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The Case for Virtual Local Area Networks (VLANs)

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Introduction

In the history of Ethernet, the virtual LAN is a recent addition. The VLAN was introduced to solve a number of networking issues. In this whitepaper you will learn about the evolution of Ethernet, the reasons VLANs were introduced, and the ways that VLANs can be used. You will also learn about the networking standards that address the VLAN implementation.

Ethernet

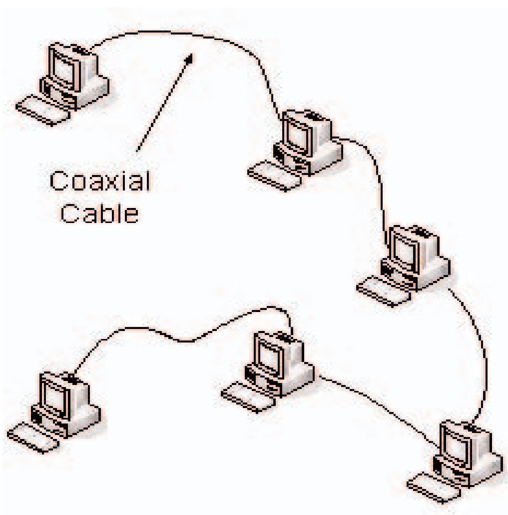


Figure 1. Coaxial Cable-Based Ethernet

As a local area networking protocol, early Ethernet was inexpensive to install and operate when compared to competing protocols such as Token Ring and Arcnet. It operated as a simple bus architecture using an access method known as Carrier Sense Multiple Access with Collision Detection or CSAM/CD. A simple contention protocol, CSMA/CD required that stations "listen" for transmissions on the coaxial cable based network and only transmit if no other transmissions were heard. If two or more devices transmitted at the same time, a collision occurred and the devices were required to transmit again. Ethernet worked well with a few networked devices but as networks grew, CSMA/CD turned out to be a protocol with a problem. Too much traffic caused too many retransmissions, and the efficiency of the network declined.

To simplify the installation of Ethernet networks, a change was made to the network topology. Networks were converted from coaxial cable to twisted pair cabling by introducing a new device into the network. That device is called a hub. The purpose of the hub was to repeat signals transmitted to it so that all devices attached to the hub reacted as if they were still attached to coaxial cable. The hub did nothing to remove the problems associated with CSMA/CD. If anything, because it was easy to interconnect hubs or add additional networking devices to a hub, networks became more crowded. A solution to the problem was necessary.

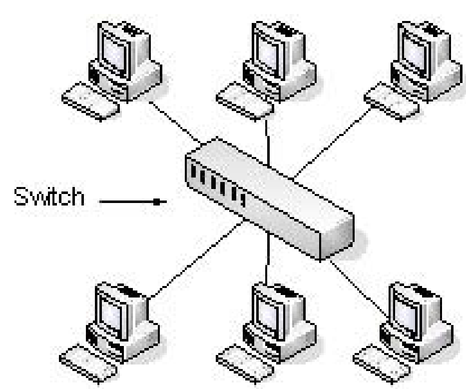
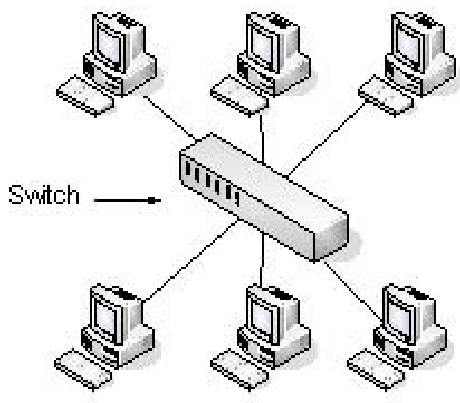


Figure 2. Hub-Based Twisted Pair Ethernet

The Switch

The solution to the performance problems with Ethernet was the switch. The outward appearance of a switch is much the same as a hub. However, the function of the switch is much different.



The switch contains circuitry that eliminates the contention mode of access found in the original CSMA/CD protocol. The switch provides for a unique pathway between each port on the switch. Modern switches include the ability to perform full duplex or simultaneous transmission and reception on each switch and network interface card (NIC) port. There is no more waiting for other devices to transmit. Each device controls its own transmissions on the network. Performance improved immediately. Speeds began to increase as well. Early Ethernet featured a 10mb per second bandwidth. Soon 100 mb and 1000 mb per second speeds were available. Switches increased their own capacities as well, matching bandwidth with "wire speed" switching capabilities.

Figure 3. Switched Ethernet

The only real downside to switching in early implementations was the cost. As usual, new technology featured a premium in the price. The per-port cost of the switch as compared the hub was very high. Over time, however, the cost of switch ports came down, and the switch replaced the hub in most Ethernet networks.

More Than One Switch

The need to interconnect switches for more connectivity resulted in the use of circuits called trunks. These simple trunks used a cable to connect a port on one switch to a port on another switch. Data was moved between the switches over interconnecting cable.

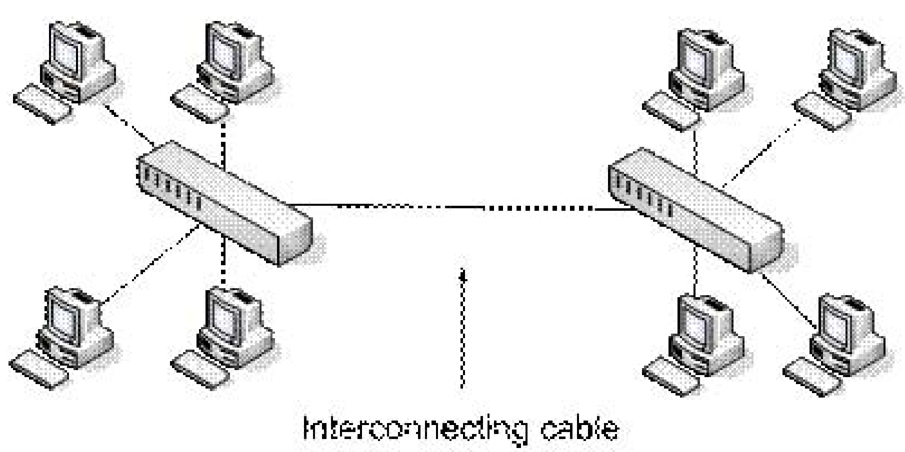


Figure 4. Multiple Switched Ethernet

Multiple switches could be connected together to form complex switching architectures. Cisco pioneered the naming of theses complex networks by defining the location of the switch by function into a hierarchy. Clients were directly attached to "access" switches. Access switches were connected to "distribution" switches and distribution switches were attached to "core" switches. The transportation paths could be well- defined and controlled by using this technique.

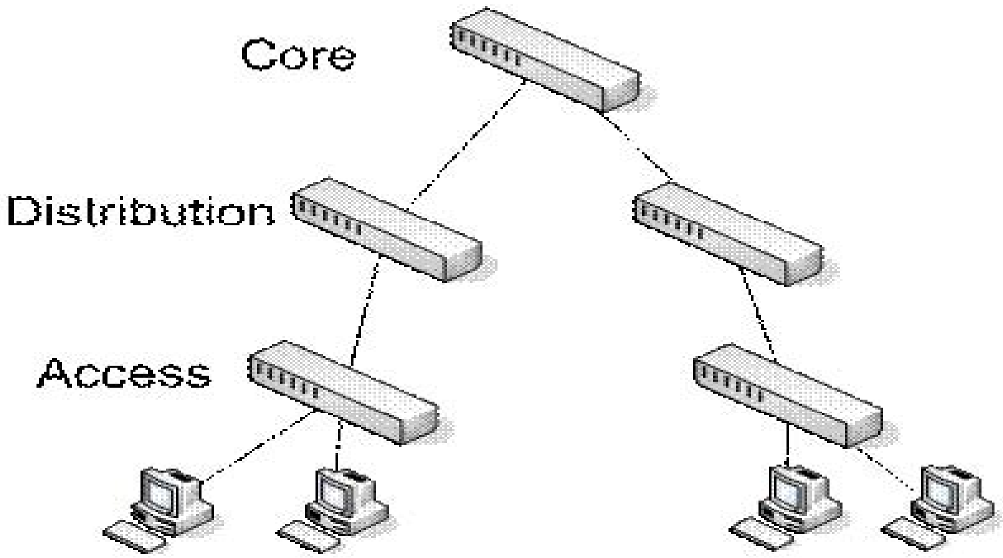


Figure 5. Hierarchical Switching Model

It's an IP World

In the examples we have presented so far, all of the devices are found in the same Ethernet broadcast domain. If one device sends out a broadcast packet, all of the devices connected to the switches will receive the traffic. That's an Ethernet rule for how traffic passes through switches. That environment also creates an IP network or subnet.

In most practical networks, all devices in a small business or enterprise network are not located on the same Ethernet network broadcast domain. We separate the networks to limit broadcast traffic among the devices or to create islands of security where devices are isolated into workgroups, departments or other similar structures. Traffic from one workgroup should not be visible to another workgroup's devices. Ethernet switches, as we have seen so far, do not have the ability to limit the traffic. A special feature of modern switches allows us to isolate traffic so that it is limited and secure. That feature is the Virtual Lan or VLAN.

The VLAN

The initial creation of a VLAN is done in the switch. For example, a small business has a single switch with 24 Ethernet ports. To separate the accounting department from the engineering department, the administrator allocates switch ports to the two departments. In the switch configuration, the administrator configures ports 1-12 for the accounting department and ports 13-24 for the engineering department. The configuration essentially creates two independent switches within the single device.

The first half of the switch is one VLAN, and the second half of the switch is another. The VLANs can be named by the administrator and are also numbered. The default VLAN number is VLAN 1. In this case, the administrator used VLAN 1 for ports 1-12 and VLAN 2 for ports 13-24. Traffic originating in VLAN 1 can only be sent to ports assigned to VLAN 1. This creates a physical security limitation within the switch. The boundary between the two VLANs on the switch cannot be bypassed by Ethernet.

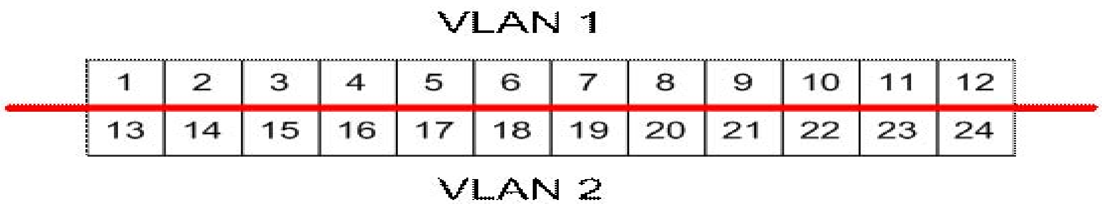


Figure 6. Simple VLANs in a 24 Port Switch

This also creates two IP networks or subnets. For traffic to flow between the two subnets, IP routing is required. This creates a logical separation between the networks.

VLAN ports do not have to be adjacent. In the example above, ports 1-12 were in one VLAN and ports 13-24 were in another. In the example below, the switch has been partitioned into three different VLANs.

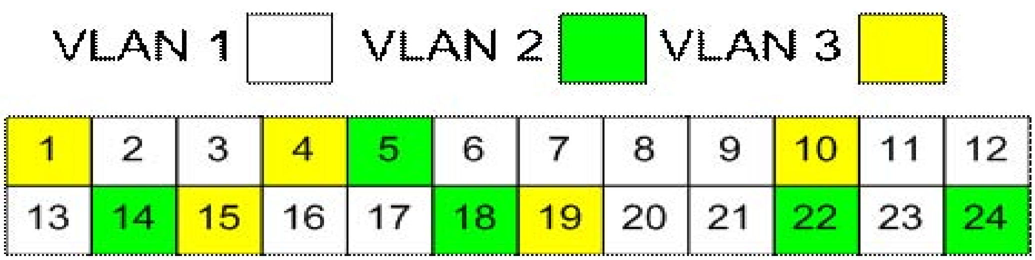


Figure 7. Multiple VLANs

Ports 2, 3, 6, 7, 8, 9, 11, 12, 13, 16, 17, 20, 21, and 23 are in VLAN 1.

Ports 5, 14, 18, 22, and 24 are in VLAN 2 and ports 1, 4, 10, 15 and 19 are in VLAN 3. Traffic among these ports is limited by the switch. Port 1 cannot send traffic to port 2 unless an IP datagram is routed between the two devices.

The creation of a VLAN is “native” to switch where it is configured. If you have four switches, each having different VLAN configurations, each switch will know it’s own VLAN configuration but will have no knowledge of the other switch VLAN configurations.

A Two-Switch Example

n the diagram above, the two workstations are attached to different switches. They are both connected to ports in the same VLAN on the two separate switches. The cable connection between the two switches originates in the same VLAN so traffic sent between the two workstations is on VLAN 2 and can be seen by the workstations with no difficulty.

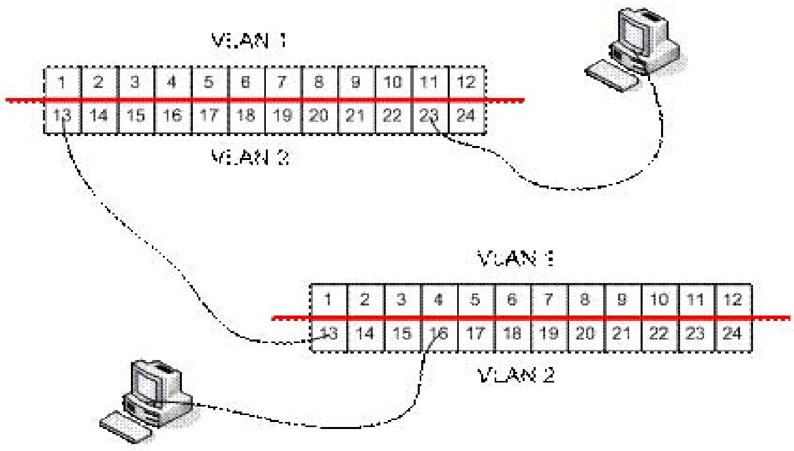


Figure 8. Interconnected VLANs

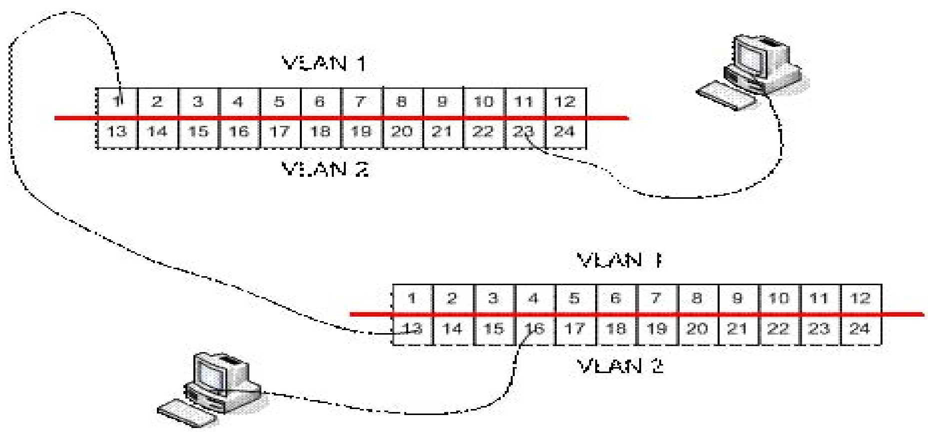


Figure 9. Miswired VLAN Connection

In this example, the connection between the two switches was made incorrectly. VLAN 1 was attached to VLAN 2. Since there is no connectivity between like VLANs, the two workstations cannot communicate.

To extend this example even more, if both switches had three VLANs, there would need to be three separate connections between the switches, one for each VLAN. This would rapidly use many switch ports and would not be efficient. To get around this problem, the VLAN process uses a special process called VLAN trunking.

The VLAN Trunk

Between switches, we only want to use one physical connection. The physical connection must also contain information about the source VLAN so that when packets arrive at the second switch, the second switch knows which VLAN to use for the information carried in the packet. A VLAN identifier must be provided in the packet as it moves between the switches.

Target Address	Source Address	Protocol	**Payload**

Figure 10. Ethernet Header

An Ethernet packet has a header that contains three elements, the target address, the source address, and the protocol type. There is no place in the header to contain a VLAN identification, and there are far too many pieces of Ethernet hardware that expects the normal format of the header to make an adjustment. The reality is that the only devices that really need to know about the VLAN identity are the switches and, occasionally, the routers.

To implement the VLAN identity in the switches, the standard calls for the definition of a special kind of switch port called the "trunk port." The administrator of the switch designates one or more ports as trunk ports. These ports may only be connected to trunk ports on other devices. Connecting a server or workstation to a trunk port will result in a failure to communicate. Connecting a trunk port to a neighboring switch port that is not a dedicated trunk port will have similar results. The reason for the failure is that the Ethernet packets going over the trunk ports have a different format.

802.1Q Trunking Protocol

The IEEE 802.1Q trunking protocol allows for the modification of the Ethernet header. The header will now include additional information that includes the VLAN identity of the packet being sent over the trunk.

Target Address	Source Address	Protocol	**Payload**

Target Address	Source Address	802 1Q Tag	Protocol	**Payload**

Figure 11. Ethernet Headers w/wo 802.1Q Tag

Notice that the Protocol and Payload has shifted, and that the 802.1Q trunking protocol element or "tag" has been inserted. Trunking ports on the switches use this information to determine the VLAN identity of the packet when it arrives at the switch. It is removed before the packet is sent to a workstation or server on the network since they will not be able to understand the modified packed.

Protocol	VLAN ID	Priority

Figure 12. 802.1Q Tag Format

The 802.1Q tag contains a protocol identifier that tells the switches that a tag is attached. Following that is an area containing the VLAN ID and then a tag element that allows the switches to prioritize traffic from various VLANs.

Using the Tag

The tag allows the switches to identify traffic by VLAN of origination. That VLAN IDid also contains the VLAN destination on another switch.

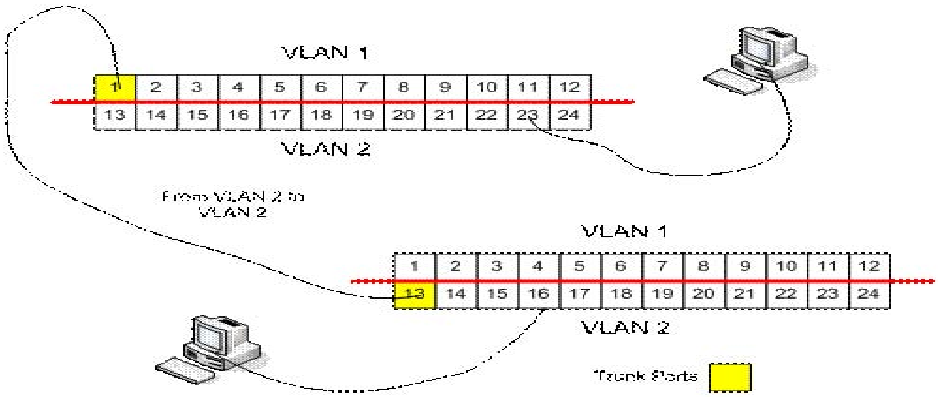


Figure 13. Trunking between switches

In the example above, ports 1 and 13 on the two switches have been converted to trunk ports. They carry information between the switches but include the 802.1Q tag indicating the VLAN information. Now, if the workstation on port 16 wants to send information to the workstation on port 23 of the other switch, the switches know the VLAN information, and the data is properly delivered. Regardless of the switch configuration and VLAN port assignments, the switches can accurately get the information from the source port to the destination port on the correct VLAN.

This example shows two switches, but VLAN tagging and VLAN support can be done at the enterprise level with many switches. The key to success is VLAN tagging and trunking the tagged frames.

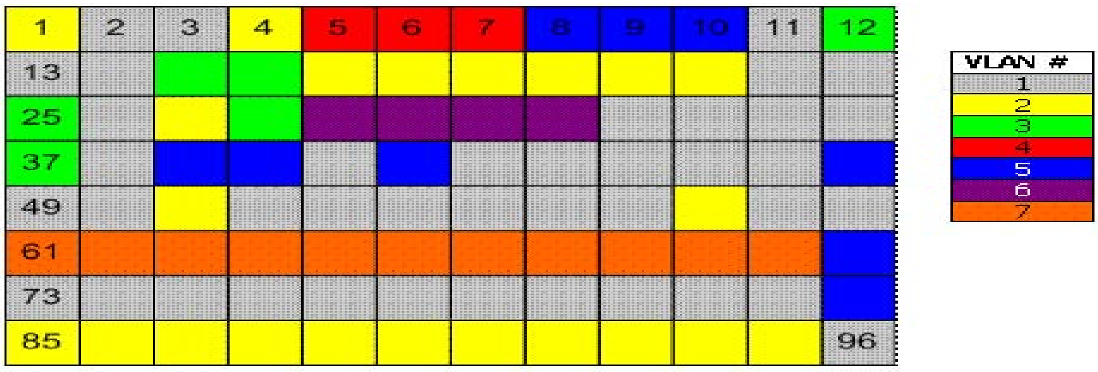
Why Use VLANs

Aside from security concerns, the VLAN provides the user with a number of other benefits. One of the first benefits is the reduction in the number of switches required in a network. The example of the accounting and manufacturing departments required that both departments be isolated from each other. Without the ability to create a virtual LAN in the single switch, the company would need to purchase two switches to perform the same task, one switch for accounting and one for manufacturing. If we expand the picture to include a large number of departments, the reduction in the number of switches could be substantial and represent a large cost savings.

Department	Switch Ports Needed	VLAN
Accounting	12	1
Manufacturing	22	2
Personnel	6	3
Shipping & Receiving	3	4
Information Technology	9	5
Executive Suite	4	6
Inventory Control	11	7

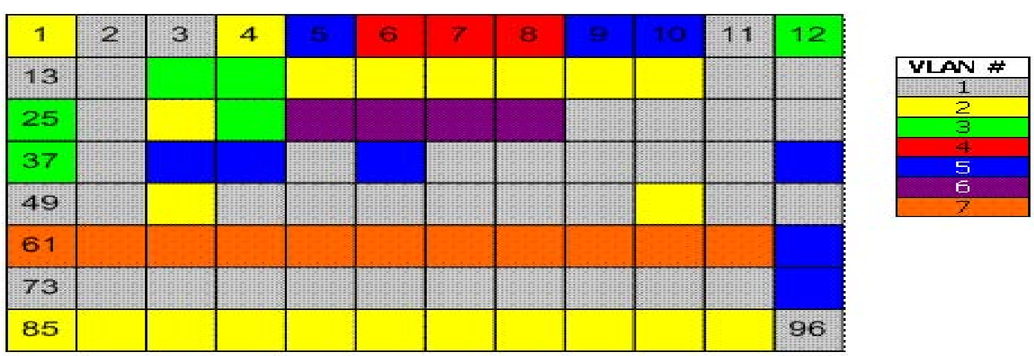
Figure 14. VLAN Table

This small business has seven separate departments. If each were to be isolated on departmental switches, seven switches would need to be purchased. If all of the ports were combined on a larger switch, a 96- port switch could be procured and seven separate VLANs created. Rather than administering seven different switches, the network personnel would only need to configure and maintain one switch. In the example below, VLAN membership is shown by the color indicated in block representing each port in the 96 port switch. All ports not assigned to VLANs 2 through 7 are automatically assigned to VLAN 1.



96 Port Switch
Figure 15. Sample VLAN Assignments

A second benefit is the reduction in the amount of administrative overhead required to manage a multi-switch environment. In the previous example with seven different switches, to move a workstation from the accounting department to the personnel department, administrators would have to change one or more cables in the patch panel and on the switches. With a VLAN, a port is assigned to a VLAN in the switch configuration. Moving a workstation between VLANs is as simple as changing the port VLAN assignment in the switch configuration. No cables are moved, only a software configuration change is needed. In the example below, the device plugged into port 5 has been moved to VLAN 5 and the device plugged into port 8 has been moved to VLAN 4. No cables were moved to change the assignment.



96 Port Switch
Figure 16. VLAN Assignment Modifications

A third benefit is physical location independence. Again, consider the seven- department model discussed earlier. As the organization expanded, the departments moved into two separate buildings. Accounting, Personnel, IT and the Executive Suite were in one Building A and Manufacturing, Shipping and Receiving and Inventory Control moved into a Building B. To support the two buildings, a second switch was procured, and a trunk was installed between the two switches. Four separate VLANS were configured on the switch in Building A, and three VLANs were configured on the switch in Building B. Appropriate port assignments were made for each VLAN for each department. Everything was going well until one of the members of the Executive Suite was sent to the Building B to oversee the operation there.

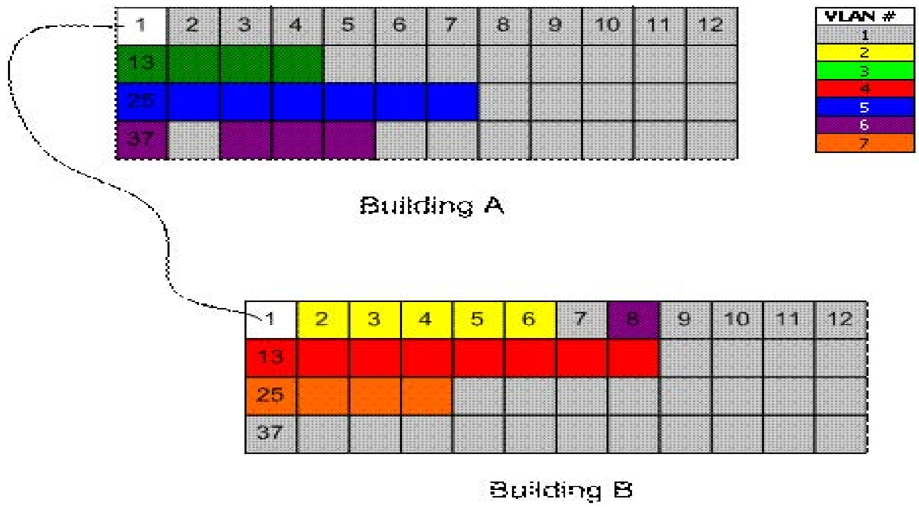


Figure 17 After moving workstation to Building B.

The network administrator simply changed one of the ports on the second switch in Building B and made it part of the Executive Suite VLAN. No major cabling changes were required to complete this operation.

Other, more advanced, benefits are available. One such benefit associates VLAN membership with a network login process. As an individual logs in to the switched network, they are identified and associated with a specific VLAN. Regardless of where the individual logs into the network, they are assigned to the correct VLAN dynamically. Special software is required for this feature to operate, and all switches are not capable of providing this type of support.

Summary

VLANs provide flexibility and security in an Ethernet network. Changes to networks can take place by changing configurations of switches rather than changing the locations of wires on networking devices.

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About the Author

Ted Rohling has been a contract instructor with Global Knowledge since 1995. With over 40 years of experience in information technology, telecommunications, and security, Ted teaches in the Networking and Security product lines and focuses on TCP/IP, Networking Fundamentals, Network Management, Storage Networking, and CISSP Preparation. He currently holds the CISSP certification and has previously held various certifications from Nortel, Cisco, and Microsoft. His educational background includes a BBA in Management Science, and MA in Information and Computer Management, and an MS in Educational Human Resource Development.