Accounting & Financial Services Corp.

Accounting & Financial Services Corp. Network Design Proposal

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Introduction

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Executive Summary

Accounting & Financial Service Corporation (AFS) is a financial accounting firm with 1,600 employees spread across seven locations in the United States. The company seeks a new network that will link all offices with the headquarters for secure file sharing and application sharing.

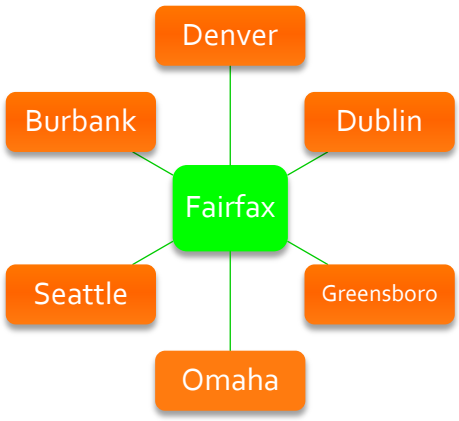
AFS's network design will consist of a wide-area-network (WAN) with 1000Base-FX Gigabit Ethernet over fiber optic cable using a star architecture. The WAN will be connected to a rack-mounted switched backbone network (BN) that uses 100Base-TX Ethernet over Category 5 cables. The BNs will contain layer 2 and layer 3 switches. The BNs will be connected to switched 100Base-TX Ethernet local-area-networks that use multipoint circuits in a star topology.

Each local-area-network (LAN) will connect several department workstations to database, file and print services, as well as the AFS BN, which will in turn connect workstations to the WAN.

Project Description

The proposed network is designed to link AFS Headquarters, located in Fairfax, VA, to the company's six branch offices, located in Burbank, CA, Denver, CO, Dublin, OH, Greensboro, NC, Omaha, NE, and Seattle, WA.

AFS HQ contains seven departments that will be linked by the network. Each branch office consists of five departments that will also be linked by the network.



The table below details the distance between each branch office and the headquarters. This will be used to determine the amount of cable needed.

BRANCH LOCATIONS

	Distance to HQ in miles	Distance to HQ in feet
DUBLIN, OH	500	2.64 Million
GREENSBORO, NC	300	1.58 Million
DENVER, CO	1,800	9.5 Million
BURBANK, CA	2,700	14.26 Million
SEATTLE, WA	2,800	14.78 Million
OMAHA, NE	1,200	6.33 Million

NETWORK OBJECTIVES

- **SECURITY**
  The network must be designed to prevent unauthorized access, both logically and physically.
- **SPEED**
  The network must provide enough bandwidth to meet demand during periods of peak usage.
- **RELIABILITY**
  The network must contain redundancy to ensure that the failure of one system will not bring the entire network down.
- **SCALABILITY**
  The network must be capable of sustaining scalability without the need to rebuild the entire network. Changes and updates must be easy to implement.

Network Objectives

The network is designed to meet the following requirements:

- **Security.** The network must be designed to prevent unauthorized access, both logically and physically.
- **Speed.** The network must provide enough bandwidth to meet demand during periods of peak usage.
- **Reliability.** The network must contain redundancy to ensure that the failure of one system will not bring the entire network down.
- **Scalability.** The network must be capable of sustaining scalability without the need to rebuild the entire network. Changes and updates must be easy to implement.

Design Assumptions

This network design makes the following assumptions:

- AFS does not currently have a network. The entire infrastructure will be built from scratch.
- AFS wants to build all circuits in the network instead of leasing them.
- Each department resides on a separate floor within AFS offices.
- AFS does not share buildings with any other businesses.
- AFS wants to use Microsoft operating systems and productivity suites. They also want to use Adobe graphic design products.
- AFS throughput rates indicate that 100Base-TX for LANs and 1000Base-FX for the WAN will suffice.
- AFS will maintain physical security of the network. The network design must only ensure that it is logically secure.

Network Needs

The majority of traffic on this network will be file sharing including reports, brochures, accounting information, financial information, and personnel profiles. The network will also need to handle graphics-heavy files, web pages, and several databases. At this time, AFS is not interested in VoIP or video teleconferencing.

The network will need to accommodate AFS's 1,600 employees across seven locations.

Geographic Scope

The AFS network will consist of the following layers:

- Access Layer: Dell OmniPlex 390 desktop or Dell Latitude E6420 laptop.
- Distribution Layer: Cisco 3560x-48T-L switch.
- Core Layer: Cisco 3750x-48P-S switch

The AFS wide-area-network (core layer) will experience most of the traffic in this network design, thus faster connections will be used in this layer. The distribution and access layers will need to meet network requirements, but they do not require the same speed as the WAN. Connections for these layers will not be as fast as those for the WAN to keep costs down.

Application Systems

AFS will have two choices of software configurations within this design. The company wants to use Microsoft operating systems and productivity suites. They also want to use Adobe graphic design products.

The first configuration includes MS Windows 7, MS Windows Server 2008, MS Office Pro, Adobe Acrobat, Sage Peachtree Quantum Platinum, Staff Files Pro, HR Document Maker, Adobe Creative Suite Master Collection, ManageEngine SupportCenter Plus, ManageEngine ServiceDesk Plus, SolarWinds Orion PM, and OmniPage Enterprise.

The second configuration includes MS Windows 7, MS Windows Server 2008, MS Office Pro, Adobe Acrobat, QuickBooks Enterprise Solution, HRA HRIS, Adobe Creative Suite Master Collection, SysAid, LBE Help Desk, AdRem NetCrunch 6, and EndNote X3.

Most of the applications in both configurations will use HTTP over TCP/IP and Windows file access. Adobe Creative Suite will also use FTP. Sage Peachtree Quantum will use Remote Desktop Protocol (RDP).

Network Users

The network needs to accommodate 1,600 users. Each department will generate different levels of traffic. The highest amount of traffic will come from the accounting and finance departments in the form of document sharing and accessing databases. Customer service will generate the least amount of traffic.

Transmission Speed Requirements

Access to network resources should be as seamless as possible, meaning that the network needs to handle transmission as quickly possible. Based on analysis of AFS's usage, data rates of 100 Mbps for LANs and 1 Gbps for the WAN will meet network demand.

Security Requirements

AFS wants a physically and logically secure network. To keep costs down, AFS has decided to keep computers and servers behind locked doors with controlled access. Access to buildings will also be controlled, with security guards, access cards, and a surveillance system.

This design will only include services to keep the network logically secure. AFS will administer physical security.

User names and passwords will be used to limit access as well. Permissions will be assigned by department to keep internal threats to a minimum. Employees will only have access to files and servers they need to perform their job functions. Should an employee need access to information beyond the scope of their job, management approval will be required.

AFS Network Design

AFS's network design consists of one wide-area-network connecting all the offices to AFS headquarters. The WAN is connected to AFS's backbone network, which will connect all the LANs in each branch office to the WAN. Each employee's workstation will be connected to a department LAN, which will allow departments to share files and database information.

AFS WAN High-Level Design

AFS's WAN employs a star architecture, which will be easier to manage than a ring architecture. The star architecture will also be faster because information will not need to make its way around the ring to get to HQ. The AFS WAN will not be meshed to save money. The high-level design appears below.

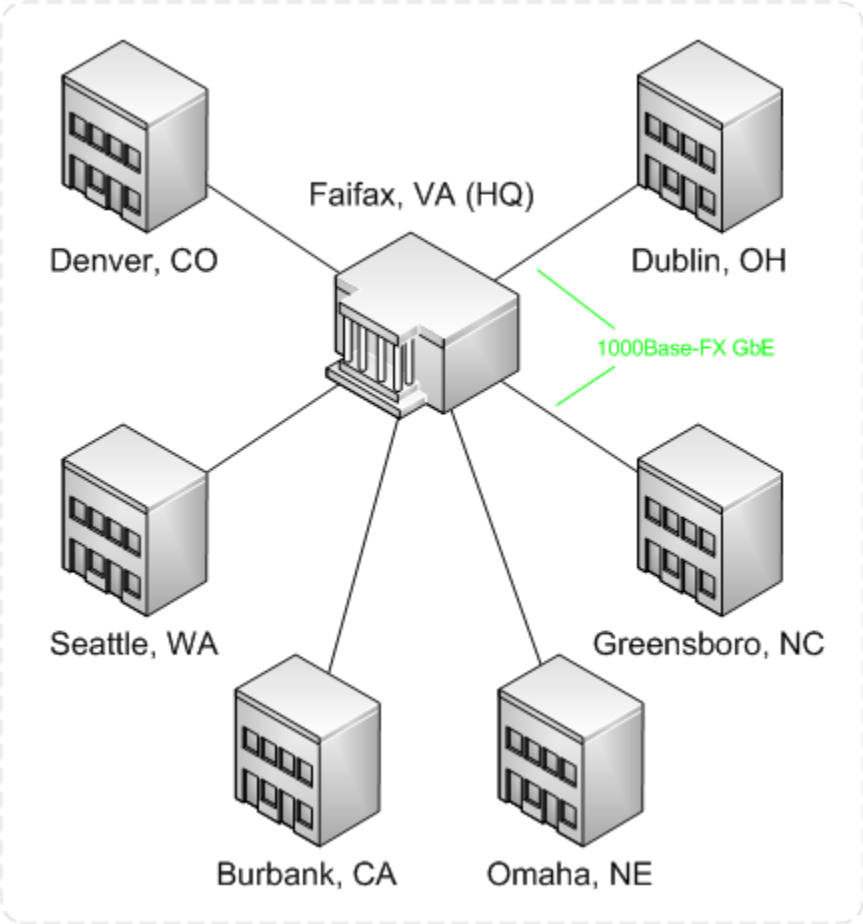


Figure 1. High-Level Design

AFS WAN Architecture

Network Technology

Frame Relay and Asynchronous Transfer Mode (ATM) were considered for use in AFS's WAN, but ultimately 1000Base-FX Gigabit Ethernet over fiber optic cable was chosen. Both Frame Relay and ATM were at a disadvantage from the start because they create latency due to protocol conversion.

With the selection of Gigabit Ethernet, the entire network topology would use the same technology, which eliminates the need for additional protocols and complexities. Gigabit Ethernet will also allow AFS to make incremental investments in expansion, should AFS decide to open another branch office in the future.

Cabling

The AFS WAN will contain connections between each branch office and the headquarters. Fiber optic cable will be laid between each office. Cabling distances were determined using the distances between cities. While this design assumes the AFS wants to lay their own cable, it is highly recommended that they use leased lines.

The table below lists the amount of 1000-ft. cable rolls needed based on distance to headquarters based on the table in the project description.

Table 1. Cabling Needs

LOCATION	1000 FT. ROLLS
DUBLIN, OH	2,641
GREENSBORO, NC	1,584
DENVER, CO	9,504
BURBANK, CA	14,256
SEATTLE, WA	14,784
OMAHA, NE	6,336
TOTAL	49,104

A total of 49,104 rolls of 1,000-ft fiber optic cable would need to be run between the offices and the HQ.

If AFS chooses to buy their fiber optic cable from FiberCables, it will cost $8.4 million. If they choose to buy from UltraSpec, the cost will be $9.8 million. This does not include the cost of shipping, nor does it include construction costs to physically lay the cable.

Security

All traffic to the Internet will be routed through AFS HQ to limit the points at which an outside attack can occur. The Dublin, OH office has redundancy built in, should the connection at HQ experience problems. If the network experiences bottlenecks, additional entry points can be added to other offices, but this increases points of entry for attackers.

AFS HQ and the Dublin office each have firewalls to protect the network. They are the only offices on the AFS network to have firewalls, as they are the only locations that have connections to the outside Internet. Additionally, they have traffic anomaly detection systems to help identify attacks, generate alarms, and terminate connections with hostile sources. They also contain intrusion prevention systems that identify malicious activity, log information about the activity, attempt to block the activity and report it.

AFS also has demilitarized zones (DMZ) at each location that contain email servers, should an intruder get past the IDS, the IPS, and firewall. The DMZ at AFS HQ also contains the company's web server.

Hardware Configuration

The AFS WAN uses 1 GbE over fiber cables. Because AFS department LANs use 100 Mbps Ethernet over Cat 5e cable, media converters must be used. AFS can choose Omnitron's iConverter GX/TM converter or Transition Networks Stand-Alone Converter SGETF1024-110. The network requires seven converters but AFS should purchase at least eight, should one experience problems. Purchasing from Omnitron would cost $12,115, while purchasing from Transition would cost $13,325.

The core layer of each office will be equipped with a layer 3 (L3) switch. By using L3 switches, AFS can configure vLANs in the future if, for example, they wanted all of the HR departments to share the same circuit. They can choose Cisco's 3750X Catalyst 48P-S or Netgear's Prosafe L3 switch. Each location needs one switch, thus eight are recommended, including one to be used if another experiences problems. The total cost for the Cisco switches will be $40,600, while the Netgear switches will cost $24,000.

The distribution layer of each office will contain six layer 2 (L2) switches (one for each LAN, one for the DMZ). Because AFS HQ has *seven* departments, that location will require *eight* switches. More details about those switches can be found in Hardware Configuration under the AFS BN section.

Diagram shows the AFS WAN configuration. The figure does not contain all branch office information, due to space constraints. The AFS LAN and BN sections contain diagrams of the specific locations. The LANs here are for illustration purpose only. Similarly, the figure does not contain all HQ information. That can be found in the AFS Hardware subsection of the AFA LAN Architecture section.

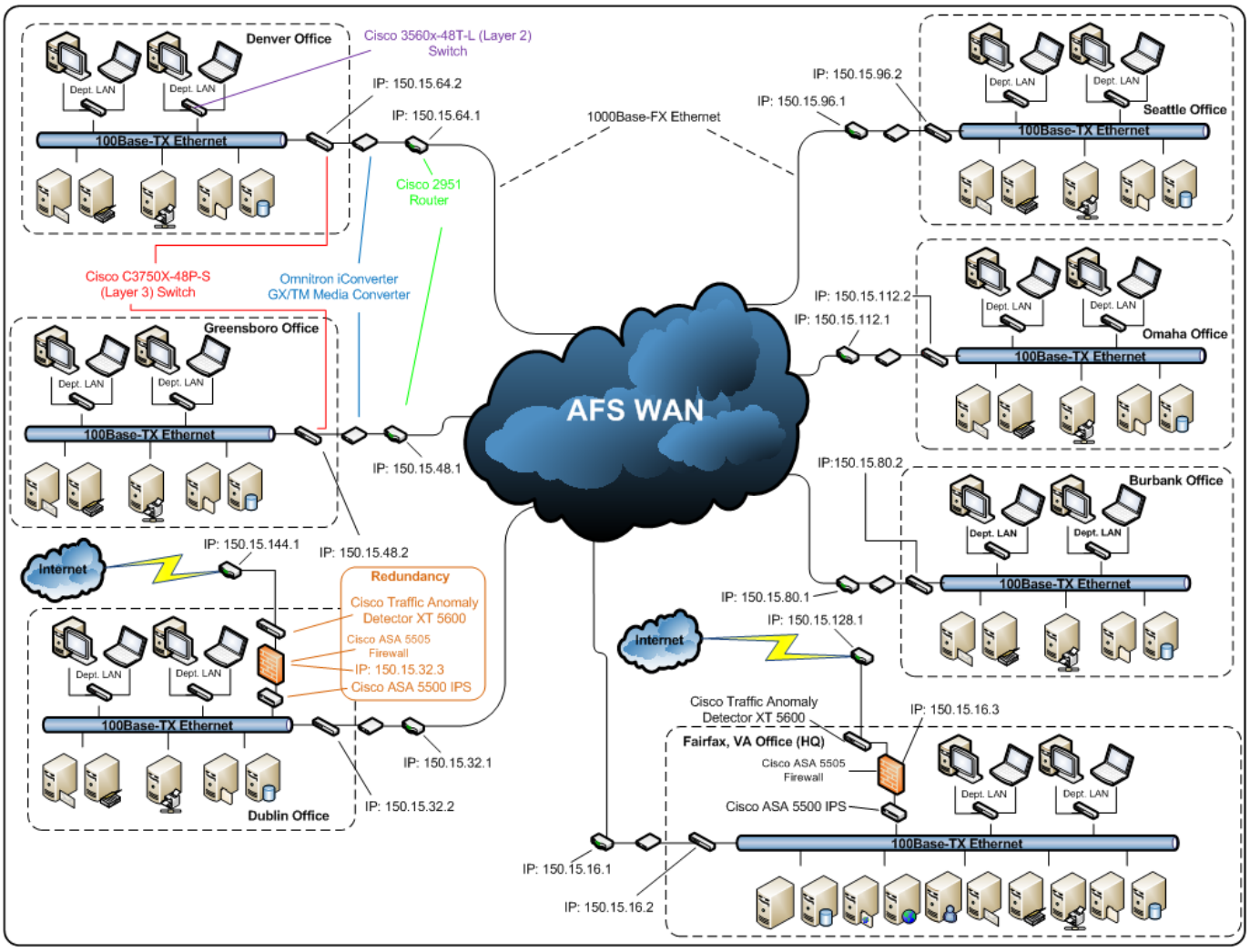


Figure 2. AFS Wide Area Network

Important Points:

- Each location has a router.
- Each location is connected to AFS HQ using 1GbE over fiber cables. (1000Base-FX).
- Each location has a media converter.
- All Internet traffic is routed to AFS HQ to limit entry points.
- The Dublin office contains redundancy, should the connection to AFS HQ experience problems.
- Both AFS HQ and Dublin have firewalls and anomaly detection systems.

- Each location has a L3 switch.

AFS BN High-Level Design

AFS's backbone network will use switched backbones with a star topology. All backbone switches are located in a secure room in the basement of each office. This design has been employed to allow easy maintenance and upgrading. While this means more cable is needed, AFS has identified scalability as an important design feature.

AFS BN Architecture

Network Technology

For AFS BNs, 100Base-TX Ethernet will be used to keep costs down. In the future, AFS can replace Ethernet with GbE, but at this time, 100 Mbps should suffice.

Switching to GbE in the BNs would not have eliminated the need for media converters in the WAN, thus the additional cost to outfit the BN with GbE was not necessary. Thus AFS decided to pass on that option.

Cabling

The GbE connection from the AFS WAN runs through the media converter to the L3 switch. Once there, the L3 switch will be connected to six L2 switches at each branch office (five department switches, one DMZ switch). In the AFS HQ BN, the L3 switch will be connected to eight L2 switches.

Because those switches will all be located in the same room, not much Cat 5e is required. Less than 10 ft. per connection should suffice. Cat 5e price information can be found under the Cabling subsection of AFS LAN Architecture.

Security

Because the WAN will only have one entry point, the BNs will not have firewalls. Security will be handled by the WAN. For more information about security, see the Security subsection under AFS WAN Architecture.

Hardware Configuration

The AFS BN s require 44 L2 switches. Six for each branch office (36 total) and eight for HQ. It is recommended that AFS purchase one additional switch for each location, bringing the total to 51. If AFS chooses the Cisco 3560X-48T-L, the total cost will be $171,360. If they choose the Netgear Prosafe L2 switch, the total cost will be $168,300.

The switches will be rack-mounted in the basement of the each building. Each location will need two racks, with the exception of the HQ, which will need four. If AFS chooses the StarTech Rack, the total cost will be about $3,700. The second option is an Innovation First rack. If AFS chooses Innovation, the total cost would be $3,100.

The diagram shows the AFS HQ BN.

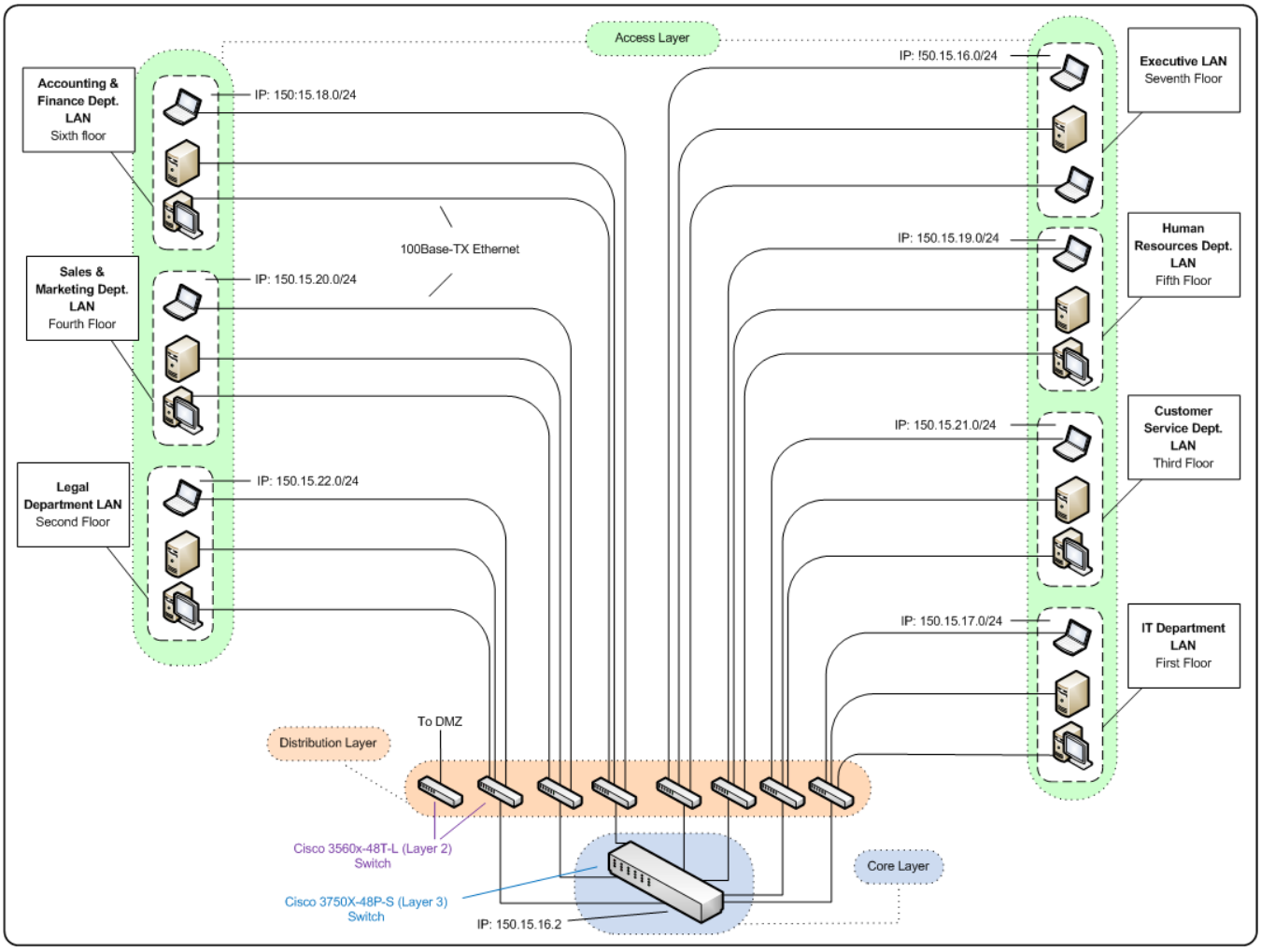


Figure 3. AFS Headquarters Backbone Network

Important Points:

- AFS headquarters has seven departments; therefore it needs eight L2 switches. One for each LAN and one for the DMZ.
- AFS HQ needs one L3 switch to connect the core layer to the distribution layer.
- 100Base-TX over Cat 5e will be used in the AFS HQ BN.
- The HQ BN will not contain any security beyond the DMZ, as security will be handled by the anomaly detector and firewall at HQ.

This diagram shows the BN of a branch office. All branch office locations will be configured in this way for simplicity. Because this diagram represents all branch offices, IP addresses were left off, as they would depend on the department and location.

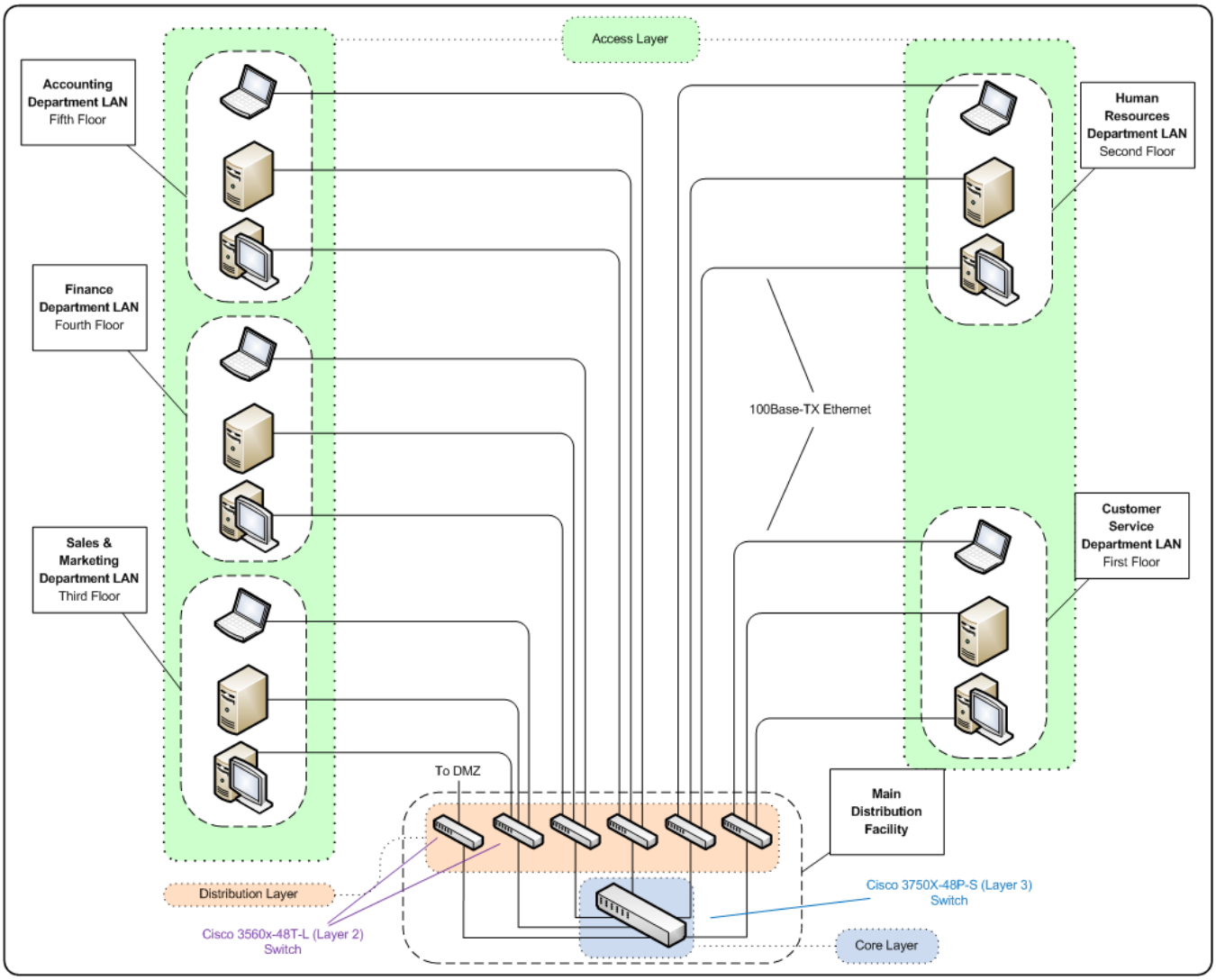


Figure 4. AFS Branch Office Backbone Network

Important Points:

- Each branch office has five departments; therefore it needs six L2 switches: one for each LAN, one for the DMZ.
- Each branch office needs one L3 switch to connect the distribution layer to the core layer.
- 100Base-TX over Cat 5e will be used in the AFS branch office BN.
- The branch office BNs will not contain any security beyond the DMZ, as security will be handled by the anomaly detector and firewall at HQ.

AFS LAN High-Level Design

AFS department LANs will be dedicated-server networks, allowing users to share files and printers. LANs of this size would be severely limited if a peer-to-peer network was used. Multipoint circuits will be used in LANs to minimize costs. LANs will have a star topology.

AFS LAN Architecture

Network Technology

For all of the local area networks in AFS's network, switched 100Base-TX Ethernet was chosen because it provides better performance than shared Ethernet using hubs, and is cheaper than fitting an entire office building with fiber optic cables, the main reason 100Base-TX not 1000Base-FX was chosen for AFS LANs.

Switched 100Base-TX was also chosen because each circuit connected to a switch acts as a separate point-to-point connection, which lowers the probability of collisions. On LANs of these size, having a hub retransmit every message to all hosts would severely slow the network, thus switched Ethernet is a better option. It has been said that Ethernet can use up to 95% of its capacity before problems arise, which translates into speeds of roughly 95 Mbps. That should be enough to meet AFS's needs.

Cabling

Operating under the assumption that AFS does not share its building with other tenants and each department is located on a different floor, at the branch offices, no employee will be more than 50 ft. vertically from the main distribution facility. Each building has five floors, with eight-foot ceilings and about two feet of structural space between floors for a total of 50 ft. At AFS HQ, using the same assumptions, no employee will be more than 70 ft. from the MDF.

Roughly 70 feet of cable per employee would most likely cover each employee (only the furthest employees will be 70 ft. from the MDF), but to be safe, 75 ft. per employee will be used, to account for Cat 5e cable needed for the BN connections. AFS HQ would require 30 rolls of 1,000-ft cable; each branch office would need 15 rolls for a total of 120 rolls.

If AFS buys their Category 5e cable from Sewell, the total will be about $7,800. If they instead choose Black Box, the cable will be $4,800.

Security

Because the WAN will only have one entry point, the LANs will not have firewalls. Security will be handled by the firewall and anomaly detector at AFS HQ. For more information about security, see the Security subsection under AFS WAN Architecture.

Hardware Configuration

AFS HQ

At AFS HQ, the MDF will house all of the servers for AFS's networks, except department file, database, and print servers. AFS HQ will require two domain controllers to handle its 400 employees. It will have one database server, which will contain information specific to all of AFS, not individual departments. AFS will also assign IP addresses at the LAN level dynamically, which will require a DHCP. HQ will also have a DNS server, an application server, an SQL server, and an IM server.

In its DMZ, it will have a web and email server. It will also have two servers for backup.

AFS has two options for servers. They can choose to use the Dell PowerEdge line or the HP Proliant line. To save money, cheaper servers were chosen when they were designated to handle processor-light functions. For example, the Dell PowerEdge R310 or the HP Proliant DL180 G6 would be used for the web server. For databases, the PowerEdge R510 or Proliant DL580 G7 would be used.

The table below contains the servers needed and the models proposed.

Table 2. AFS Server Options

SERVER	DELL POWEREDGE	HP PROLIANT
DATABASE	R510	DL580 G7
DHCP	R310	DL180 G6
DOMAIN CONTROLLER	R310	DL180 G6
DNS	R310	DL180 G6
EMAIL	R310	DL180 G6
FILE	R410	DL380 G7
IM	R310	DL180 G6
PRINT	R410	DL380 G7
SQL	R510	DL580 G7
WEB	R310	DL180 G6

Figure 5 shows what AFS's HQ MDF will look like logically.

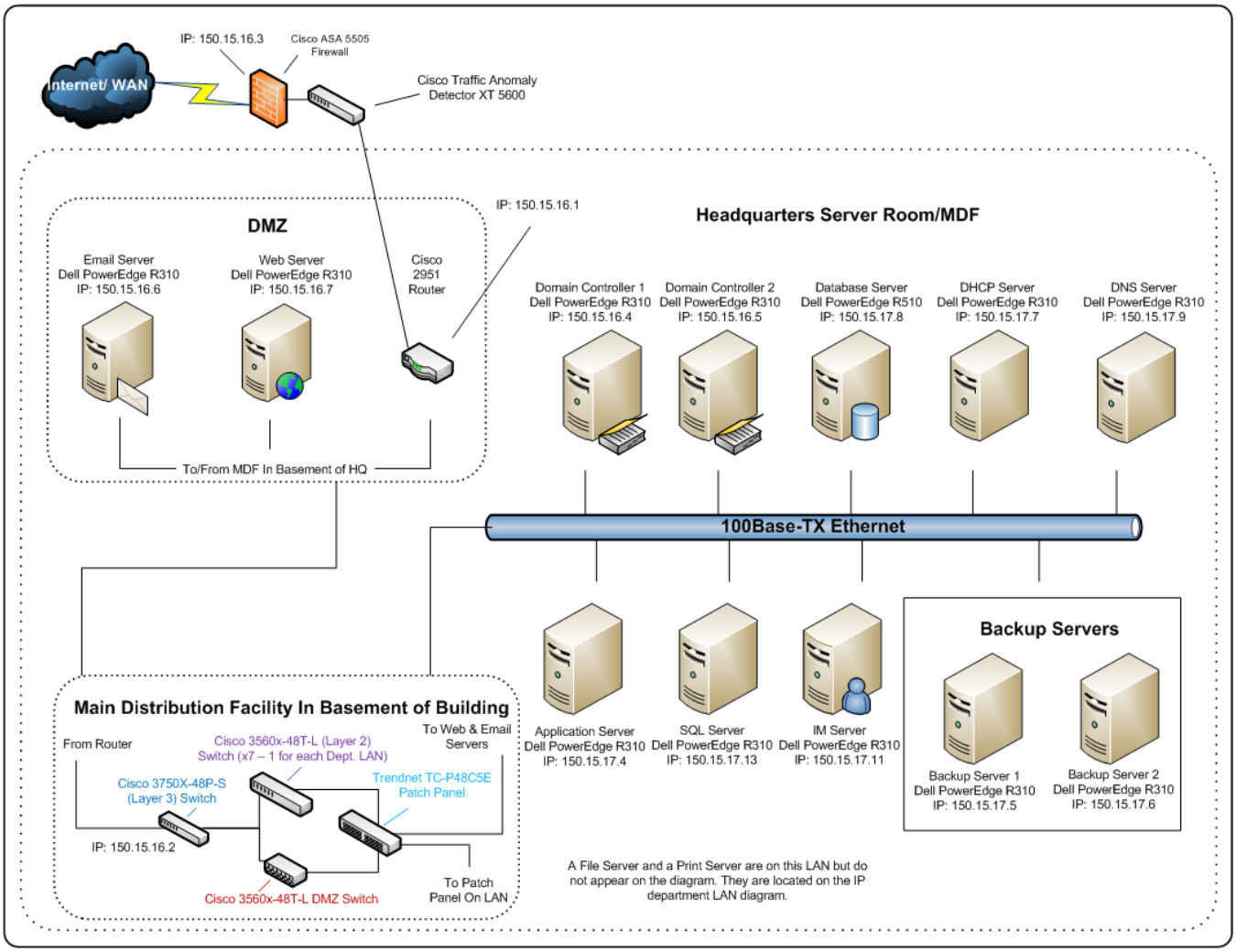


Figure 5. AFS HQ DMZ, Server Room, Main Distribution Facility Diagram

Important Points:

- The AFS HQ MDF will contain a firewall, an anomaly detector, and IPS to keep the network secure. Branch office MDFs do not have firewalls, IPSs or traffic anomaly detectors with the exception of Dublin.
- HQ MDF will have a web server in its DMZ, while branch offices do not have web servers.
- HQ MDF will house all of the servers for the company except individual department servers.
- HQ has seven departments, compared to five departments for each branch office.

Each department at AFS HQ will have its own database, file and print server. At AFS HQ, the accounting and finance departments have been combined and share a LAN. The other departments are customer service, executives, HR, IT, legal, and sales & marketing. Both accounting & finance and sales & marketing have been allocated two database servers, two file servers, and two print servers because they will generate the most network traffic.

As AFS does not have an existing network, it is assumed that they require all equipment, including workstations. They have two options for desktops: Dell OptiPlex 390 running Windows 7, or the HP Compaq 6200 Pro, also running Windows 7. For laptops, they have a choice of the Dell Latitude E6420 laptop and HP Elitebook 8460P. To configure the entire office with desktops and laptops, it would cost $2.9 million for Dell and $2.8 million for HP. The cost includes monitors and docking stations or port replicators for the laptops.

AFS uses Xerox printers. Some employees have local printers, but because they are not on the network, they do not appear on these diagrams. The following diagrams show the logical design of HQ LANs:

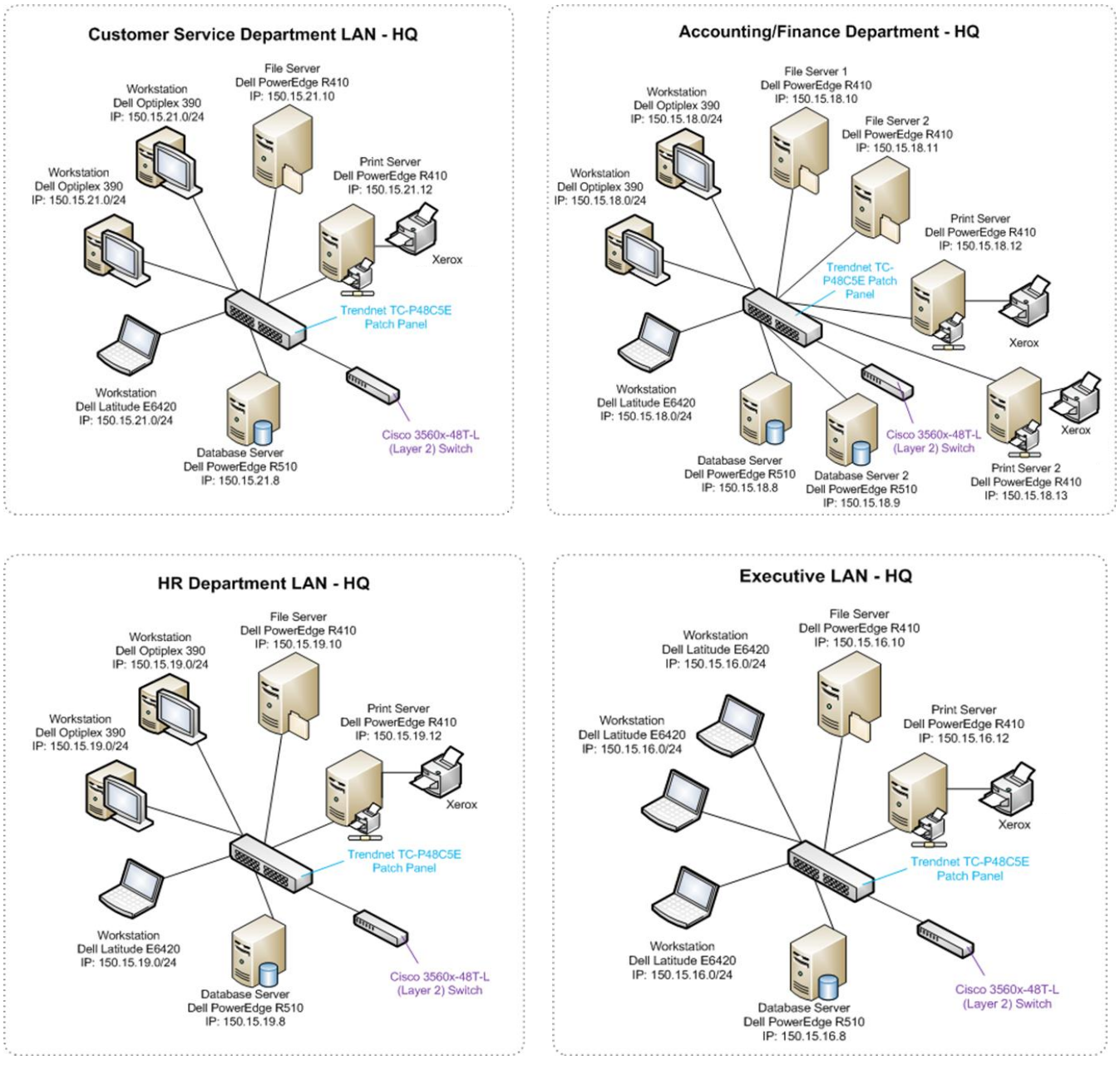


Figure 6. AFS HQ Department LAN Diagrams

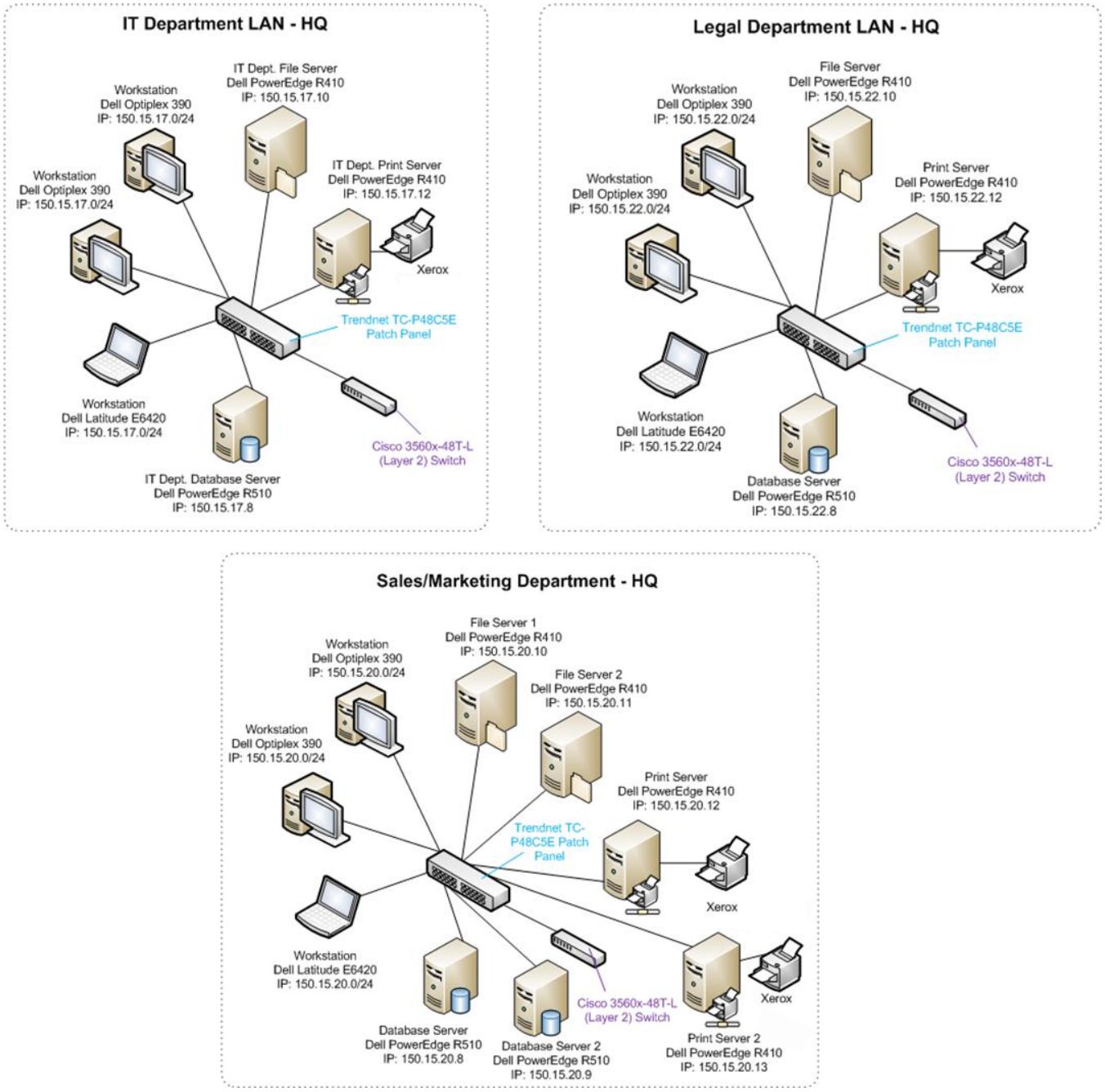


Figure 7. AFS HQ Department LAN Diagrams

All of the network LANs are configured basically the same. The only difference is that the accounting & finance department and the sales & marketing department each have two database servers, two file servers, and two print servers.

On the LAN level, the departments at AFS HQ will have the same design and structure as those at branch offices.

Branch Offices

LANs at AFS branch offices will have similar configurations to those at AFS HQ, but branch office MDFs will only house two servers: the domain controller and the email server. The email server will be located in the location's DMZ. All other required network services will be provided by the servers at HQ.

All LAN workstations will be connected to a patch panel located on the same floor as the department. Cable will run from that patch panel to a patch panel in the MDF, where it will connect to its L2 switch. The L2 switch will be connected to an L3 switch, which will be connected to the router. The router will connect to the WAN.

The following diagram shows what the Dublin, OH branch office MDF will look like logically. Other branch offices will have a slightly different configuration because Dublin will contain the network redundancy. Other branch offices will not have the firewall or the traffic anomaly detector.

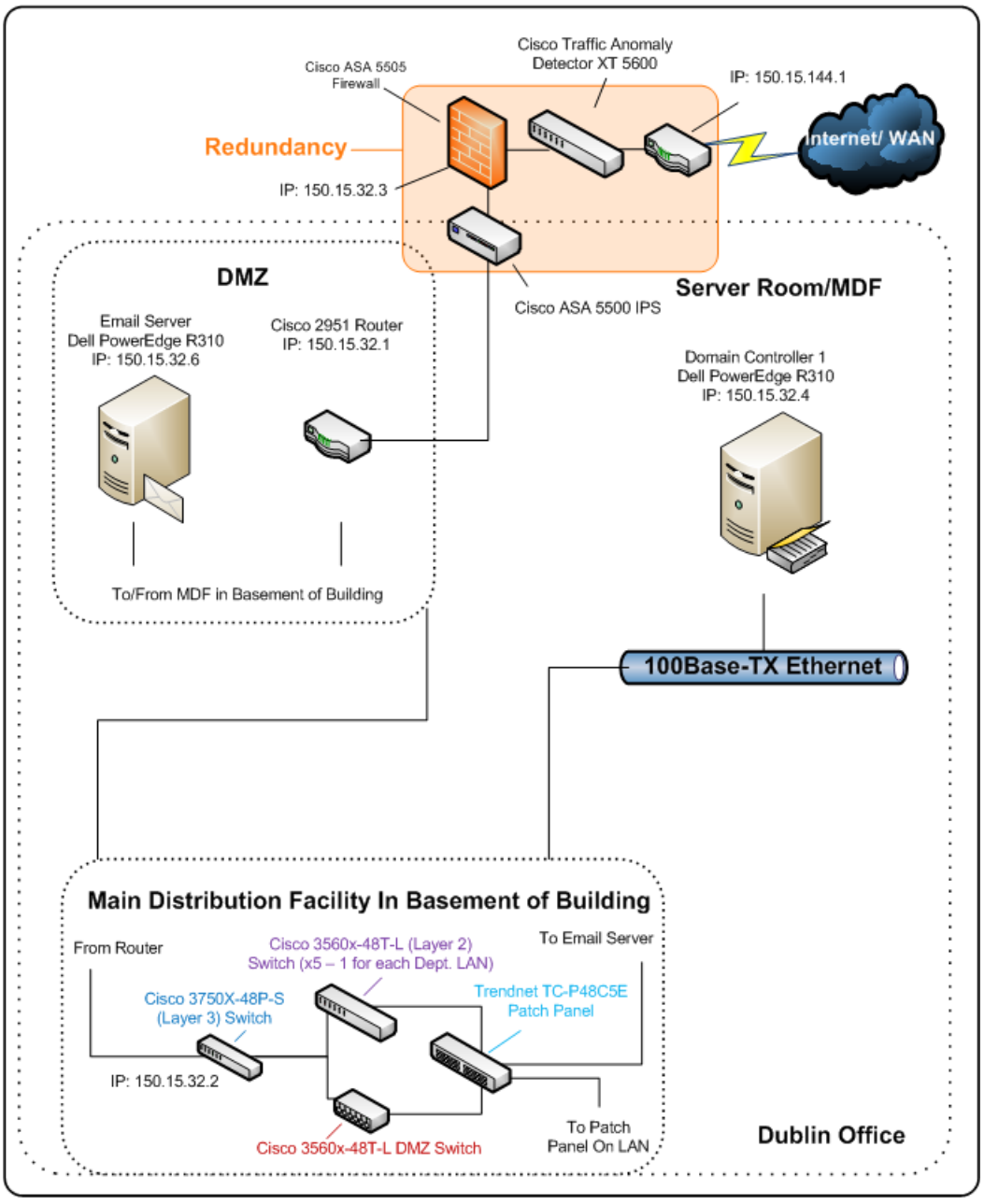


Figure 8. AFS Branch Office DMZ, Server Room, Main Distribution Facility Diagram

Important Points:

- The Dublin office will contain network redundancy. Therefore that office will have a firewall, an IPS, and a traffic anomaly detector. Others branch offices will not.
- Branch office department LANs will have DMZs that contain the email server.

Much like the department LANs at HQ, branch office department LANs will each have their own database, file and print servers.

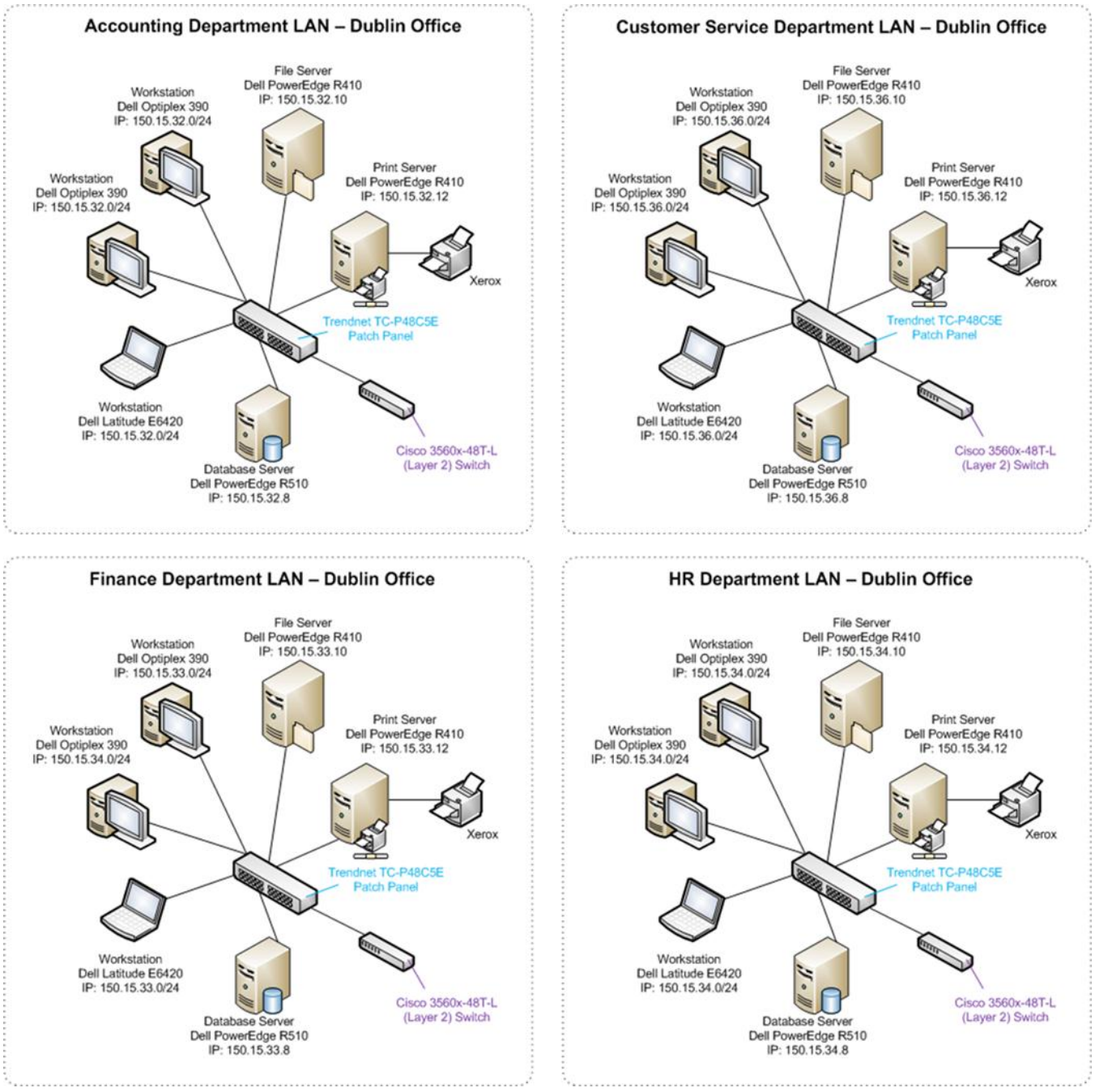


Figure 9. AFS Branch Office Department LAN Diagrams

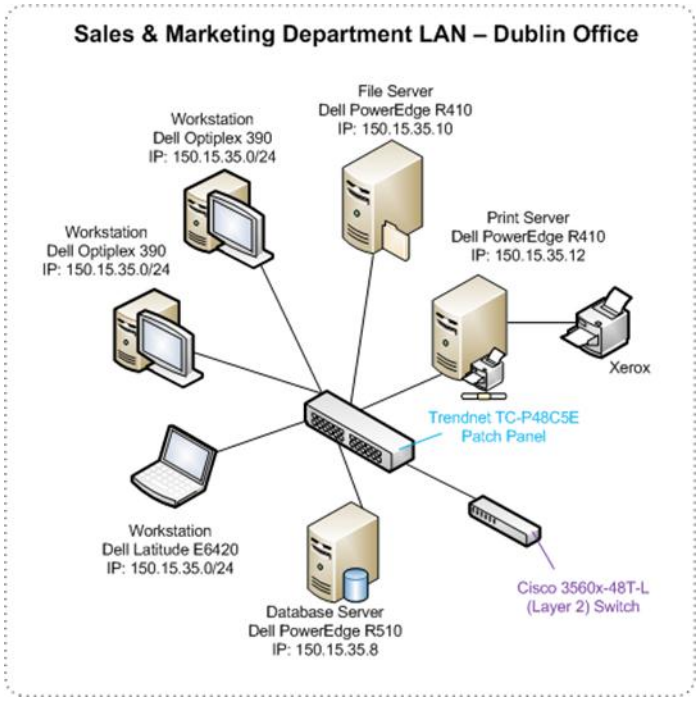


Figure 10. AFS Branch Office Department LAN Diagram

Important Points:

- Each department has its own database, file, and print server.
- Branch office departments will only require one patch panel and switch. If the departments grow beyond 48 network devices, a second panel and switch will need to be added.

IP Addressing

Given that AFS was assigned a Class B block of IP addresses (150.15.x.x) and that the company had seven locations, the network needed to be divided into seven segments. Using the equation $2^{x}-2 \geq y$, the correct subnet mask would be 255.255.240.0 or 150.15.0.0/20. With that subnet mask, the first location's IP address would be 150.15.16.x. The IP addresses would increase at intervals of 16. The IP addresses for the seven locations are shown in the table below.

Table 3. AFS Location IP Addresses

LOCATION	IP ADDRESS
FAIRFAX, VA (HQ)	150.15.16.0/20
DUBLIN, OH	150.15.32.0/20
GREENSBORO, NC	150.15.48.0/20
DENVER, CO	150.15.64.0/20
BURBANK, CA	150.15.80.0/20
SEATTLE, WA	150.15.96.0/20
OMAHA, NE	150.15.112.0/20

AFS has seven departments at its headquarters and five departments at each of the remaining six branch offices. Therefore, the subnets would need to be further divided. Using the equation above, we would need to take four more bits from the host ID for the network ID, which would result in a subnet mask of 255.255.255.0 or 150.15.0.0/24. That gives us 254 hosts per subnet, which is more than enough to meet AFS's needs and potential future expansion.

Table 4. AFS Department IP Addresses

LOCATION	IP ADDRESS
FAIRFAX (HQ)	150.15.16.0/20
EXEC.	150.15.16.0/24
IT DEPT	150.15.17.0/24
ACCT & FIN DEPT	150.15.18.0/24
HR DEPT	150.15.19.0/24
SALES & MKTG DEPT	150.15.20.0/24
CUST SVC DEPT	150.15.21.0/24
LEGAL DEPT	150.15.22.0/24
DUBLIN	150.15.32.0/20
ACCOUNTING DEPT	150.15.32.0/24
FINANCE DEPT	150.15.33.0/24
HR DEPT	150.15.34.0/24
SALES & MKTG DEPT	150.15.35.0/24
CUST SVC DEPT	150.15.36.0/24
GREENSBORO	150.15.48.0/20
ACCOUNTING DEPT	150.15.48.0/24
FINANCE DEPT	150.15.49.0/24
HR DEPT	150.15.50.0/24
SALES & MKTG DEPT	150.15.51.0/24
CUST SVC DEPT	150.15.52.0/24
DENVER	150.15.64.0/20
ACCOUNTING DEPT	150.15.64.0/24
FINANCE DEPT	150.15.65.0/24
HR DEPT	150.15.66.0/24
SALES & MKTG DEPT	150.15.67.0/24
CUST SVC DEPT	150.15.68.0/24
BURBANK	150.15.80.0/20
ACCOUNTING DEPT	150.15.80.0/24
FINANCE DEPT	150.15.81.0/24
HR DEPT	150.15.82.0/24
SALES & MKTG DEPT	150.15.83.0/24
CUST SVC DEPT	150.15.84.0/24
SEATTLE	150.15.96.0/20
ACCOUNTING DEPT	150.15.96.0/24
FINANCE DEPT	150.15.97.0/24
HR DEPT	150.15.98.0/24
SALES & MKTG DEPT	150.15.99.0/24
CUST SVC DEPT	150.15.100.0/24
OMAHA	150.15.112.0/20
ACCOUNTING DEPT	150.15.112.0/24
FINANCE DEPT	150.15.113.0/24
HR DEPT	150.15.114.0/24
SALES & MKTG DEPT	

CUST SVC DEPT	150.15.115.0/24 150.15.116.0/24

IP addresses were assigned consistently across the network. For example, routers were all assigned the first IP of the location. For example, the Fairfax router is 150.15.16.1. Layer 3 switches used to connect the core layer to the distribution layer were assigned the second IP address, which in the case of Fairfax is 150.15.16.2.

Domain controllers were assigned the third IP address at each location. AFS headquarters has two domain controllers, so the fourth address was assigned to the second domain controller. Email servers were assigned to the fourth IP address, with the exception of AFS HQ, where the second domain controller was assigned the fourth IP address. As a result, the HQ email server is assigned to the fifth address: 150.15.16.5.

The web server is located at HQ, and was assigned the sixth IP address. No other locations have web servers.

IP's were assigned consistently across all branch offices so that IT staff can identify the branch office, the department, and the type of server by the IP address. For example, if the server with the IP address 150.15.84.10 was experiencing problem, the technician could look at "84.10" and know that the "8" refers to Burbank, CA (IP addresses 150.15.80.1 – 150.15.95.254), the "4" refers to the Customer Service Department, and that the "10" refers to a file server.

AFS Headquarters was configured similarly, but it could not be exactly the same, as HQ has more servers than the branch offices. At HQ, database servers end in .8 and .9, file servers end in .10 and .11, and print servers end in .11 and .12, just as they do at the branch offices.

Workstations would be assigned IP addresses dynamically, with a scope within their subnet.

OSI Model

The table below lists all of the network services and protocols that AFS will use, including the protocols required for the software they chose.

Table 5. OSI Model & Protocols Used

OSI MODEL LAYERS	PROTOCOLS USED
APPLICATION LAYER	HTTP, FTP, SMTP, POP, SNMP, Telnet, RDP, DHCP, DNS, RTP(optional)
PRESENTATION LAYER	MIME, TLS, SSL
SESSION LAYER	NetBIOS
TRANSPORT LAYER	TCP, UDP
NETWORK LAYER	IP, ICMP, OSPF
DATA LINK LAYER	IEEE 802.3, Ethernet, ARP
PHYSICAL LAYER	100BASE-TX, 1000BASE-FX

Because the sales & marketing department will employ graphic designers who will use Mac Pros, the following Apple protocols will be required.

Table 6. OSI Model & Apple Protocols Used

OSI MODEL LAYERS	APPLE PROTOCOLS USED
APPLICATION LAYER	AFP
PRESENTATION LAYER	AFP
SESSION LAYER	
TRANSPORT LAYER	AEP
NETWORK LAYER	DDP
DATA LINK LAYER	AARP
PHYSICAL LAYER	Ethernet driver

The table below is a breakdown of all the hardware AFS's network will use mapped to its OSI model layer.

Table 7. OSI Model & Hardware Used

OSI MODEL LAYERS	HARDWARE USED
APPLICATION LAYER	Web browser
PRESENTATION LAYER	
SESSION LAYER	SQL software application
TRANSPORT LAYER	TCP/IP software
NETWORK LAYER	Cisco 3750x switch, Cisco 2951 router, Omnitron GX/TM media converter, Cisco ASA 5505 firewall, TCP/IP software
DATA LINK LAYER	Cisco 3560x switch, Realtek Ethernet NIC (included w/ desktops),
PHYSICAL LAYER	Ethernet port, Cat 5e cable, optical cable

Cost

To install configuration one, AFS would have to spend $14.2 million. That cost would include hardware, software, and network equipment. Installation of configuration two would cost $15.4 million.

Most of that cost would come from laying cable for the wide-area-network. In configuration one, the cost of laying cable would account for nearly 60% of the total cost of the network. In configuration two, the cost of laying cable would account for 64% of the total cost of the network.

Non-network hardware (workstations) would cost $625k for AFS HQ under configuration one, while configuration two would cost $599k. Non-network hardware for branch offices would cost $387k under configuration one. It would cost $365k under configuration two.

Table 8. Non-Network Hardware Cost

LOCATION	CONFIG. 1	CONFIG. 2
FAIRFAX	$624,724	$599,202
DUBLIN	$387,136	$365,184
GREENSBORO	$387,136	$365,184
DENVER	$387,136	$365,184
BURBANK	$387,136	$365,184
SEATTLE	$387,136	$365,184
OMAHA	$387,136	$365,184

Network hardware (including switches, firewalls, routers, cable, media converters, and racks) would cost $57k for configuration one. Under configuration two, network hardware would cost $52k. At branch offices, network hardware would cost between $315k and $2.6 million for configuration one, depending on distance to HQ. For configuration two, it would cost between $355k and $3 million, depending on distance.

Table 9. Network Equipment Cost

LOCATION	CONFIG. 1	CONFIG. 2
FAIRFAX	$56,288	$52,073
DUBLIN	$500,088	$572,275
GREENSBORO	$312,159	$355,399
DENVER	$1,668,538	$1,939,320
BURBANK	$2,482,366	$2,889,672
SEATTLE	$2,567,895	$2,988,844
OMAHA	$1,125,986	$1,305,751

Software for the entire network would cost $750k for configuration one at HQ. Configuration two would cost $724k. At branch offices, software configuration one will cost $372k while software configuration two will cost $368k.

Table 10. Total Network Cost

	CONFIG. 1	CONFIG. 2
EQUIPMENT TOTAL	$11,576,657	$12,804,339
SOFTWARE TOTAL	$2,596,782	$2,566,284
TOTAL COST	**$14,173,439**	**$15,370,624**

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