

18-441/741: Computer Networks Assignment Project Exam Help Lecture Stack

<https://eduassistpro.github.io/>

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Swarun

Today's Lecture

- Network applications
 - Requirements
 - Latency and bandwidth
- Internet architecture <https://eduassistpro.github.io/>
 - Protocols Add WeChat edu_assist_pro
 - A layered design
 - Life of a packet
- Network utilities

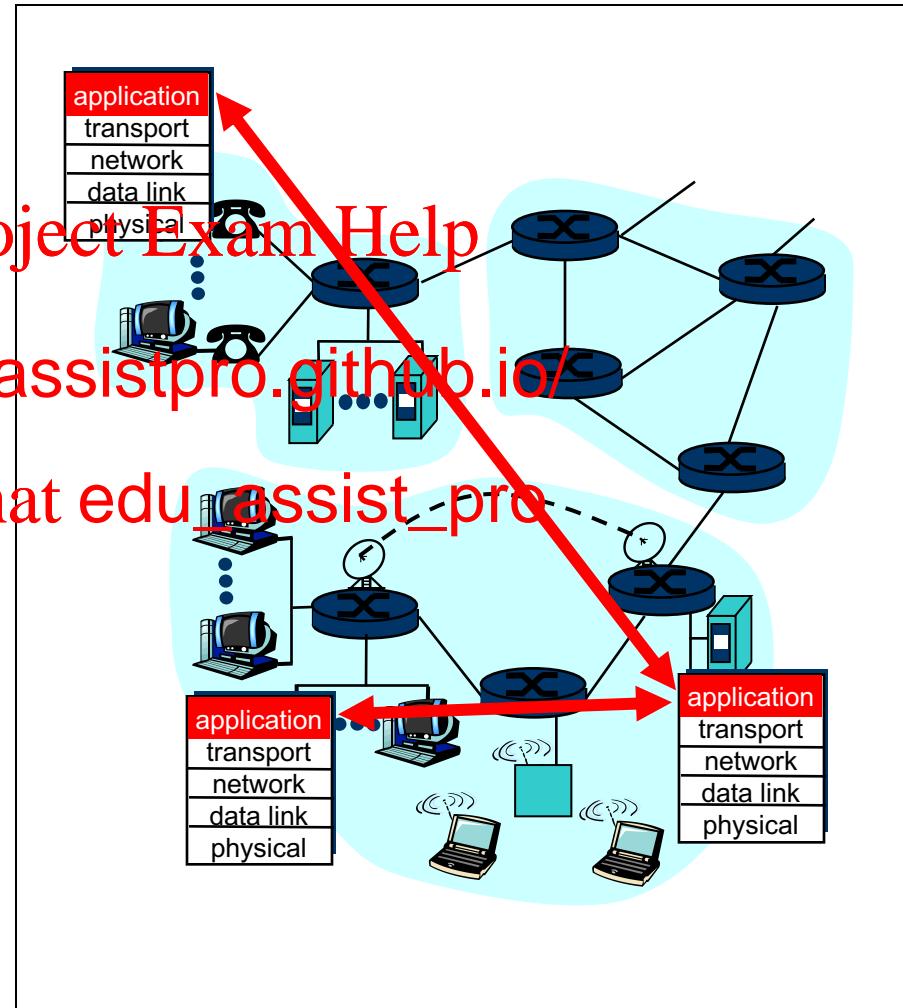
Applications and Application Protocols

- Application: communicating, distributed processes

- Running in network hosts in “user space”
- Exchange messages
- Implement app <https://eduassistpro.github.io/>
- e.g., email, file transfer

- Application protocols

- One “piece” of an app
- Define messages exchanged by apps and actions taken
- User services provided by lower layer protocols



Client-Server Paradigm

Typical network app has two pieces: *client* and *server*

Client:

- Initiates contact with server (“speaks first”)
- Typically request
- Web: client is imp browser; e-mail: in mail reader

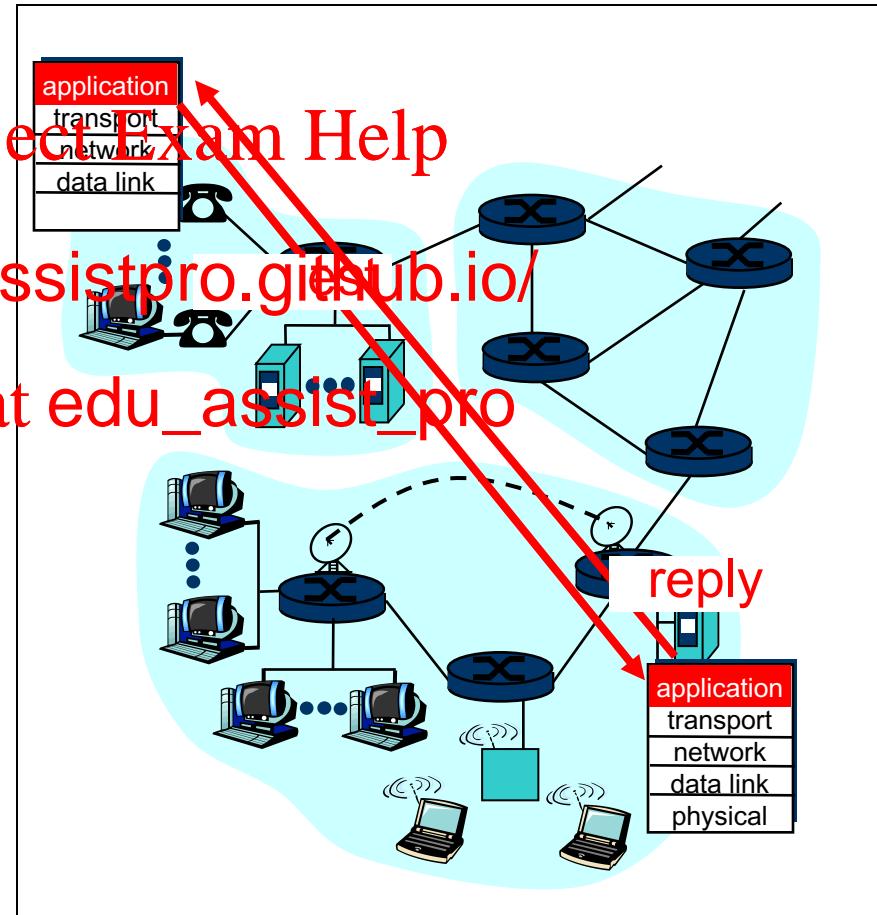
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Server:

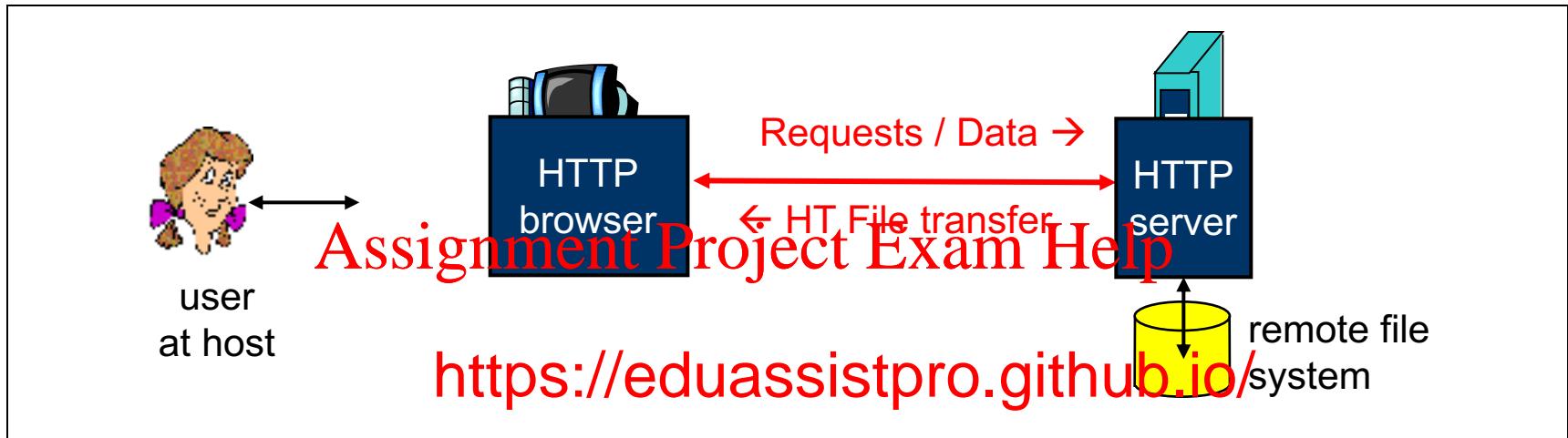
- Provides a service to client
- e.g., Web server sends requested Web page, mail server delivers e-mail



Yesterday's Applications

- FTP: transfer files to a host
 - No distributed file systems!
 - Mostly replaced by “the web” – http://AssignmentProjectExamHelp
- Telnet: use https://eduassistpro.github.io/telnet
 - Similar to Add WeChat edu_assist_pro security
- Mail: exchange emails
 - Similar today (kind of)
 - Initially host-to-host: name@my.computer.edu
 - Already very useful!

HTTP: The Hypertext Transfer Protocol



- Transfer (hypertext) files as they are
- Add WeChat [edu_assist_pro](https://eduassistpro.github.io/)
- Client/server model that allows clients to access multiple servers as per their need
- The Hypertext markup language (HTML) allows for describing rich content (video, text, audio, images, etc)
- Project: will learn more about HTTP

Today's Applications

- Amazon, Facebook, etc.
 - 2009 quote: “Amazon found every 100ms of *latency* cost them 1% in sales”
- Video streaming
 - Accounts for video delivery width
 - Interactive versus broadcast video
 - What matters most?
- Audio and video conferencing (Skype, Facetime,...)
 - Traditional telephone app
 - What matters most?

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<https://eduassistpro.github.io/>

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Requirements

- Performance: latency and throughput
- Network reliability
 - Network service must always be available
- Security: for
 - Privacy, authentication itself
 - Attacks on the network, various attacks, ...
- Scalability.
 - Scale to large numbers of users, traffic flows, ...
- Manageability: monitoring, enforcing policies, billing, ...

What Service Does an Application Need?

Data loss

Timing

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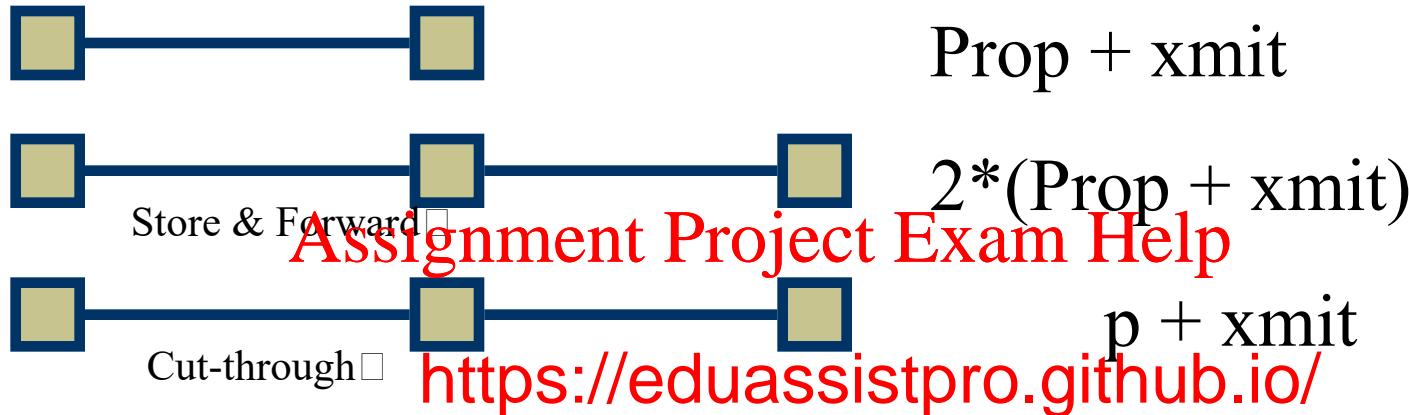
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Bandwidth

Transport Service Requirements of Common Apps

Application	Data loss	Bandwidth	Time Sensitive
file transfer	no loss	elastic	no
e-mail	no loss	elastic	no
web documents			no
real-time audio/ video		-1Mb Mb	yes, 100's msec
stored audio/video	loss-tolerant	ve	yes, few secs
interactive games	loss-tolerant	few Kbps	yes, 100's msec
financial apps	no loss	elastic	yes and no

A Closer Look at Packet Delay

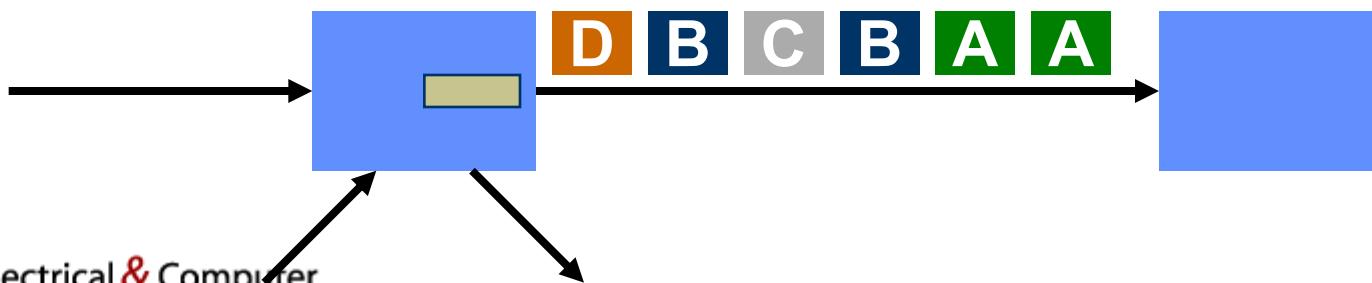


Next: Routers have finite speed (processing delay)

Routers may buffer packets (queueing delay)

Packet Delay Components

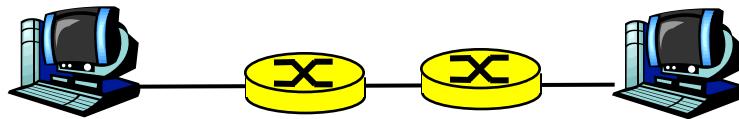
- Sum of a number of different delay components.
- Propagation delay on each link.
 - Proportional to the length of the link
- Transmission delay on each link.
 - Proportion speed
- Processing
 - Depends on the speed of the
- Queuing delay on each router
 - Depends on the traffic load and queue size



A Word about Units

- What do “Kilo” and “Mega” mean?
 - Depends on context
- Storage works in powers of two.
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 - 1 Byte = 8 bits
 - 1 KByte = 1024 bytes
 - 1 MByte = 1024 Kbytes
- Networks work in decimal units.
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 - Network hardware sends bits, not Bytes
 - 1 Kbps = 1000 bits per second
 - To avoid confusion, use 1 Kbit/second
- Why? Historical: CS versus ECE.

Application-level Delay



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Delay of
one packet

Average
sustained
throughput

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delay* + $\frac{\text{Size}}{\text{Throughput}}$
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Units: seconds +
bits/(bits/seconds)

* For minimum sized packet

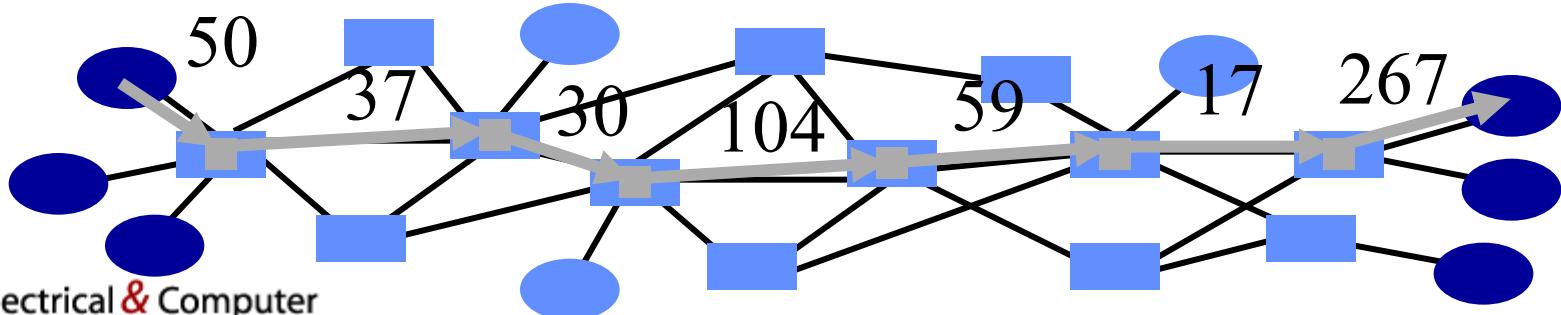
Sample Quiz Question

- How long does it take to send a 100 Kbit file?
 - Assume a perfect world.. Fill in the blanks..
- Is the transfer latency or throughput limited?
- What about a ~~Assignment Project Exam Help~~ file?

Throughput Latency	https://eduassistpro.github.io/	
500 μ sec		100 Mbit/s
10 msec		
100 msec		

A Closer Look at Throughput

- When streaming packets, the network works like a pipeline.
 - All links forward different packets in parallel
- Throughput is determined by the slowest stage.
 - Called the <https://eduassistpro.github.io/>
- Does not matter why it is slow!
 - Low link bandwidth
 - Many users sharing the link bandwidth



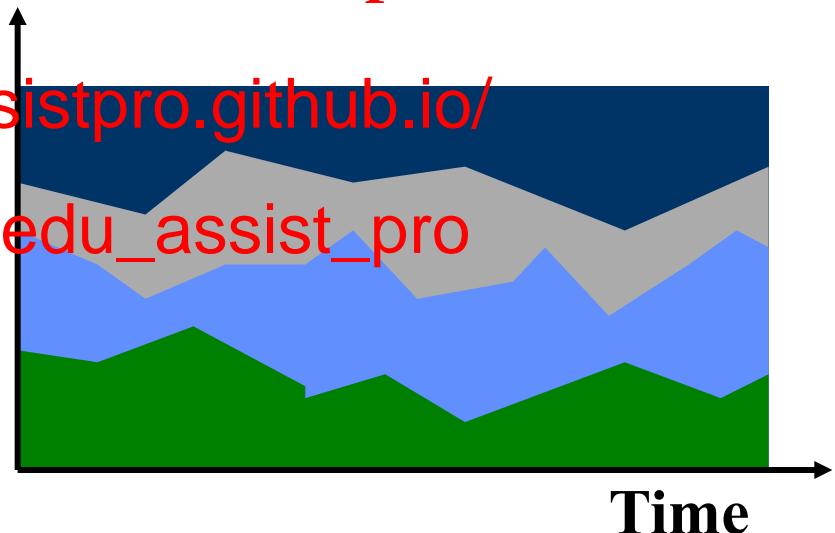
Bandwidth Sharing

- Bandwidth received on the bottleneck link determines end-to-end throughput.
- Router before the bottleneck link decides how much bandwidth each user gets.
 - Users that try to send at a higher rate will see packet loss
- User bandwidth can fluctuate quickly as flows are added or end, or as flows change their transmit rate.

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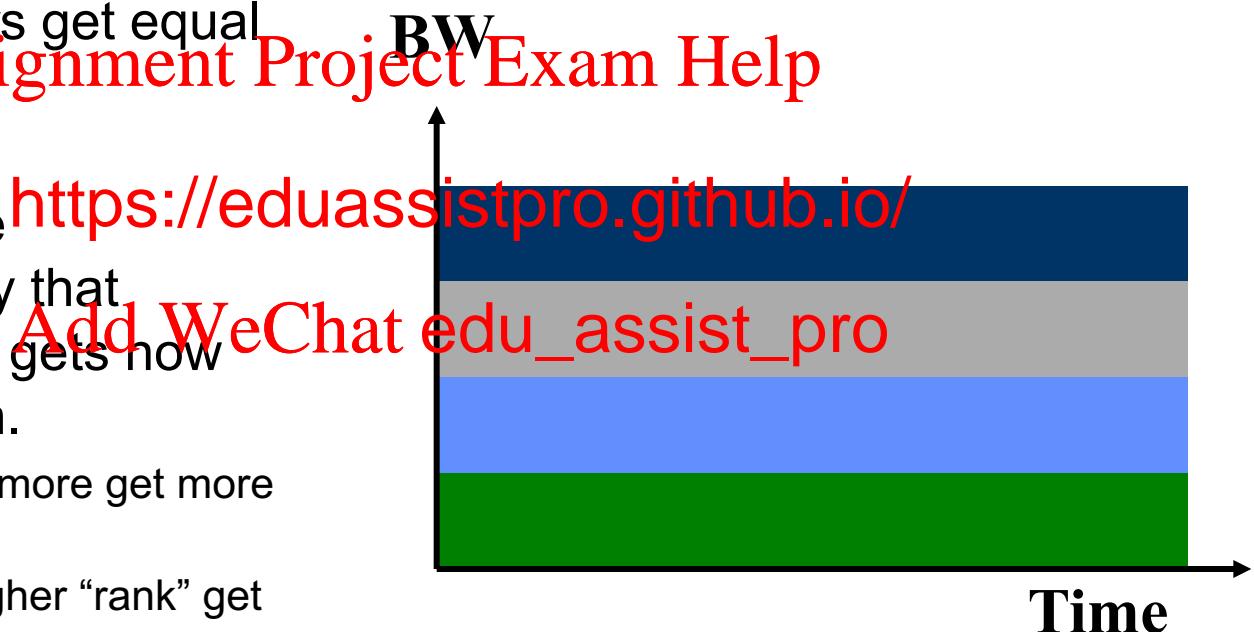
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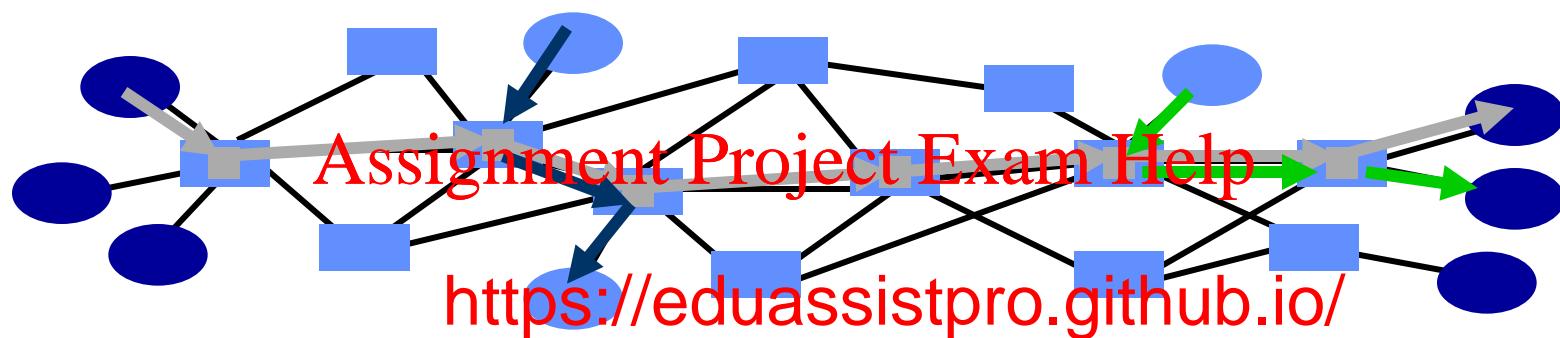


Fair Sharing of Bandwidth

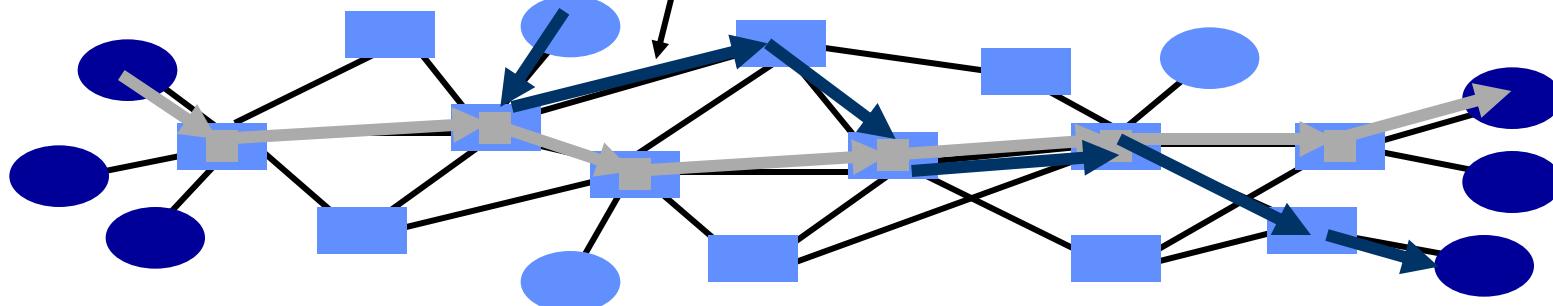
- All else being equal, fair means that users get equal treatment.
 - Sounds fair
- When things are <https://eduassistpro.github.io/> we need a policy that determines who gets how much bandwidth.
 - Users who pay more get more bandwidth
 - Users with a higher “rank” get more bandwidth
 - Certain classes of applications get priority



But It is Not that Simple



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Bottleneck



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- Internet at <https://eduassistpro.github.io/>
 - Protocols Add WeChat edu_assist_pro
 - A layered design
 - Life of a packet
- Network utilities

Lots of Protocols (and Acronyms!)

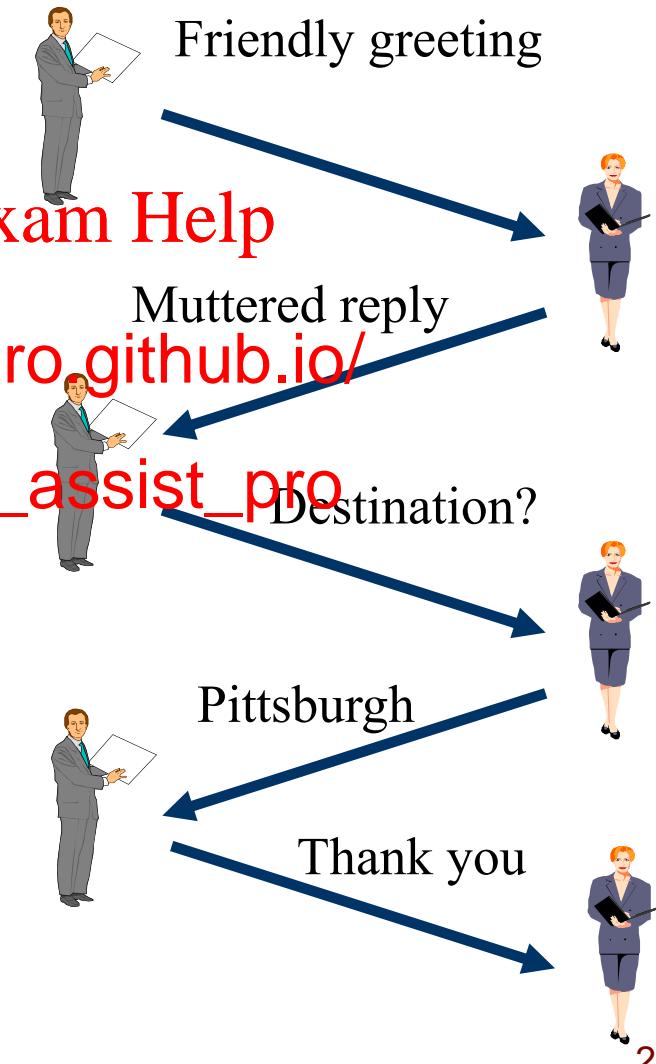
- IP: Internet protocol
- UDP: User datagram protocol
- TCP: Transmission control protocol
- FTP: File transfer protocol
- SMTP: Simple <https://eduassistpro.github.io/>
- HTTP: Hypertext transfer pro
- ARP: Address resolution prot
- BGP: Border gateway protocol
- ICMP: Internet control message protocol
- DHCP: Dynamic host configuration protocol
- And many more ...

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What are Protocols?

- An agreement between parties on how communication should take place
- Module in layered structure
- Protocols define:
<https://eduassistpro.github.io/>
(syntax & semantics)
 - Actions taken on reception of messages
 - Format and order of messages
 - Error handling, termination, ordering of requests, etc.
- Example: Buying airline ticket



How to Design a Network?

- Has many users
- Offers diverse services
- Mixes very diverse technologies

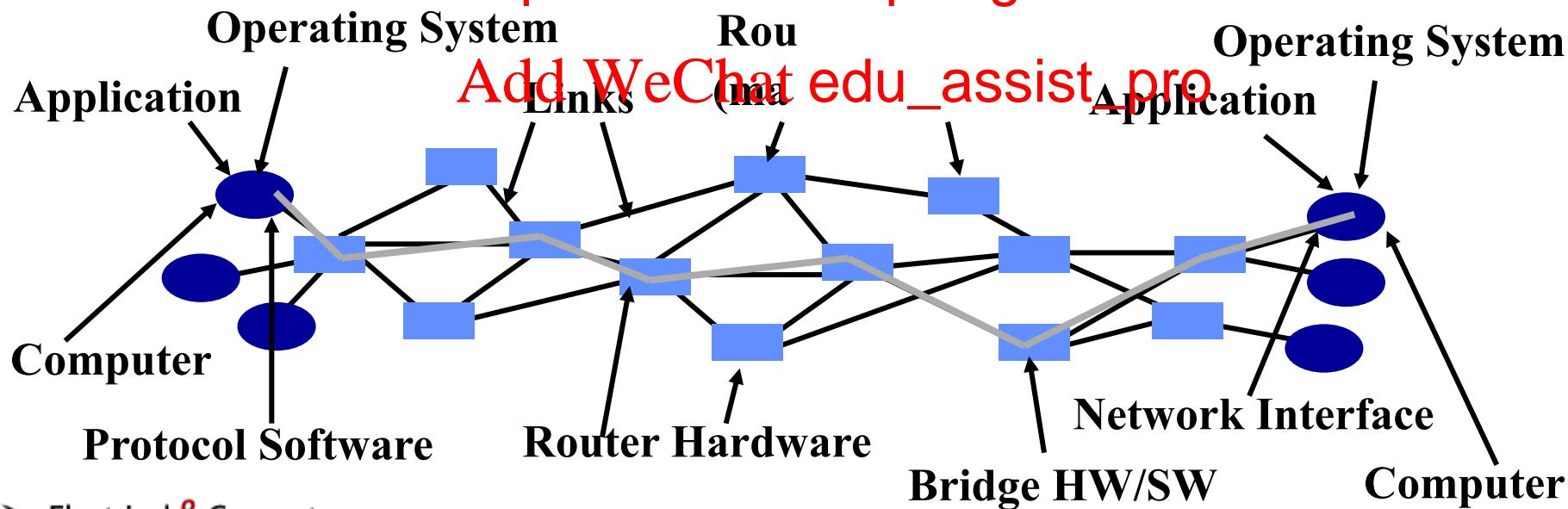
- Components built by many companies

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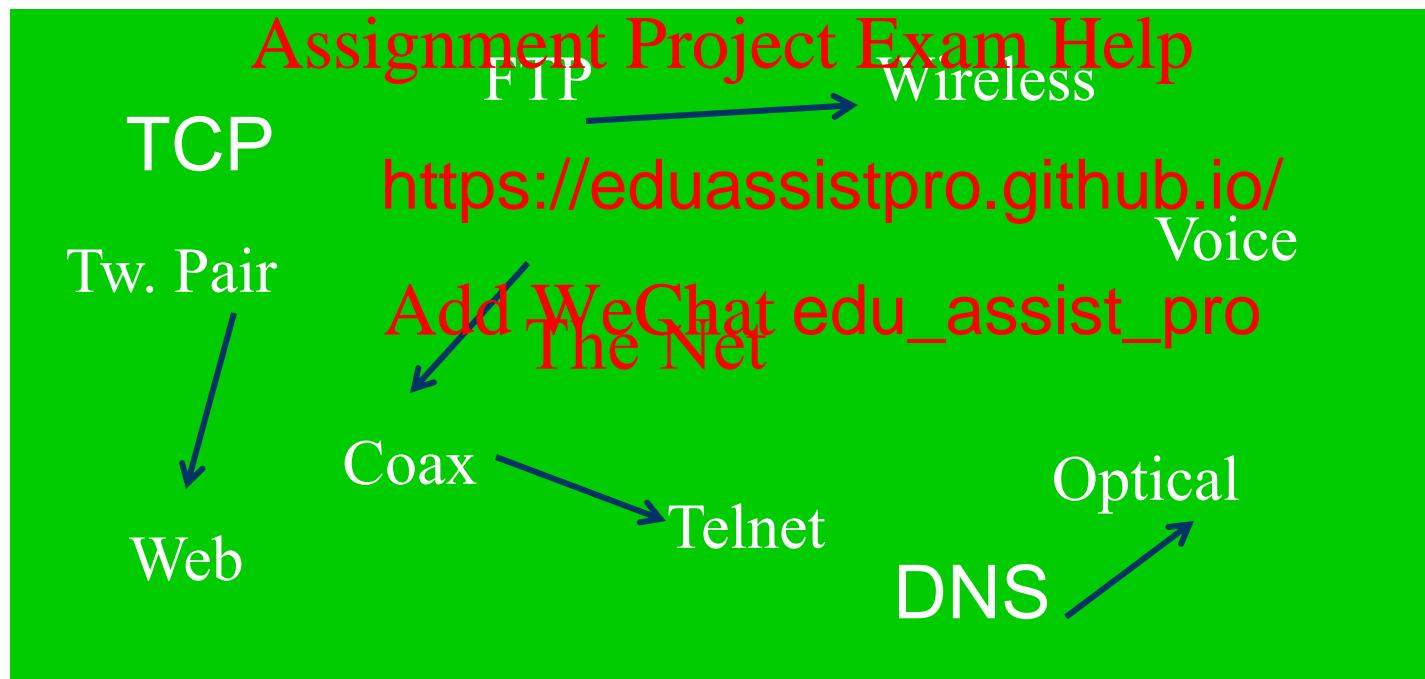
Diverse Ownership

Solve over time

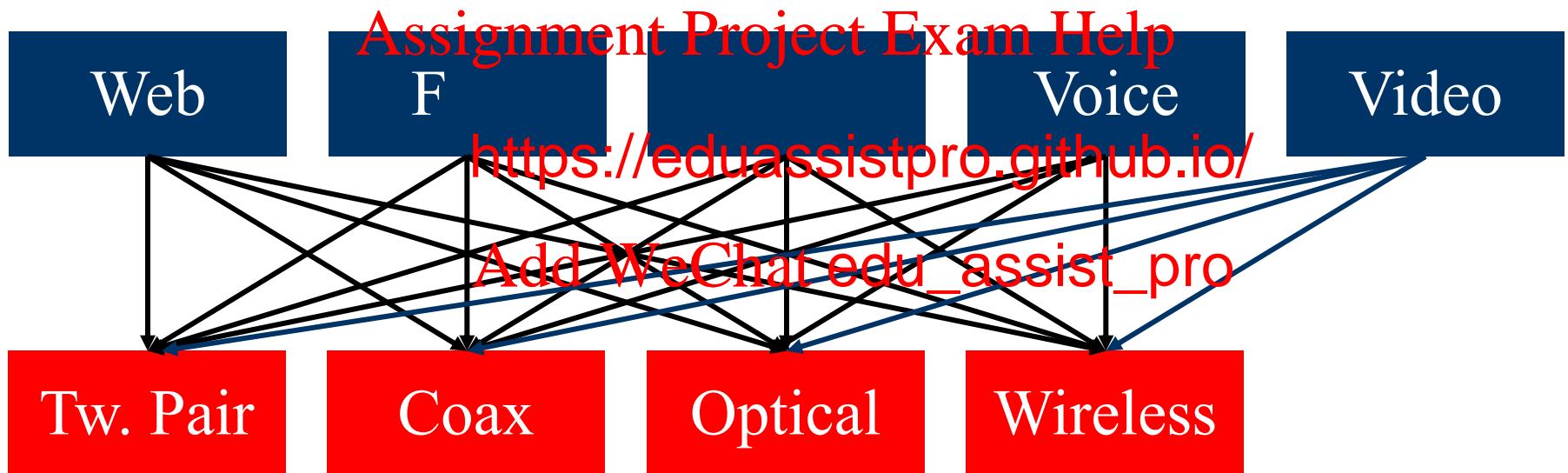
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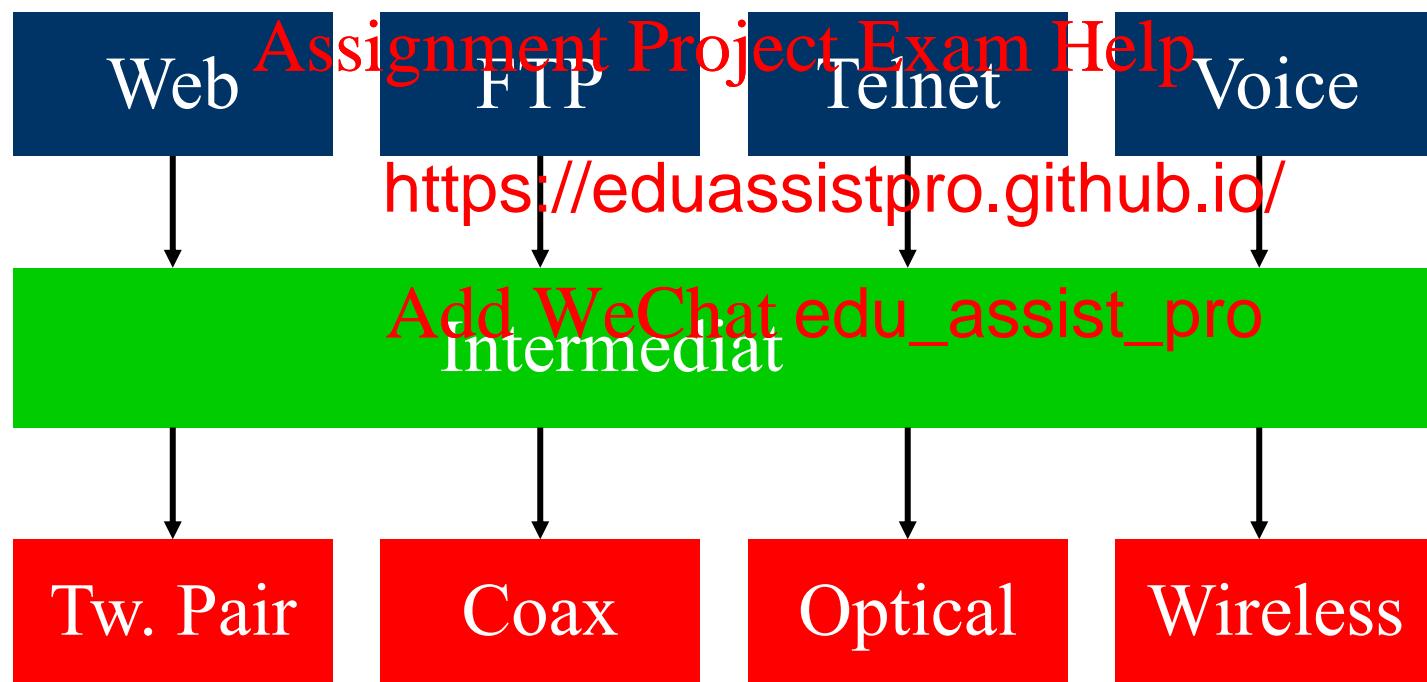
Solution #1



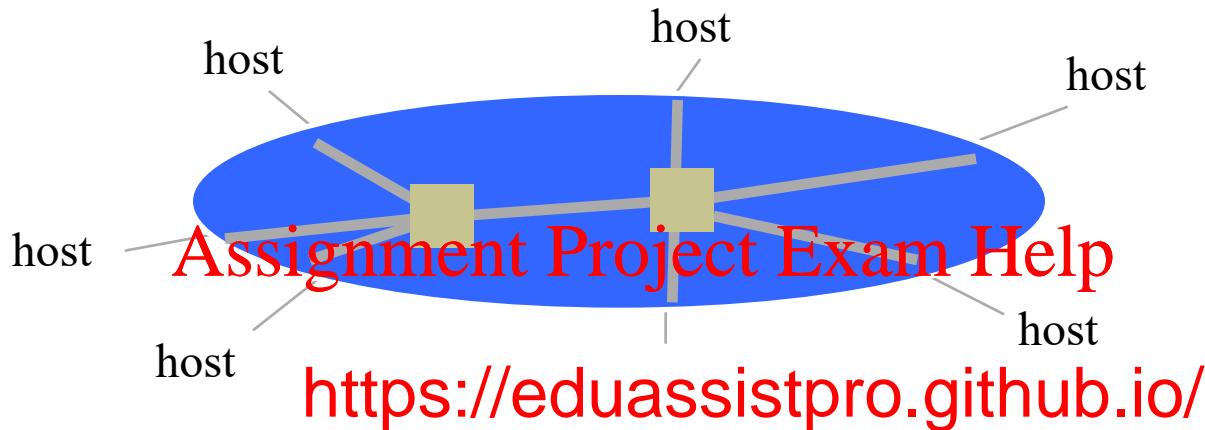
Solution #2?



Solution #3

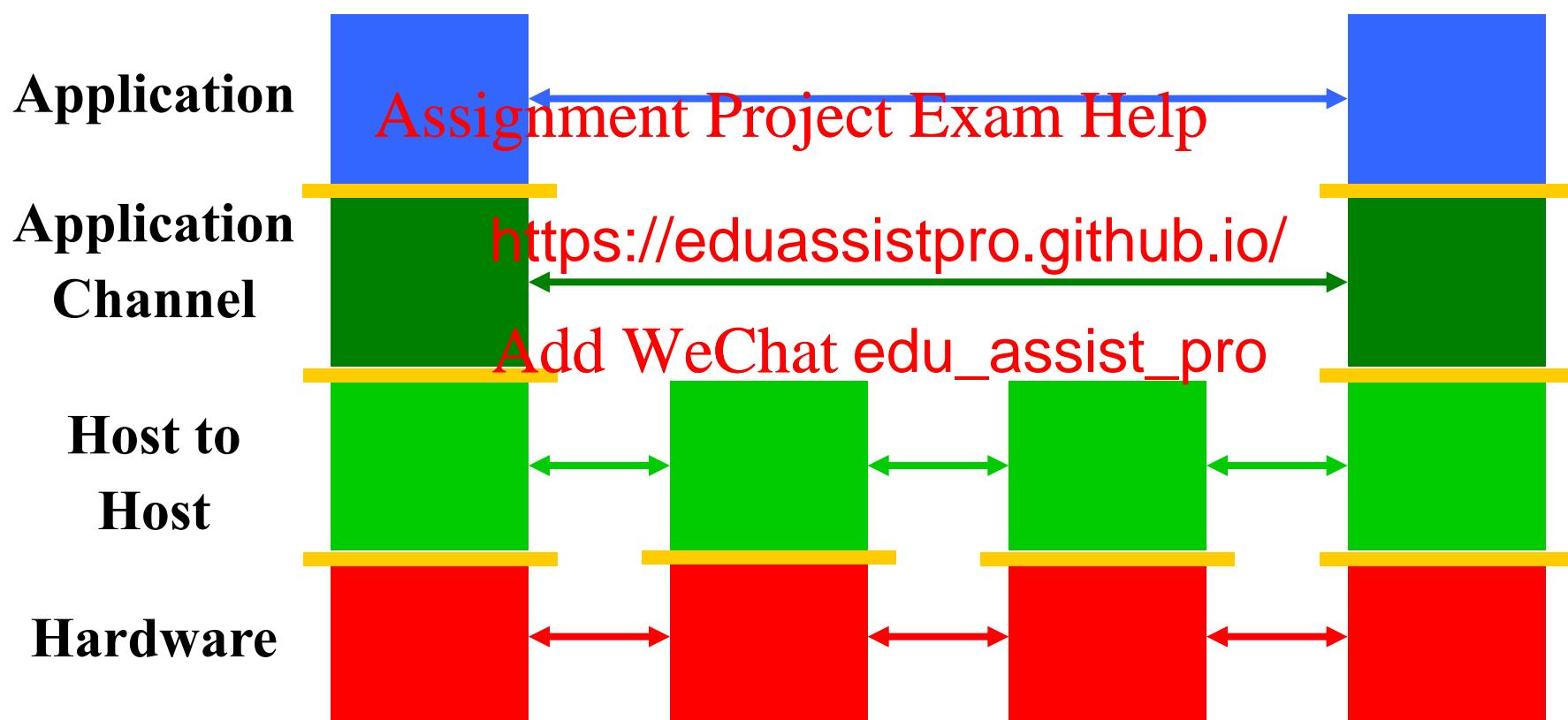


Types of Protocols



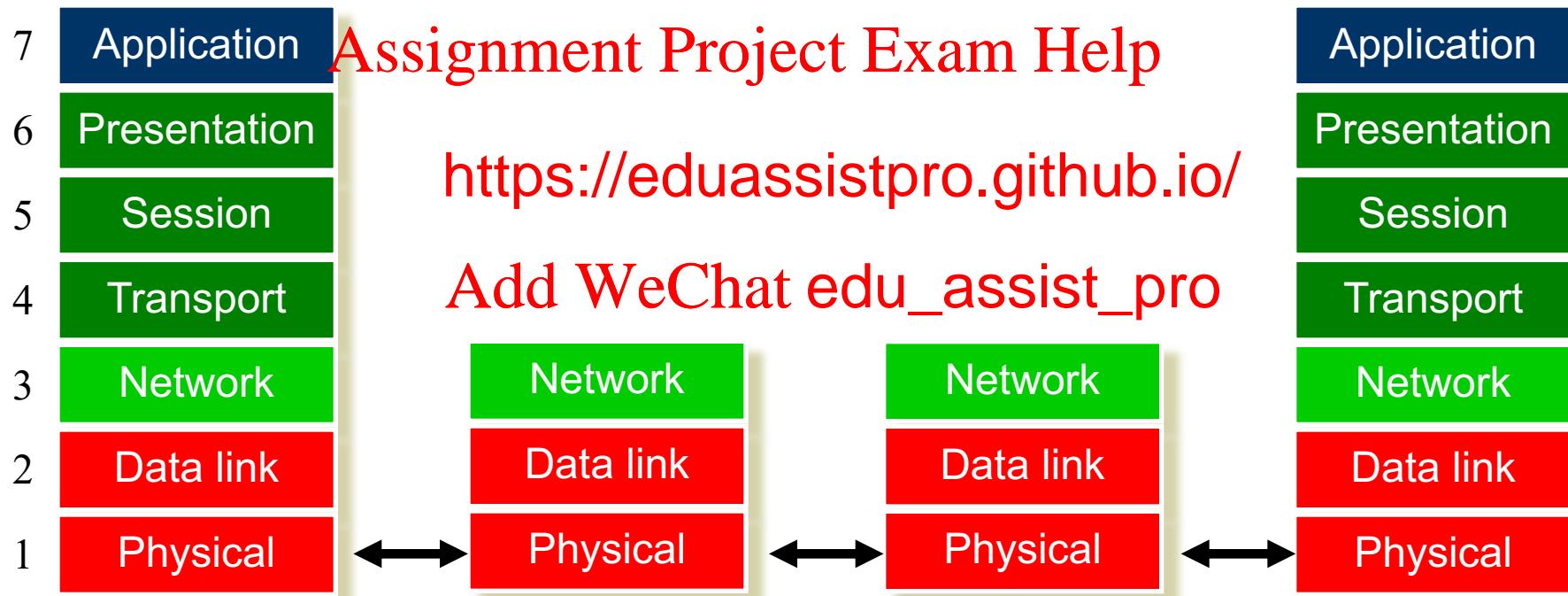
- Core network: responsible for moving data between a sending and receiving host
- End-to-end protocols: present a network service to applications and users.
 - May add value to the core network protocols
 - Driven by differences in constraints: scalability, power, management, speed, etc.

Protocol and Service Levels



A Layer Network Model

The Open Systems Interconnection (OSI) Model



Layering Characteristics

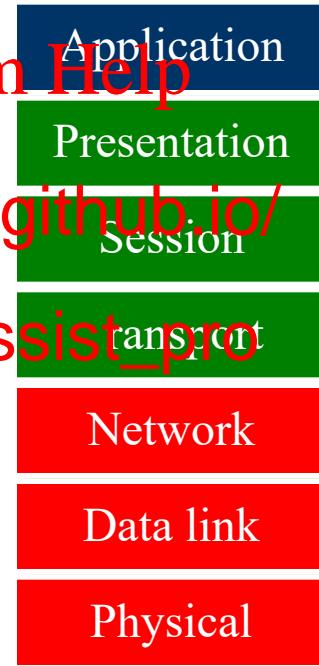
- Each layer relies on services from layer below and exports services to layer above
- Interface ~~Assignment Project Exam Help~~ with peer on other hosts <https://eduassistpro.github.io/>
- Modules hide ~~Add WeChat~~ ~~edu_assist_pro~~ layers can change without disturbing other layers (black box)

OSI Model: 7 Protocol Layers

- Physical: how to transmit bits
 - Data link: how to transmit frames
 - Network: how to route packets
 - Transport: how to establish end2end connections
 - Session: how to synchronize
 - Presentation: how to represent data
 - Application: everything else
-
- TCP/IP has been amazingly successful, and it is not based on rigid OSI model. The OSI model has been successful at shaping thought

Different Sources of Components

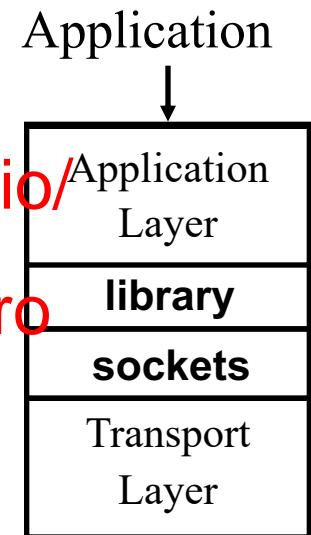
- Application: web server/browser, mail, distributed game,..
- Presentation ~~Assignment Project Exam Help~~
 - Often part of a
- Transport/network <https://eduassistpro.github.io/>
 - Typically part of the operating system
- Datalink
 - Often written by vendor of the network interface hardware
- Physical
 - Hardware: card and link



Application & Upper Layers

- Application Layer: Provides services that are frequently required by a web access, fi <https://eduassistpro.github.io/>
- Presentation Layer: machi independent representation data...
- Session Layer: dialog management, recovery from errors, ...

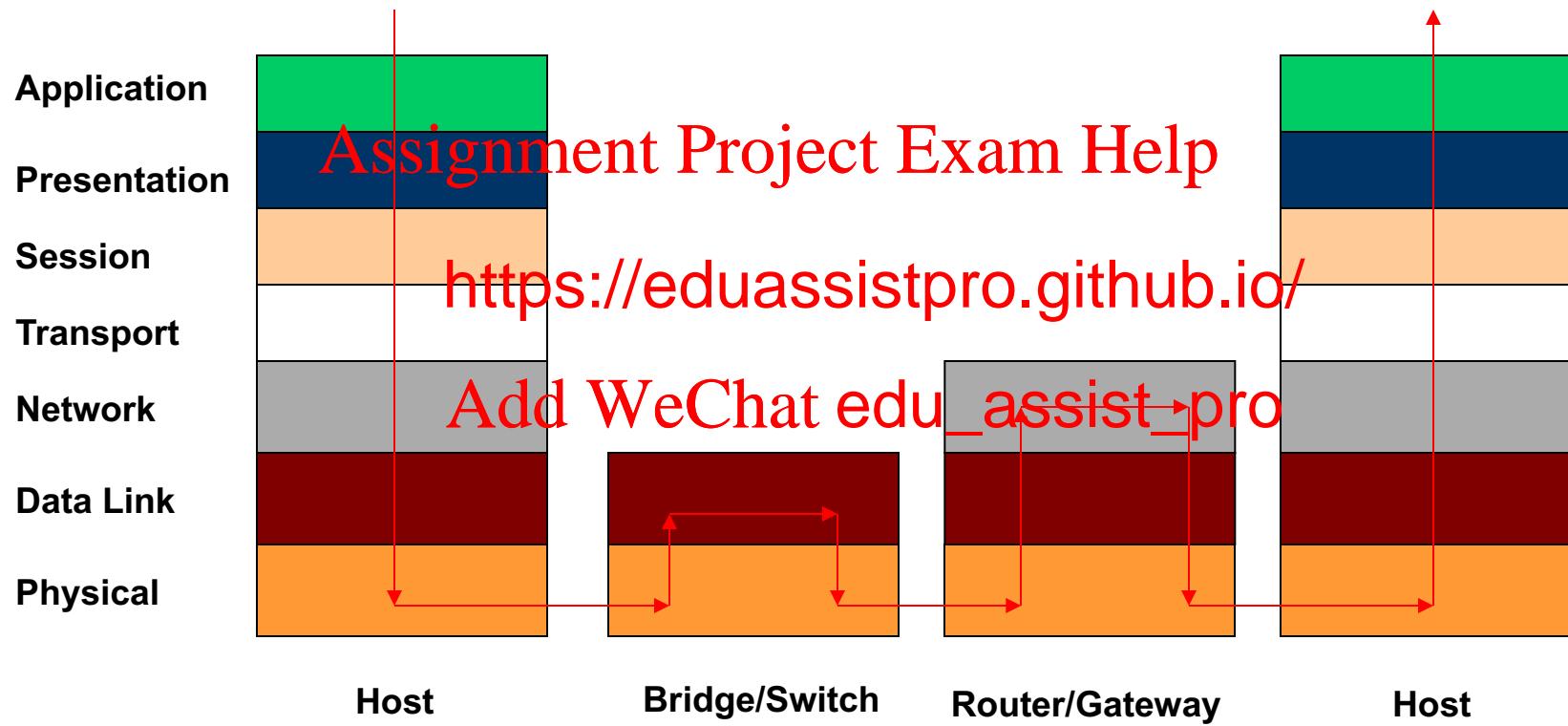
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Mostly incorporated into Application Layer



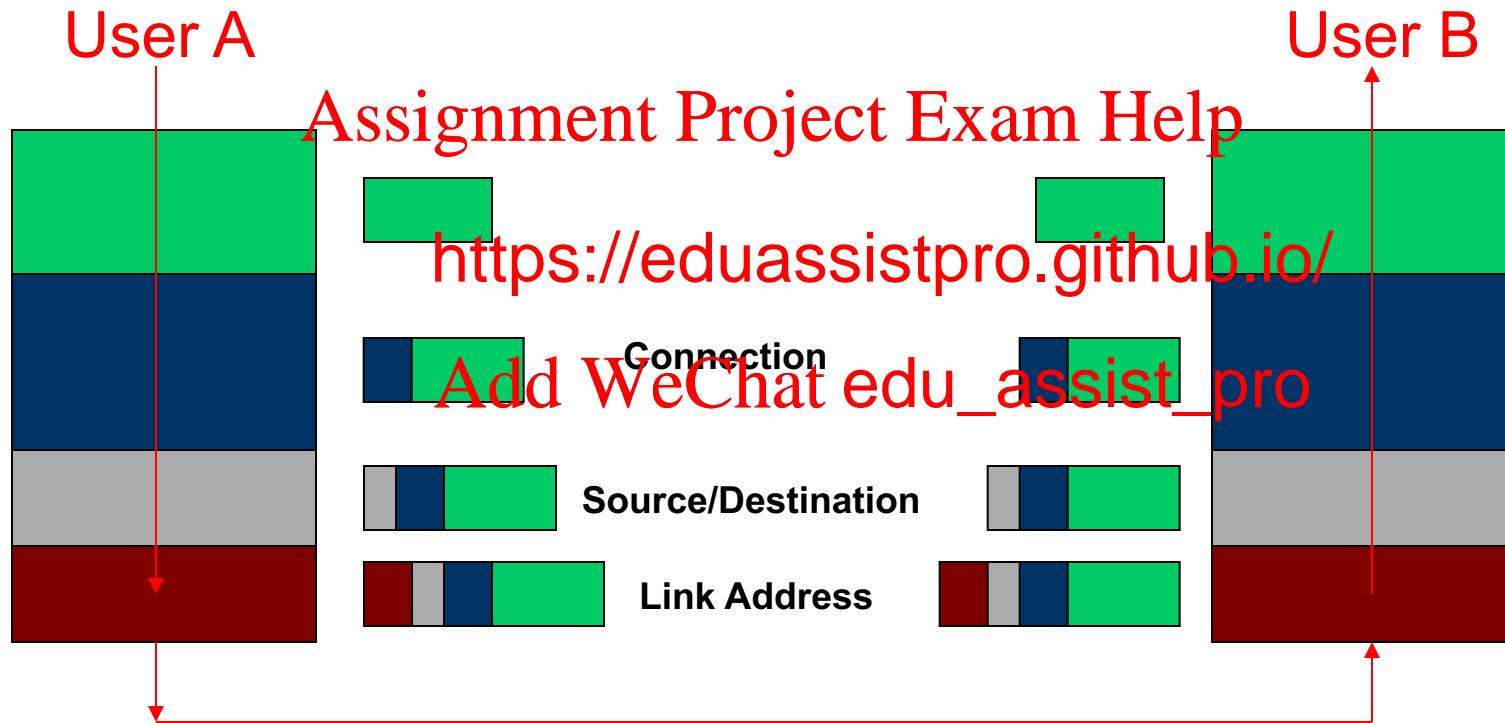
The Internet Engineering Task Force

- Standardization is key to network interoperability
 - The hardware/software of communicating parties are often not built by the same vendor → yet they can communicate because they use the same protocol
- Internet Engin
 - Based on work <https://eduassistpro.github.io/> specific issues
- Request for Comments
 - Document that provides information or defines standard
 - Requests feedback from the community
 - Can be “promoted” to standard under certain conditions
 - consensus in the committee
 - interoperating implementations
 - Project 1 will look at the Internet Relay Chat (IRC) RFC

Life of Packet



Layer Encapsulation



Multiplexing and Demultiplexing

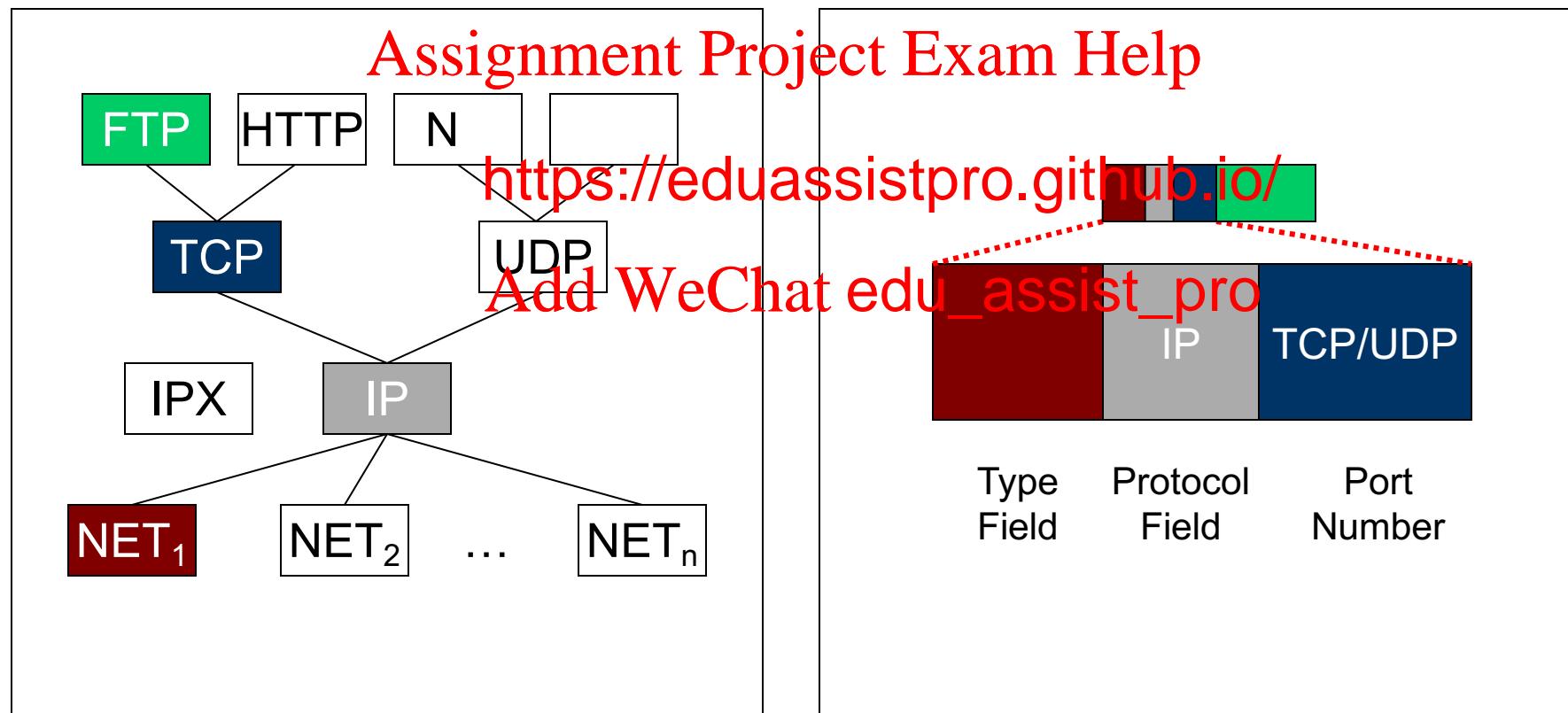
- There may be multiple implementations of each layer.
 - How does the receiver know what version of a layer to use?
- Each header is <https://eduassistpro.github.io/> demultiplexing field that is used to identify the next layer.
 - Filled in by the sender
 - Used by the receiver
- Multiplexing occurs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



OS	Length	
ID	Flags/Offset	
TTL	Prot.	H. Checksum
Source IP address		
Destination IP address		
Options..		

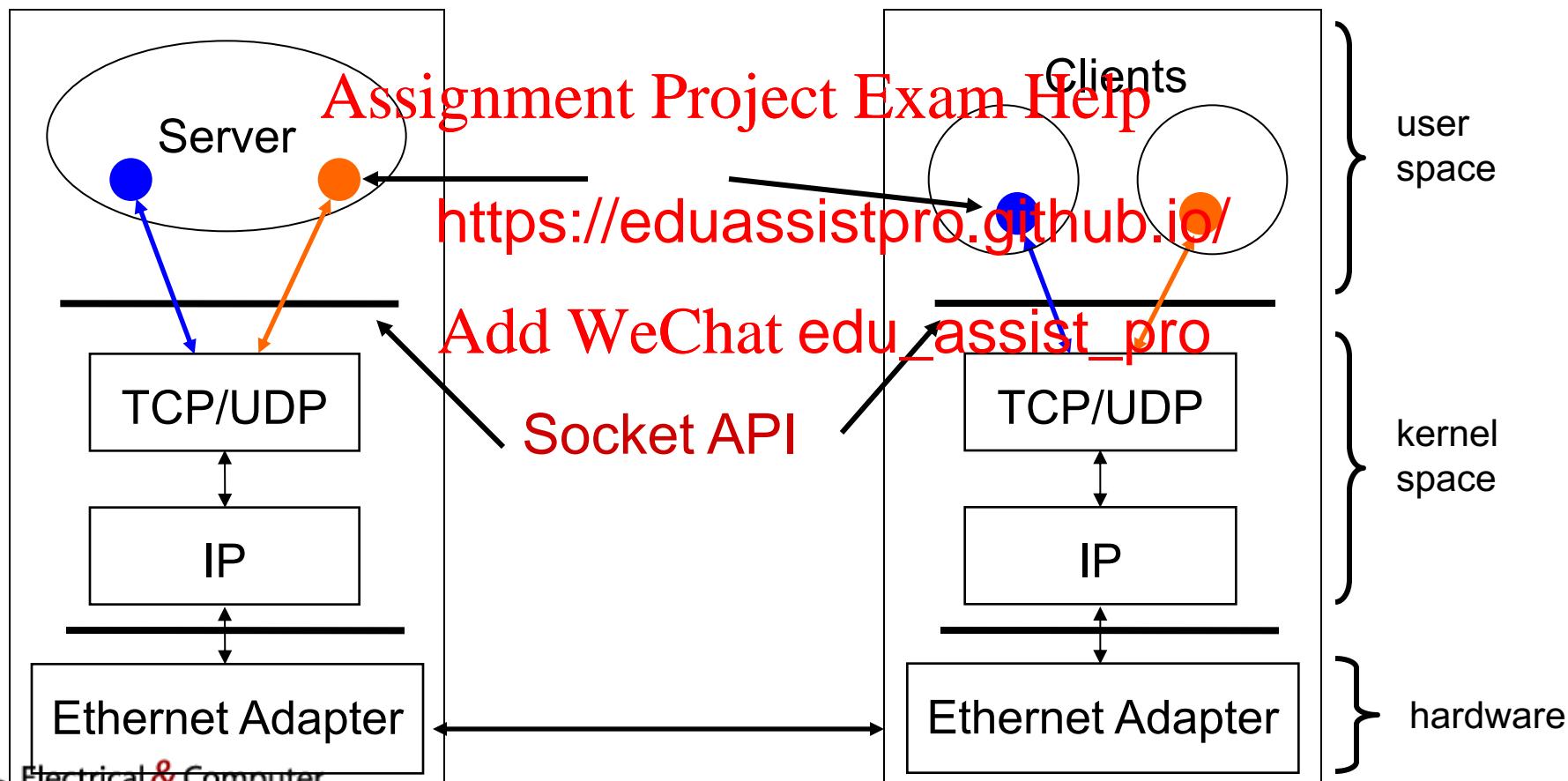
Protocol Demultiplexing

- Multiple choices at each layer

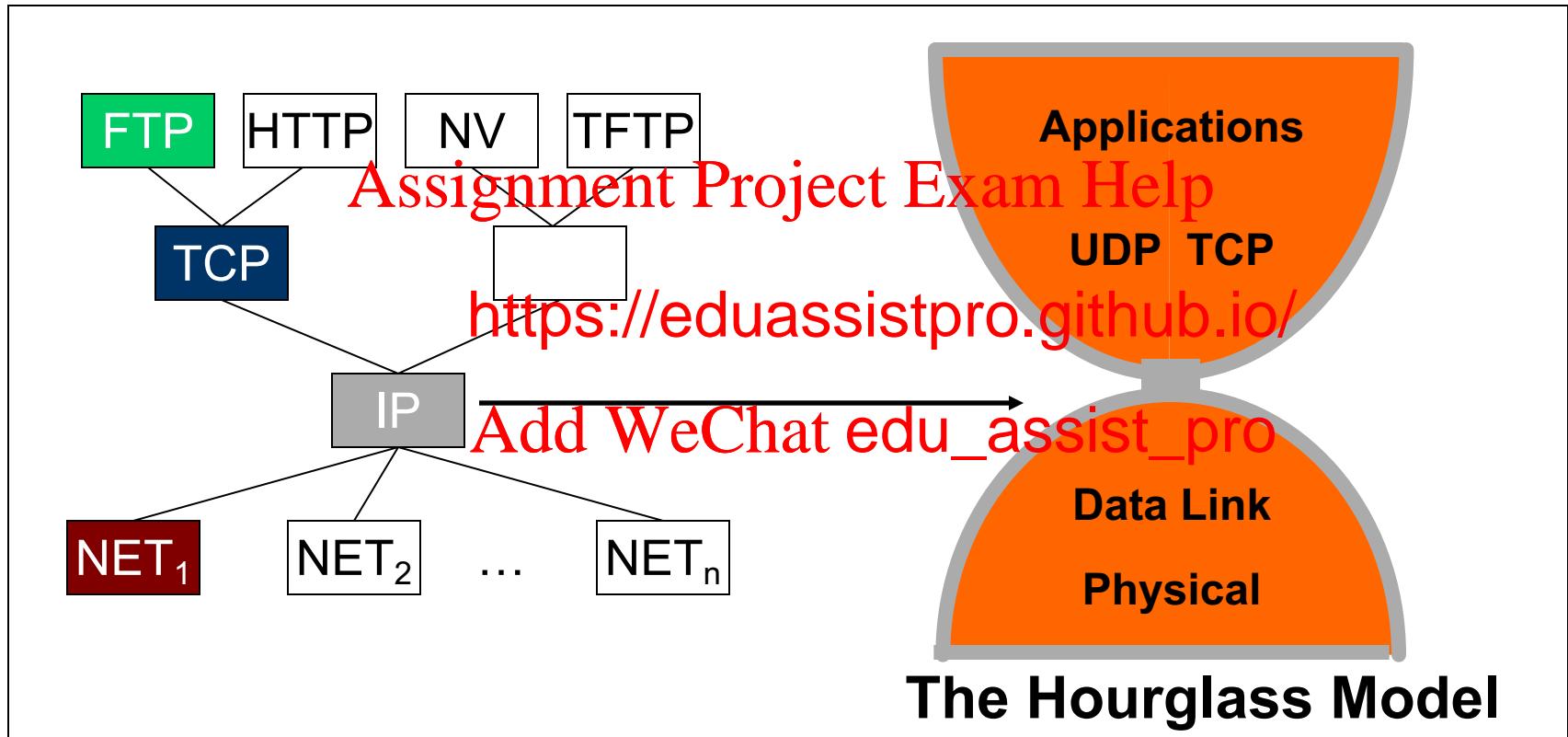


Server and Client

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
 - Addressing, forwarding, routing
- Smart end system
 - Transport layer
 - Flow control, error control, connection management
- Advantages
 - Accommodate heterogeneous technologies (Ethernet, modem, satellite, wireless)
 - Support diverse applications (telnet, ftp, Web, X windows)
 - Decentralized network administration

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<https://eduassistpro.github.io/> more sophisticated functionalitie

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Sample Quiz Question

- Question: Which of these will be hardest launch at Internet-scale: a new version of TCP, a new version of IP, or a new version of WiFi? <https://eduassistpro.github.io/>
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- Answer: New IP (why?)

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Network tools

- **ping**
- **traceroute** Assignment Project Exam Help
- **ipconfig** <https://eduassistpro.github.io/>
- **tcpdump** Add WeChat edu_assist_pro
- ...

ping

- Application to determine if host is reachable
- Based on Internet Control Message Protocol
 - ICMP ~~Assignment Project Exam Help~~ encounter by routers or by destination host <https://eduassistpro.github.io/>
 - ICMP Echo message received from destination host ~~Add WeChat edu_assist_pro~~
- PING sends echo message & sequence #
- Determines reachability & round-trip delay
- Sometimes disabled for security reasons

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traceroute

- Find route from local host to a remote host
- Time-to-Live (TTL)
 - IP packets have TTL field that specifies maximum # Assignment Project Exam Help hops traversed before packet discarded
 - Each rout <https://eduassistpro.github.io/> rded
 - When TTL
- Traceroute Add WeChat edu_assist_pro
 - 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)

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ipconfig

- Utility in Microsoft Windows to display TCP/IP information about a host
 - Assignment
 - Project
 - Exam
 - Help
- Many options
 - Simplest: <https://eduassistpro.github.io/> mask, default gateway for the host Add the host `edu_assist_pro`
 - 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

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netstat

- Queries a host about TCP/IP network status
- Status of network drivers & their interface <https://eduassistpro.github.io/>
 - #packets in, #packet red packets,
...
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- State of routing table in host
- TCP/IP active server processes
- TCP active connections

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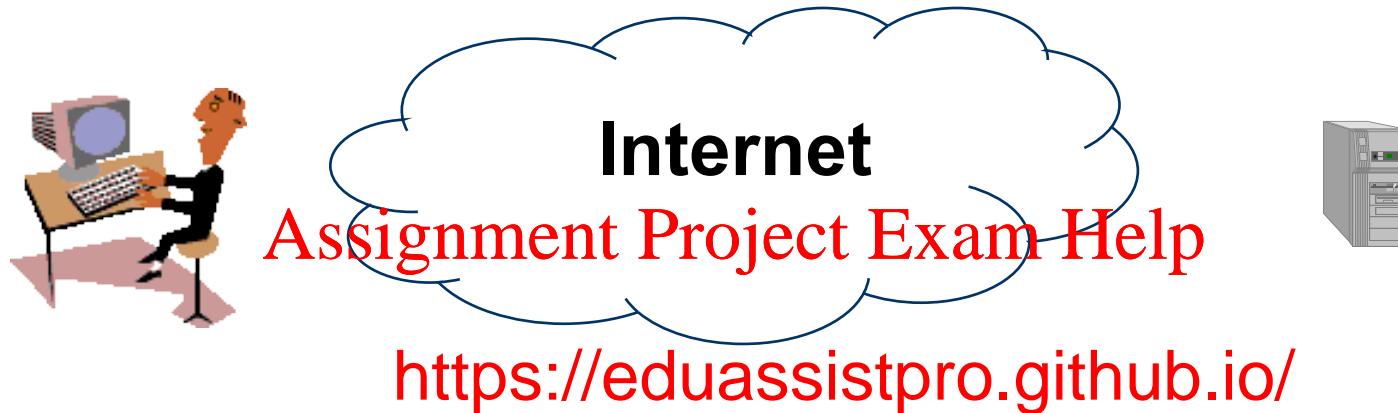
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tcpdump and Network Protocol Analyzers

- tcpdump program captures IP packets on a network interface (usually Ethernet NIC)
- Filtering used to select packets of interest
- Packets & high level protocols be displayed and analyzed
<https://eduassistpro.github.io/>
- tcpdump basis for many network troubleshooting tools and analyzers for col analyzers for
- We use the open source Ethereal analyzer to generate examples (or wireshark, etc.)
 - www.ethereal.com

How the layers work together: Network Analyzer Example



- User clicks on Add WeChat `edu_assist_pro`
- *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

Ethernet PWS

Top Pane shows
frame/packet
sequence

Middle Pane shows
encapsulation for a
given frame

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Bottom Pane shows hex & text

Top pane: frame

DNS Query

TCP Connection Setup

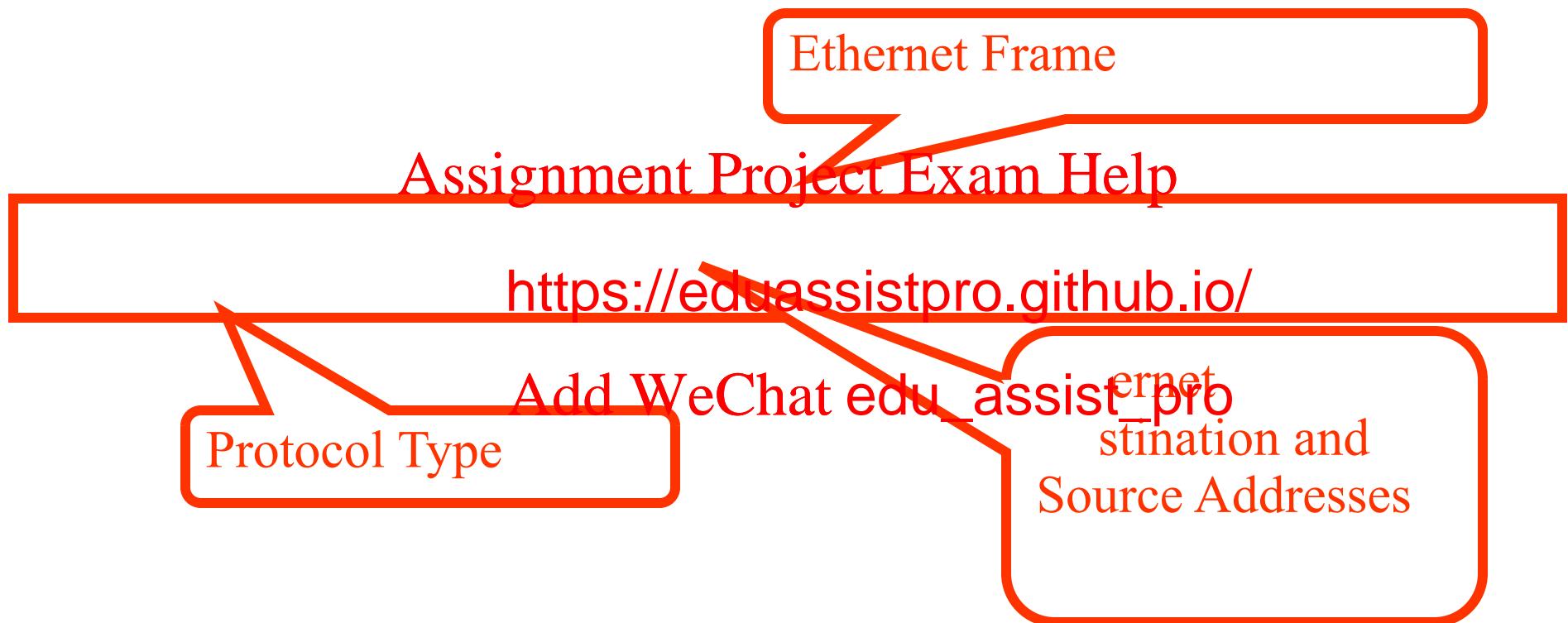
HTTP Request & Response

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Middle pane: Encapsulation



Middlebox Emulation

And a lot of other stuff!

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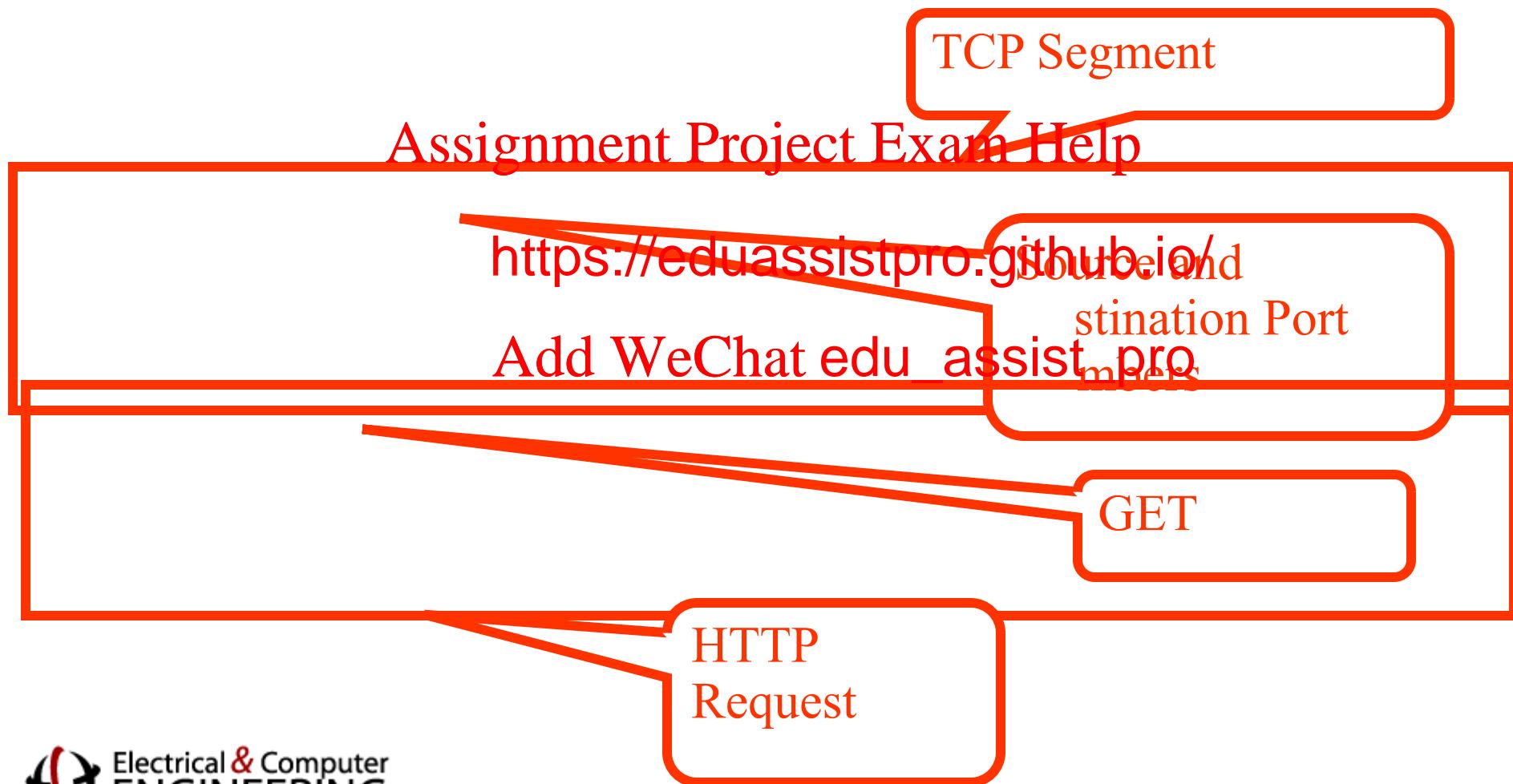
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P_Source and
Destination
Addresses

Protocol Type

Middle pane: Encapsulation



Goals [Clark88]

0 Connect existing networks

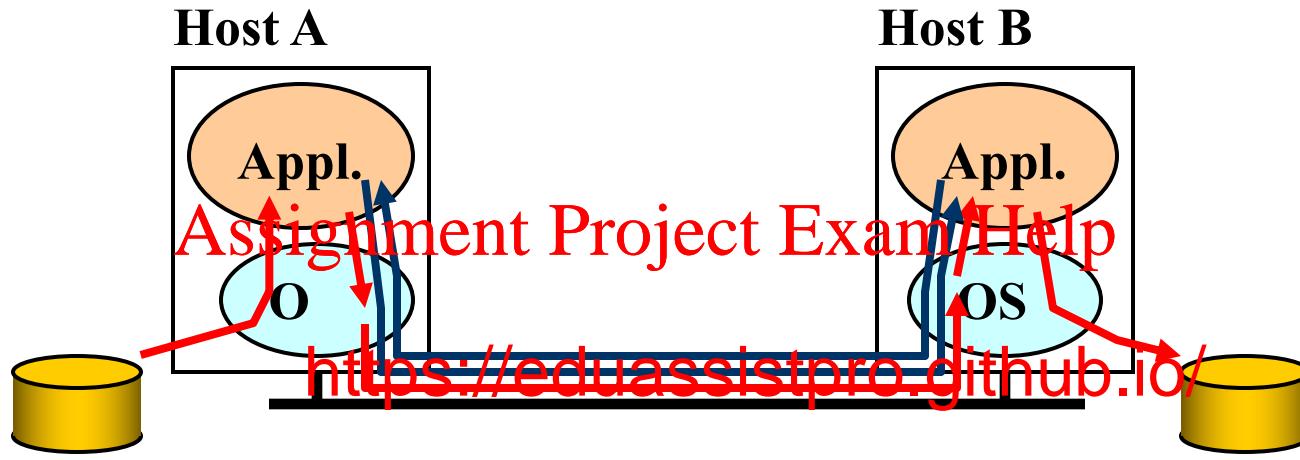
initially ARPANET and ARPA packet radio network

1. Survivability
 - Assignment Project Exam Help
 - ensure comm n the presence of
 - network an <https://eduassistpro.github.io/>
2. Support multiple types of
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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 functionality
 - Inside the <https://eduassistpro.github.io/> elements)
 - At the edges [Add WeChat edu_assist_pro](#)
- 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

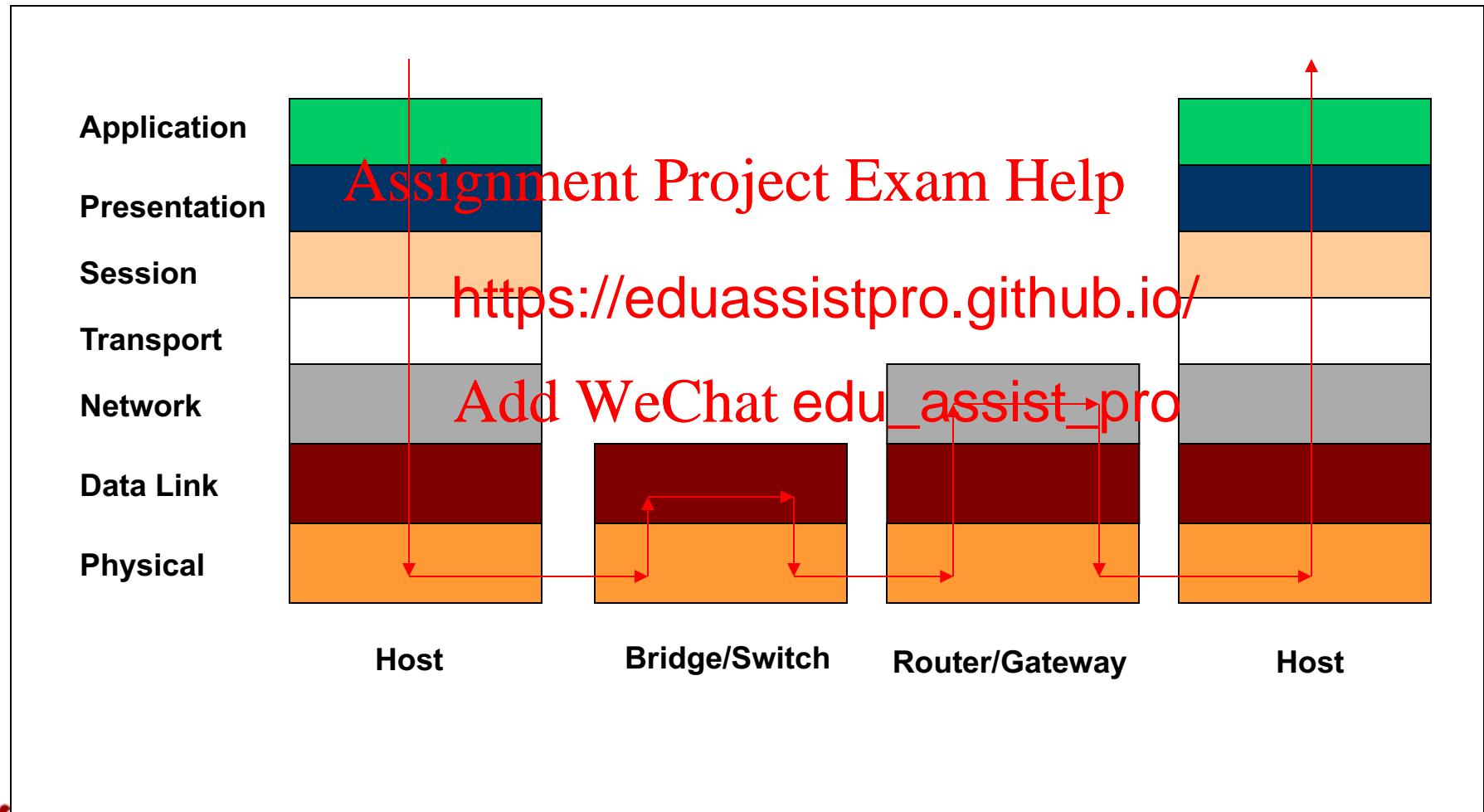


- Solution 1: make each step reliable, and then concatenate them
- Solution 2: end-to-end check and retry

Sample Quiz Question

- Question: A switch and a router both cost \$100 and have similar specs and achieve similar performance in packet switching/r <https://eduassistpro.github.io/>, al buyer, which should you buy?
[Assignment](#) [Project](#) [Exam](#) [Help](#)
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- Answer: The router (why?)

Life of Packet



Next Lecture

- The “PHY”

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