Note: We will start at 12:53 pm ET

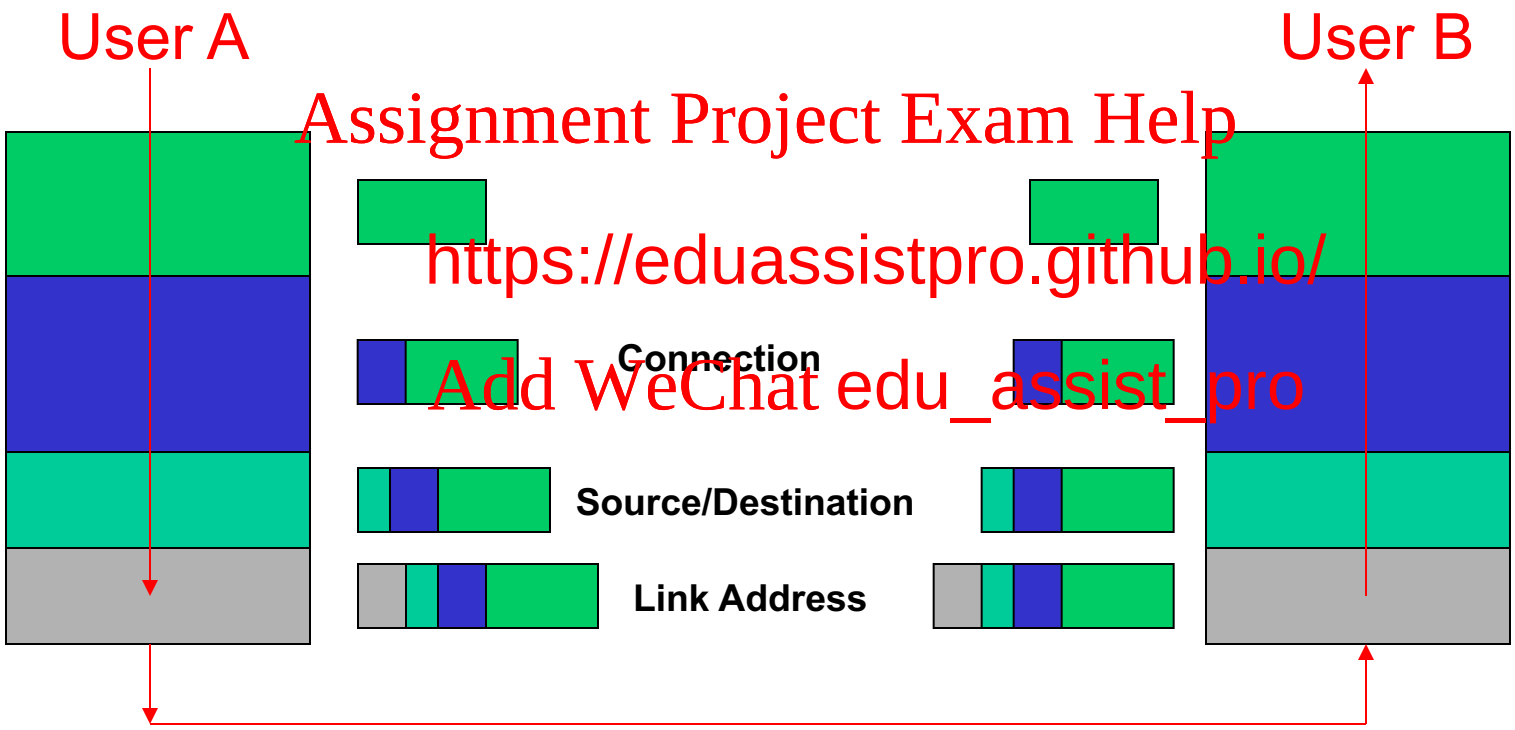
→

18-441/741: Computer Networks

Lectur **& PHY I**

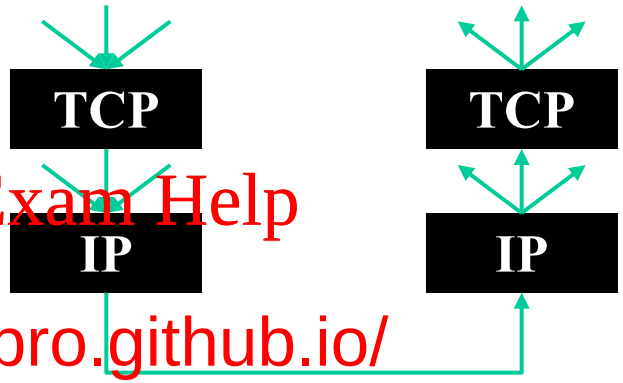
Swarun

Layer Encapsulation



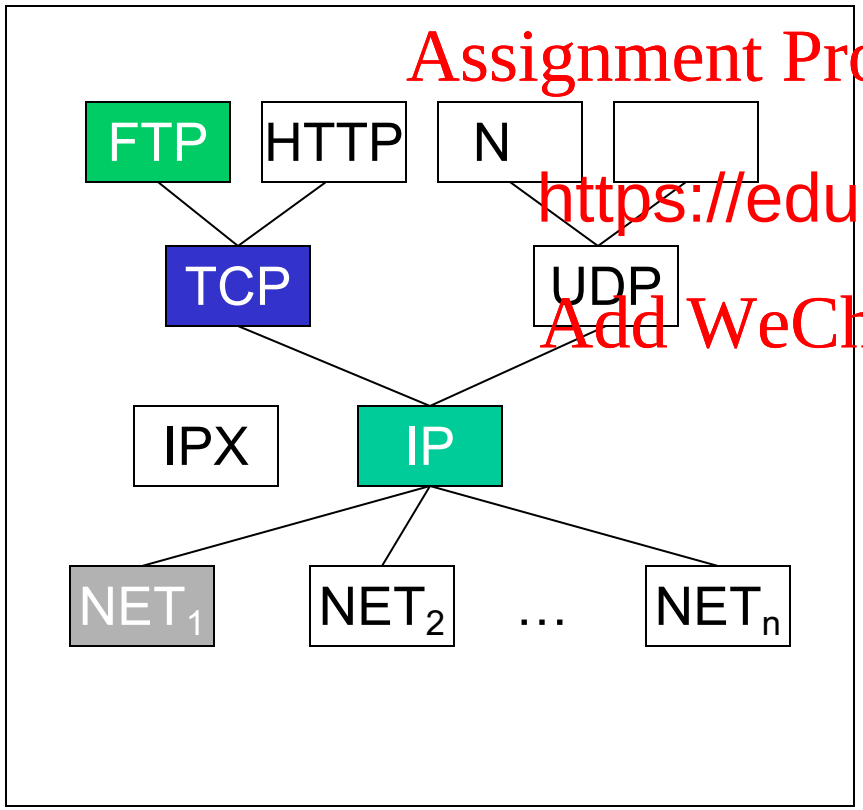
Multiplexing and Demultiplexing

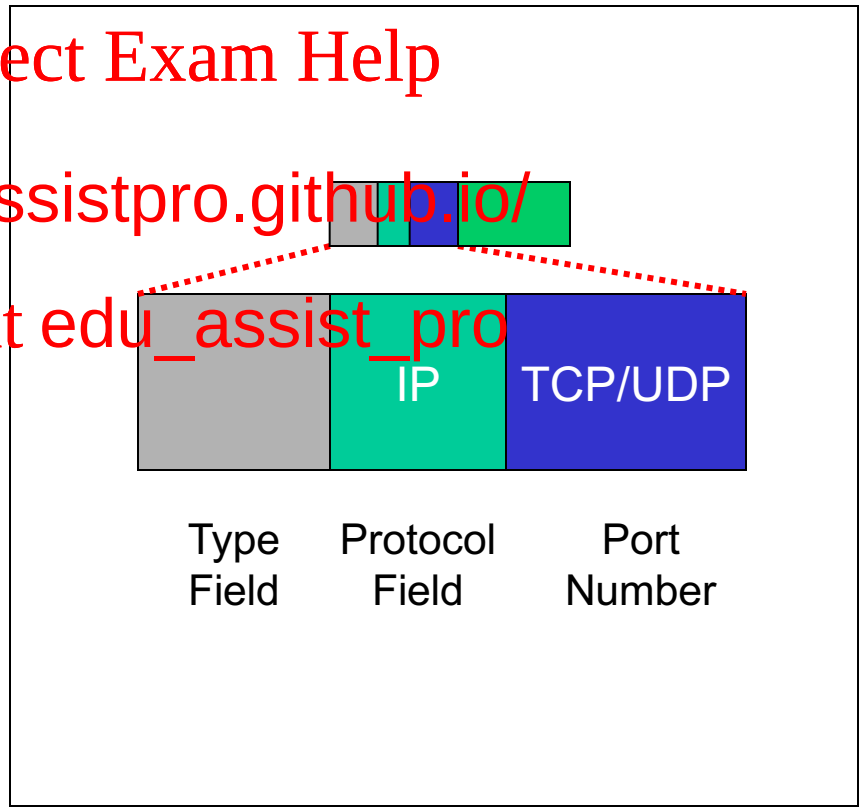
- There may be multiple implementations of each layer.
  - How does the receiver know what version of a layer to use?
- Each header i demultiplexing field that is used to identify the next layer.
  - Filled in by the sender
  - Used by the receiver
- Multiplexing occurs at multiple layers. E.g., IP, TCP, …



Protocol Demultiplexing

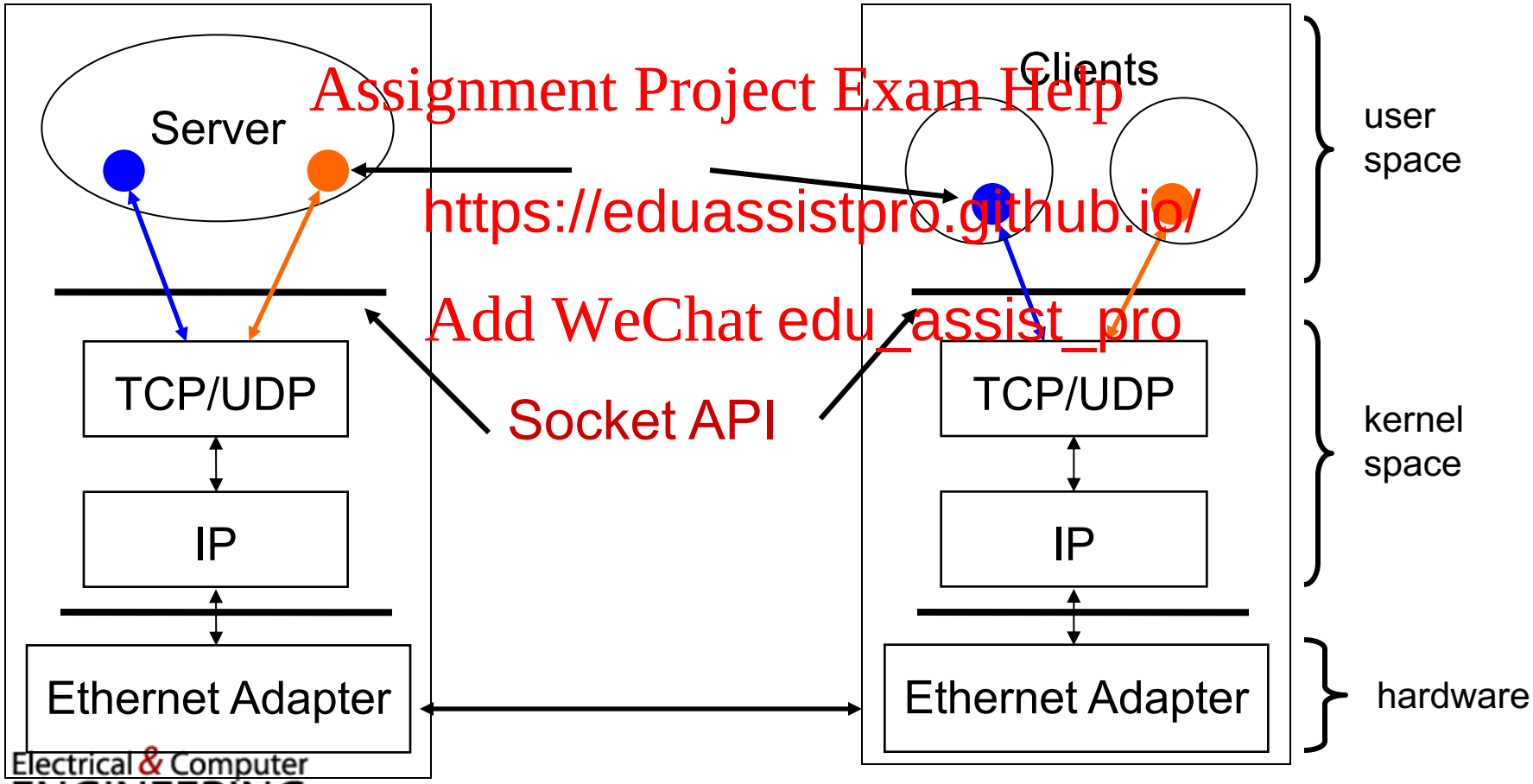
- Multiple choices at each layer



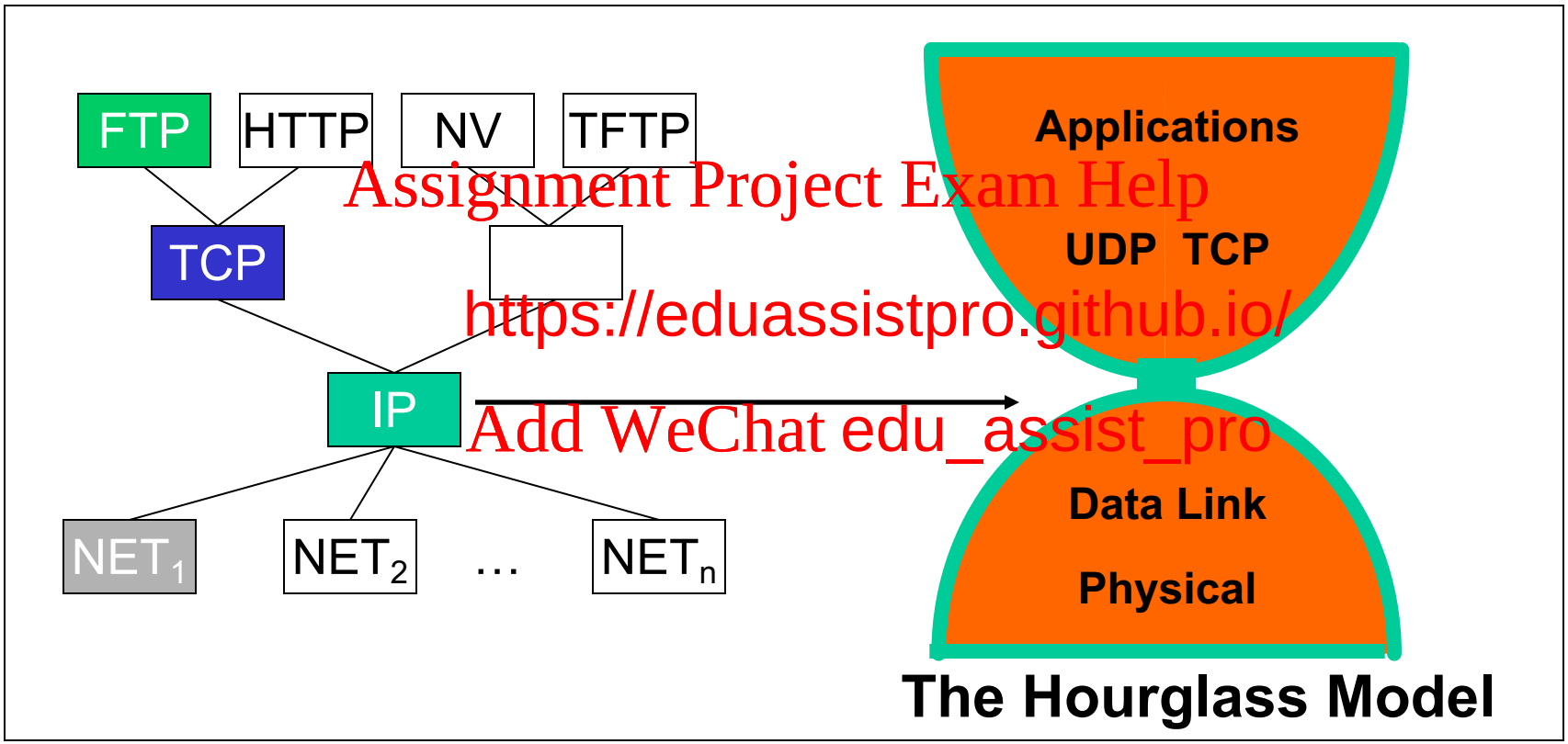


Server and Client

Server and Client exchange messages over the network through a common Socket API



The Internet Protocol Suite



The waist facilitates interoperability

… but evolution is hard

IP based on a Minimalist Approach

- Dumb network
  - IP provide minimal functionalities to support connectivity
    - Addressi
- Smart end s
  - Transport l s more sophisticated functionalitie
    - Flow control, error control, trol
- Advantages
  - Accommodate heterogeneous technologies (Ethernet, modem, satellite, wireless)
  - Support diverse applications (telnet, ftp, Web, X windows)
  - Decentralized network administration

Sample Quiz Question

- Question: Which of these will be hardest launch at Internet-scale:

  [Option A] a new ver CP.
  [Option B] a new ver
  [Option C] or a new version of WiFi

- Answer: New IP (why?)

Today's Lecture

- Network applications
  - Requirements
  - Latency
- Internet architecture
  - A layered design
  - Protocols
  - Life of a packet
- Network utilities

Protocol Stack (cotd.)

- Network applications
  - Requirements
  - Latency
- Internet architecture
  - A layered design
  - Protocols
  - Life of a packet
- Network utilities

Network tools

- ping
- traceroute
- ipconfig
- tcpdump
- …

ping

- Application to determine if host is reachable
- Based on Internet Control Message Protocol
  - ICMP informs source host about errors encountering by routers or by destination host
  - ICMP Echo message received from destination host
- PING sends echo message & sequence #
- Determines reachability & round-trip delay
- Sometimes disabled for security reasons

traceroute

- Find route from local host to a remote host
- Time-to-Live (TTL)
  - IP packets have TTL field that specifies maximum # hops traversed before packet discarded
  - Each rout
  - When TTL rded
- Traceroute
  - Send UDP to remote host with TTL=1
  - First router will reply ICMP Time Exceeded Message
  - Send UDP to remote host with TTL=2, …
  - Each step reveals next router in path to remote host
- **`tracert`** (windows), **`tracepath`** (linux)

ipconfig

- Utility in Microsoft Windows to display TCP/IP information about a host
- Many opti
  - Simplest: mask, default gateway for the host
  - Information about each IP interface of a host
    - DNS hostname, IP addresses of DNS servers, physical address of network card, IP address, …
  - Renew IP address from DHCP server

netstat

- Queries a host about TCP/IP network status
- Status of network drivers & their interface
  - #packets in, #packet red packets, …
- State of routing table in host
- TCP/IP active server processes
- TCP active connections

`tcpdump` and Network Protocol Analyzers

- `tcpdump` program captures IP packets on a network interface (usually Ethernet NIC)
- Filtering used to select packets of interest
- Packets & high [illegible] be displayed and analyzed
- `tcpdump` basis for many net[illegible]col analyzers for troubleshooting networks
- We use the open source Ethereal analyzer to generate examples (or wireshark, etc.)
  - www.ethereal.com

How the layers work together: Network Analyzer Example

Internet

- User clicks on
- *Ethereal* network analyzer captures all frames observed by its Ethernet NIC (or Wireshark)
- Sequence of frames and contents of frame can be examined in detail down to individual bytes

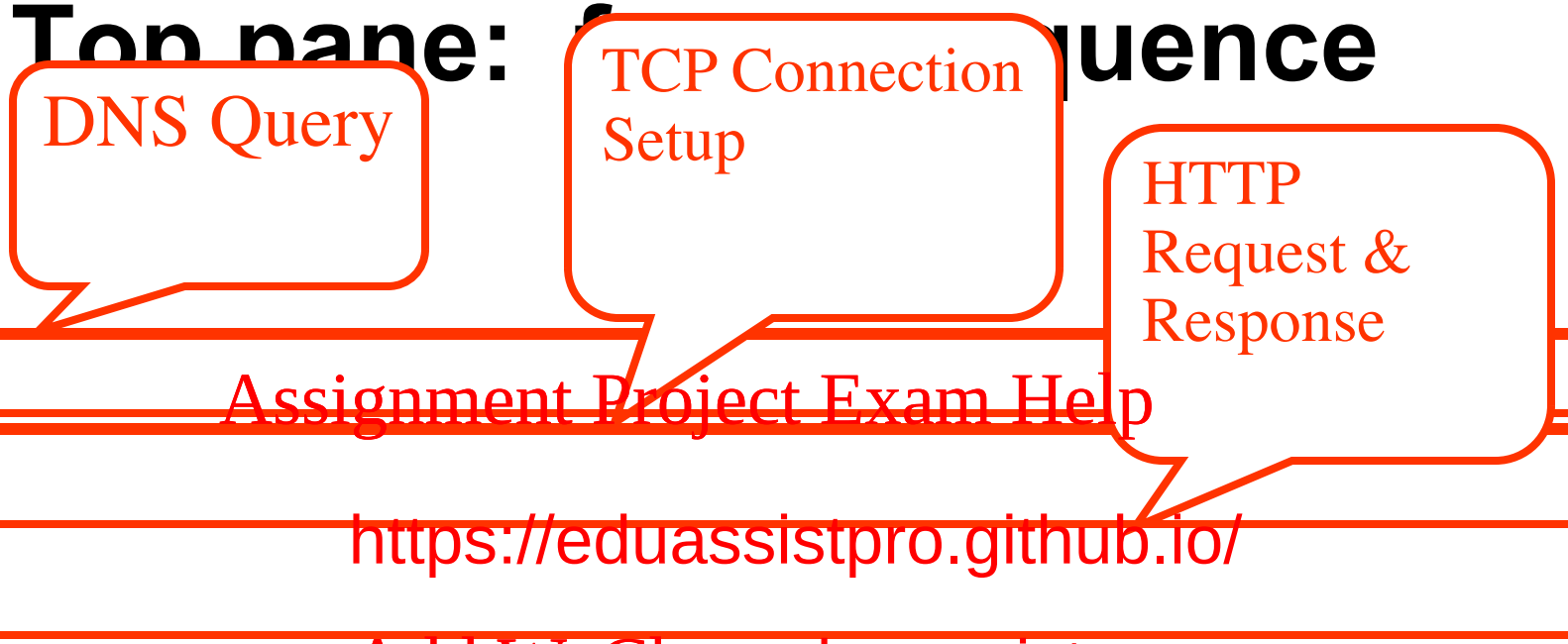
eal wind

Top Pane shows frame/packet sequence

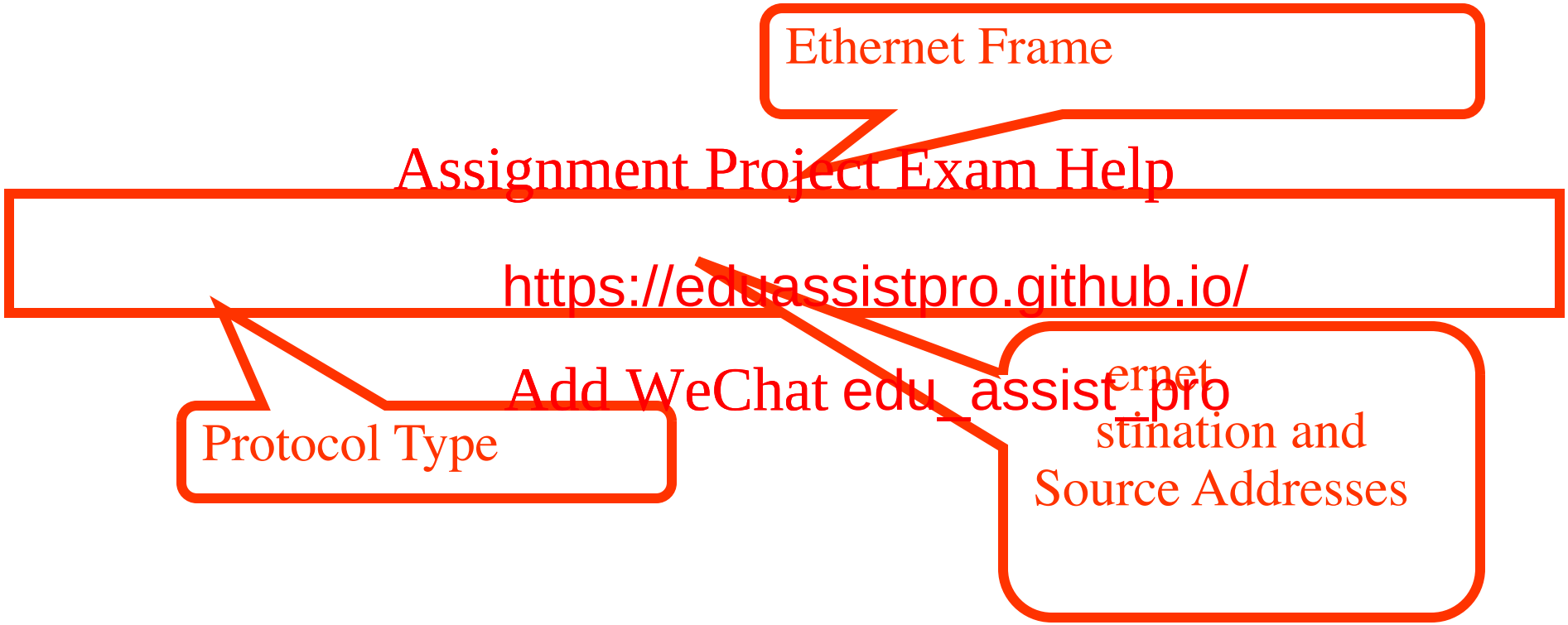
Middle Pane shows encapsulation for a given frame

Bottom Pane shows hex & text

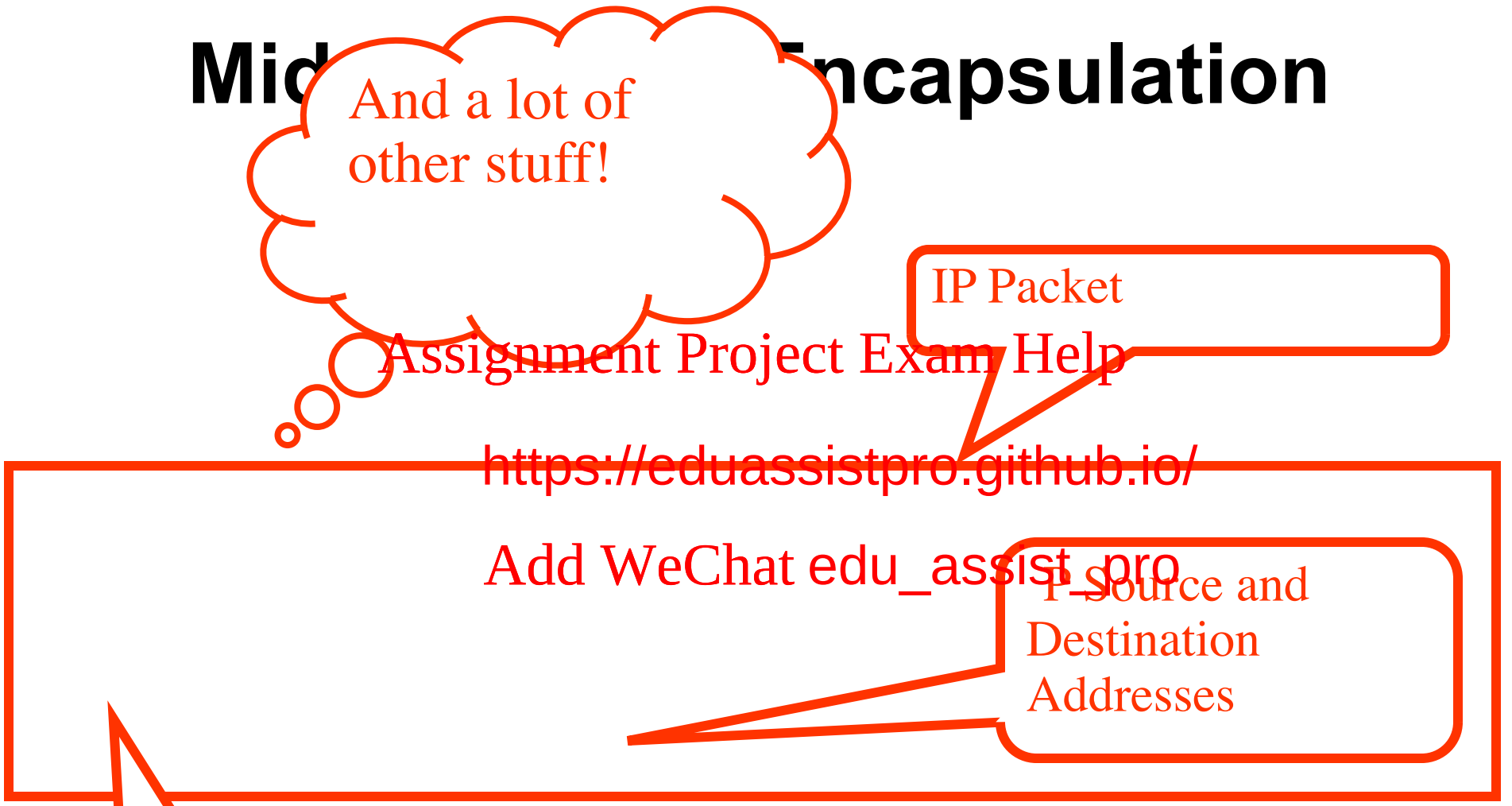
Top pane: f quence



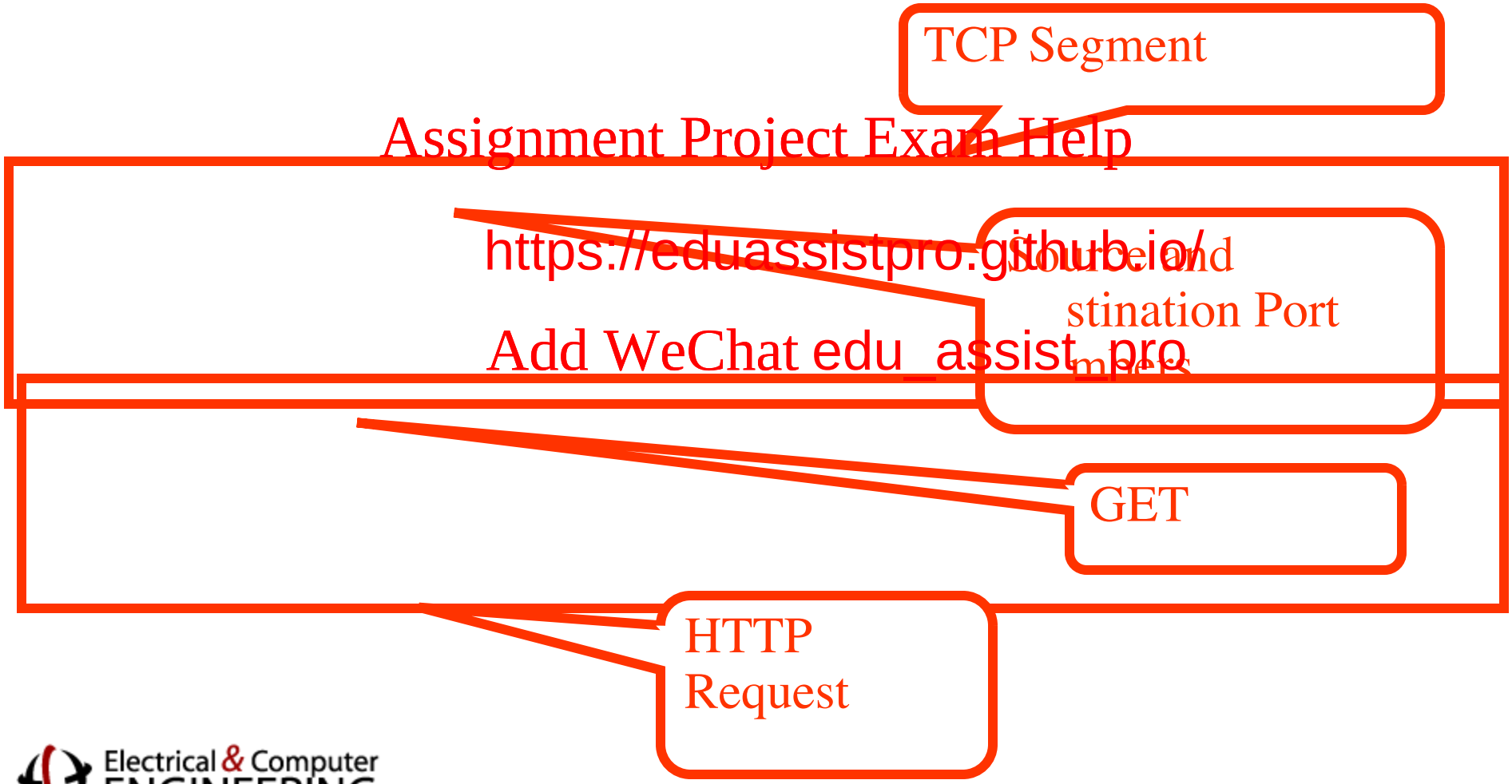
Middle pane: Encapsulation



Mid Encapsulation



Middle pane: Encapsulation



Goals [Clark88]

0 **Connect existing networks**

initially ARPANET and ARPA packet radio network

1. Survivability

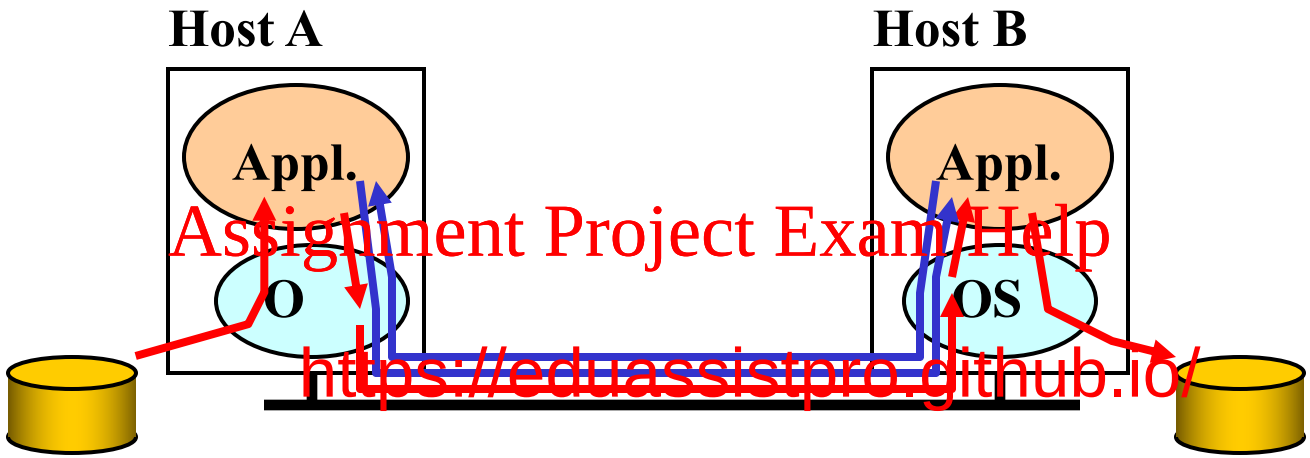
ensure comm n the presence of network an

2. Support multiple types of
3. Must accommodate a variety of networks
4. Allow distributed management
5. Allow host attachment with a low level of effort
6. Be cost effective
7. Allow resource accountability

Principle: End-to-End Argument (Saltzer'81)

- Focus of the paper is "system"
  - Not a pure networking paper
- Deals with ionality
  - Inside the network (in sw ents)
  - At the edges
- Argument: Some functions can only be correctly implemented by the endpoints – do not try to implement these elsewhere
  - Not a law – more of a "best practices"

Example: Reliable File Transfer



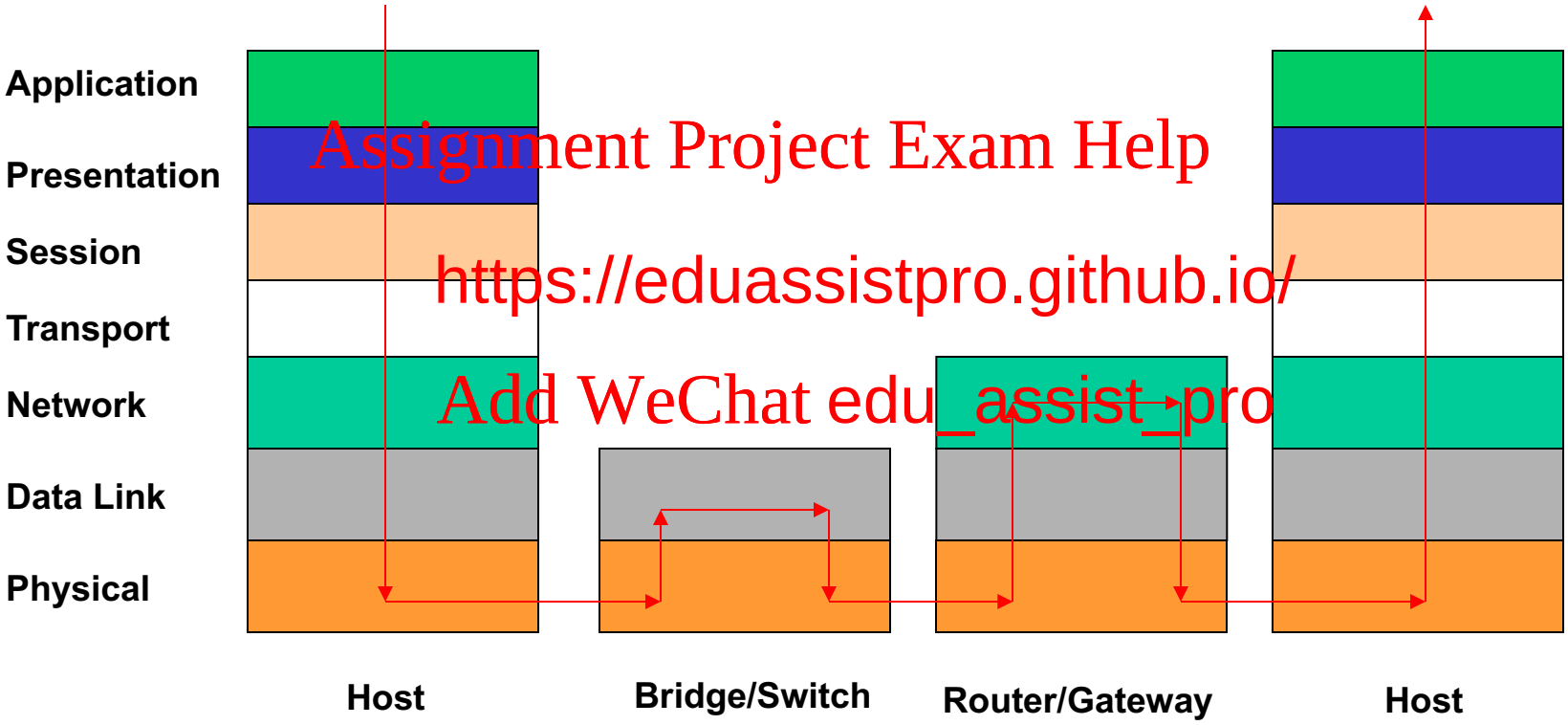
- Solution 1: make each step reliable, and then concatenate them
- Solution 2: end-to-end check and retry

Sample Quiz Question

- Question: A switch and a router both cost $100 and have similar specs and achieve si in packet switching/routing. As al buyer, I would buy the router alse]

- Answer: True, the router (why?)

Life of Packet



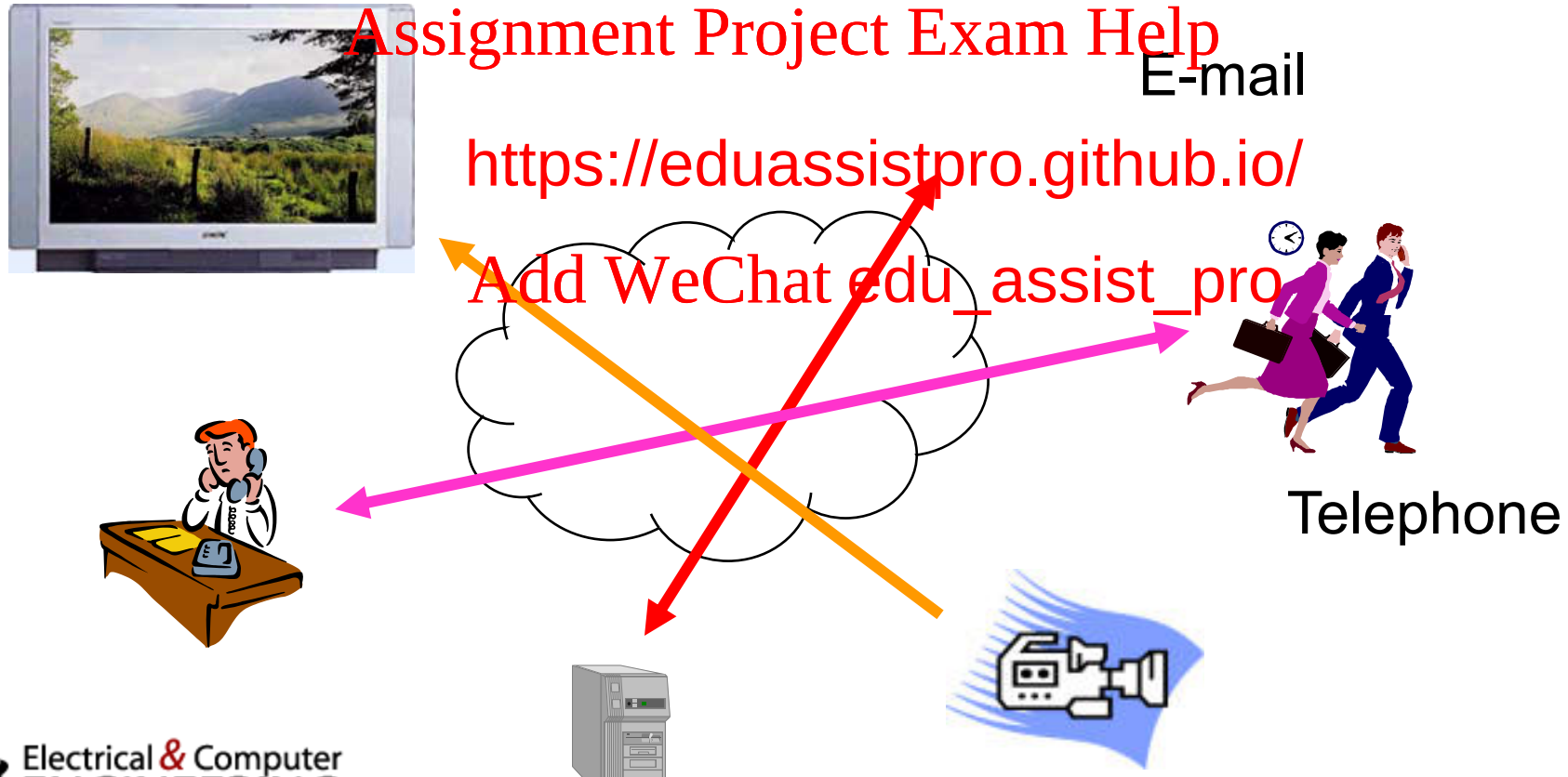
Phy HY) - I

Physical Layer: Outline

- Digital networking
- Modulation
- Characteriz tion Channels
- Fundament ansmission
- Modems and Digital Mo
- Line Coding
- Properties of Media and Digital Transmission Systems
- Error Detection and Correction

Digital Networks

- Digital transmission enables networks to support many services



Analog versus Digital Information

- Analog information takes on continuous values
  - Sound, im
- Digital infor rete values
  - Text, banking data, etc.
- Can convert between the two representations of information
  - Sampling and interpolation

Block vs. Stream Information

Block

- Information that occurs in a single block
  - Text message
  - Data file
  - JPEG image
  - MPEG file
- Size = bits / block

  or Bytes/block
  - 1 KByte (KB) = 2^{10} bytes
  - 1 MByte (MB) = 2^{20} bytes
  - 1 GByte (GB) = 2^{30} bytes

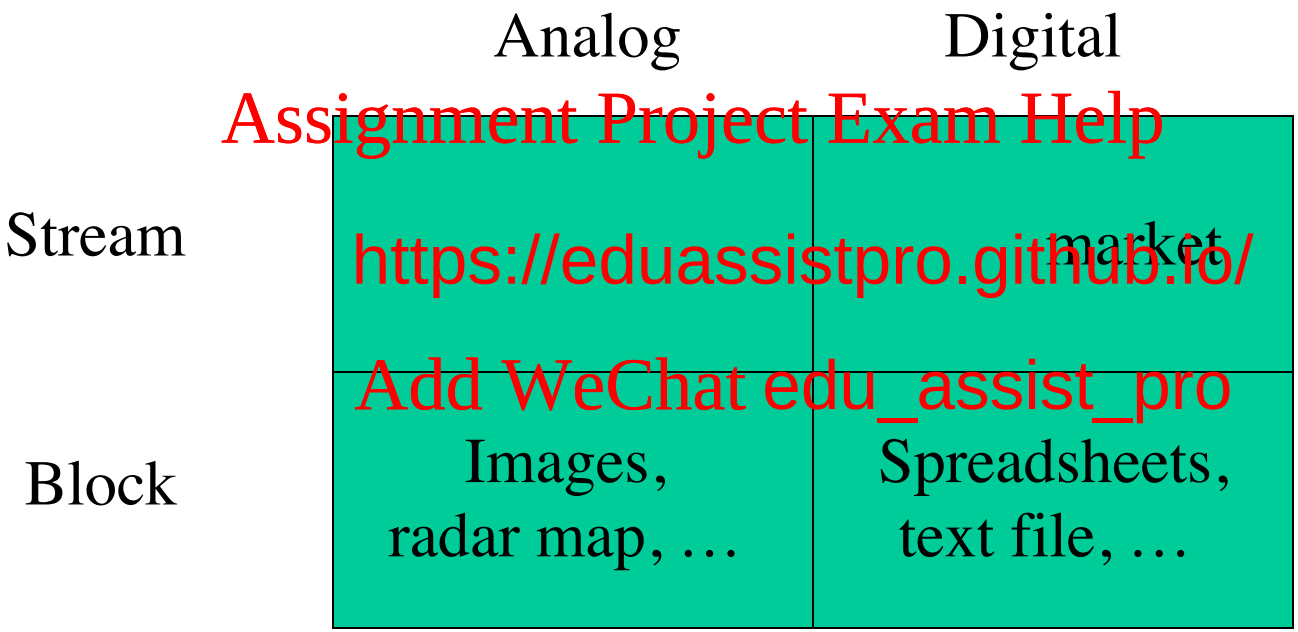
Stream

- Information that is produced & transmitted *continuously*

  time voice

  ming video
- bits / second
  - 1 Kbps = 10^3 bps
  - 1 Mbps = 10^6 bps
  - 1 Gbps = 10^9 bps

Many Types of Information



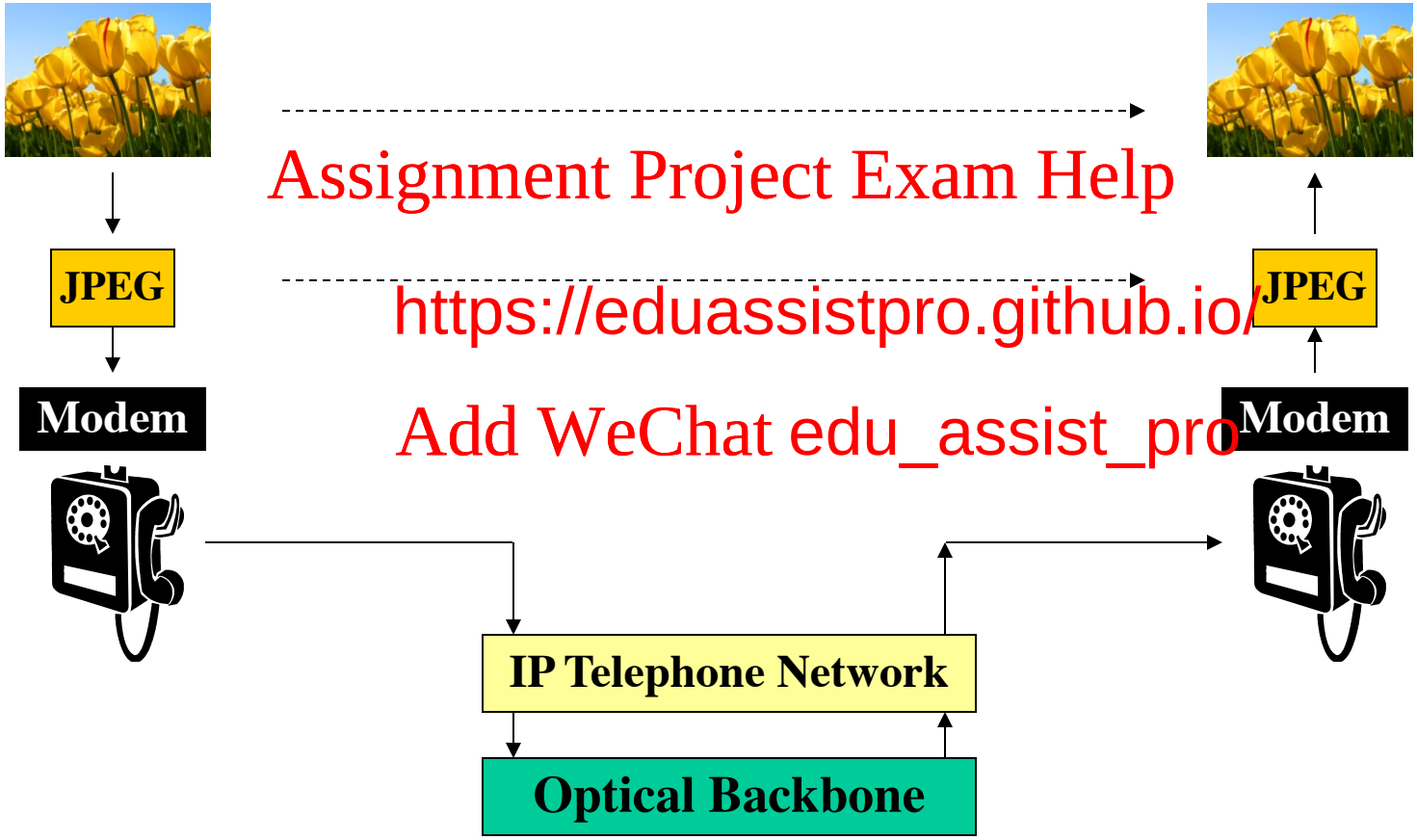
Traditional Communication Options

- Send analog information over analog networks
  - Voice ove
  - Video usi
  - Pictures using the USPS
- Send digital information over digital networks
  - Messages via telegraph: beacons … electrical
  - Internet: many applications, e.g., http, (text) email, ssh, social networks, …

But Can Mix and Match

- Analog information can be digitized and sent over digital network
  - Video be
  - Image becomes JPE
- Digital networks use analog channels
  - Bits are encoded on analog waveforms
  - But switching is done based on the bits

Example

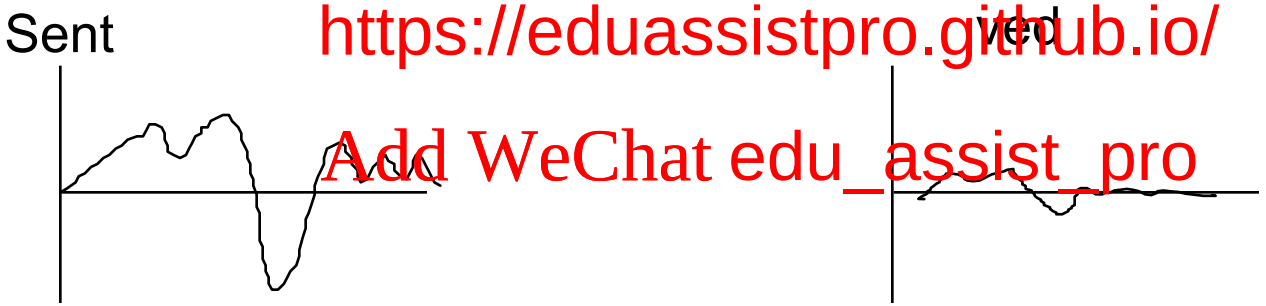


Why Use a Single Digital Network?

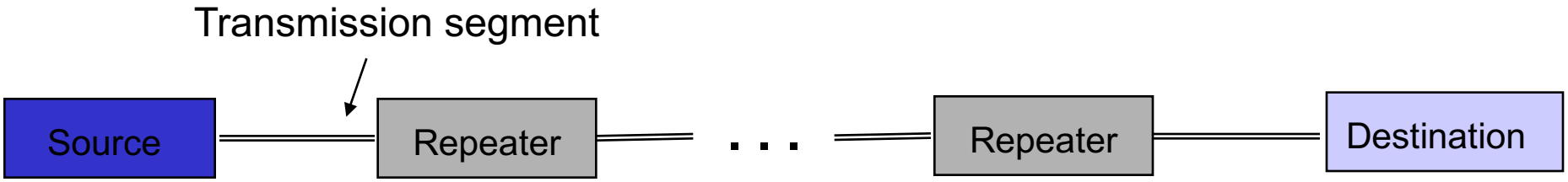
- Economically advantageous to have a single network
- Multimedia applications want to mix different types of da
  - More con rks is used
- Computers operate onl l data
- Digital transmission can recover from errors (e.g. noise, distortion)
  - Not possible when transmitting analog information over an analog network

Analog Transmission

All details must be reproduced accurately



Why digital? Problem with Analog Long-Distance Communications

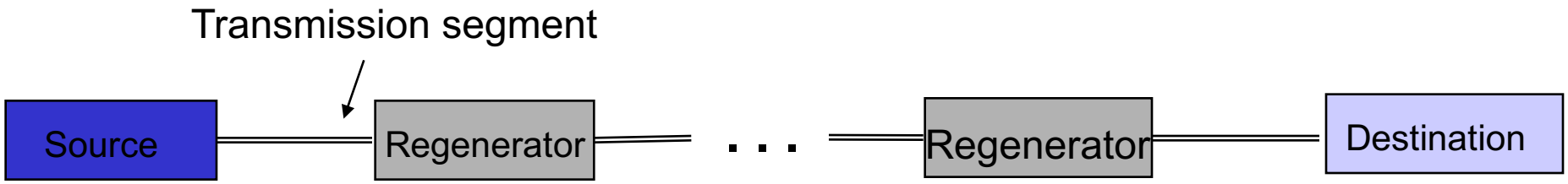


- Each repeater attempts to restore analog signal to its original for
- Restoration i
  - Distortion is not completel
  - Noise & interference is only partially removed
- Signal quality decreases with # of repeaters
- Communications becomes distance-limited
- Still used in analog cable TV systems
- Analogy: Copy a song using a cassette recorder

Digital Transmission

Only discrete levels need to be reproduced

Digital Long-Distance Communications



- Regenerator recovers original data sequence and retransmits on
- Can design so small
- Then each regeneration is like one!
- Analogy: copy an MP3 file
- Communications is possible over very long distances
- Digital systems advantage over analog systems
  - Less power, longer distances, lower system cost
  - Monitoring, multiplexing, coding, encryption, protocols…