Internet Protocols EBU5403
Live Lecture D1/D2

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	Part 1	Part 2	Part 3	Part 4
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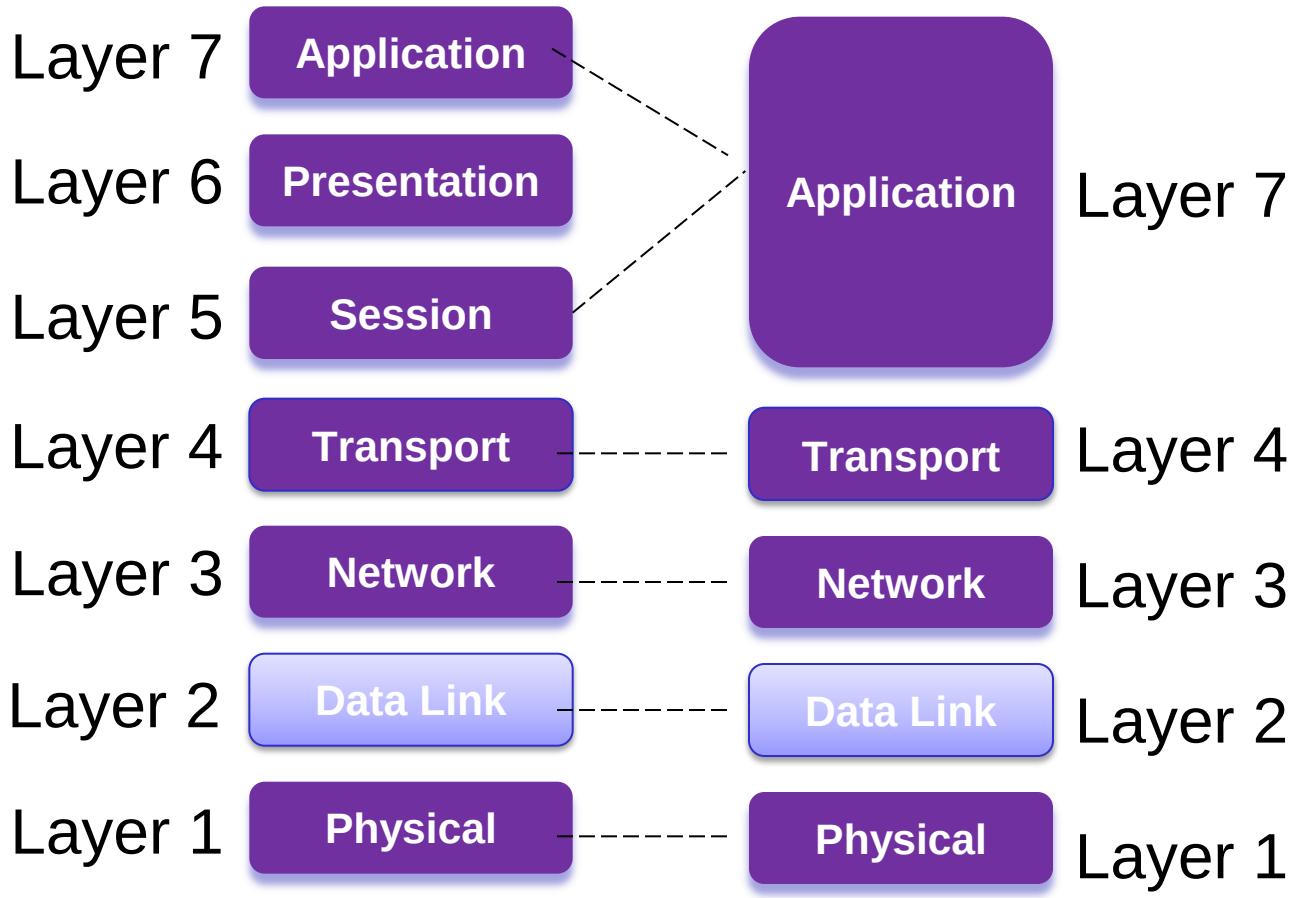
Telecoms 2	Michael Chai			

Structure of course

- Part A
  - Introduction to IP Networks
  - The Transport layer (part I)
- Part B
  - The Transport layer (part II)
  - The Network layer (part I)
  - Class test
- Part C
  - The Network layer (part II)
  - The Data link layer (part I)
  - Router lab tutorial (assessed lab work after this week)
- Part D
  - The Data link layer (part II)
  - Network management and security
  - Class test

Data Link Layer



Reminder of lecture contents

- Lecture D1
  - Slotted ALHOA
  - Pure ALOHA
  - CSMA
  - CSMA/CD
  - CSMA/CA
- Lecture D2
  - MAC address
  - ARP
  - *Switches*

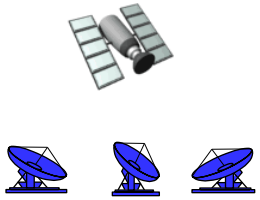
Multiple access links, protocols

two types of "links":

- point-to-point (connect two computers only)
- *broadcast (shared wire or medium)*
  - old-fashioned Ethernet
  - upstream HFC (hybrid fibre coaxial)
  - 802.11 wireless LAN
- Problems: "collision" – 2 or more transmissions at once
- Solution: Multiple access protocol – "share" medium

shared wire (e.g., cabled Ethernet)

shared RF (radio frequency) (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a cocktail party (shared air, acoustic)

Multiple access links, protocols

- Question: What are the three types of multiple access mechanism?

Multiple access links, protocols

- **Question:** What are the three types of multiple access mechanism?
- **Answer:**

  1) Channel partitioning such as TDMA, FDMA;
  2) Random access
  3) Take turns

Random access protocols

- **Question:** What are the examples of random access protocols?

Random access protocols

- **Question:** What are the examples of random access protocols?
- **Answer:**

  1) slotted ALOHA

  2) Pure ALOHA

  3) CSMA, CSMA/CD, CSMA/CA

Slotted ALOHA

assumptions:

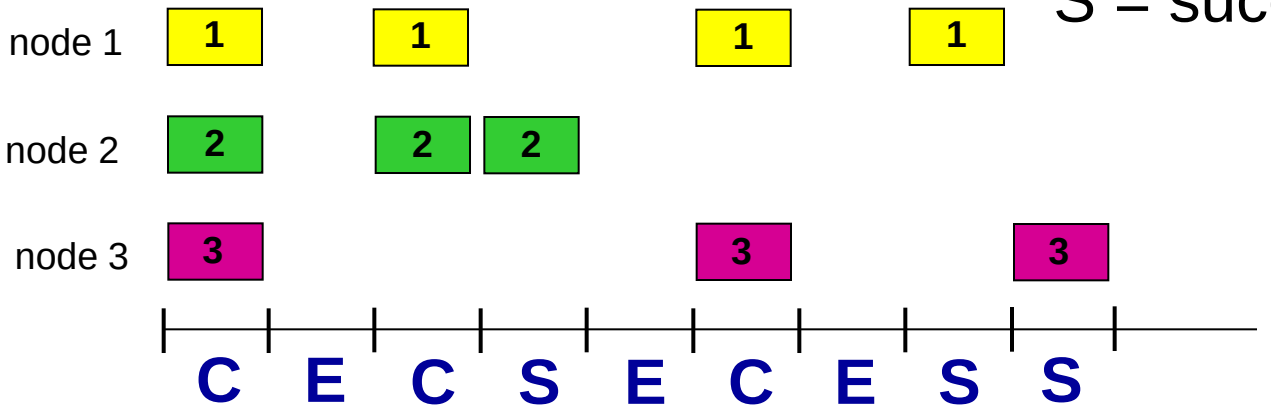
- all frames have the same size
- time divided into equal size slots (time to transmit 1 frame)
- nodes start to transmit only slot beginning
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

operation:

- when node obtains fresh frame, transmits in next slot
  - *if no collision:* node can send new frame in next slot
  - *if collision:* node retransmits frame in each subsequent slot with prob. p until success

Slotted ALOHA

C = collision
E = empty
S = successfully sent



Pros:

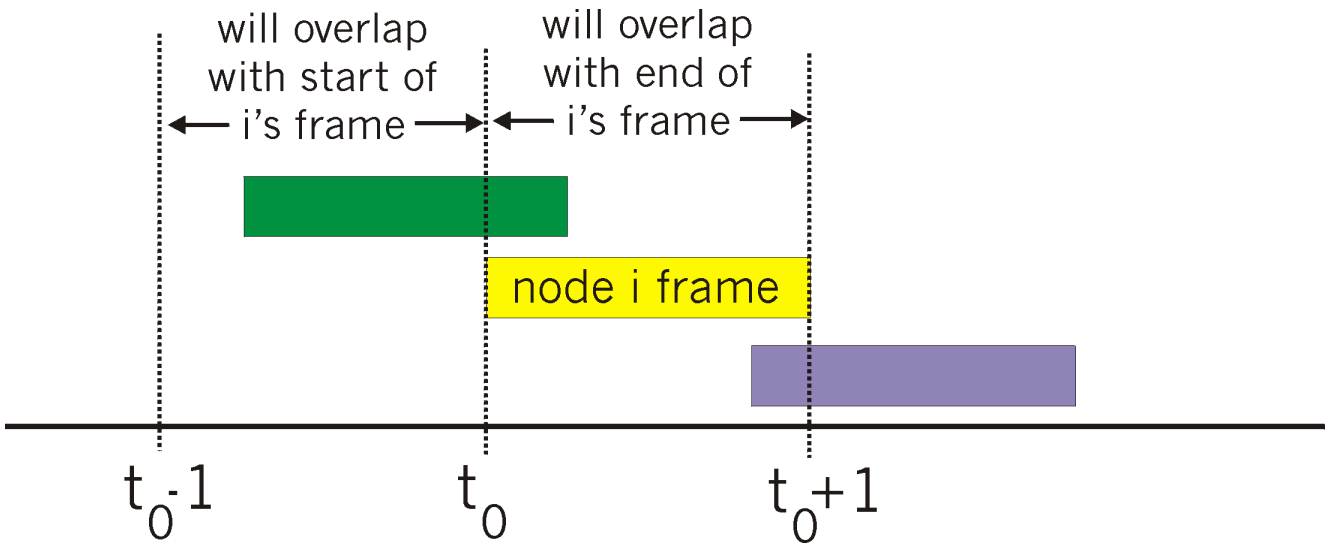
- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

Cons:

- collisions, wasting slots
- idle slots
- nodes should be able to detect collision in less than time to transmit packet
- clock synchronization

Pure (unslotted) ALOHA

- unslotted ALOHA: simpler, no synchronization
- when frame first arrives
  - transmit immediately
- collision probability increases:
  - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$
- Doesn't need unified clock but half as efficient as slotted.



Slotted ALOHA v.s. Pure ALOHA

- **Question:** What are differences between ALOHA and Pure ALOHA?

Slotted ALOHA v.s. Pure ALOHA

- **Question:** What are differences between slotted ALOHA and Pure ALOHA?
- **Answer:**

1) Different operation mechanisms:

For slotted ALOHA, when new frame arrives, it will transmit in the next time slot. For pure ALOHA, the new arrived frame will be transmitted immediately.

2) Different operation efficiency:

The efficiency of pure ALOHA is just half that of slotted ALOHA.

3) Different operation complexities:

Pure ALOHA is simple and no synchronization, while Slotted ALOHA needs synchronization.

CSMA

- Question: What is the full name of CSMA, and what is its operation mechanism?

CSMA

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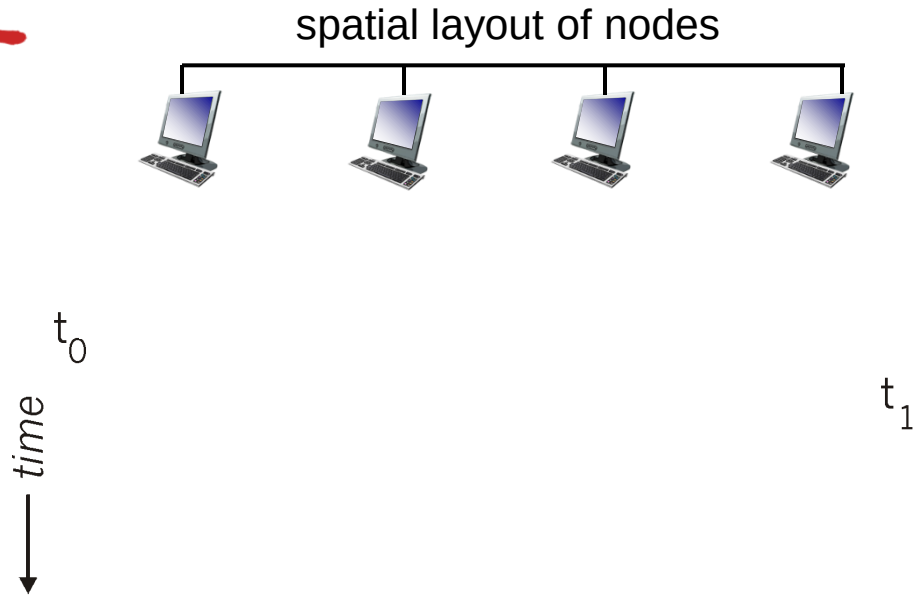
- **Answer:**

Full name of CSMA is carrier sense multiple access.

The operation mechanism of CSMA is listen before talk. If channel is sensed idle, it transmits entire frame, otherwise, defer transmission.

CSMA collisions

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



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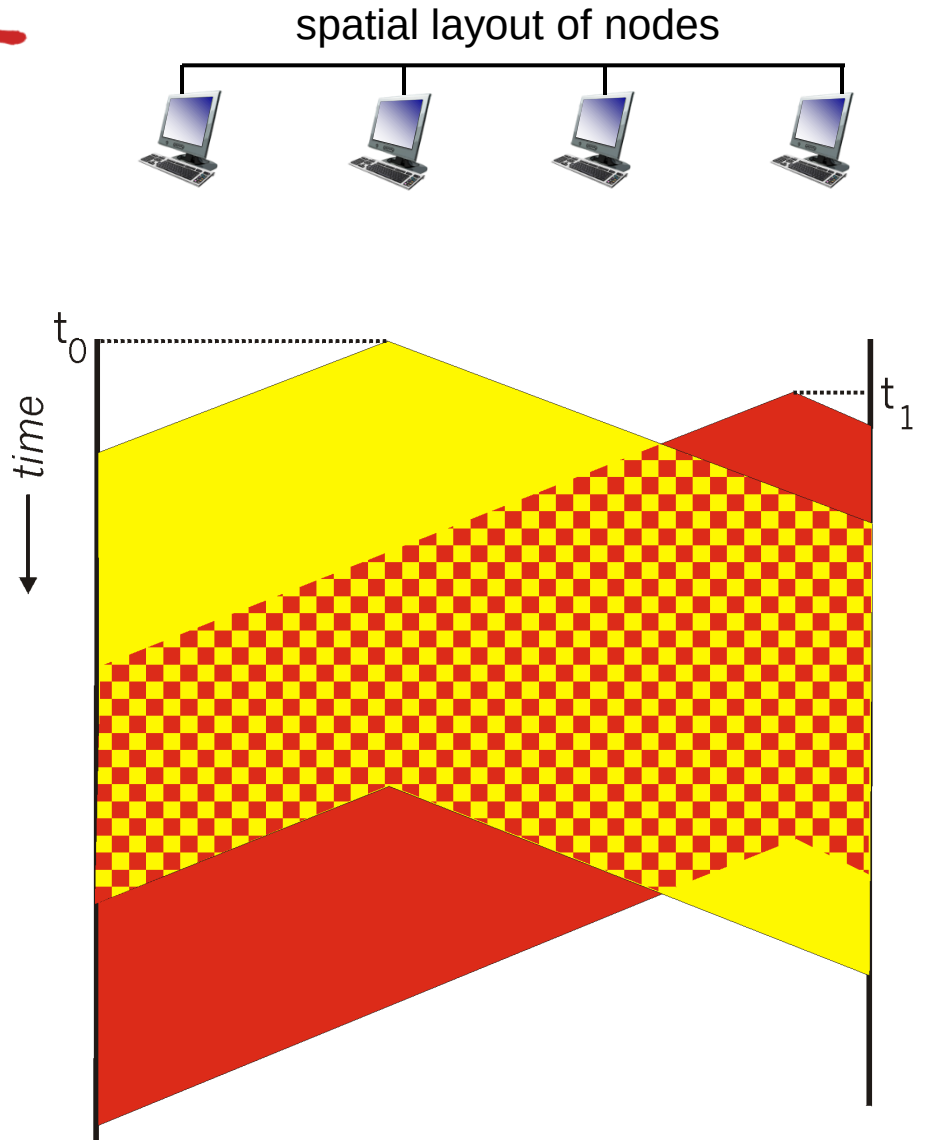


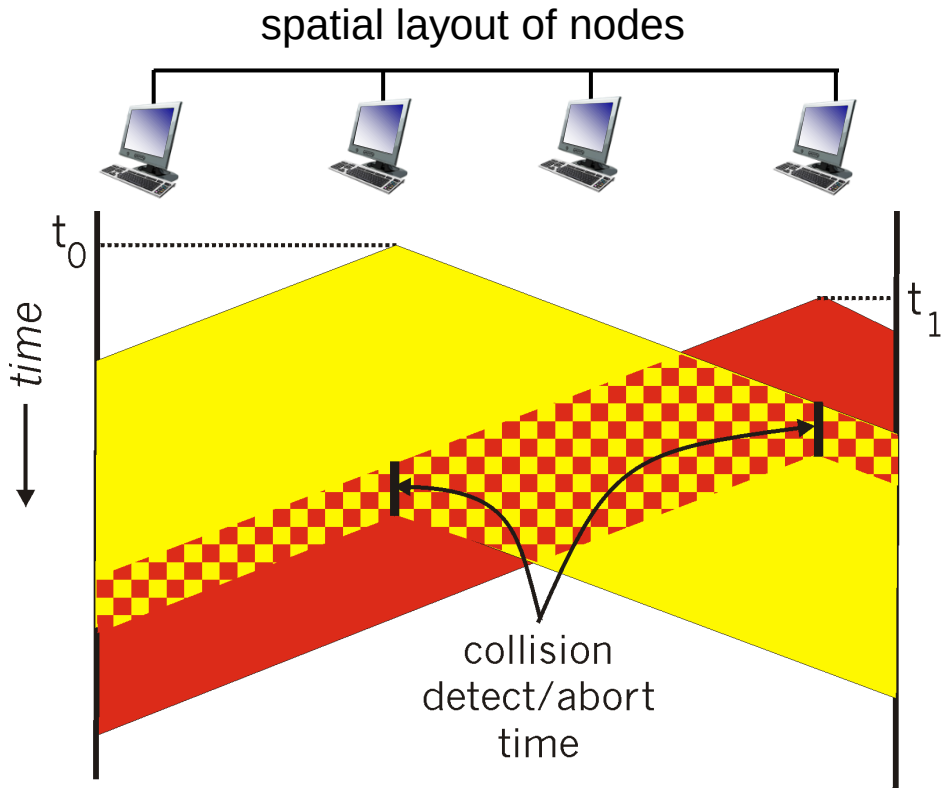
CSMA/CD (collision detection)

CSMA/CD: carrier sensing, deferral (backs off transmission) as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength

CSMA/CD (collision detection)



CSMA/CD

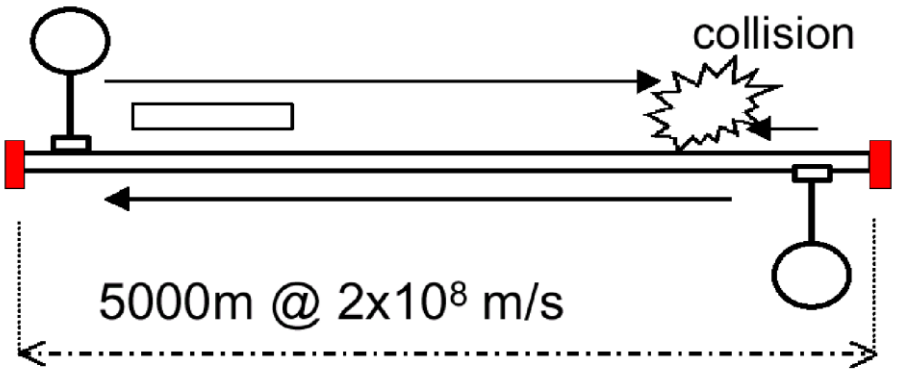
- **Question:** Why CSMA/CD requires a frame to have minimum size?

CSMA/CD

- **Question:** Why CSMA/CD requires a frame to have minimum size?
- **Answer:** If two frames are transmitted within certain time, collisions will occur. Both senders need to detect collision. The senders only detect collision during transmission. If transmission is too short, the senders cannot detect collision. If the transmission is long enough, the senders can detect collision.

CSMA/CD: Frame size

- Collision Detection
- Collision Window
  - Related to end-to-end propagation delay
- Minimum packet size must be greater than collision window
  - For 5000m (5km) bus @ 10 Mbits/sec,
  - RTT = 2x5000m/2x10^8 m/s = 0.00005s
    min frame size = 0.00005s x 10,000,000 bits/sec
    = (500 bits) ~64 octets



2x10^8 m/s = 2/3 speed of light = speed of signal in copper wire

CSMA/CD

- **Question:** Why the minimum packet should transmit at least twice the propagation delay between any two distant nodes?

CSMA/CD

- **Question:** Why the minimum packet should transmit at least twice the propagation delay between any two distant nodes?
- **Answer:** Consider two distant nodes A and B. The one way trip time is denoted as T. Assume A sends a frame at time T0. Node B just sends a frame just before A's frame arrives at node B. Then, we can approximately assume that node B sends its frame at time T0+T. After T0+T, node B can detect collision due to the frame from node A. Then, after one way trip time T, node B's frame arrives at node A, and node A can detect the collision due to the frame from node B at time T0+2T. From T0 to T0+2T, node A should keep transmitting since the node only detects the collision during transmitting.

CSMA/CD

- **Question:** Why CSMA/CD is not applicable in wireless communications?

CSMA/CD

- **Question:** Why CSMA/CD is not applicable in wireless communications?
- **Answer:**

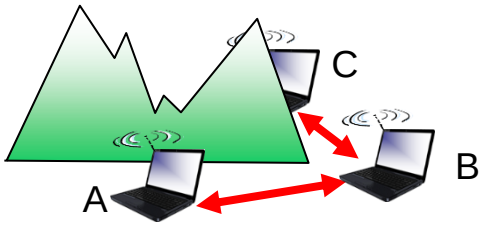
The received signal is too weak compared with its local signal power due to the severe path loss in wireless communications.

Hidden Problem in Wireless Communications

- **Question:** Please explain what is the hidden problem is wireless communications? What is main technique to deal with this issue?

Hidden Problem in Wireless Communications

- **Question:** Please explain what is the hidden problem is wireless communications? What is the main technique to deal with this issue?
- **Answer:** Consider the following example, node A and node C is blocked by obstacles such that node A cannot hear the signals from C. When node C sends packet to node B, node A cannot detect the existence of node C and will send packet to node B as well. This will cause collision.



- The main technique is CSMA/CA.

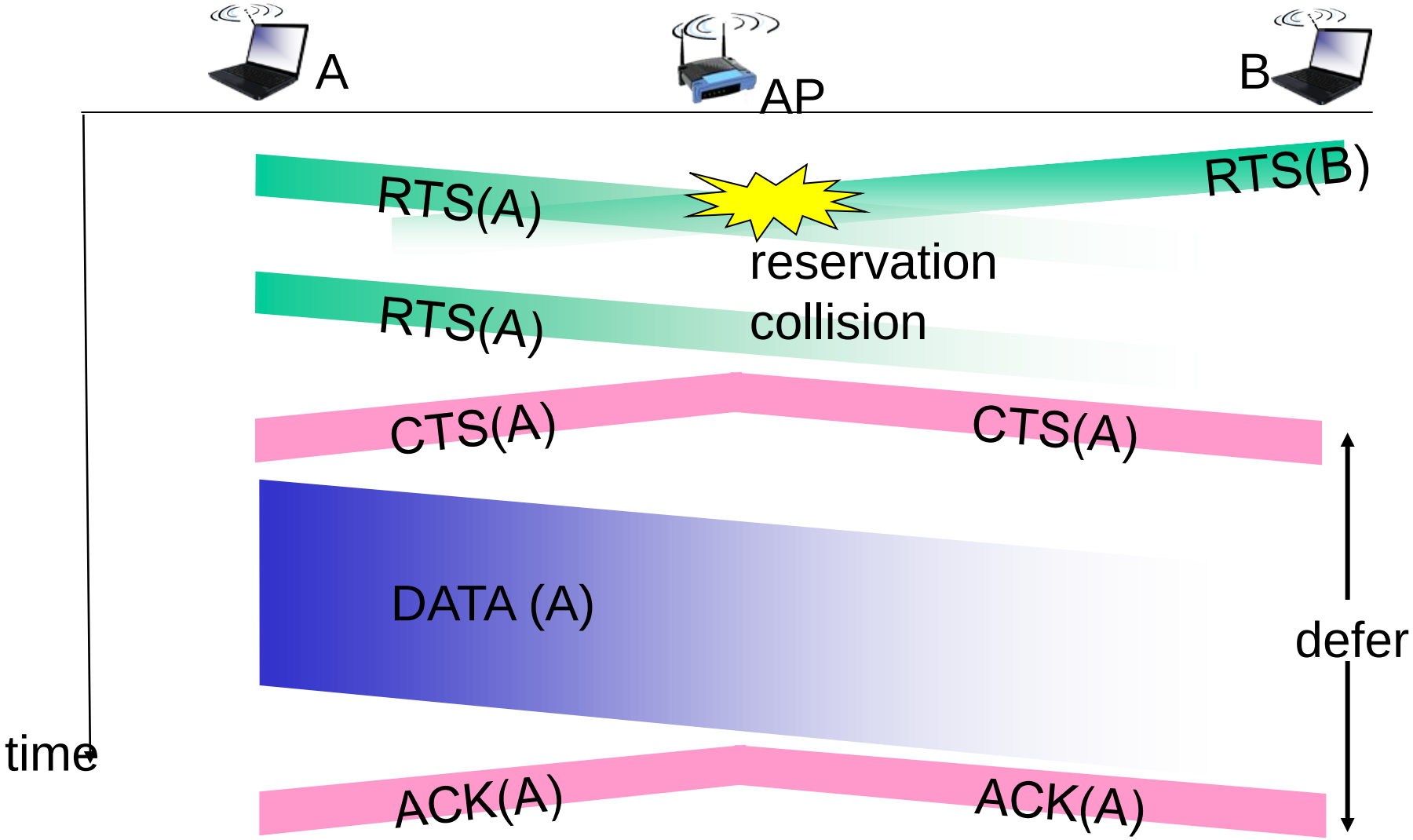
CSMA/CA (Collision avoidance)

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to base station (BS) using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts **clear-to-send** CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



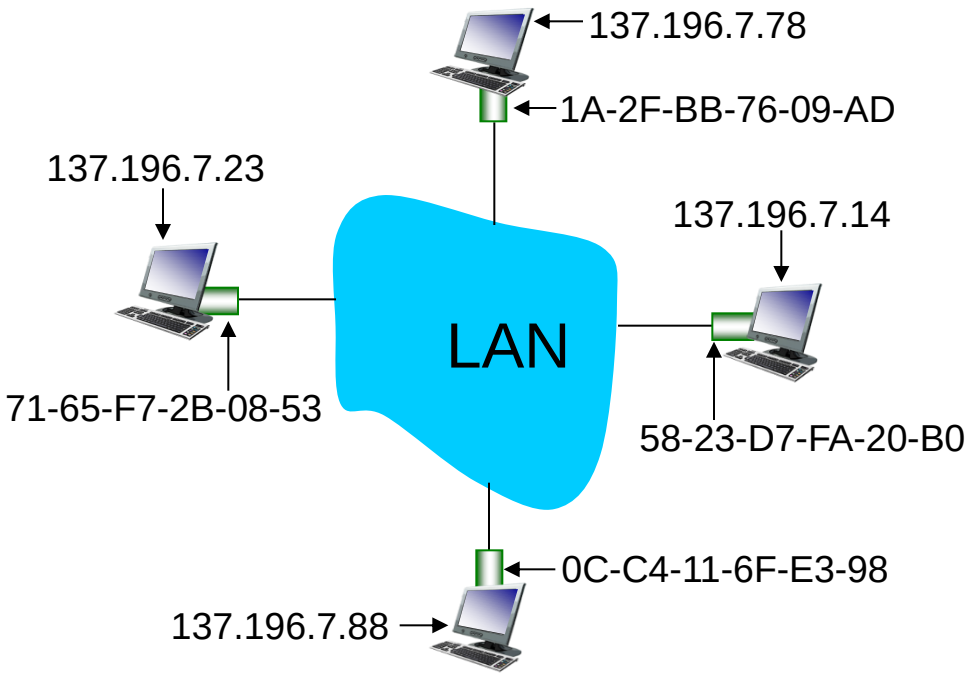
MAC addresses and ARP

- 32-bit IP address:
  - *network-layer* address for interface
  - used for layer 3 (network layer) forwarding
- MAC (or LAN or physical or Ethernet) address:
  - function: *used 'locally" to get frame from one interface to another physically-connected interface (same network, 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)

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: same LAN

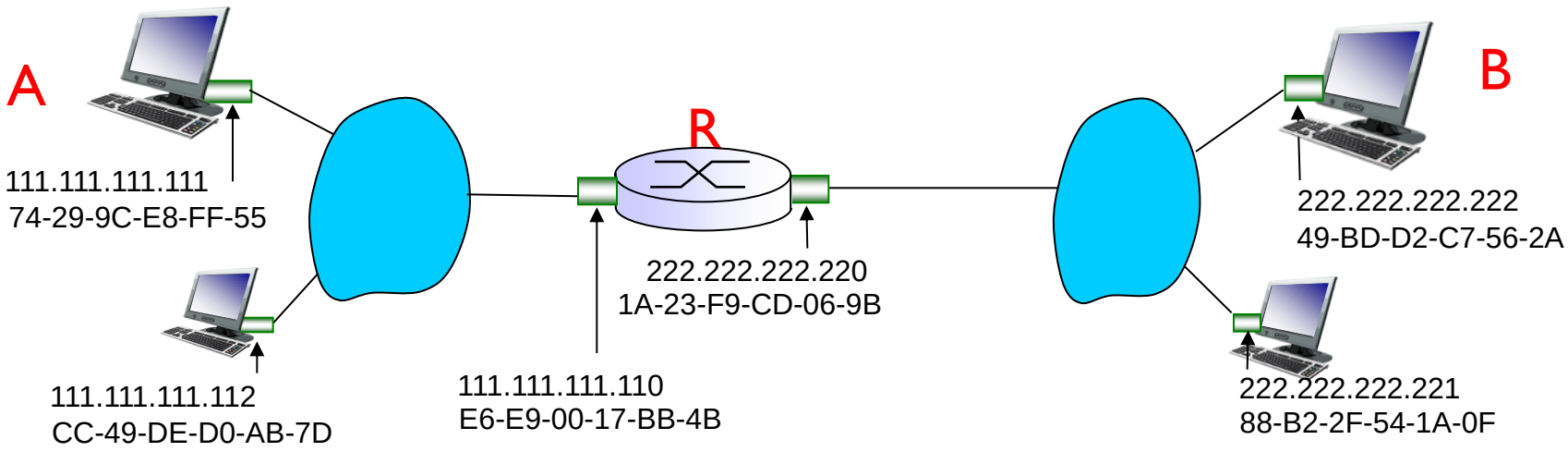
- A wants to send datagram to B
  - B's MAC address not in A's ARP table.
- A broadcasts ARP query packet, containing B's IP address
  - destination MAC address = FF-FF-FF-FF-FF-FF
  - all nodes on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's MAC address (unicast)

- A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play":
  - nodes create their ARP tables *without intervention from net administrator*

Addressing: routing to another LAN

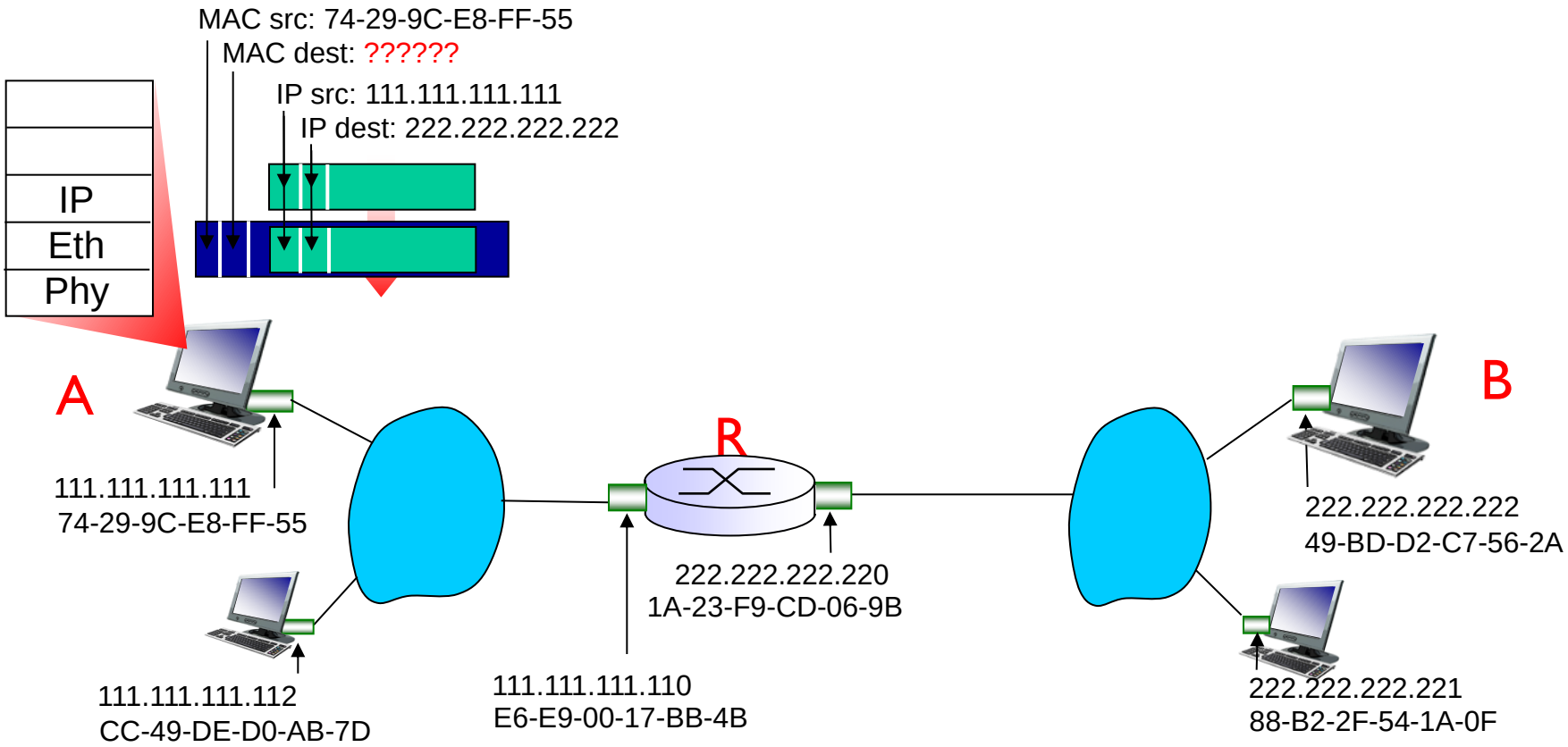
walkthrough: send datagram from A to B via R

- focus on addressing – at IP (datagram) and MAC layer (frame)
- assume A knows B's IP address
- assume A knows IP address of first hop router, R (how?)
- assume A knows R's MAC address (how?)



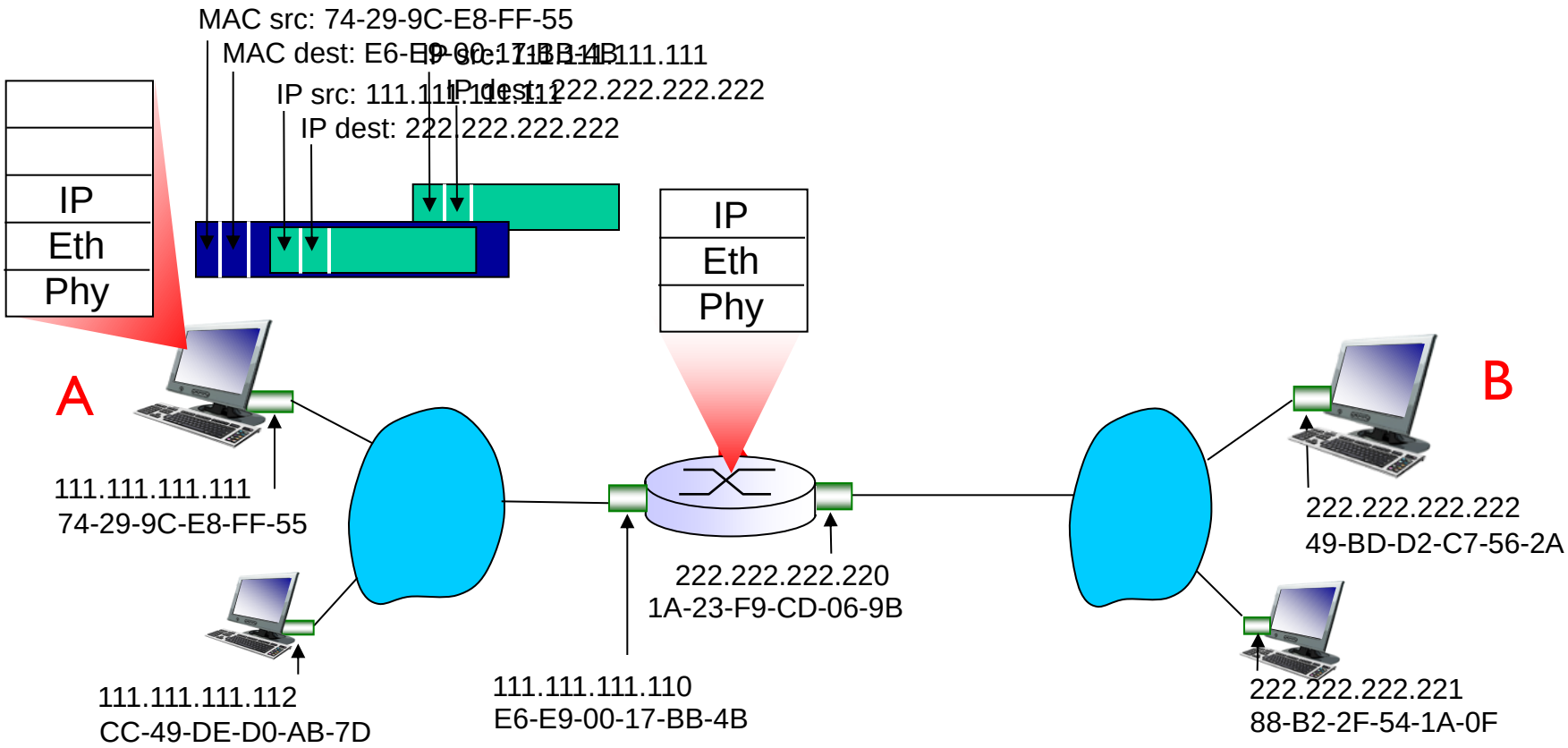
Addressing: routing to another LAN

- A creates IP datagram with IP source A, destination B
- A creates link-layer frame with R's MAC address as destination address, frame contains A-to-B IP datagram



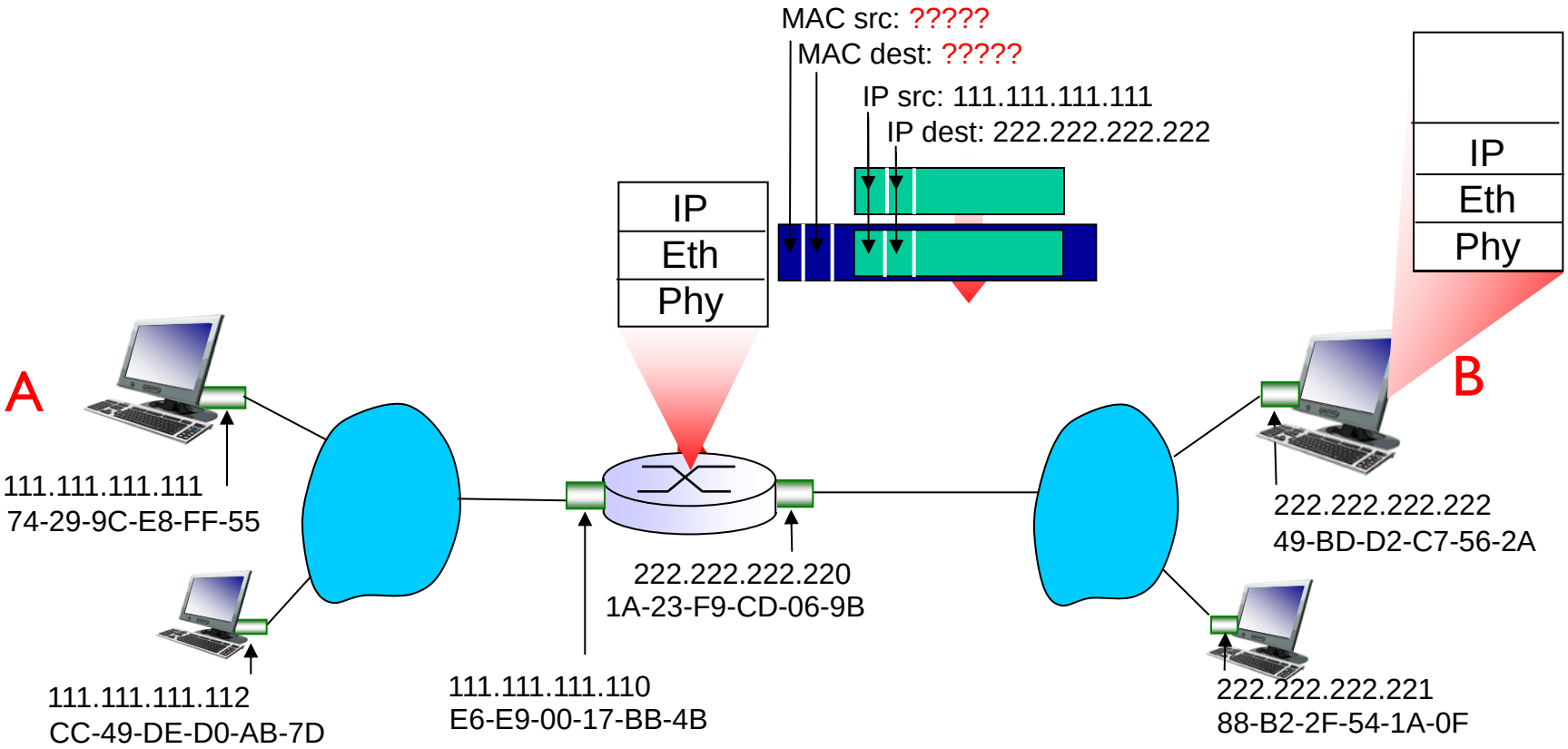
Addressing: routing to another LAN

- frame sent from A to R
- frame received at R, datagram removed, passed up to IP



Addressing: routing to another LAN

- R forwards datagram with IP source A, destination B
- R creates link-layer frame with B's MAC address as destination address, frame contains A-to-B IP datagram



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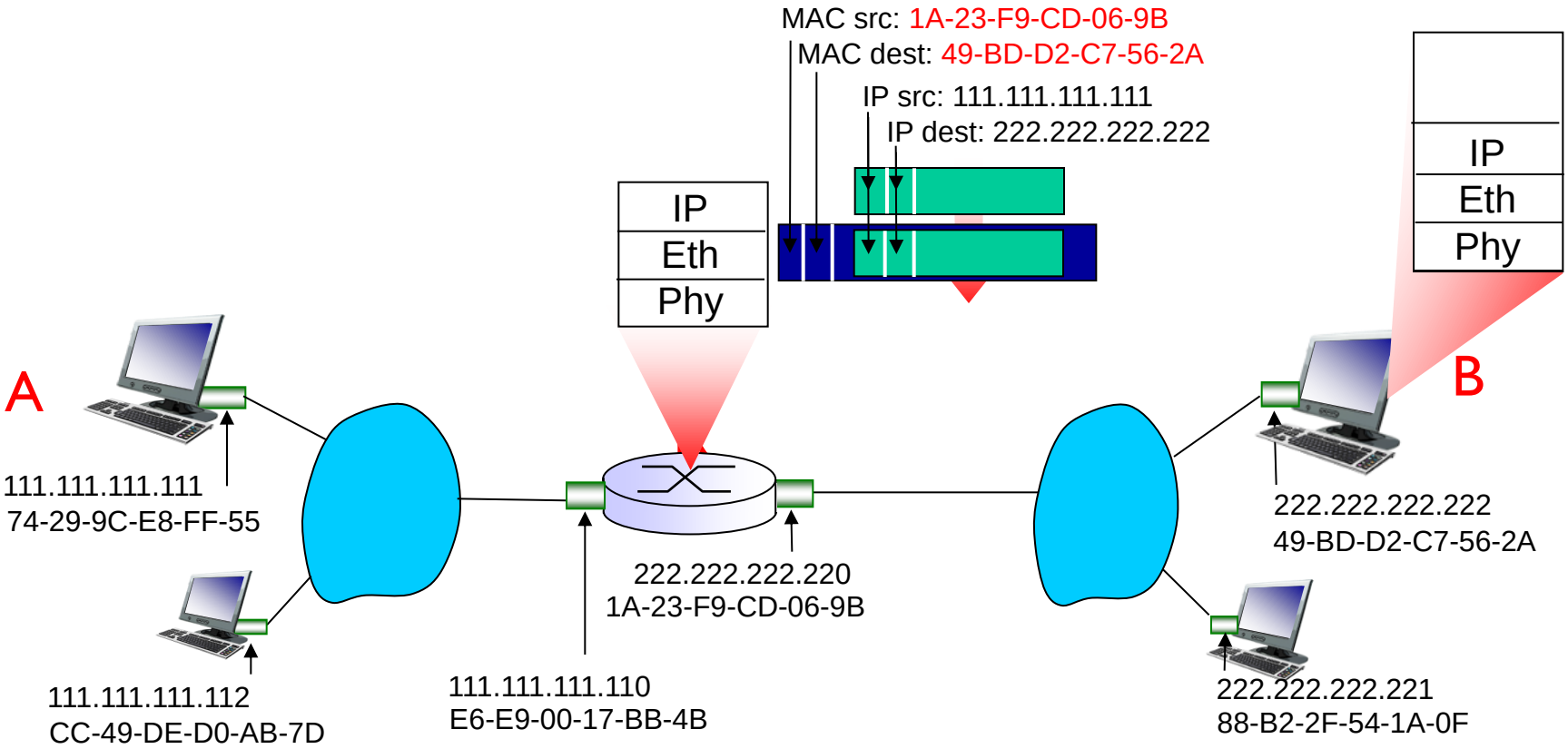

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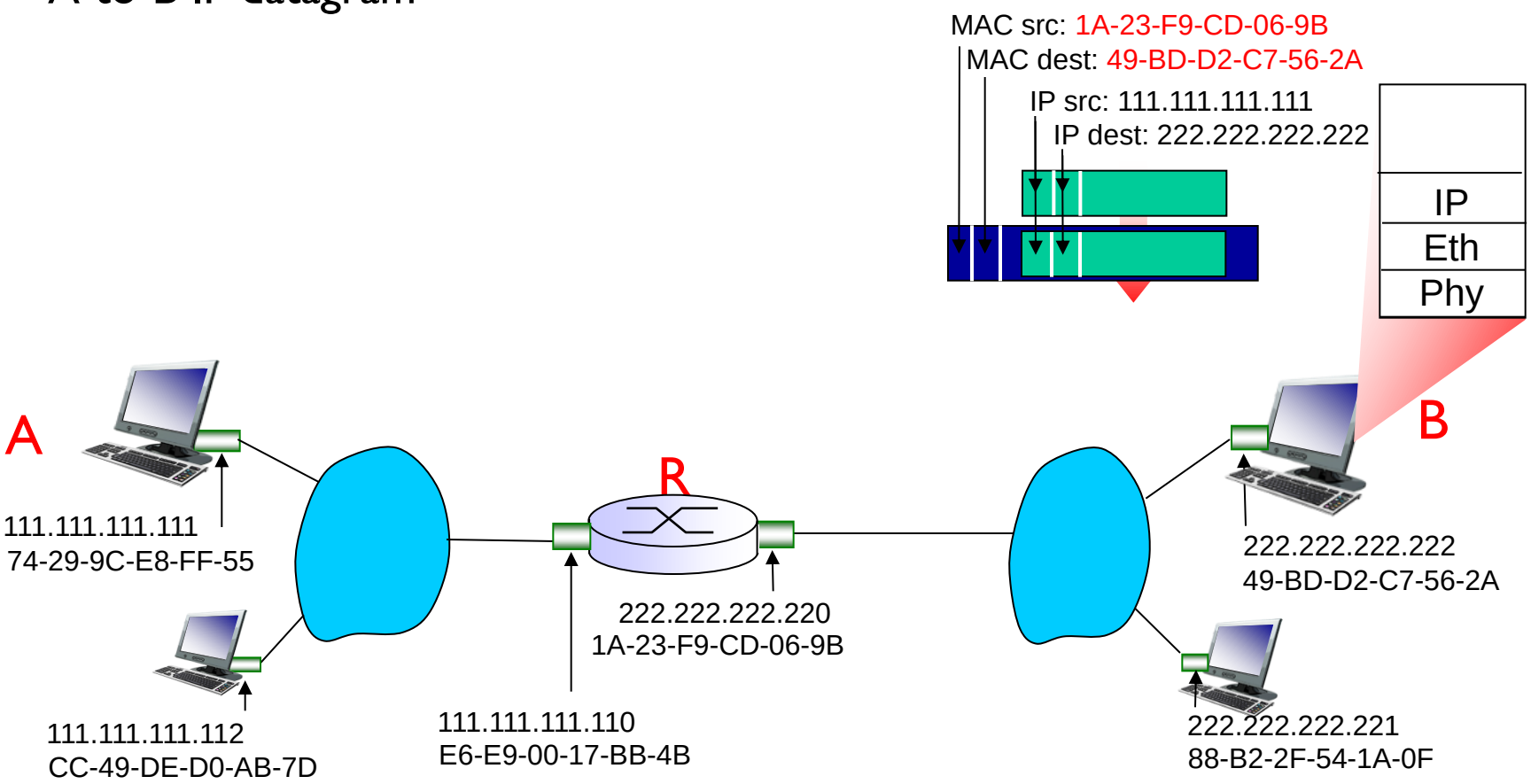
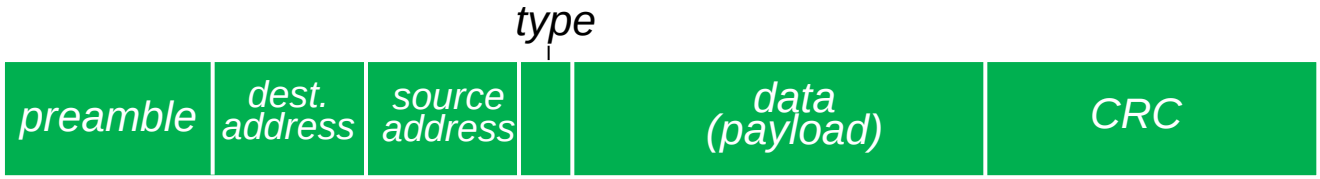


* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

Ethernet frame structure

sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- used to synchronize receiver, sender clock rates

Ethernet switch

- link-layer device: takes an *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, uses CSMA/CD to access segment
- *transparent*
  - hosts are unaware of presence of switches
- *plug-and-play, self-learning*
  - switches do not need to be configured

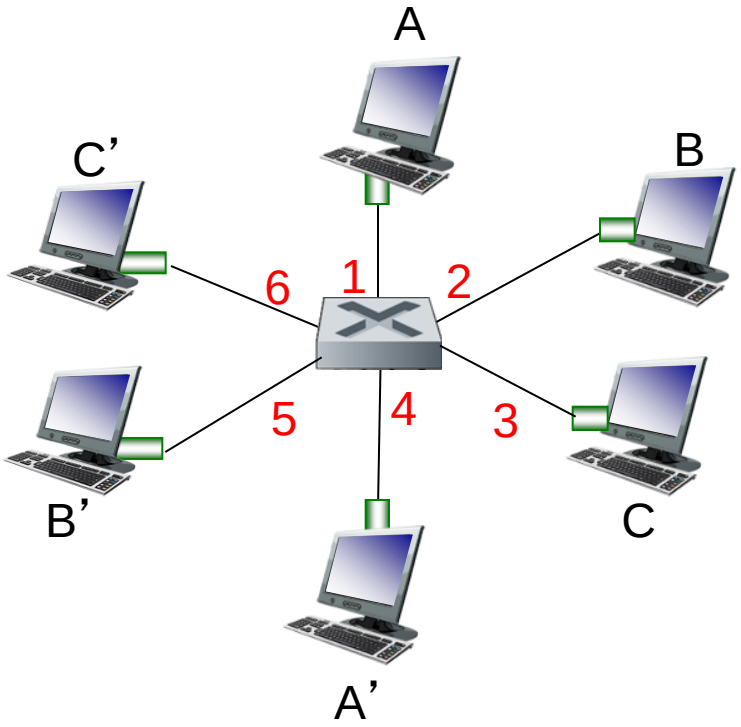
Switch forwarding table

Q: how does switch know 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)
  - looks like a routing table!

Q: how are entries created, maintained in switch table?

- something like a routing protocol?



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

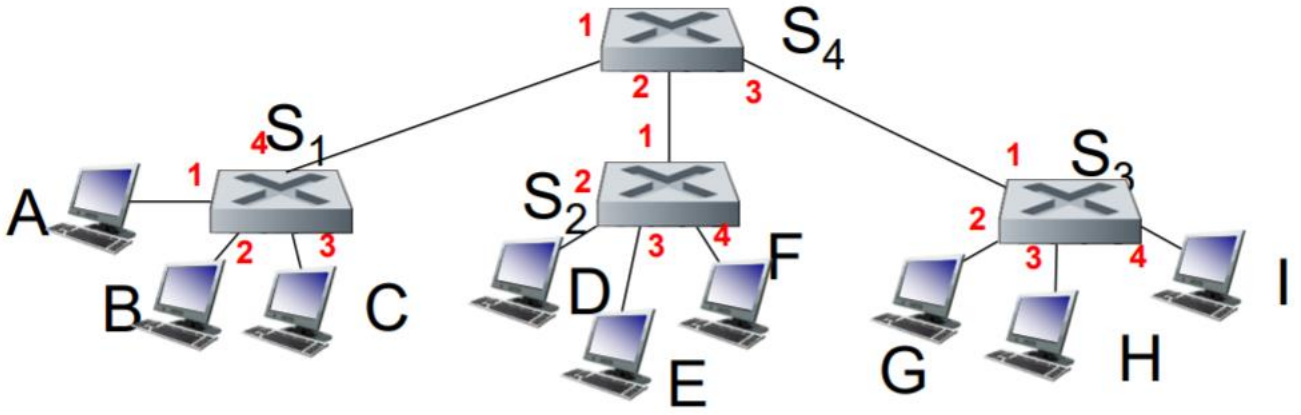
Switch: self-learning

when frame received at switch:

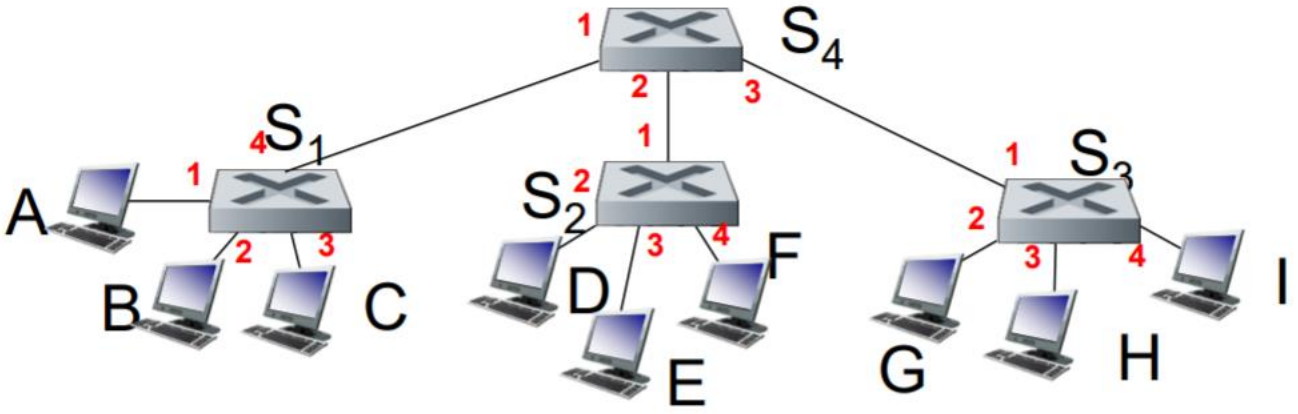
1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
   if destination on segment from which frame arrived
   then drop frame
   else forward frame on interface indicated by entry
   }
   else flood /* forward on all interfaces except arriving interface */

Interconnecting switches

Question: For the following example, sending from A to E, and E replies to A, pls show the switch forwarding table at each switch.



Interconnecting switches



Answer:

S1

MAC addr	interface
A	I
E	4

S2

MAC addr	interface
A	I
E	3

S3

MAC addr	interface
A	I

S4

MAC addr	interface
A	I
E	2

What have we learned

- Slotted ALHOA
- Pure ALOHA
- CSMA
- CSMA/CD
- CSMA/CA
- MAC address
- ARP
- *Switches*