Chapter 7.B and 7.C

Link Layer & Network Layer

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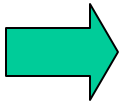
Some slides are from lectures by Nick Mckeown, Ion Stoica, Frans Kaashoek, Hari Balakrishnan, and Sam Madden

Previous Lecture

We learned how to share the network infrastructure between many connections/flows

We also learned about the implications of the sharing scheme (circuit or packet switching) on the service that the traffic receives

This Lecture

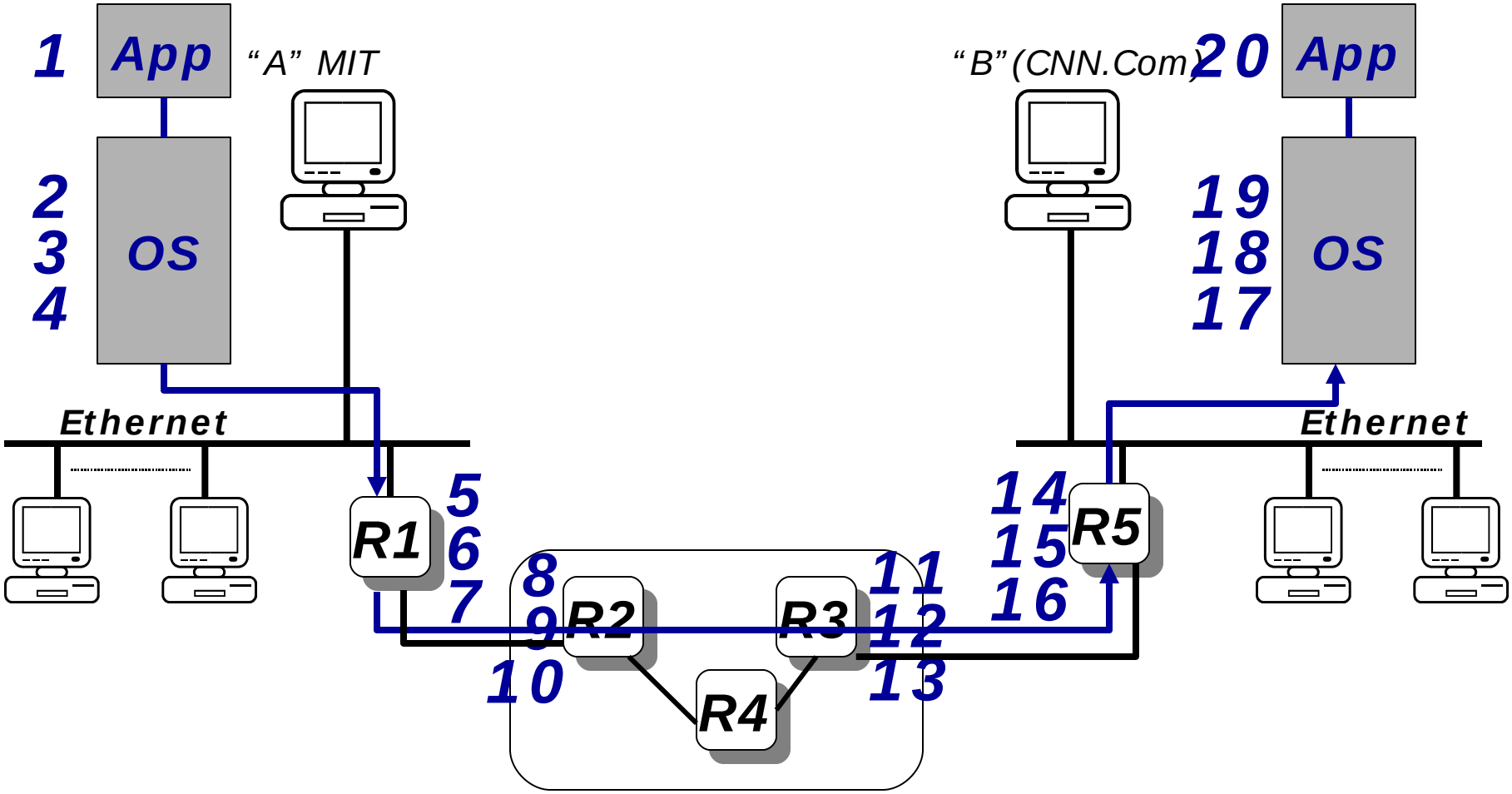


An Example: HTTP

Layering

Link Layer

Example: HTTP over the Internet Using TCP/IP and Ethernet



In the sending host

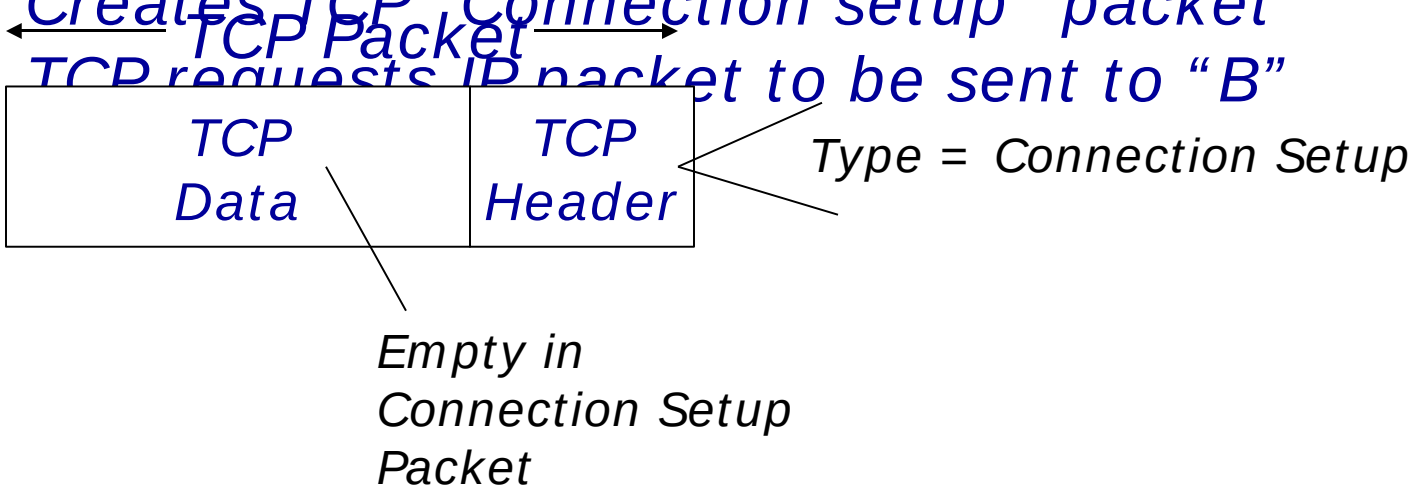
1. ***Application-Programming Interface (API)***

   Application requests TCP connection with "B"

2. ***Transmission Control Protocol (TCP)***

   Creates TCP "Connection setup" packet

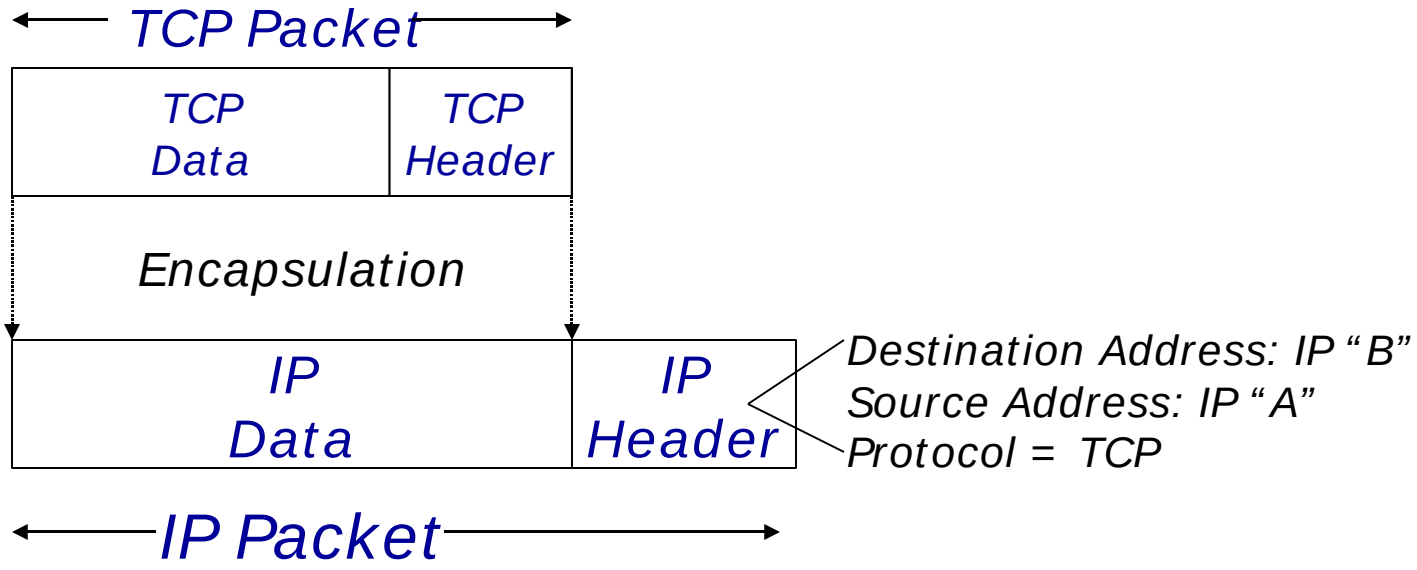
   TCP requests IP packet to be sent to "B"



In the sending host (2)

3. Internet Protocol (IP)

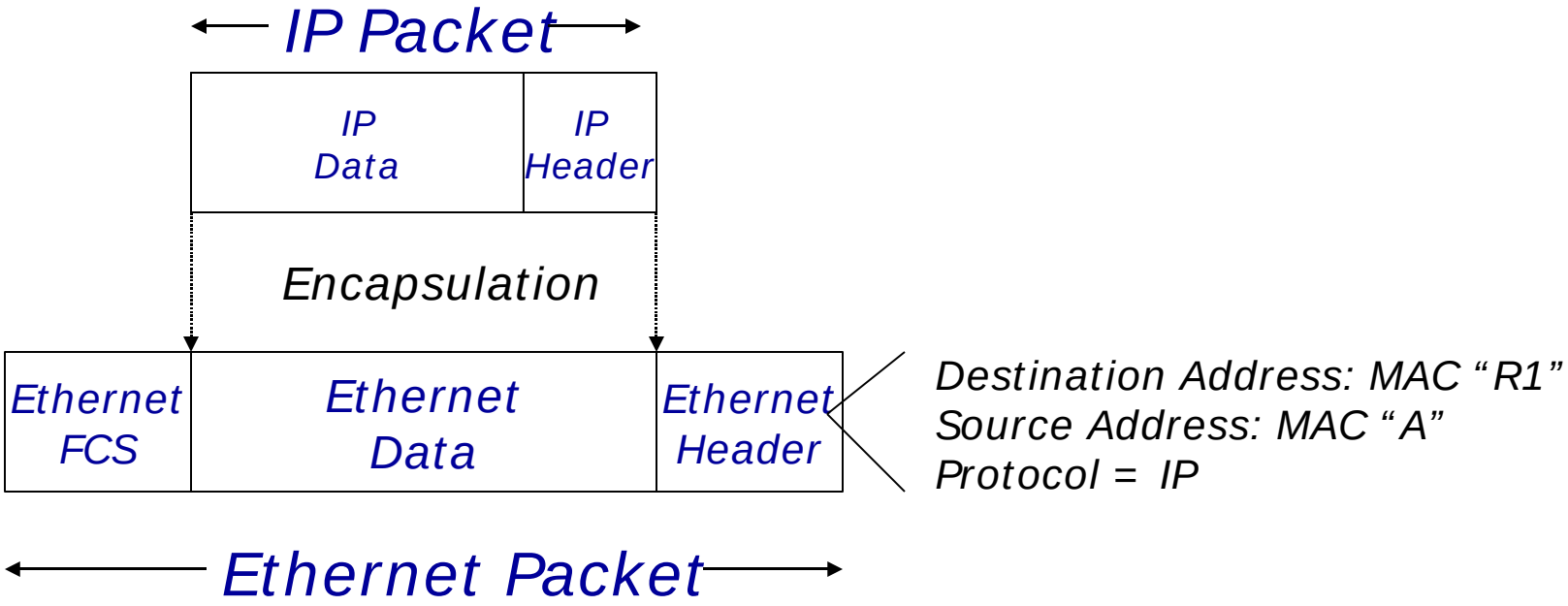
Creates IP packet with correct addresses.
IP requests packet to be sent to router.



In the sending host (3)

4. Link ("MAC" or Ethernet) Protocol

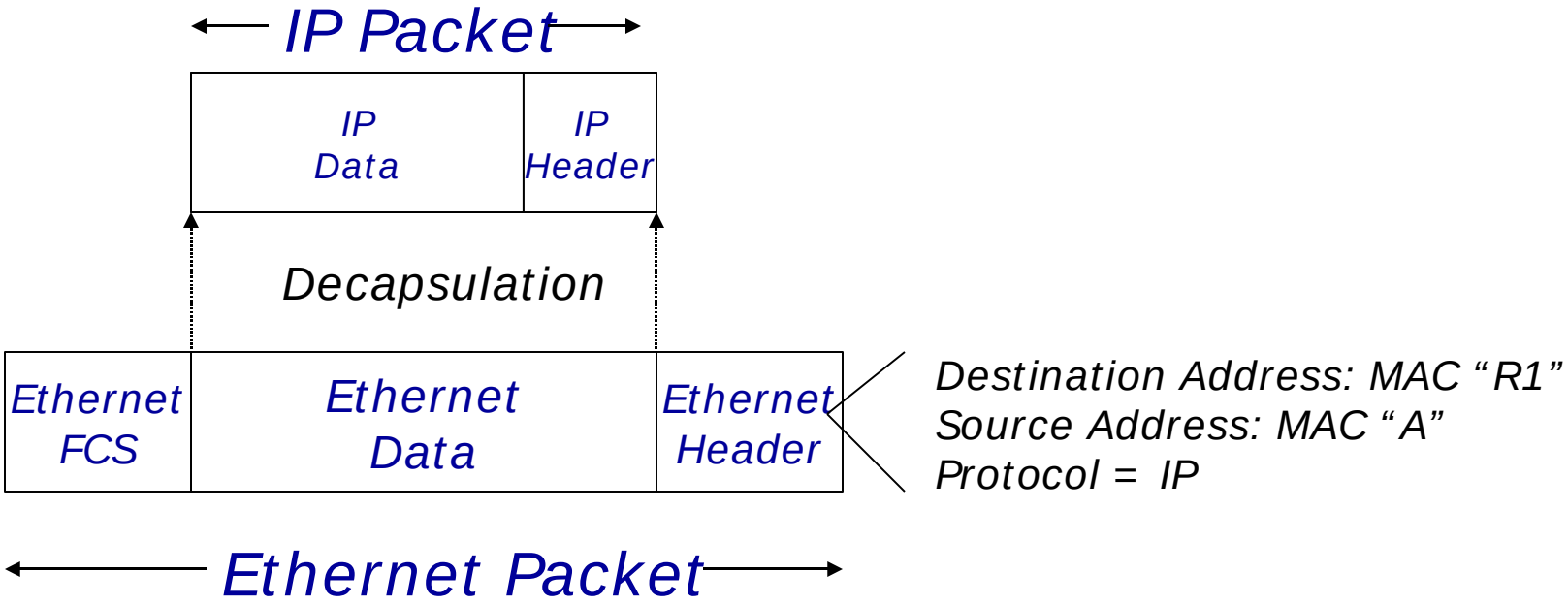
Creates MAC frame.
Wait for access to the line.
Send each bit of the frame.



In Router R1

5. Link ("MAC" or Ethernet) Protocol

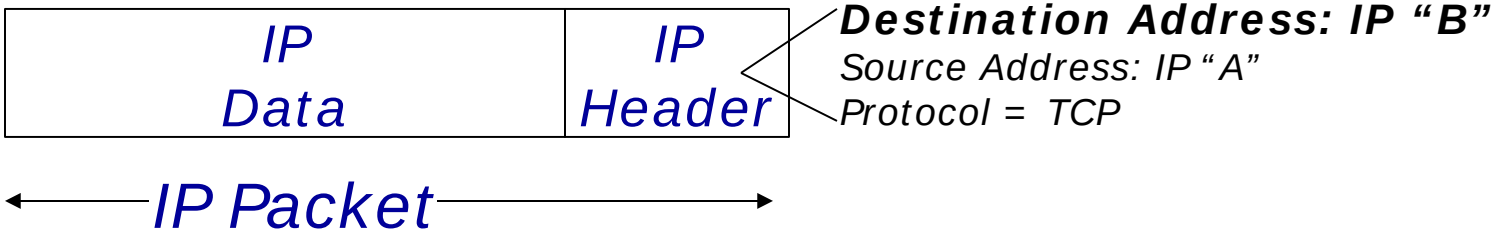
Accept MAC frame, check address and Frame Check Sequence (FCS) to ensure no bit errors. Pass data to IP Protocol.



In Router R1

6. Internet Protocol (IP)

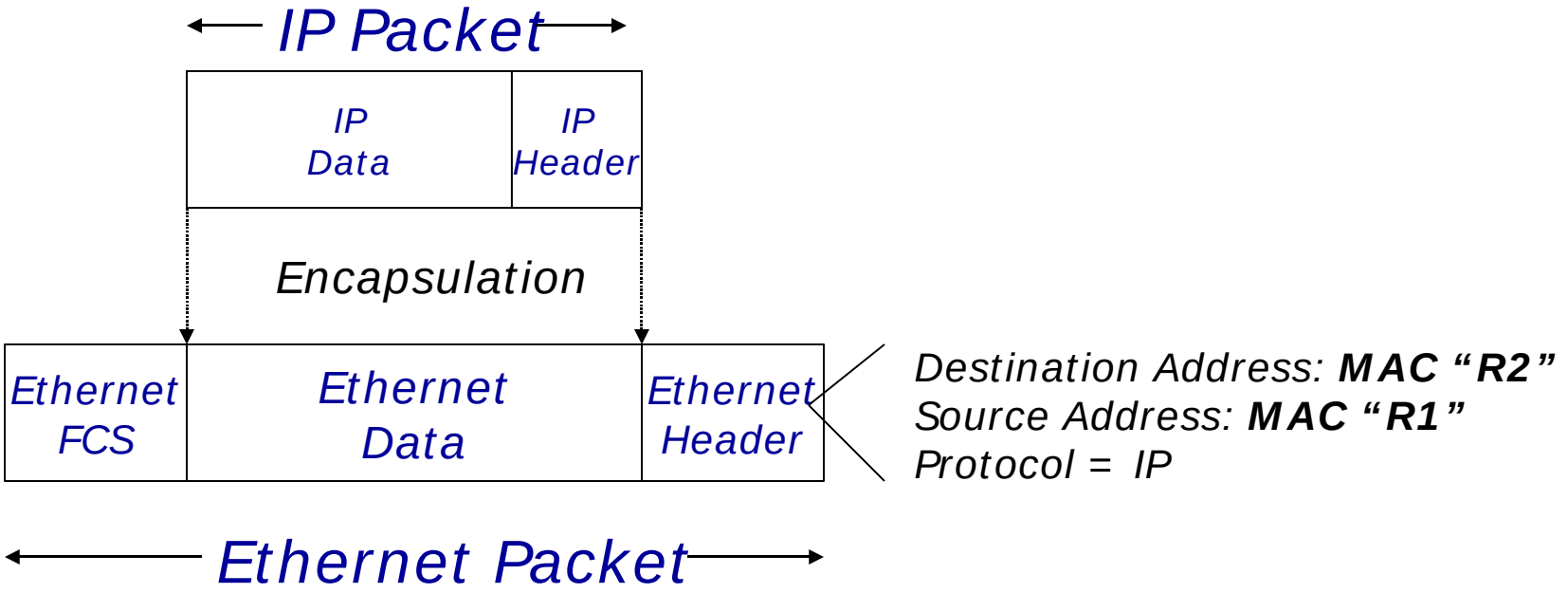
Use IP destination address to decide where to send packet next ("next-hop routing").
Request Link Protocol to transmit packet.



In Router R1

7. Link ("MAC" or Ethernet) Protocol

Creates MAC frame.
Wait for access to the line.
Send each bit of the frame.

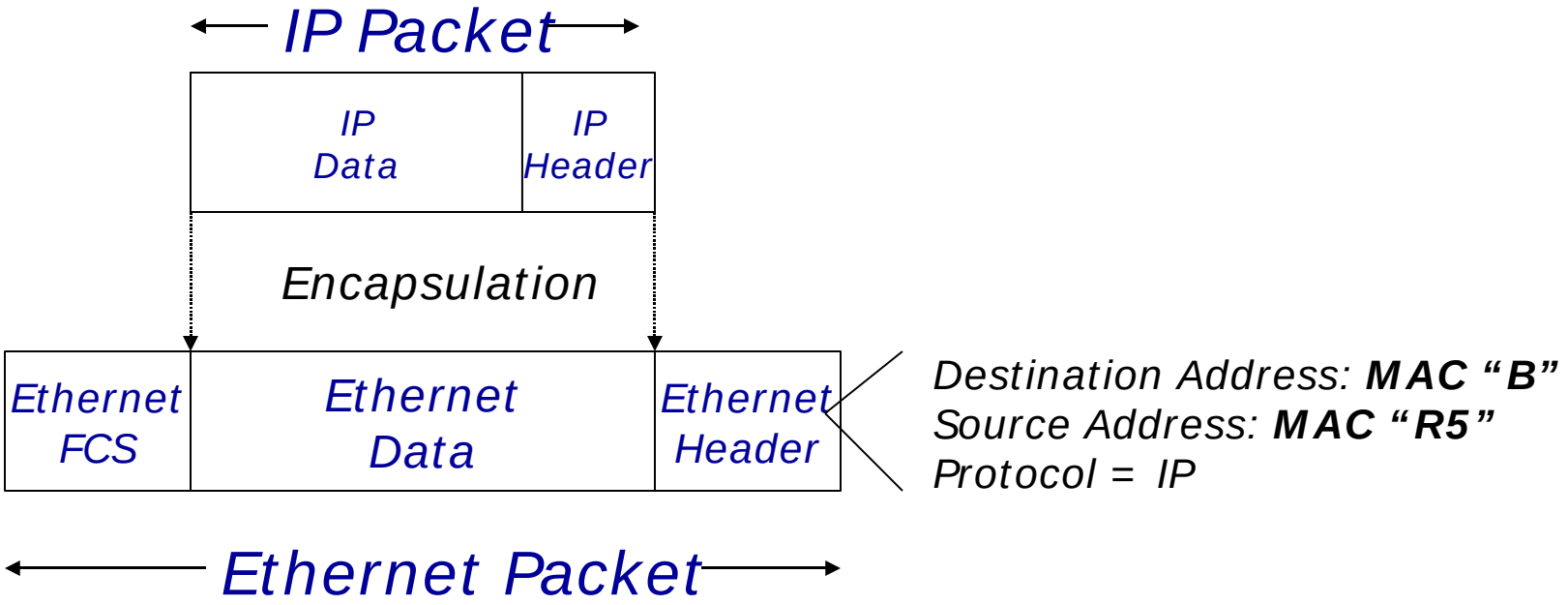


Steps 8- 15 are the same as before ...

In Router R5

16. Link ("MAC" or Ethernet) Protocol

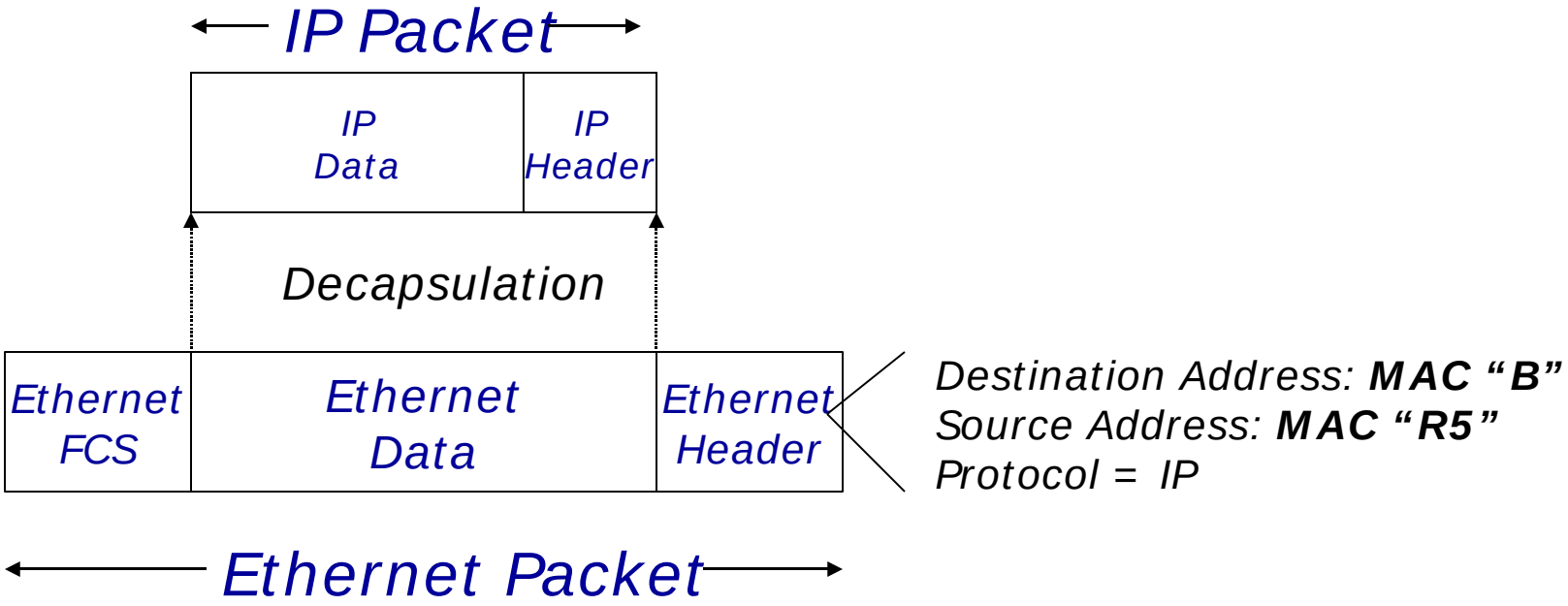
Creates MAC frame.
Wait for access to the line.
Send each bit of the frame.



In the receiving host

17. Link ("MAC" or Ethernet) Protocol

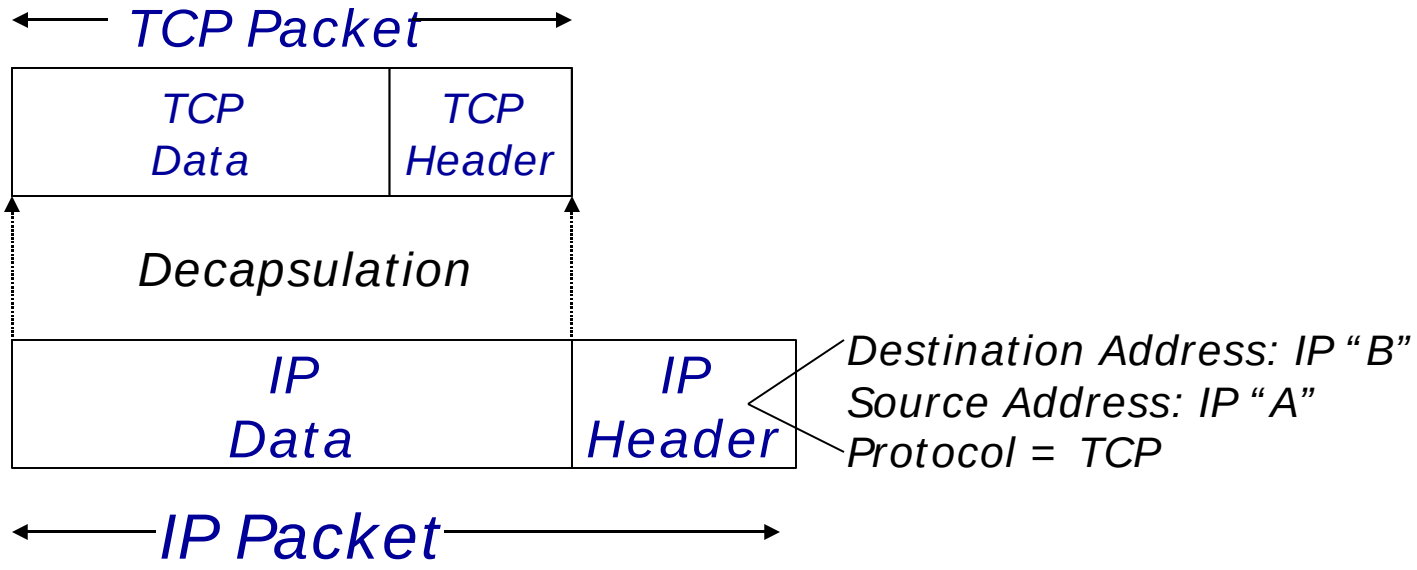
Accept MAC frame, check address and Frame Check Sequence (FCS) for bit errors.
Pass data to IP Protocol.



In the receiving host (2)

18. Internet Protocol (IP)

Verify IP address.
Extract/decapsulate TCP packet from IP packet.
Pass TCP packet to TCP Protocol.



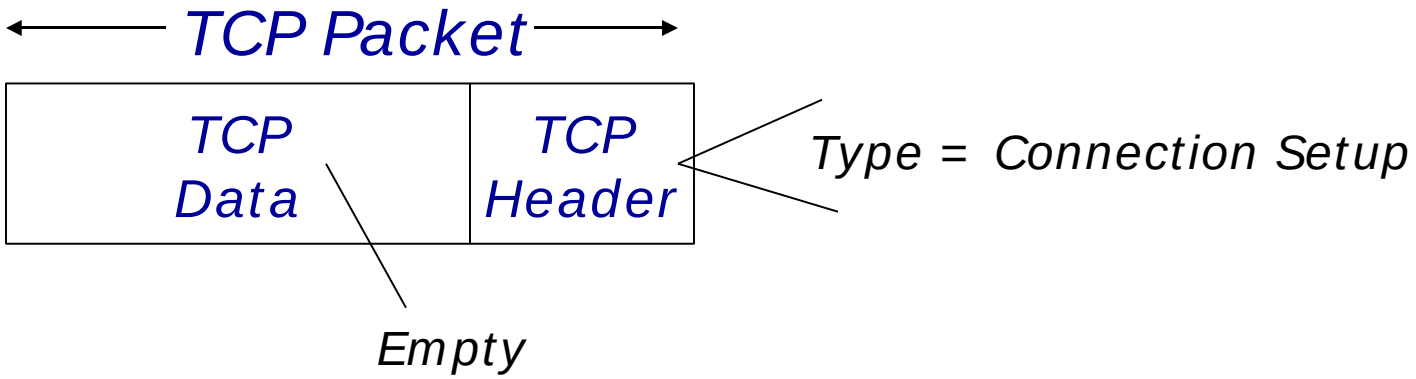
In the receiving host (3)

19. Transmission Control Protocol (TCP)

Accepts TCP "Connection setup" packet
Establishes connection by sending "Ack".

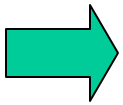
20. Application-Programming Interface (API)

Application receives request for TCP connection with "A".



This Lecture

An Example: HTTP



Layering

Link Layer

Network Architecture

Problem

Networks are complex (heterogeneity, distributed, delay, losses, reordering, ...)

How do we organize a network implementation?

Solution

To deal with complexity use layering

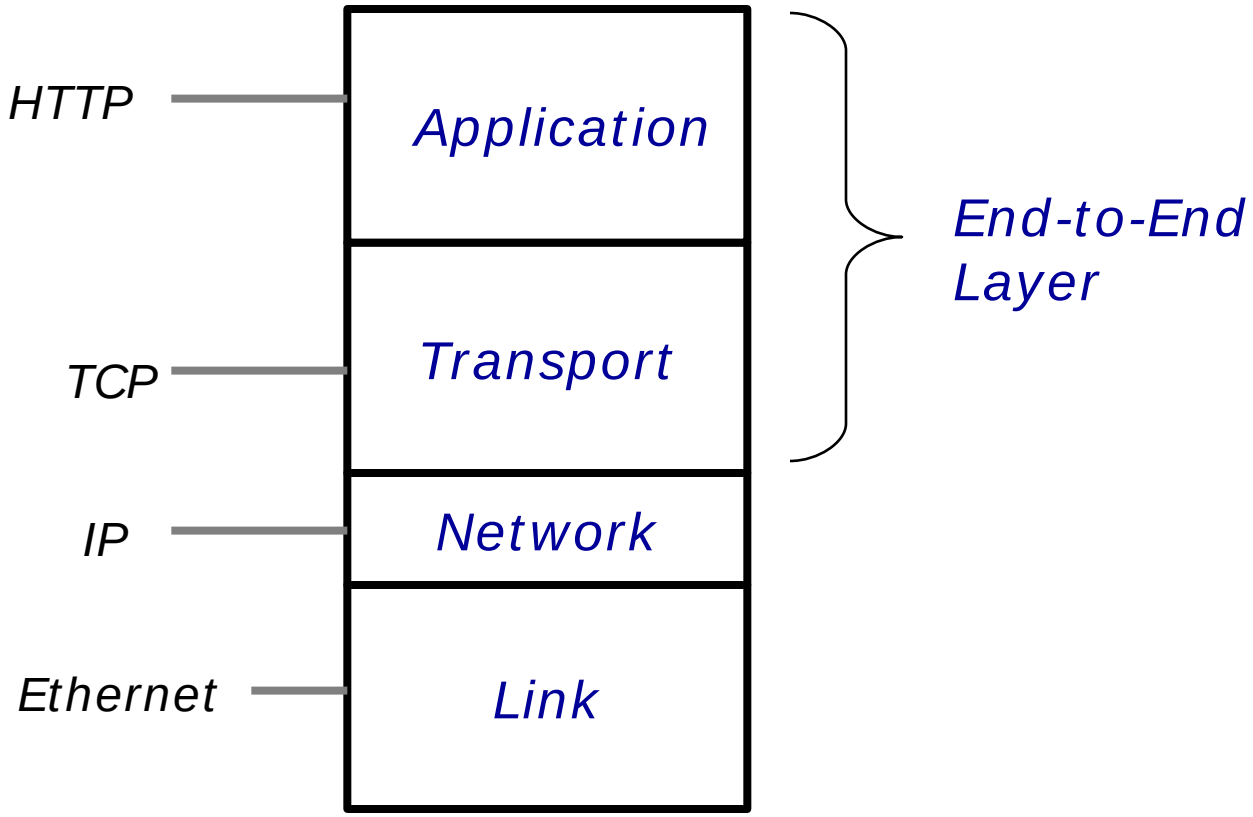
Layering

Layering is a particular form of abstraction

The system is broken into a vertical hierarchy of logically distinct entities (layers)

The service provided by one layer is based solely on the service provided by layer below

Layering: Our HTTP Example



The 4-layer Internet model

Who Does What?

Link Layer:

- *Delivers data from one end of a link to the other*

Network Layer

- *Routes packets and delivers them to their destination*

Transport Layer

- *Provides useful abstractions: stream, message*
- *Can provide reliability*
- *Can provide congestion control*

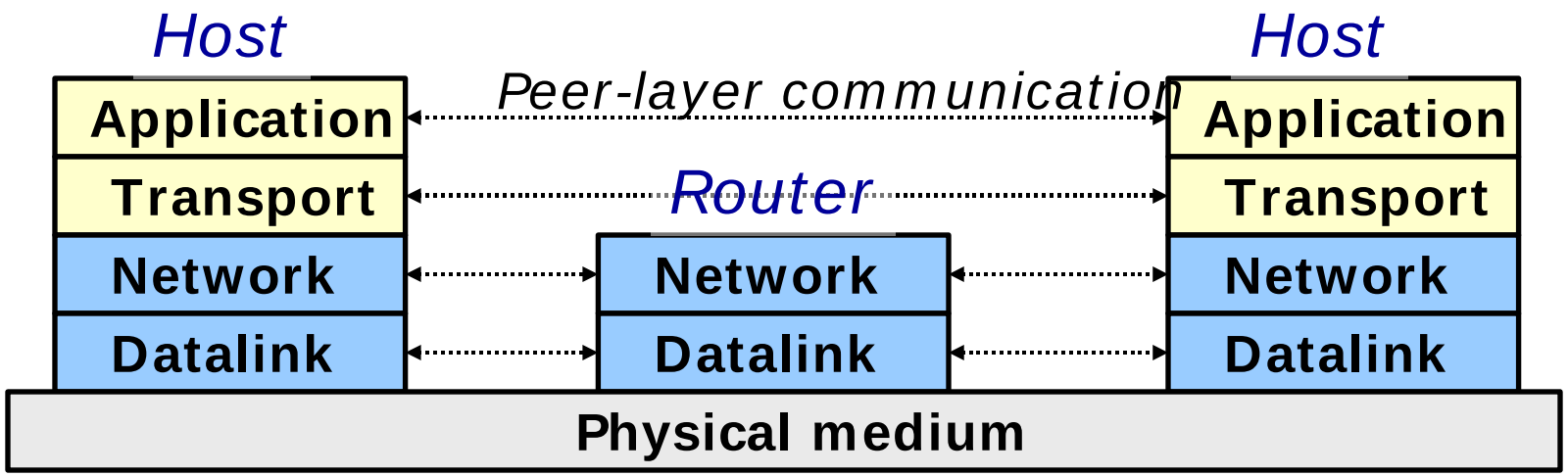
Application Layer

- *Your application: HTTP, FTP, etc.*

Where are these layers?

Link and network layers are implemented everywhere

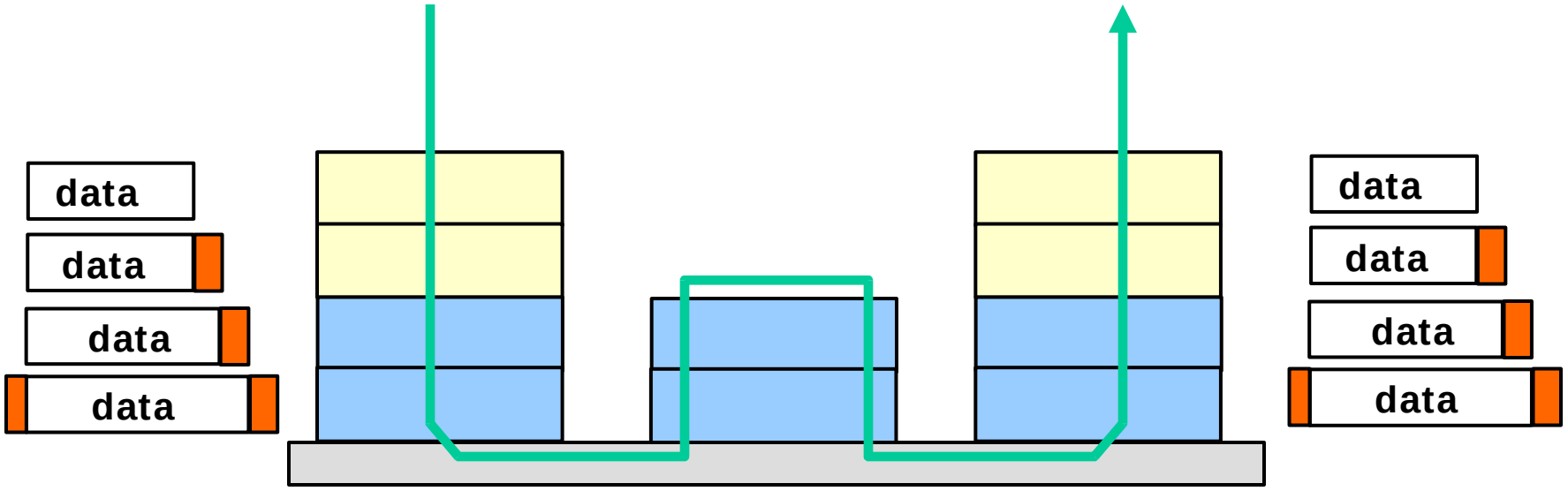
The end-to-end layer (i.e., transport and application) is implemented only at hosts



Encapsulation

A layer can use only the service provided by the layer immediate below it

Each layer may change and add a header to data packet



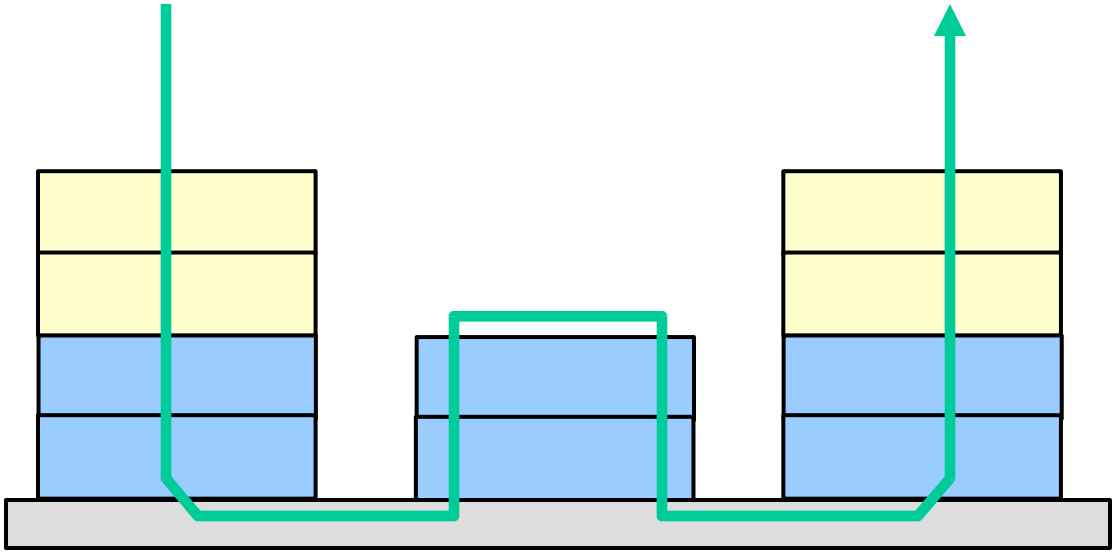
Interface

Higher layer calls lower layer

e.g., Link_Send(this_data, this_link)

Lower layer uses an up-call function to inform the higher layer of data arrival

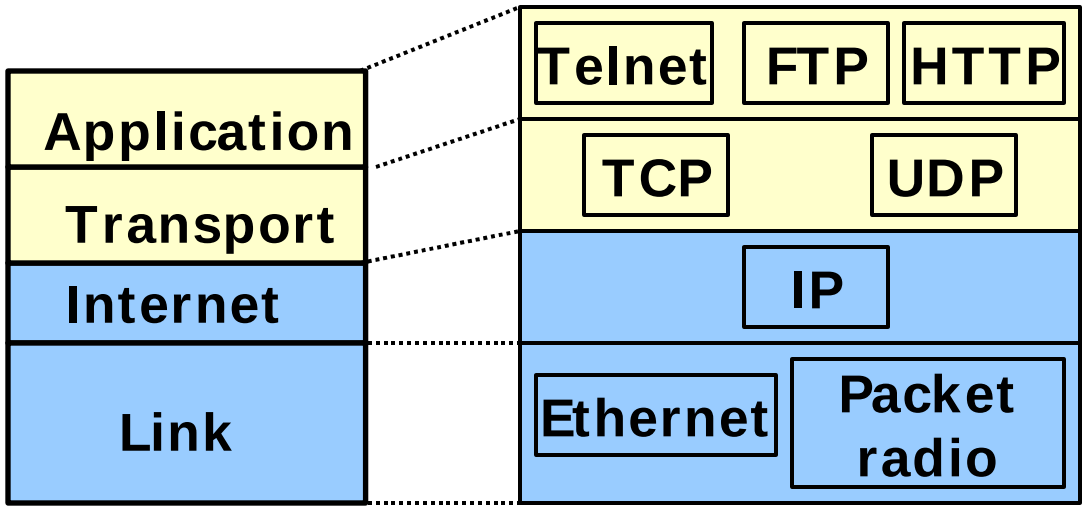
e.g., Network_Handle()



Multiplexing in the Internet

Many possible applications, transports, and link layers

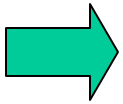
But they all use IP at the network layer



This Lecture

An Example: HTTP

Layering



Link Layer

Link Layer

Problem:

Deliver data from one end of the link to the other

Need to address:

Bits Analog Bits

Framing

Errors

Medium Access Control (The Ethernet Paper)

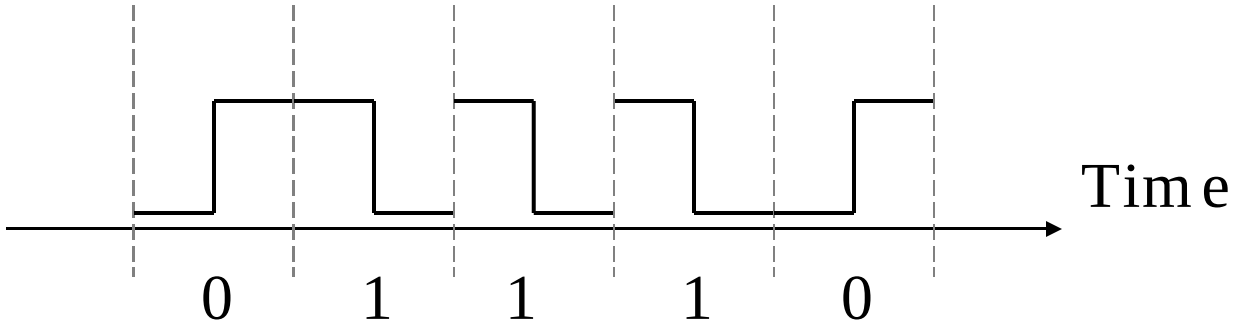
Sending bits

Bits Analog Bits

Receiver needs to detect the value of the bits

Manchester Encoding: each bit is a transition

Having a transition in each bit allows the receiver to synchronize to the sender's clock



Framing

Receiver needs to detect the beginning and the end of a frame

Use special bit-pattern to separate frames

- *E.g., pattern could be 1111111 (7 ones)*

Bit stuffing is used to ensure that a special pattern does not occur in the data

- *If pattern is 1111111 Whenever the sender sees a sequence of 6 ones in the data, it inserts a zero (reverse this operation at receiver)*

Error Handling

Detection:

Use error detection codes, which add some redundancy to allow detecting errors

When errors are detected

Correction:

- Some codes allow for correction

Retransmition:

- Can have the link layer retransmit the frame (rare)

Discard:

- Most link layers just discard the frame and rely on higher layers to retransmit

This Lecture

To cope with the complexity, the network architecture is organized into layers

The link layer delivers data between two machines that are directly connected using a link