
University of Colorado Boulder

Fundamentals of Data Communications CSCI 5010

OSI Model

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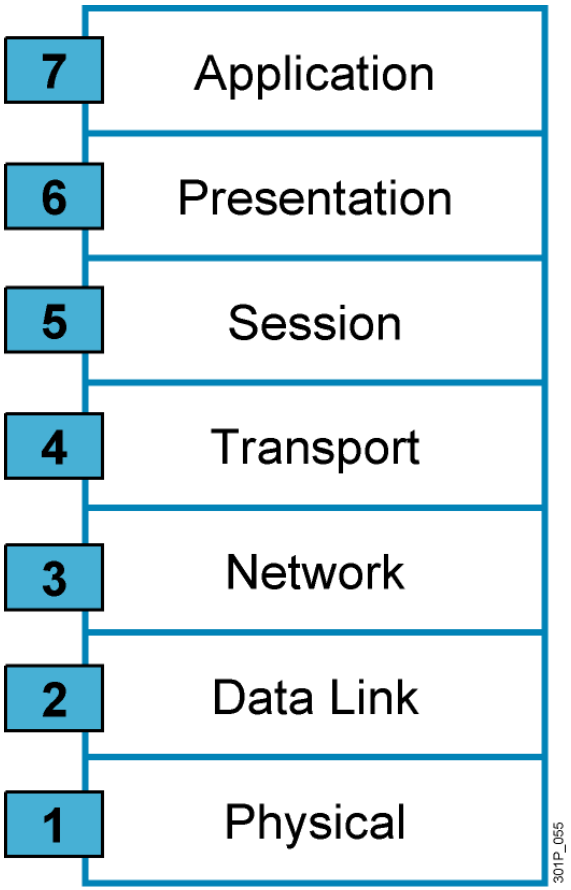
Review

- **OSI Model**
  - Names and Numbers
  - Focus on Layers 1-4
  - Encapsulation & Decapsulation
  - Protocol Datagram Units (PDU)
    - ***Layers 1-4***
  - Devices at each layer (1-3)
- **TCP & UDP**
  - Connectionless vs connection
    - ***Pro/con***
- **ARP**
  - Process (in depth)
  - MAC
  - IP Address
- **Default Gateway**

Understanding Host-to-Host Communications

- Theoretical model that specifies how data gets from the application on one machine, across a network, to the application on another machine.
- Older model
  - ***Proprietary***
  - ***Application and combinations software controlled by one vendor***
- Standards-based model
  - ***Multivendor software***
  - ***Layered approach***

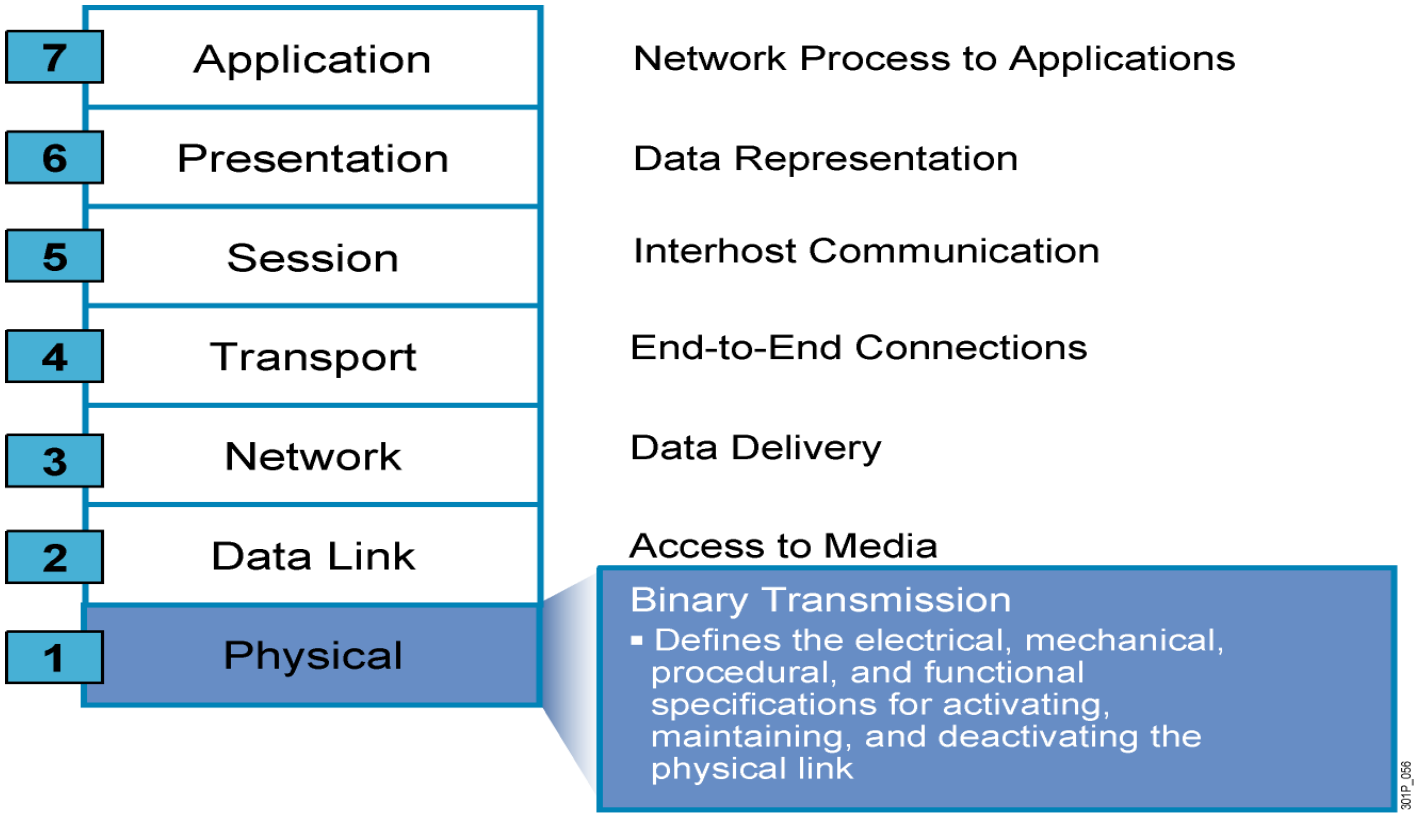
Why a Layered Network Model?



- Reduces complexity
- Standardizes interfaces
- Facilitates modular engineering
- Ensures interoperable technology
- Accelerates evolution
- Simplifies teaching and learning

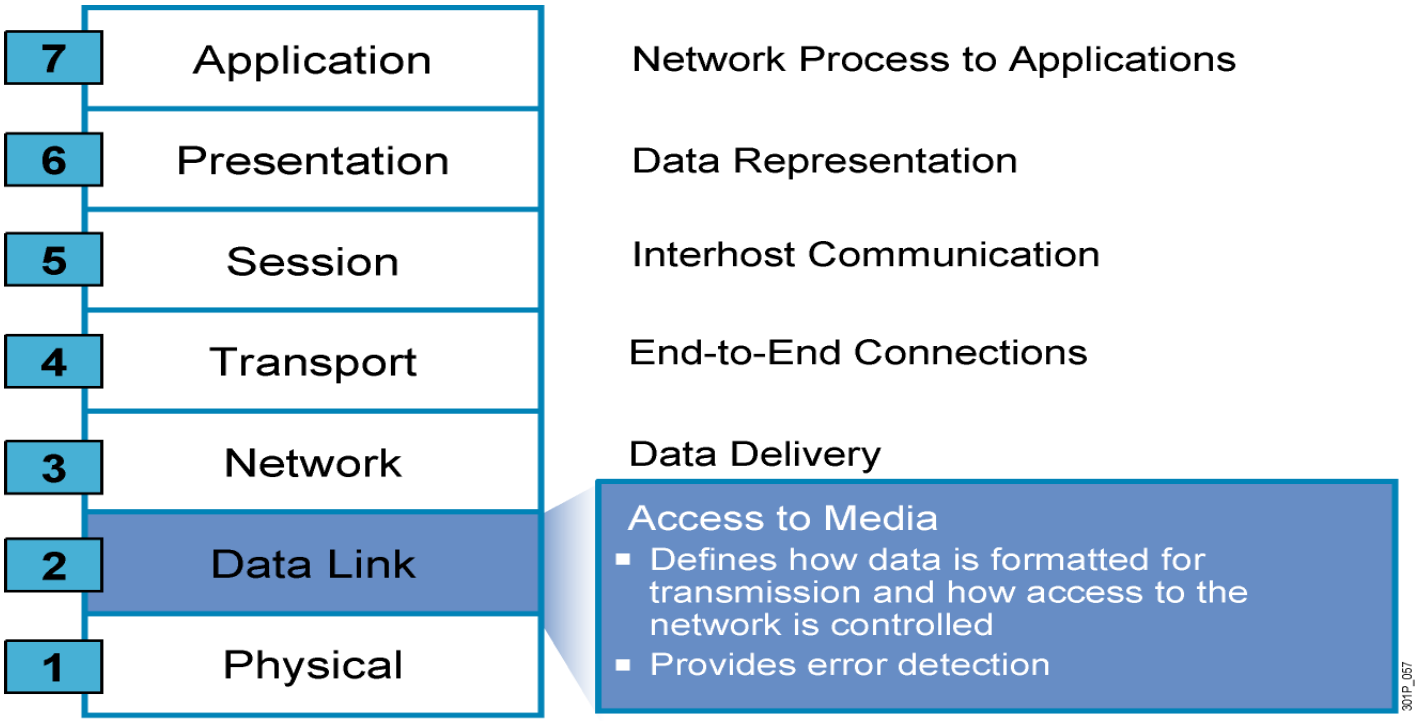
- **Make sure to learn the name and corresponding number for each layer!**

The Seven Layers of the OSI Model



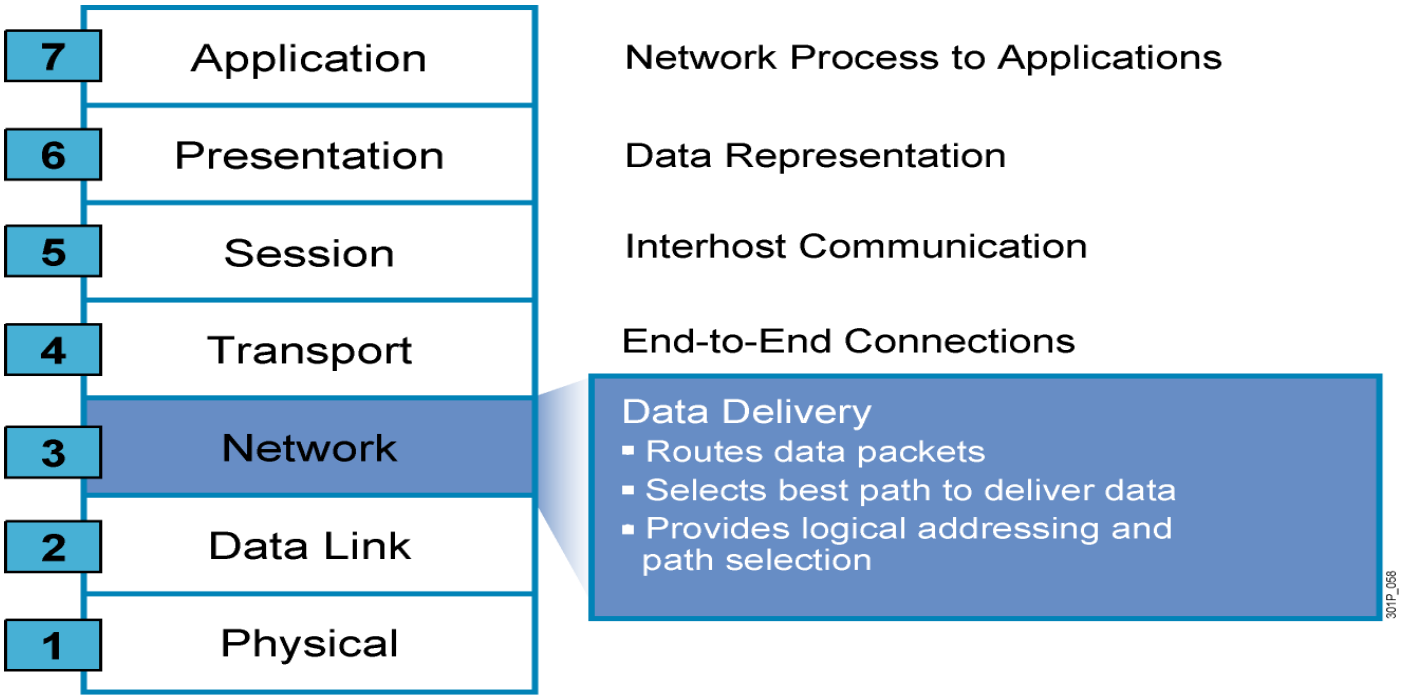
- Electrical Signals
- PDU = Bits (1s and 0s)
- Examples = Serial, Repeater, Hub, physical cabling/power, etc.

The Seven Layers of the OSI Model (Cont.)



- Ethernet uses MAC addresses (physical addressing)
- PDU = Frames
- Examples = Switch, NIC, Bridge

The Seven Layers of the OSI Model (Cont.)



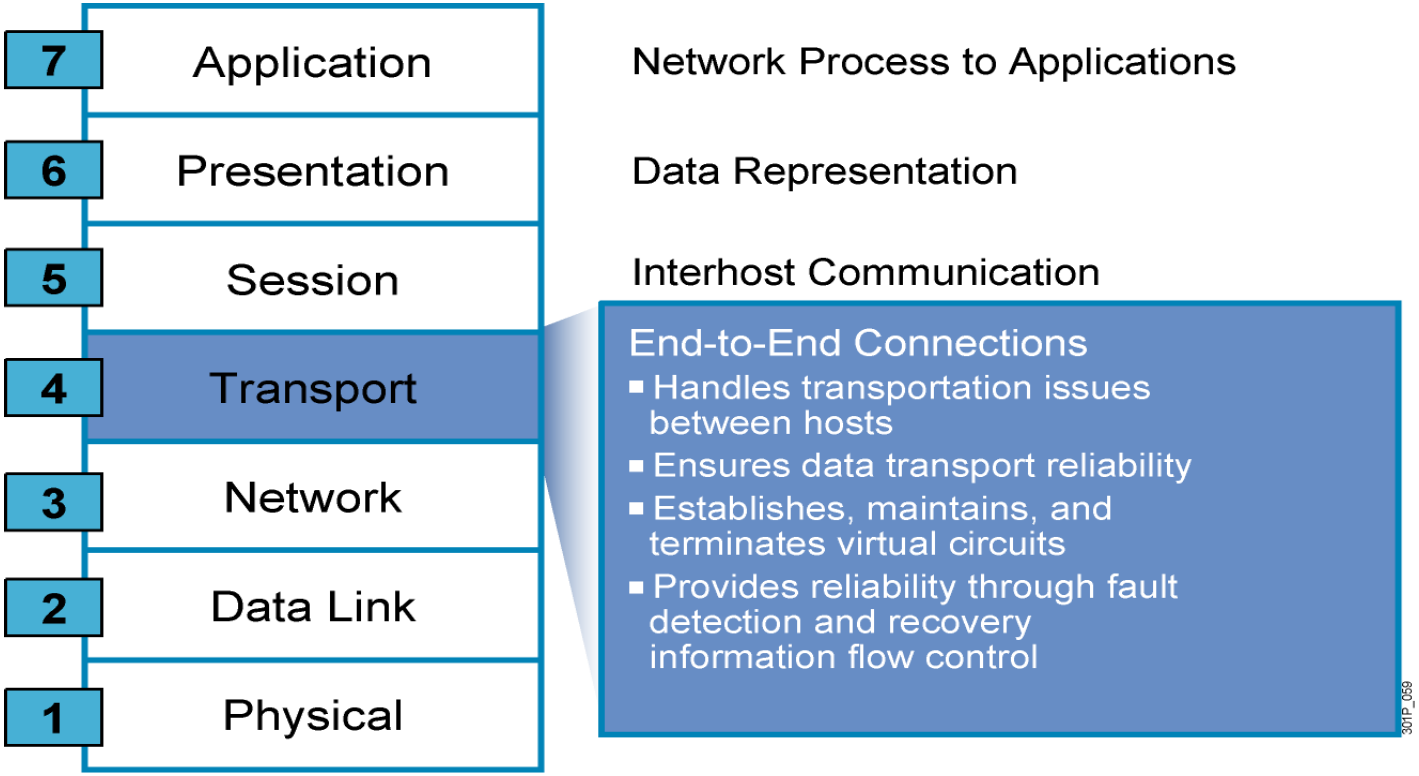
- Uses Internet Protocol (IP) / IP addresses (logical addressing)
- PDU = Packets
- Examples = Routers

Exercise

- **On your laptop**
  - Find your MAC address
    - ***hint***
  - Find your IP address

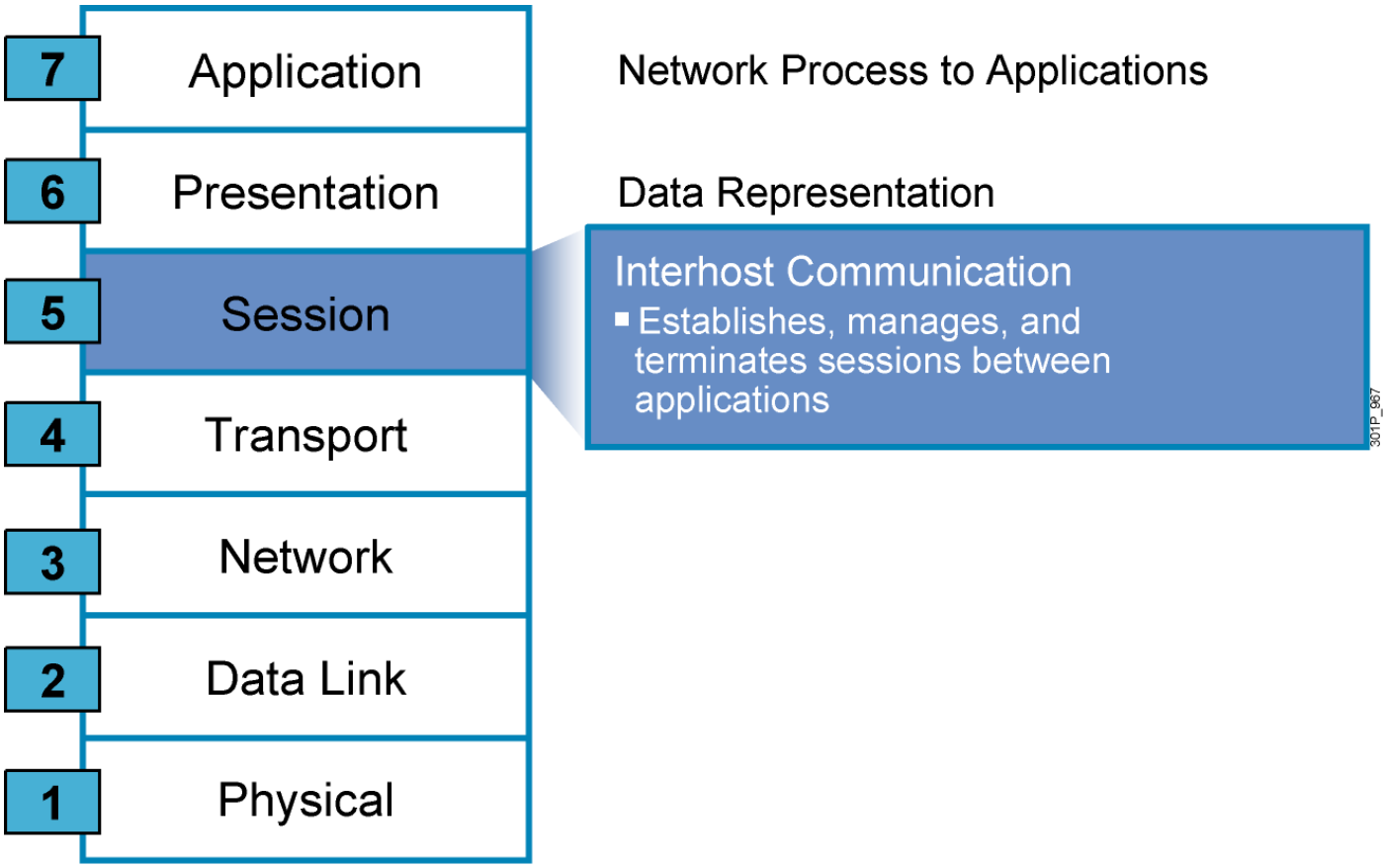
- **To do this, you will need to use command prompt/terminal**
  - Search > “cmd” > enter
  - ipconfig/all

The Seven Layers of the OSI Model (Cont.)

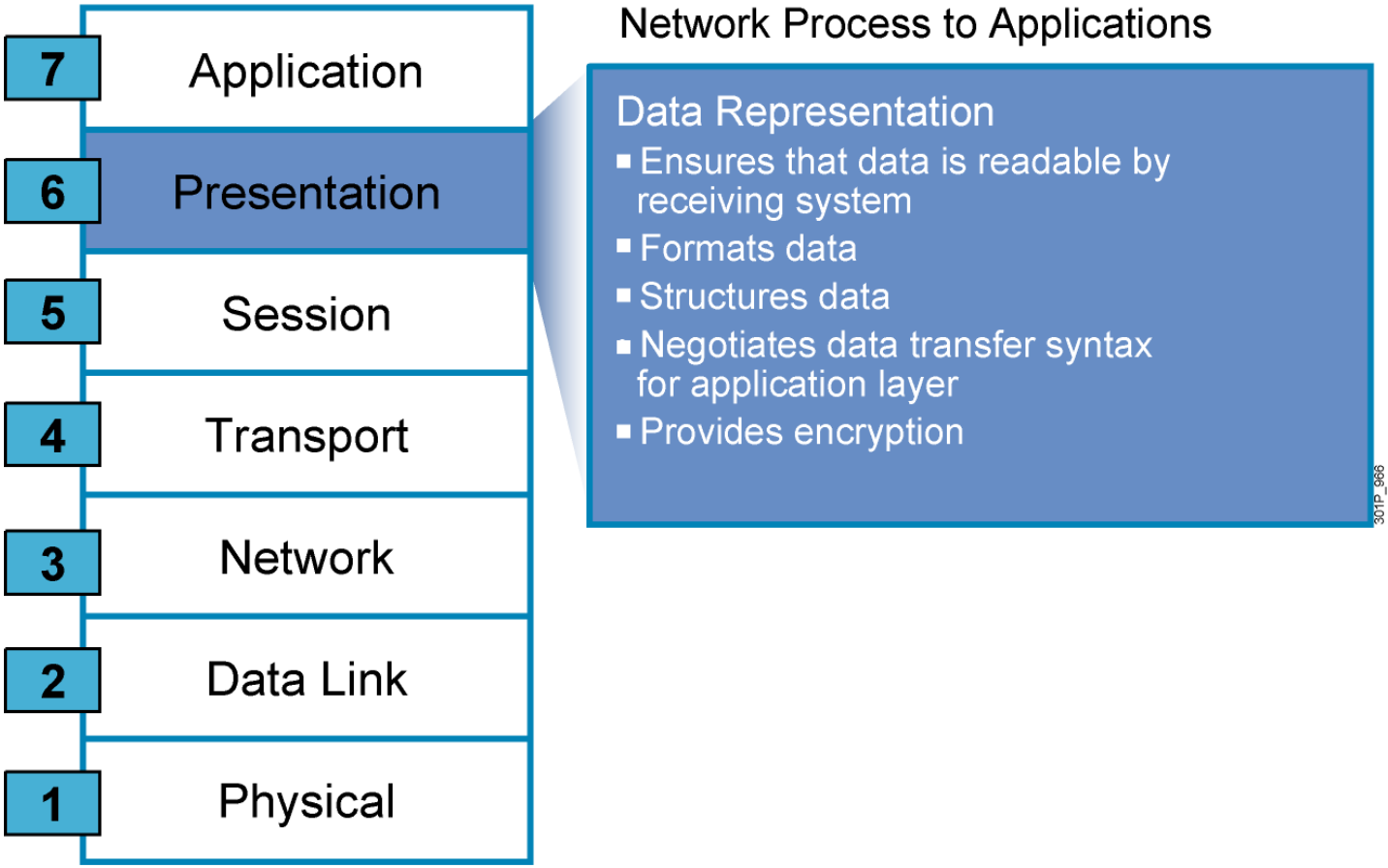


- PDU = Segments
- Examples = TCP & UDP

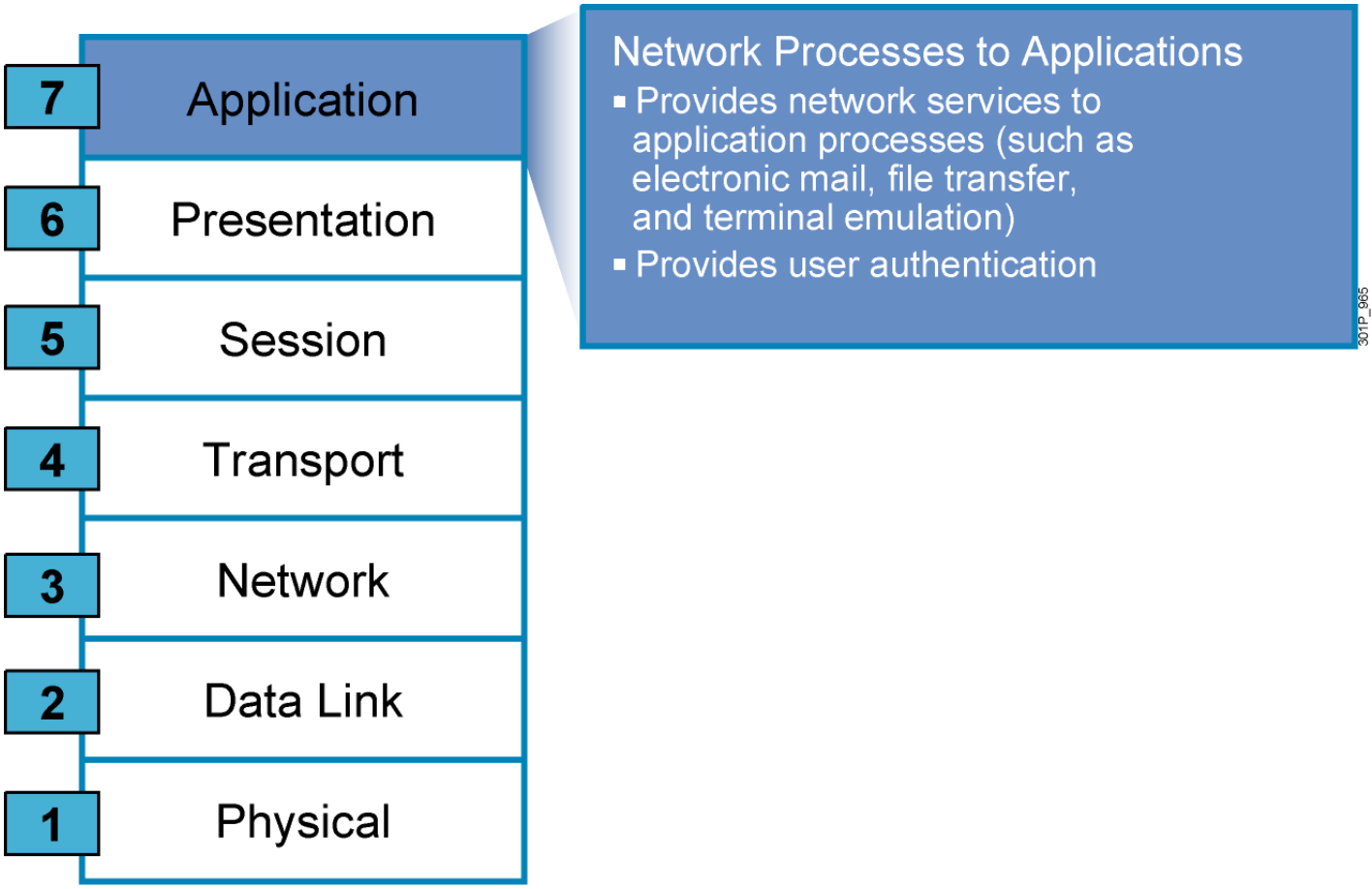
The Seven Layers of the OSI Model (Cont.)



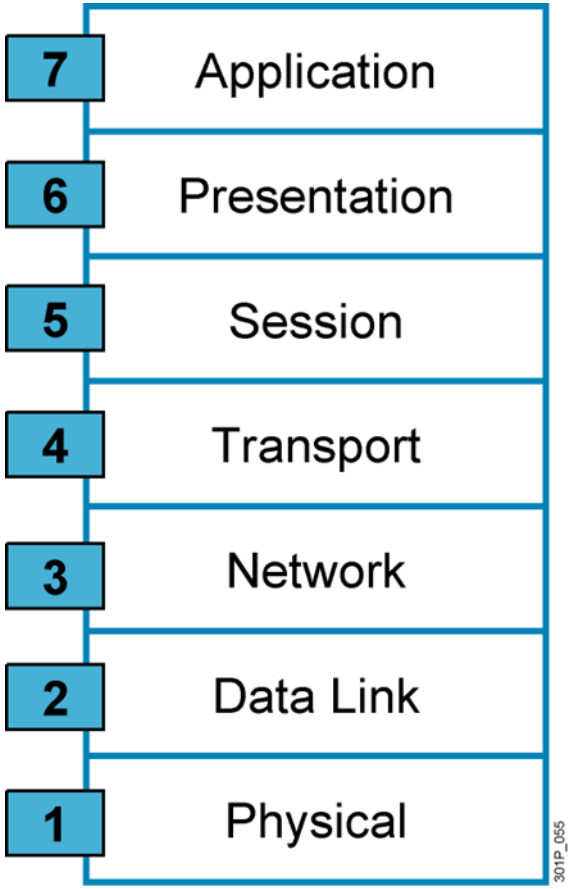
The Seven Layers of the OSI Model (Cont.)



The Seven Layers of the OSI Model (Cont.)



- **Assignment**
- **Perfect**
- **Sam's**
- **Touch**
- **Not**
- **Do**
- **Please**



The Postal Analogy

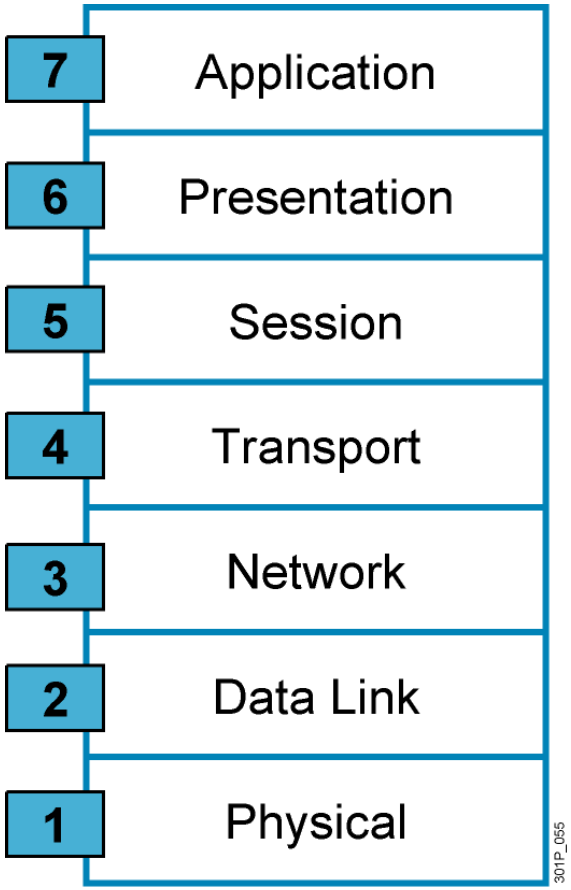
How would the OSI compare to the regular Post Office

- Application
- Presentation
- Session
- Transport
- Network
- Data-Link
- Physical

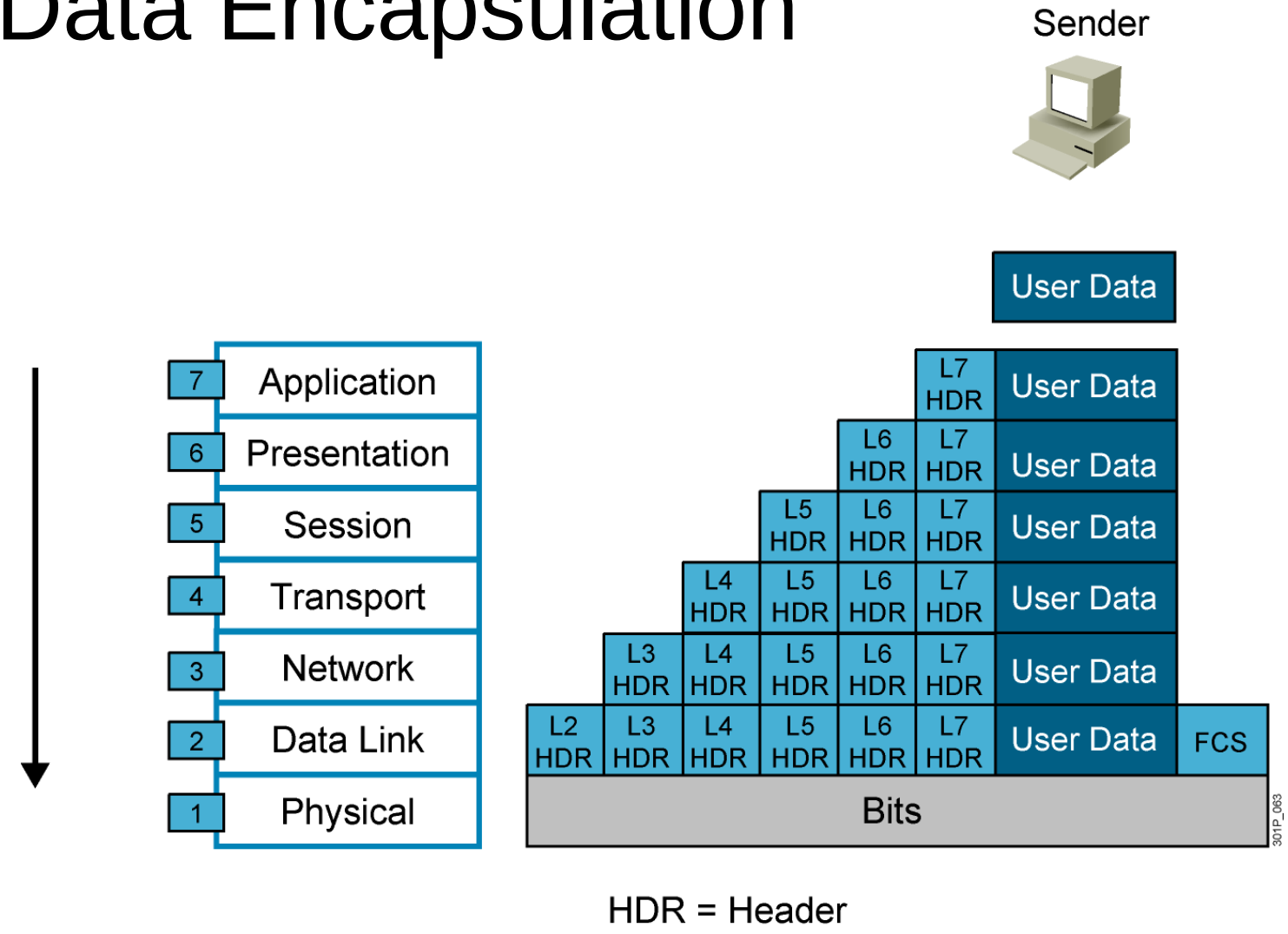
- **A-** Write a 20 page letter to a foreign country.
- **P-** Translate the letter so the receiver can read it.
- **S-** Insure the intended recipient can receive letter.
- **T-** Separate and number pages. Like registered mail, tracks delivery and requests another package if one is "lost" or "damaged" in the mail.
- **N-** Postal Center sorting letters by zip code to route them closer to destination.
- **D-** Local Post Office determining which vehicles to deliver letters.
- **P-** Physical Trucks, Planes, Rail, autos, etc which carry letter between stations.

Data Encapsulation & De-encapsulation

- Data or data packets
  - ***The information sent on a network***
- If one computer wants to send data to another computer, the data must first be packaged
  - ***encapsulation***
- When the remote device receives a sequence of bits, the physical layer at the remote device passes the bits up the OSI model to the data link layer for manipulation
  - ***de-encapsulation***

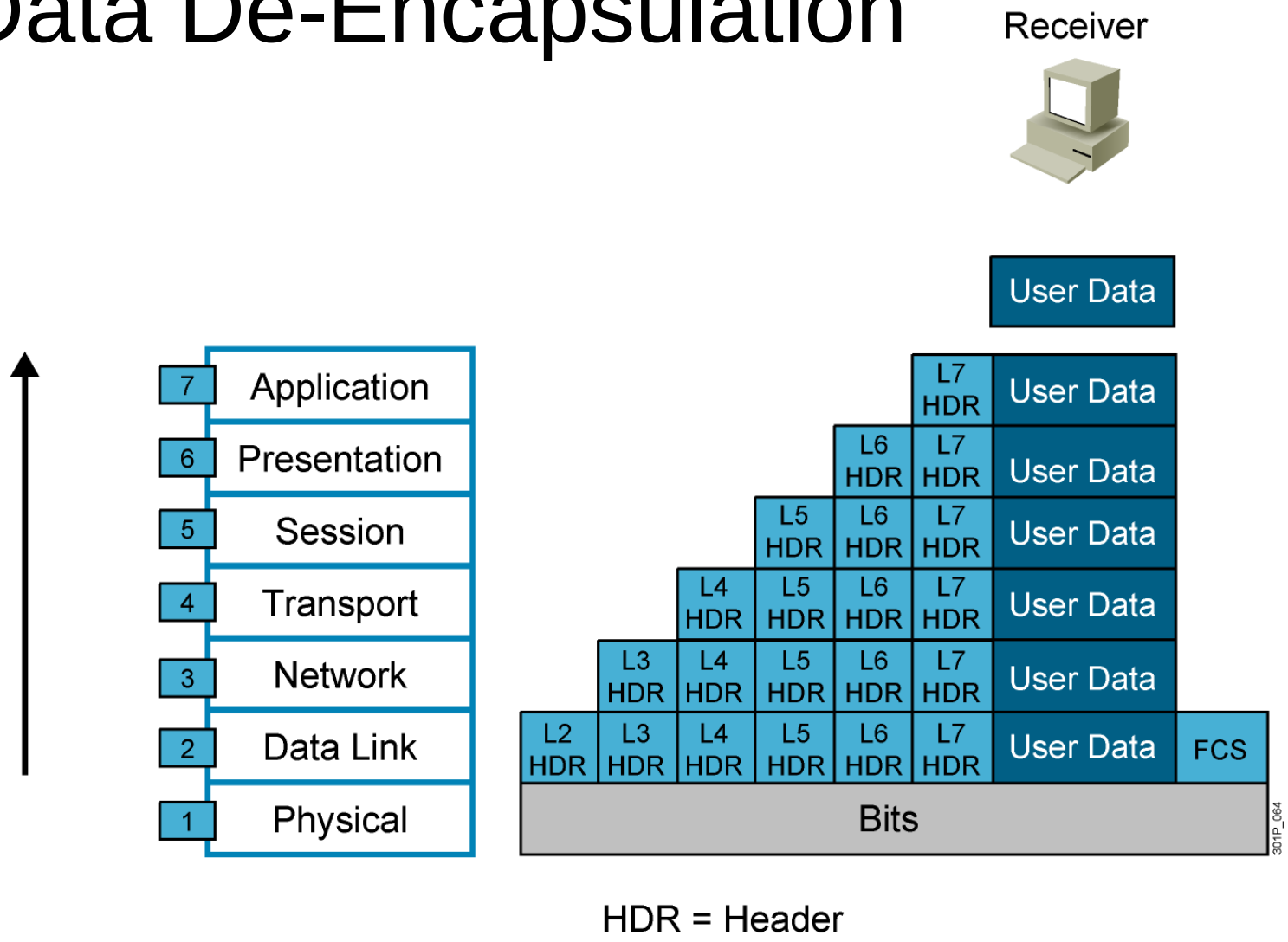


Data Encapsulation



HDR = Header

Data De-Encapsulation

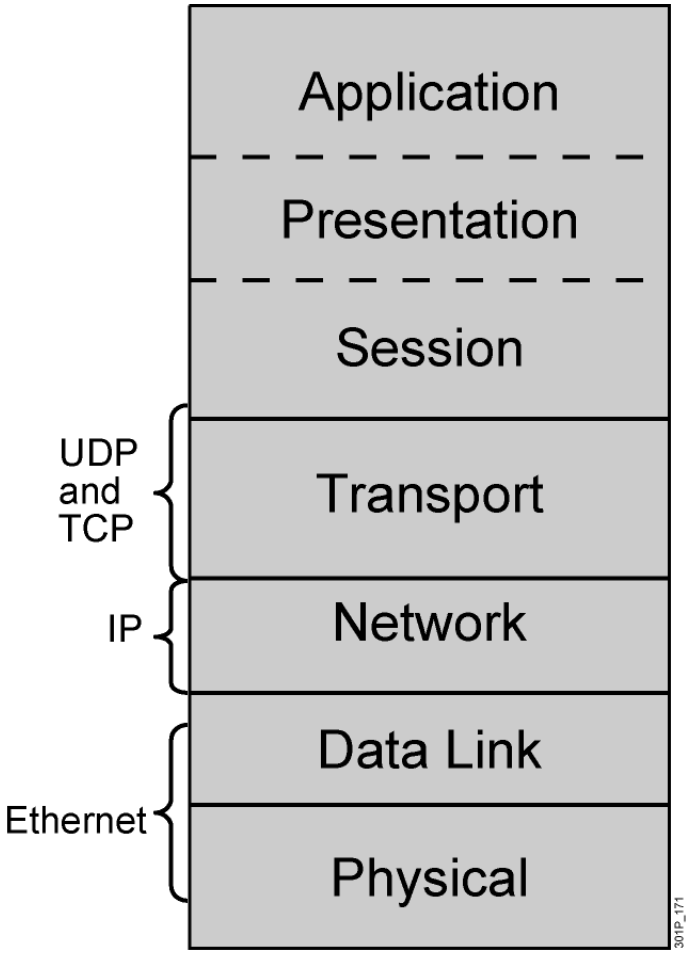


HDR = Header

Example Analogy

- **Russian nesting doll**

Transport Layer – TCP & UDP



- Session multiplexing
- Segmentation
- Flow control (when required)
- Connection-oriented (when required)
- Reliability (when required)

Transport Layer – TCP & UDP

- **Hide the network requirements from the application layer**

- **Connection-oriented**
  - Reliable transport
  - TCP
    - ***connection-oriented***
    - ***provides error checking***
    - ***delivers data reliably***
    - ***operates in full-duplex mode***

- **Connectionless**
  - Best-effort transport
  - UDP
    - ***provides applications with access to the network layer without the overhead of the reliability mechanisms of TCP.***
    - ***Connectionless / best-effort***

Reliable vs. Best-Effort Comparison

	Reliable	Best-Effort
Connection Type	Connection-oriented	Connectionless
Protocol	TCP	UDP
Sequencing	Yes	No
Uses	▪ E-mail ▪ File sharing ▪ Downloading	▪ Voice streaming ▪ Video streaming

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UDP Characteristics

- Operates at transport layer of OSI and TCP/IP models
- Provides applications with access to the network layer without the overhead of reliability mechanisms
- Is a **connectionless** protocol
  - ***Faster***
- Provides limited error checking
- Provides **best-effort delivery**
  - ***Real-time communications***
    - **Voice & Video**
- Has no data-recovery features

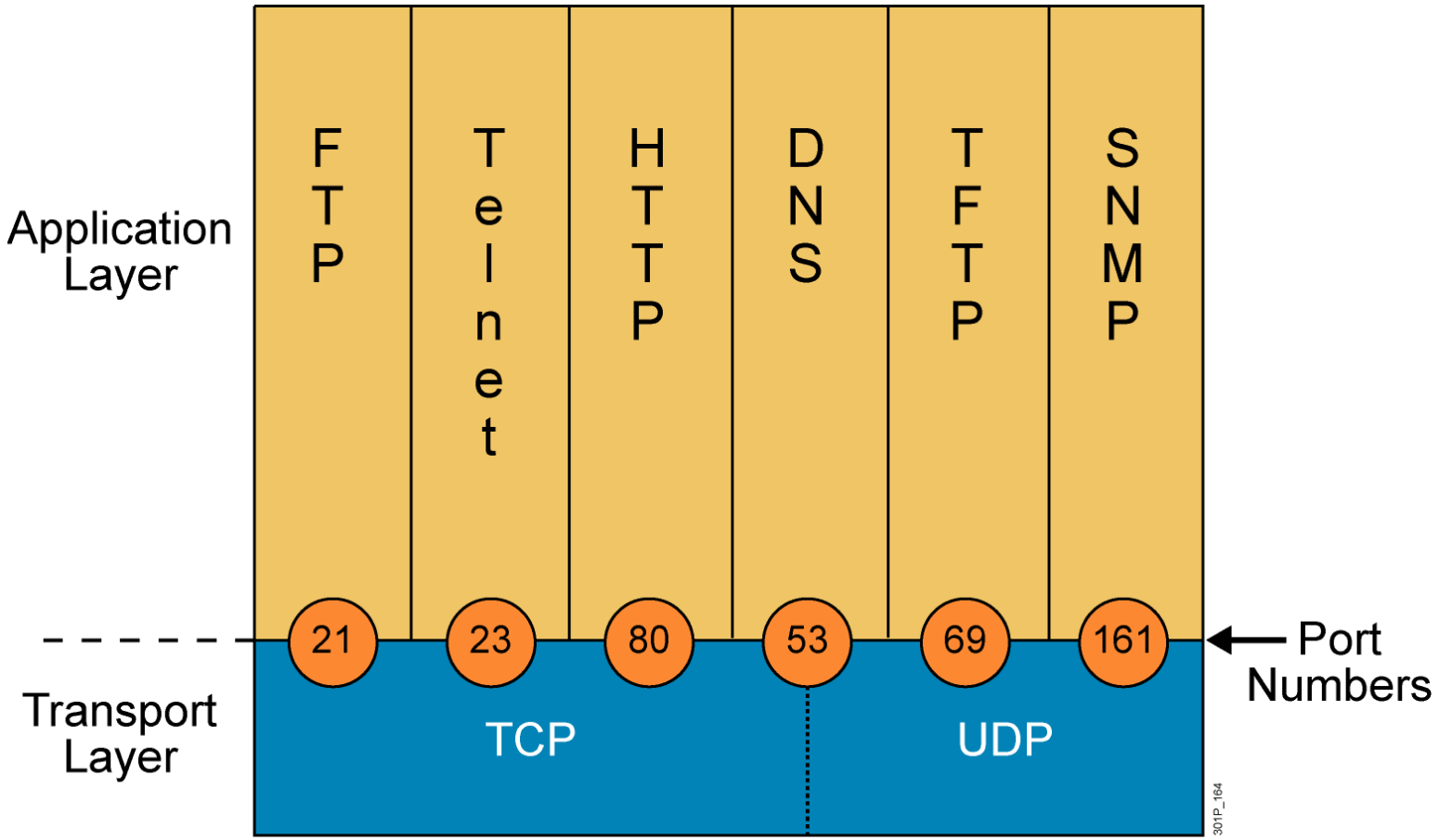
TCP Characteristics

- Transport layer of the TCP/IP stack
- Access to the network layer for applications
- **Connection-oriented** protocol
  - ***reliable***
- Full-duplex mode operation
- Error checking
- Sequencing of data packets
- Acknowledgement of receipt
- Data-recovery features

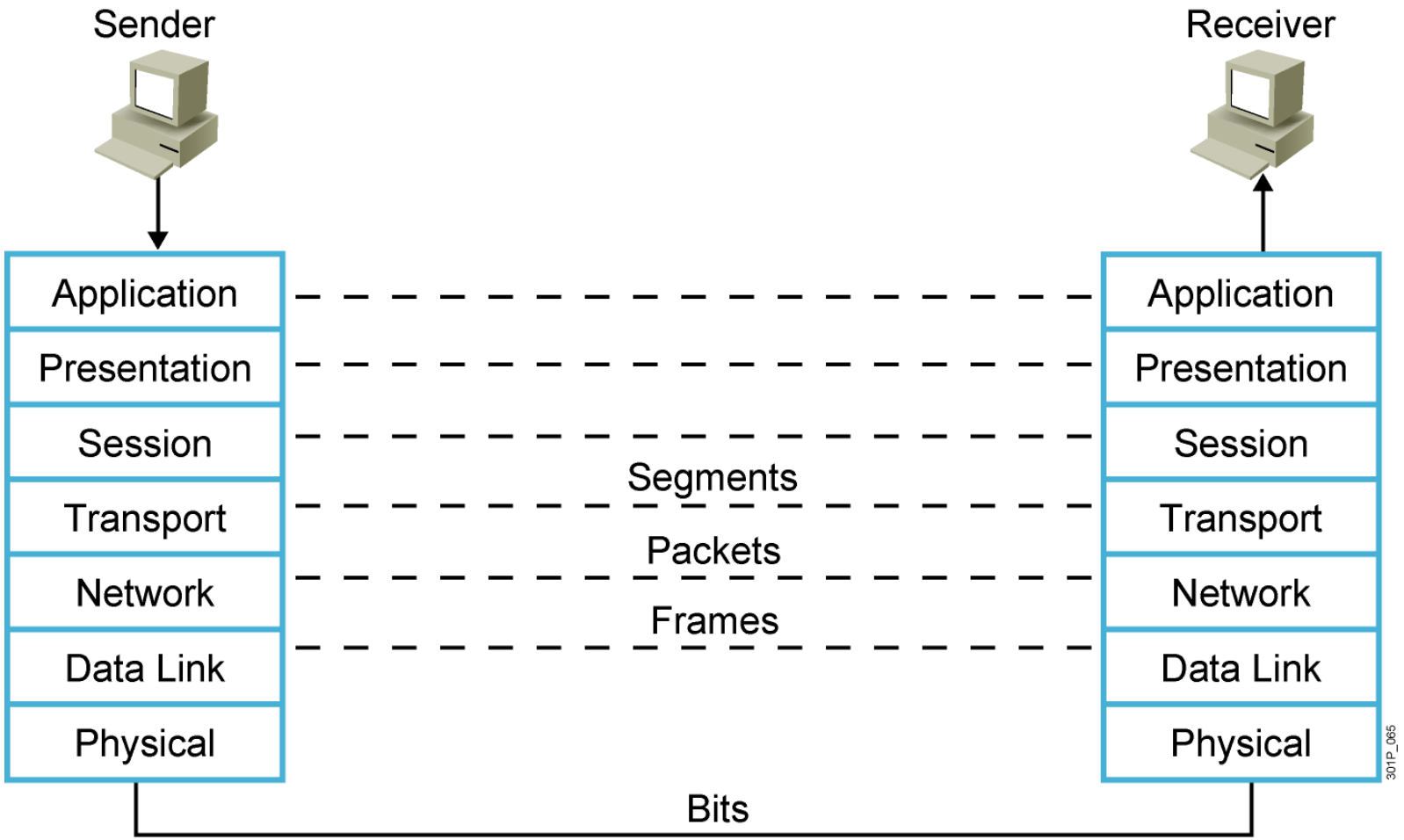
TCP

- Flow control
  - ***Prevents sending to a host and overflowing the buffer***
    - Results in slowing down the network
- Sequencing of segments / acknowledgment
  - ***When a single segment is sent, receipt is acknowledged, and the next segment is then sent***
  - ***Send <-> Ack***
- Window size
  - ***Allows a specified number of unacknowledged segments to be sent***
  - ***Sliding window***
    - window that can change size dynamically to accommodate the flow of segments

Mapping L4 to L7 (Applications)

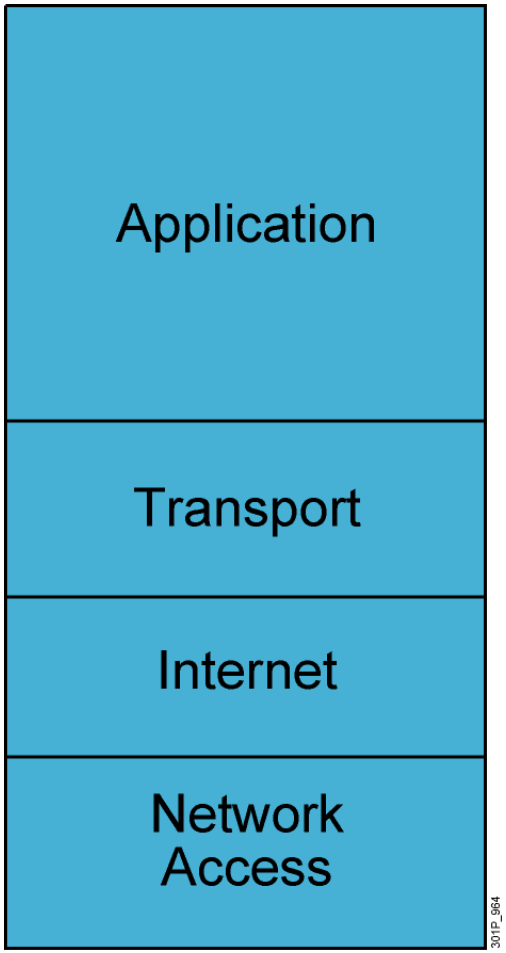


Peer-to-Peer Communication

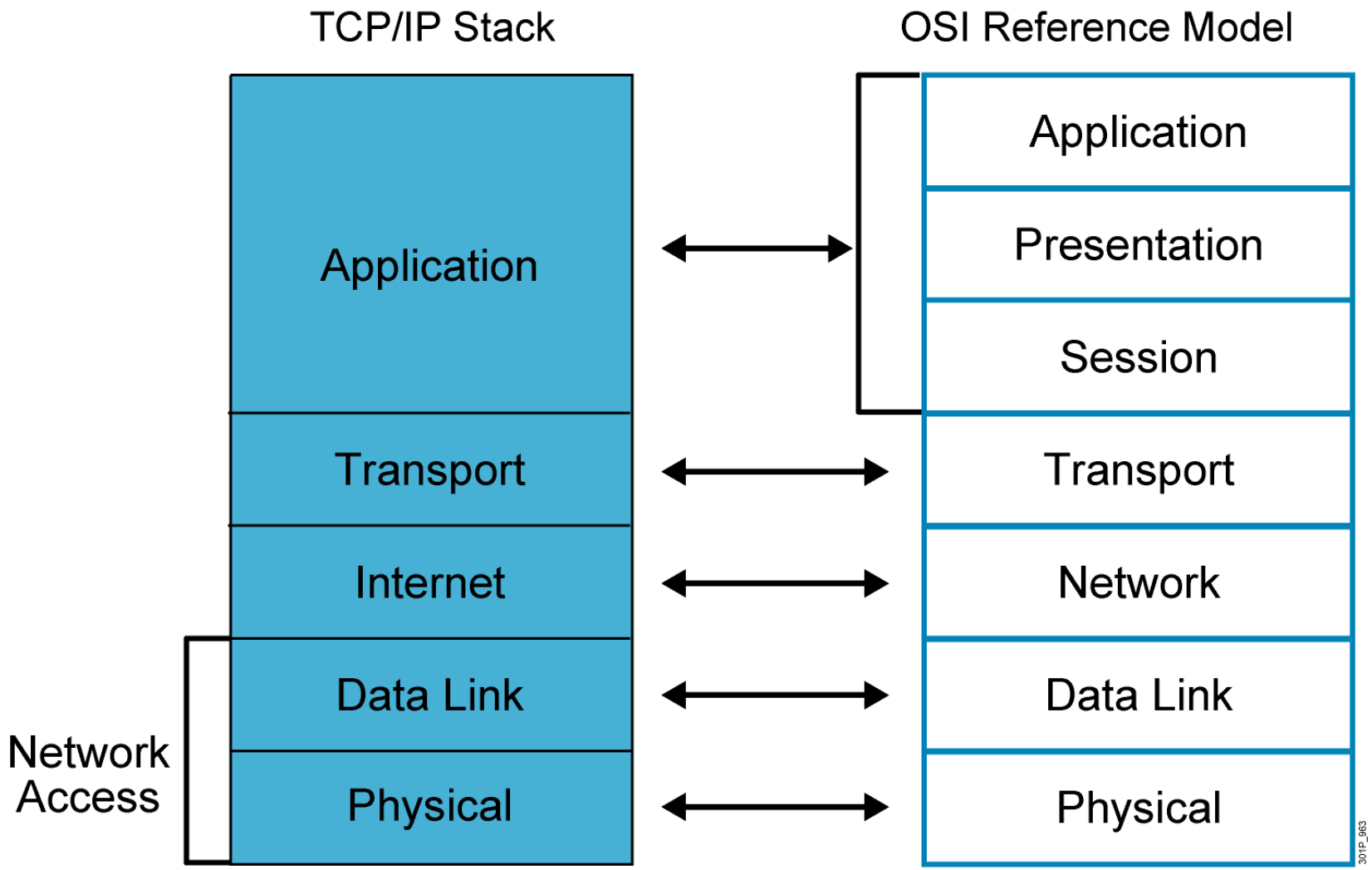


TCP/IP Stack

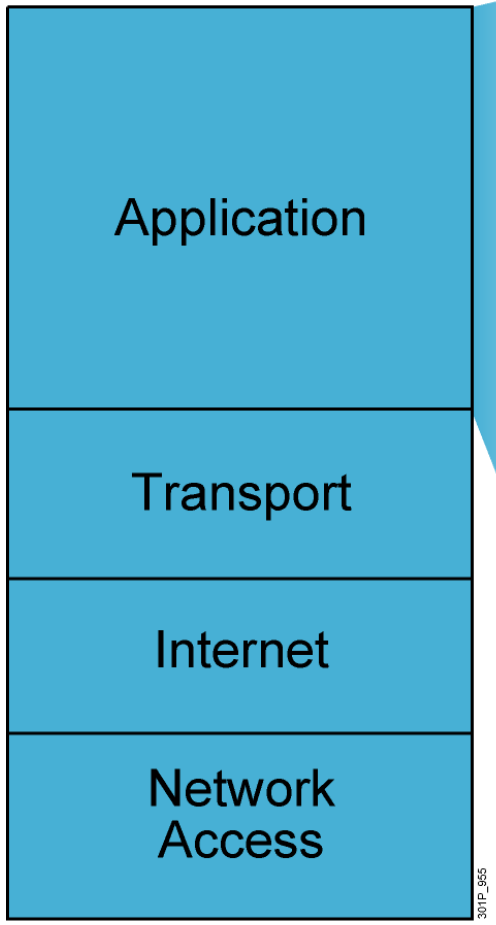
- Defines four layers
- Uses different names for Layers 1 through 3
- Combines Layers 5 through 7 into single application layer



TCP/IP Stack vs. OSI Model

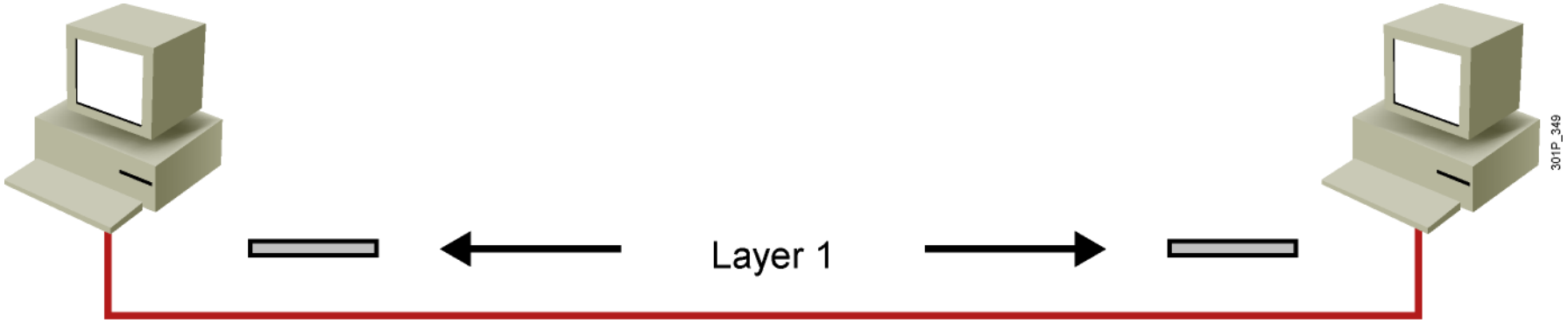


TCP/IP Application Layer Overview



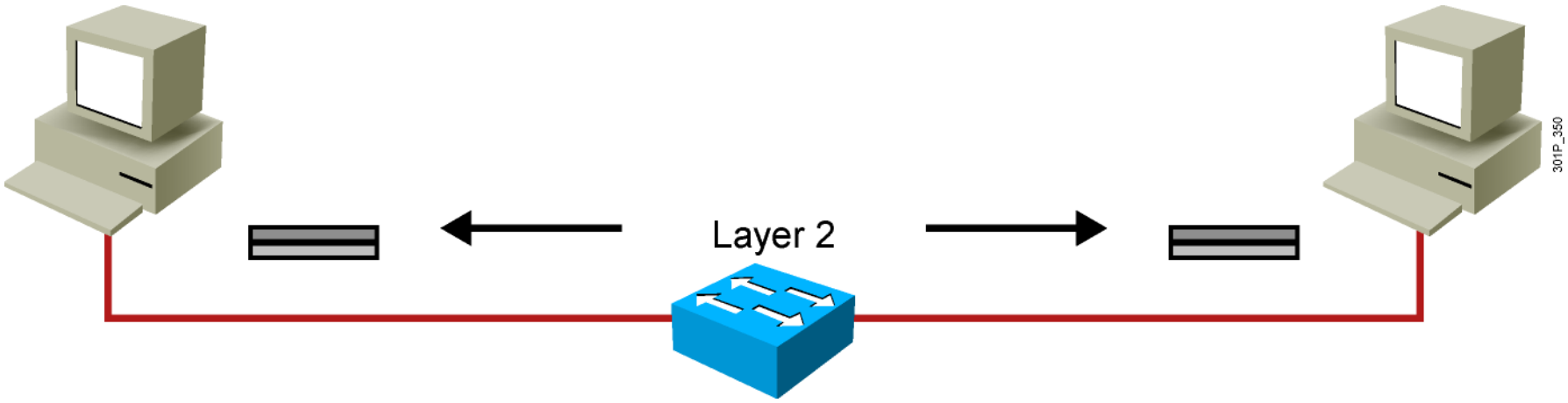
- File transfer
  - FTP (20/21)
  - TFTP (69)
  - Secure Copy Protocol (SCP – 22)
- E-mail
  - Simple Mail Transfer Protocol (SMTP - 25)
- Remote login
  - Telnet (23)
  - SSH (22)
- Network management
  - Simple Network Management Protocol (SNMP - 161)
- Name management
  - Domain Name System (DNS - 53)

Layer 1 Devices



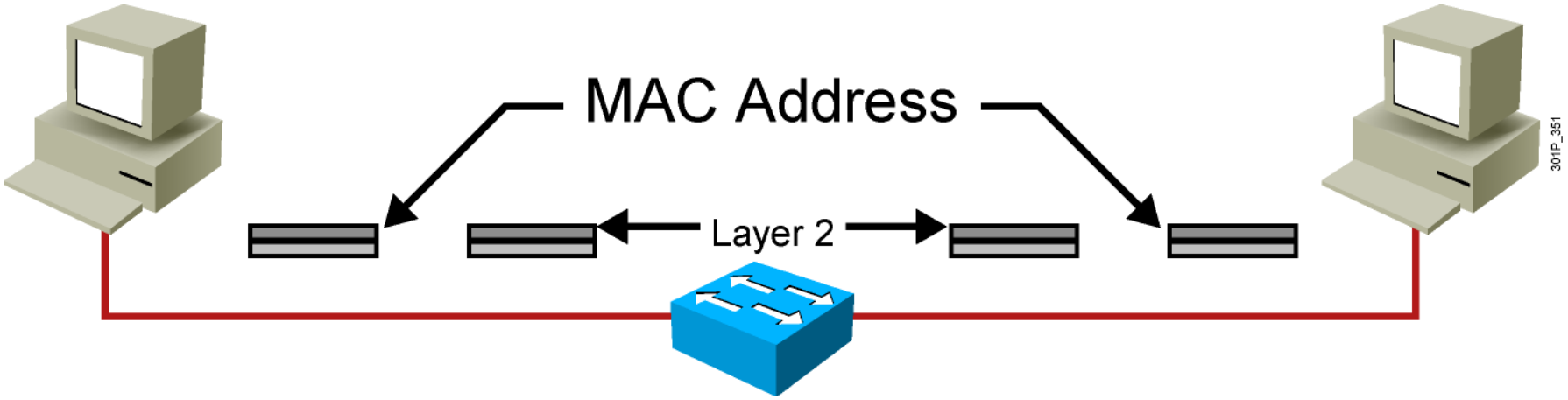
- Layer 1 provides the physical media and its encoding
- PDU = Bits – 1s and 0s
- Examples:
  - ***Serial***
  - ***Repeater / Hub***
  - ***Physical interface of the NIC***
  - ***Electrical signals***
  - ***Power cables***

Layer 2 Devices



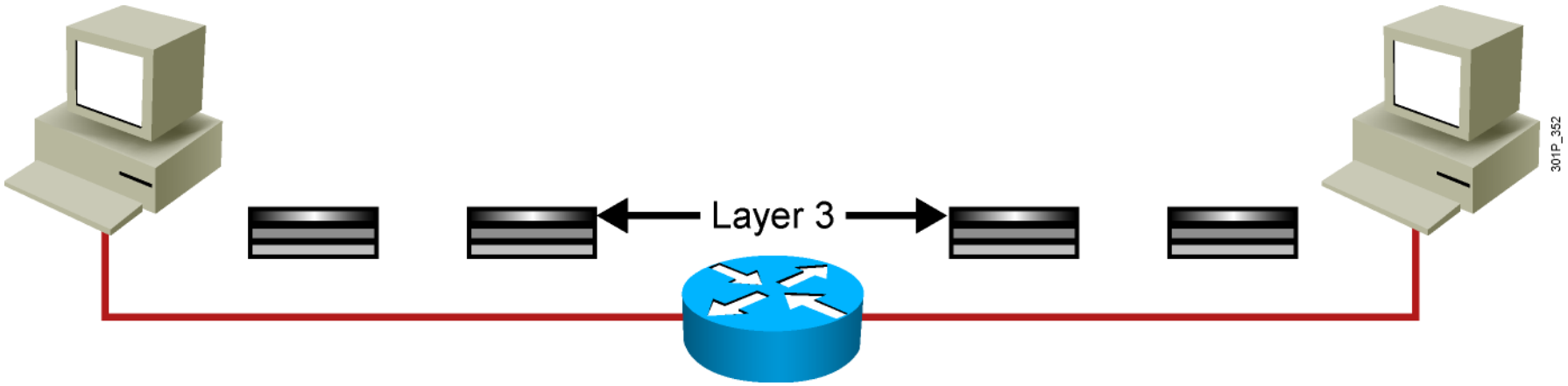
- Layer 2 devices provide an interface with the physical media and physical addressing
- PDU = Frames
- Examples:
  - ***NIC***
  - ***Bridge***
  - ***Switch***

Layer 2 Addressing



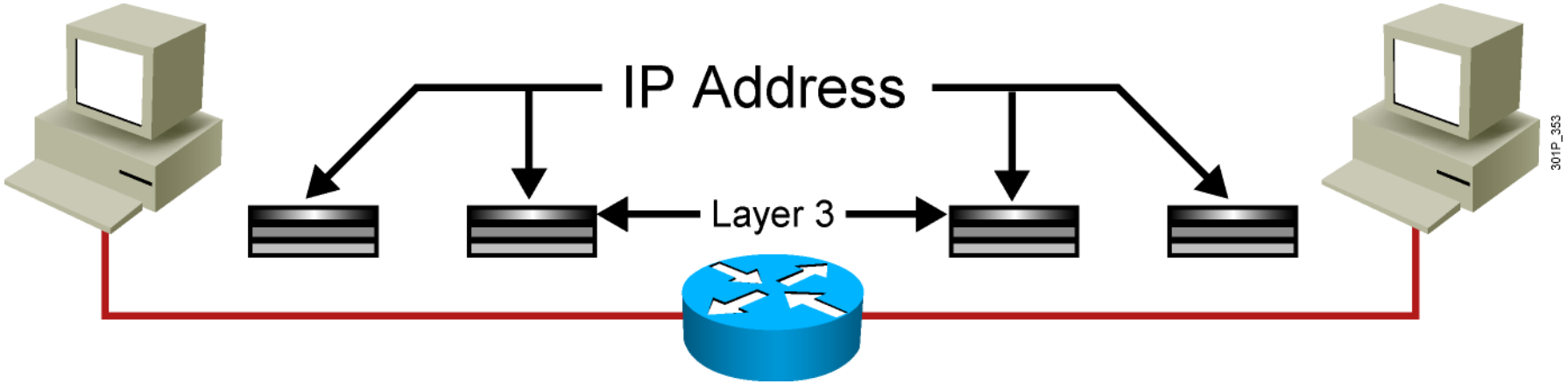
- MAC address
  - ***48-bit address (in Hexadecimal)***
  - ***24 bits vendor specific & 24 bits host specific***
- Assigned to end devices
  - ***Unique world-wide***
- This is how devices on the same segment communicate!
- In class exercise
  - ***MAC address lookup***
    - Vendor Specific

Layer 3 Devices and Their Function



- The network layer provides connectivity and path selection between two host systems.
- In the host, this is the path between the data link layer and the upper layers.
- In the router, it is the actual path across the network (routing and forwarding).

Layer 3 Addressing



- Each networking device has its own Layer 3 logical address (IP address)
- PDU = Packets
- Examples:
  - ***Routers***

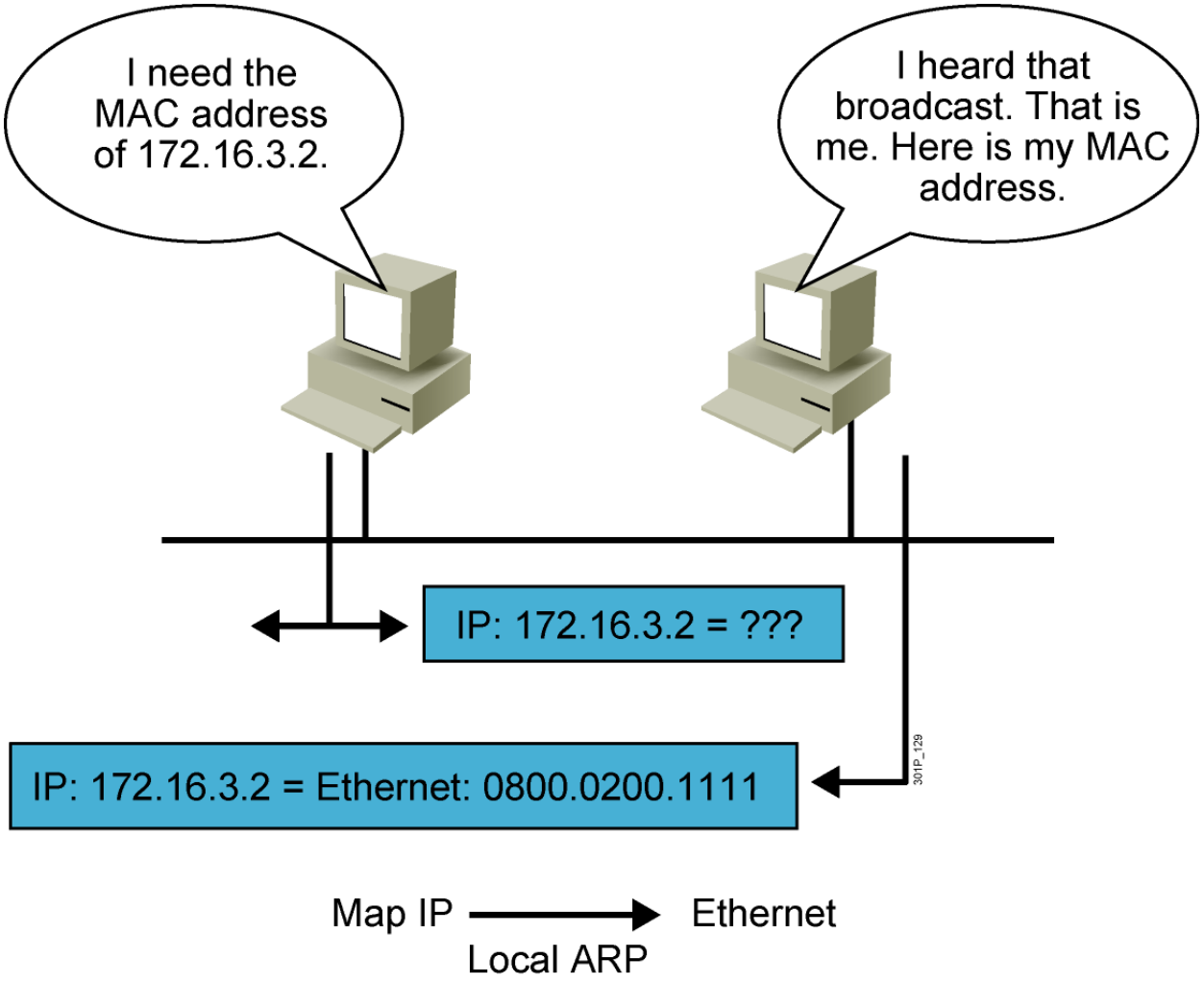
Address Resolution Protocol (ARP)

- **Provides a map of IP address to MAC address**

- **"I know the IP address (Layer 3), but I need the MAC address (Layer 2) to talk to it directly on my link (Ethernet)."**

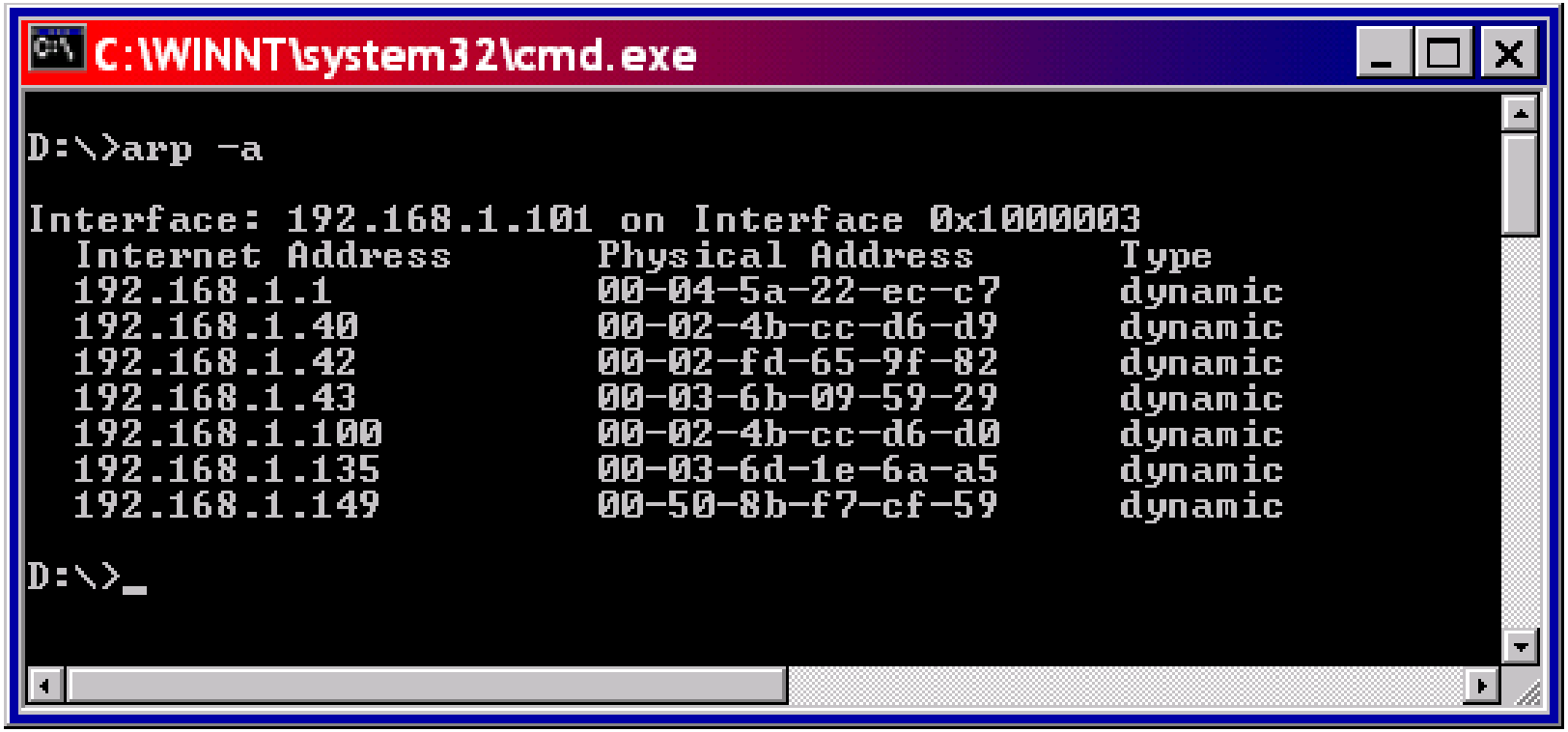
- **Broadcast & Unicast**
  - Same link/network

Address Resolution Protocol (ARP)



ARP (See Appendix B for ARP)

ARP Table


C:\WINNT\system32\cmd.exe
D:\>arp -a
Interface: 192.168.1.101 on Interface 0x1000003
Internet Address Physical Address Type
192.168.1.1 00-04-5a-22-ec-c7 dynamic
192.168.1.40 00-02-4b-cc-d6-d9 dynamic
192.168.1.42 00-02-fd-65-9f-82 dynamic
192.168.1.43 00-03-6b-09-59-29 dynamic
192.168.1.100 00-02-4b-cc-d6-d0 dynamic
192.168.1.135 00-03-6d-1e-6a-a5 dynamic
192.168.1.149 00-50-8b-f7-cf-59 dynamic
D:\>_

Review

- **ARP**
  - Broadcast
  - Maps known IP address to MAC address

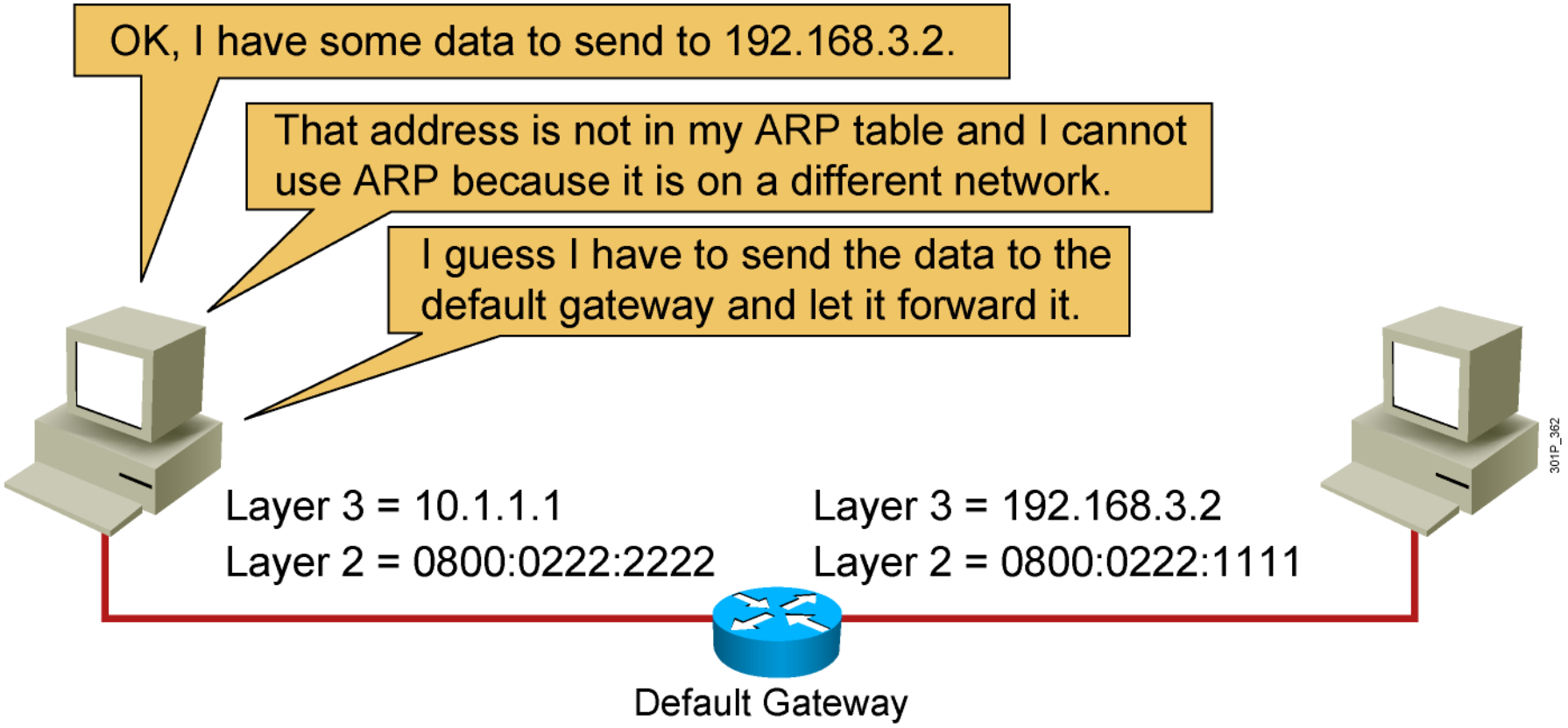
- **MAC address is how devices communicate at Layer 2**

- **IP address is how devices communicate at Layer 3**

Remote Network

- **What happens if you want to send traffic to a device outside of your local network?**
  - IP address
  - Subnet mask
  - ARP
  - Default gateway

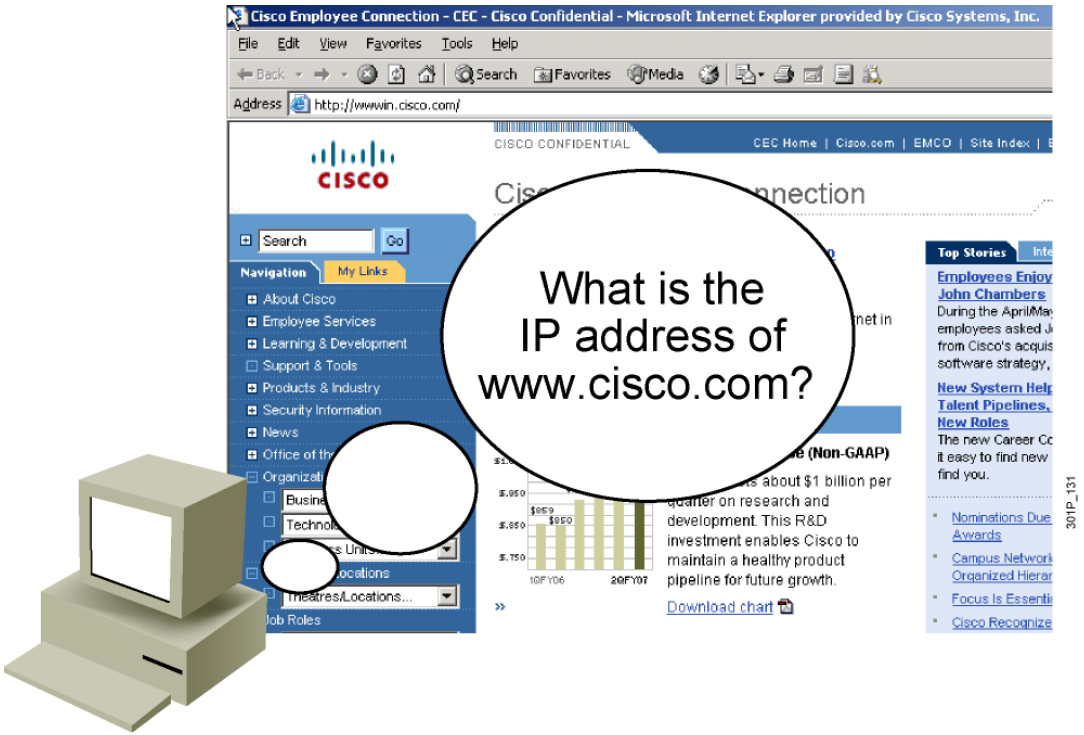
Default Gateway



ipconfig/all (Windows) or *ifconfig* | *more* (Linux/Mac)

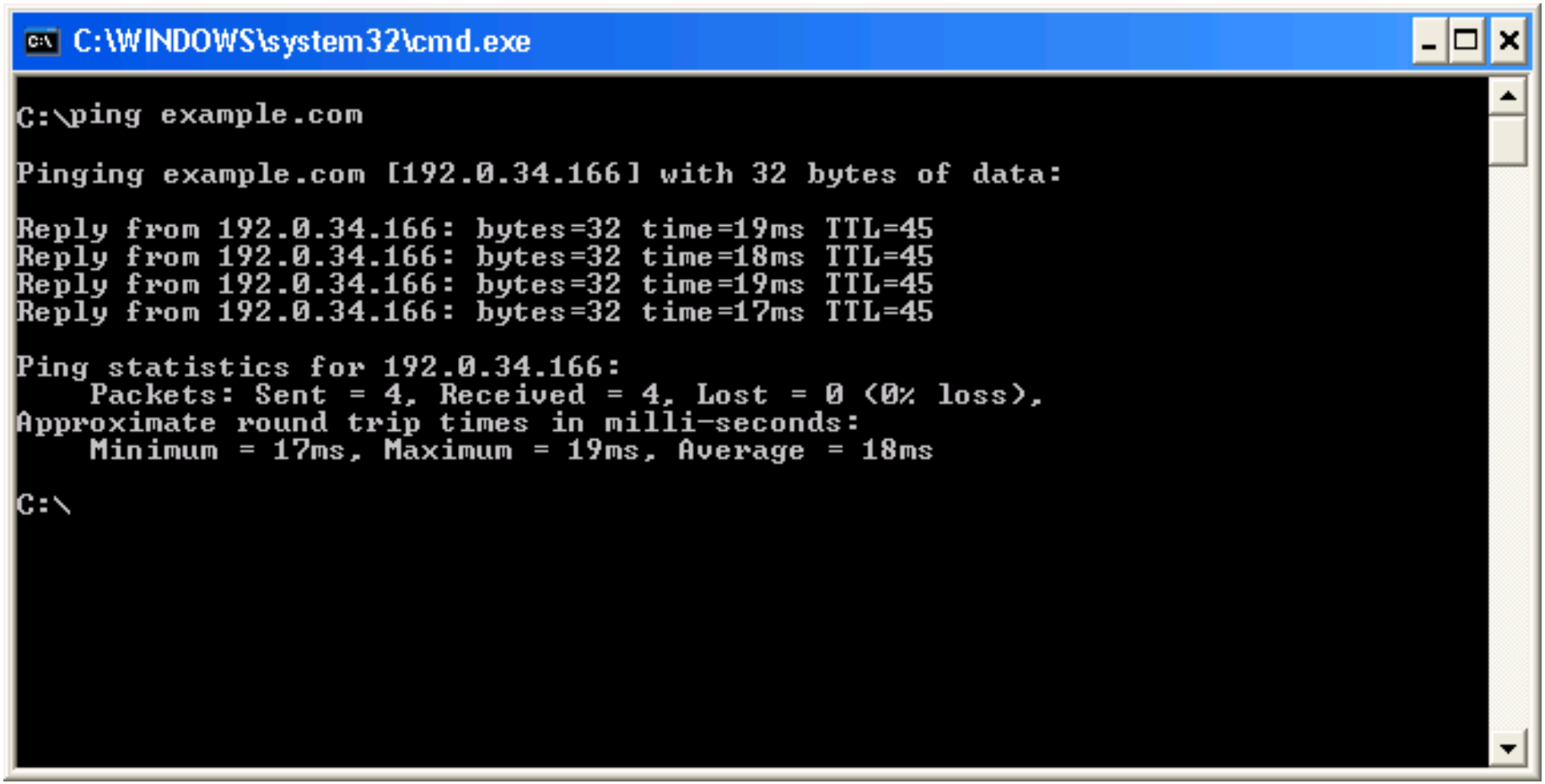
```
Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) Dual Band Wireless-AC 7260
   Physical Address. . . . . . . . . : CC-3D-82-87-20-94
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::dc91:eadf:2fc7:a4c2%15(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.111.103(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Monday, August 29, 2016 8:28:21 AM
   Lease Expires . . . . . . . . . . : Tuesday, August 30, 2016 8:28:20 AM
   Default Gateway . . . . . . . . . : 192.168.111.254
   DHCP Server . . . . . . . . . . . : 192.168.111.254
   DHCPv6 IAID . . . . . . . . . . . : 80493954
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-1C-C8-5E-5B-28-80-23-0B-6D-C4
   DNS Servers . . . . . . . . . . . : 208.67.222.222
                                       208.67.220.220
                                       192.168.111.254
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

DNS



- Application specified in the TCP/IP suite
- A way to translate human-readable names into IP addresses

Host-Based Tools: ping

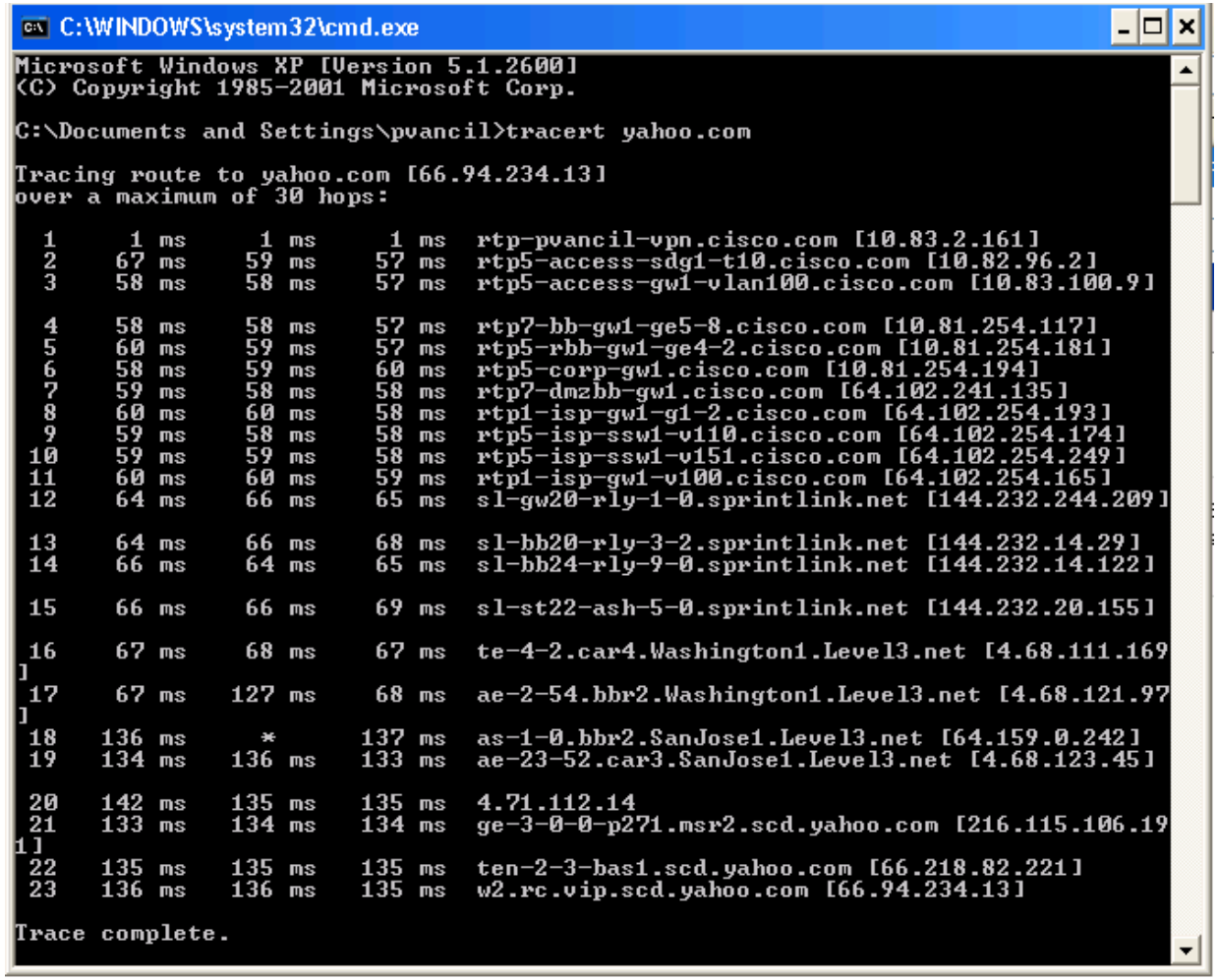


ICMP: Internet Control Message Protocol

- Used by hosts & routers to communicate network-level information
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- Network-layer "above" IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

Type	Code	description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Host-Based Tools: traceroute



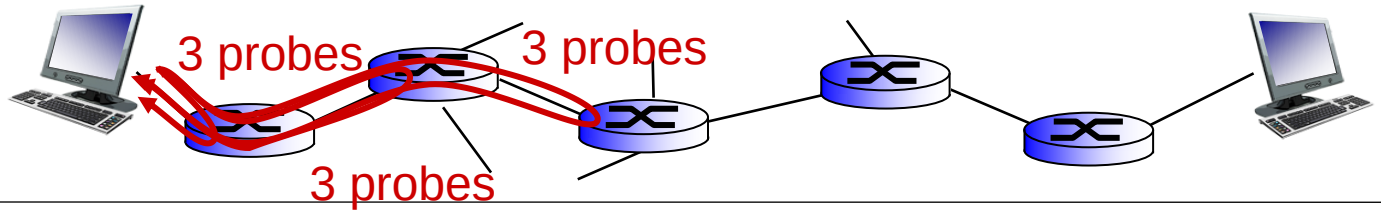
Traceroute and ICMP

- **Source sends series of UDP (depends on OS) segments to destination**
  - first set has TTL =1
  - second set has TTL=2, etc.
  - unlikely port number
- **When datagram in *n*th set arrives to nth router:**
  - router discards datagram and sends source ICMP message (type 11, code 0)
  - ICMP message include name of router & IP address

- **When ICMP message arrives, source records RTTs**

Stopping criteria:

- UDP segment eventually arrives at destination host
- Destination returns ICMP "port unreachable" message (type 3, code 3)
- Source stops

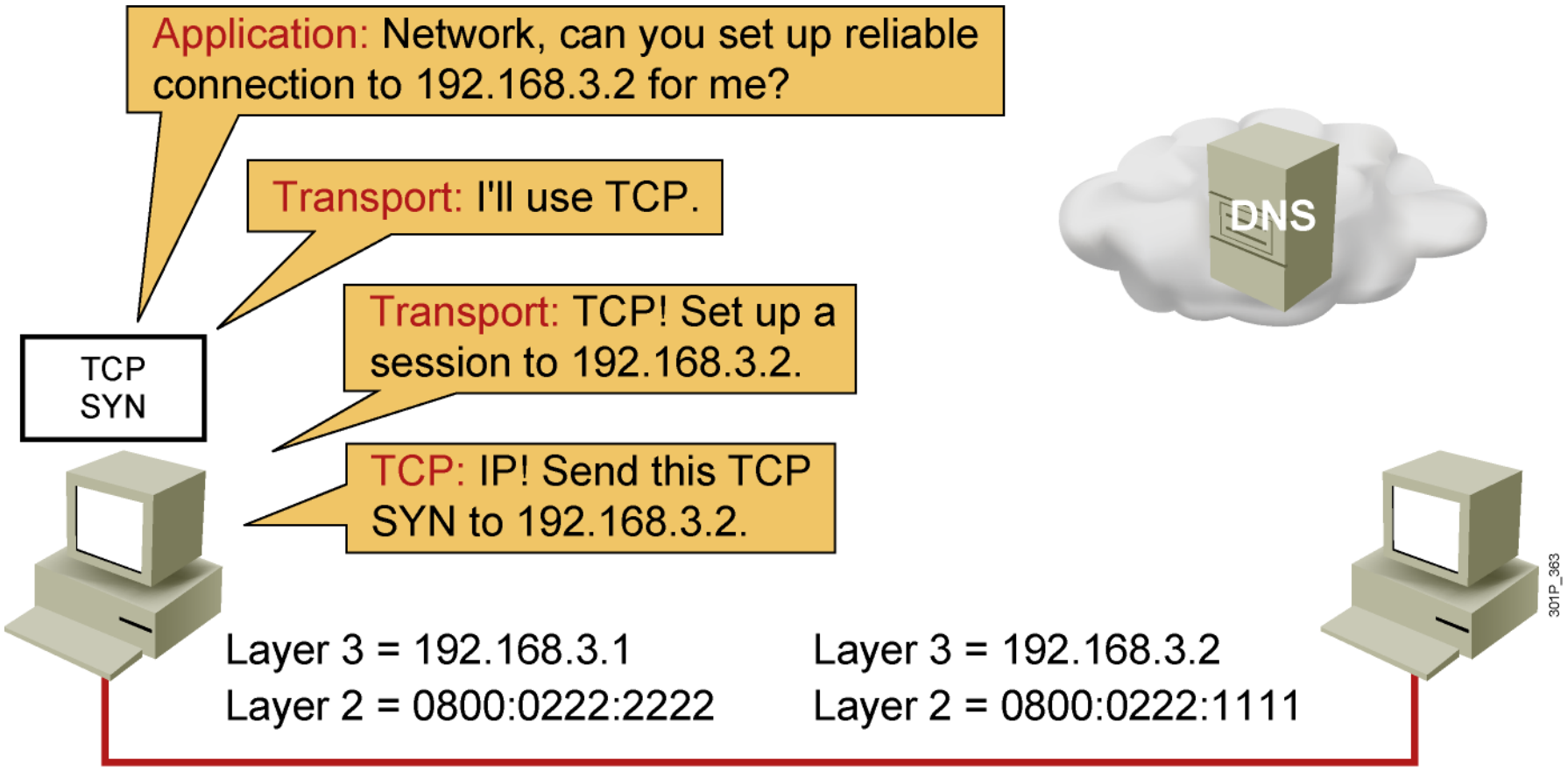


Questions?

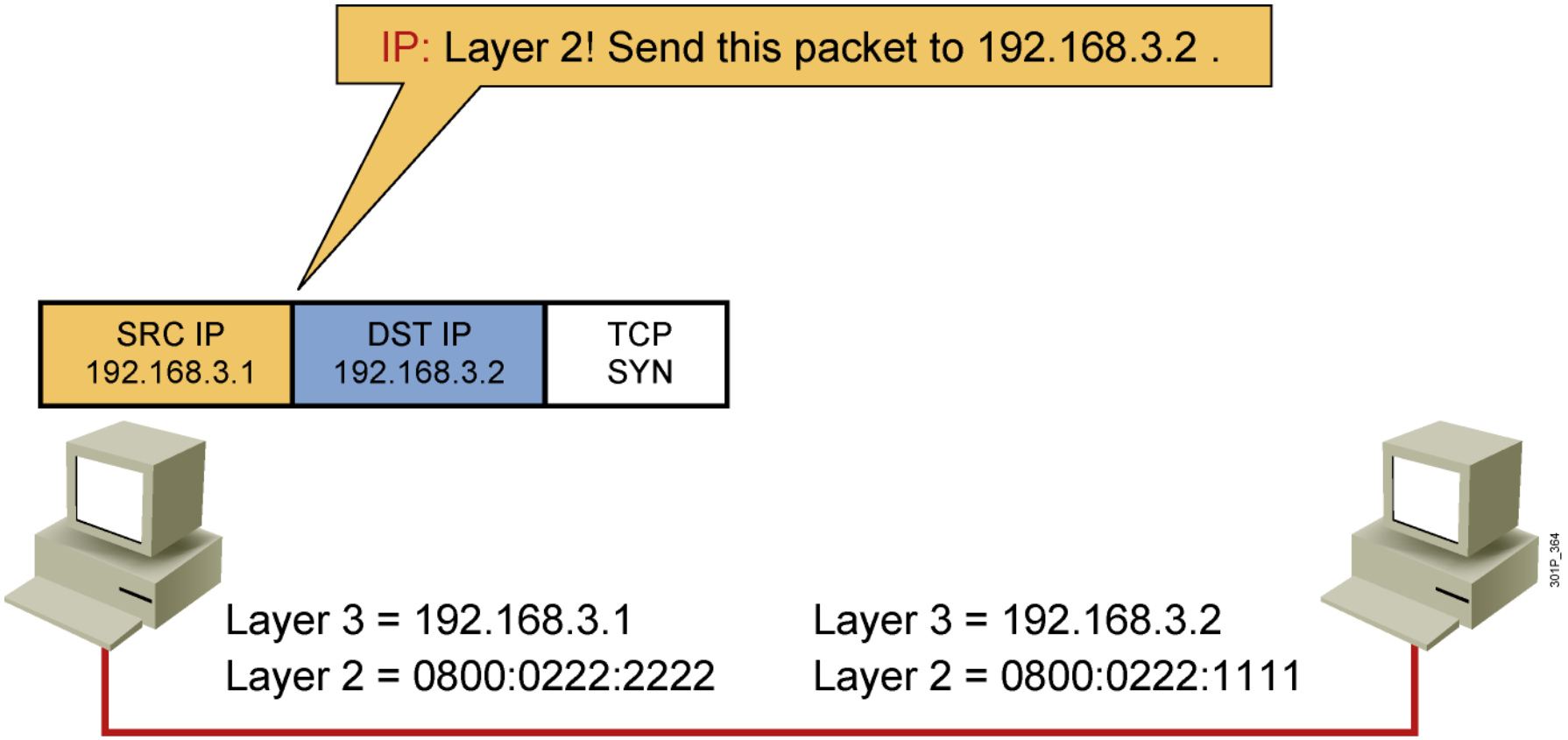
Lab

Appendix B - ARP

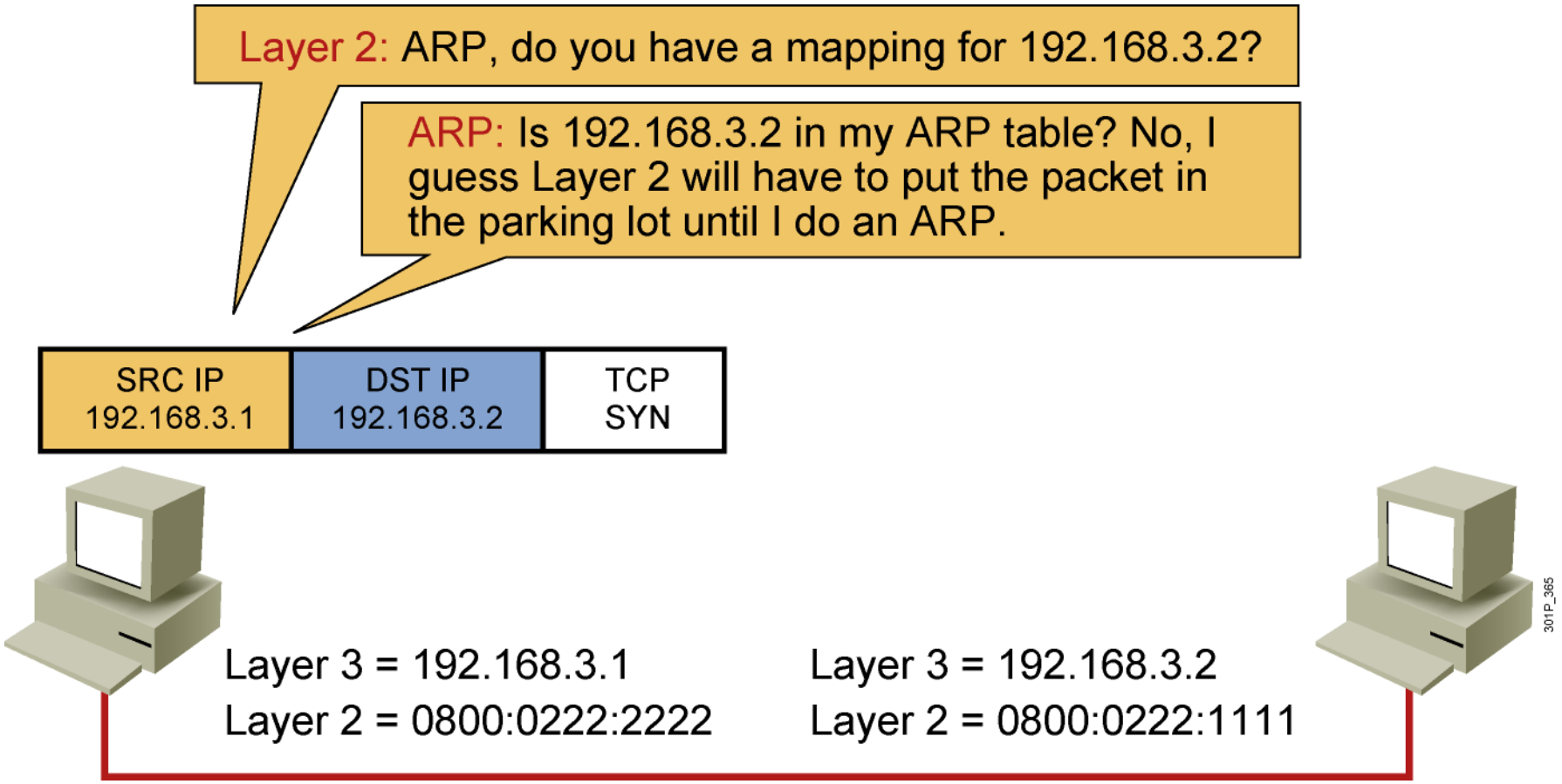
Host-to-Host Packet Delivery (1 of 22)



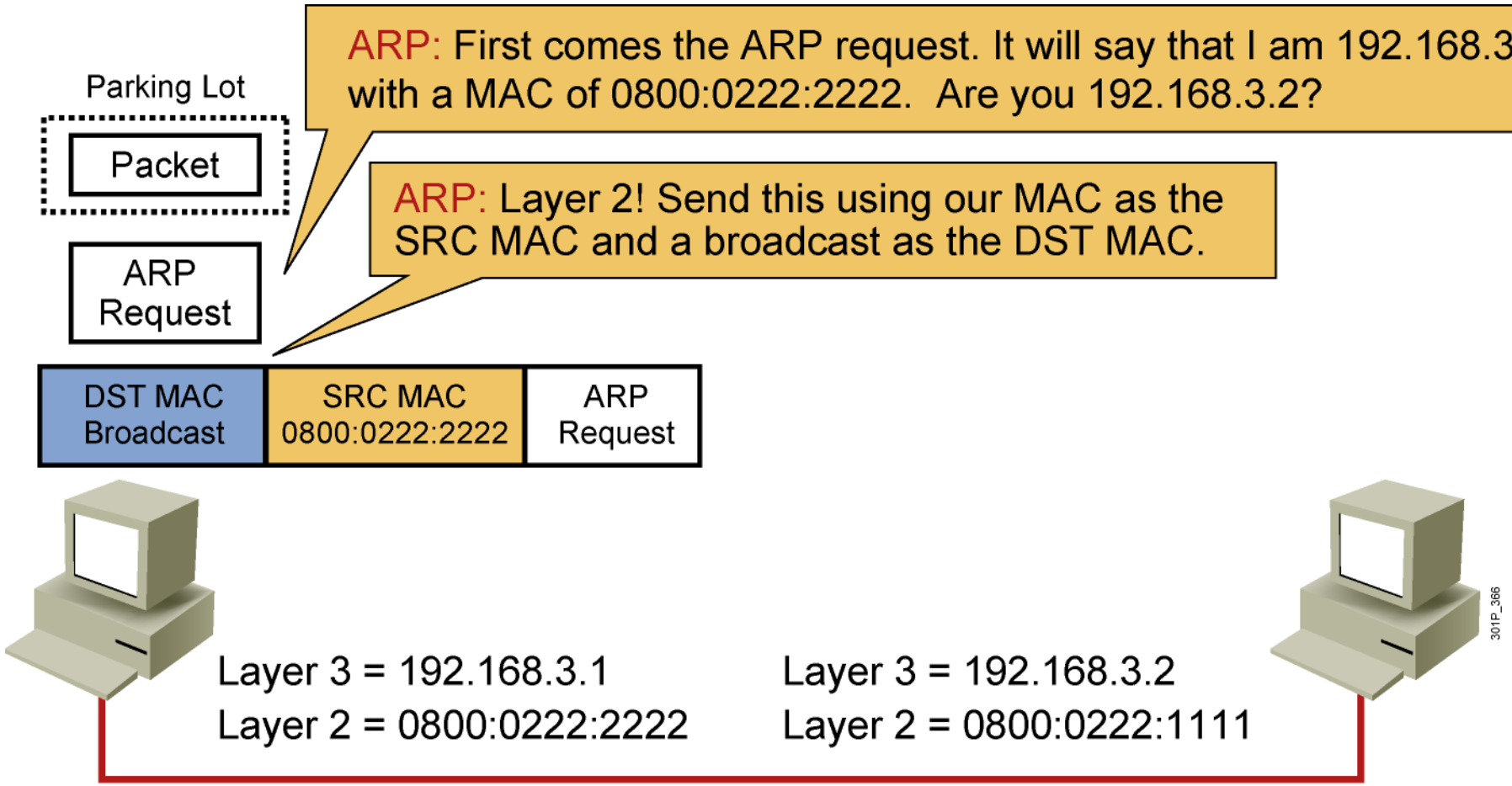
Host-to-Host Packet Delivery (2 of 22)



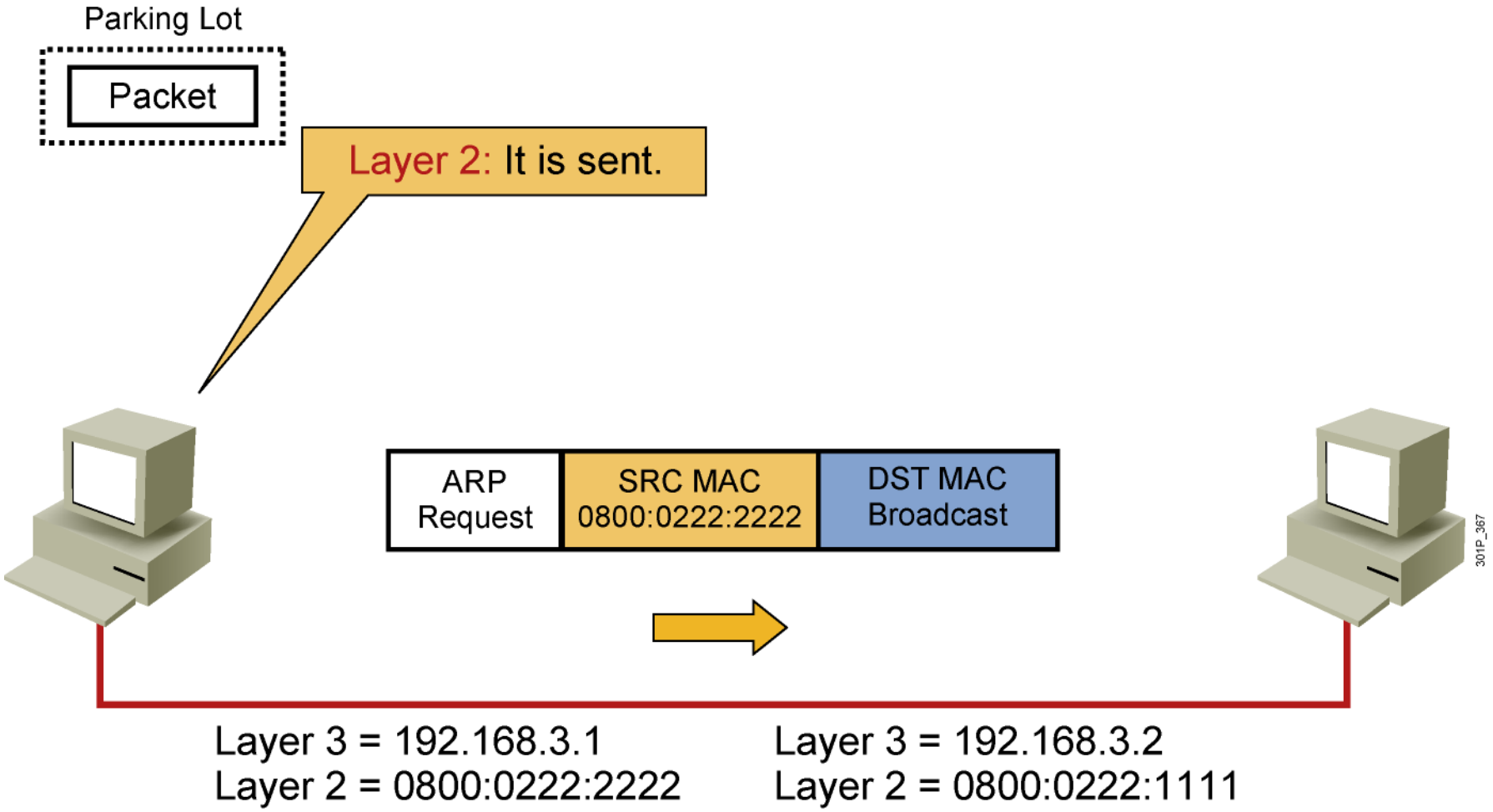
Host-to-Host Packet Delivery (3 of 22)



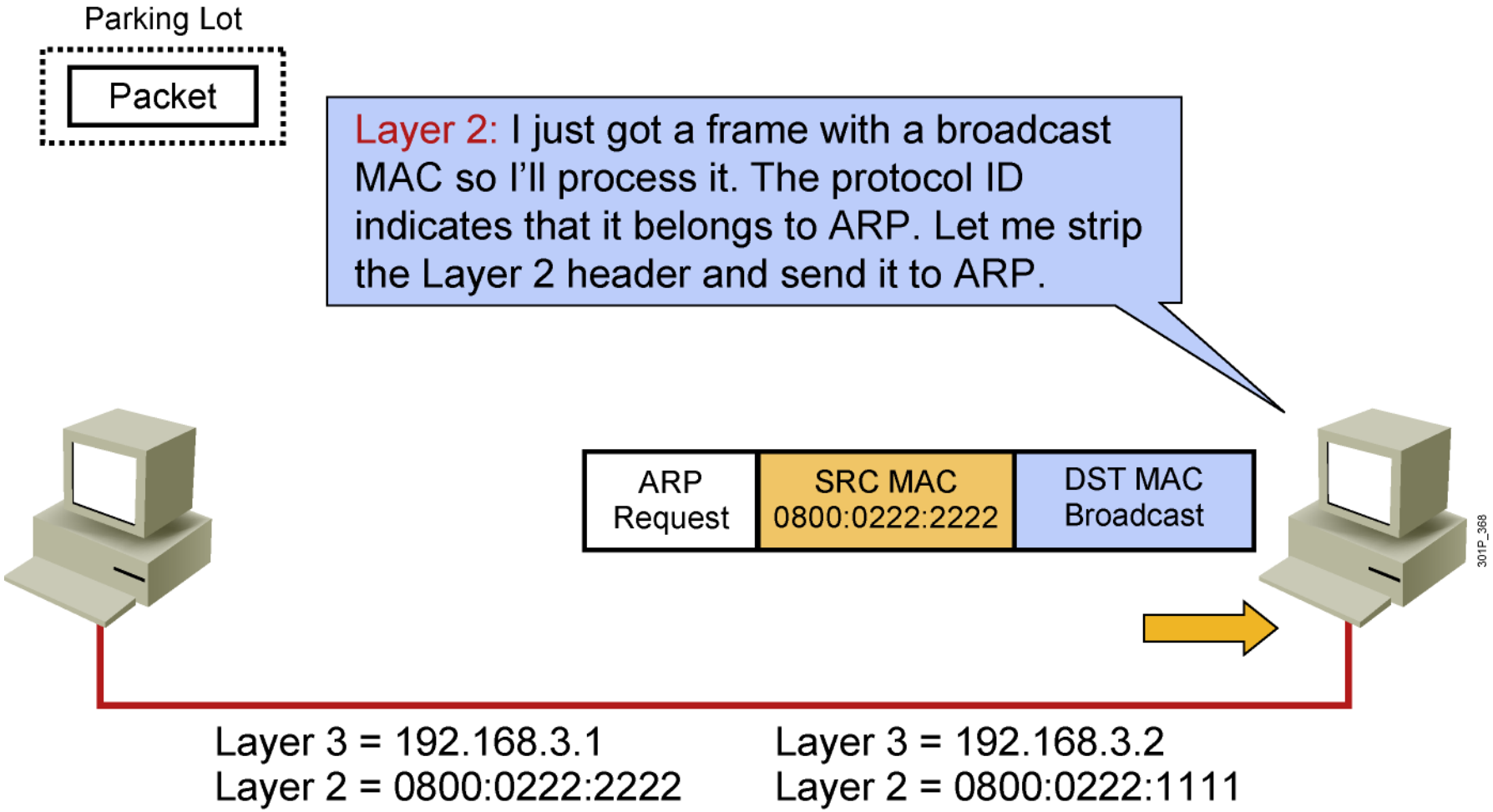
Host-to-Host Packet Delivery (4 of 22)



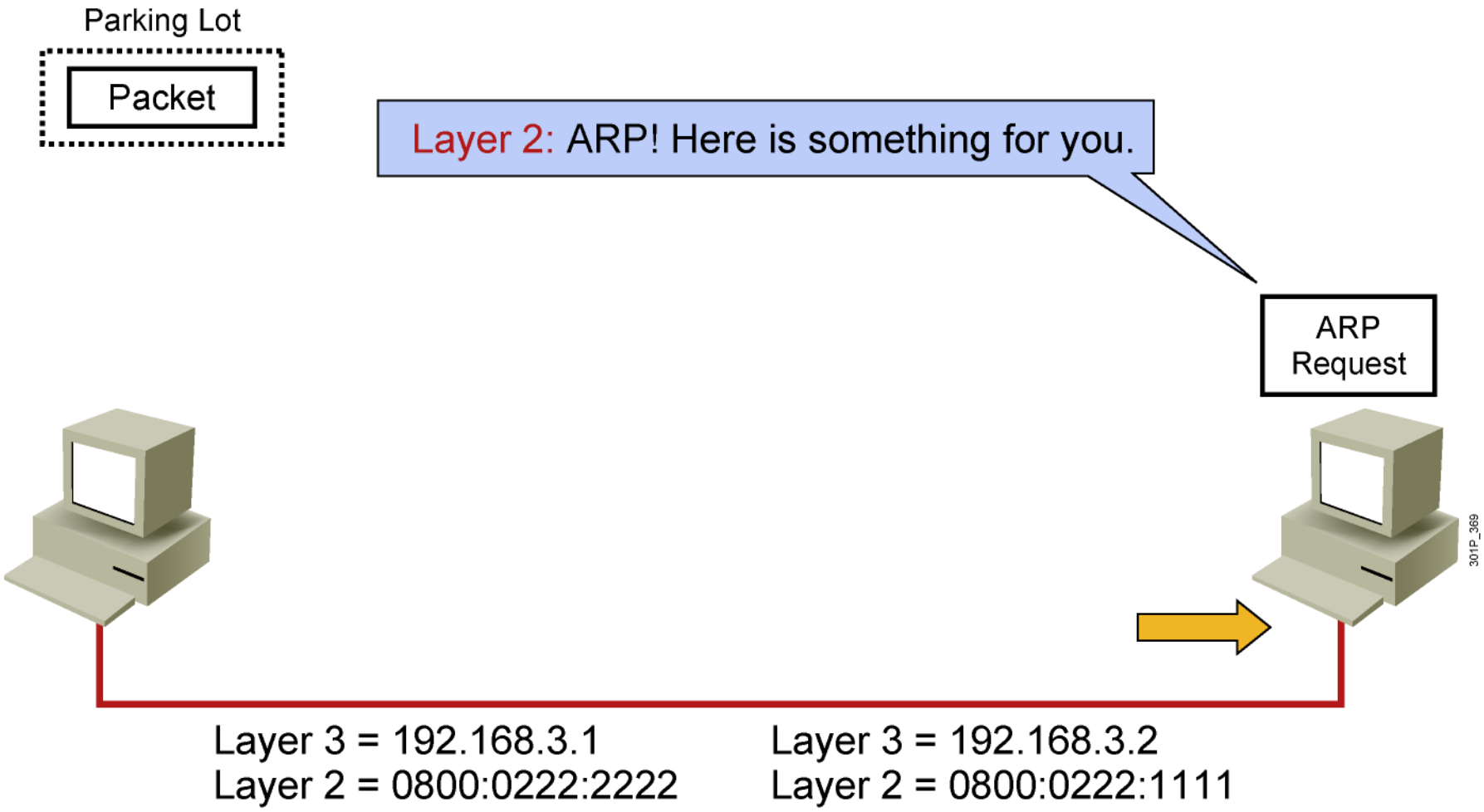
Host-to-Host Packet Delivery (5 of 22)



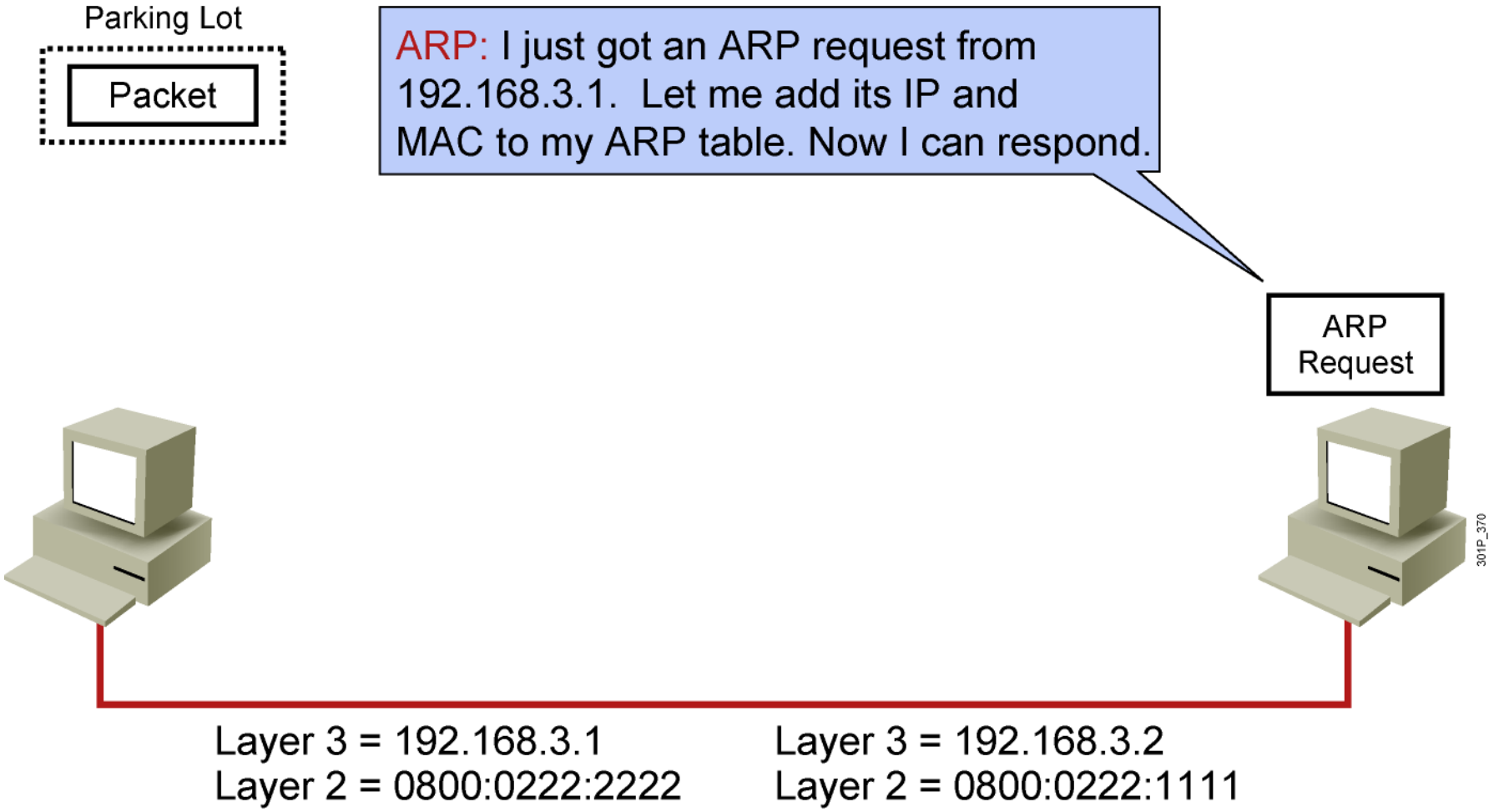
Host-to-Host Packet Delivery (6 of 22)



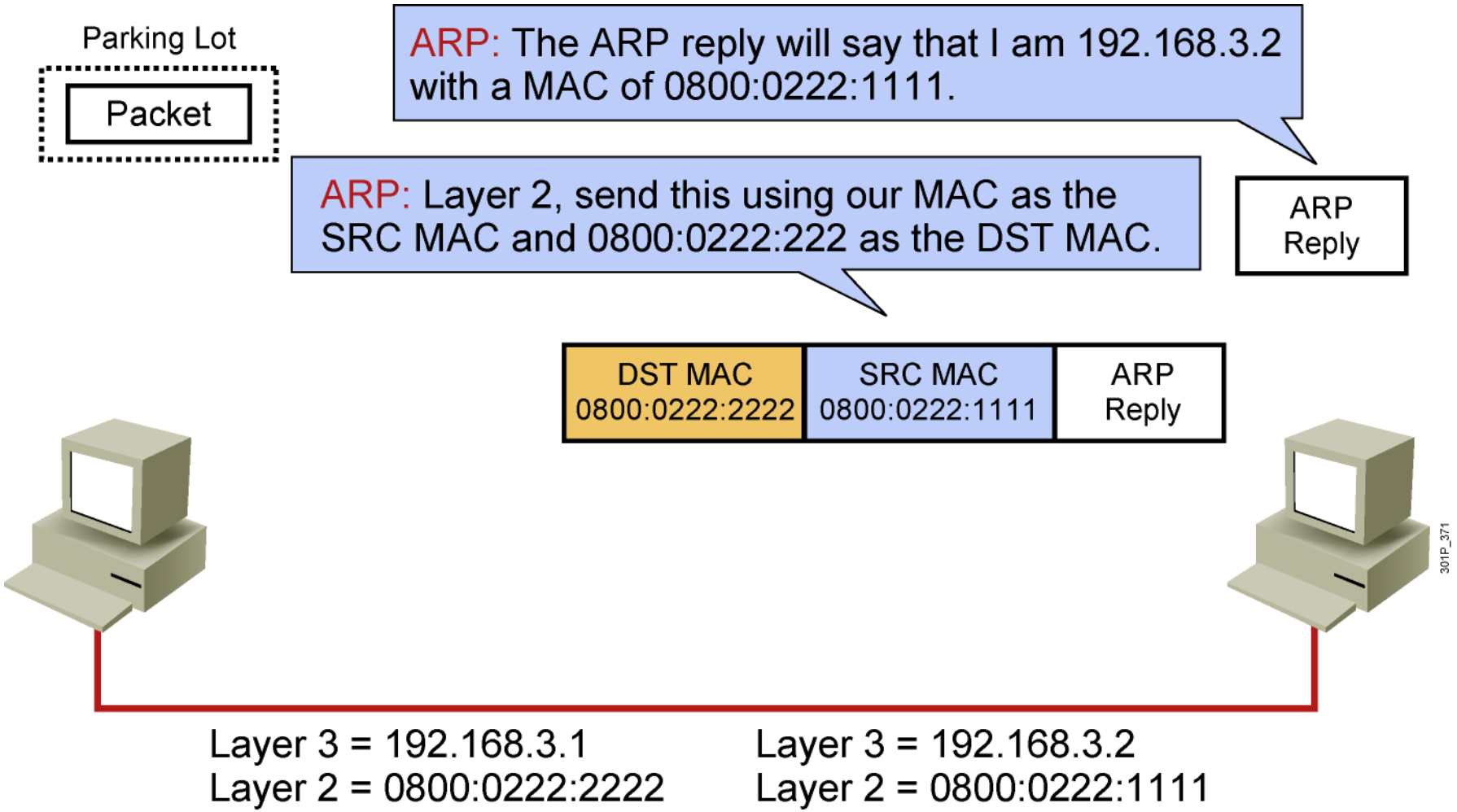
Host-to-Host Packet Delivery (7 of 22)



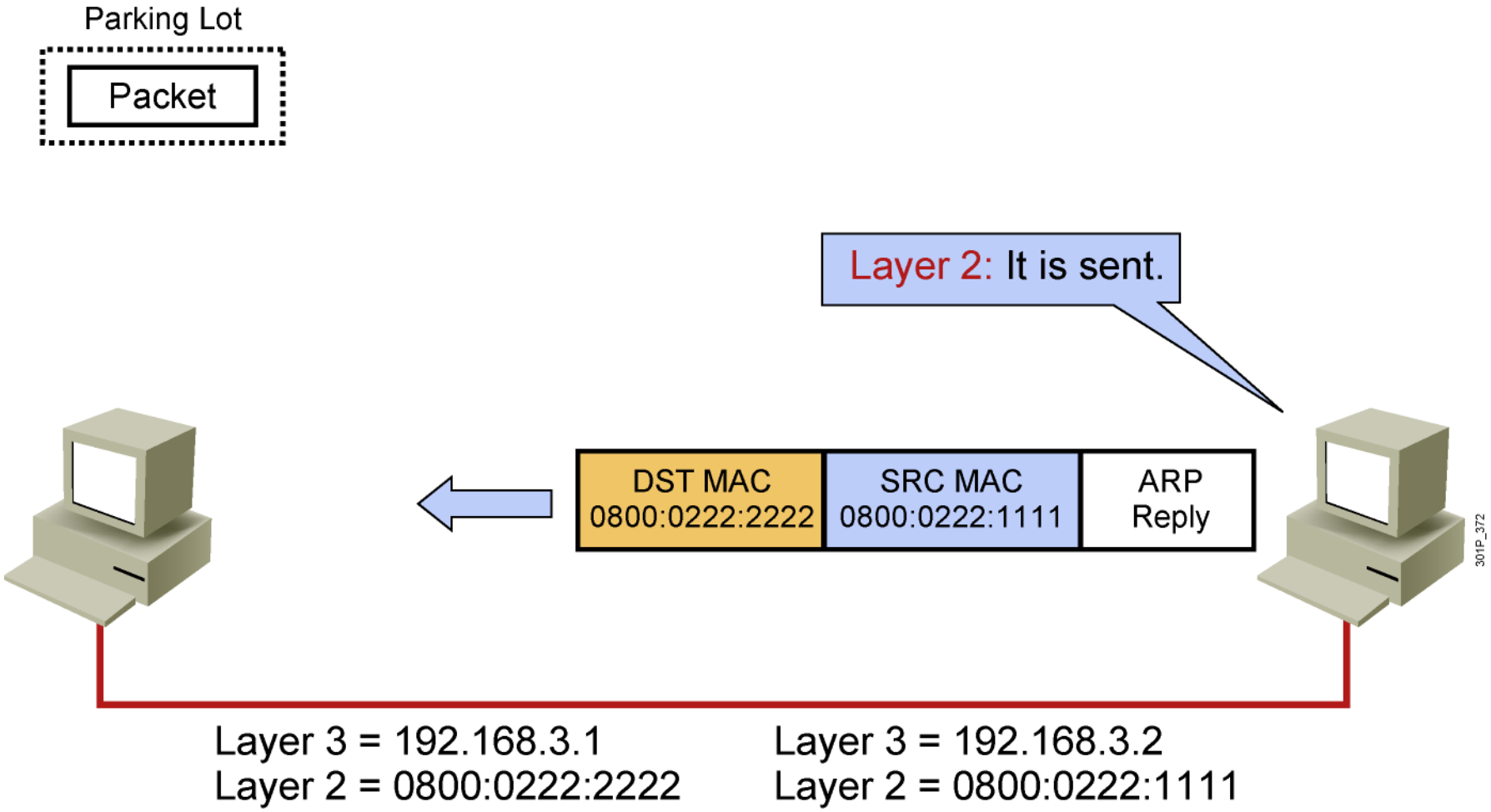
Host-to-Host Packet Delivery (8 of 22)



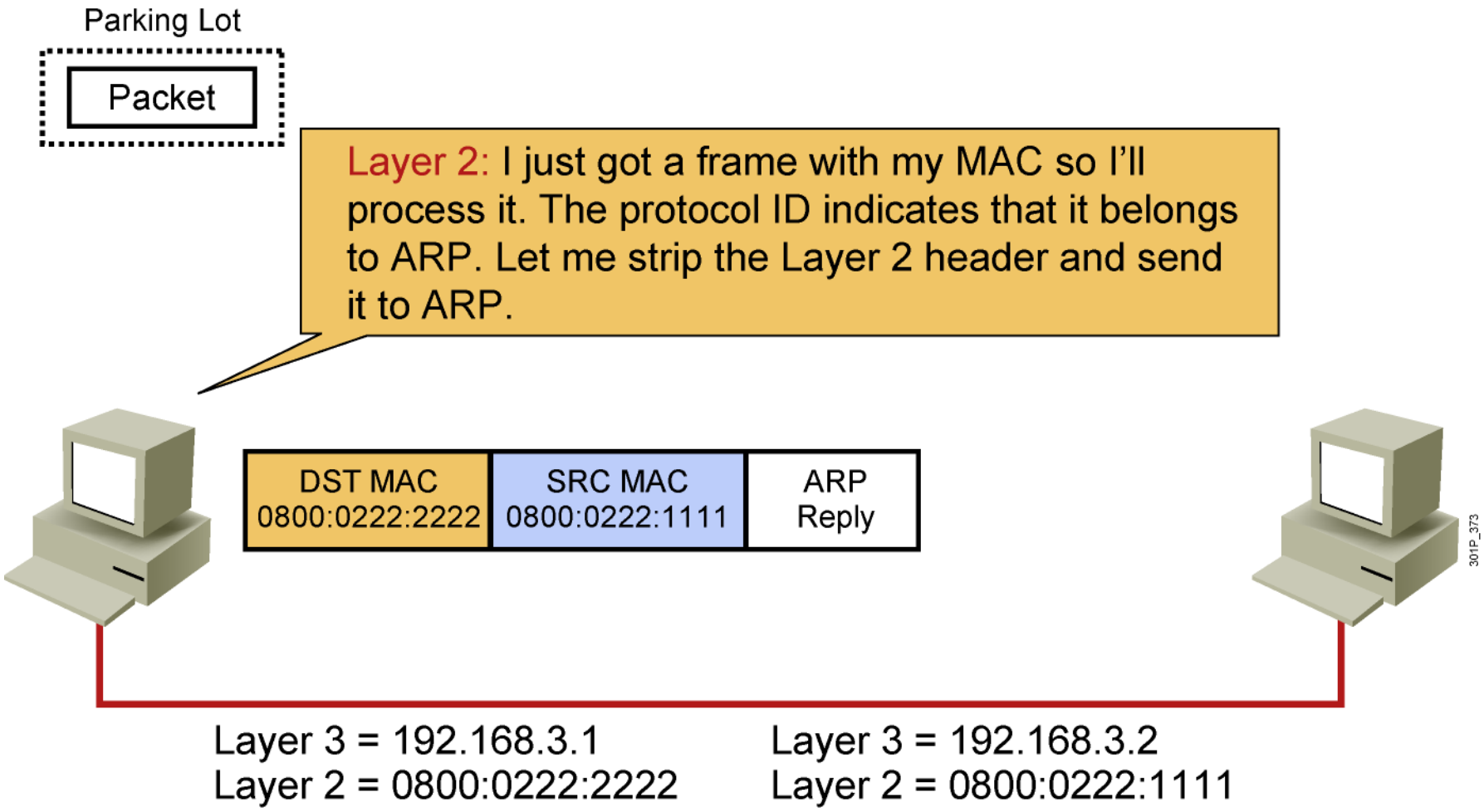
Host-to-Host Packet Delivery (9 of 22)



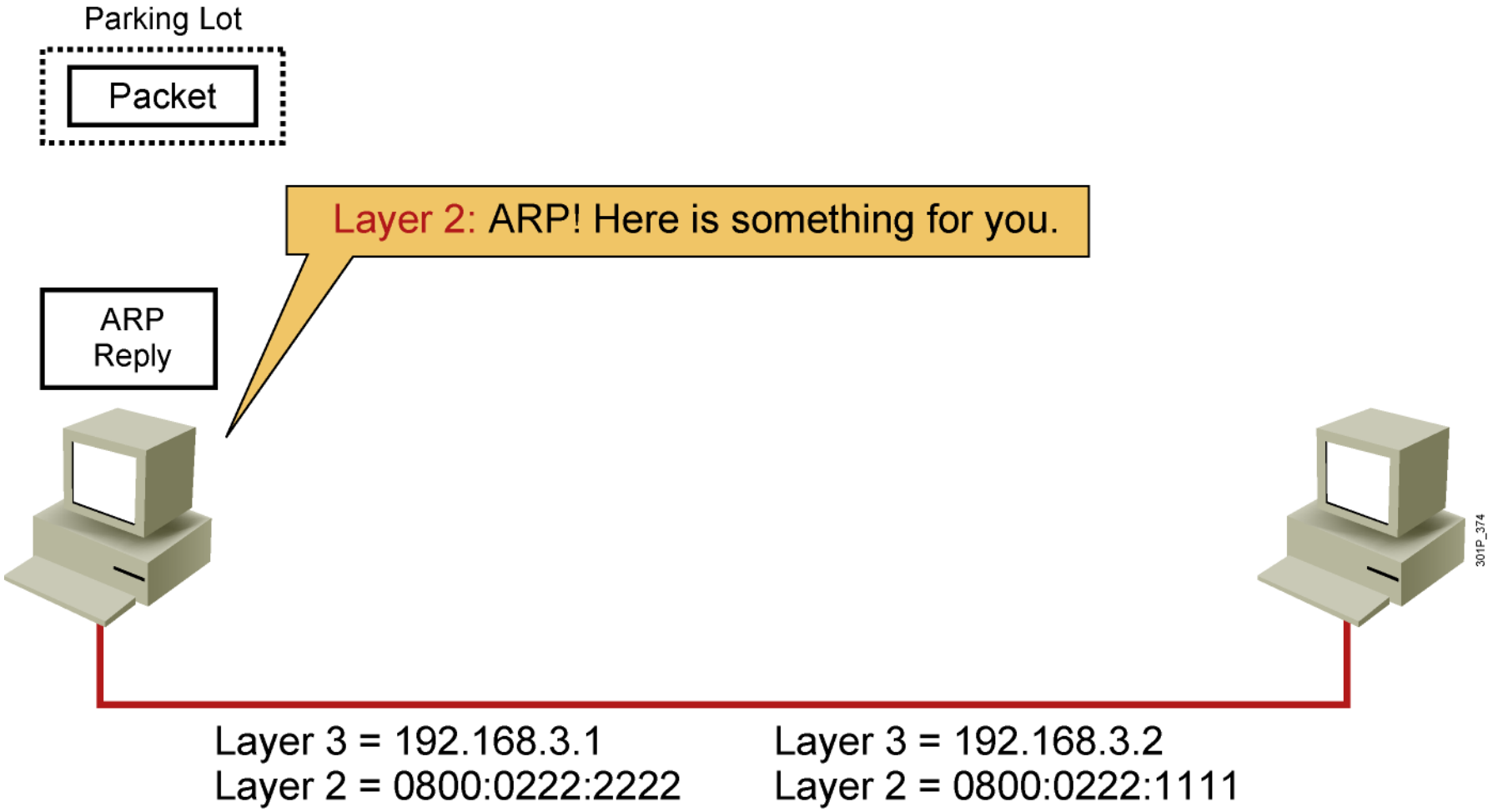
Host-to-Host Packet Delivery (10 of 22)



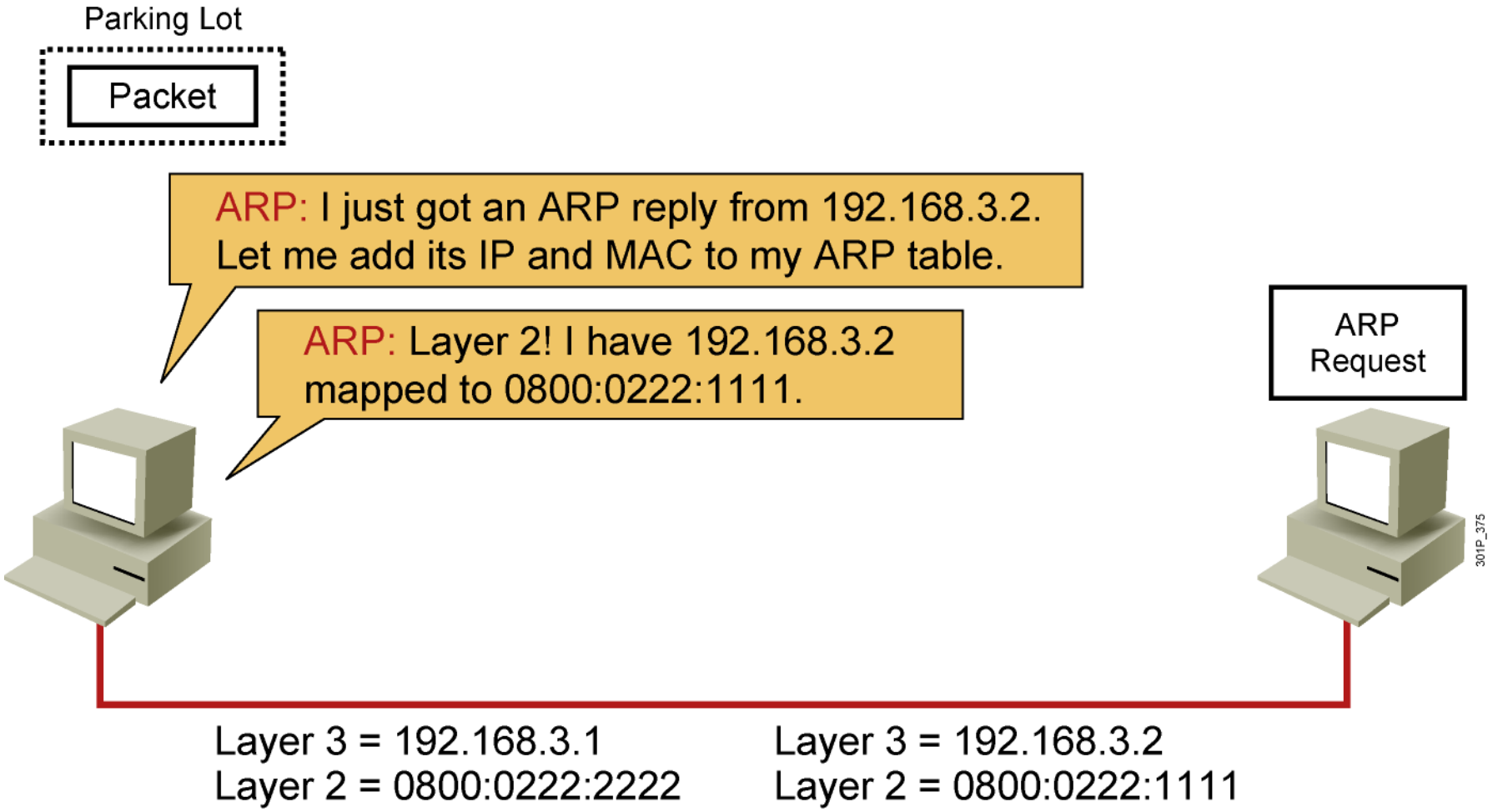
Host-to-Host Packet Delivery (11 of 22)



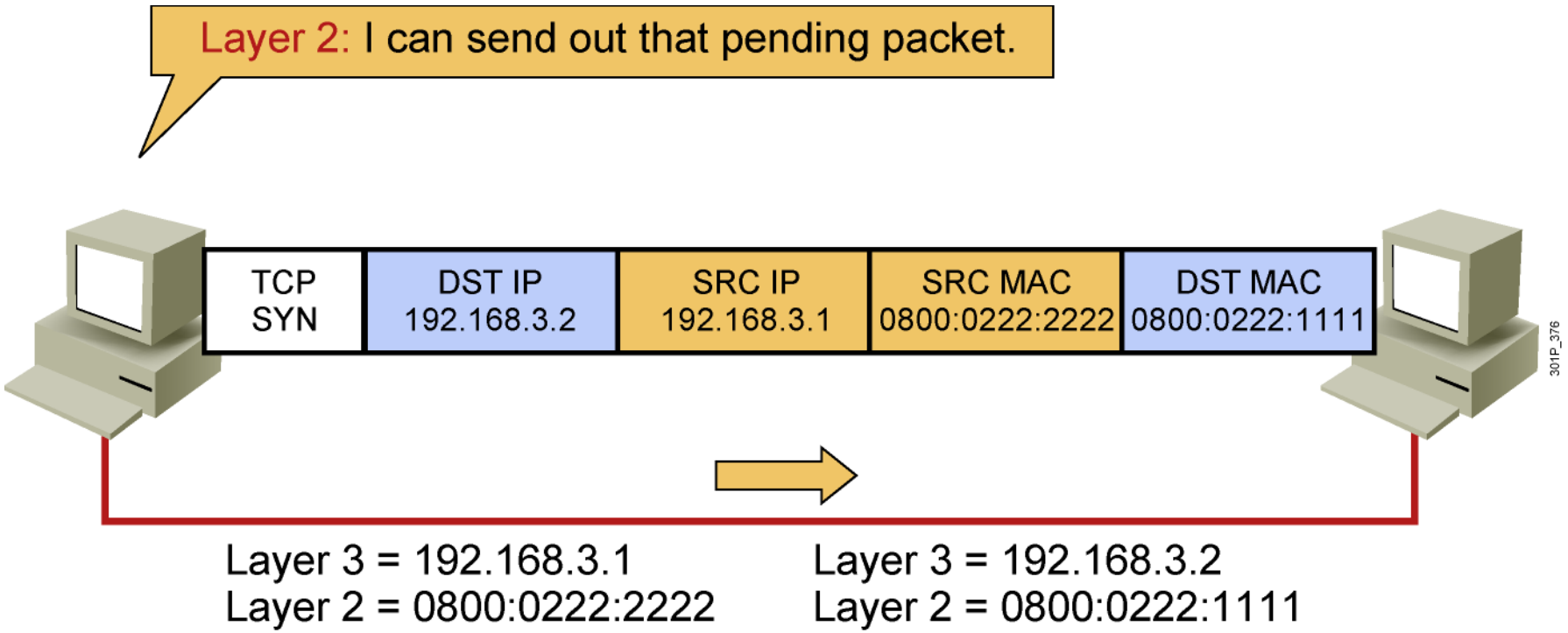
Host-to-Host Packet Delivery (12 of 22)



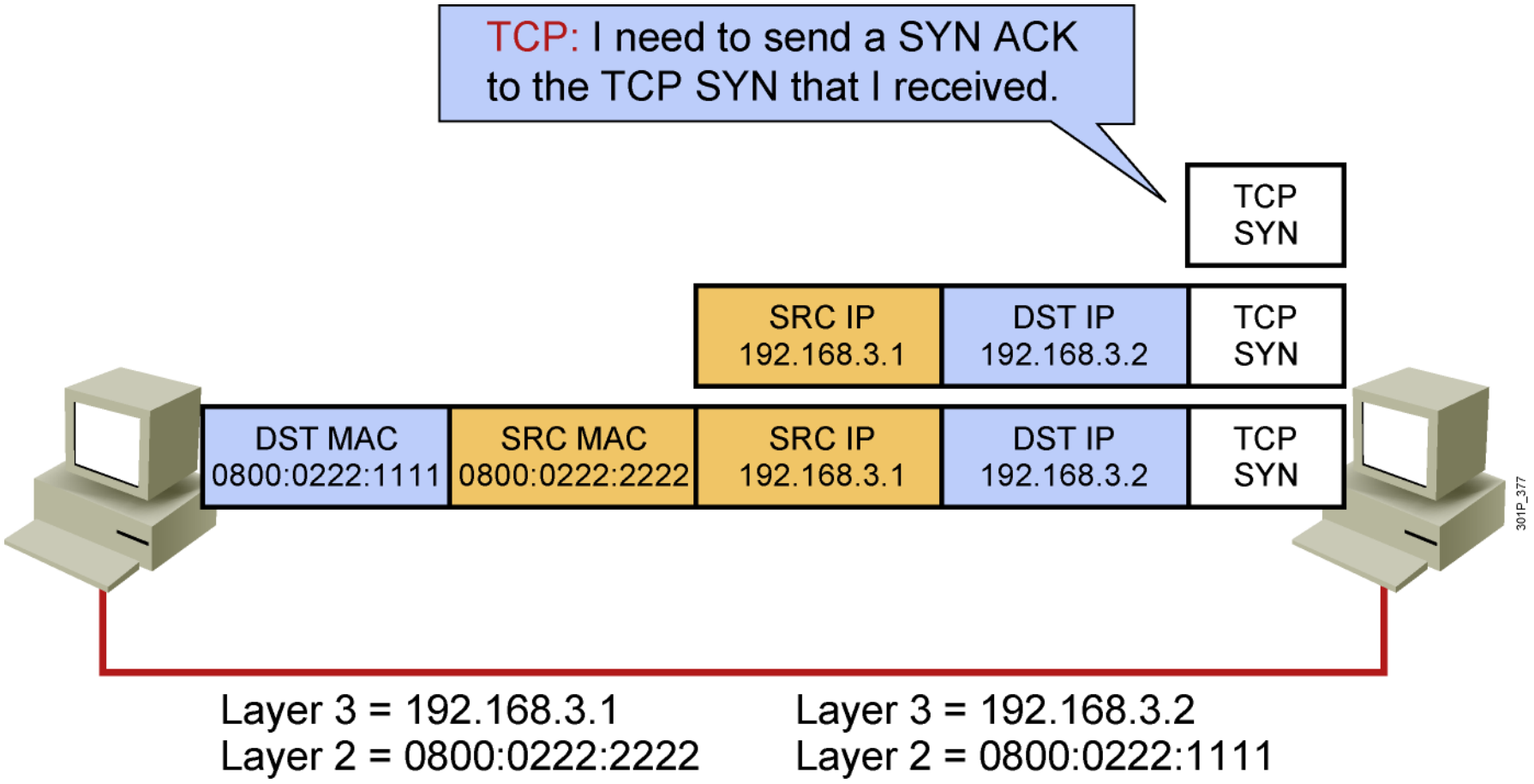
Host-to-Host Packet Delivery (13 of 22)



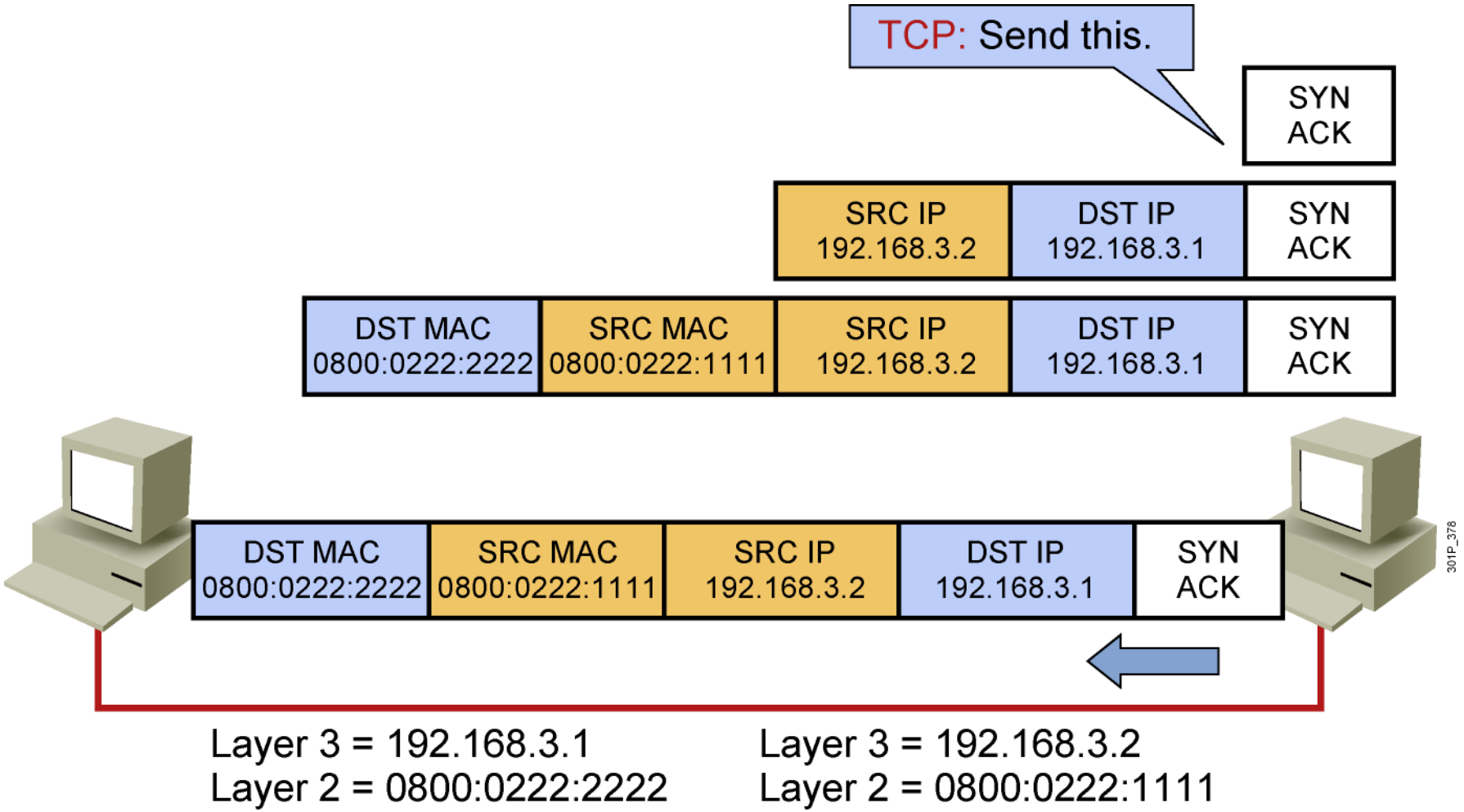
Host-to-Host Packet Delivery (14 of 22)



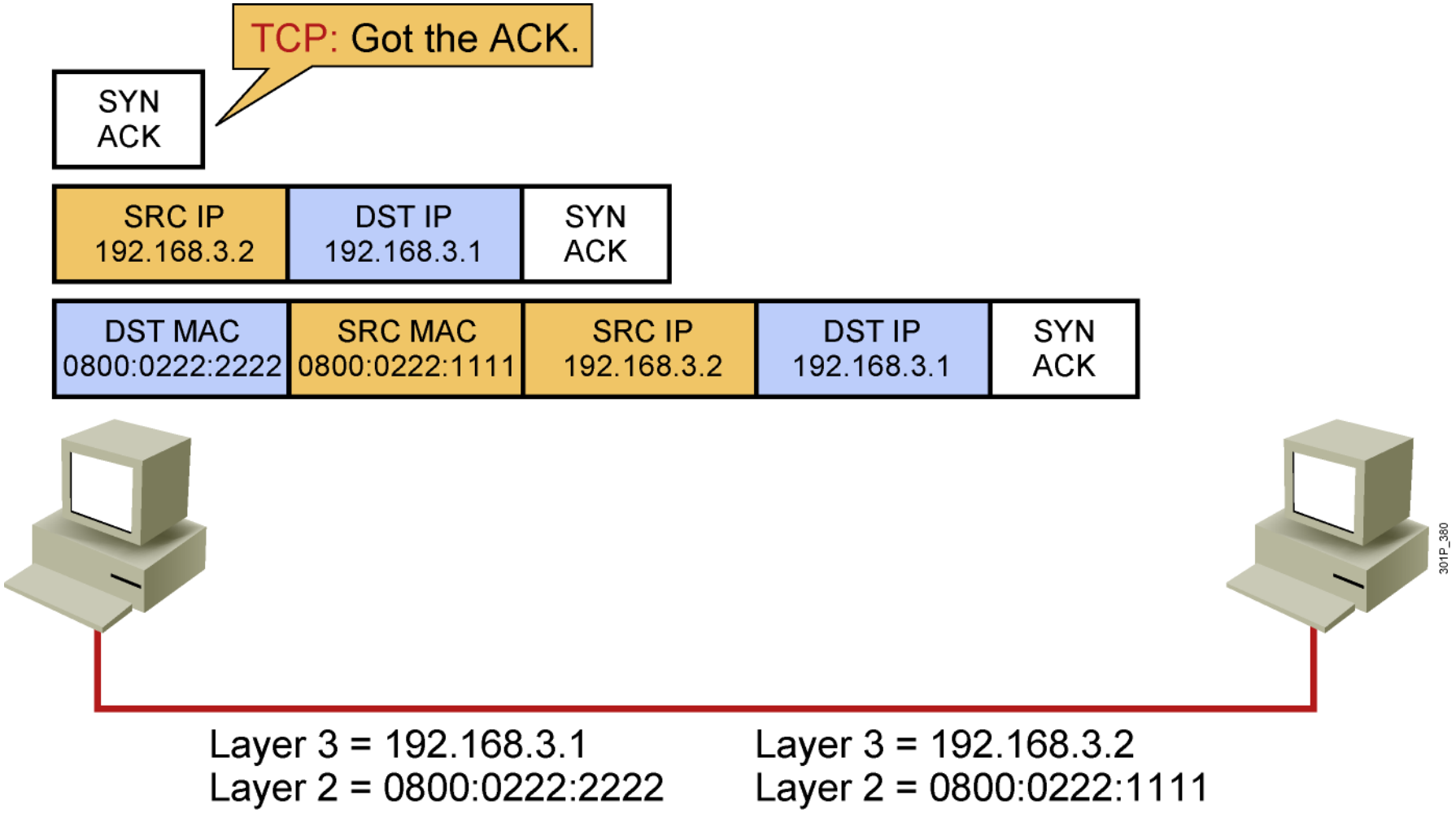
Host-to-Host Packet Delivery (15 of 22)



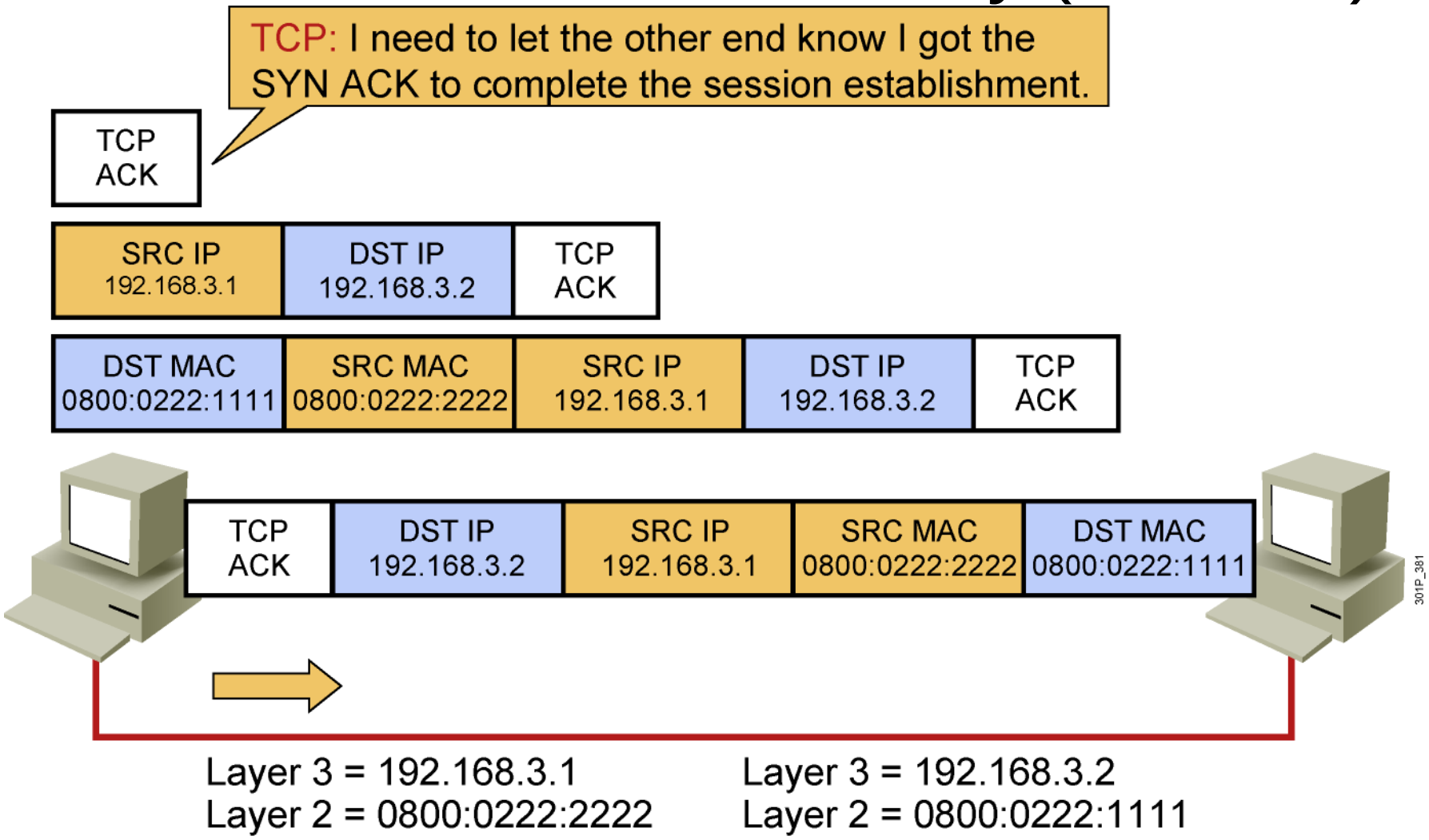
Host-to-Host Packet Delivery (16 of 22)



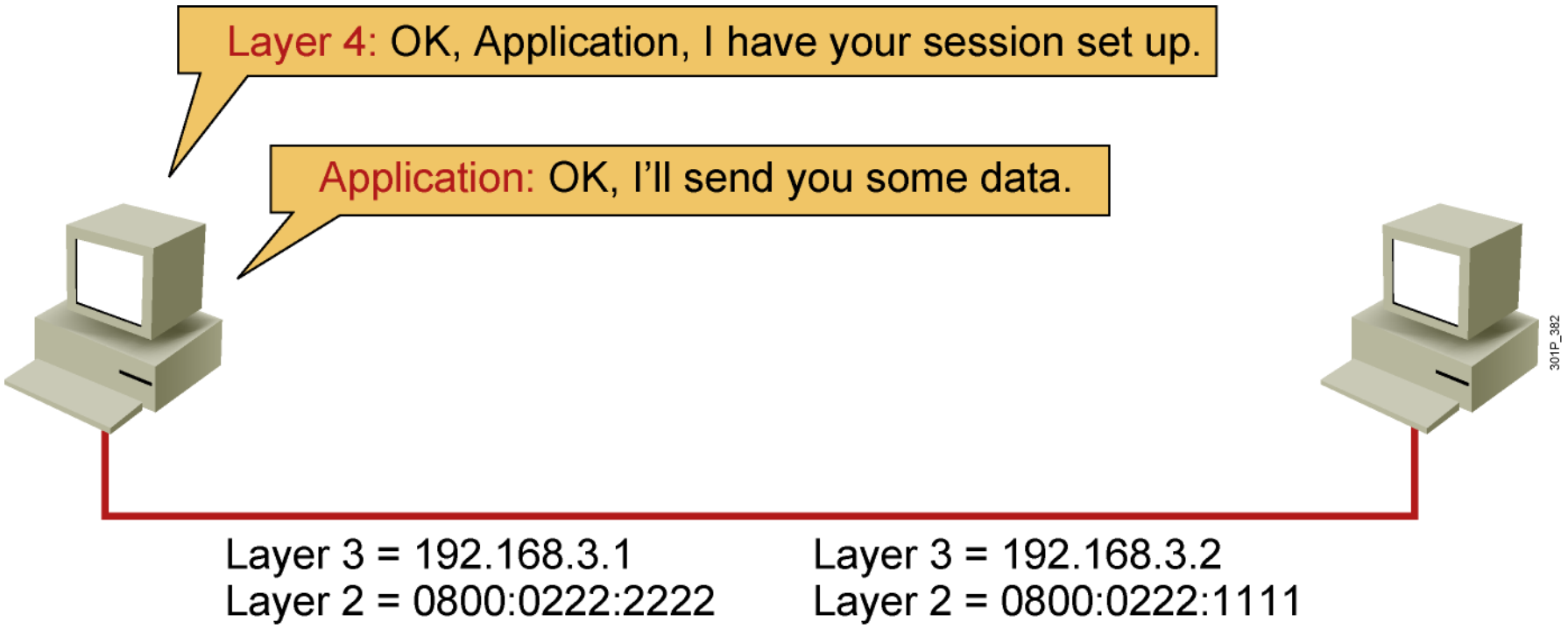
Host-to-Host Packet Delivery (17 of 22)



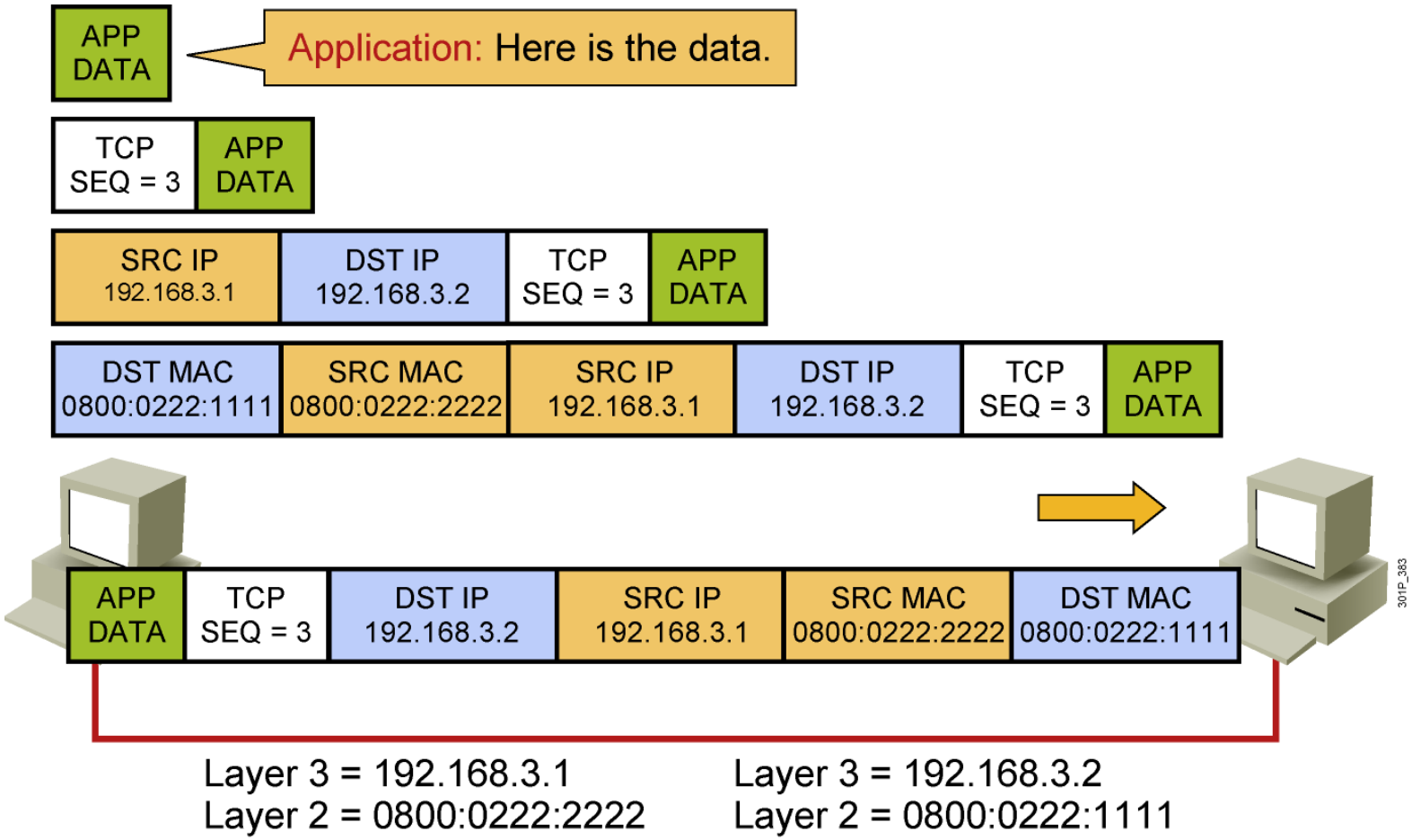
Host-to-Host Packet Delivery (18 of 22)



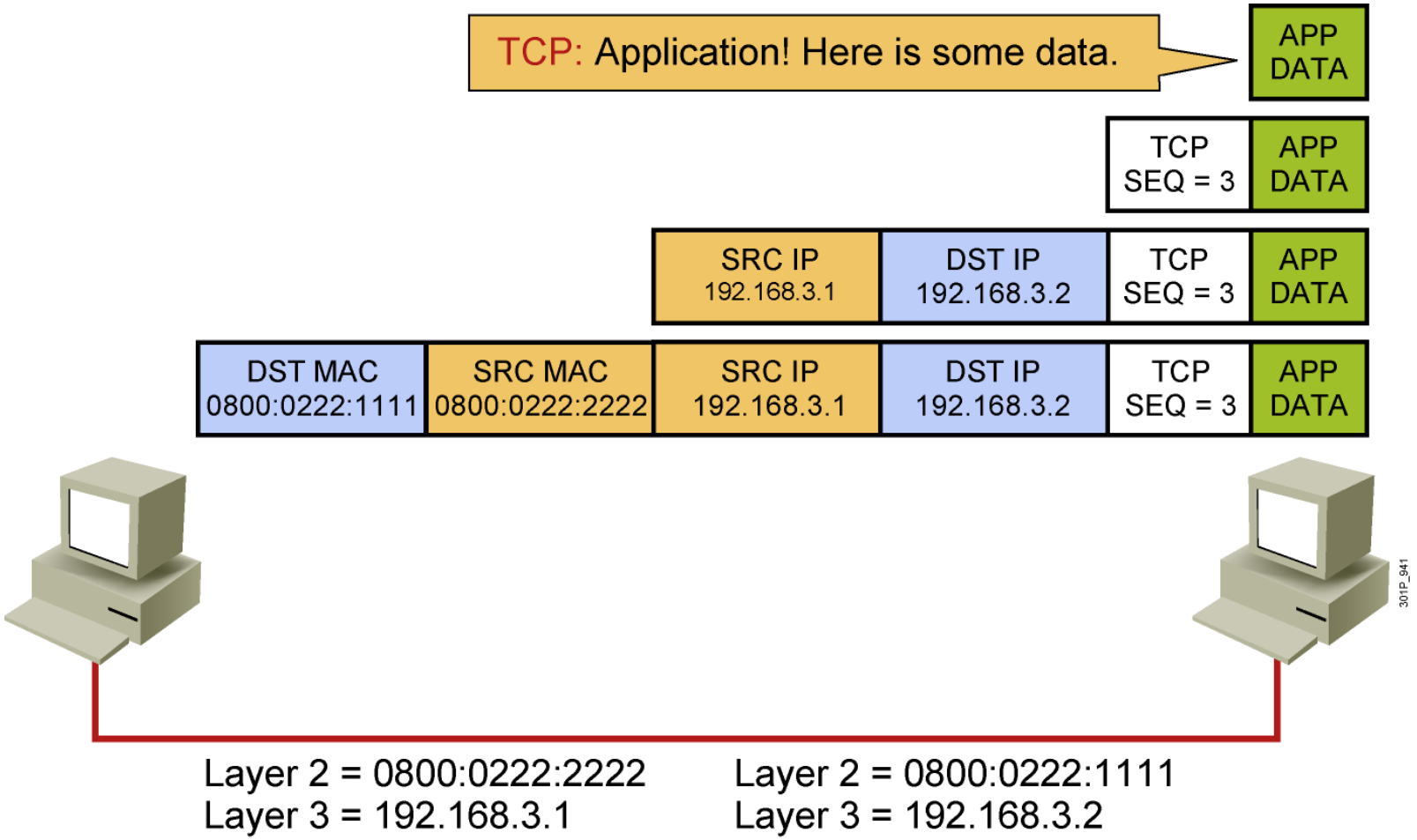
Host-to-Host Packet Delivery (19 of 22)



Host-to-Host Packet Delivery (20 of 22)



Host-to-Host Packet Delivery (21 of 22)



Host-to-Host Packet Delivery (22 of 22)