COMP 3721
Introduction to Data Communications

09b - Week 9 - Part 2

COMP 3721数据通信导论

09b - 第9周 - 第2部分

Learning Outcomes

- By the end of this lecture, you will be able to
  - Explain what are VLANs and what is the benefit of using them.

学习成果

- 通过本讲的学习，您将能够
  - 解释什么是VLAN以及使用它们的好处。

TCP/IP Protocol Suite Review

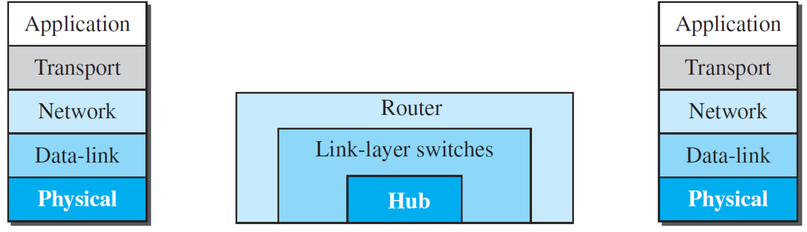
- **Physical layer** and **data-link layer** typically implemented in a **NIC** (Network Interface Card) and they handle **communication over a specific link**.
- **Hosts** (**end systems**) implement all 5 layers of the TCP/IP protocol stack.
- A link-layer address is also called MAC address, or hardware address, or physical address.
- **48-bit MAC address** (for most LANs) burned in NIC.
  - e.g., 1A-2F-BB-76-09-AD
- Each interface in a LAN, has a **unique MAC address**.
- Switches are called **link-layer devices**.

TCP/IP 协议套件回顾

- **物理层** 和 **数据链路层** 通常在 **NIC** （网络接口卡）中实现，负责处理 **特定链路上的通信**。
- **主机**（**终端系统**）实现了 TCP/IP 协议栈的全部 5 层。
- 链路层地址也称为 MAC 地址、硬件地址或物理地址。
- **48-位 MAC 地址**（对于大多数局域网）烧录在 NIC 中。
  - 例如，1A-2F-BB-76-09-AD
- 局域网中的每个接口都具有一个 **唯一的 MAC 地址**。
- 交换机被称为 **链路层设备**。

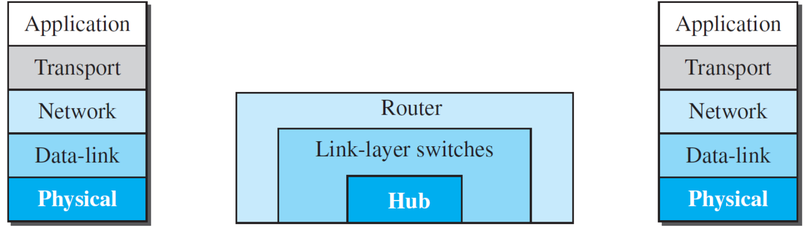
Connecting Devices

- We use **connecting devices** to connect hosts together to make a network or to connect networks together to make an **internet**.
- We discussed three kinds of connecting devices:
  - Hubs
  - Link-layer switches
  - Routers



连接设备

- 我们使用 **连接设备** 将主机连接在一起形成网络，或将网络连接在一起形成 **互联网**。
- 我们讨论了三种连接设备：
  - 集线器
  - 链路层交换机
  - 路由器



Link-layer Switches

- A **link-layer switch** receives incoming link-layer **frames** and forwards them onto outgoing links (forwards frames based on **destination MAC address**).
- **Transparent**: hosts unaware of presence of switches.
- **Plug-and-play** (**Self-learning**)
  - Switches do not need to be configured.
  - Switch learns which hosts can be reached through which interfaces.
- **Filtering**: whether to forward a frame to an interface or drop it.
- **Forwarding**: determines the interface to which the frame should be directed and moves the frame to that interface.

链路层交换机

- 一个 **链路层交换机**接收传入的链路层**帧**，并根据**目的MAC地址**将它们转发到出站链路上。

- **透明性**：主机察觉不到交换机的存在。
- **即插即用**（**自学习**）
  - 交换机无需配置。
  - 交换机会学习哪些主机可以通过哪些接口到达。
- **过滤**：是否将帧转发到接口或丢弃它。
- **转发**：确定帧应发送到的接口，并将帧移至该接口。

Link-layer Switches

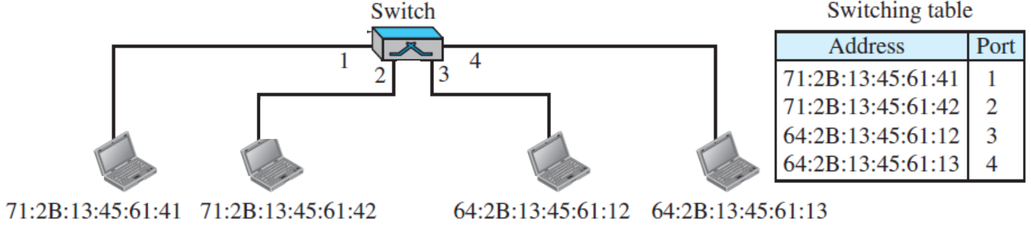
- In a switch-based Ethernet LAN there are no collisions and, therefore, there is **no need for CSMA/CD protocol**! (A switch never forwards more than one frame onto the same interface at any time).

链路-层交换机

- 在基于交换机的以太网局域网中，不存在冲突，因此不需要CSMA/CD协议！（交换机永远不会在同一时间将多个帧转发到同一接口上）。

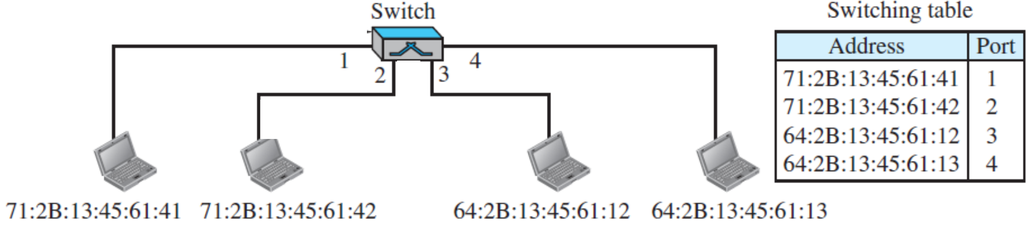
Switching Table

- **Switching table** includes entries for hosts and routers.
  - It is initially empty.
  - An entry in the table: **MAC address**, **port**, **other info**

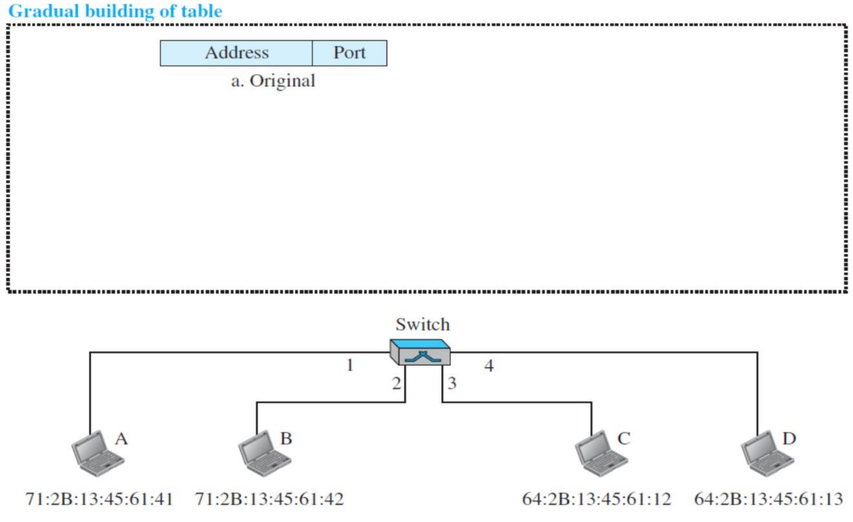


交换表

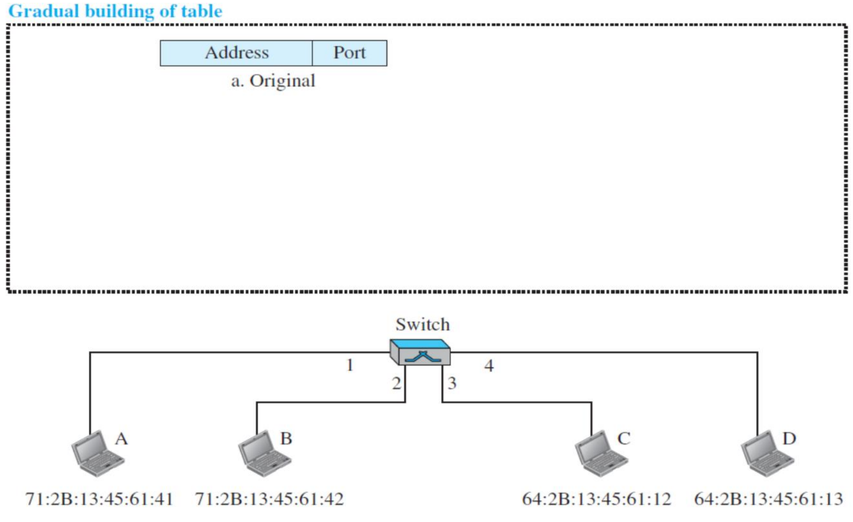
- **交换表**包含主机和路由器的条目。
  - 它初始时为空。
  - 表中的一个条目： **MAC地址**， **端口**， **其他信息**



Link-layer Switches Self-learning



链接-层交换机自学习



Link-layer Switches Self-learning

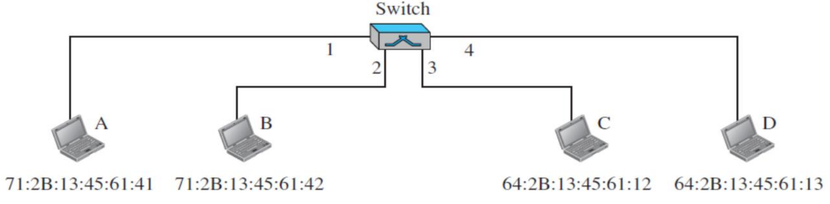
Gradual building of table

Address	Port

a. Original

Address	Port
71:2B:13:45:61:41	1

b. After A sends a frame to D



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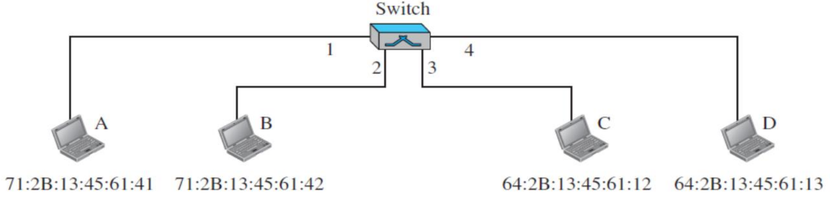

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Address	Port
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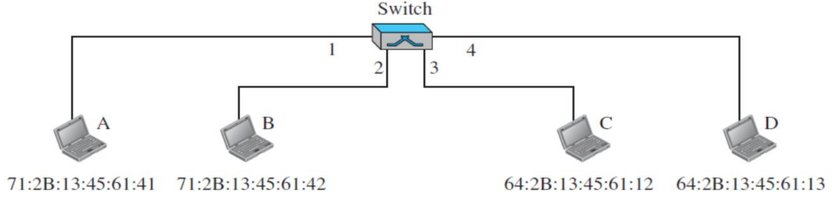
64:2B:13:45:61:13	4

c. After D sends a frame to B



链接-层交换机自学习

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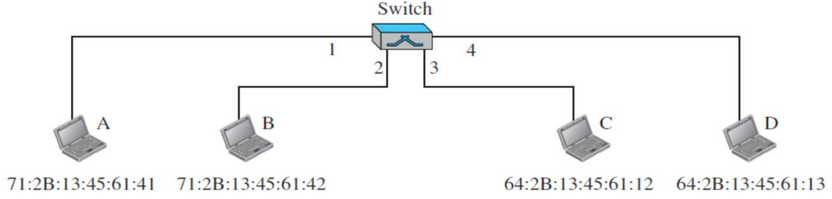

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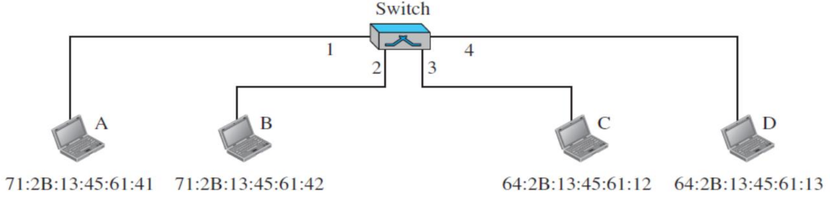
c. After D sends a frame to B

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2

d. After B sends a frame to A



链接-层交换机自学习

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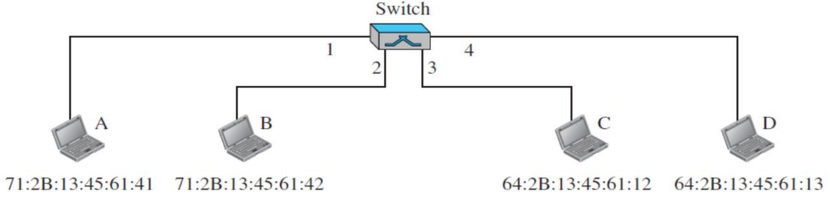

Link-layer Switches Self-learning

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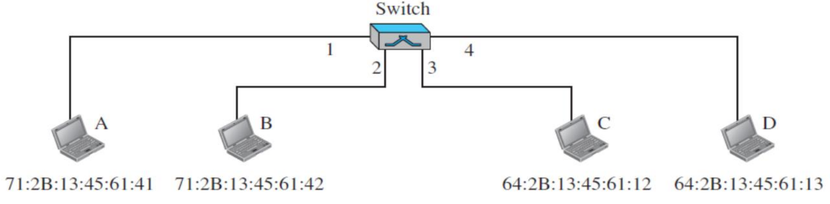
71:2B:13:45:61:42	2

d. After B sends a frame to A

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3

e. After C sends a frame to D



链接-层交换机自学习

Gradual building of table

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64:2B:13:45:61:13	4

c. After D sends a frame to B

Address	Port
71:2B:13:45:61:41	1
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d. After B sends a frame to A

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64:2B:13:45:61:12	3

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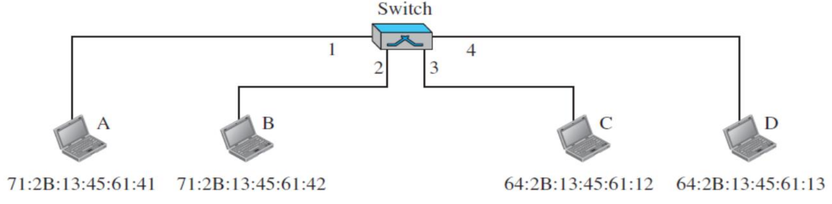


Link-layer Switches Filtering/Forwarding and Self-Learning

- The table is empty at first.
- When frame received at switch:

1. The switch records the source MAC address of the frame and the interface from which the frame arrived in the table (if not already in the table)
2. **if** entry found for **destination MAC address**: /*used as an index to access the table*/

   if destination is on segment from which frame arrived (i.e., the associated port in the table is the same as the port from which the frame arrived)

   drop frame /* discard the frame */

   else

   forward frame on interface indicated by entry

   else:

   flood /* forward on all interfaces except arriving interface, i.e., broadcast the frame*/

链路层交换机的过滤/转发与自学习

- 表格最初为空。

- 当交换机接收到帧时：

1. 交换机会将该帧的源MAC地址以及帧到达的接口记录在表中（如果表中尚不存在）
2. **如果**在表中找到目标**MAC地址**的条目：/*用作访问表格*/

   如果 目的地位于帧到达的网段上（即，表中对应的端口与帧到达的端口相同）

   丢弃帧 /* 丢弃该帧 */

   else

   转发帧 到条目所指示的接口

   否则:

   泛洪 /* 在除到达接口外的所有接口上转发，即广播该帧 */

Link-layer Switches Advantages

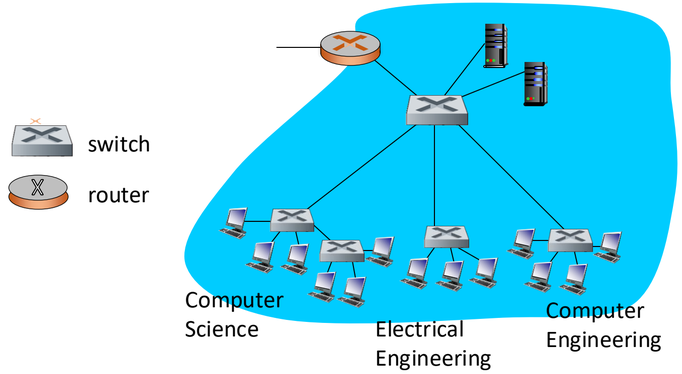
- **Collision elimination**
  - The switches buffer frames and never transmit more than one frame on a segment at any one time.
- **Heterogeneous links**
  - Links with different speeds and running over different transmission medium
- **Ease of network management**
  - Detecting and disconnecting malfunctioning adapters, etc.
  - Statistics on bandwidth usage, traffic types, etc.

链接-层交换机优势

- **消除冲突**
  - 交换机对帧进行缓冲，从不在同一时间在一个网段上发送多个帧。
- **异构链路**
  - 具有不同速率并在不同传输介质上运行的链路
- **网络管理简便**
  - 检测并断开出现故障的适配器等。
  - 带宽使用情况、流量类型等的统计信息。

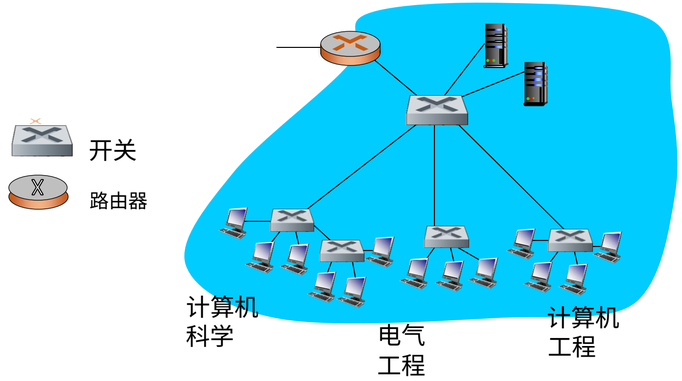
Link-layer Switches Disadvantages

- Lack of traffic isolation/single broadcast domain
- Security/privacy/efficiency
- User management



链接-层交换机缺点

- 缺乏流量隔离/单一广播域
- 安全性/隐私性/效率
- 用户管理



Virtual LANs (VLANs)

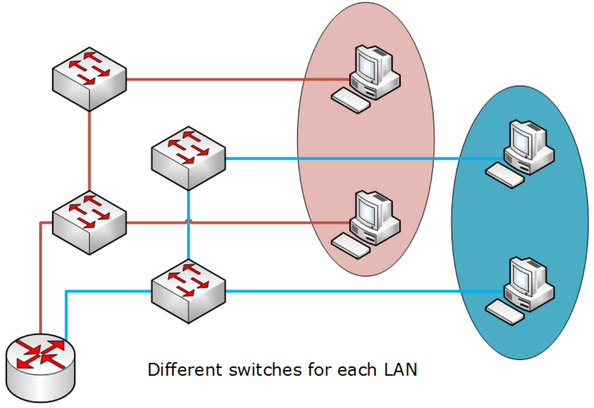
- Before the advent of VLANs, if you wanted networks separated by department, function, or subnet, you needed hubs or switches that were separated by routers.
- VLANs allow different **logical networks** to share the same **physical hardware**.

虚拟局域网（VLAN）

- 在VLAN出现之前，如果你想按部门、功能或子网划分网络，则需要使用路由器将集线器或交换机相互隔离。
- VLAN允许不同的 **逻辑网络** 共享相同的 **物理硬件**。

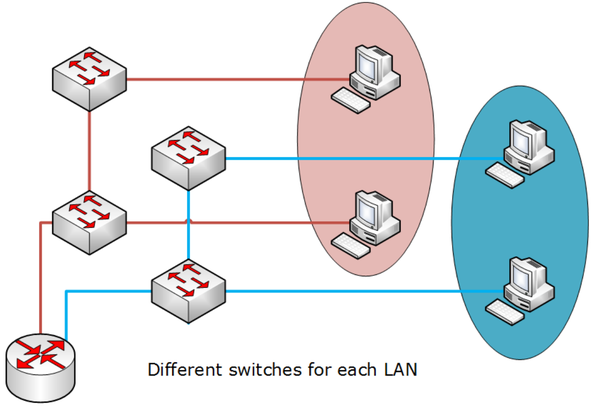
Traditional LANs

- In this graphic, the red devices are isolated from the blue devices by the router, while there is a separated switch used for each device in different floor e.g.



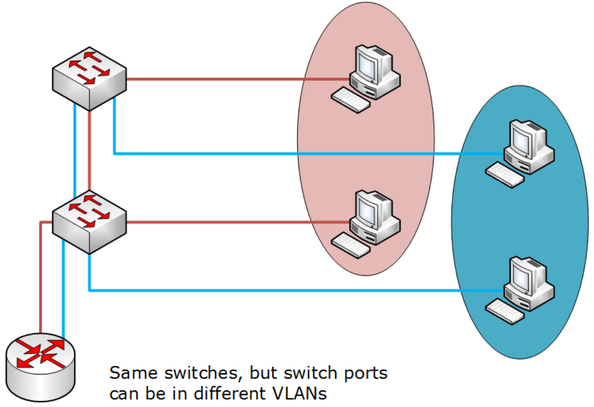
传统局域网

- 在此图中，路由器将红色设备与蓝色设备隔离开来，同时每个楼层的不同设备使用独立的交换机，例如。



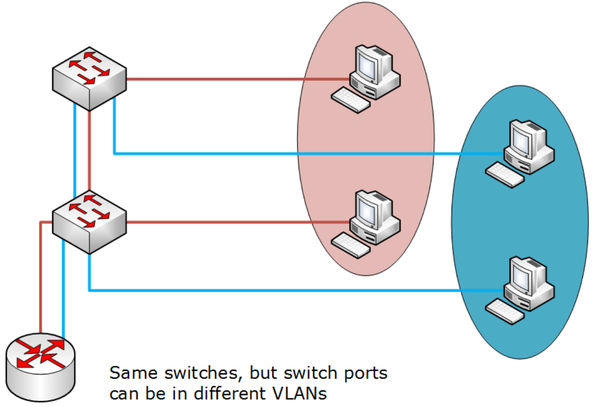
Virtual LANs

- The red hosts are now connected to the **same switches** as the blue hosts, even though they are in different subnetworks. A **VLAN** port assignment can make this work.



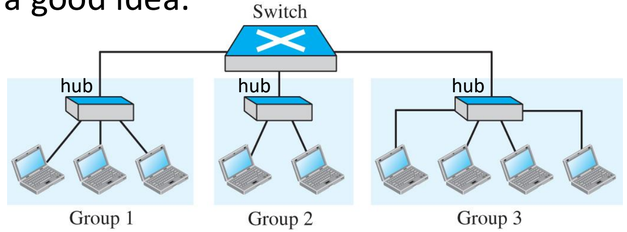
虚拟局域网

- 红色主机现在通过**相同的交换机**与蓝色主机相连，即使它们位于不同的子网络中。通过分配**VLAN**端口即可实现此连接。



Example 1

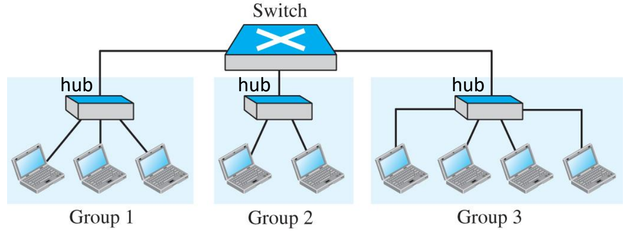
- Three groups of engineers, each group is working on a project.
- Each group forms a LAN.
- Three LANs are connected by a switch.
- What if the manager wants to move two engineers from the first group to the third group to speed up the project? Rewiring for each change is not a good idea.



Nine stations are grouped into three LANs that are connected by a switch.

示例 1

- 三组工程师，每组都在进行一个项目。
- 每组构成一个局域网。
- 三个局域网通过一个交换机连接。
- 如果经理想把第一组的两名工程师调到第三组以加快项目进度怎么办？每次变更都重新布线并不是一个好办法。



九个站点被分为三个局域网，并通过一个交换机连接。

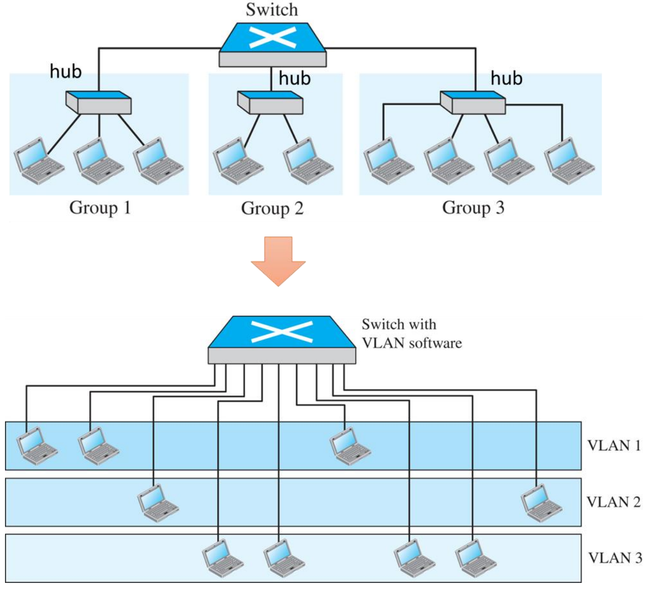
Virtual LANs

- What if we require a virtual connection between two stations belonging to two different physical LANs? Use a **VLAN** (**Virtual LAN**).
- A **VLAN** is a LAN configured by **software**, not by physical wiring.
- **Main idea**: A LAN is divided into several **logical LANs**, called VLANs.
- VLANs define **broadcast domains**.
  - VLANs group stations belonging to one or more physical LANs into broadcast domains.
  - The stations in a VLAN communicate with one another as though they belonged to a physical segment.

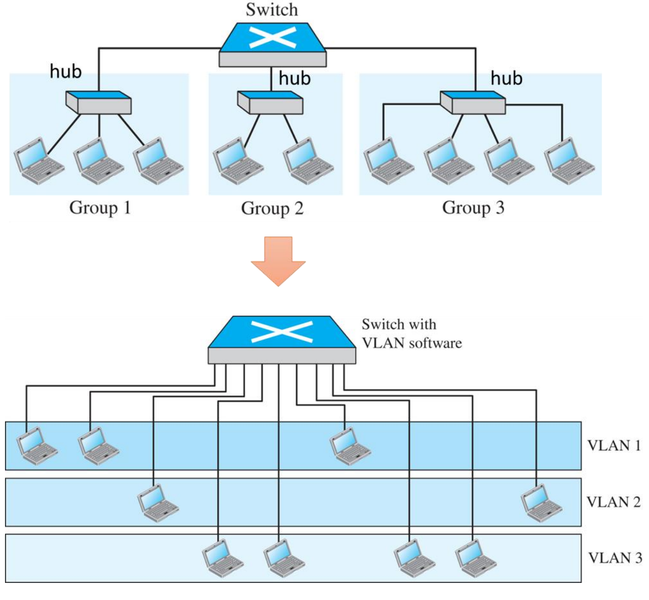
虚拟局域网

- 如果要求两个属于不同物理局域网的站点之间建立虚拟连接，该怎么办？使用**VLAN**（**虚拟局域网**）。
- 一个**VLAN**是由**软件**配置的局域网，而不是通过物理布线实现的。
- **主要思想**：将一个局域网划分为多个**逻辑局域网**，称为VLAN。
- VLAN定义了**广播域**。
  - VLAN将属于一个或多个物理局域网的站点分组为广播域。
  - VLAN 中的站点彼此通信，就像它们属于同一个物理网段一样。

Virtual LANs Configuration Example

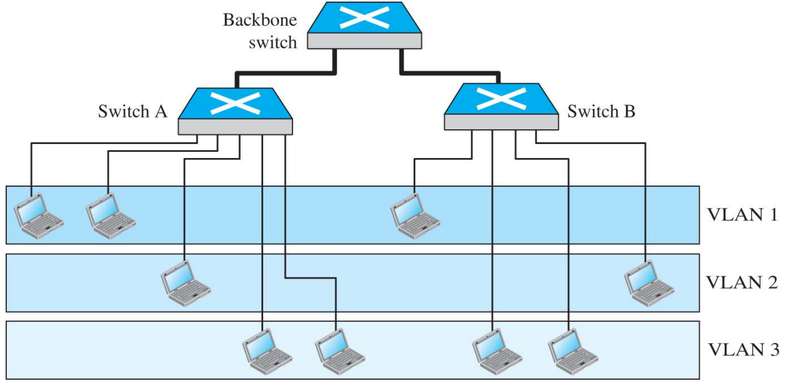


虚拟局域网配置示例



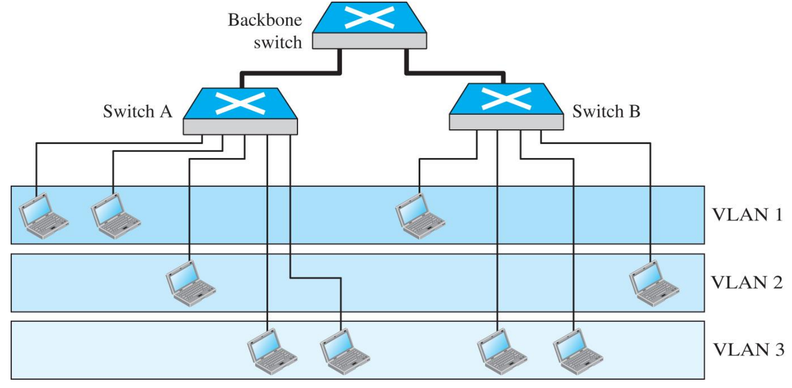
Virtual LANs Example 2

- A company with two separate buildings.
- People in the first building and people in the second building can be in the same work group although they are connected to different physical LANs.



虚拟局域网示例 2

- 一家公司拥有两栋独立的建筑。
- 第一栋建筑中的人和第二栋建筑中的人虽然连接到不同的物理局域网，但仍可属于同一个工作组。



VLAN Membership

- How to group stations in a VLAN?
  - Interface numbers (ports)
  - MAC addresses
  - IP addresses
  - A combination of different characteristics

VLAN 成员关系

- 如何将站点分组到 VLAN 中?
  - 接口编号（端口）
  - MAC 地址
  - IP 地址
  - 多种不同特性的组合

VLAN Configuration

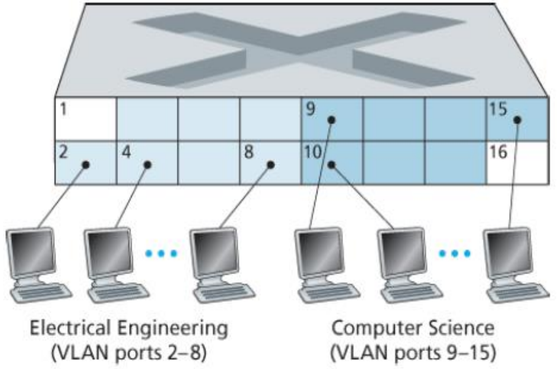
- It is a **logical configuration** and is performed using the **VLAN software**.
- Ways of configuration:
  1. Manual (during setup or migration)
  2. Automatic (criteria defined by the administrator)
  3. Semiautomatic (usually, manual setup and automatic migration)

VLAN 配置

- 它是一种**逻辑配置**，通过**VLAN 软件**完成。
- 配置方式：
  1. 手动（在安装或迁移期间）
  2. 自动（由管理员定义条件）
  3. 半自动（通常为手动安装和自动迁移）

Example of Port-Based VLANs

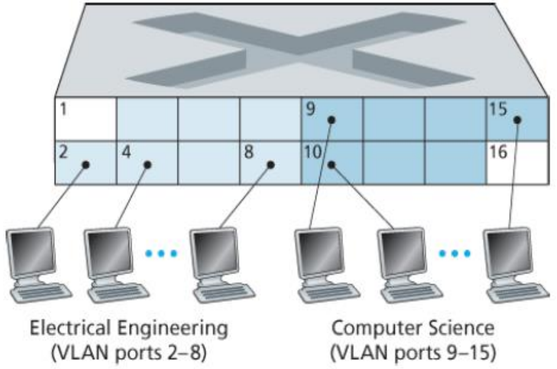
- Broadcast traffic from one port can only reach other ports in the group (same VLAN).
- A table of port-to-VLAN mappings is maintained within the switch.
- Switch hardware only delivers frames between ports belonging to the same VLAN.



Two VLANs: EE VLAN, CS VLAN

端口示例-基于VLAN

- 来自一个的广播流量
  端口只能访问组内
  其他端口（同一VLAN）。
- 交换机内维护着一个端口到VLAN的映射表。
- 交换机硬件仅在同一VLAN内的端口之间转发帧。



两个VLAN：EE VLAN、CS VLAN

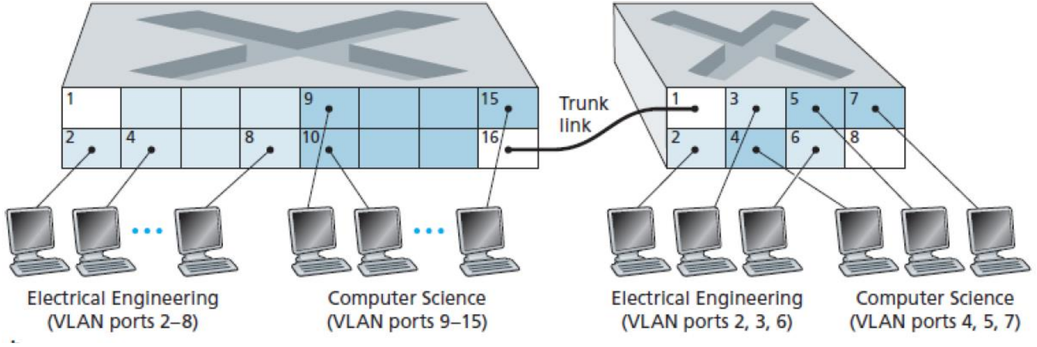
Communication Among Switches

- A switch must know:
  - Membership of stations to VLANs (not only for its connected stations)
- **Frame tagging** and **VLAN trunking**
  - A special port (**trunk port**) on each switch is configured as the trunk port to provide connection to other VLAN switches.
  - An extra header is added to the MAC frame to define the destination VLAN.
  - Receiving switches use the **frame tag** (**VLAN tag**) to indicate the VLANs that should receive the broadcast message.
  - **IEEE standard 802.1Q**

交换机之间的通信

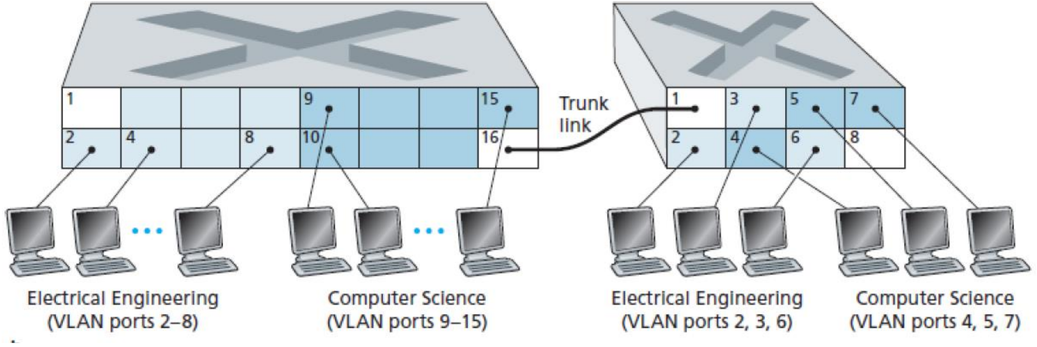
- 交换机必须知道：
  - 站点所属的VLAN（不仅限于其连接的站点）
- **帧标记** 和 **VLAN中继**
  - 每个交换机上的一个特殊端口（**中继端口**）被配置为中继端口，以提供与其他VLAN交换机的连接。
  - 在MAC帧上添加一个额外的头部，用于定义目标VLAN。
  - 接收交换机使用**帧标签**（**VLAN 标签**）来指明应接收该广播消息的 VLAN。
  - **IEEE 标准 802.1Q**

Interconnecting VLAN Switches – VLAN Trunking



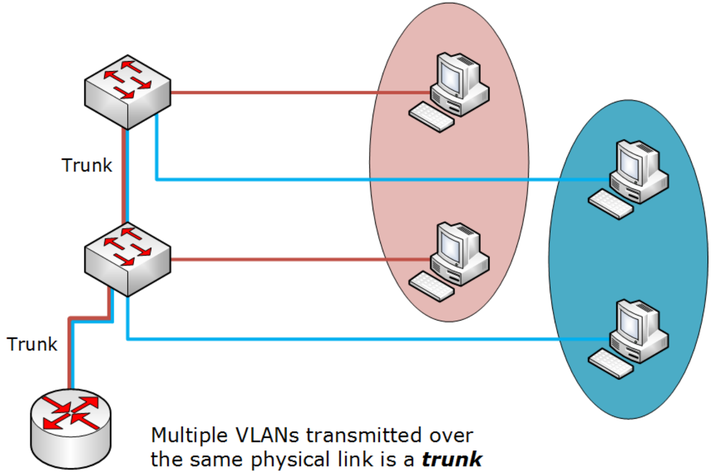
Two VLANs: EE VLAN, CS VLAN

互连VLAN交换机 — VLAN中继

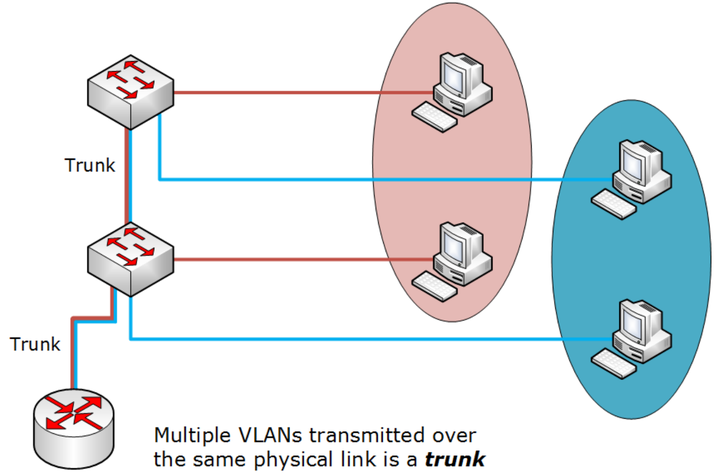


两个VLAN：EE VLAN，CS VLAN

Interconnecting VLAN Switches – VLAN Trunking



互连VLAN交换机 – VLAN中继



VLANs – Advantages

- **Cost and time reduction**
  - Decreasing migration cost (physical reconfiguration is time-consuming and costly).
- **Creating virtual work groups**
  - Easier collaboration and user management.
- **Security** (**traffic isolation**)
  - Users in other groups (VLANs) will not receive the messages.

VLAN – 优势

- **降低成本和时间**
  - 降低迁移成本（物理重新配置既耗时又昂贵）。
- **创建虚拟工作组**
  - 更易于协作和用户管理。
- **安全性** （**流量隔离**）
  - 其他组（VLAN）中的用户将不会收到这些消息。

Summary

- By using VLANs we can **logically group different stations in a LAN** based of characteristics such as switch port numbers, MAC addresses, etc.
- VLANs provide **easy and low-cost migration** among different virtual groups.
- **VLAN trunking** and **frame tagging** is used to interconnect the VLAN switches.

摘要

- 通过使用 VLAN，我们可以根据交换机端口号、MAC 地址等特征，**在局域网中对不同的站点进行逻辑分组**。
- VLAN 提供了 **简单且低成本的迁移方式**，可在不同的虚拟组之间进行切换。
- **VLAN 中继** 和 **帧标记** 用于连接 VLAN 交换机。

References

[1] Behrouz A.Forouzan, Data Communications & Networking with TCP/IP Protocol Suite, 6th Ed, 2022, McGraw-Hill companies.

[2] J.F. Kurose, K.W. Ross, Computer Networking: A Top-Down Approach, 7th Ed, 2017, Pearson Education, Inc.

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[1] Behrouz A.Forouzan, Data Communications & Networking with TCP/IP Protocol Suite, 6th Ed, 2022, McGraw-Hill companies.

[2] J.F. Kurose, K.W. Ross, Computer Networking: A Top-Down Approach, 7th Ed, 2017, Pearson Education, Inc.

Reading

- Chapter 6 of the textbook, sections 6.1 and 6.2.
- Chapter 6 of the textbook, section 6.4 (Practice Test)

阅读

- 教材第6章，第6.1节和6.2节。
- 教材第6章，第6.4节（练习测试）