TCP/IP Programming

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Course Roadmap

- NM055 (11:00-12:00) Important Terms and Concepts
  - TCP/IP and Client/Server Model
  - Sockets and TLI
  - Client/Server in TCP/IP
- NM056 (1:00-2:00) Socket Routines
- NM057 (2:00-3:00) Library Routines
- NM058 (3:00-4:00) Sample Client/Server
- NM059 (4:00-5:00) VMS specifics (QIOs)
- NM067 (6:00-7:00) Clinic - Q&A

TCP/IP Programming

Slides and Source Code available via anonymous FTP:

Host:: ftp.process.com
Directory: [pub.decus]
Slides: DECUS_F96_PROG.PS
Examples: DECUS_F96_PROG_EXAMPLES.TXT

Host: ftp.opus1.com
Slides: DECUS_F96_PROG.PS
Examples: DECUS_F96_PROG_EXAMPLES.TXT

Session NM055

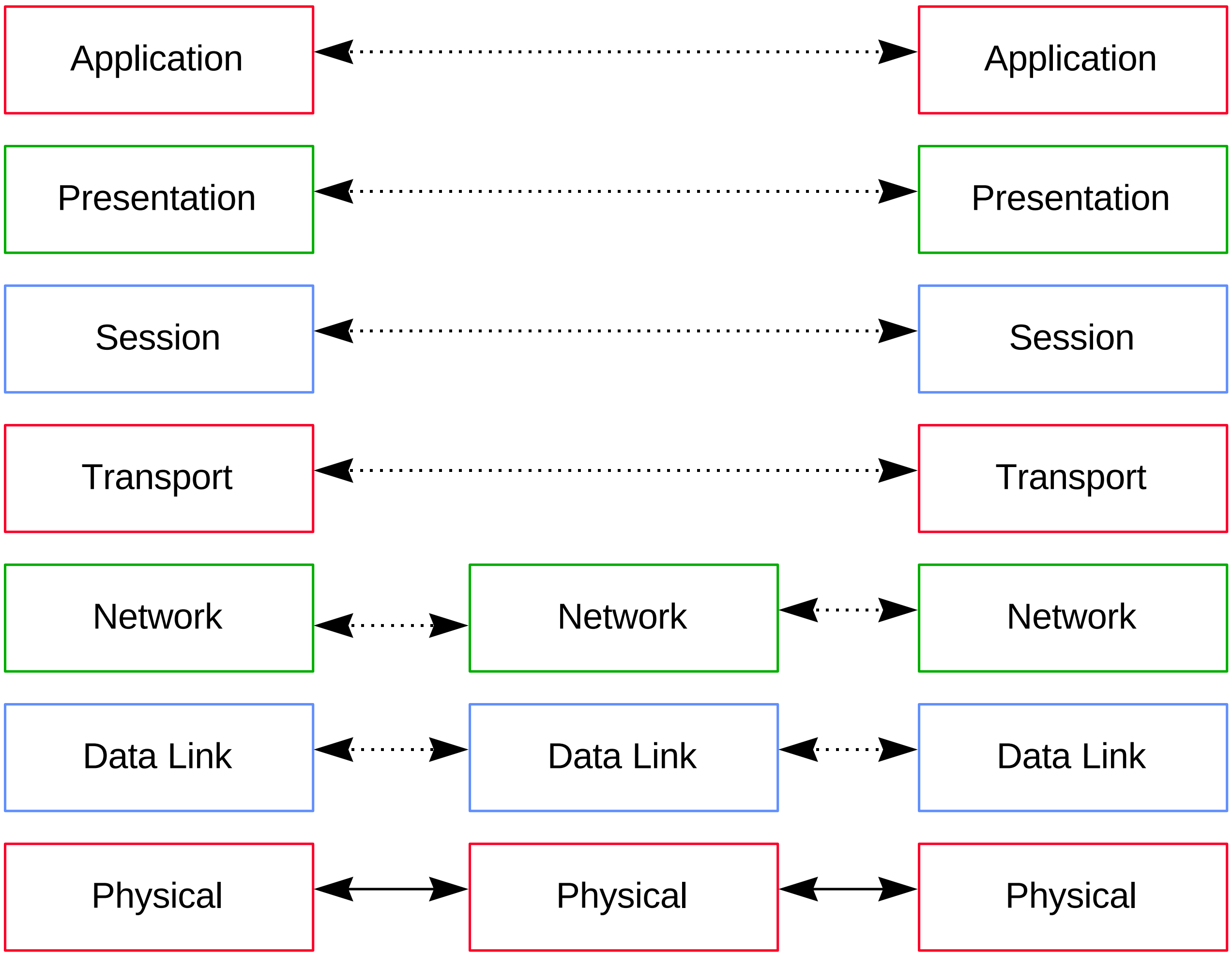
TCP/IP Programming Terms and Concepts

Joel Snyder
Opus1

Terms and Concepts Overview

- What is the TCP/IP model?
- What is the client/server model?
- What are sockets and TLI?
- What is network byte order?
- What is encapsulation? Multiplexing? Demultiplexing? Fragmentation?
- What are addresses?

Networks are layered to simplify construction

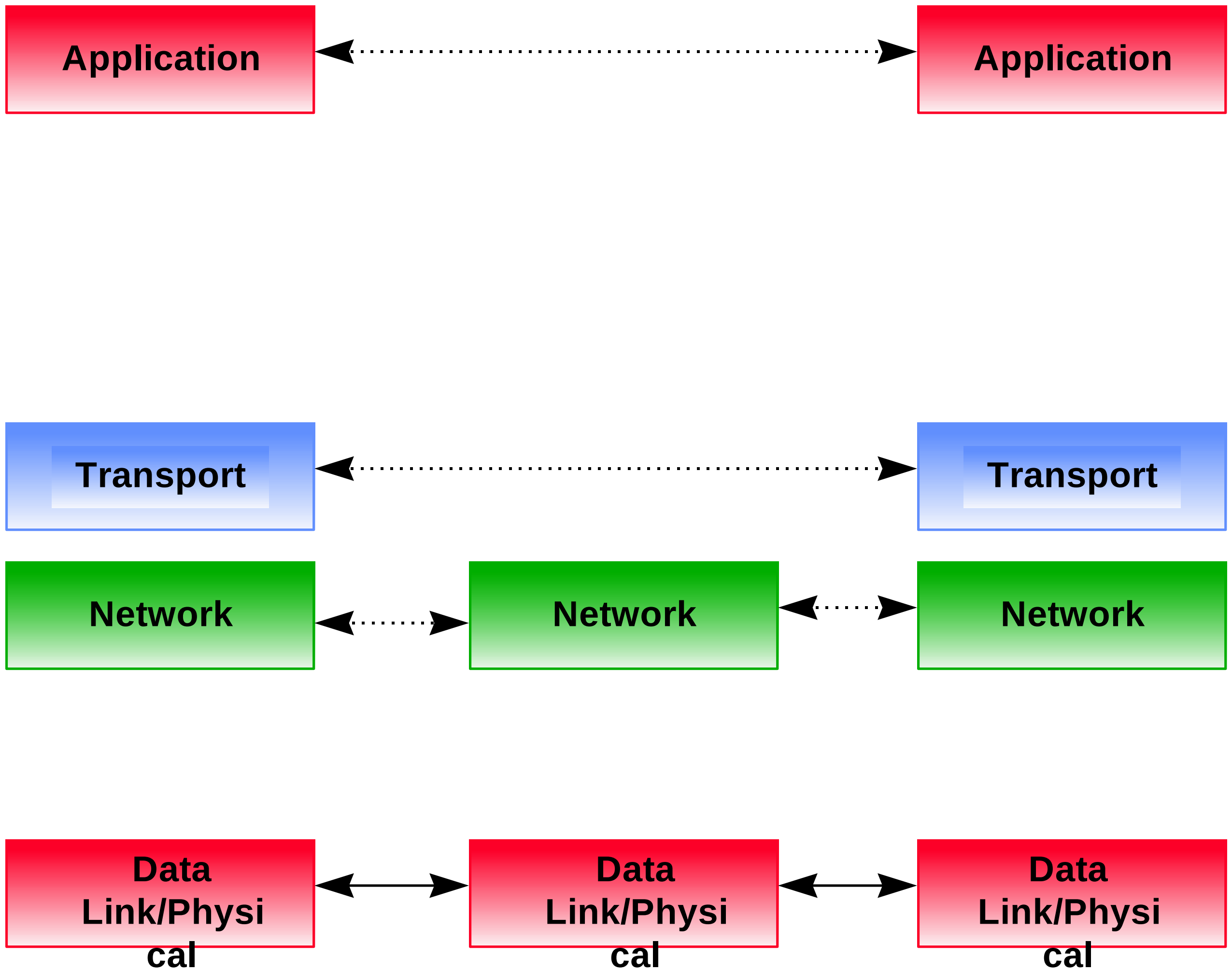


The Famous OSI 7-Story Apartment Building with attached Parking Garage

The OSI Model (similar to the Holy Grail)

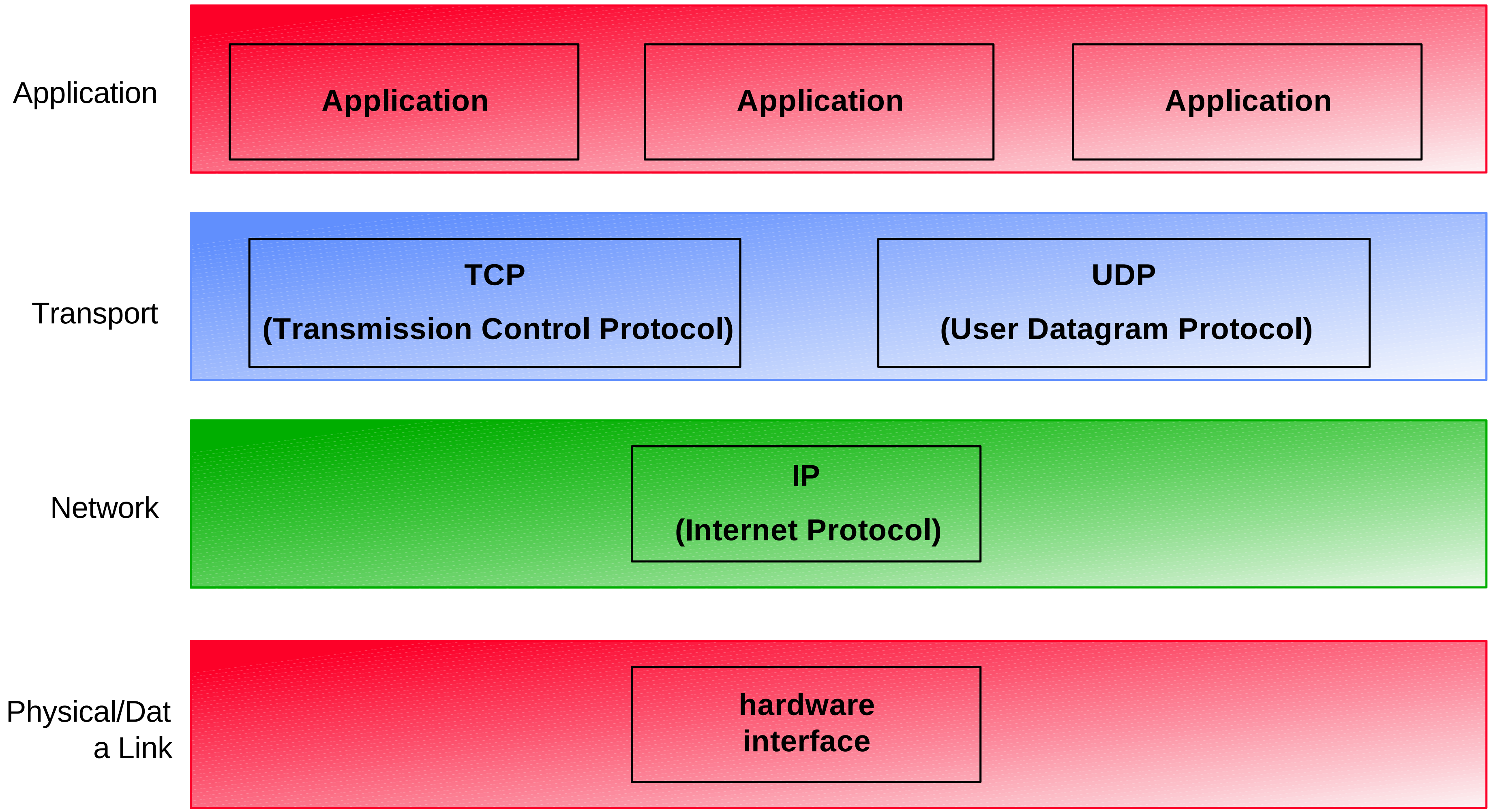
OSI layer	Function provided
Application	Network applications such as file transfer and terminal emulation
Presentation	Data formatting and encryption
Session	Establishment and maintenance of sessions
Transport	Provision for end-to-end reliable and unreliable delivery
Network	Delivery of packets of information, which includes routing
Data Link	Transfer of units of information, framing, and error checking
Physical	Transmission of binary data of a medium

TCP/IP is (usually) sliced up into four layers



There are actually more layers to TCP/IP than this set of four, but from the programming point of view, this will do just fine.

We care most about the two center layers



TCP

- Transmission Control Protocol is defined by RFC-793
- TCP provides connection-oriented transport service
- End-to-end transparent byte-stream

UDP

- User Datagram Protocol is defined by RFC-768
- UDP provides datagram service
- Connectionless

Client/Server is application-to-application

- TCP/IP and DECnet are client/server networks
- A client/server application has two parts
  - One which runs on one side of the network
  - One which runs on the other side of the network
- Differentiate this from a terminal-based network or most Netware applications

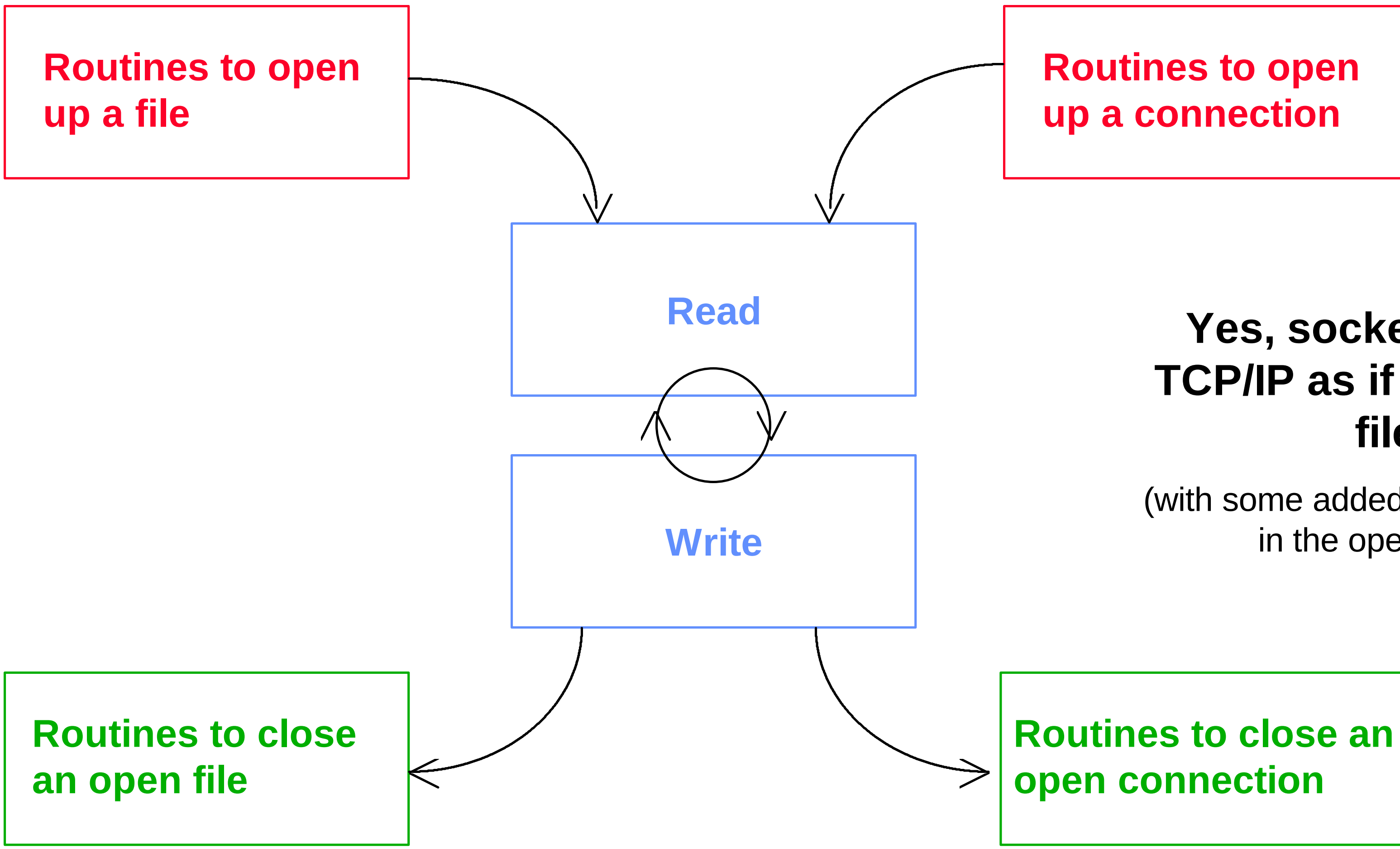
Clients and Servers use IPC to talk to each other

- Inter-Process Communication mechanisms let two cooperating applications communicate
- There are **LOTS** of IPC mechanisms for local communications
- The two popular TCP/IP based IPCs are Sockets (Berkeley Unix) and TLI (AT&T Unix System V)

Sockets is the standard API for TCP/IP IPC

- Normally, you'd have an operating system specific routine set to talk to the network
- In the world of standardized APIs, you would have an operating system **independent** set of routines
- Sockets takes it one step further: it makes the network look much like a file system

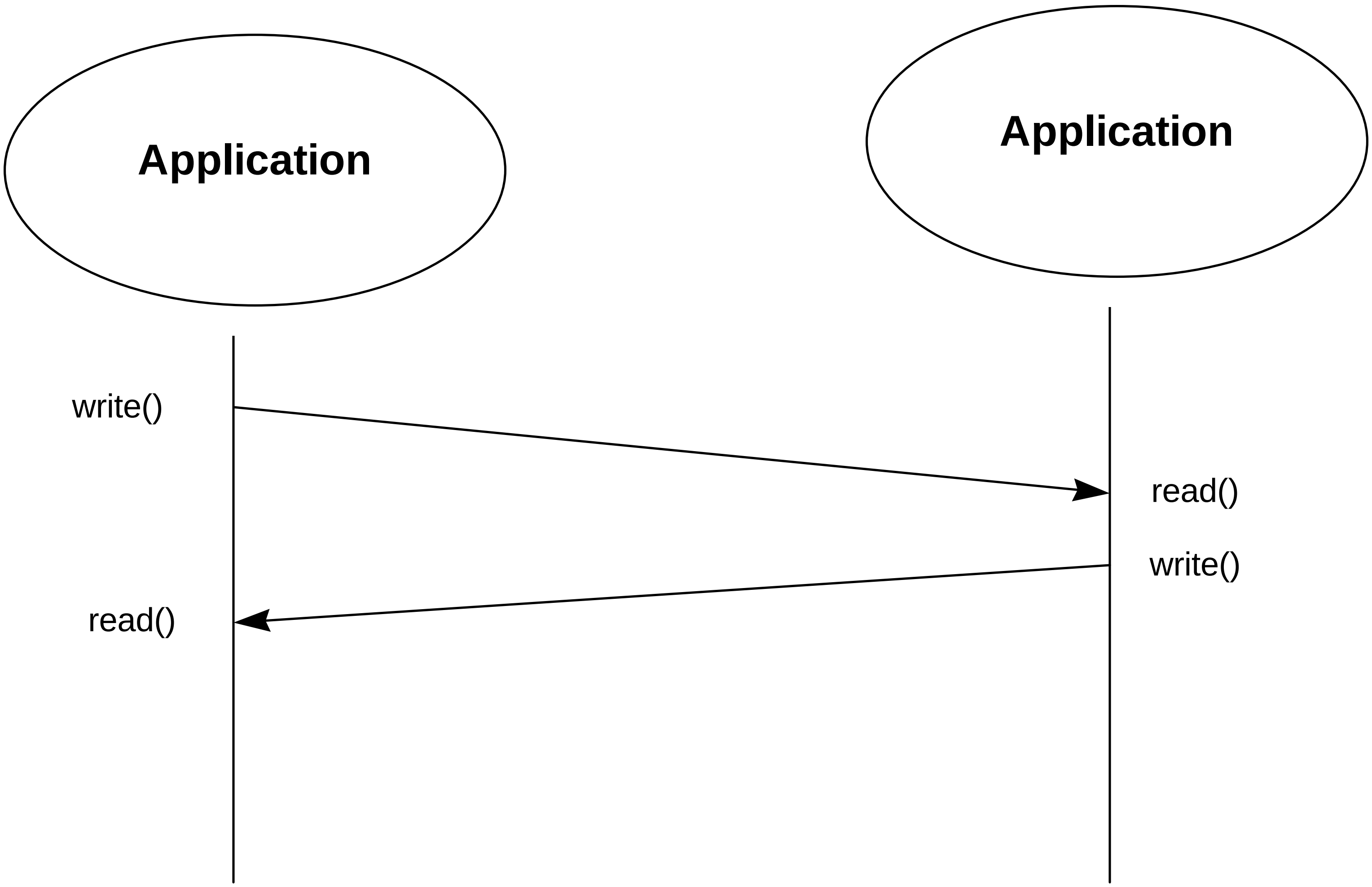
TCP/IP is a file system?



Yes, sockets treats TCP/IP as if it were a file system

(with some added complexity in the open and close routines)

It looks like a file, but it's really a network interface



Life was easy when machines had 8-bit words

- Welcome to the concept of “network byte order”
- Remember that “network byte order” is not the same as “host byte order”
- You have to convert to network byte order!

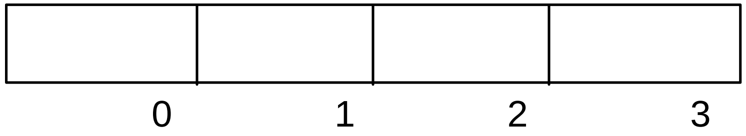
There are two ways to store multi-byte integers

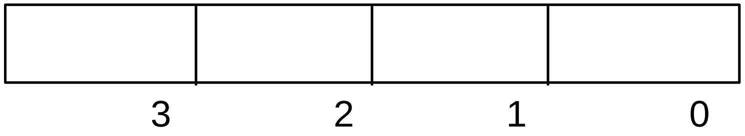
big endian	high order byte	low order byte
	Address n	Address n+1

little endian	high order byte	low order byte
	Address n+1	Address n

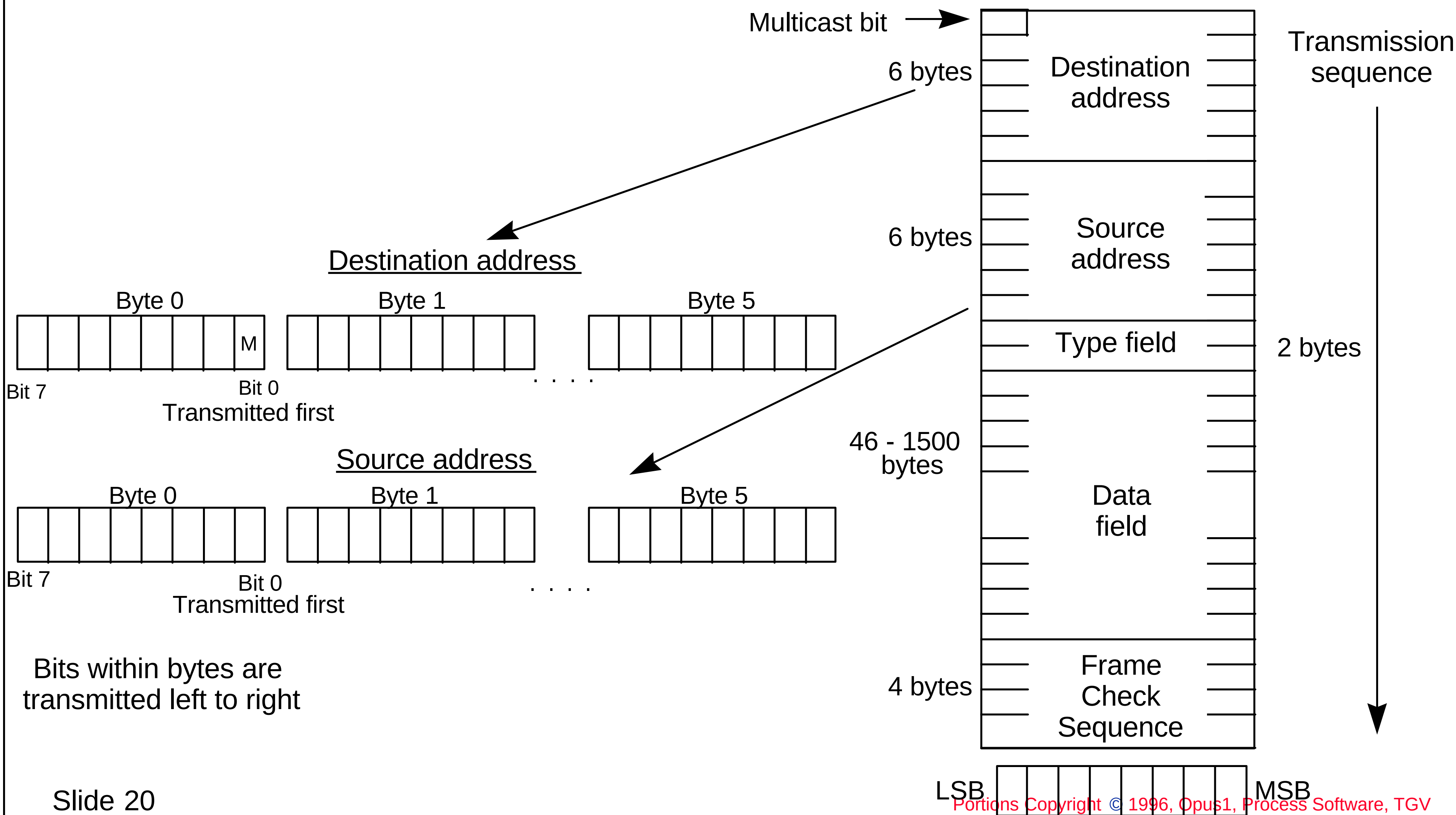
VMS systems are little endian architectures

Big-endian architectures	Little-endian architectures
Motorola 68xxx	Intel 80x86
IBM 370	VAX & Alpha (VMS)
	PDP-11(sort of)



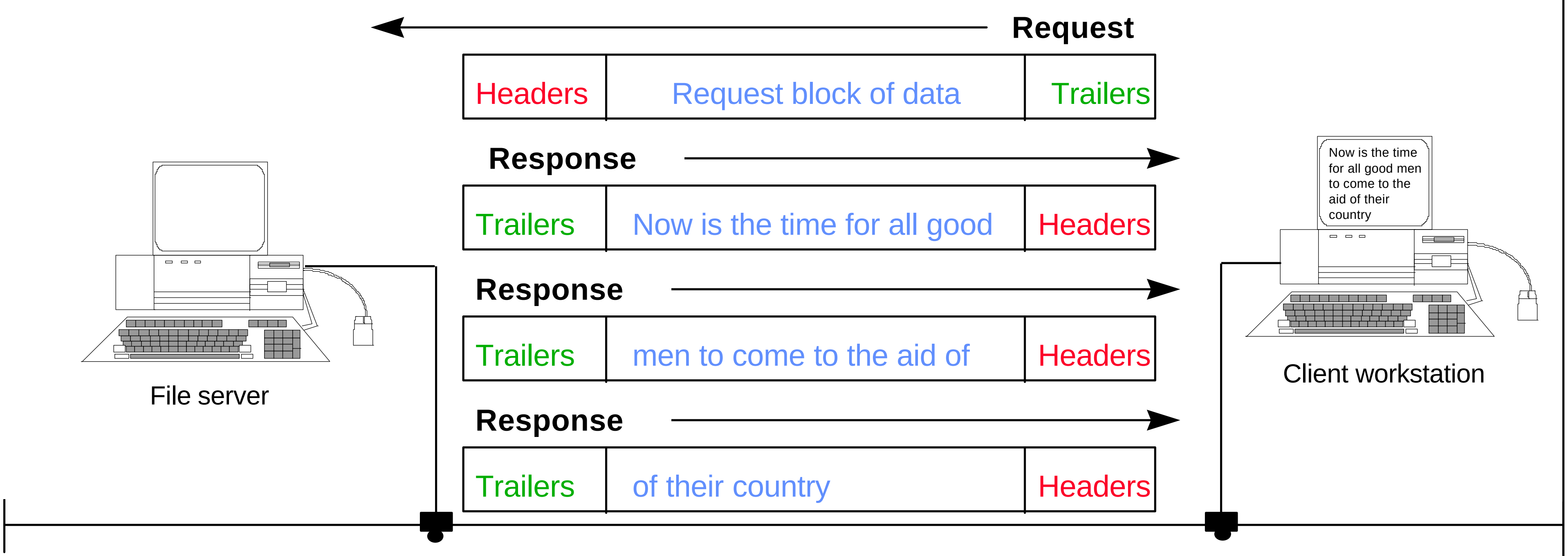


Relax: you could be doing Ethernet and Token Ring

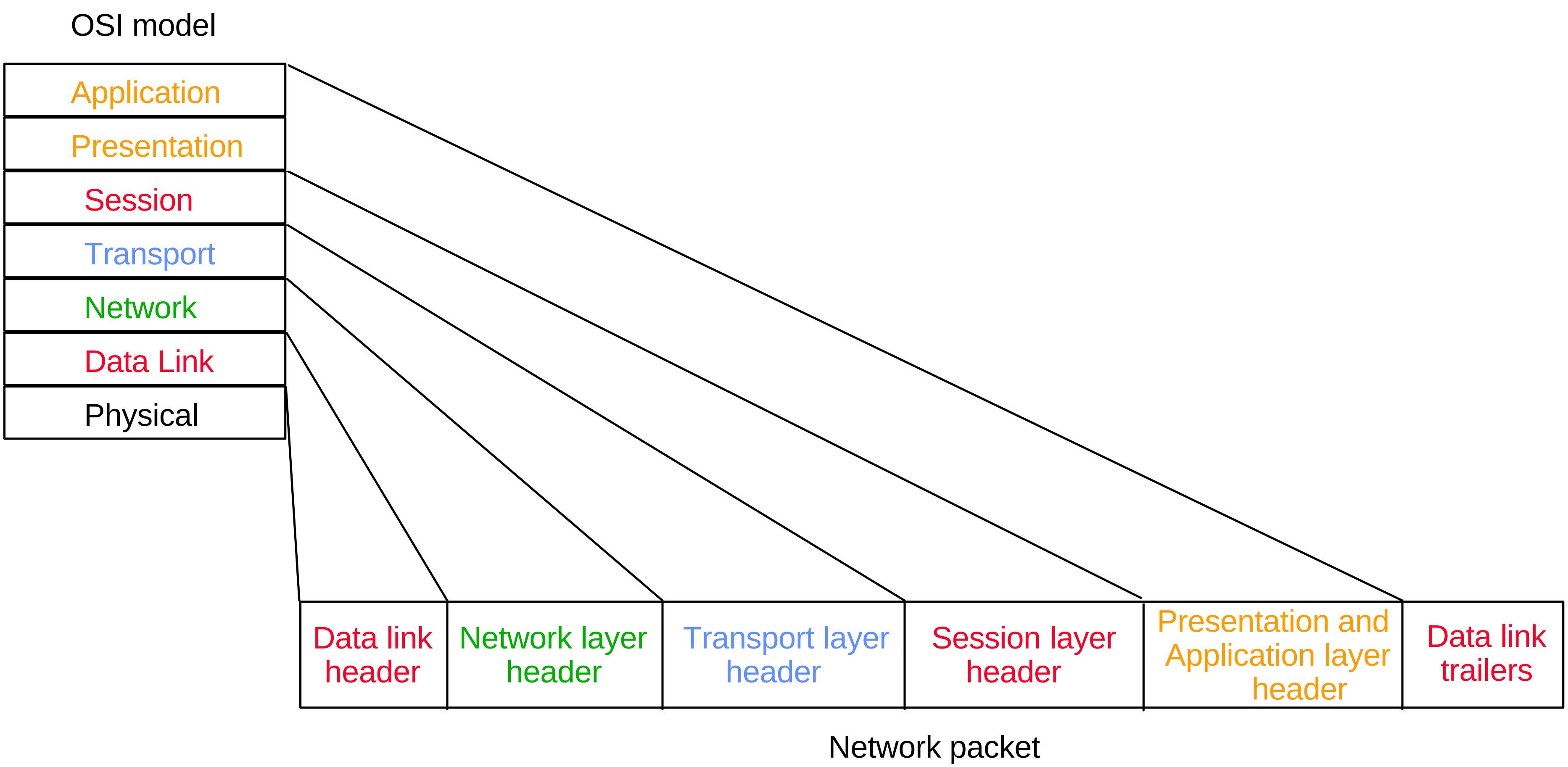


Encapsulation adds control information to data

Network headers	**Data field** Data from user program such as an application program or session control information	Network trailers

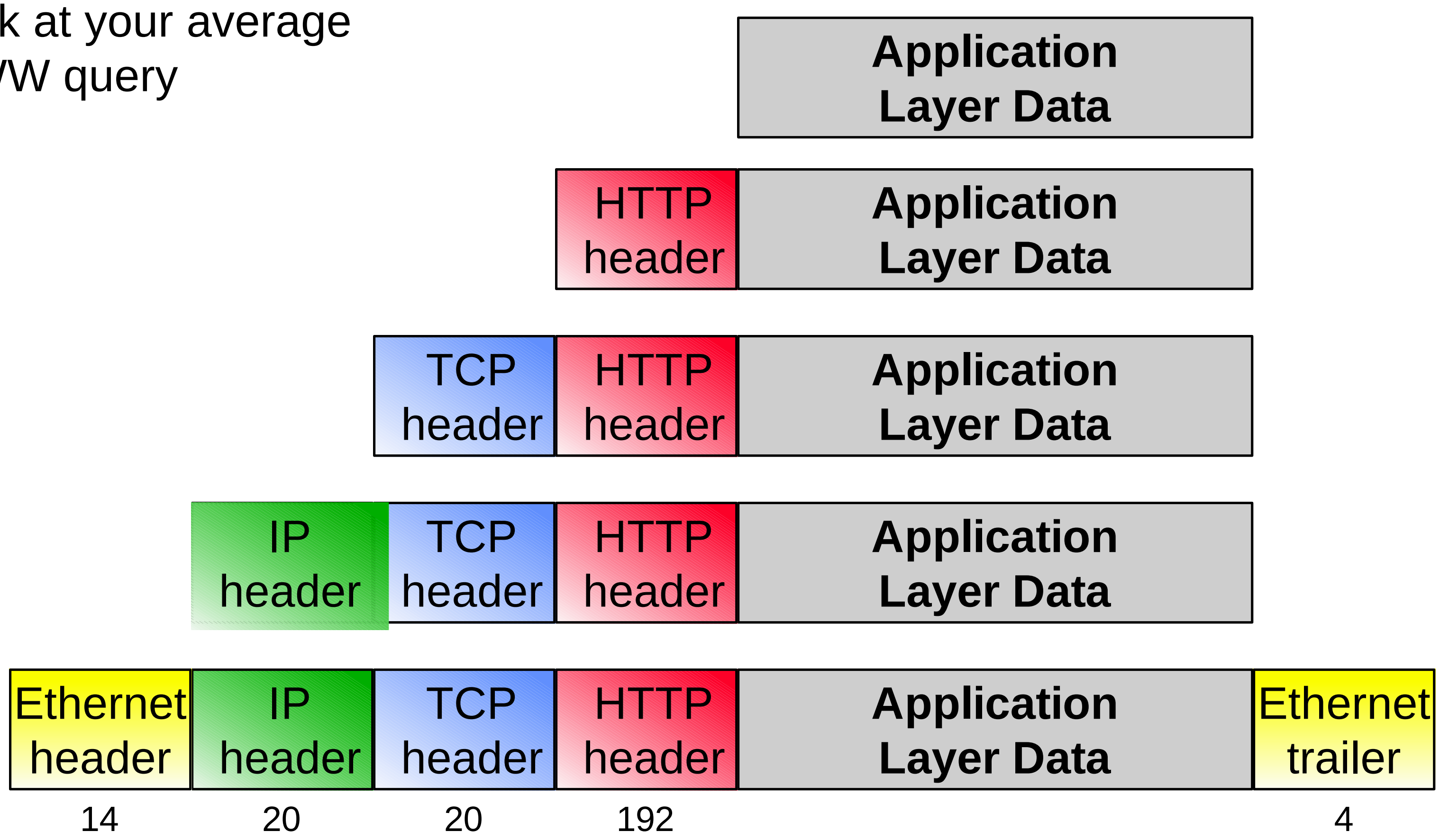


Each layer encapsulates the layer below it



Things can be added on and peeled off at the ends

Look at your average WWW query



Make sure you memorize all of this encapsulation info

Ethernet V2.0

6 bytes	6 bytes	2 bytes	Up to 1500 bytes	4 bytes
Destination address	Source address	Type field	Data field	CRC

IEEE 802.3

6 bytes	6 bytes		Up to 1496 bytes	4 bytes
Destination address	Source address	Length field	Data field	CRC

IEEE 802.3 with IEEE 802.2

6 bytes	6 bytes	2 bytes	1 byte	1 byte	*		4 bytes
Destination address	Source address	Length field	DSAP	SSAP	CTRL	Data field	CRC

IEEE 802.3 SNAP

6 bytes	6 bytes	2 bytes	1 byte	1 byte		3 bytes	2 bytes	1492 bytes	4 bytes
Destination address	Source address	Length field	DSAP	SSAP	CTRL	OUI	EtherType	Data field	CRC

SNAP header

Novell proprietary

6 bytes	6 bytes	2 bytes	Up to 1500 bytes	4 bytes
Destination address	Source address	Length field	FFFF Data field	CRC

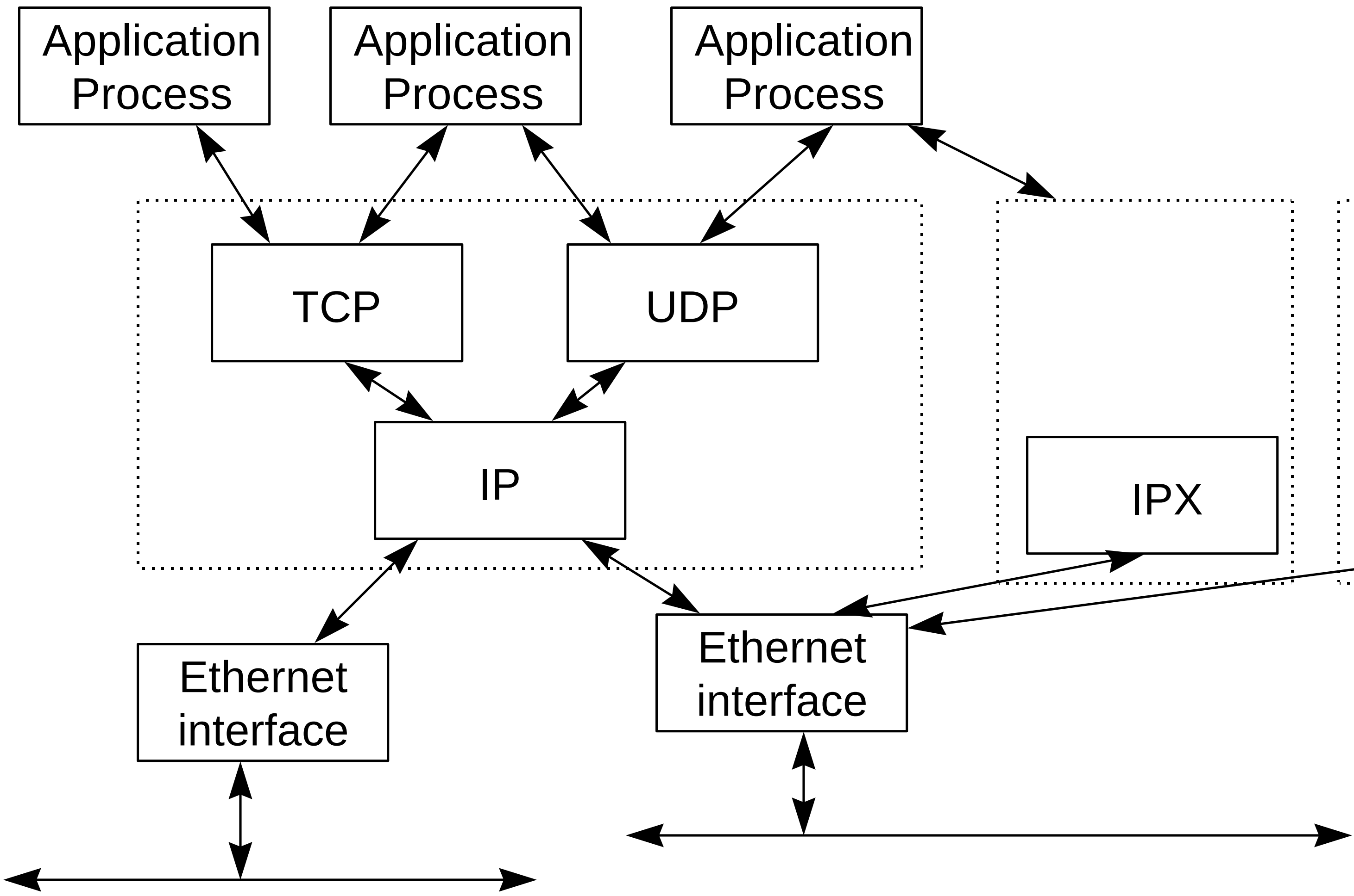
Token Ring

			6 bytes	6 bytes		1 byte	1 byte		4472 (4 Mbps or 17800 (16 Mbps) bytes	4 bytes	
SD	AC	FC	Destination address	Source address	RIF	DSAP	SSAP	CTRL	Data field	CRC	FS

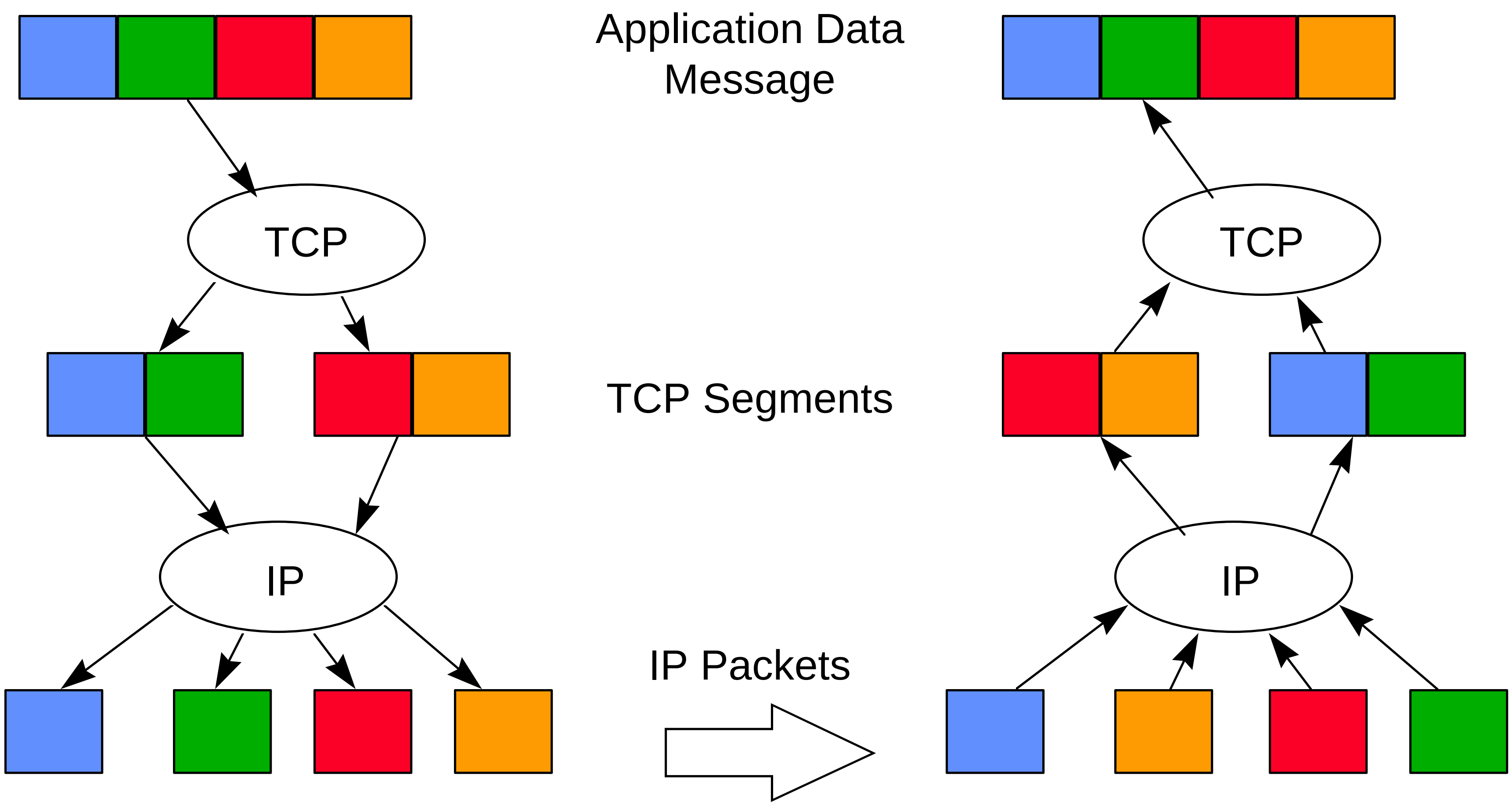
FDDI

			6 bytes	6 bytes	2 bytes	1 byte	1 byte		4472 bytes	4 bytes	1 byte	1 byte
Preamble	SD	FC	Destination address	Source address	Length field	DSAP	SSAP	CTRL	Data field	FCS	ED	FS

Multiplexing and Demultiplexing



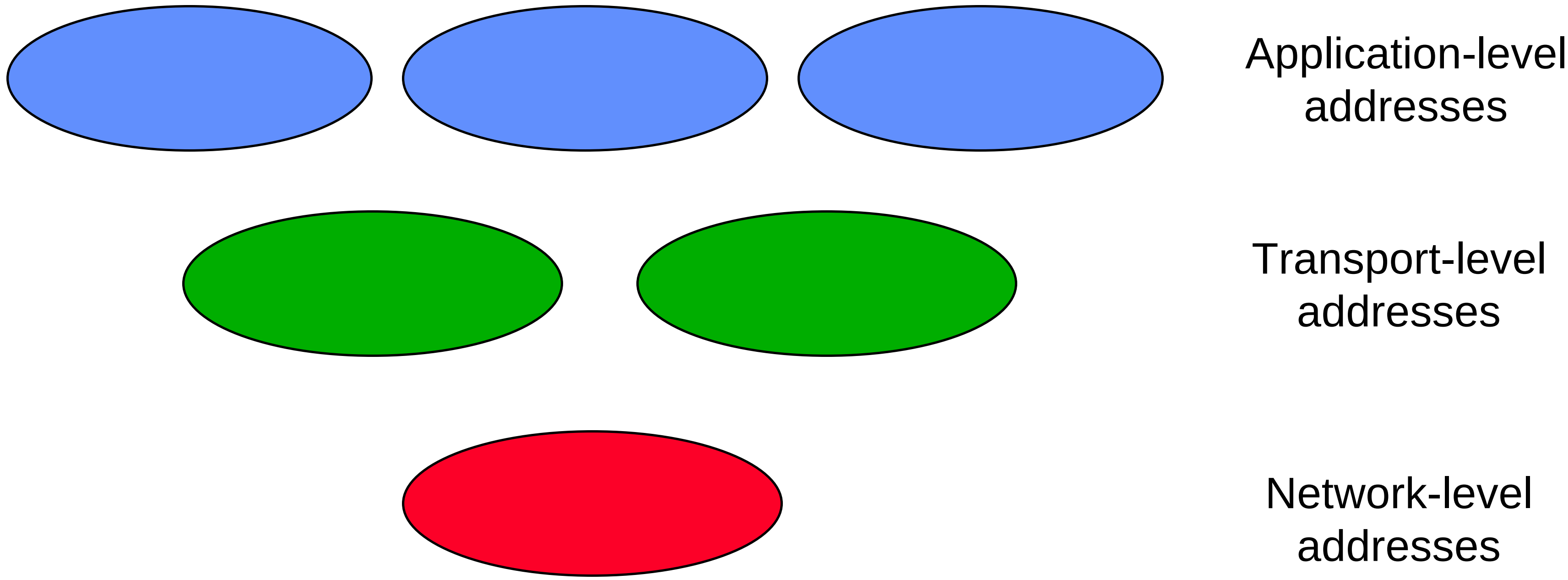
Segmentation and Reassembly



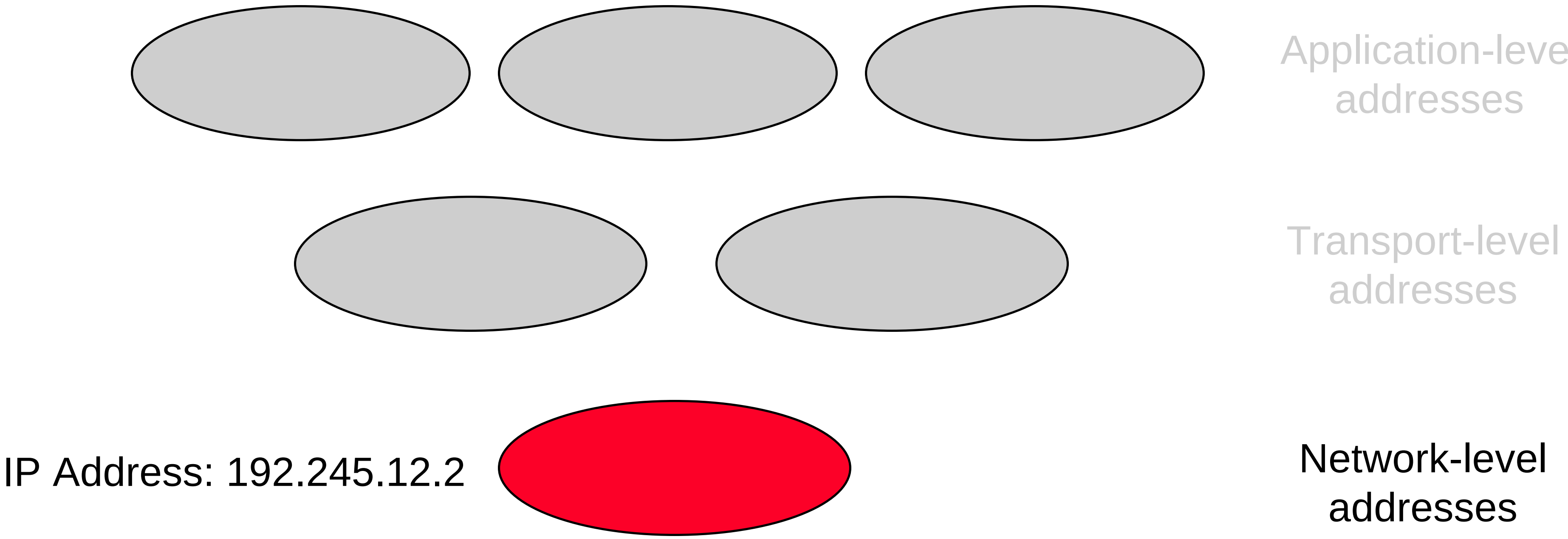
Addressing identifies entities in the network

- Each layer in a TCP/IP stack has an address made up of two parts
  - The address of everything below it
  - The address of itself
- In some cases, lower-level addresses are implied and do not have to be stated
  - For example, Ethernet MAC addresses are tied directly to IP addresses, so they can be omited

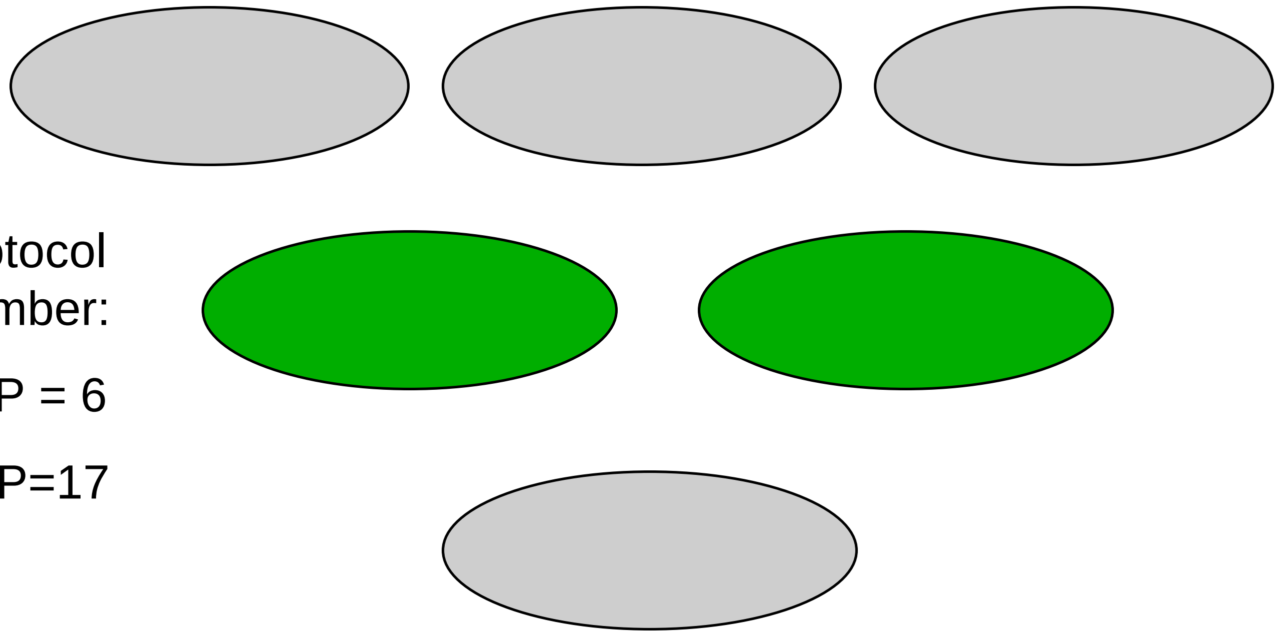
Three addresses are important: IP, Protocol, Port



IP addresses are 32-bit integers



Transport addresses are 8-bit protocol numbers



Application-level addresses

Protocol Number:

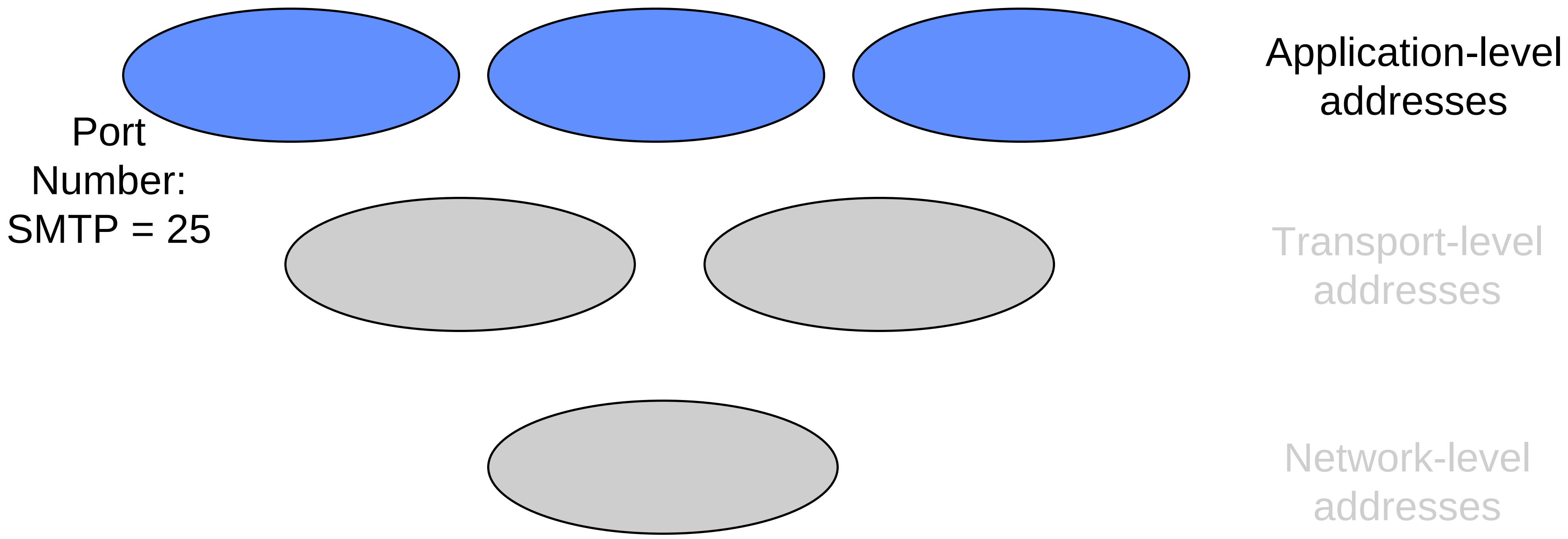
TCP = 6

UDP=17

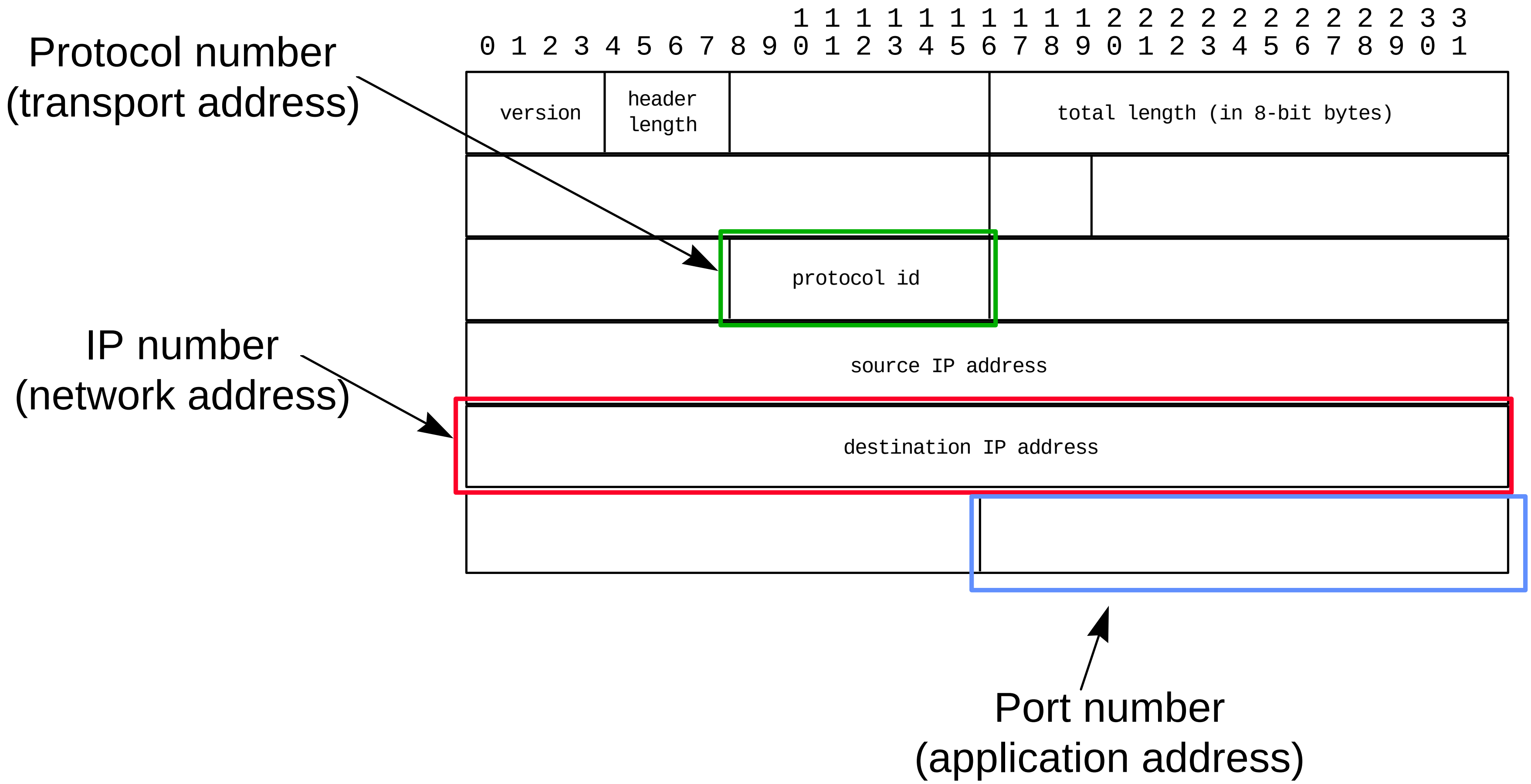
Transport-level addresses

Network-level addresses

Port Numbers are 16-bit integers



The triplet (IP,Proto,Port) identifies a process



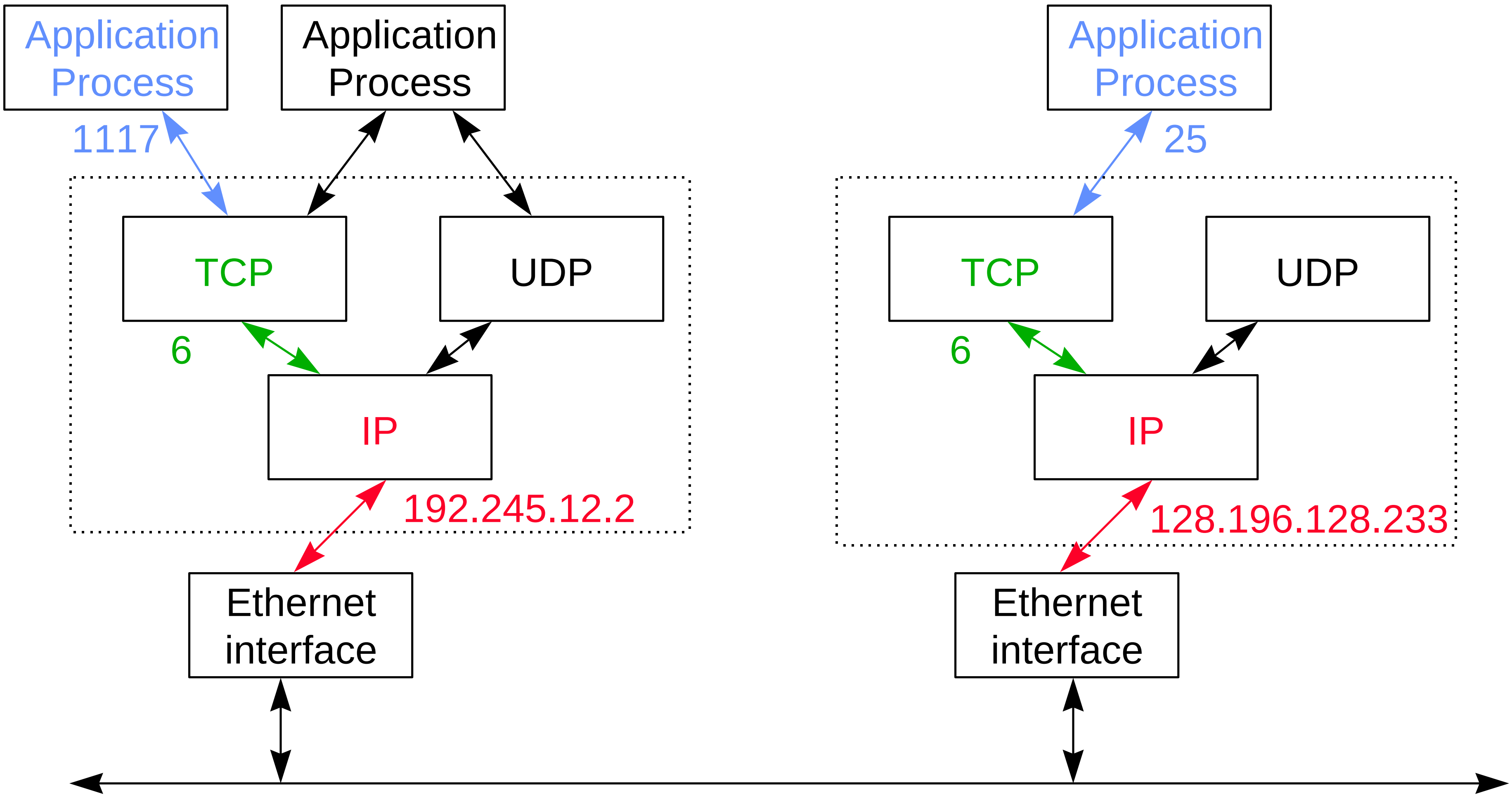
Two triplets identify a connection

- Now we have a socket!
  - (sometimes called a “socket pair”)

Application number 1117
on protocol number 6 (TCP)
at IP address 192.245.12.2

Application number 25
on protocol number 6 (TCP)
at IP address 128.196.128.233

A socket maps one application to another



Addresses are assigned by different entities

- IP addresses are assigned by the InterNIC and are managed by the local network manager
- Protocol numbers are assigned by the IANA (Internet Assigned Number Authority) and are fixed across the Internet (RFC 1700)
- Application port numbers come from two sources
  - Servers are assigned by IANA (RFC 1700)
  - Clients are handled by the network kernel

IP Addressing

- IP is the Internet Protocol, currently version 4
- IPNG is the Next Generation (also known as IPv6)
- IP is defined by RFC-791
- IP uses four octet (8-bit byte) addresses
- IP takes care of getting packets to destination

Client and Server Port Numbers are coordinated

- NORMALLY, Server port numbers are low numbers in the range 1-1023
  - Defined in RFC 1700
- NORMALLY, Client port numbers are high numbers starting at 1024
  - These are called “ephemeral ports”

You only pick server ports

- A server running on a “well-known port” lets the operating system know what port it wants to listen on
- A client simply lets the operating system pick a new port (ephemeral) that isn’t already in use

Well-Known-Servers

- Public services (e.g. and email server) are assigned a particular number by IANA
- These numbers are stored in the Internet Assigned Numbers RFC (changing number, latest is 1797)
- These are called Well-Known-Servers
- Examples of these include TELNET (23), SMTP (25), FINGER (79), HTTP (80), RLOGIN (512) and others

Important Terms
Key Concepts

- TCP/IP networks are layered
- TCP/IP uses a client/server paradigm
- Addressing triples (IP, protocol, port) identify applications in TCP/IP
- A pair of triples beats a full house

Client/Server in TCP/IP

Client/Server in TCP/IP Overview

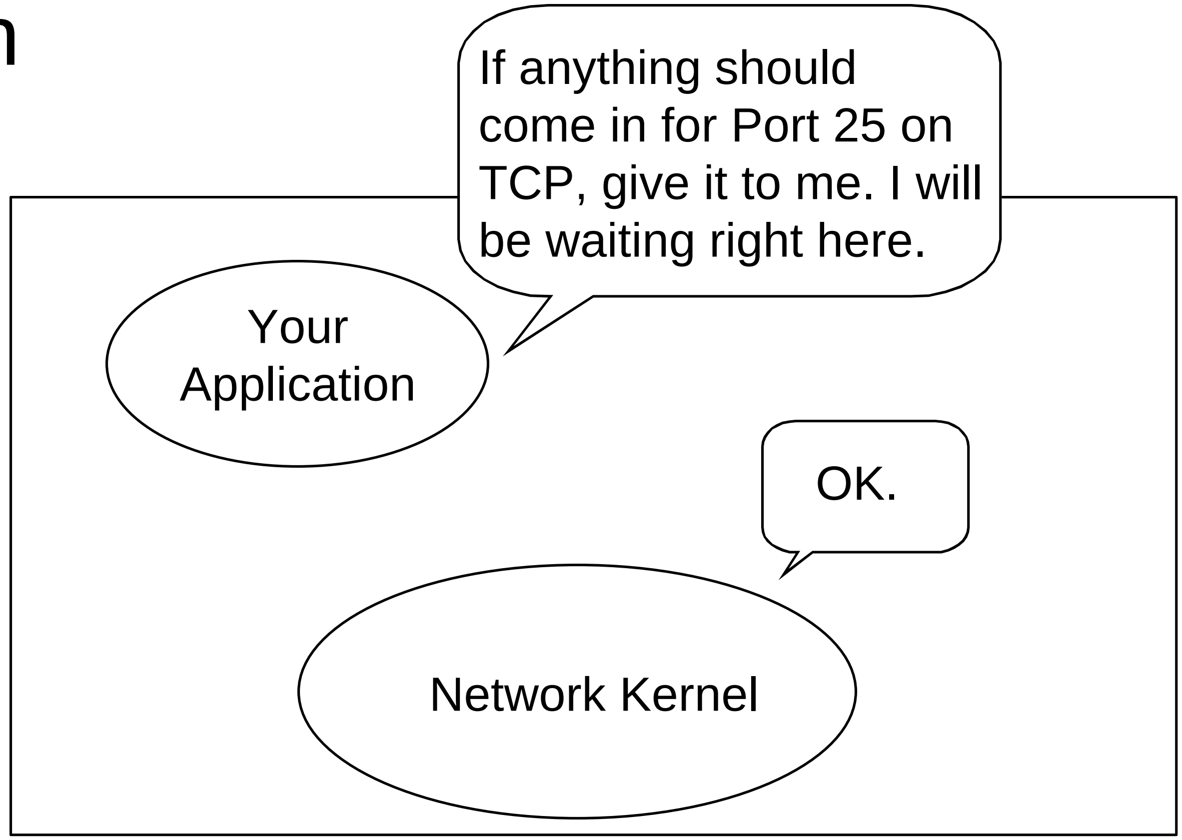
- What is the server process (INETD)?
- What are ephemeral ports?
- How can you have multiple connections?
- How are processes identified?
- What is Connection-oriented? Connection-less?

Making the initial connection to a server

- When a connection enters a TCP/IP system, someone has to handle it
  - Either a running daemon is waiting (your application)
  - or a running daemon is waiting (InetD)
- Trade off efficiency for performance
  - Choose whichever model you want based on individual application characteristics
  - Seldom used? <u>Inetd</u>
  - Constantly used? <u>True Daemon</u>

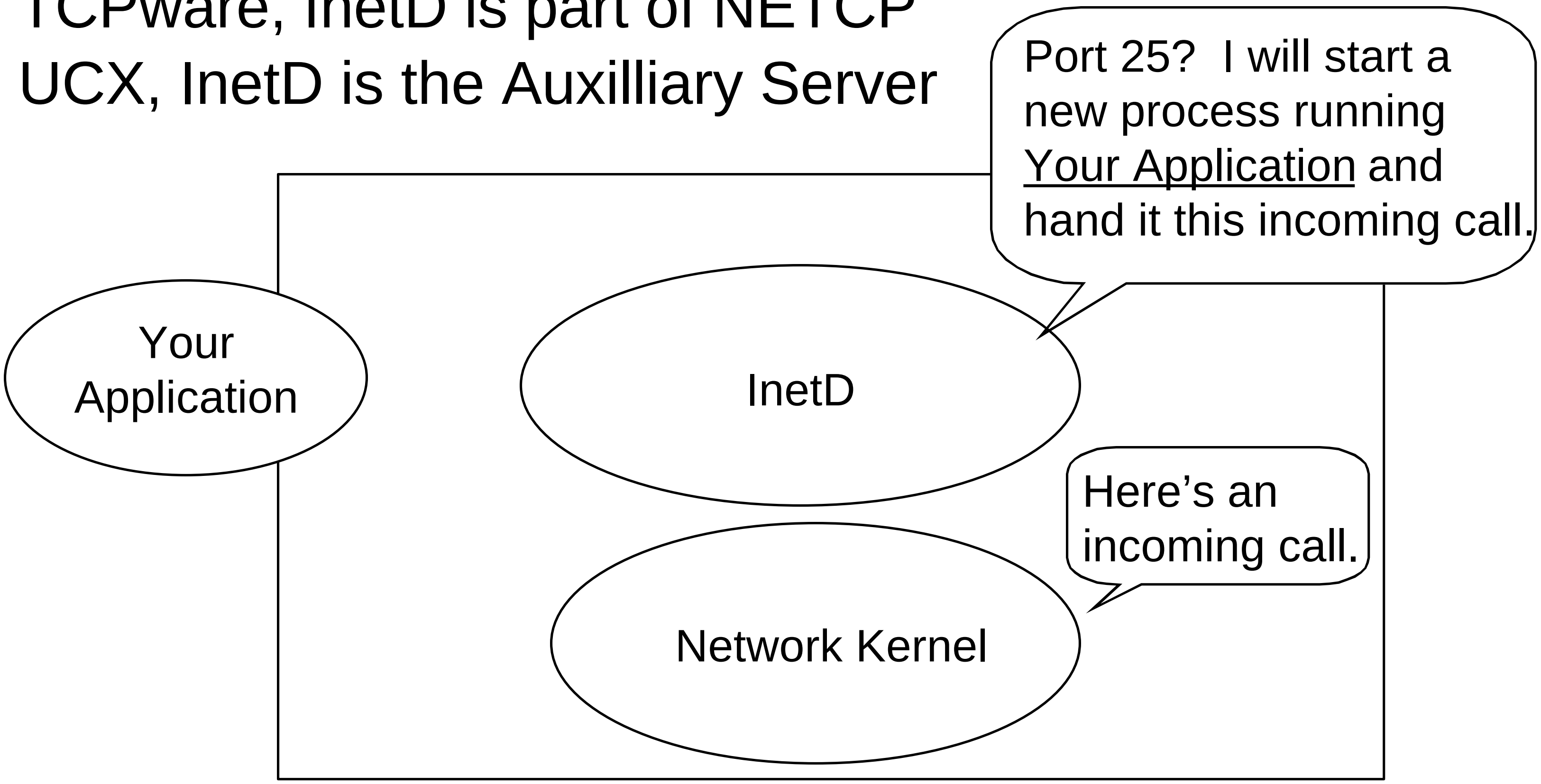
Your application can wait for an incoming connection

- This is called the “Daemon” (or Demon) approach



Or you can have the InetD do it for you

- In Multinet, InetD is known as the Master Server
- In TCPware, InetD is part of NETCP
- In UCX, InetD is the Auxilliary Server

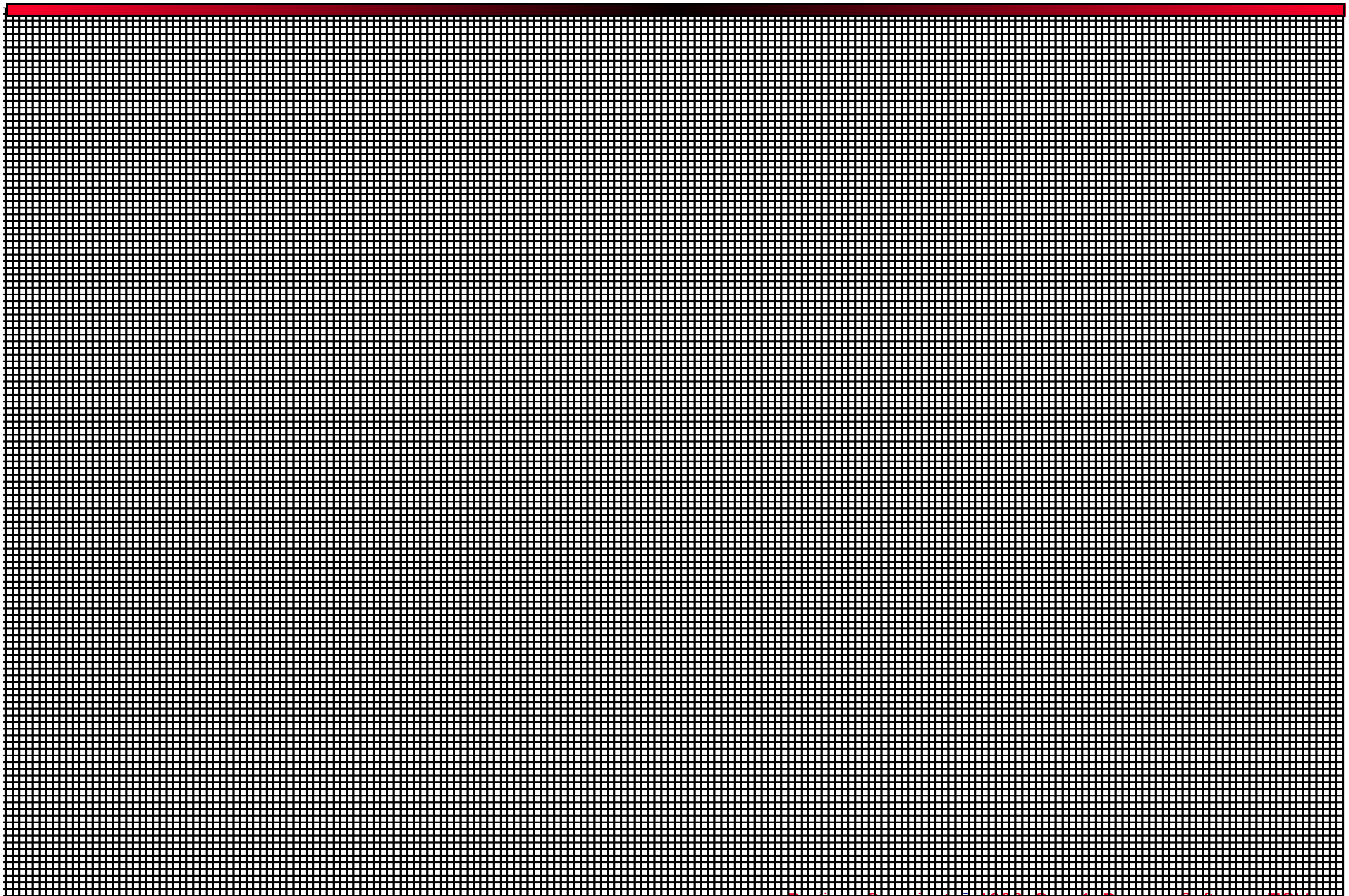


Servers low, Clients high

Servers:
ports
1-1023

Clients:

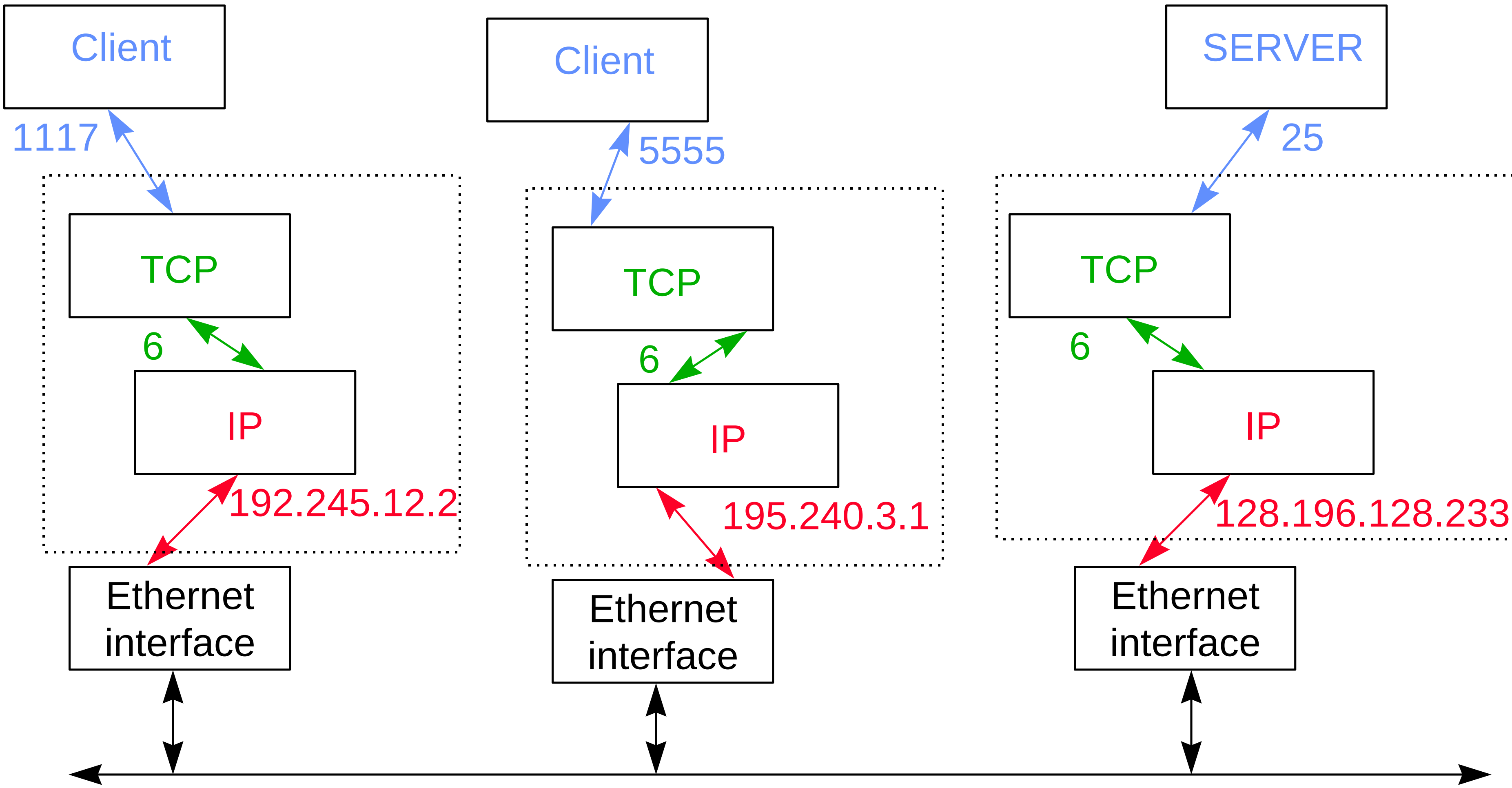
“ephemeral ports” above 1023



A Server may connect to multiple clients

- Each connection is a pair of triples (IP, protocol, port)
- The server side may remain the same across multiple clients
- Of course, the server programmer has to keep it all straight

Socket-pairs leave no ambiguity between 2 clients



Applications are known by their port numbers

- A process is identified by its 16-bit port number
- If a server uses both TCP and UDP, it will often use the same port number for both protocols
  - Protocol number means no ambiguity
- The concept of low-numbered ports as "privileged" disappeared with PCs
  - Don't base your security on port numbers!
- Some services use a meet-me approach

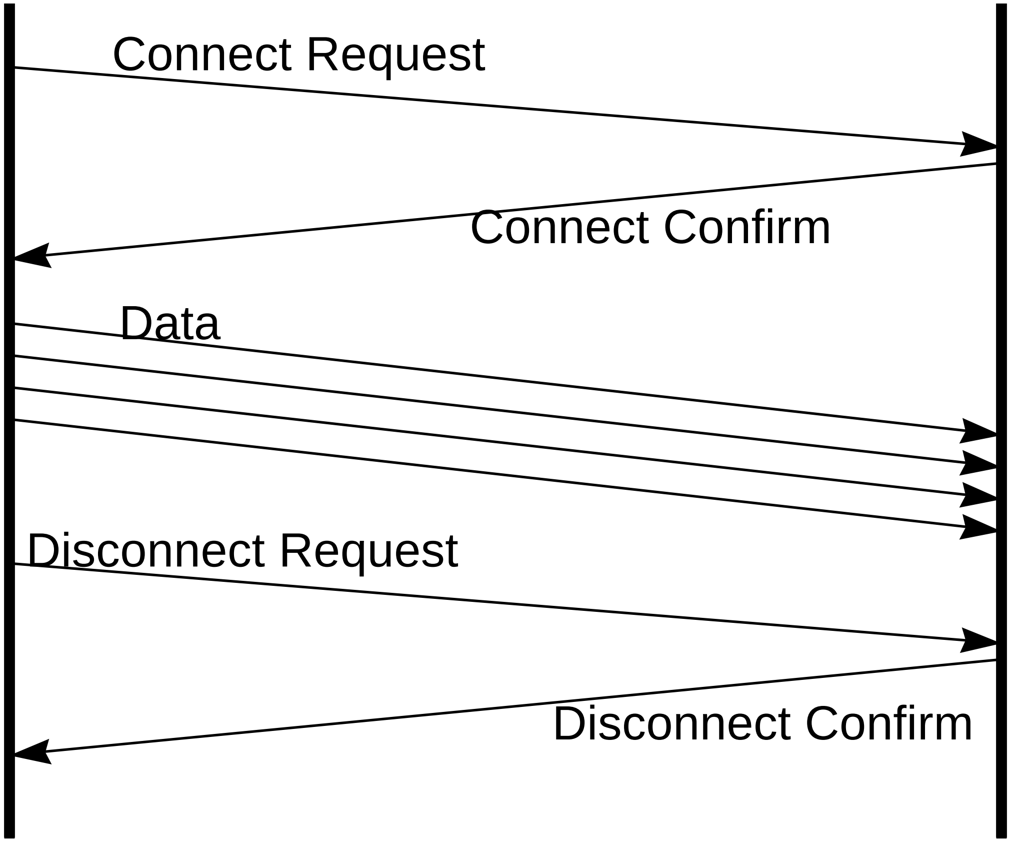
TCP/IP supports CL and CO at transport layer

- CO = Connection Oriented
  - TCP
  - “Stream”
- CL = Connectionless
  - UDP
  - “Datagram”
- CL can be provided by pure IP
  - Unusual
  - “Raw”

Connection oriented is like a phone call

- Connection oriented data communications arrived before connectionless
  - Used primarily over noisy serial lines in original intention.
    - not necessarily an issue with TCP
  - Two stations must establish a connection before data is transmitted.
  - Connection is strictly maintained using sequence numbers, acknowledgments, retries and so on.

Connect, Transfer, Disconnect



Note: This is **almost** like how it's done in TCP. Take the internals course for more info.

Connectionless is like a postcard

- Connectionless allows data to be transmitted without a pre-established connection between two stations.
  - This type of service flourished with the proliferation of LANs.
    - LANs tend to have a very low error rate and a connection need not be established to ensure the integrity of the data.
  - This type of service does not provide error recovery, flow or congestion control.
    - upper layer network protocols can accomplish this.
  - It requires less overhead and is implicitly faster.

Nike style data communications

Note: This is **exactly** like how it's done in UDP. Take the internals course for more info.

Client/Server in TCP/IP Key Concepts

- Servers are handled in one of two ways: resident daemons or InetD
- Server ports are low-numbers; client ports are high-numbered ephemeral ports
- A server can talk to many clients if the programmer can keep them straight
- TCP is CO; UDP is CL