Chapter 7.B and 7.C

Network Architecture: Layers

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

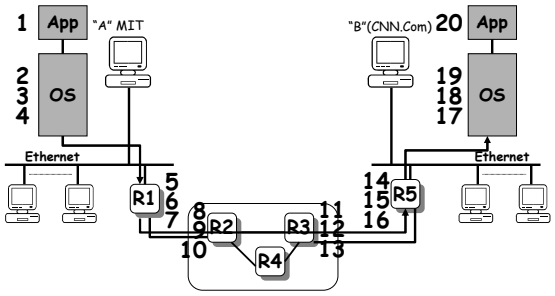
Last Lecture

- 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

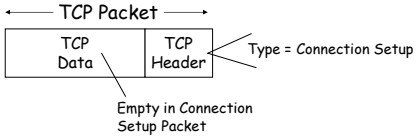
- An Example: HTTP
- Layering (read 7.B)
- Link Layer (read 7.C)

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



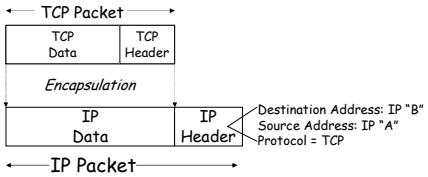
In the sending host

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)

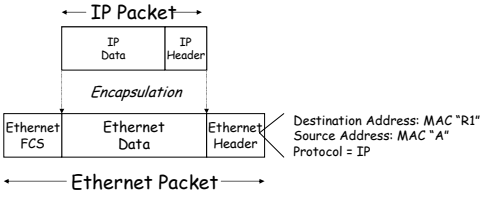
3. **Internet Protocol (IP)**
   - Creates IP packet with correct addresses.
   - IP requests packet to be sent to router.



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.



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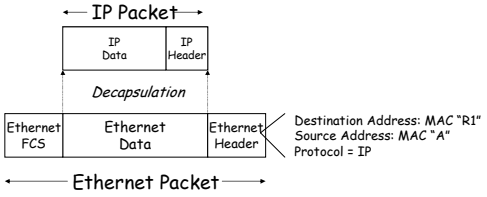
In Router R1

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.



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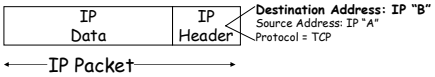
In Router R1

6. Internet Protocol (IP)

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



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In Router R1

7. Link ("MAC" or Ethernet) Protocol

- Creates MAC frame.
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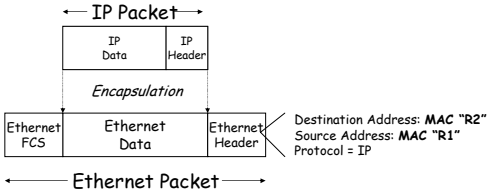

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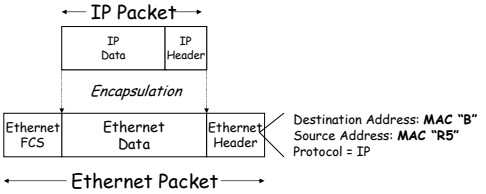
Steps 8-15 are the same as before …

In Router R5

16. Link ("MAC" or Ethernet) Protocol

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



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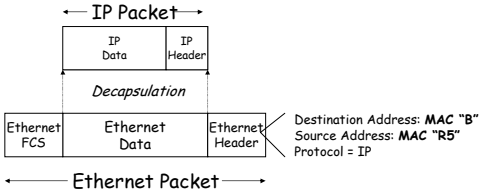
In the receiving host

17. Link ("MAC" or Ethernet) Protocol

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



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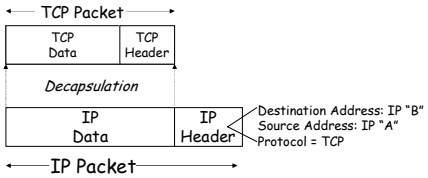
In the receiving host (2)

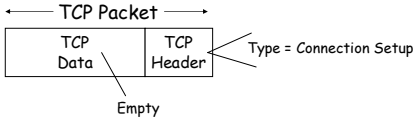
18. Internet Protocol (IP)
- Verify IP address.
- Extract/decapsulate TCP packet from IP packet.
- Pass TCP packet to TCP Protocol.



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

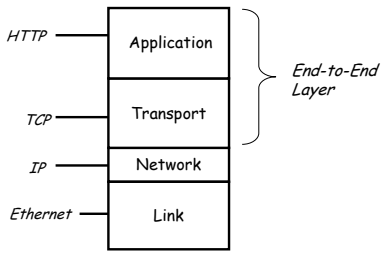
Problem
- Networks are complex (heterogeneity, distributed, delay, losses, reordering, …)
- How do we organize a network implementation?

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.

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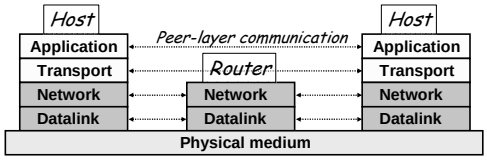
Where are these layers?

- Link and network layers are implemented everywhere
- The end-to-end layer (i.e., transport and application) is implemented only at hosts



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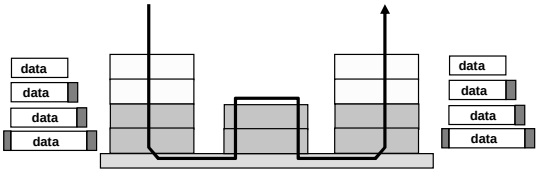
Encapsulation

- 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



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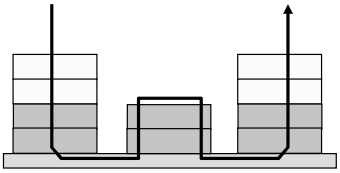
Interface

- 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()`



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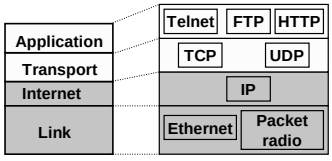
Multiplexing in the Internet

- Many possible applications, transports, and link layers
- But they all use IP at the network layer



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This Lecture

- An Example: HTTP
- Layering
- Link Layer

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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)

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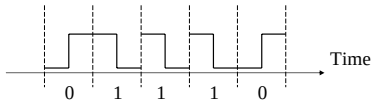
Sending bits

- 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



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Framing

- Receiver needs to detect the beginning and the end of a frame
- Use special bit-patterns at the beginning and the end of the frame
- Bit stuffing is used to ensure that a special pattern does not occur in the data
  - E.g., pattern is 1111111 (7 ones)
  - Bit stuffing: whenever the sender sees a sequence of 6 ones in the data, it inserts a zero (reverse this operation at receiver)

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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

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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

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