколько подсетей, каждый из которых связан с отдельной VLAN, изолируя трафик друг от друга. Коммутаторы Ethernet могут ограничивать скорость входящих или исходящих потоков через свои физические интерфейсы, используя встроенные функции ограничения скорости.

Большинство из этих механизмов структурирования в современных коммутаторах Ethernet доступны через интерфейсы SNMP, HTTP или командной строки. Можно программно настроить VLAN и связанные с ними связующие сети, а также ограничения скорости интерфейса, используя протоколы управления. Также возможно удаленное отслеживание коммутаторов на предмет сбоев, и различные действия могут быть инициированы в ответ на эти события сбоев.

В статье в качестве примера рассматривается расположение топологии сети трех кафедр факультета «IT-технологий, автоматизации и механизации агропромышленного комплекса» Казахского национального аграрного университета (КазНАУ).

Для экспериментальной работы мы создали следующую топологию в Cisco Packet Tracer: кафедра «IT и автоматизации», кафедра «Профессионального обучения», кафедра «Энергосбережения и автоматизации».

В данной работе мы показали, что, независимо от физического расположения, можно логически объединять узлы в группы, тем самым изолируя их от других. Такая топология очень удобна, когда сотрудники физически работают в разных местах, но должны быть объединены. И конечно, с точки зрения безопасности, VLAN не являются взаимозаменяемыми. Главное, чтобы ограниченный круг людей имел доступ к сетевым устройствам.

В результате проведенной работы были выявлены следующие преимущества при использовании сетей Vlan между подразделениями:

- облегчает перемещение, добавление устройств и изменение их соединений друг с другом;
- большая степень административного контроля достигается за счет наличия устройства, выполняющего маршрутизацию между сетями VLAN на 3-м уровне;
- потребление полосы пропускания снижается по сравнению с ситуацией одного широковещательного домена;
- предотвращение широковещательных штормов и предотвращение петель.

Построенная топология позволило разделить локальную сеть факультета на 3 отдельные сегменты, которая значительно снизил трафик загружаемости сети. Построенная топология предложена системным администраторам КазНАУ для внедрения.

Ключевые слова: компьютерные сети, IP-адреса, Cisco Packet Tracer, Ping Test, виртуальный транкинговый протокол, подсети, VLAN.

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