**Richardson School District**

**Network Design Project**

**CASE STUDY**

You will be applying what you have learned to the Richardson School District Network Design Project. The fictional Richardson School District is located in Richardson, Texas. The school district is in the process of designing and implementing an enterprise-wide network, which will include LANs at each site and a wide-area network (WAN) to provide data connectivity between all school sites. You have consulted with teachers, students, administrators, and staff members to determine need, mission-critical data and operations, availability, and future plans.

Objective: To apply your networking knowledge to a real-life example and to help you review concepts integral to the CCNA Certification Exam.

Outcomes: You will work independently as you document the Richardson School District LAN and WAN designs by creating a portfolio.

**LOCAL AREA NETWORK (LAN)**

**Richardson School District Project Task: User Requirements**

You will begin studying the Richardson School District Network Design Project. You will be assigned one school site. You need to complete the following tasks:

1. You will be assigned one school site.

**Richardson School District Project Task: User Requirements, Site Maps, Handling Graphics**

You will continue studying the Richardson School District Network Design Project, focusing on the LAN requirements. You should begin work on your school site wiring diagrams (physical topologies). You need to complete the following tasks:

1. Familiarize yourself with the LAN sections and User Counts.
2. Begin working on your site wiring diagrams

**Richardson Project: Designing the Network**

You will begin the process of designing the LAN at your specific site within Richardson School District WAN. As concepts and requirements are introduced, you will be able to apply them in your network design. You will need to make sure to address the following requirements:

* The LAN is meant to serve different "workgroups" of staff members and students. This logical division will require the use of VLANs and will be a major design decision. For example, VLANs should be used to secure the administrators' machines from the students' machines.
* Access to the Internet from any site in the school district, via the District WAN, is also an integral part of this implementation.
* Because this network implementation must be functional for a minimum of 7-10 years, all design considerations should include at least 10x (times) growth in the LAN throughput, 2x (times) growth in WAN throughput, and 10x (times) growth in the District Internet connection throughput.
* A minimum of 100 Mbps to any host computer in the network and 1000 Mbps to any server host in the network is required.
* Routed protocols may be implemented in the network: TCP/IP.

**Richardson Project: Server Placement and Function**

You should categorize all file servers for the Richardson School District as enterprise or workgroup types, and then place servers in the network topology according to the anticipated traffic patterns of users and according to the following functions:

* DNS and E-Mail Services - Each district hub location should contain a DNS server to support the individual schools serviced out of that location. Each school site should also contain a host for DNS and e-mail services (that is, a local post office) that will maintain a complete directory of the staff members and students for that location.
* The Administrative Server - Each school site location should have an administration server for the student tracking, attendance, grading, and other administrative functions. This server should run TCP/IP as its protocol suite and should be made available only to teachers and staff members.
* Application Server - All computer applications will be housed in a central server at each school site location. As applications such as Word Processing, Excel, PowerPoint, etc. are requested by users, these applications will be retrieved from the application server. This will provide district support staff with an easy and efficient method for upgrading applications without having to reload new software on each computer in the district network. This server will use TCP/IP as its OSI layer 3 and 4 protocols and will be made available to anyone at the school site.
* Other Servers - Any other servers implemented at the school sites should be considered departmental (workgroup) servers, and should be placed according to user group access needs. An example would be a server running an instructional application for a specific school site.

**Richardson Project: Determining Network Traffic Load**

You need to determine the network traffic load for the Richardson School District before developing a network structure and acquiring hardware. Additionally, when analyzing the district's technical requirements, you should estimate the traffic load caused by applications in packet size (for example, you need to estimate the size of files in bytes per second needed to be transmitted over the network).

Certain types of network use can generate large volumes of traffic and, therefore, can cause congestion, including congestion of the following:

* Internet access
* Computers loading software from a remote site
* Anything that transmits images or video
* Central database access
* Department file servers

You should estimate worst-case traffic load on the network during the busiest times for users and during regularly scheduled network services, such as file server backups.

**Richardson Project: Speed and Expansion**

For the Richardson School District network, you need to build the Layer 1 components of the district network with speed and expansion capabilities. As you know, the physical layer controls the way data is transmitted between the source and a destination node. Therefore, the type of media and topology you select helps you determine how much data can travel across the network and how quickly.

**Richardson Project: Catchment Areas**

Determine the number of horizontal cable runs to each room that the MDF or IDF will be servicing in its catchment area.

**Richardson Project: Connection Speeds**

In the Richardson School District network, the vertical cabling should carry all data traffic between the IDFs and MDFs. Therefore, the speed of this connection should be designed to be the fast link in the network. This link should be at least 1000 Mbps.

**Richardson Project: LAN Wiring Scheme Requirements**

As you're planning the wiring for the sites of the Richardson School District network, you need to take into account certain LAN requirements related to user access, segmentation, infrastructure, cabling, MDFs, and IDFs. Therefore, you should address the requirements described here when designing the network.

**Requirement 1**   
Two LAN segments need to be implemented in each school site and the district office. One LAN needs to be designated for student usage and the other needs to be designated for instructor/administration usage.

**Requirement 2**   
The LAN infrastructure needs to be based on Ethernet LAN switching, which will allow for a migration to faster speeds (that is, more bandwidth) to the individual computers and between MDFs and IDFs without revamping the physical wiring scheme to accommodate future applications. The transport speeds need to be at a minimum Ethernet 100BASE-TX, 100BASE-FX or higher.

**Requirement 3**   
Horizontal cabling needs to be Category 6 UTP and needs to have the capacity to accommodate at least 100 Mbps. Vertical (backbone) cabling needs to be fiber-optic multi-mode cable. The cabling infrastructure needs to comply with TIA/EIA-568-A/B and/or TIA/EIA-569 standards.

**Requirement 4**   
In each school site location, an MDF room needs to be established as the central point to which all LAN cabling will be terminated. This will also be the point of presence (POP) for the WAN connection. The IDF should service its geographical area, and the IDF should be connected directly to the MDF in a star or extended star topology.

**Richardson Project: Layer 2 Design Goals**

The following are Layer 2 LAN topology design goals for the sites of the Richardson School District network:

* You should install LAN switching devices that use segmentation in order to reduce the collision domain size.
* You should create VLANs and unique broadcast domains based on user workgroups.

**Richardson Project: Deployment of Switches**

As part of the Richardson School District network design and implementation, you need to determine what type of switches to obtain, how many of them to obtain, and where to place them in the network. Possible locations include the MDFs and IDFs in the school site locations and at the main district office. Additionally, you need to determine what types of switches are needed, such as LAN or WAN switches, and whether they need to be Layer 2 or Layer 3 switches. Finally, you need to determine the segmentation and security required to establish the types, number, and placement of switches in the network.

**Richardson Project: LAN Topology Requirements**

As you're planning the LAN topology for your school site, you need to keep in mind certain requirements for rooms that need access to the network and the room's wiring POP.

**Requirement 1**   
Each room requiring connection to the network needs to be able to support the required number of workstations with Category 6 UTP runs for data, with one run terminated at the teacher's workstation. These cable runs should be terminated in the closest MDF or IDF. All Category 6 UTP cable runs need to be tested end-to-end for at least 100 Mbps bandwidth capacity.

**Requirement 2**

A single location on each floor needs to be designated as the wiring POP for that floor. It needs to consist of a lockable cabinet containing all cable terminations and electronic components. Network 1 needs to be allocated for general student use, and Network 2 needs to be allocated for instructor/administrative use.

**Richardson Project: LAN User Counts**

There will be 250 computers in each school site for student usage and 75 computers in each school site for instructor/administration usage. *(See School Site Diagram)*

Each District Hub is responsible for 11 schools. You have been assigned one school within your respective District Hub.

**Richardson Project: Layer 3 Design Goals**

The following are Layer 3 LAN topology design goals for your site:

* Build a path between LAN segments that will filter the flow of data packets.
* Isolate ARP broadcasts.
* Isolate collisions between segments.
* Filter Layer 4 services between segments.

**Richardson Project: Addressing**

The District Office/Network Operations Center should develop a complete TCP/IP addressing and naming convention scheme for all hosts, servers, and network interconnection devices. The implementation of unauthorized addresses should be prohibited. All computers located on the instructor/administrative networks should have static addresses. Student computers should obtain addresses by utilizing Dynamic Host Configuration Protocol (DHCP). DHCP provides a mechanism for allocating IP addresses dynamically so that addresses can be reused when hosts no longer need them. While the District Office/Network Operations Center (NOC) should design, implement, and enforce the overall addressing scheme for the network, DHCP should be administered by the local school site within the confines of the address blocks they were assigned. The District Addressing Scheme can be implemented in a number of ways. Ideas you should consider are Class A, B, and C Addresses with appropriate subnetting, Network Address Translation (NAT), and Private Network Numbers.

**Richardson Project: Network Management**

A master network management host will be established at the District Office/Network Operations Center and will have total management rights over all devices in the network. This host will also serve as the router configuration host and maintain the current configurations of all routers in the network. The management scheme for the data portion of the network will be based on the Simple Network Management Protocol (SNMP) standards. All routers will be pointed to the master Network Management host for the purpose of downloading new or existing configurations. The District Office/Network Operations Center will maintain the super user passwords for all network devices and configuration changes on these devices will be authorized from the District Office/Network Operations Center.

**Richardson School District Project Task: LAN Design**

You have learned concepts that will help you begin the design process for the Richardson School District network. As part of the LAN design process, you need to complete the following tasks:

1. Gather all information required to design a LAN for your school site in the Richardson School District, doing additional research as needed.
2. Design the LAN for your school site based on the requirements gathered in step 1, in the context of developing an overall IP addressing scheme for the school district. Some ideas to consider are Class A, B, and C networks with proper subnetting; Network Address Translation (NAT), and Private Network numbers. The District Office/Network Operations Center (NOC) will control the distribution of all IP addresses. Once the NOC distributes IP address blocks to school sites, you can assign static and dynamic IP addresses within their individual LANs.
3. Develop and document an overall LAN design based on the user and district requirements. To properly design your site's LAN, complete these tasks:
   * A user requirements document (your interpretation and proposal of what is means and the District and site needs.)
   * An overall design document, which includes a logical LAN design (logical topology) of the school and a complete physical design (physical topology) that includes:
     1. Details of all MDFs/IDFs in the rooms, including a to-scale diagram (can be hand-drawn but must be legible)
     2. The number of HCCs, VCCs, and LAN switch ports required to meet the existing and projected growth needs
     3. LAN Electronics List: what devices (hubs, switches, routers, servers, computers for students and instructor/administration, and any others) are needed
     4. Specifications on the type and quantity of cable media for all horizontal and vertical runs
     5. Specifications on security, VLANs, and the separation of staff and student networks
     6. The overall district IP addressing scheme and how it is applied at the local school site
     7. Price list of equipment and cabling

**Richardson Project: Routing Protocols and Implementing OSPF**

Routing protocols (such as EIGRP, RIP, OSPF) route routed/routable protocols (such as IP, AppleTalk and IPX) through a network. You will apply OSPF to the network design you have been creating for the Richardson School District Network Design project. In addition, you will learn how to implement OSPF and all the OSPF-required configurations needed for the network implementations.

**Richardson Project: OSPF Design Goals**

You will learn the concepts and configuration techniques to help address the following design goals for OSPF implementation in the Richardson School District network:

* The network should use stable routing, and no routing loops should occur
* The network should quickly respond to changes in the network topology.
* The network should have low overhead, and OSPF itself should not use more bandwidth than is actually needed for its task.
* The network design should take into account error rates and level of traffic on different paths.

**Richardson Project: Autonomous (AS) Number**

Autonomous (AS) number consistency is a design issue. You need to have the same number throughout the Richardson School District network. The AS is assigned a 16-bit number by the Internet Assigned Numbers Authority. You have been assigned AS number 18.

**Richardson School District Project Task: Routing Protocols and Configuring OSPF**

You have learned concepts and configuration processes that will help you implement OSPF as the routing protocol in the Richardson School District network. As part of the OSPF configuration and implementation, you need to complete the following tasks:

1. Identify and gather the information required to implement OSPF at the schools' networks and across the district network. Add the information you gather to the existing user requirements and LAN design.
2. Identify and document the networks that will be advertised by the routers in the school district and add that information to the requirements and LAN design.
3. Document the router command sequence needed to implement OSPF on the school site’s router.
4. Identify the best settings for hold-down timer, update timer, and so on. Also, document appropriate bandwidth settings for serial interfaces.
5. Continue LAN Design Tasks: Site Wiring Designs, LAN Logical Designs, Typical MDF and IDF Designs and Equipment Tables, Site-specific LAN Equipment List, and a Price List of all devices and cabling.
6. Apply the CCNA Certification Exam Learning Objectives to your specific design. In this way, you will be studying for their CCNA Certification Exam as you work through the case study. (These objectives are used as a reference and don’t have to be answered).

**Richardson School District Project: ACLs**

You have learned the concepts and configuration commands that will help you use and implement ACLs in the Richardson School District network. You have learned how data traffic flows across a LAN and the methods for controlling the flow of these data packets based on layers 2 & 3 addressing and layer 4 services. In addition, you will be able to apply ACLs to your school site design and implementation.

**Richardson Project: Security Requirements**

The LAN design for all schools in the Richardson School District requires that each school have two networks: one for students and the other for instructors/administration. Each unique LAN segment should be connected to a separate Ethernet port on the router to service that LAN or the use of subinterfaces. Such routers exist; search <http://www.cisco.com> for more information. As part of the security solution, you need to devise an ACL for the local site access router that will deny users access from the student LAN segment into the instructor/administrative LAN segment, yet continue to give the instructor/administrative LAN complete access to the student LAN segment. Exceptions to this ACL can be made on an individual basis.

One exception to this ACL is that the router is to pass any Domain Name System (DNS) or e-mail traffic to the DNS/e-mail server, which is located on the instructor/administration LAN segment. This is traffic originating on the LAN that is accessed by the students. Therefore, if a student is surfing the Web and needs the DNS server to resolve host names, this ACL will allow for host name resolution. In addition, this ACL will allow students to send and receive e-mail.

**Richardson Project: Using ACLs**

When you use ACLs on the local site access routers, all traffic from the student LANs should be prohibited on the instructor/administration LAN. You can make exceptions to this requirement by allowing applications, such as e-mail and directory services, to pass freely because they pose minimal risk.

E-mail and DNS need to be available throughout the district, and these types of services should not allow any unauthorized access to the instructor/administration network. All the ACLs you create need to be controlled at the District Office/Network Operations Center (NOC), and you need to review exceptions to the ACLs prior to implementation.

In response to the network design and security requirements, you need to complete the following tasks:

1. Document the router command sequence required to implement each ACL on each of the local school site router's interfaces.
2. Continue LAN Design Tasks: Site Wiring Designs, LAN Logical Designs, Typical MDF and IDF Designs and Equipment Tables, Site-specific LAN Equipment List, and a Price List of all devices and cabling.

**Richardson Project: User Permission**

You need to develop a user ID and password policy for all computers in the District. This policy should be published and strictly enforced. Finally, you need make sure that all computers in the district network will have full access to the Internet.

**Richardson Project: Firewall Implementation**

The Internet connectivity you will need to implement in the Richardson School District requires a firewall implementation. Those applications that are exposed to the Internet need to reside on a public backbone network. You need to ensure that all connections initiated from the Internet into each school's private network will be refused. In the District security model, the network will be divided into three (3) logical network classifications, instructor/administration, student, external with secured interconnections between them.

**Richardson Project: IPv4 Implementation**

You will learn how to implement IPv4 in the Richardson School District network. The school district needs a workgroup server in each building at the school site. The computer labs are located on the student LAN segments of their respective sites. IPv4 services need to be advertised across the school district network to other student LAN segments.

**Richardson Project: Configuring Subinterfaces**

If a router's interface needs to exist on two different IPv4 networks to accommodate two different frame types or two different IP subnets, or if you run out of host space, then you can configure subinterfaces, if needed.

You have learned some basic principles of network management that would help you administer the LAN you have designed. You need to complete the following tasks to make sure the LAN part of your solution is finished:

* LAN User Requirements Document
* Site LAN Wiring Plan (physical topology)
* Site LAN Logical Topology (including IP Addressing Scheme)
* Wiring Closet Diagrams
* LAN Electronics/Devices with pricing
* LAN Media with pricing
* OSPF Implementation
* Access Control Lists
* Simple Network Management Protocol
* Firewall Implementation
* IPv4 Implementation
* Switch security and VLANs
* Server placement and function
* User permissions policy

# WIDE AREA NETWORK (WAN)

**Richardson School District Project Task: WANs**

For the remainder of the case study, you will shift your focus to WANs and your case study tasks will shift to WANs as well.

**Richardson Project: WAN Implementation**

The Richardson School District WAN should connect all school sites and administrative offices with the district office for the purpose of delivering data. The information presented will help you understand and design a district WAN that connects all the schools and administrative offices.

**Richardson Project: WAN Technology Design**

The WAN technology required for the Richardson District WAN's link to the Internet is running at T1 speed. You will use a static default route to forward traffic to the Internet.

**Richardson Project: Deployment of CSUs/DSUs**

As part of the Richardson School District network design and implementation, you need to determine what kind of CSU/DSUs to obtain, how many of them to obtain, and where to place them in the network. Possible locations include the MDFs in the school site locations and at the main district office, where the WAN links will be terminated. Keep in mind that CSUs/DSUs need to be located close to routers.

**Richardson Project: Dedicated Lines**

The Richardson School District should use dedicated lines (T1) for its WAN core. You will need to determine the types of equipment must be purchased (such as CSUs/DSUs). You will not have to get pricing for the purchase of T1 lines from a provider.

* Two T1 data lines will provide Point-to-Point connectivity between each of the three District Hubs:
  + District Office (Network Operations Center)
  + Education Service Center I (District Hub I)
  + Education Service Center II (District Hub II)
* One T1data line will provide Point-to-Point connectivity from a District Hub to a connected school site.
* One T1 data line will connect all sites to the Internet. This connection will occur at the District Office (Network Operations Center) from the firewall router(s) to the "cloud."

**Richardson Project School District Project Task: WANs**

You have learned about the WAN technologies that enable you to interconnect all the individual Richardson School District sites into the WAN topology.

You need to complete the following tasks:

1. Select WAN services for the district WAN-to-site, WAN core-to-WAN core, and WAN-to-Internet connections.
2. Begin Documenting the WAN design.
3. Apply the CCNA Certification Exam Learning Objectives to your specific design. In this way, you will be studying for their CCNA Certification Exam as you work through the case study. (These objectives are used as a reference and don’t have to be answered).

**Richardson Project: WAN Design**

You will learn about WAN design processes that will enable you to implement WAN services requirements into the Richardson School District network design. The district WAN should connect all school and administrative offices with the district office for the purpose of delivering data.

Mission-critical data and operations are considered key to the business, and access to them is critical to the business running on a daily basis. The District Office/Network Operations Center (NOC) has authority over mission-critical data and operations, along with addressing, naming, topology design, and configuration. Some districts have a central Management Information System (MIS) department that controls everything. Some districts have very small MIS departments and, therefore, must pass on authority to other departments and local school sites.

**Richardson Project: Analyzing Availability**

When analyzing your district's technical requirements, estimate the traffic load caused by applications and by normal protocol behavior (for example, a new node joining the network). Estimate worst-case traffic load during the busiest times for users and during regularly scheduled network services, such as file server backups. This will help you understand what availability means to your customers.

**Richardson Project: Analyzing Network Traffic Load and Traffic Problems**

Before you develop a district network structure and select hardware, you need to determine the network traffic load that the district WAN needs to handle. You should determine all the sources of traffic and define what source characteristics must be ascertained. At this step, it is very important to define the sources in sufficient detail that source traffic can be measured or estimated.

Additionally, you need to evaluate applications that might cause traffic problems in the Richardson School District WAN. The following applications can generate large volumes of traffic and therefore can cause network problems such as congestion:

* Internet access
* Computers loading software from a remote site
* Anything that transmits images or video
* Central database access
* Department file servers

The introduction of new sources or applications into the Richardson School District WAN must be projected, along with likely growth rates. Finally, district network management data is an important source that you should not overlook because it could take up more than 15% of the total traffic volume.

**Richardson Project: The WAN Core**

The WAN core for the Richardson School District network should be a high-speed backbone designed to route packets as quickly as possible. School site locations should connect to the WAN core based on physical location.

**Richardson Project: The Two-Layer Hierarchical Model**

The Richardson School District WAN should be based on a two-layer hierarchical model. Three regional Hubs should be established – one at the District Office (Network Operations Center), one at the Education Service Center I (District Hub I), and one at the Education Service Center II (District Hub II) – in order to form a fast WAN core network.

**Richardson Project: WAN Link**

You should provide access to the Internet or any other outside network connections through the Richardson School District office by using a default static route. For security purposes, no other connections should be permitted.

**Richardson Project: Internet Connectivity**

All Internet connectivity will be supplied through the District Office/Network Operations Center with the District Office being the single point of contact for all schools and organizations within the district. This connection will be highly controlled and capacity (bandwidth) upgraded as usage dictates. The Internet connection will utilize firewall implementation with a public network established for services that will be exposed to the Internet such as Email and DNS. All connectivity that is initiated from the Internet to the internal District network will be protected via Access Control Lists (ACLs) on the routers that make up the firewall architecture. Any connectivity initiated from the District Office/Network Operations Center to the Internet will be permitted to communicate freely. Email and DNS services will communicate freely in both directions since these applications pose no security threat.

**Richardson Project: WAN Design**

You have learned about the WAN design process, so now you can focus on interconnecting all the individual Richardson School District sites into a WAN topology that satisfies the users' requirements.

Complete the following tasks:

1. Create a WAN design that includes the following:
   * Create a WAN User Requirements Document focusing on interconnecting your assigned school site into a WAN topology.
   * Document WAN link speeds.
   * Develop a list of additional equipment, such as CSUs/DSUs (channel service units/data service units) and router interfaces required to implement the district-wide WAN.
   * Price list of equipment and cabling.
2. Document all the router commands necessary to configuration local site access routers in order to implement the WAN design.
3. Apply the CCNA Certification Exam Learning Objectives to your specific design. In this way, you will be studying for their CCNA Certification Exam as you work through the case study. (These objectives are used as a reference and don’t have to be answered).
4. **Richardson Project: PPP Encapsulation**

Although both PPP and HDLC are appropriate frame types for point-to-point connections, you should use PPP on point-to-point links in the Richardson School District network. PPP offers the following advantages:

* Interoperability between networking vendors
* LCP for negotiating basic line interoperability
* A family of network control protocols for negotiating individual Layer 3 protocols

**Richardson Project: Applying PPP**

You learned about WAN design and developed the Richardson School District's WAN design to allow connectivity between all sites in the district. Without a Layer 2 protocol, the physical WAN links have no mechanism to transmit data and implement flow control. You will apply PPP as the data link-layer protocol to be used in the district WAN implementation. You can enable PPP on serial lines to encapsulate IP and other network-layer protocol datagrams.

**Richardson Project: Applying PPP Multilink**

Multilink PPP provides a method for spreading traffic across multiple physical WAN links. It allows packets to be fragmented and sends these fragments simultaneously over multiple point-to-point links to the same remote address.

**Richardson School District Project Task: PPP and PPP Multilink**

You learned concepts and configuration processes that will help you configure PPP and PPP Multilink in the Richardson School District network. As part of the configuration, you need to complete the following tasks:

1. Apply PPP and PPP Multilink where appropriate to the existing WAN designs.
2. Document the router commands necessary to implement PPP and/or PPP Multilink on the router interfaces.

**Richardson School District Project Task: Finish the Case Study**

You have learned about network management techniques that could help you run the individual school site LANs and the overall Richardson School District WAN.

You now need to complete all WAN tasks. Be sure you have completed the following WAN tasks:

* WAN Requirements Document
* WAN Physical Topology
* WAN Logical Topology, including IP Addressing Scheme
* WAN Electronics/Devices with pricing
* WAN Media
* Static default route(s)
* PPP and PPP Multilink Implementation
* Traffic flow and Routing Update Analysis
* WAN line speeds
* ACL/firewall implementation