# Internet Architecture Overview

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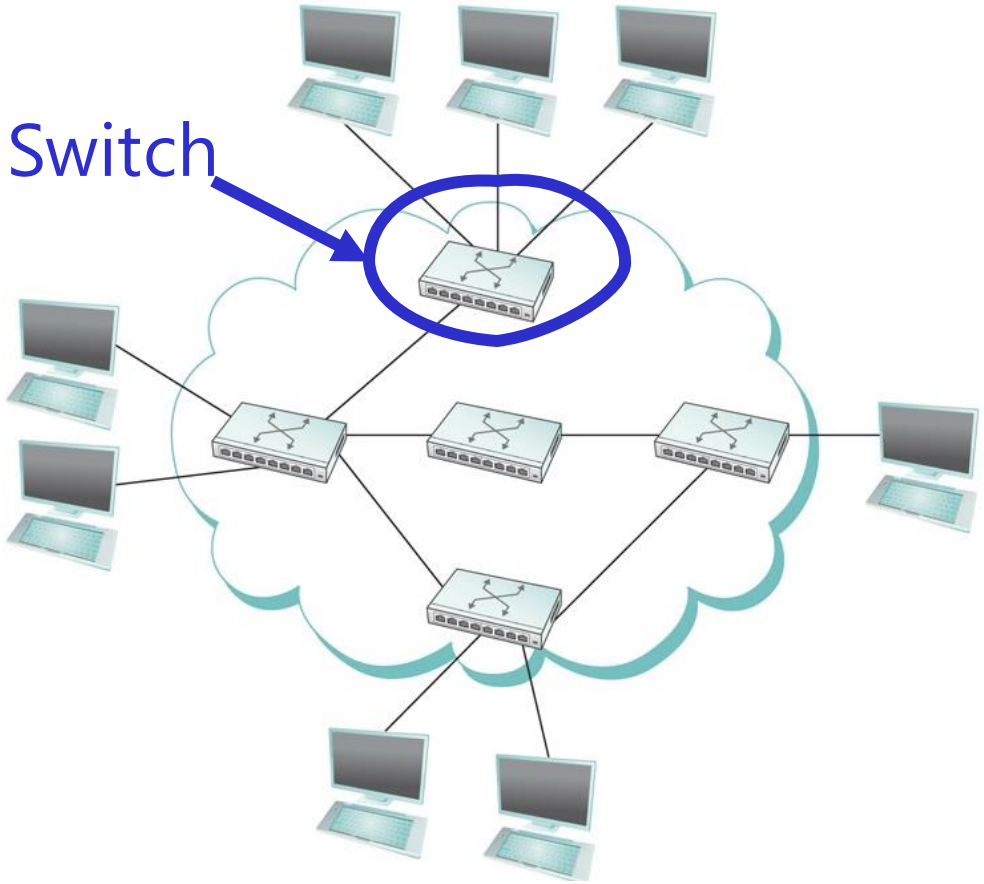
Some graphics are borrowed from the Peterson & Davie book (referred to as P&D)

# Recap: How do we make the internet scalable?




- Divide data into small chunks called packets
- End hosts create packets containing the destination address
- The network tries its “best” to get the packet to the destination
- Routers in the network store and forward packets to the (hopefully) correct next hop

# Two forwarding strategies

**Store and forward**

- Packet enters the switch. The switch stores it in memory
- Switch reads the packet's destination to figure out where to send it
- Switch starts sending packets

**Cut through switching**

- Packet enters the switch
- As soon as the destination address is clear, the switch starts to forward the packet

Most switches store and forward

# Advantages of the two kinds

**Store and forward**

- Easier to implement
- If input rate exceeds the output rate, the packets must be enqueued anyway
- More complex processing is possible if you store the packets

**Cut through switching**

- Lower latency
- Sometimes it is easier to implement, e.g. with optics, you can use a tiny mirror to just redirect the bits to a given port

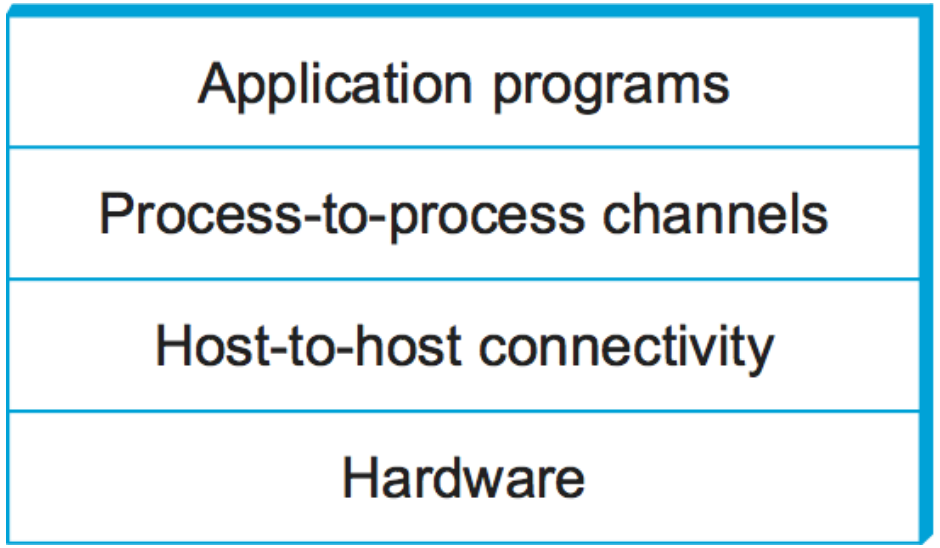
Note: understanding every aspect of this is not important for quizzes. This is more of an example of the type of reasoning you should learn to do.

# How do we make it adaptable?

Principle 1: Precisely specify interfaces between different components, often arranged as layers

- Everyone can have their own implementation and yet interoperate with each other
- When possible, allow for flexibility within a component without having to change the interface (very tricky to get right)

Layering abstractions (P&D chapter 1.3)



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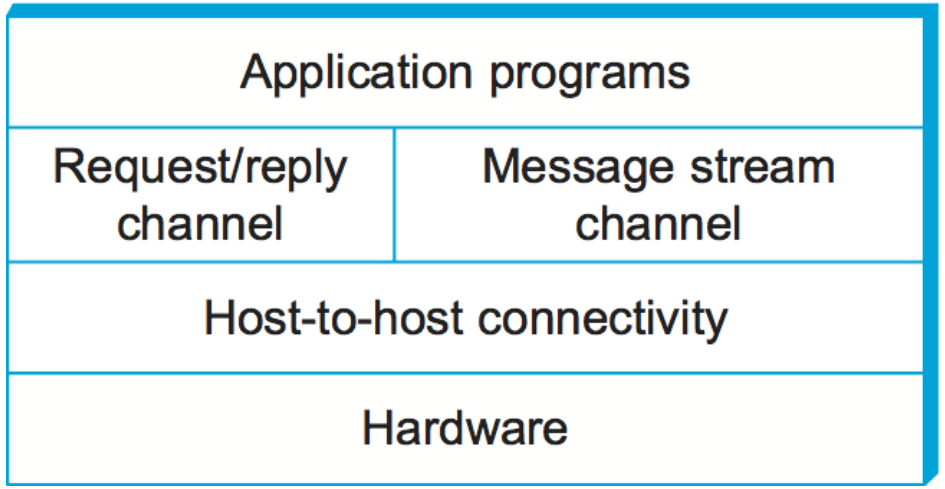



One layer can have many abstractions

# How do we make it adaptable?

Principle 2: Move all intelligence to the end hosts when possible

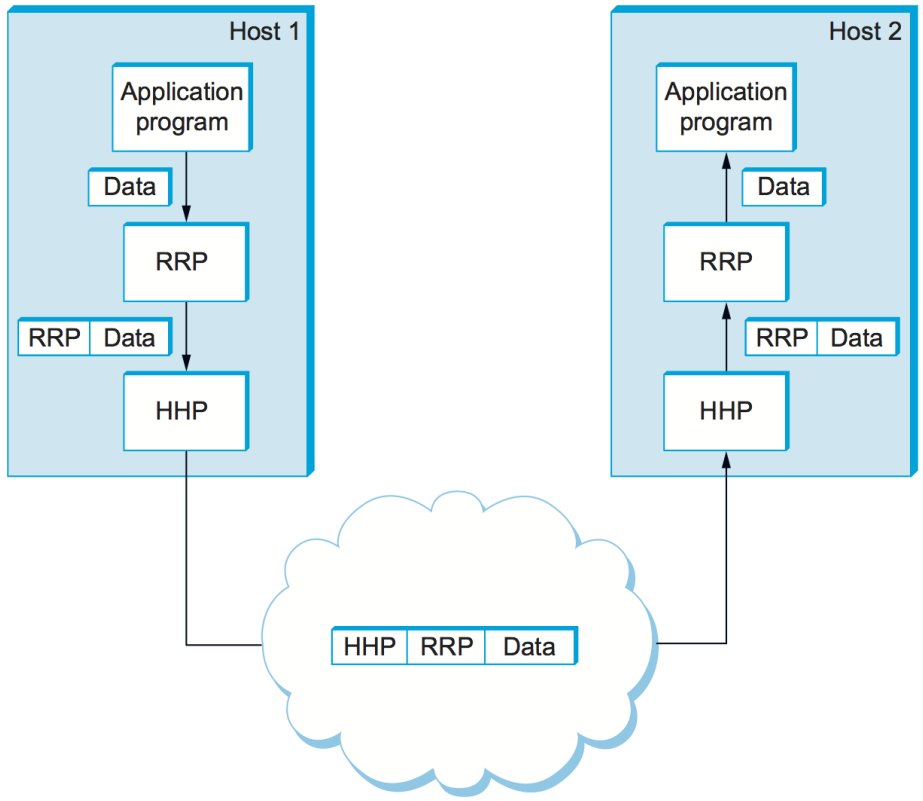
- Popularly called the “end-to-end” principle
- This way, the network is only responsible for transporting packets from one machine to the other.
- Further, we only expect it to put in its “best effort”
- Everything else is handled in the end hosts: reliability, security/encryption, assigning meaning to the bits, and application specific logic
- End hosts are easier to change. It is still difficult to get consensus from everybody though

**Examples where adaptation has succeeded because of this**

- Applications like zoom and slack can unilaterally change their interfaces because they are a single administrative entity
- Email, in contrast, cannot evolve as rapidly since it is run by many entities through a common protocol. However, it is much more universal
- When people realize a cryptographic technique is broken, individual software developers slowly start phasing it out (e.g. web browsers and web servers). For example, people are trying to stop using encryption mechanisms that can be broken by quantum computers. Browser and web-server developers can begin to do this unilaterally
- If a company is large enough, it can unilaterally implement a new protocol. For example, Google implemented a new transport protocol called QUIC because they control a lot of browsers and servers. Now others also use it.

# Implementing layers using encapsulation

Every layer adds its own header to the data. On the other end, every layer removes its header



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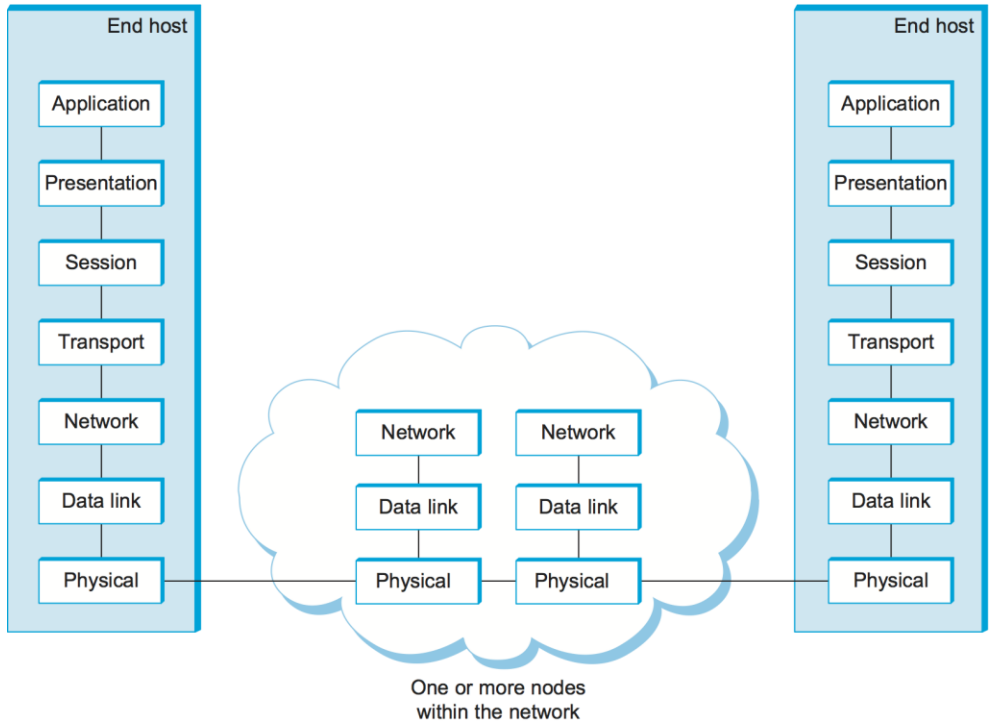
Not all nodes will implement all the layers. Usually, higher layers are only implemented at the end hosts

The picture on the right is the “OSI” model. Nobody uses “Presentation” and “Session” layers anymore.



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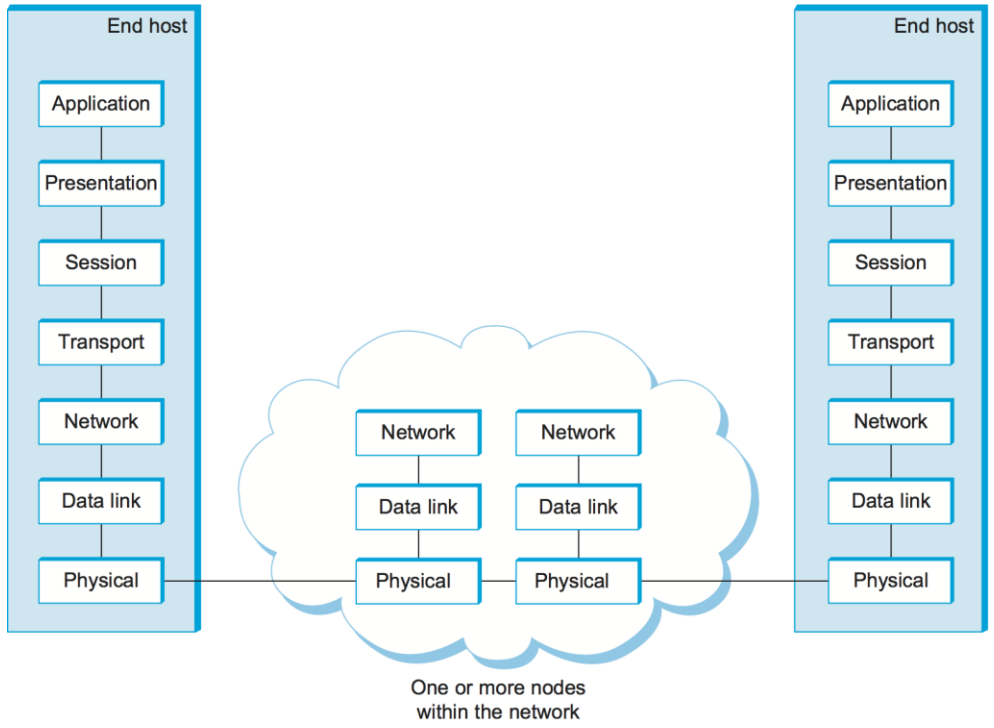
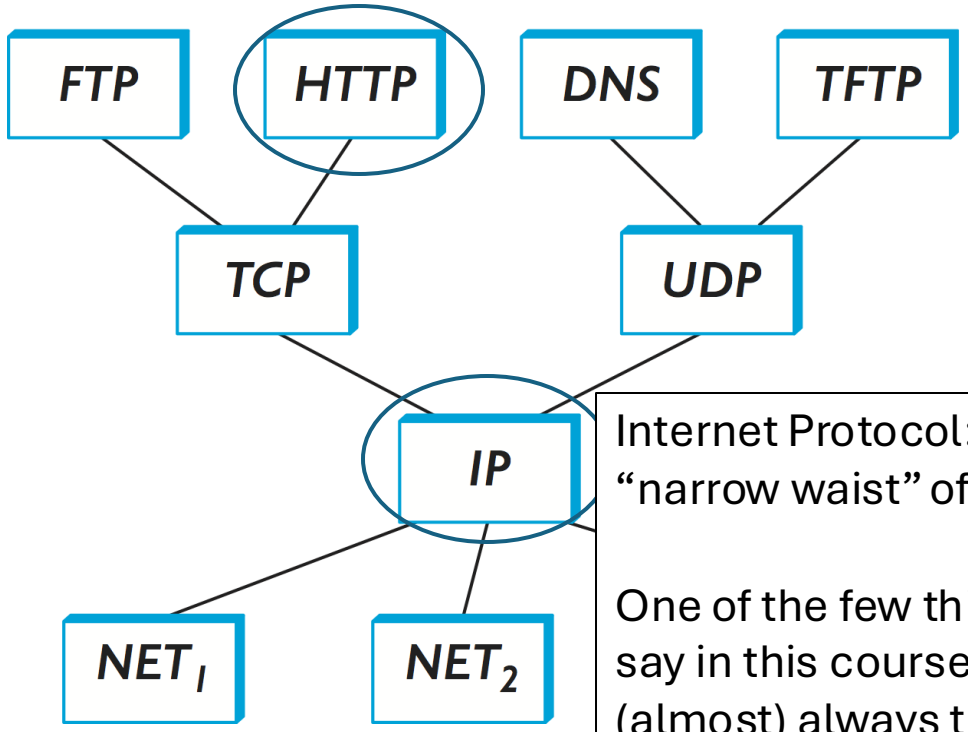


# Todays' protocol stack

HTTP is slowly becoming another narrow waist




Internet Protocol: The "narrow waist" of the internet

One of the few things I will say in this course that is (almost) always true

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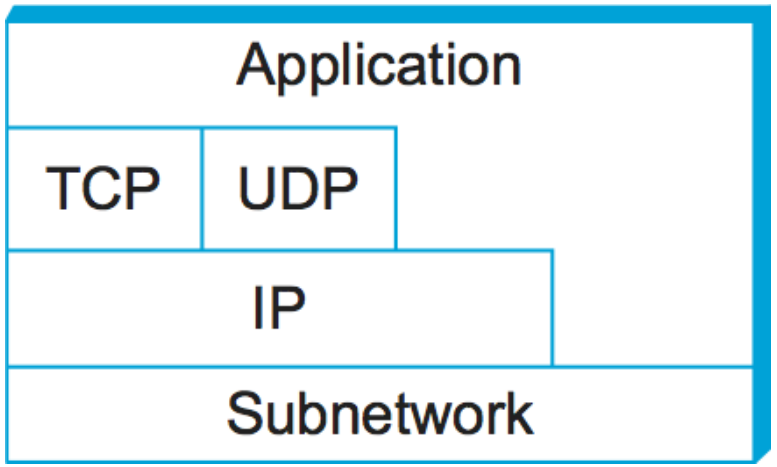

# How can you use the internet? Sockets

C API is explained in P&D chapter 1.4

The client side is used in the assignment 1. The server side will be used in assignment 3

## Server

```python
import socket

def start_server(ip_address, port):
    try:
        # Create a socket object
        with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
            # Bind the socket to the IP address and port
            s.bind((ip_address, port))
            # Enable the server to accept connections (max 5)
            s.listen(5)
            print(f"Server listening on {ip_address}:{port}")

            # Wait for a connection
            # Warning: does not use multiple threads
            conn, addr = s.accept()
            with conn:
                print(f"Connected by {addr}")
                while True:
                    # Receive data from the client
                    data = conn.recv(1024)
                    if not data:
                        # Break the loop if client disconnected
                        break
                    print(f"Received message: {data.decode('utf-8')}")
                    # Optionally, send a response back to the client
                    conn.sendall(b"Message received")
```

## Client

```python
def send_message(ip_address, port, message):
  try:
    # Create a socket object
    with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
      # Connect to the server
      s.connect((ip_address, port))
      # Send the message
      s.sendall(message.encode('utf-8'))

      # Receive the response
      response = s.recv(10000)
      return response.decode('utf-8')
  except Exception as e:
    return f"An error occurred: {e}"

# Example usage
response = send_message("127.0.0.1", 8000, "Hello world")
print(response)
```

# Meta questions

- Where else do you see a layered architecture for modularity?
  - OS: User processes, syscall interface, kernel land, drivers, hardware
  - Compilers: Lexing, parsing, semantics, optimization, code generation, linking
  - Databases: data layout, buffer manager, file manager, access methods (indices), query process, user interface (e.g. SQL)
  - UI toolkits: semantic representation (e.g. DOM in the web), layout, rendering, compositing (putting together layers), presentation (showing to the screen)
- What is the tradeoff between store-and-forward switches vs pass-through switches?