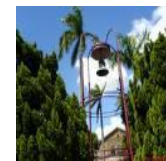


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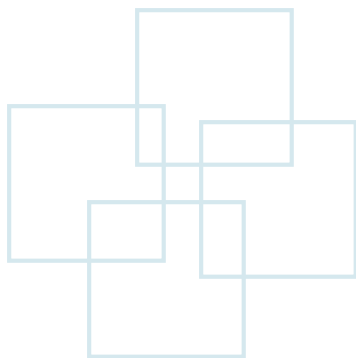


# Auxiliary Protocol

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# Outline

- Introduction
- ARP Process
  - APR Table
  - APR Request/Reply
  - APR Package
- ICMP
  - Error Reporting
  - Query



# Introduction

- IP provides communication between two remote hosts
- However, IP lacks error detection and reporting mechanisms
  - Auxiliary protocols are used to deal with these problems



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March 4, 2021

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# Address Resolution Protocol **ARP**



# ARP



- Both IP address and MAC address are required to delivery packets in the Internet
- Question: how to determine destination MAC address by only knowing its IP address?
- A mechanism is needed to translate IP addresses to MAC addresses

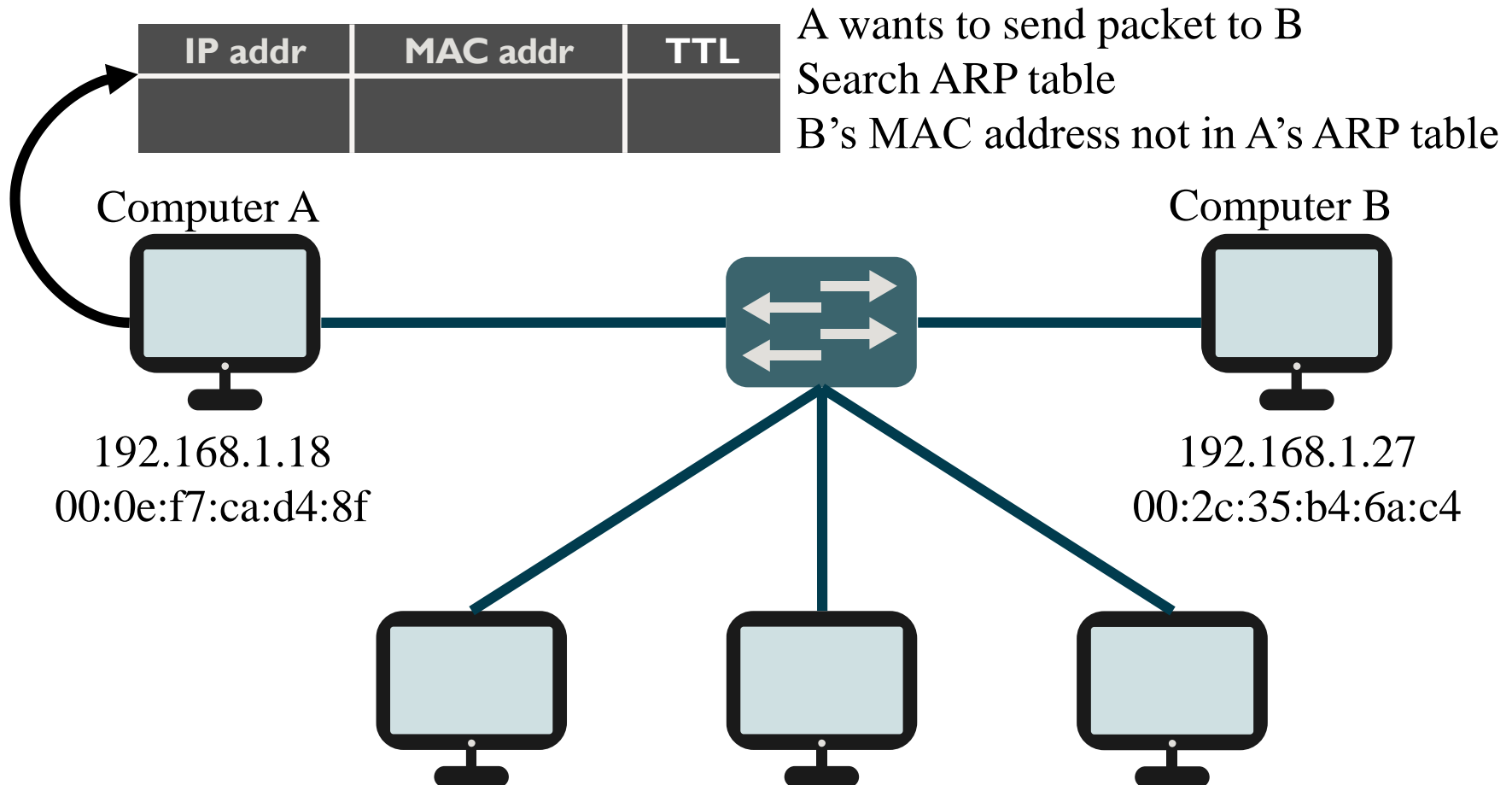


# ARP Table

- Each IP node (e.g., host, router, etc.) on LAN has an ARP table
- ARP Table: IP/MAC address mappings for some LAN devices
  - $\langle \text{IP address; MAC address; TTL} \rangle$ 
    - TTL (Time To Live): time after the address mapping will be expired (typically 20 min)

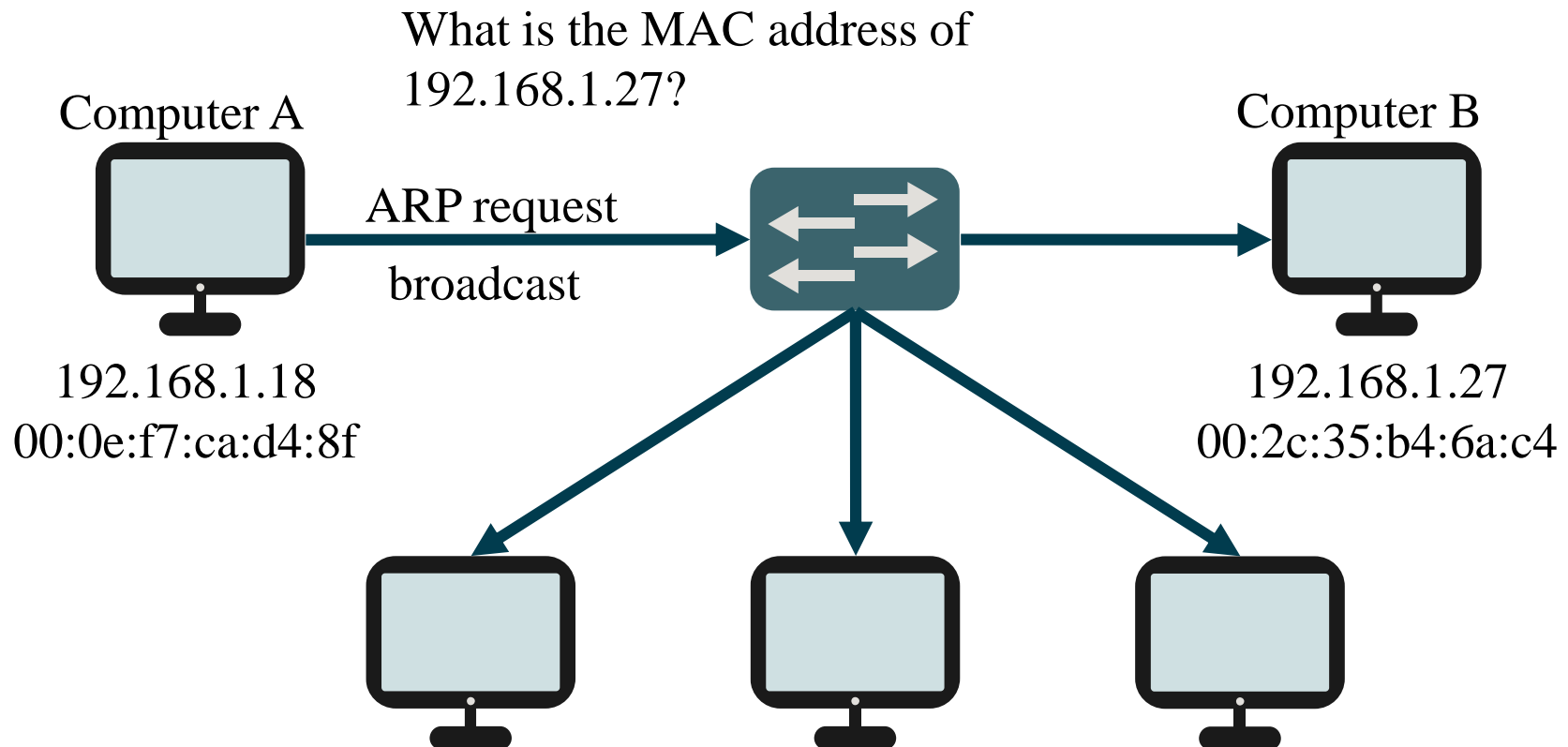


## Example of ARP Process





# ARP Request



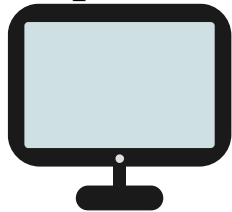




# ARP Reply

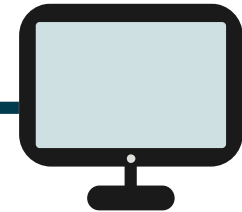
The MAC address of 192.168.1.27 is  
00:2c:35:b4:6a:c4

Computer A



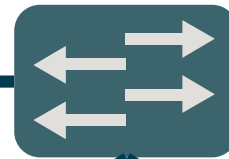
192.168.1.18  
00:0e:f7:ca:d4:8f

Computer B



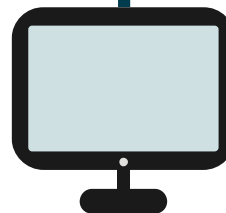
192.168.1.27  
00:2c:35:b4:6a:c4

ARP reply



IP addr	MAC addr	TTL
192.168.1.27	00:2c:35:b4:6a:c4	20

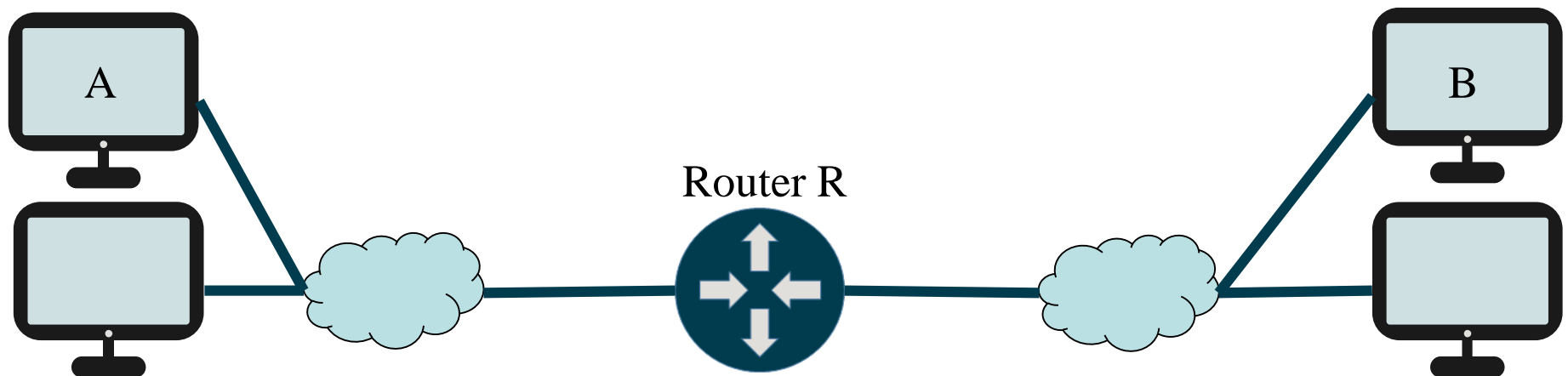
ARP Table in A





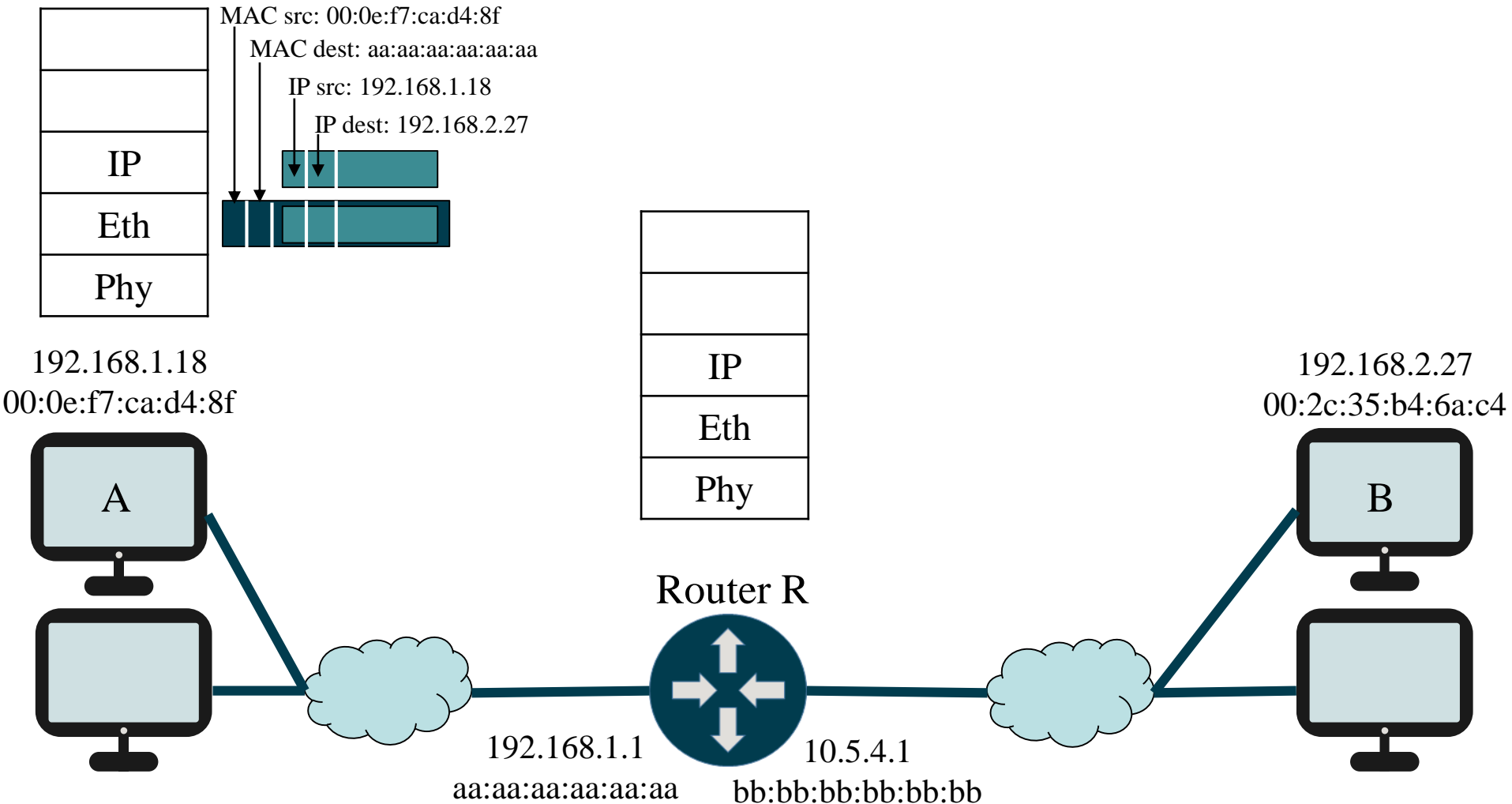
## Routing to Another Subnet

- Sending a datagram from A to B via R
  - focus on IP (datagram) and MAC layer (frame) levels
  - assume that:
    - A knows B's IP address
    - A knows IP address of router R (how?)
    - A knows R's MAC address (how?)



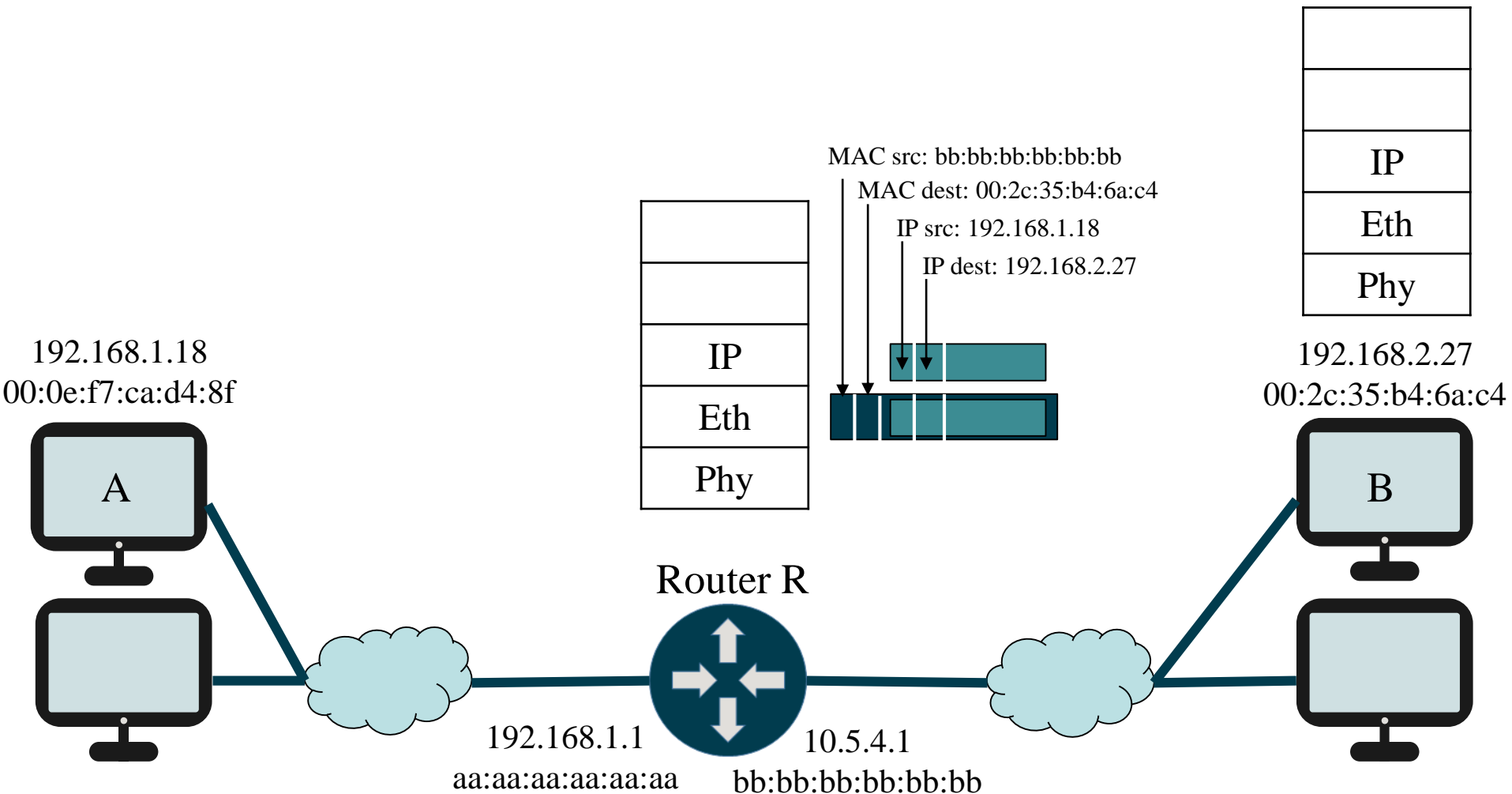


## Routing to Another Subnet



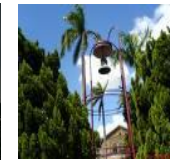


# Routing to another subnet





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## Example of ARP Table



命令提示字元

Microsoft Windows [版本 10.0.17134.523]  
 (c) 2018 Microsoft Corporation. 著作權所有，並保留一切權利。

C:\Users\user>arp -a

介面: 192.168.0.2 --- 0x4

網際網路網址	實體位址	類型
192.168.0.1	10-be-f5-7b-0a-ab	動態
192.168.0.106	68-17-29-fb-c3-f4	動態
192.168.0.255	ff-ff-ff-ff-ff-ff	靜態
224.0.0.2	01-00-5e-00-00-02	靜態
224.0.0.22	01-00-5e-00-00-16	靜態
224.0.0.251	01-00-5e-00-00-fb	靜態
224.0.0.252	01-00-5e-00-00-fc	靜態
239.255.255.250	01-00-5e-7f-ff-fa	靜態
255.255.255.255	ff-ff-ff-ff-ff-ff	靜態



IP address



MAC address



Type



# ARP Packet Format

Hardware type (16 bits)		Protocol type (16 bits)
Hardware address length (8 bits)	Protocol address length (8 bits)	Operation (16 bits)
Sender HA (48 bits or other)		
Sender protocol address (32 bits or other)		
Target HA (48 bits or other)		
Target protocol address (32 bits or other)		



# Internet Control Message Protocol

## ICMP



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# ICMP

- If a packet must be dropped by router due to
  - Destination is unreachable
  - TTL is zero
- ICMP is used to
  - Error reporting
  - Status query



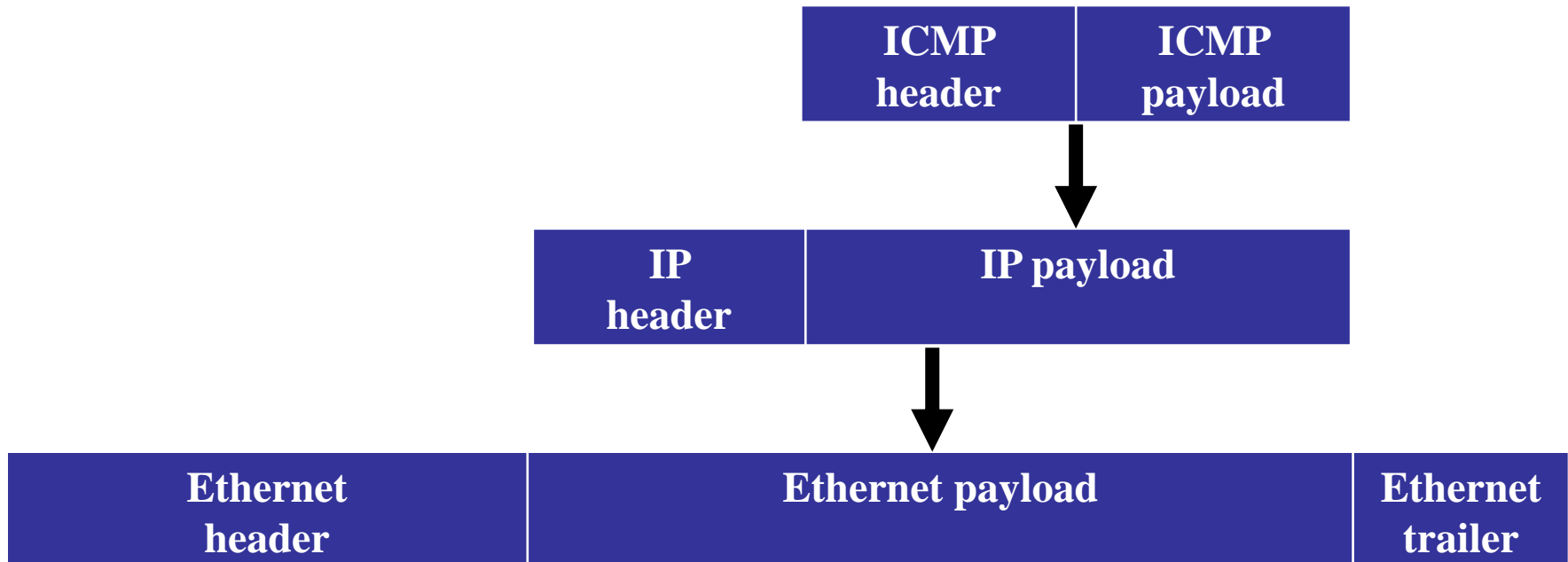


## ICMP

- Used by hosts & routers to communicate network-level information
  - Error reporting: unreachable host, network, port, protocol
  - Query message: echo request/reply (used by ping)
- Network-layer “above” IP:
  - ICMP messages carried in IP datagrams



# ICMP Format





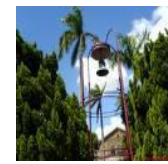
# ICMP Packet Format

- Error reporting



Type (8 bits)	Code (8 bits)	Checksum (16 bits)
Undefined or other (32 bits)		
Data section (IP header + 64 bits of original data)		

- Query (e.g., echo request/reply)

Type (8 bits)	Code (8 bits)	Checksum (16 bits)
Identifier (16 bits)		Sequence number (16 bits)
Data section (Option Data)		



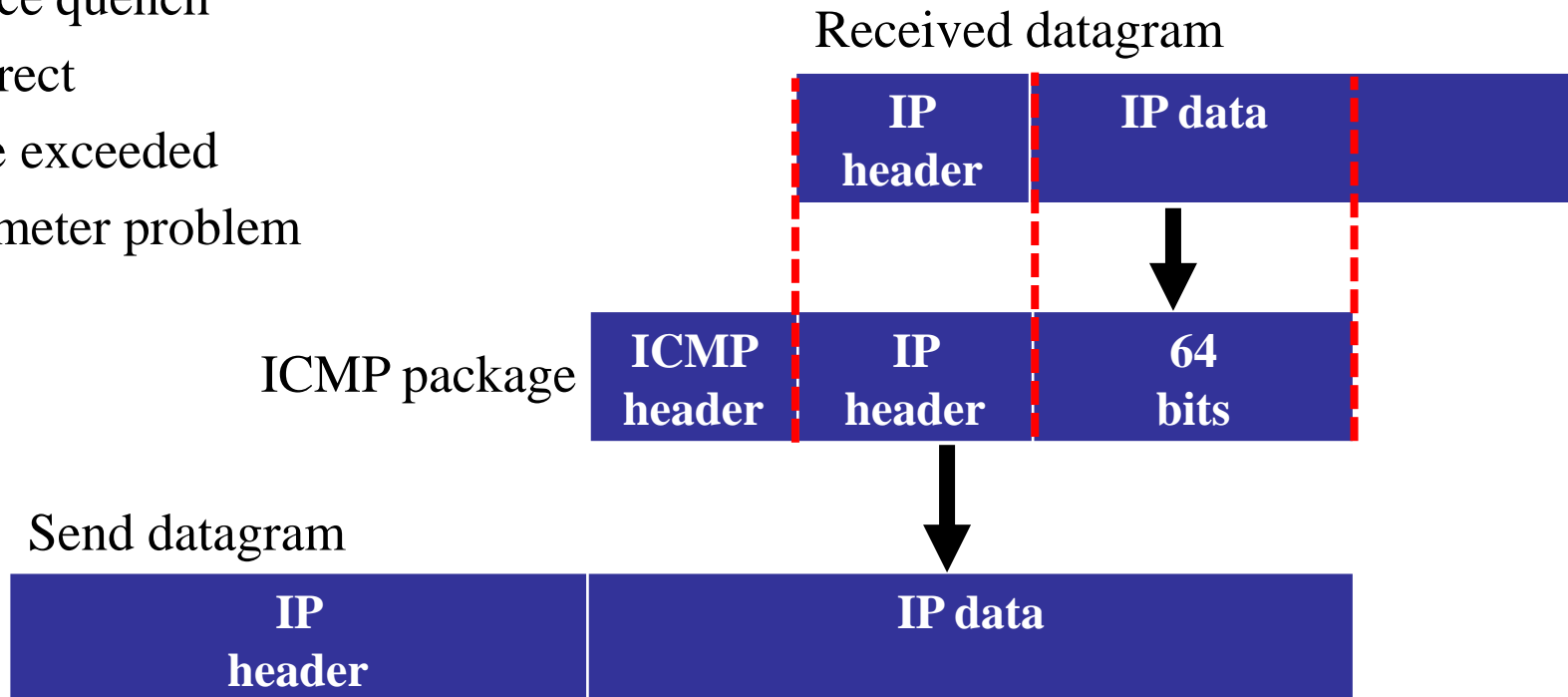
# ICMP Message Types

ICMP type	Description	Error reporting	Query
0	Echo reply (to ping)		✓
3	Destination unreachable	✓	
4	Source quench	✓	
5	Redirect	✓	
8	Echo request		✓
9	Router advertisement 		✓
10	Router solicitation 		✓
11	Time exceeded	✓	
12	Parameter problem	✓	



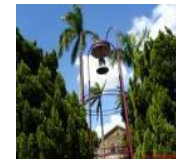
# Error Reporting

- Report problems (5 types)
  - Destination unreachable
  - Source quench
  - Redirect
  - Time exceeded
  - Parameter problem





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## Query

- Get specific information
  - Echo Request / Reply
    - Ping , Traceroute
  - Router Advertisement
  - Router Solicitation
  - Timestamp Request / Reply
    - Synchronize , Delay , Host Time



# Traceroute

- Source sends series of UDP segments to dest
  - First has TTL = 1
  - Second has TTL=2, etc.
  - Unlikely port number 🗨️
- When nth datagram arrives to nth router
  - Router discards datagram
  - And sends to source an ICMP message (type 11, code 0)
  - Message includes name of router & IP address
  - When ICMP message arrives, source calculates RTT
  - Traceroute does this 3 times



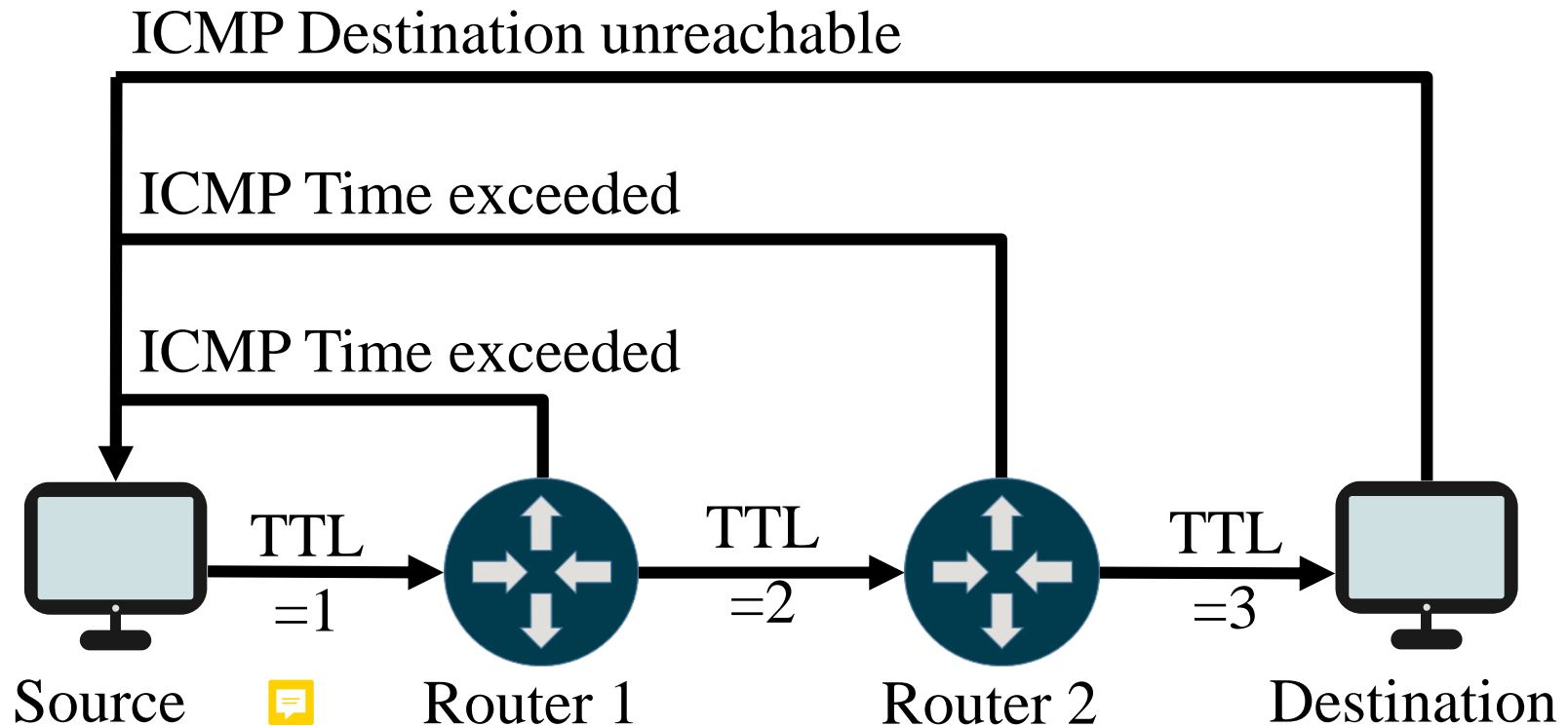
## Traceroute (cont.)

- Stopping criterion
  - UDP segment eventually arrives at destination host
  - Destination returns ICMP “destination unreachable” packet (type 3, code 3)
  - When source gets this ICMP, stops





# An Example of Traceroute





## Reference

- Computer Networking: A Top-Down Approach Featuring the Internet. Jamess F. Kurose, Keith W. Ross, 6rd Edition, Addison Wesley
- RFC 792 - Internet Control Message Protocol - IETF Tools