Packet Switched Networks

Acknowledgements
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Goals

- Understanding principles behind packet switched networks
- Introducing some examples of packed switched networks

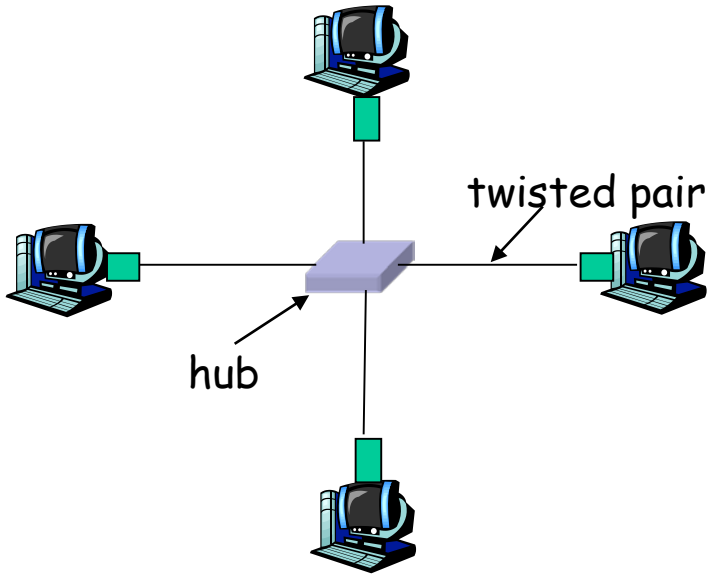
Packet Switched Networks

- Link-layer switches
- Switched Ethernet
- Virtual LANs
- Wide-Area Packet Switched Networks
  - ATM Networks
- Link virtualization

Hubs

… physical-layer ("dumb") repeaters:

- bits coming in one link go out *all* other links at same rate
- all nodes connected to hub can collide with one another
- no frame buffering
- no CSMA/CD at hub: host NICs detect collisions

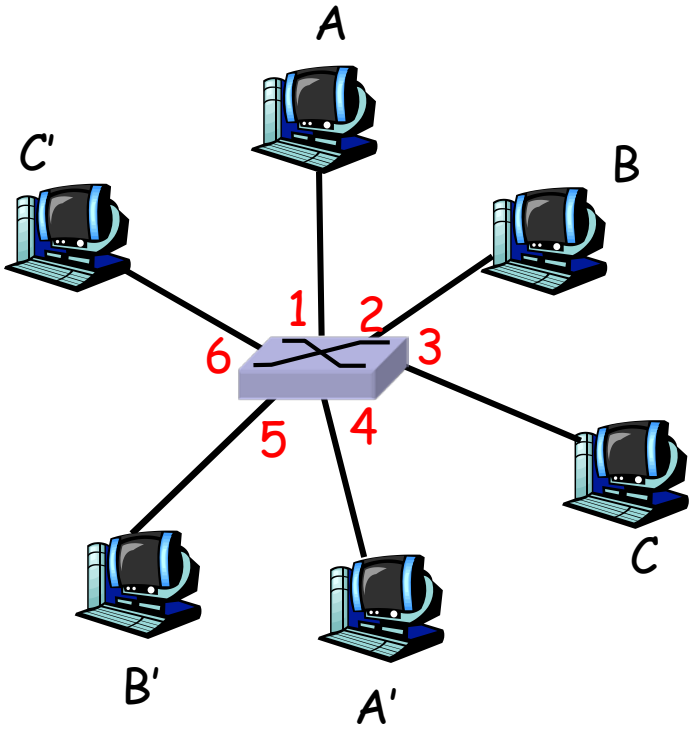


Switch

- link-layer device: smarter than hubs, take *active* role
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment
- *transparent*
  - hosts are unaware of presence of switches
- *plug-and-play, self-learning*
  - switches do not need to be configured

Switch: allows *multiple* simultaneous transmissions

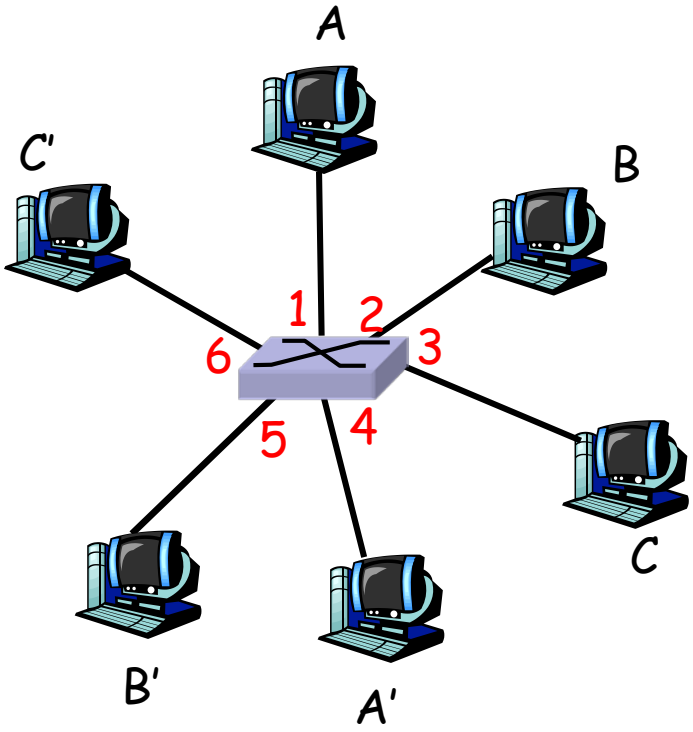
- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *switching:* A-to-A' and B-to-B' simultaneously, without collisions
  - not possible with dumb hub



switch with six interfaces (1,2,3,4,5,6)

Switch Table

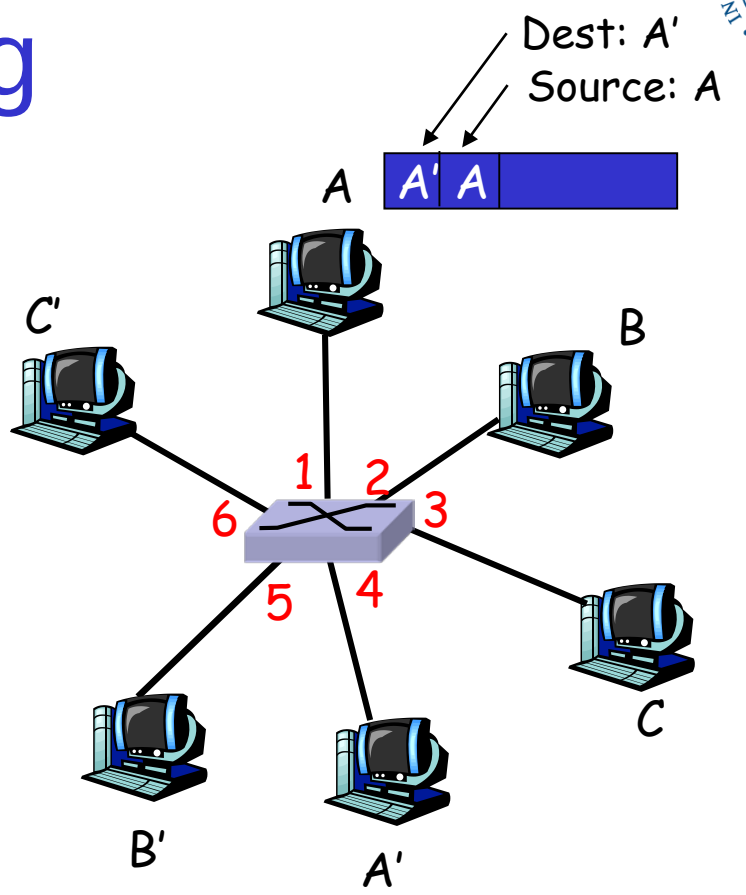
- Q: how does switch know that A' reachable via interface 4, B' reachable via interface 5?
- A: each switch has a switch table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
- Q: how are entries created, maintained in switch table?



switch with six interfaces (1,2,3,4,5,6)

Switch: self-learning

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table

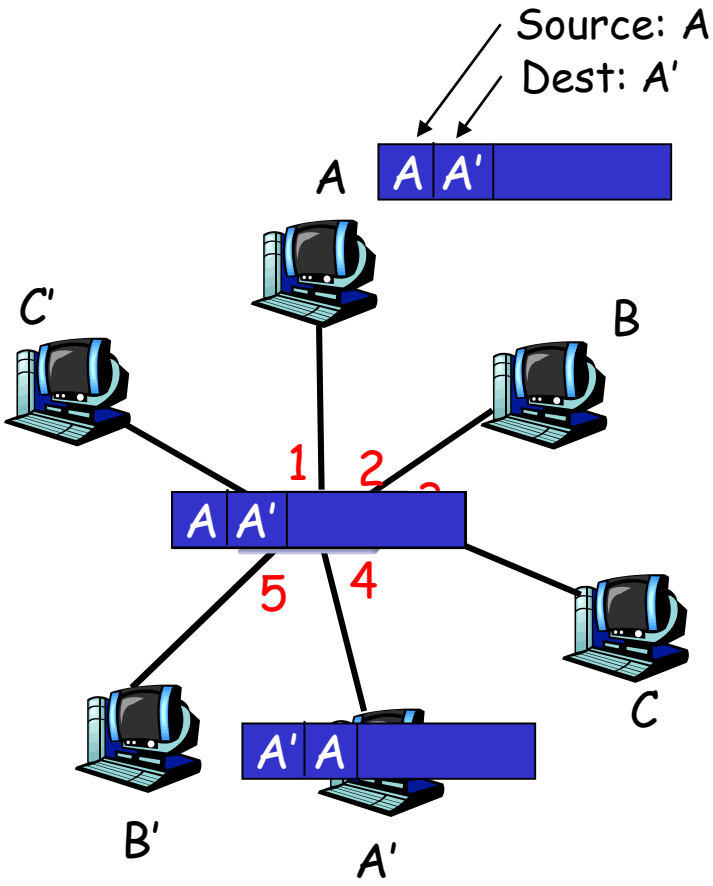


MAC addr	interface	TTL
A	1	60

Switch table (initially empty)

Self-learning, forwarding: example

- frame destination unknown: *flood*
- destination A location known: *selective send*



MAC addr	interface	TTL
A	1	60
A'	4	60

Switch table (initially empty)

Switch: frame filtering/forwarding

When frame received:

1. record link associated with sending host
2. index switch table using MAC dest address
3. **if** entry found for destination
   then {
   if dest on segment from which frame arrived
   then drop the frame
   else forward the frame on interface indicated
   }
   else flood

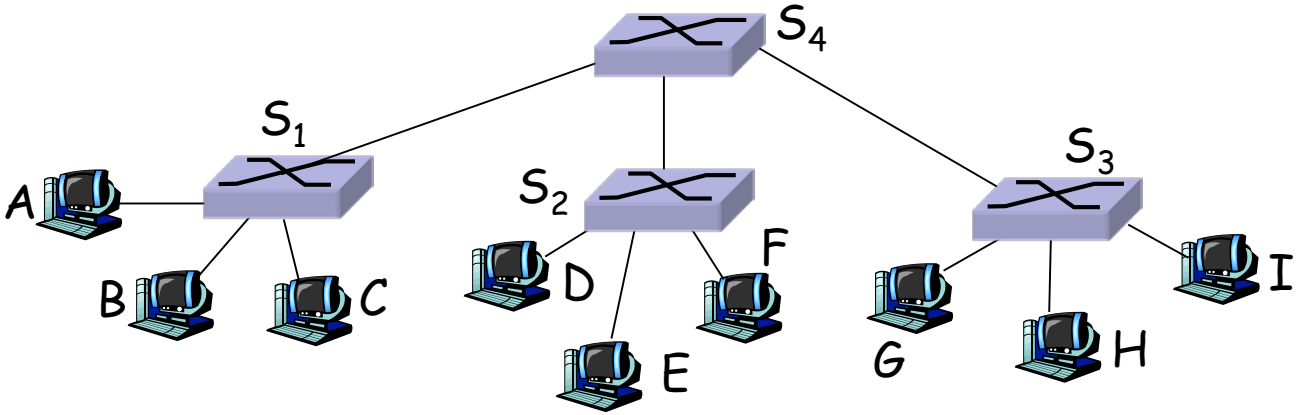
forward on all but the interface on which the frame arrived

Packet Switched Networks

- Link-layer switches
- Switched Ethernet
- Virtual LANs
- Wide-Area Packet Switched Networks
  - ATM Networks
- Link virtualization

Interconnecting switches

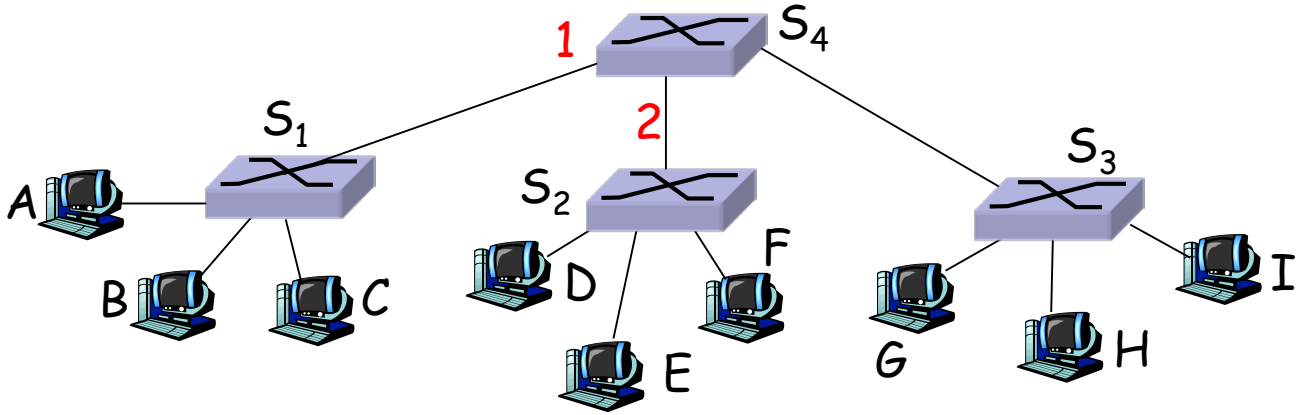
- switches can be connected together



- Q: sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3?
- A: self learning! (works exactly the same as in single-switch case!)

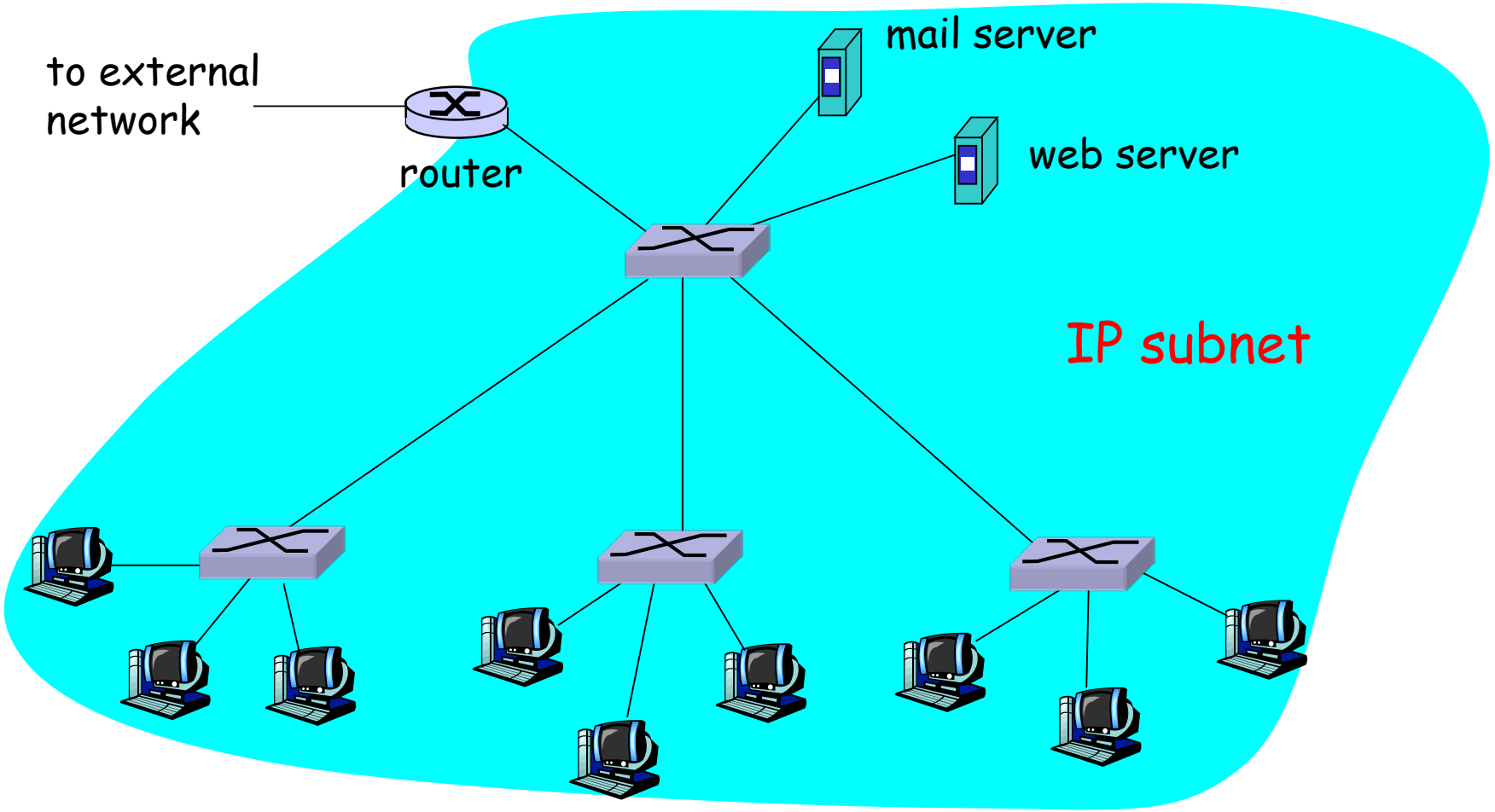
Self-learning multi-switch example

Suppose C sends frame to I, I responds to C



- Q: show switch tables and packet forwarding in S_1, S_2, S_3, S_4

Institutional network



Properties of Switched Ethernet

- Elimination of Collision
  - Significant performance improvement
- Support of heterogeneous links
  - The switch is able to adapt to different links (10BaseT, 100BaseT, 100BaseFX, …
- Easy Management
  - Faulty links can be automatically disconnected by the switch
- Improved Security
  - Sniffing frames is more difficult
  - Switch poisoning still possible

Packet Switched Networks

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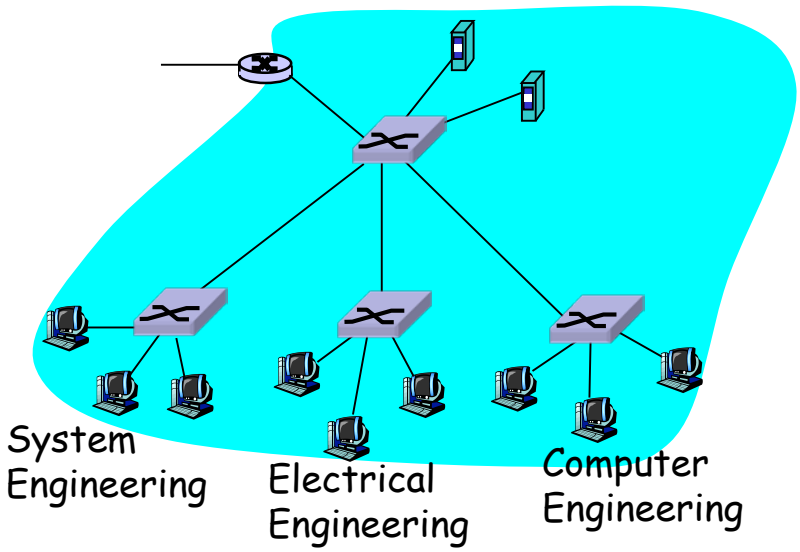
VLANs: motivation

What's wrong with this picture?



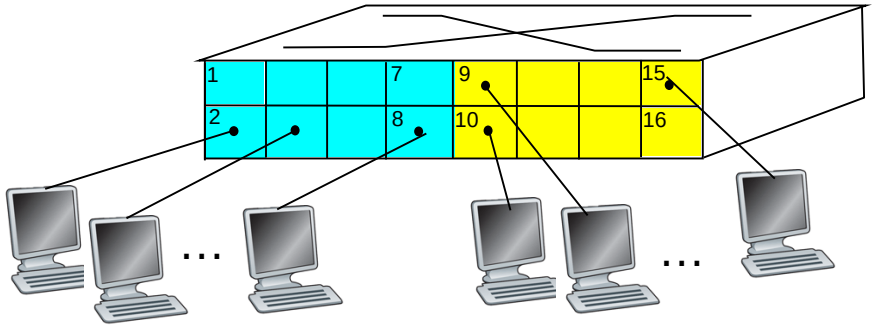
- Single broadcast domain:
  - all layer-2 broadcast traffic (ARP, DHCP) crosses entire LAN (security/privacy, efficiency issues)
- Inefficient use of switches
  - each lowest level switch has only few ports in use
  - A single big switch could be enough
- Managing users
  - A SE user moves office to EE, but wants connect to SE switch
  - Cabling should be changed

VLANs

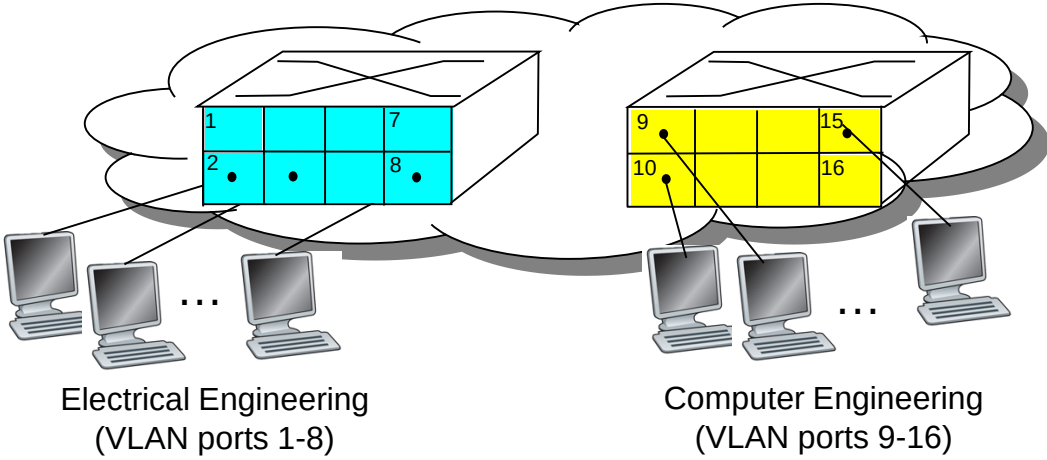
Virtual Local Area Network

Switch(es) supporting VLAN capabilities can be configured to define multiple ***virtual*** LANS over single physical LAN infrastructure.

Port-based VLAN: switch ports grouped (by switch management software) so that *single* physical switch ……

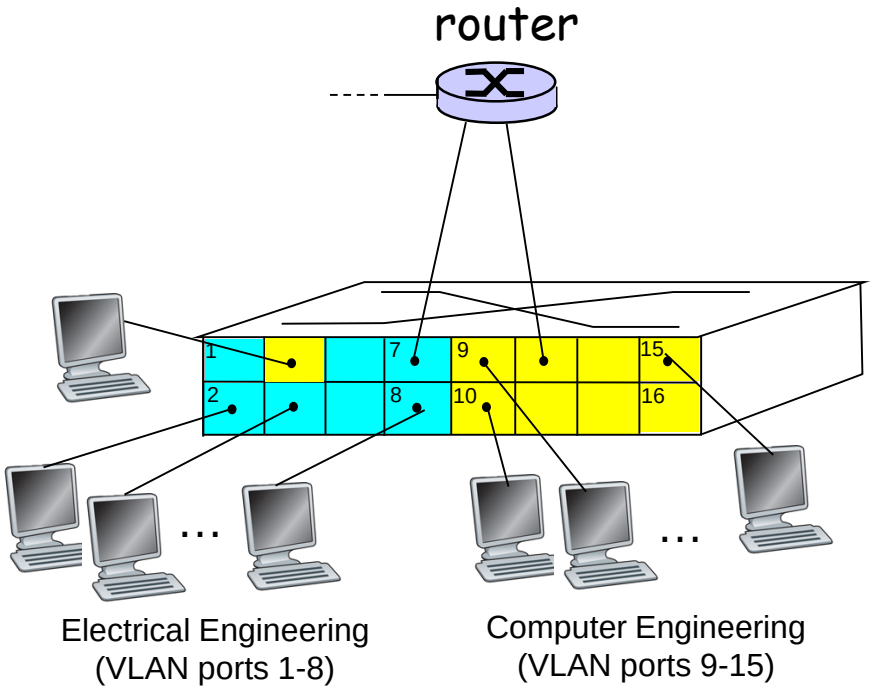


… operates as *multiple* virtual switches

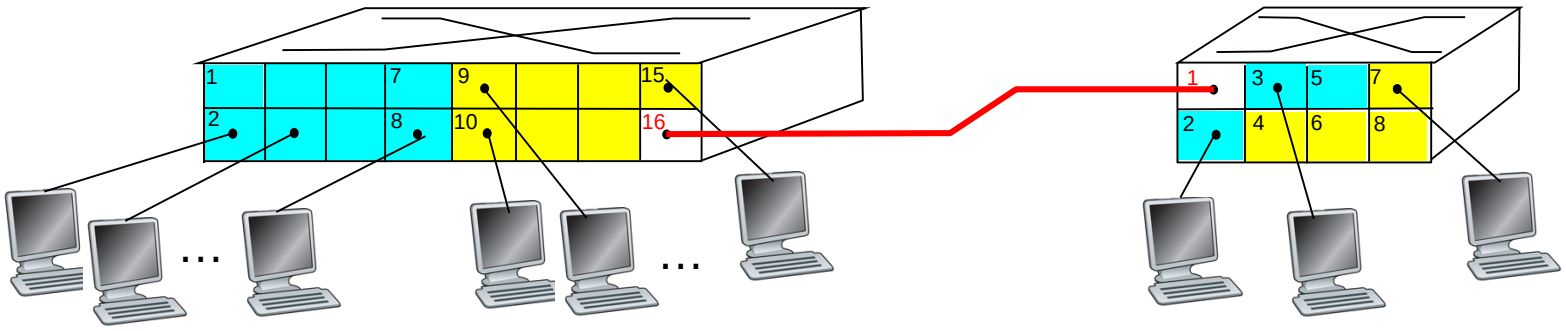


Port-based VLAN

- *traffic isolation:* frames to/from ports 1-8 can *only* reach ports 1-8
  - can also define VLAN based on MAC addresses of endpoints, rather than switch port
- *dynamic membership:* ports can be dynamically assigned among VLANs
- *forwarding between VLANS:* done via routing (just as with separate switches)
  - in practice vendors sell combined switches plus routers

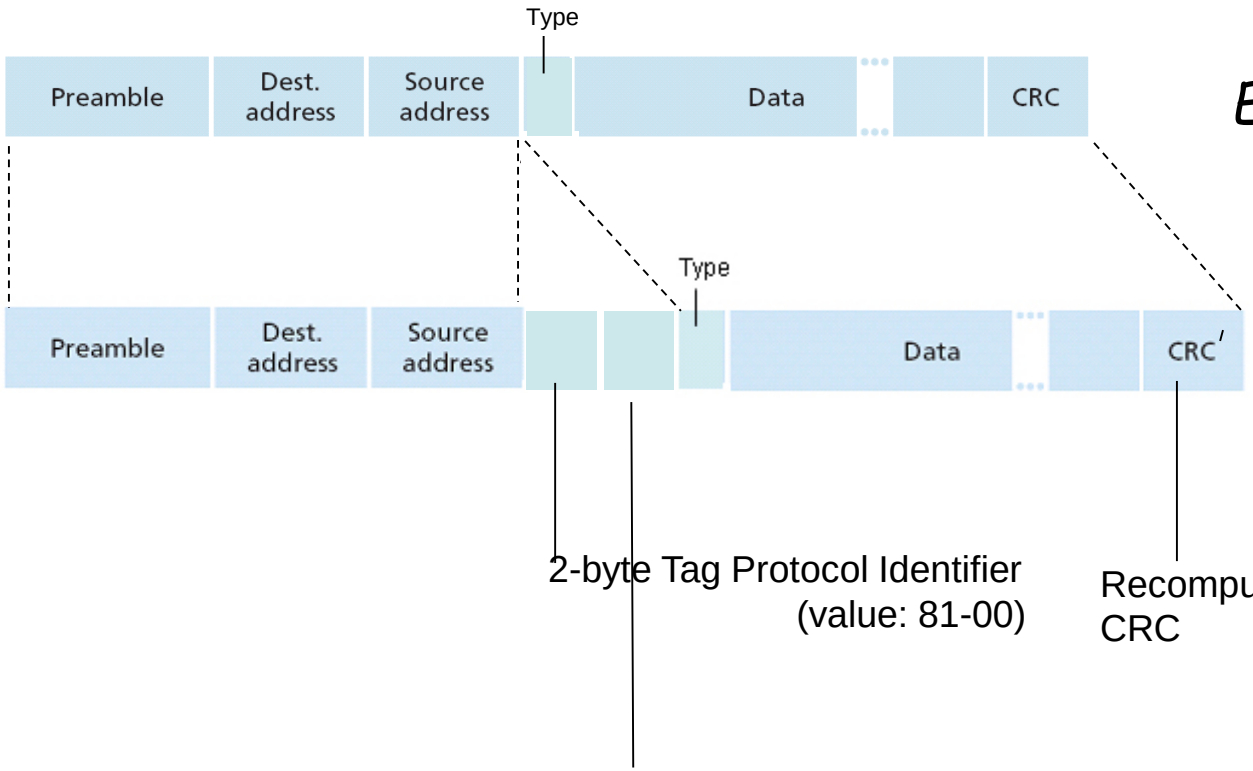


VLANS spanning multiple switches



- *trunk port:* carries frames between VLANS defined over multiple physical switches
  - frames forwarded within VLAN between switches can't be vanilla frames (must carry VLAN ID info)
  - 802.1q protocol adds/removed additional header fields for frames forwarded between trunk ports

802.1Q VLAN frame format



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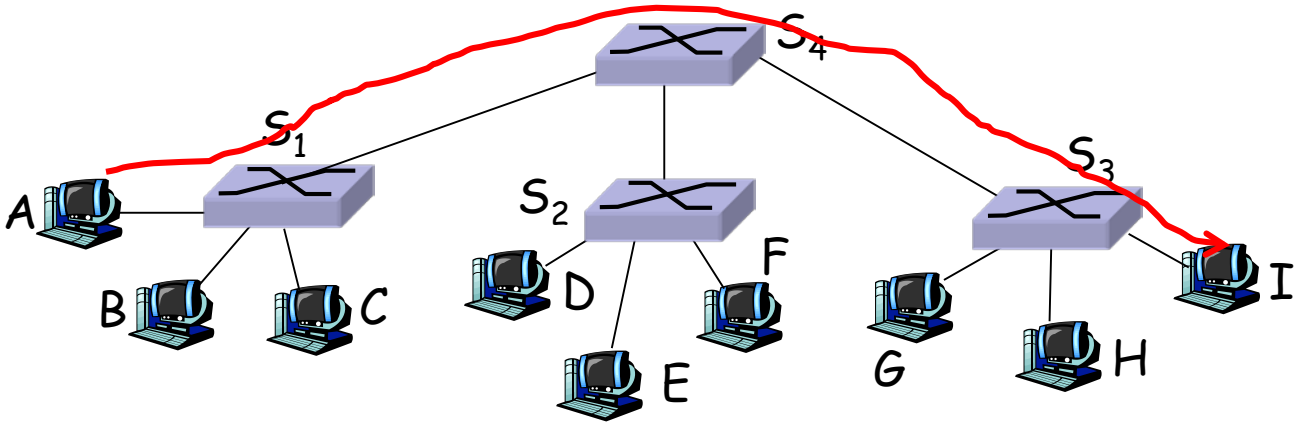
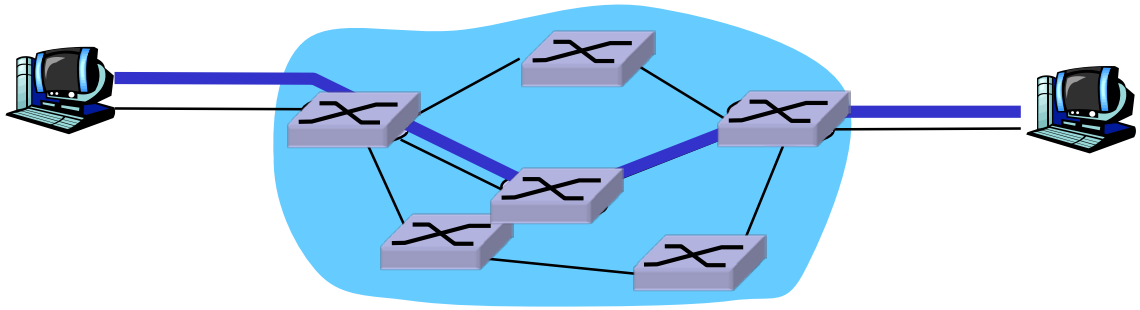
Switched Ethernet

- Path from Host/Router A to Host/Router I



Packet-switched Wide Area Network

- Nodes identified through a unique address
  - Similar to the Ethernet MAC address



Type of Service

- Connectionless: each packet is managed on an individual basis
  - Also known as datagram service
- Connection: Virtual Circuit is preliminary established and all packets follow the same path

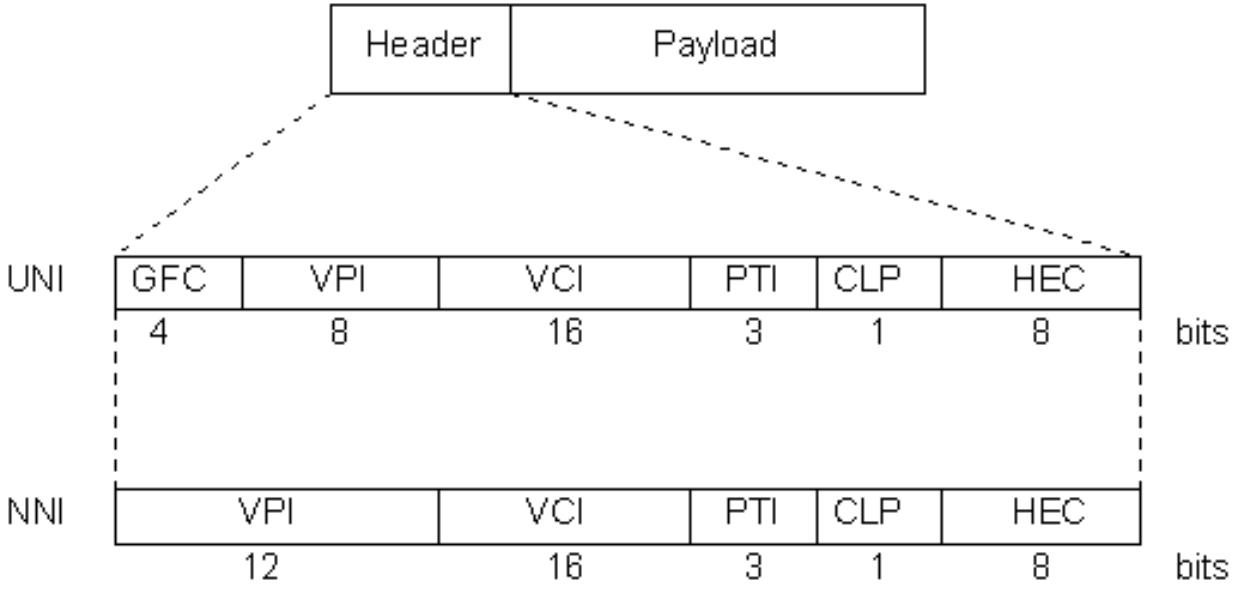
Asynchronous Transfer Mode: ATM

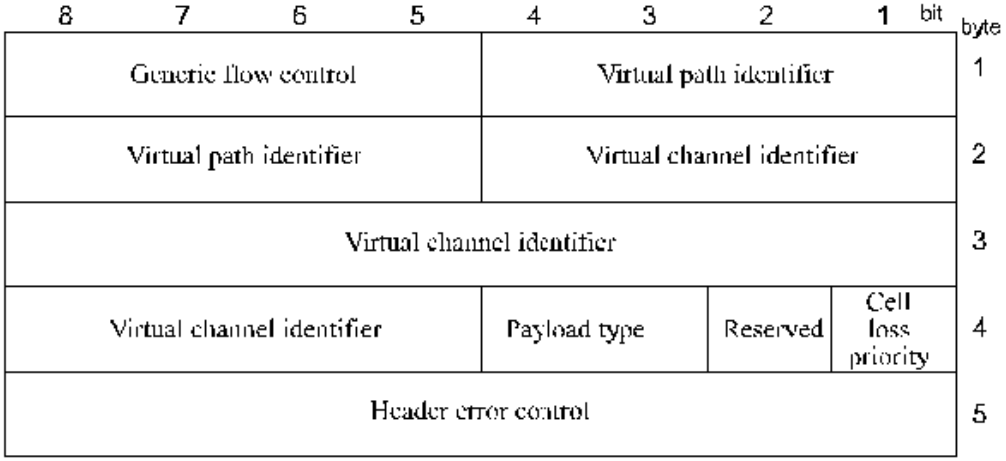
- **1990's standard for high-speed** (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport of voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
  - packet-switching (fixed length packets, called "cells") using virtual circuits

ATM Services

- Constant Bit Rate (CBR)
- Variable Bit Rate (VBR)
- Available Bit Rate (ABR)
- Unspecified Bit Rate (UBR)

ATM Cell


Header
Payload
UNI
GFC
VPI
VCI
PTI
CLP
HEC
4
8
16
3
1
8
bits
NNI
VPI
VCI
PTI
CLP
HEC
12
16
3
1
8
bits


8 7 6 5 4 3 2 1 bit
byte
Generic flow control
Virtual path identifier
1
Virtual path identifier
Virtual channel identifier
2
Virtual channel identifier
3
Virtual channel identifier
Payload type
Reserved
Cell loss priority
4
Header error control
5

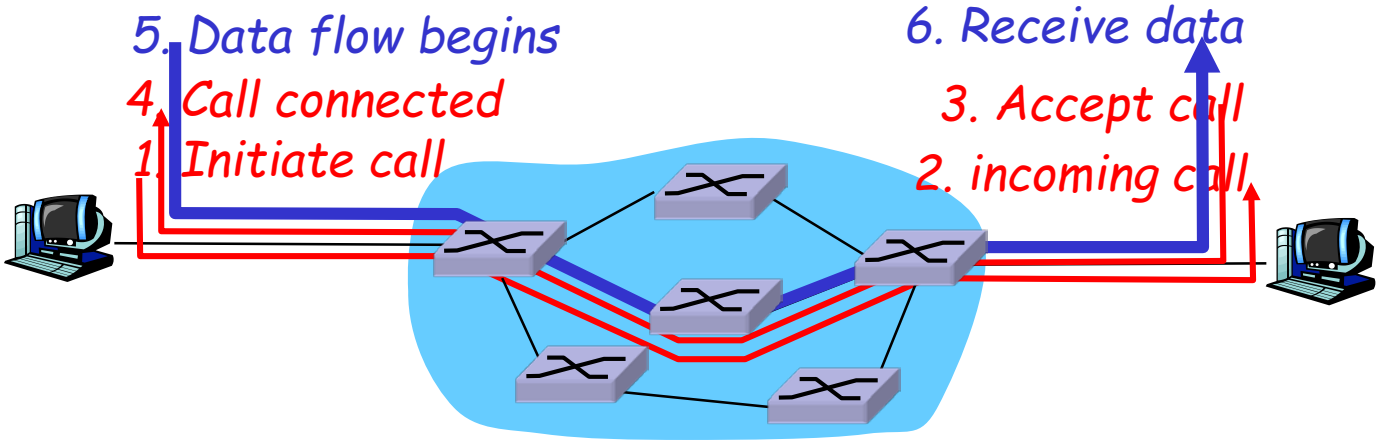
Virtual Circuit (VC)

source-to-destination path
- behaves much like telephone circuit
- performance-wise
- network actions along source-to-dest path

- call setup, teardown for each call *before* data can flow
- each packet carries VC identifier (not destination host address)
- *every* switch on source-dest path maintains "state" for each passing connection
- link, switch resources (bandwidth, buffers) may be *allocated* to VC (dedicated resources = predictable service)

VC setup (and teardown)

- Used in ATM, frame-relay, X.25



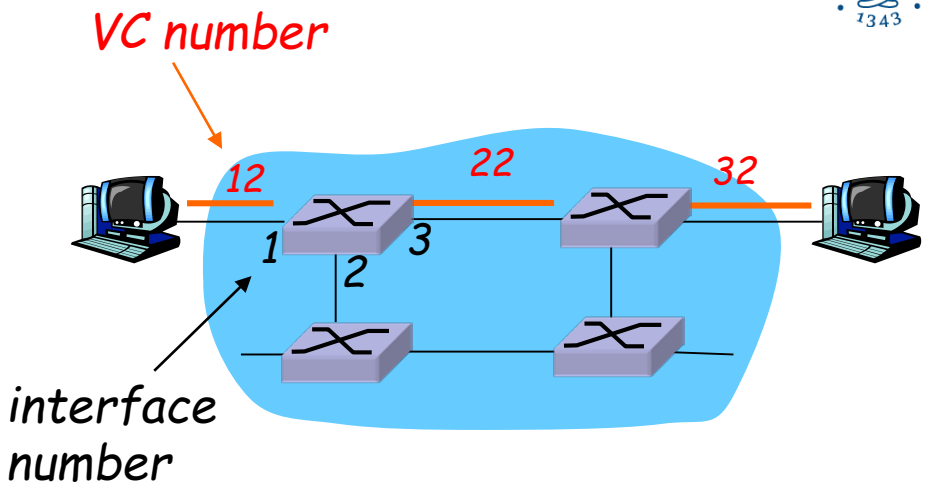
VC implementation

a VC consists of:

1. path from source to destination
2. VC numbers, one number for each link along path
3. entries in forwarding tables in routers along path

- packet belonging to VC carries VC number (rather than dest address)
- VC number can be changed on each link.
  - New VC number comes from forwarding table

Forwarding table



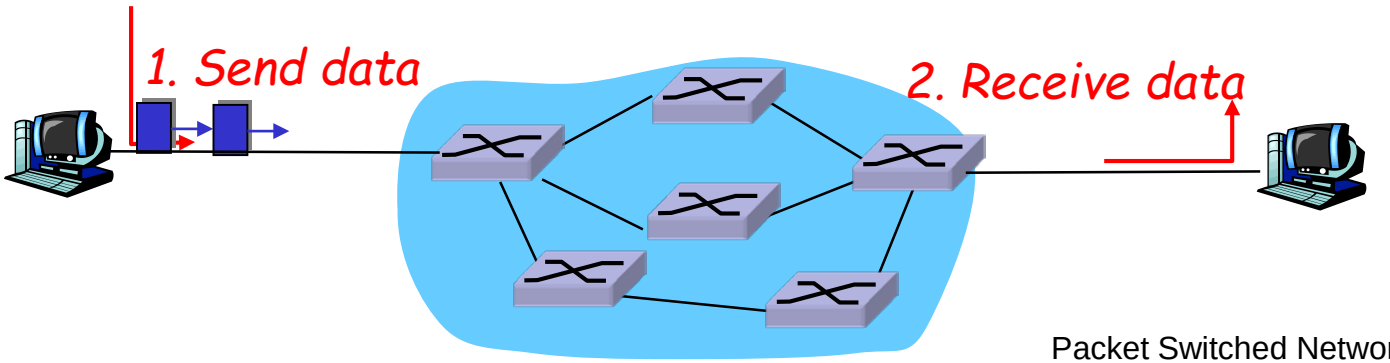
Forwarding table in
A switch

Incoming interface	Incoming VC #	Outgoing interface	Outgoing VC #
1	12	3	22
2	63	1	18
3	7	2	17
1	97	3	87
…	…	…	…

Switches maintain connection state information!

Datagram service

- no call setup at network layer
- switches: no state about end-to-end connections
  - no concept of "connection"
- packets between the same source-destination pair may take different paths
- packets forwarded using destination host address



Forwarding table

Destination Address Range	*Link Interface*
11001000 00010111 00010000 00000000 through 11001000 00010111 00010111 11111111	*0*
11001000 00010111 00011000 00000000 through 11001000 00010111 00011000 11111111	*1*
11001000 00010111 00011001 00000000 through 11001000 00010111 00011111 11111111	*2*
otherwise	*3*

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Virtualization of Networks

- Virtualization of resources: powerful abstraction in systems engineering:
  - virtual memory
  - virtual devices
  - virtual machines: e.g., java
- Virtual Link:
  - The path from S to D is regarded as a point-to-point virtual link
  - Just like a physical point-to-point link
  - The service type is thus not relevant from the Internet point of view

Summary

- Principles behind packet switched networks
- Switched LANS, VLANs
- Wide-Area Packet-Switched Networks
  - ATM
- Virtualized networks as a point-to point link