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Computer Networks

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Class 6: Link Layer (Continued)

[K] Chapter 6

[T] Chapters 3 and 4

Roadmap

- Introduction
- Error Control
- Medium Access Control (MAC)
  - Introduction
  - Channel Partitioning Protocols
    - TDMA, FDMA, CDMA
  - “Taking Turns” Protocols
    - Polling, Token Passing
  - Random Access Protocols
    - ALOHA, Slotted ALOHA
    - **CSMA, CSMA/CD**
- LANs

Class 5

Today

MAC – Summary

- Channel Partitioning:
  - Time Division Multiple Access (TDMA), FDMA, etc.
- Taking Turns:
  - Polling from central site and token passing
  - Application examples: Bluetooth, token ring
- Random Access:
  - ALOHA, Slotted ALOHA
  - Carrier Sensing: easy in some technologies (wire), hard in others (wireless)
    - CSMA/CD used in Ethernet
    - CSMA/CA used in 802.11

MAC – Random Access Protocols: Carrier Sense Multiple Access (CSMA)

simple CSMA: listen before transmit:

- if channel sensed idle: transmit entire frame
- if channel sensed busy: defer transmission

- human analogy: don't interrupt others!

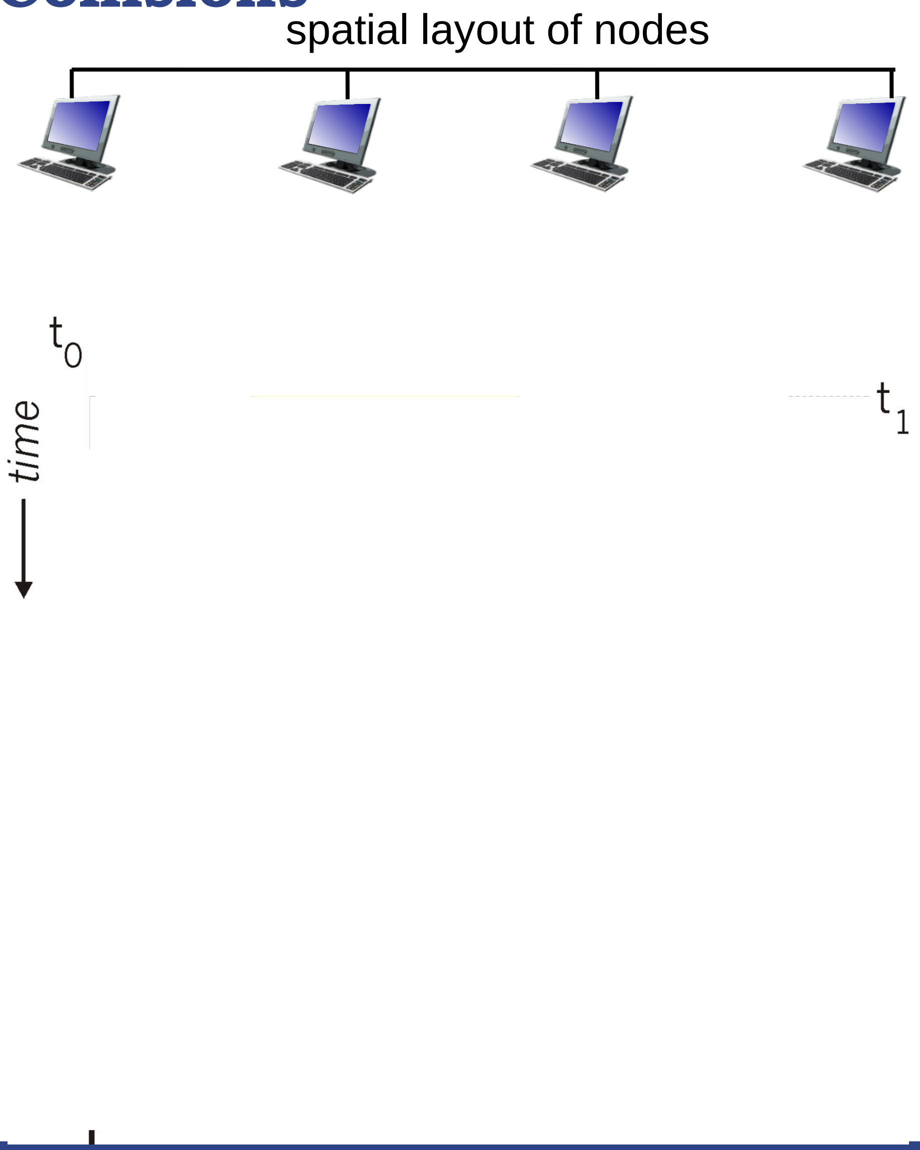
CSMA/CD: CSMA with *collision detection*

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage
- collision detection easy in wired, difficult with wireless

- human analogy: the polite conversationalist

MAC – Random Access Protocols: CSMA Collisions

- collisions *can* still occur with carrier sensing:
  - propagation delay means two nodes may not hear each other's just-started transmission
- collision: entire packet transmission time wasted
  - distance & propagation delay play role in determining collision probability



MAC – Random Access Protocols: CSMA/CD Algorithm

1. NIC receives datagram from network layer, creates frame
2. If NIC senses channel:
   if idle: start frame transmission.
   if busy: wait until channel idle, then transmit
3. If NIC transmits entire frame without collision, NIC is done with frame !
4. If NIC detects another transmission while sending: abort, send jam signal
5. After aborting, NIC enters *binary (exponential) backoff:*
   - after *m*th collision, NIC chooses *K* at random from $\{0,1,2, \ldots, 2^m-1\}$. NIC waits $K \cdot$ “512 bit times”, returns to Step 2
   - more collisions: longer backoff interval

MAC – Random Access Protocols: CSMA/CD Efficiency

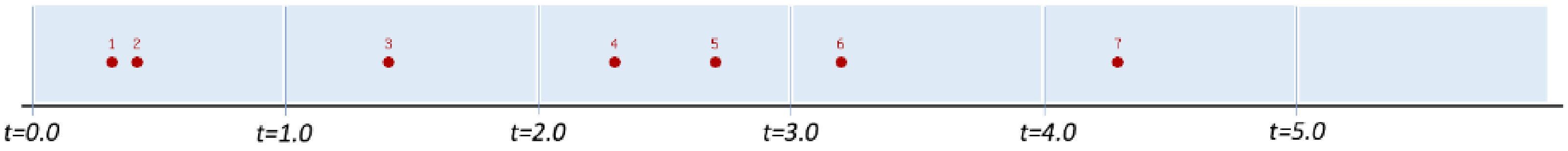
- t_{prop} = max propagation delay between 2 nodes in LAN
- t_{trans} = time to transmit max-size frame

$$efficiency = \frac{1}{1 + 5t_{prop}/t_{trans}}$$

- efficiency goes to 1
  - as t_{prop} goes to 0
  - as t_{trans} goes to infinity
- better performance than ALOHA: and simple, cheap, decentralized!

MAC – Random Access Protocols: CSMA Collision Exercise

Consider the figure below, which shows the arrival of 7 messages for transmission at different multiple access wireless nodes at times t = <0.3, 0.4, 1.4, 2.3, 2.7, 3.2, 4.3> and each transmission requires exactly one time unit.



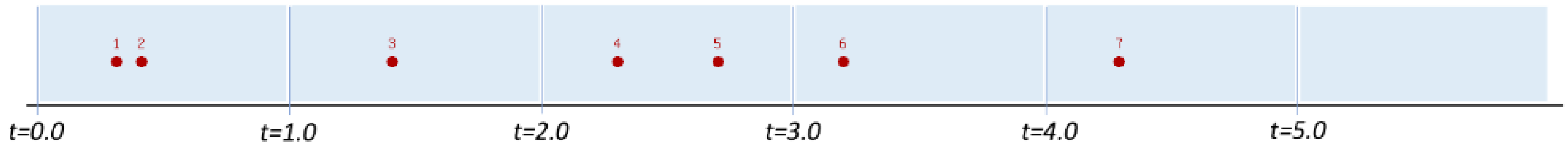
Suppose all nodes are implementing Carrier Sense Multiple Access (CSMA), but without collision detection. Suppose that the time from when a message transmission begins until it is beginning to be received at other nodes is 0.4 time units. (Thus if a node begins transmitting a message at t=2.0 and transmits that message until t=3.0, then any node performing carrier sensing in the interval [2.4, 3.4] will sense the channel busy.)

Q1: Which messages are transmitted?

Q2: Which messages are successfully transmitted?

MAC – Random Access Protocols: CSMA/CD Collision Exercise

Consider the figure below, which shows the arrival of 7 messages for transmission at different multiple access wireless nodes at times t = <0.3, 0.4, 1.4, 2.3, 2.7, 3.2, 4.3> and each transmission requires exactly one time unit.



Suppose all nodes are implementing CSMA/CD. Suppose that the time from when a message transmission begins until it is beginning to be received at other nodes is 0.4 time units. (Thus if a node begins transmitting a message at t=2.0 and transmits that message until t=3.0, then any node performing carrier sensing in the interval [2.4, 3.4] will sense the channel busy.)

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Roadmap

- Introduction
- Error Control
- Medium Access Control (MAC)
- **LANs**
  - **Addressing, ARP**
  - **Ethernet**
  - **Switches**
  - **VLANs**

MAC addresses

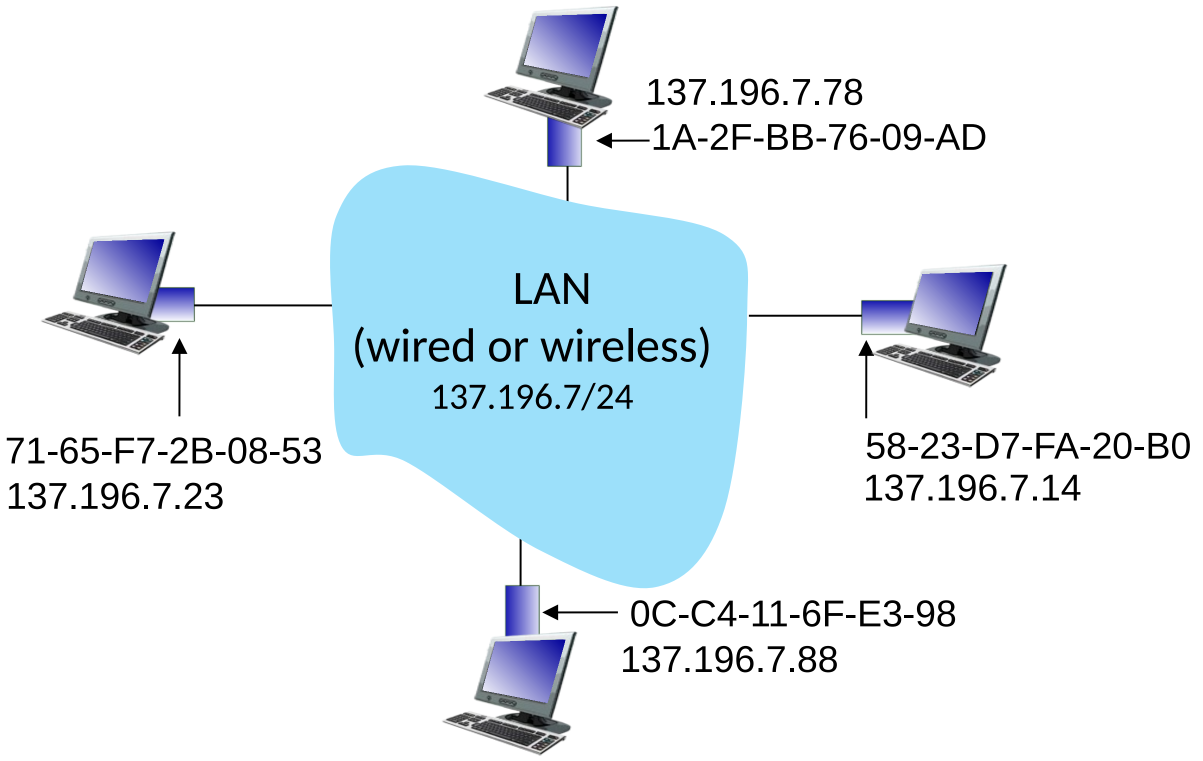
- 32-bit IP address:
  - *network-layer* address for interface
  - used for layer 3 (network layer) forwarding
  - e.g.: 128.119.40.136
- MAC (or LAN or physical or Ethernet) address:
  - function: used "locally" to get frame from one interface to another physically-connected interface (same subnet, in IP-addressing sense)
  - 48-bit MAC address (for most LANs) burned in NIC ROM, also sometimes software settable
  - e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each "numeral" represents 4 bits)

MAC addresses

each interface on LAN

- has unique 48-bit MAC address
- has a locally unique 32-bit IP address (as we will see)

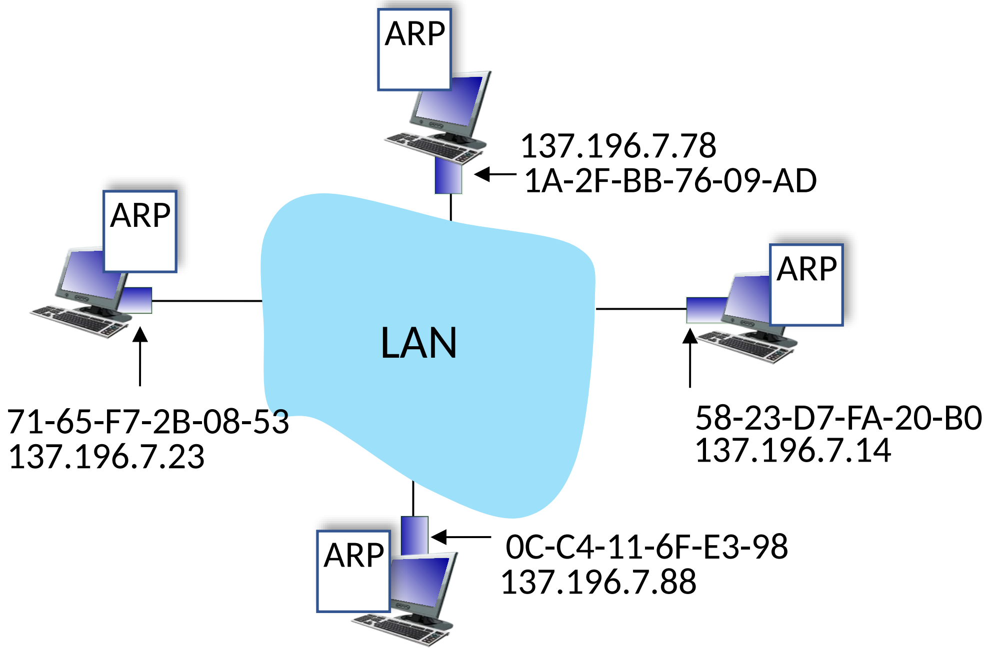


MAC addresses

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- analogy:
  - MAC address: like Social Security Number
  - IP address: like postal address
- MAC flat address: portability
  - can move interface from one LAN to another
  - recall IP address *not* portable: depends on IP subnet to which node is attached

ARP: address resolution protocol

Question: how to determine interface's MAC address, knowing its IP address?



ARP table: each IP node (host, router) on LAN has table

- IP/MAC address mappings for some LAN nodes:

  < IP address; MAC address; TTL>

- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP protocol in action

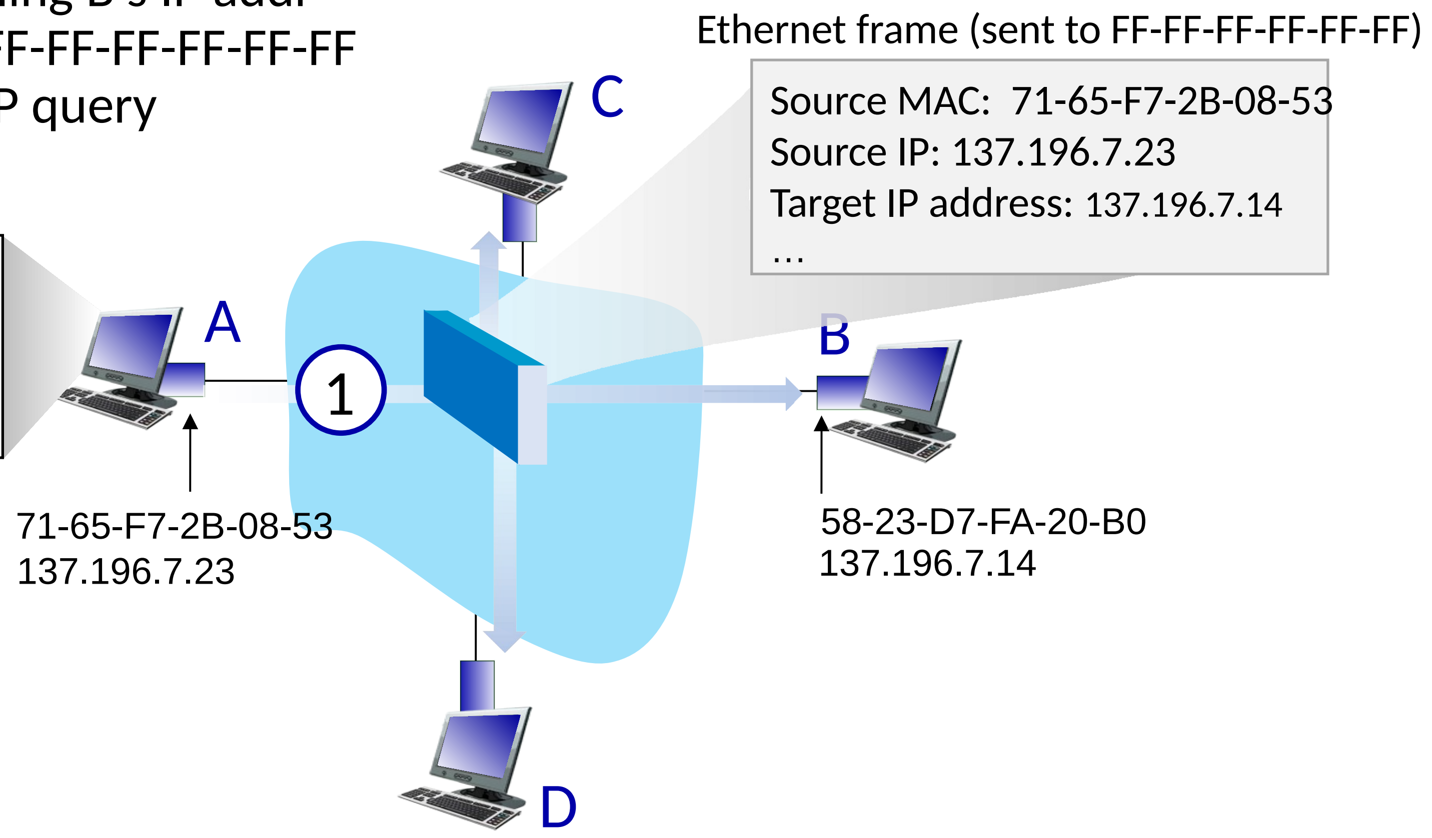
example: A wants to send datagram to B

- B's MAC address not in A's ARP table, so A uses ARP to find B's MAC address

1 A broadcasts ARP query, containing B's IP addr
- destination MAC address = FF-FF-FF-FF-FF-FF
- all nodes on LAN receive ARP query

ARP table in A

IP addr	MAC addr	TTL



ARP protocol in action

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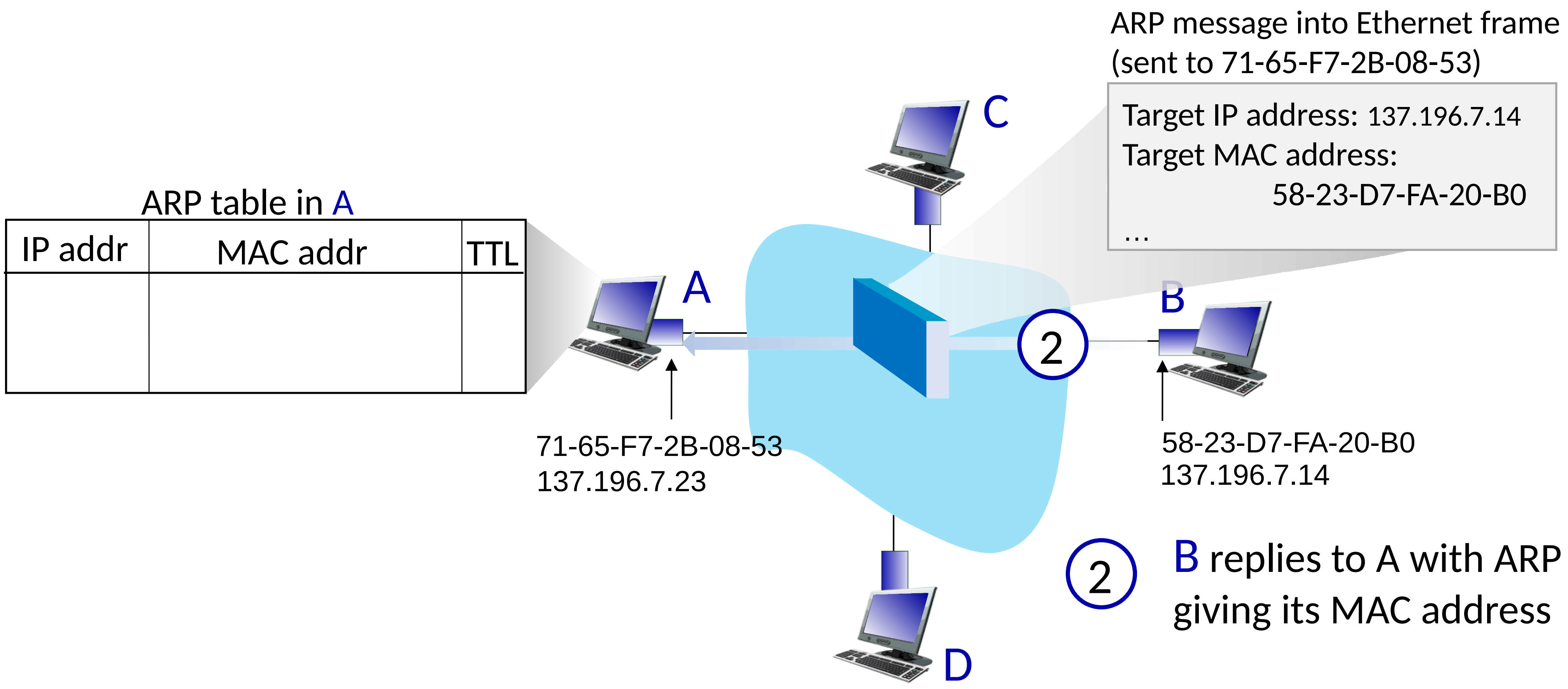


2 B replies to A with ARP response, giving its MAC address

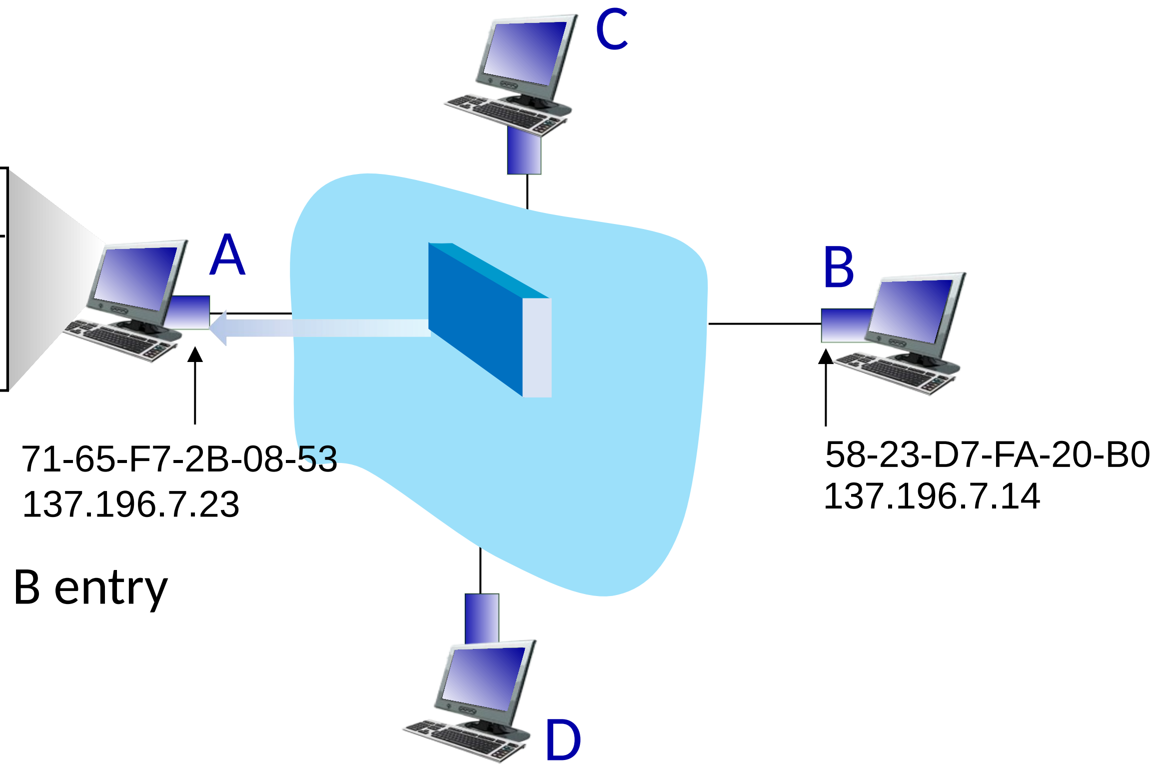
ARP protocol in action

example: A wants to send datagram to B

- B's MAC address not in A's ARP table, so A uses ARP to find B's MAC address

ARP table in A

IP addr	MAC addr	TTL
137.196.7.14	58-23-D7-FA-20-B0	500



3 A receives B's reply, adds B entry into its local ARP table

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