15-441 15-641 Computer Networking

Lecture 2 – Protocol Stacks

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www.cs.cmu.edu/~prs/15-441-F16

Announcements

- Sign up for piazza:
  https://piazza.com/cmu/fall2016/15441641
- P1 will be posted tomorrow
  - There will also be a recitation session tomorrow
- Waiting list – significant progress
  - Moved 20+ students to the roster
    - Some students could not be used because they have too few credits
  - Should be able to move more students later today
- Getting questions answered:
  - Administrative: start with web site
  - Course material: class, office hours
  - Projects: piazza, office hours

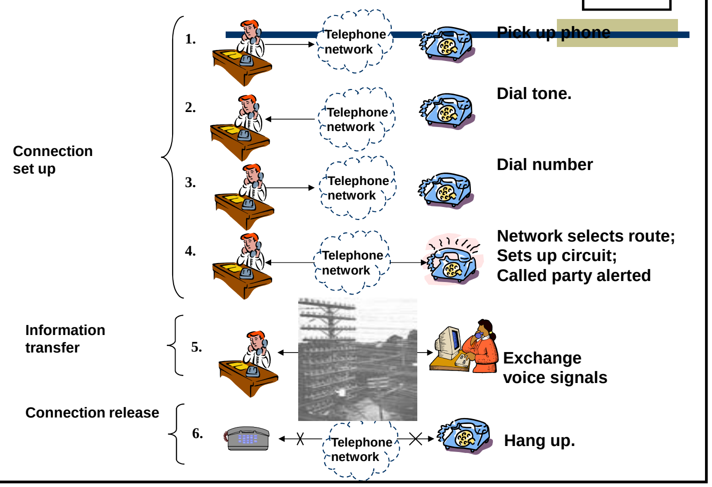
Today's Lecture

- Packet versus circuit switching
- How to design a large Internet
  - Protocols
  - Strawman designs
  - A layered design
  - Life of a packet

What is the Objective of the Internet?

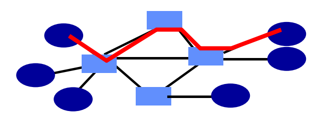
- Enable communication between diverse applications on diverse devices …
  - Web, peer-to-peer, video streaming, distributed processing, transactions, map-reduce, video and audio conferencing, …
- … over very diverse infrastructures
  - The "Internet", WiFi and cellular, data center networks, corporate networks, dedicated private networks, …
- In contrast: previous networks were special purpose and fairly homogeneous in terms of technology
- Context: it is the 1960's and you are asked to design an Internet …
- … your starting point is the telephone network

Three Phases of a Connection



Circuit Switching

- Source first establishes a connection (circuit) to the destination
  - Each switch along the way stores info about connection (and possibly allocates resources)
- Source sends the data over the circuit
  - No need to include the destination address with the data since the switches know the path
- The connection is explicitly torn down
- Example: telephone network (analog)



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Circuit Switching Discussion

- Circuits have some very attractive properties.
  - Fast and simple data transfer, once the circuit has been established
  - Predictable performance since the circuit provides isolation from other users
  - E.g. guaranteed bandwidth
- But it also has some shortcomings.
  - How about bursty traffic?
    - Do you need a permanent circuit to Facebook?
      - And are you willing to pay for it
    - Circuit will be idle for significant periods of time
  - In practice you will need circuits to many destinations
  - How about users with different bandwidth needs?

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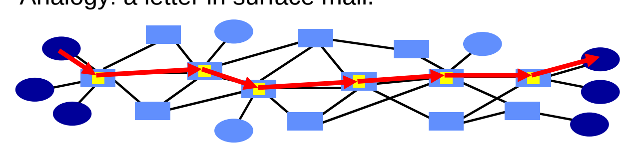
Contrast this with Packet Switching (our emphasis)

- Source sends information as self-contained messages that have an address.
  - Source may have to break up single message in multiple packets
- Each packet travels independently to the destination host.
  - Switches use the address in the packet to determine how to forward the packets
  - Store and forward
- Analogy: a letter in surface mail.



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Packet Switching Discussion

- General: Multiple types of applications
- Efficient: Can send from any input that is ready
- Accommodates bursty traffic efficiently
  - Statistical multiplexing
- Store and forward architecture
  - Packets are self contained units
  - Can use alternate paths – potentially more robust
  - Requires buffering to absorb bursts
- Contention (i.e. no isolation)
  - Congestion
  - Delay

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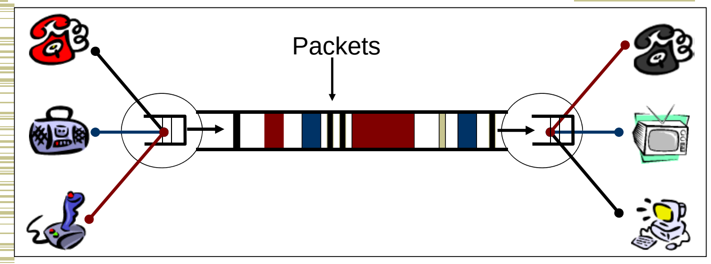
Statistical Multiplexing



- Users share the wires at a fine grain - packets
- Links are never idle when there is traffic - Efficient!
- Requires queues to buffer packets
  - Creates challenges: congestion, losses, fairness, …

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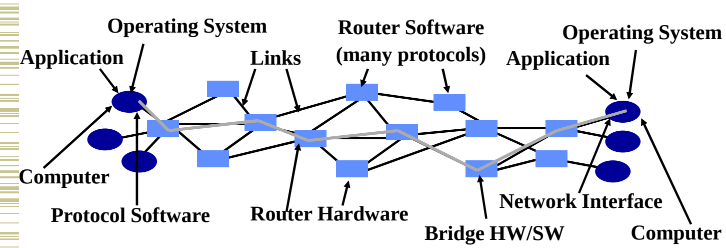
Why is Designing an Internet Hard?

- Has many users
- Offers diverse services
- Mixes very diverse technologies
- Components built by many companies
- Diverse ownership
- Can evolve over time



Oh, and it is really big!

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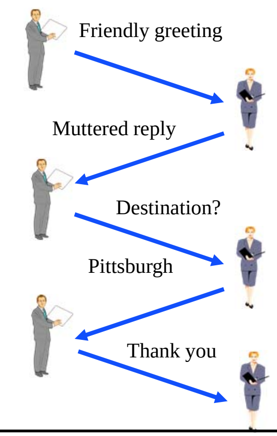
But We Can Handle It! What Do We Definitely Need?

We must have communication hardware and applications:

- Two “devices” must be able to talk to each other
- Applications since they make the network useful and fun
  - Nobody cares if there are no applications
- We also need to design the network so it can grow very big and is always available
  - We need to be able to expand, fix, and improve it …
  - While it is up and running: you cannot reboot the Internet

Protocol: Enable Communication

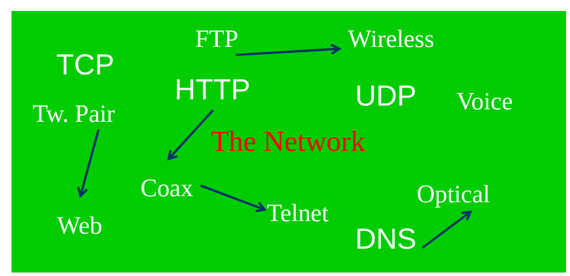
- An agreement between parties on how communication should take place.
- Protocols have to define many aspects of the communication:
- Syntax:
  - Data encoding, language, etc.
- Semantics:
  - Error handling, termination, ordering of requests, etc.
- Example: Asking for directions
  - English, facial expression, …
- Example: Buying airline ticket by typing.
  - English, ascii, lines delimited by “\n”



Do We Only Need Protocols?

- We also need to deal with:
  - Many pieces of functionality and significant complexity
  - Many parties involved building and running the network
  - A very long life time
- The solution for dealing with complexity is modularity: break up the Internet “system” in a set of modules with well-defined interfaces
  - Each module performs specific functions
  - Implementation of module can change
  - Can build a large complex system from modules implemented by many parties
- Let us start with multiple protocols …

Solution #1



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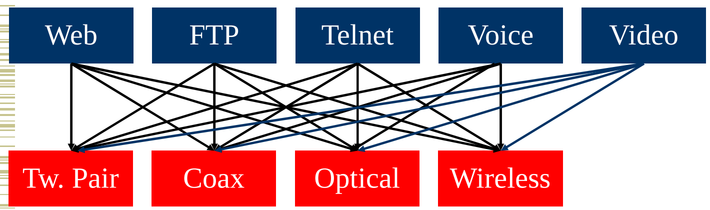
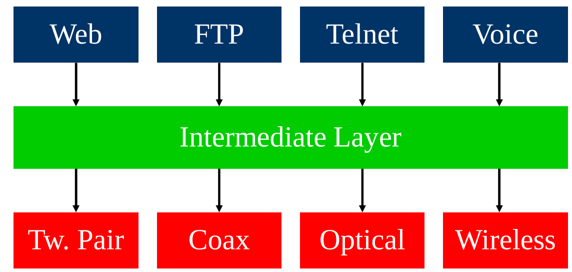
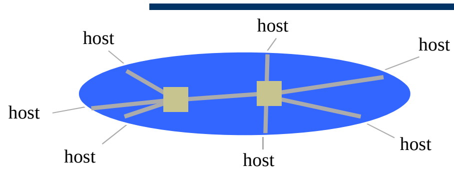
Solution #2?



Solution #3

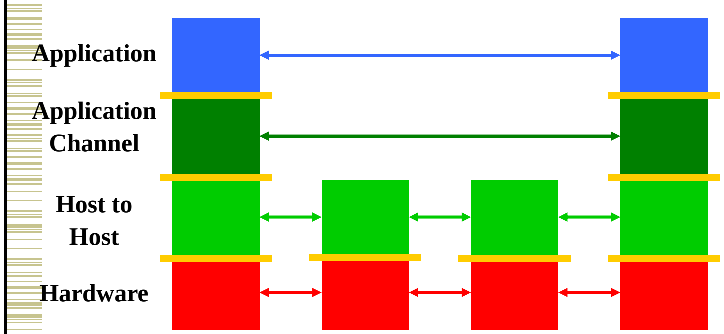


Types of Protocols



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

Protocol and Service Levels



Layering: modular approach to network functionality

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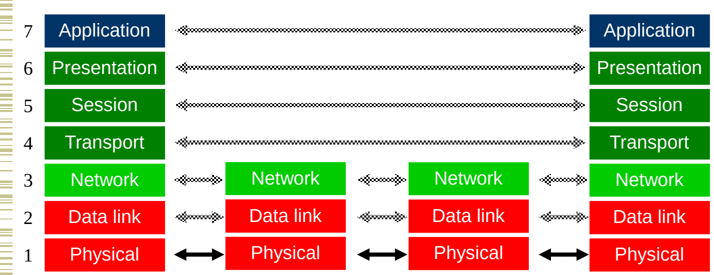
A Layer Network Model

The Open Systems Interconnection (OSI) Model



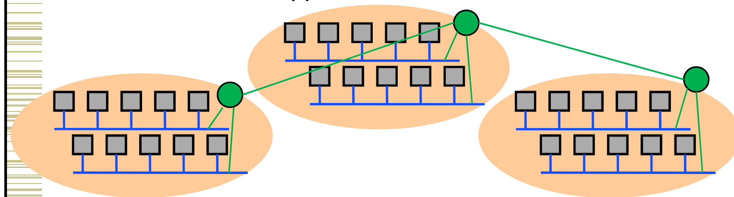
OSI Model: 7 Protocol Layers

- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

- TCP/IP has been amazingly successful, and it is not based on a rigid OSI model. The OSI model has been very successful at shaping thought

Let Us Try Again a Bit More Systematically

- Two or more hosts talk over a wire — Physical
- Groups of hosts can talk at two levels
  - Hosts talk in a network is homogeneous in terms of administration and technology — Datalink
  - Hosts talk across networks that have different administrators and may use different technology — Internet
- We run some applications over that

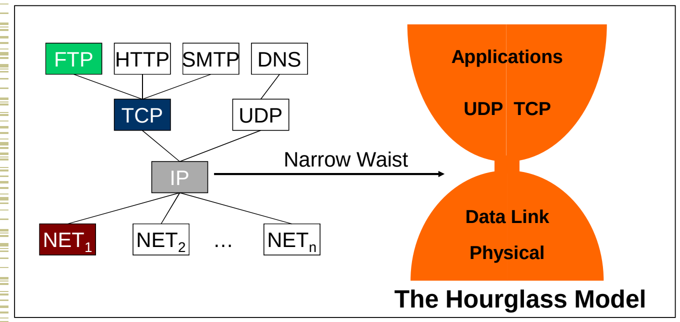


A Bit More Detail

- Physical layer delivers bits between the two endpoints of a “link”
  - Copper, fiber, wireless, visible light, …
- Datalink layer delivers packets between two hosts in a local area network
  - Ethernet, WiFi, cellular, …
  - Best effort service: should expect a modest loss rate
  - “Boxes” that connect links are called bridges or switches
- Network layer connects multiple networks
  - The Inter-net protocol (IP)
  - Also offers best effort service
  - Boxes that forward packets are called routers

Scaling up the network

The Internet Protocol Suite



The waist facilitates interoperability
… but evolution is hard

Example: Retrieving a Web Page

- Application: HTTP – GET files specified by URL and deal with web features (attributes, cookies, …)
- Presentation: MIME - specify format of the content
- Session: sockets and TCP – maintain state to optimize data transfer, security, …
- Transport: TCP – recover from errors, flow and congestion control, …
- Network: IP – best effort datagram service
- Datalink: Ethernet, .. – best effort packet transfer over different link technologies
- PHY: Twisted pair, fiber, .. – exchange bits between hosts

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Layering Characteristics

- The stack has two types of interfaces
  - Service: each layer relies on services from layer below and exports services to layer above
  - Protocol: defines interaction with peer on other hosts
- Modules hide implementation - layers can change without disturbing other layers
- A layer can implement multiple protocols that offer the same/similar or different services
  - Datalink: Wifi versus Ethernet
  - Transport: TCP versus UDP

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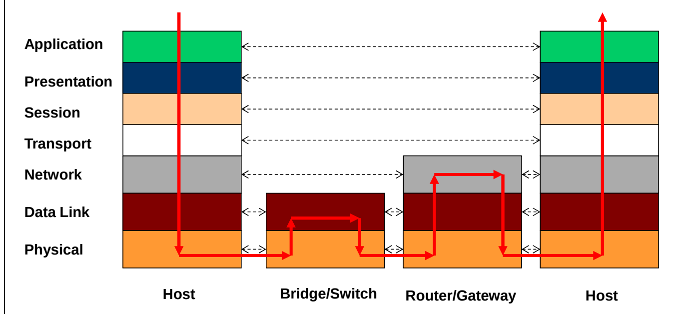
Life of Packet



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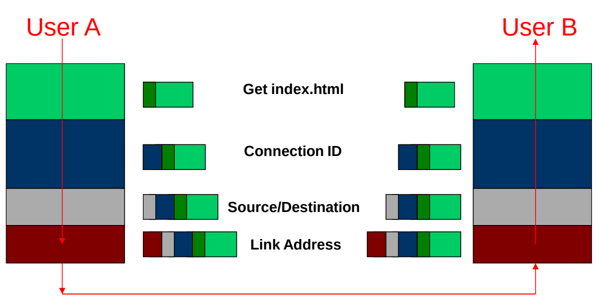
How do Peers Communicate: Headers and Layer Encapsulation



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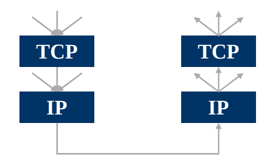
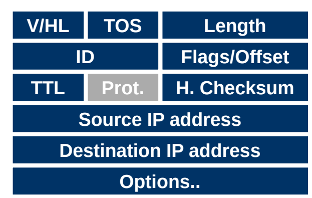
Multiplexing and Demultiplexing

- Multiple choices at each layer: how does a protocol on receiver know what protocol is next?
- Headers include a demultiplexing field that is by receiver used to identify the protocol in the next layer.
  - Filled in by the sender
  - Used by the receiver





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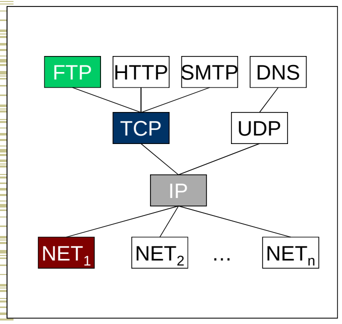
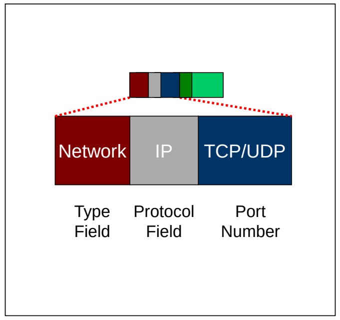
Protocol Demultiplexing





- What layers do not need a protocol field?

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 Engineering Task Force
  - Based on working groups that focus on 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

Other Relevant Standardization Bodies

- ITU-TS - Telecommunications Sector of the International Telecommunications Union.
  - government representatives (PTTs/State Department)
  - responsible for international "recommendations"
- T1 - telecom committee reporting to American National Standards Institute.
  - T1/ANSI formulate US positions
  - interpret/adapt ITU standards for US use, represents US in ISO
- IEEE - Institute of Electrical and Electronics Engineers.
  - responsible for many physical layer and datalink layer standards
- ISO - International Standards Organization.
  - covers a broad area