CS 725/825 & IT 725

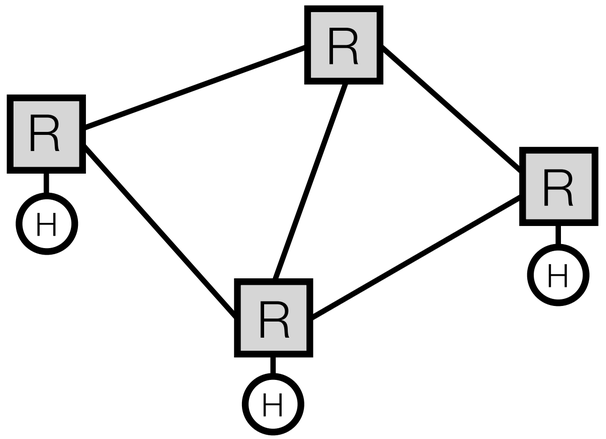
Lecture 8

Networking Fundamentals

September 25, 2023

Recall…

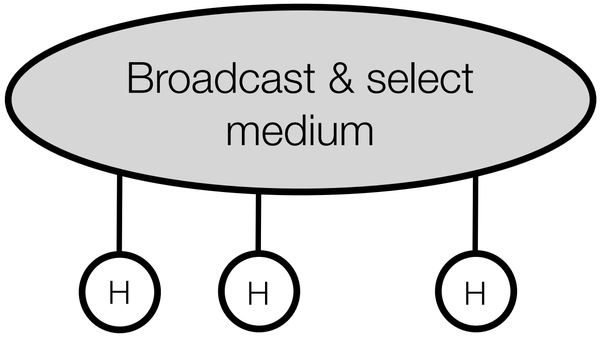
- Routed networks



- topology driven by geography
- long distances (high latency)
- need for scalability
- location-related addresses
- routing

➡ **Network Layer (L3)**

- Broadcast & select



- everyone connected to everyone
- short distances (low latency)
- lesser need for scalability
- arbitrary addresses
- address discovery

➡ **Link Layer (L2)**

Routing Alternative: Bridging

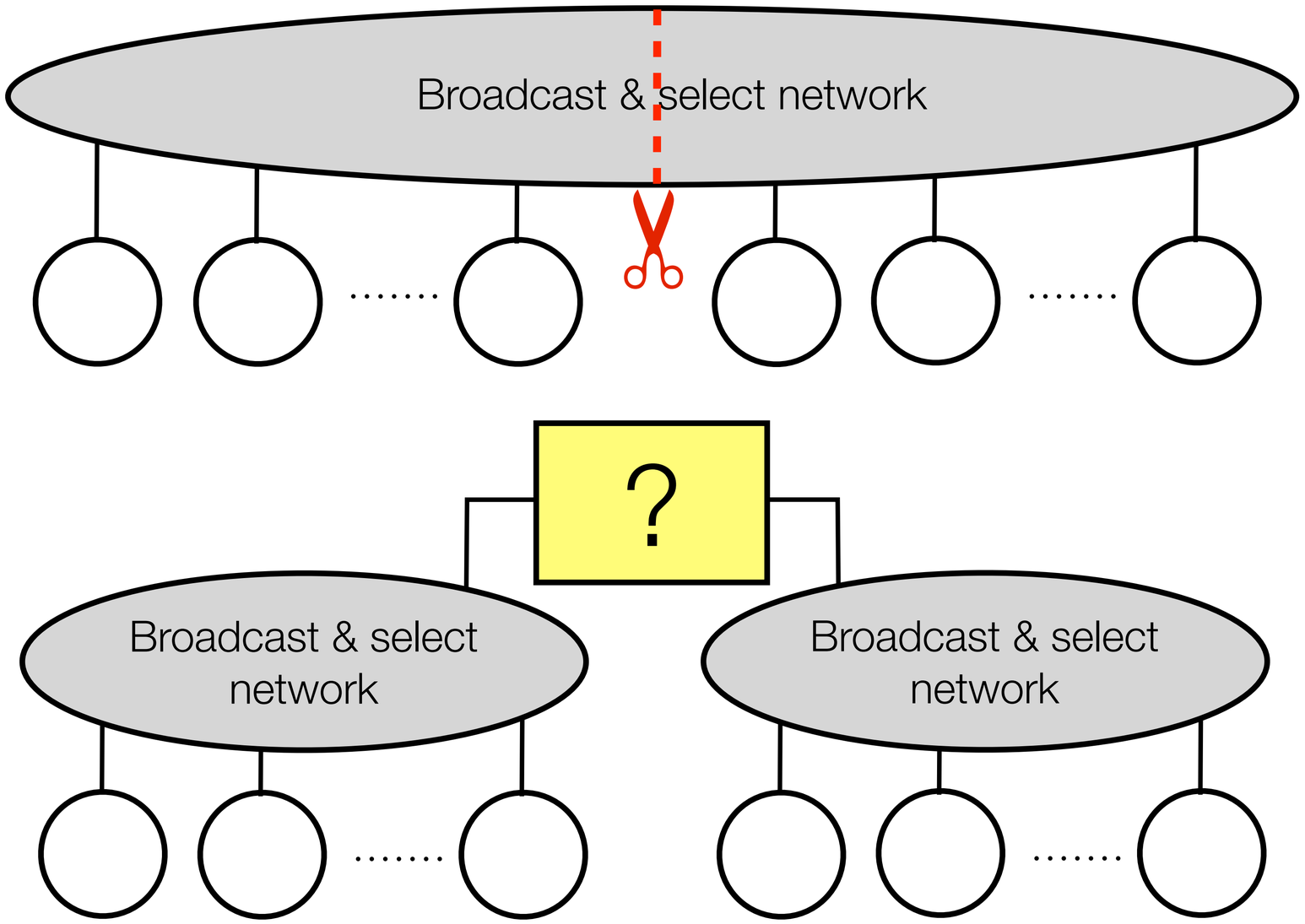
- Motivation
  - L2 networks do not scale due to the broadcast nature of the underlying medium
  - Routers are expensive and require configuration
- Approach - extend the reach of L2
- Solution - limit the scope of packet delivery (bridging)

Motivation (personal)

John Green Hall, the former home of the *Department of Mathematics and Computer Science*, University of Denver

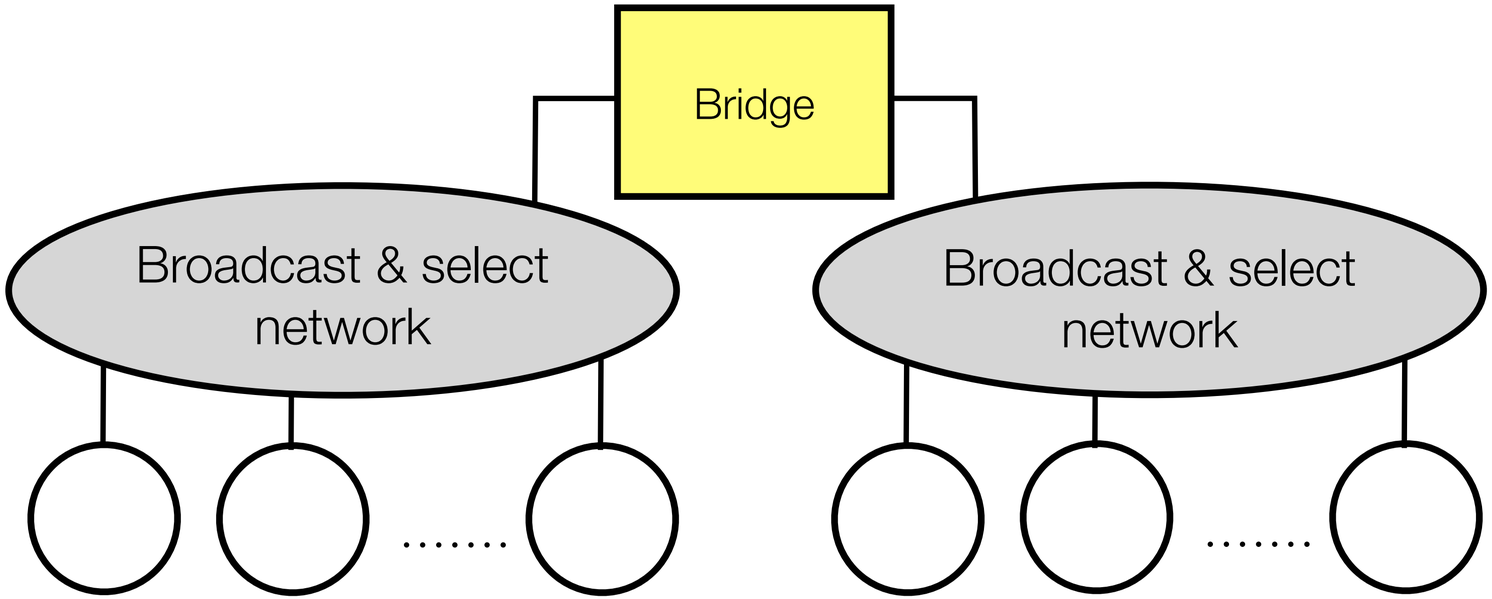
Image source: University of Denver

Historical Evolution



Link Layer Bridging

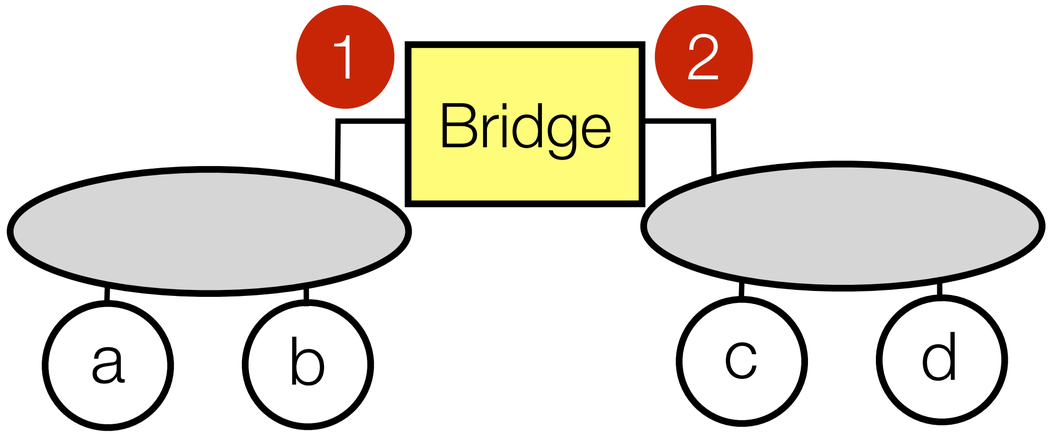
- Bridge “opens” for non-local traffic and broadcasts
- Bridge learns node locations from passing traffic and stores them in its Forwarding Database (FDB) (a.k.a. bridge, bridging, or switching table)



Transparent Bridging

- Initially, the bridging table (FDB) is empty
- Broadcast traffic is let to pass, source address recorded in the FDB
- Traffic to an unknown destination is let to pass through the bridge, source address address is recorded in the FDB
- Non-local traffic (to a known destination that is associated with different interface, e.g., *a* to *d*) is let to pass, “local” traffic (e.g., *a* to *b*) is blocked

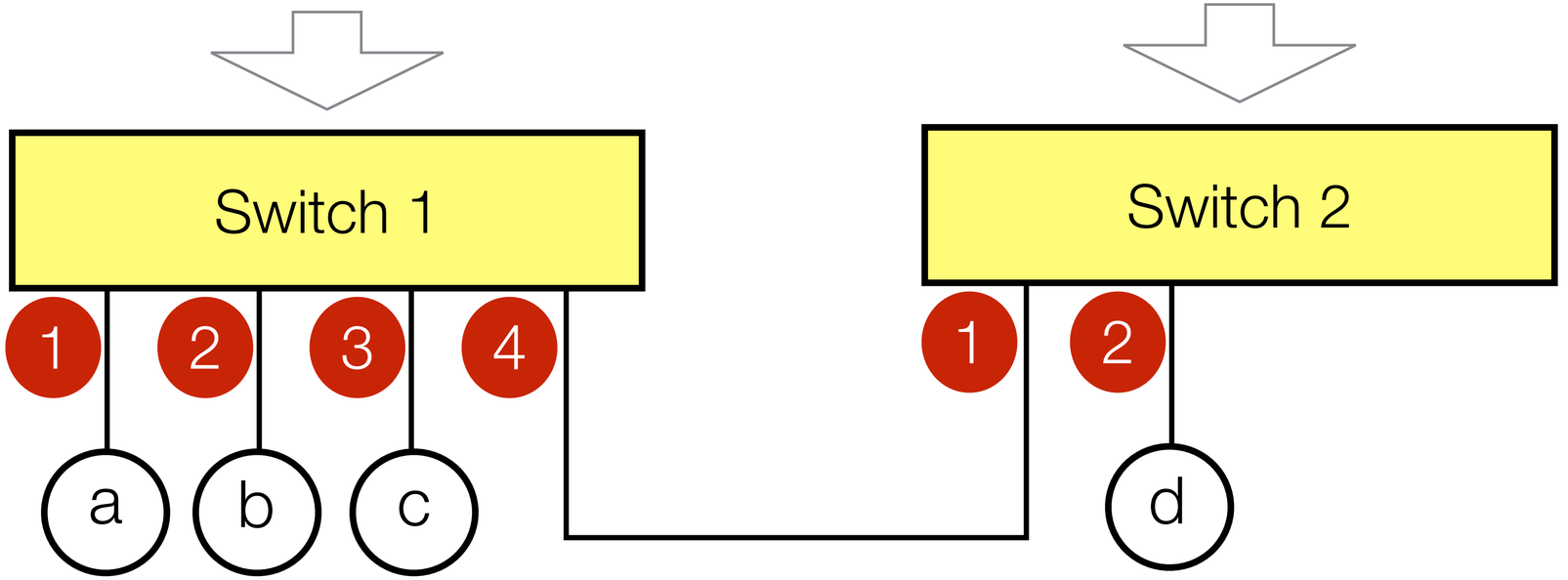
MAC	Interface
a	1
b	1
c	2
d	2



L2 (Ethernet) Switching

MAC	Interface
a	1
b	2
c	3
d	4

MAC	Interface
a	1
b	1
c	1
d	2



Unicast packet from a to d

MAC	Interface
a	1
b	2
c	3
d	4

MAC	Interface
a	1
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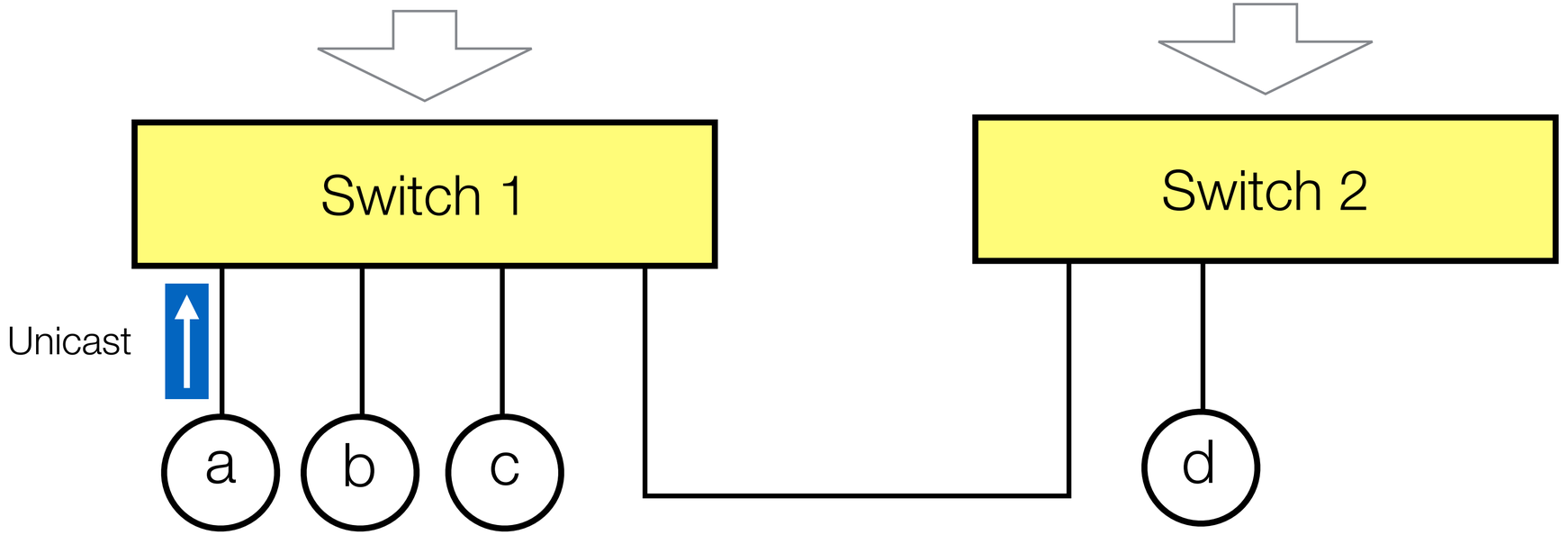
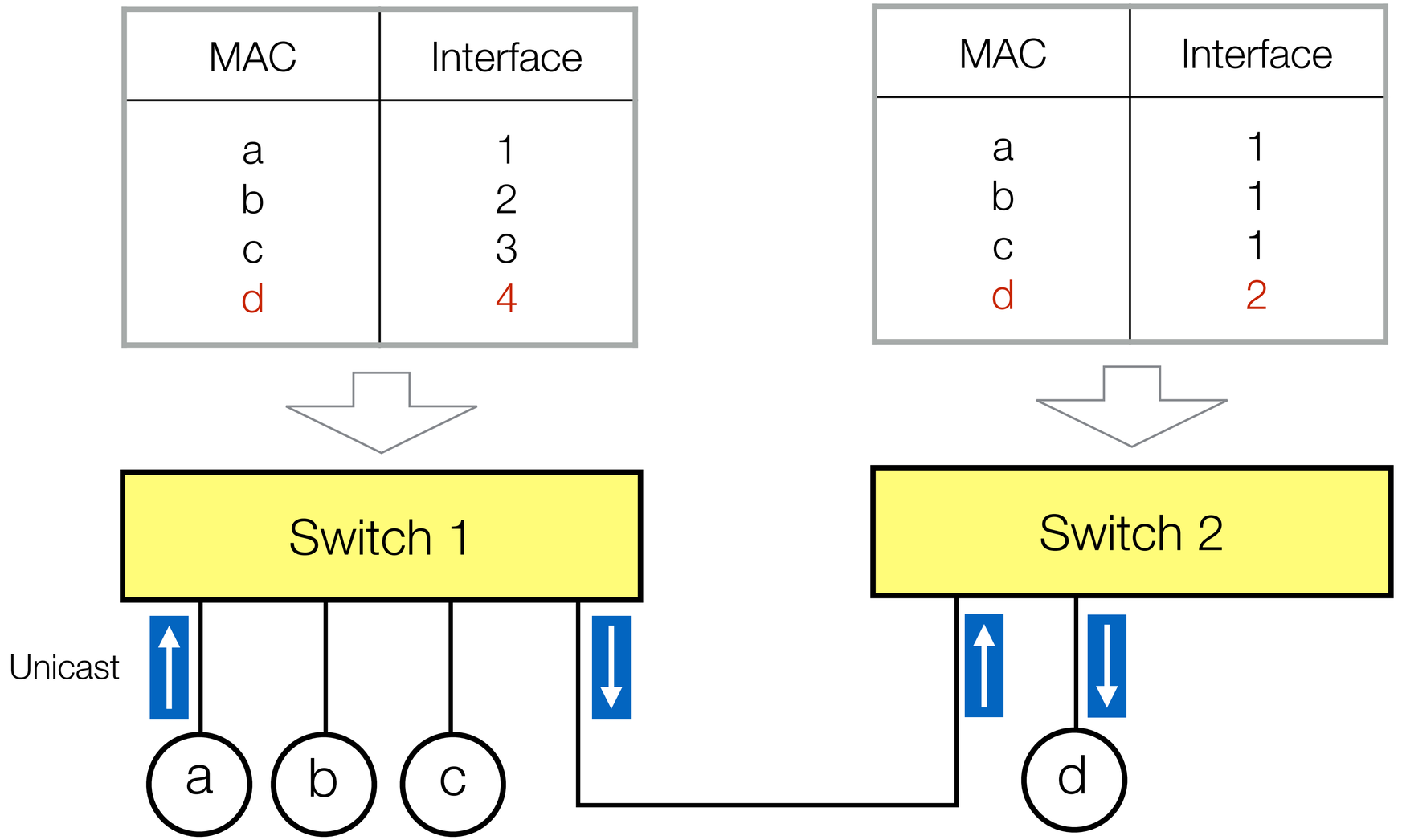
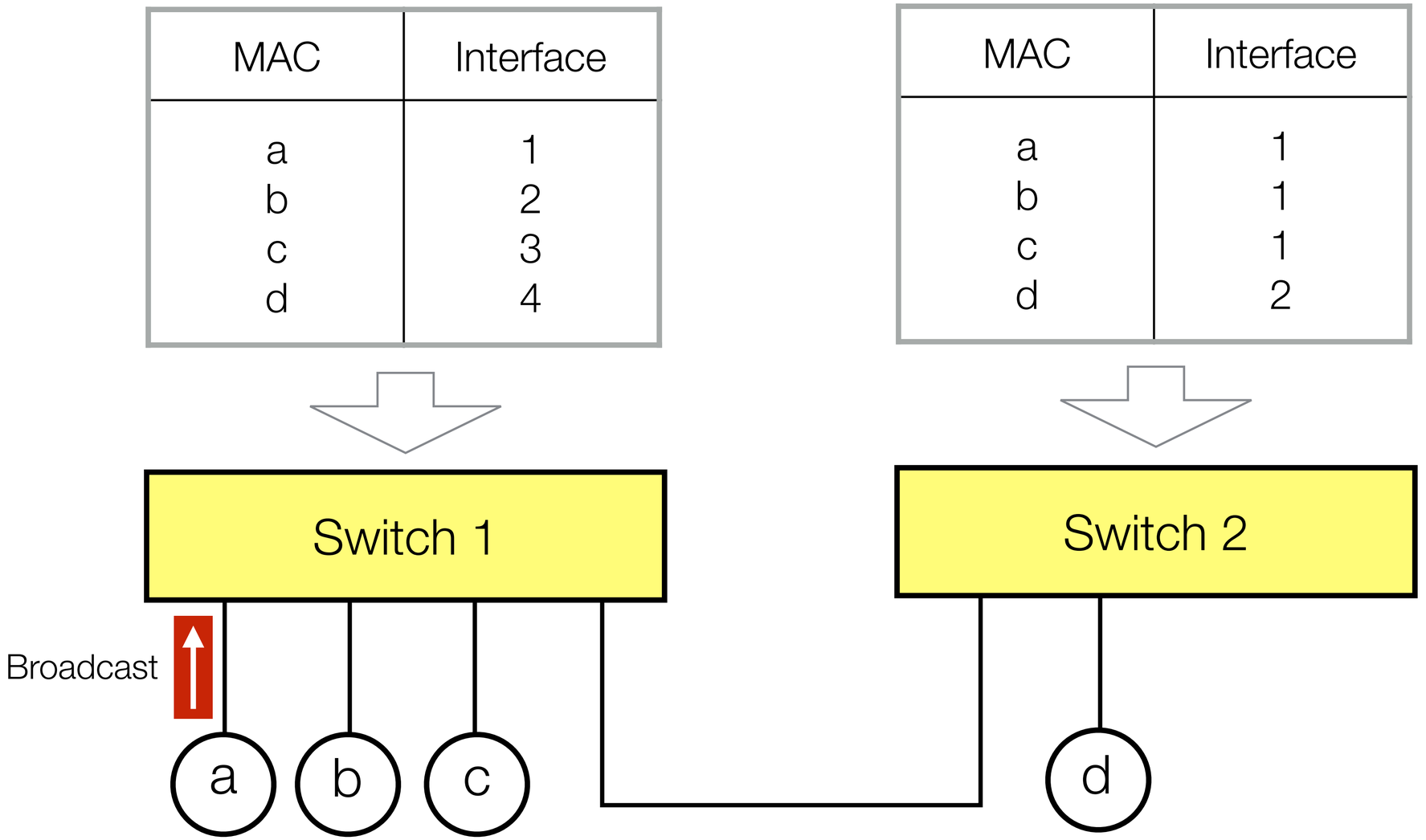


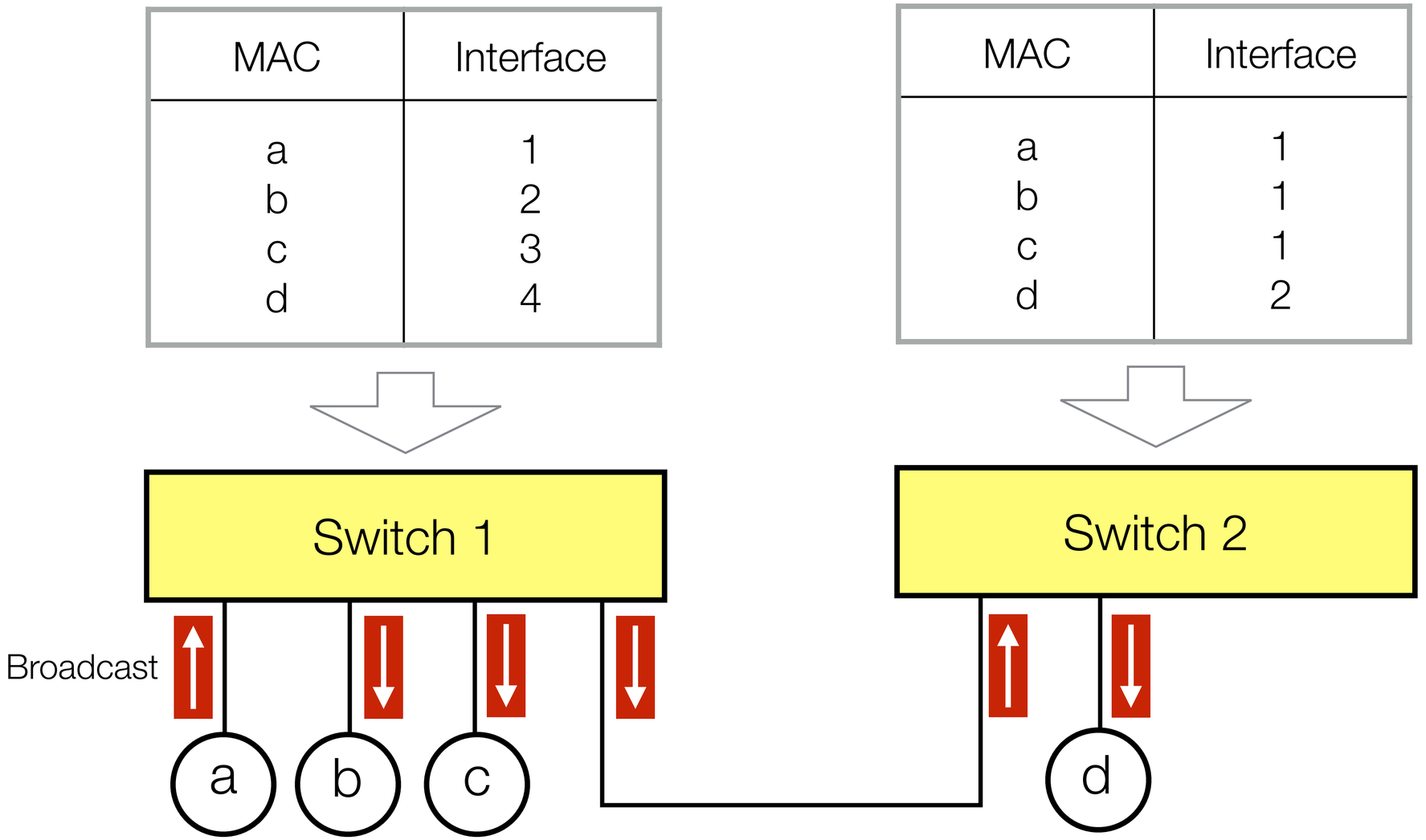
Unicast packet from a to d



Broadcast packet



Broadcast packet



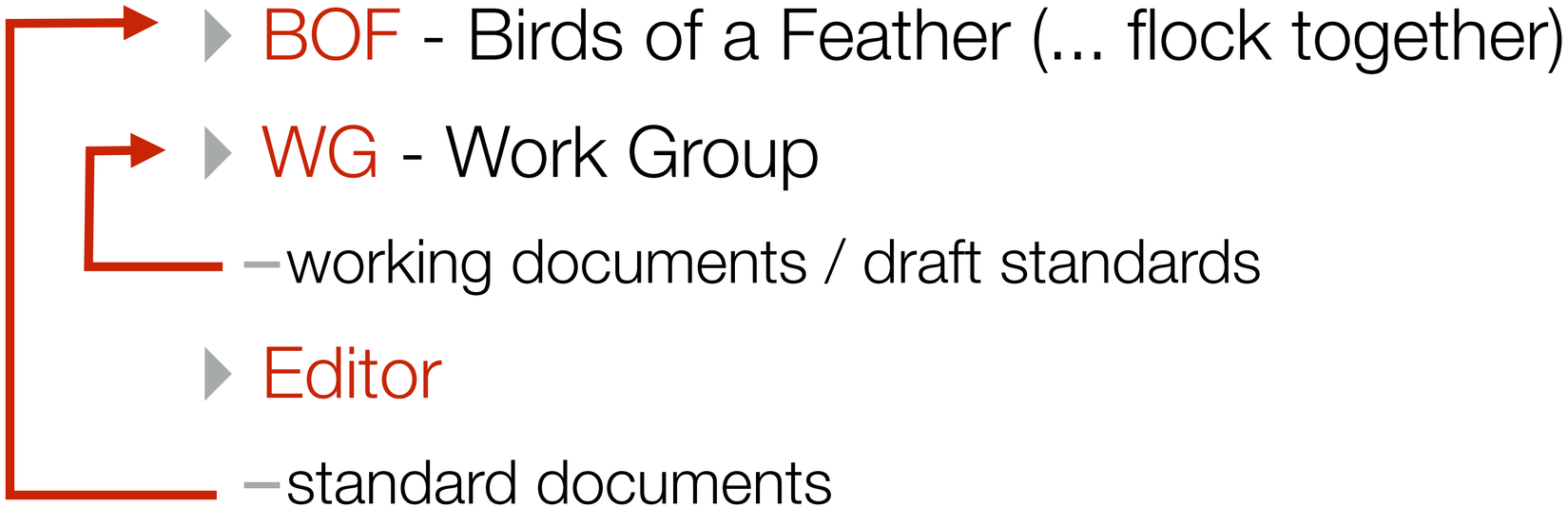
Standardization

- ISO - International Organization for Standardization
- ITU-T - International Telecommunication Union - Telecommunication Sector
- IEEE - Institute of Electrical and Electronic Engineers
- IETF - Internet Engineering Task Force
- *x* Forum / *x* Alliance / *x* Group

Standardization

- IEEE - Institute of Electrical and Electronic Engineers
  - 802.3an: 10GBASE-T 10 Gbit/s (1,250 MB/s) Ethernet over unshielded twisted pair (UTP)
  - 802.11ad: (in works) gigabit “WiFi” in 60 GHz band
- IETF - Internet Engineering Task Force
  - RFC791: Internet Protocol - DARPA Internet Program Protocol Specification (1981)

Standardization Process



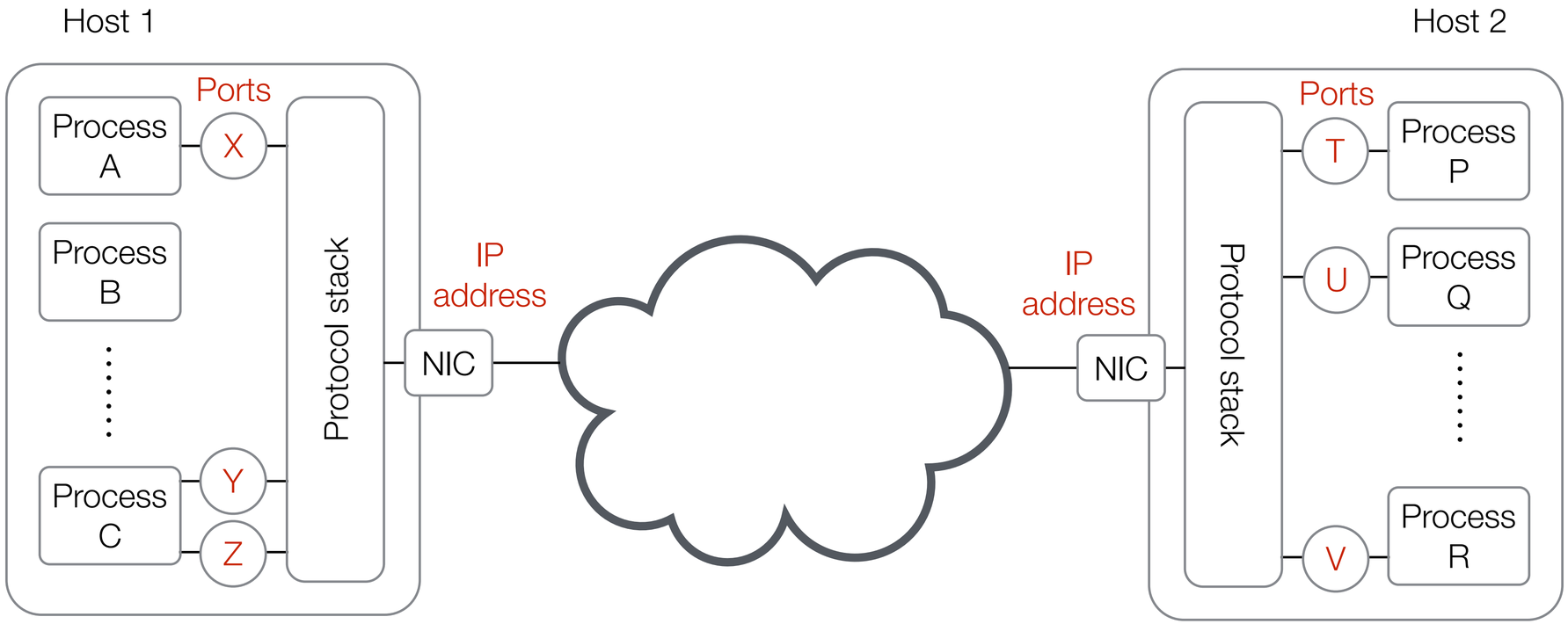
Application Layer

Application Layer

- Assumptions:
  - each host (each network interface, actually) has a globally unique id (IP address)
  - each communication endpoint of an application has an id that is unique within the host (port number)
  - underlying network provides reliable connection-oriented or unreliable connection-less service (TCP or UDP)

- For a particular transport protocol, each “communication” is uniquely identified by a quadruple: *src/dst IP addresses* & *src/dst port numbers*

Client and Server

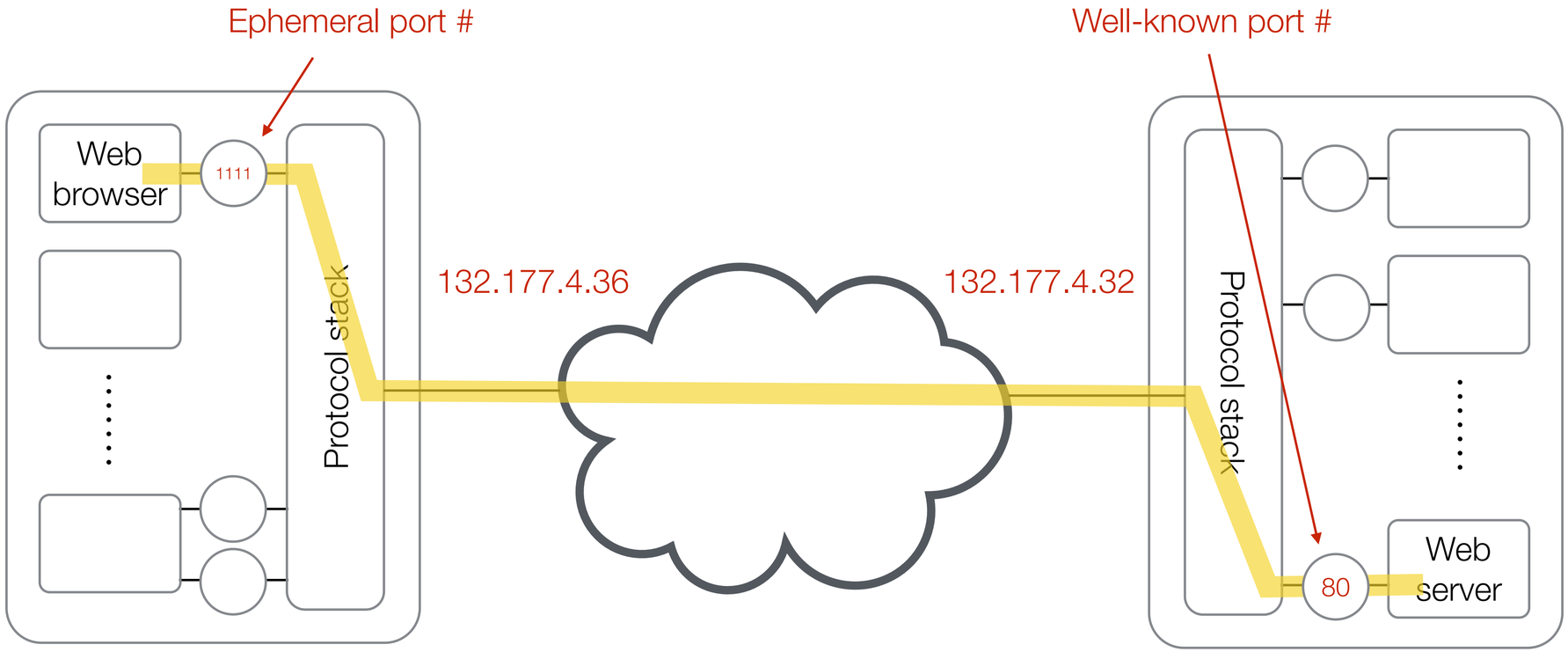


NIC - Network Interface Card

Client and Server

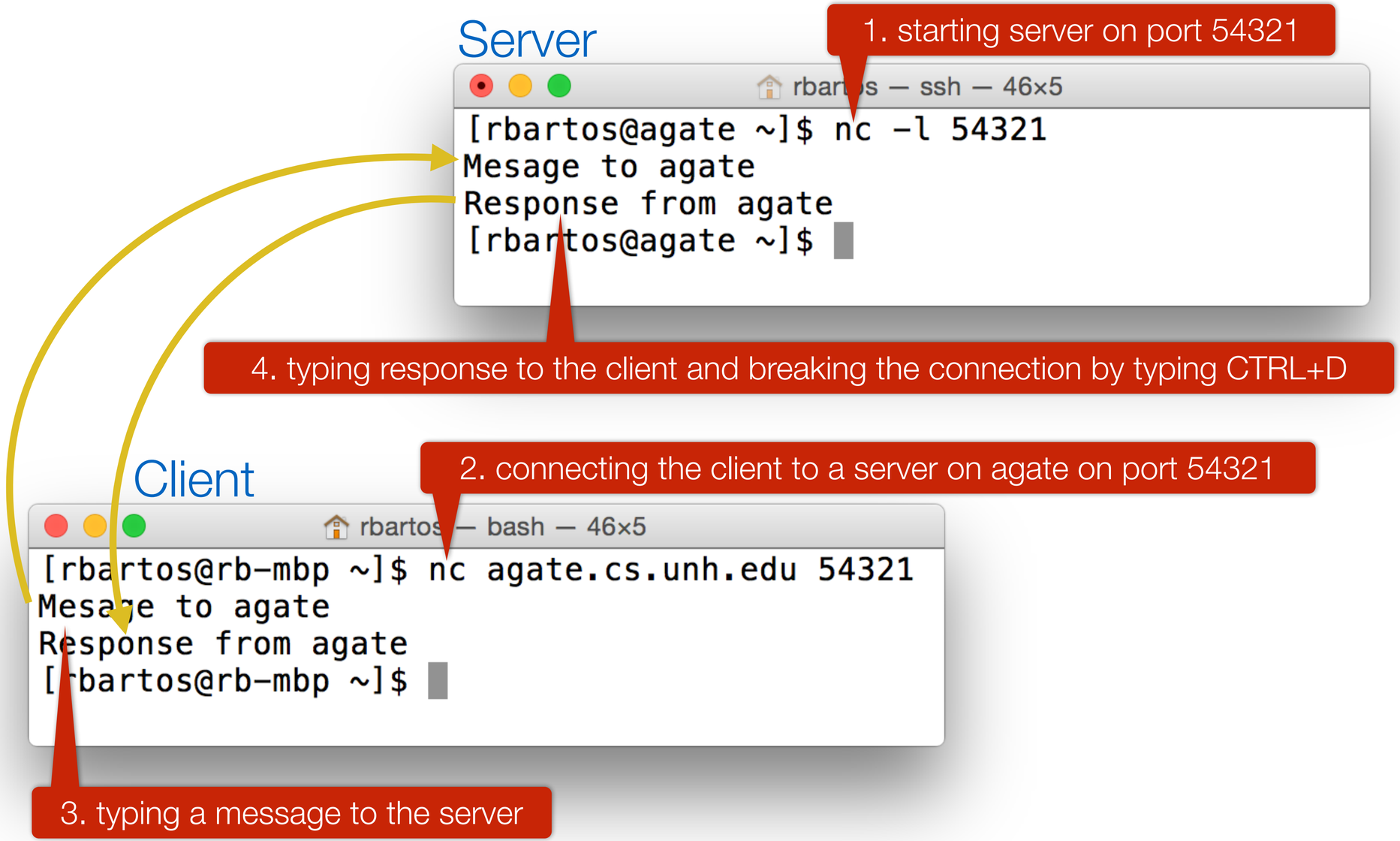
- Client (caller)
  - actively opens connection to a server
  - must know server's IP address and port #
  - typically uses *ephemeral* source (local) port number
- Server (callee)
  - connects to a local port (typically a well-known one)
  - waits for clients to connect
  - may handle multiple simultaneous client connections

Client and Server

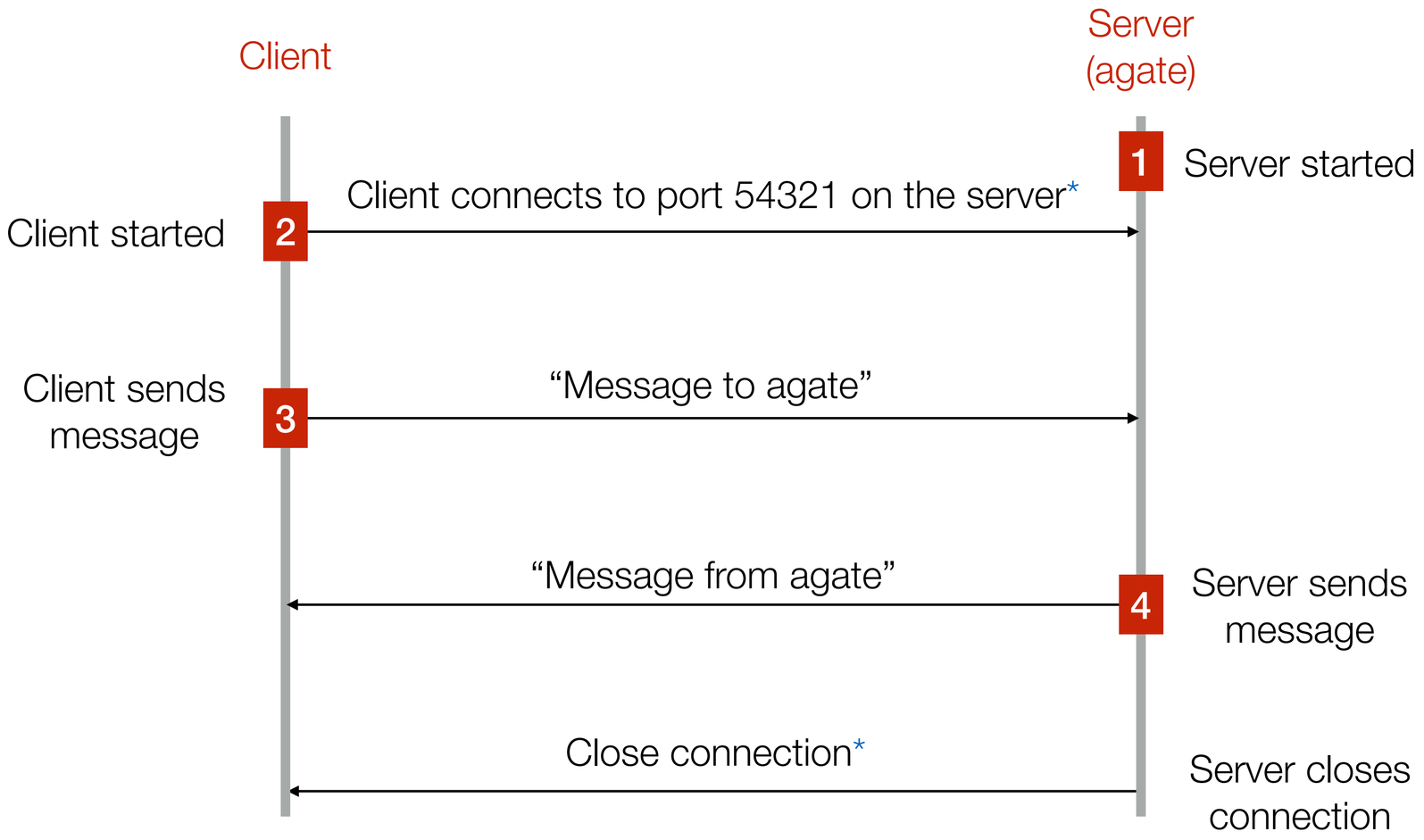


A process (web browser) connected to ephemeral port 1111 on a host with IP address 132.177.4.36 opens connection to a process that listens on well-known port 80 (web server) on a host with IP address 132.177.4.32

Command Line Utility: nc



Sequence Diagram



(*) this is a more complex interaction than show here

Socket API

- Berkeley socket API (4.2 BSD Unix, 1983)
- POSIX socket API (reentrant)
- Designed to support any protocol - not just TCP/UDP/IP
- Defined in C, but adopted by essentially all programming languages