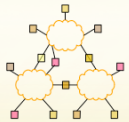
15-446 Distributed Systems Spring 2009



L-2 Internet Design Philosophy

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Today's Lecture

- Layers and protocols
- Design principles in internetworks

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Lots of Functions Needed

- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

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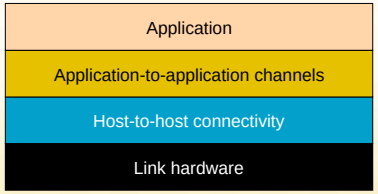
What is Layering?

- Modular approach to network functionality
- Example:



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Protocols

- Module in layered structure
- An agreement between parties on how communication should take place
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer (syntax & semantics)
    - Actions taken on receipt of a messages
    - Format and order of messages
    - Error handling, termination, ordering of requests, etc.
- Example: Buying airline ticket

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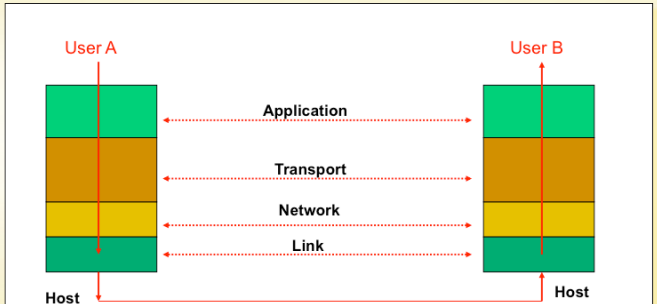
Layering



Layering: technique to simplify complex systems

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Layering Characteristics

- Each layer relies on services from layer below and exports services to layer above
- Interface defines interaction
- Hides implementation - layers can change without disturbing other layers (black box)

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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

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E.g.: 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's not based on a rigid OSI model. The OSI model has been very successful at shaping thought

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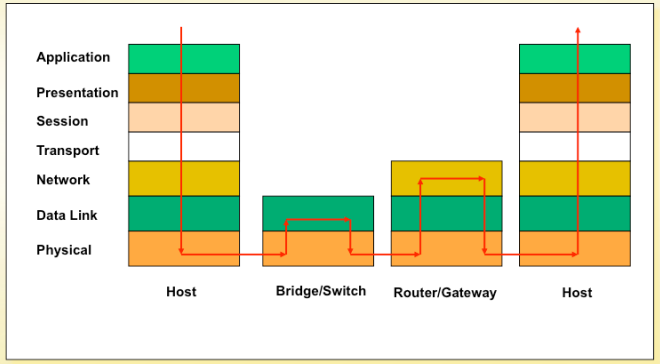
OSI Layers and Locations



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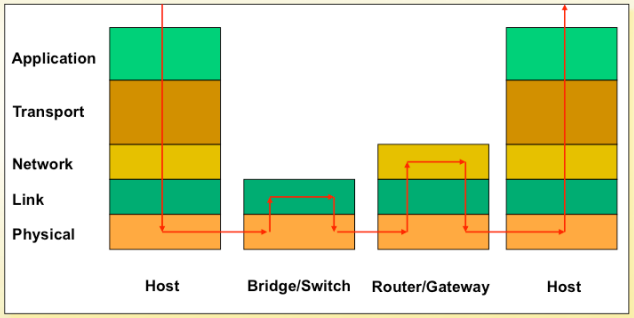
IP Layering

- Relatively simple



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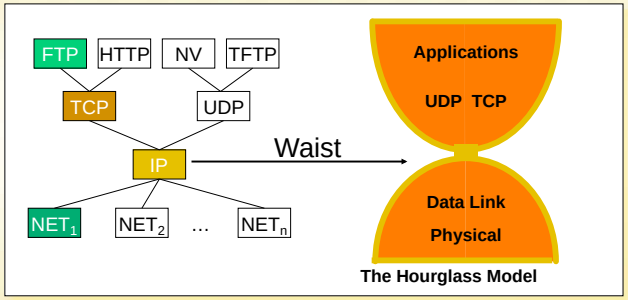
The Internet Protocol Suite



The waist facilitates interoperability

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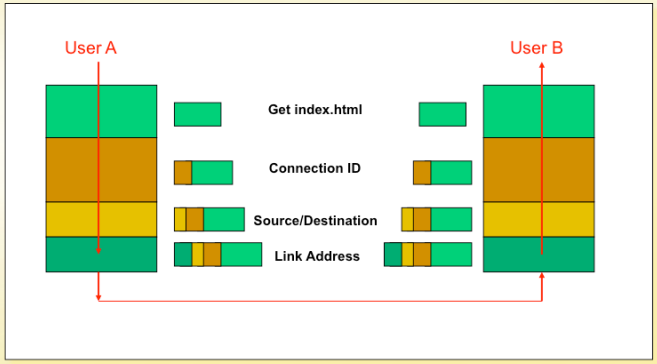
Layer Encapsulation



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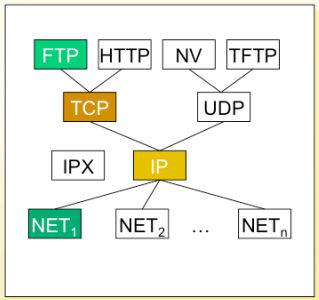
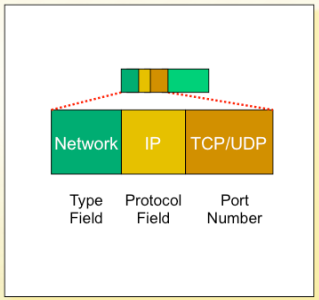
Protocol Demultiplexing

- Multiple choices at each layer





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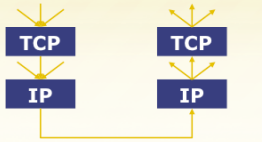
Multiplexing and Demultiplexing

- There may be multiple implementations of each layer.
  - How does the receiver know what version of a layer to use?
- Each header includes a 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, …



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Is Layering Harmful?

- Layer N may duplicate lower level functionality (e.g., error recovery)
- Layers may need same info (timestamp, MTU)
- Strict adherence to layering may hurt performance
- Some layers are not always cleanly separated.
  - Inter-layer dependencies in implementations for performance reasons
  - Some dependencies in the standards (header checksums)
- Interfaces are not really standardized.
  - It would be hard to mix and match layers from independent implementations, e.g., windows network apps on unix (w/ out compatibility library)
  - Many cross-layer assumptions, e.g. buffer management

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Today's Lecture

- Layers and protocols
- Design principles in internetworks

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Goals [Clark88]

0. **Connect existing networks**
   initially ARPANET and ARPA packet radio network
1. Survivability
   ensure communication service even in the presence of network and router failures
2. Support multiple types of services
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

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Priorities

- The effects of the order of items in that list are still felt today
  - E.g., resource accounting is a hard, current research topic
- Let's look at them in detail

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0. Connecting Existing Networks

- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to internetwork various network technologies

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Address Formats

- Map one address format to another?
  - Bad idea → many translations needed
- Provide one common format
  - Map lower level addresses to common format

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Different Packet Sizes

- Define a maximum packet size over all networks?
  - Either inefficient or high threshold to support
- Implement fragmentation/re-assembly
  - Who is doing fragmentation?
  - Who is doing re-assembly?

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Gateway Alternatives

- Translation
  - Difficulty in dealing with different features supported by networks
  - Scales poorly with number of network types (N^2 conversions)
- Standardization
  - **"IP over everything"**
  - Minimal assumptions about network
  - Hourglass design

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1. Survivability

- If network disrupted and reconfigured:
  - Communicating entities should not care!
  - No higher-level state reconfiguration
- How to achieve such reliability?
  - Where can communication state be stored?

	Network	Host
Failure handing	Replication	"Fate sharing"
Switches	Maintain state	Stateless
Host trust	Less	More

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Fate Sharing

- Lose state information for an entity if (and only if?) the entity itself is lost.
- Examples:
  - OK to lose TCP state if one endpoint crashes
    - NOT okay to lose if an intermediate router reboots
  - Is this still true in today's network?
    - NATs and firewalls

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Soft-State

- Basic behavior
  - Announce state
  - Refresh state
  - Timeout state
- Penalty for timeout – poor performance
- Robust way to identify communication flows
  - Possible mechanism to provide non-best effort service
- Helps survivability

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End-to-End Argument

- Deals with where to place functionality
  - Inside the network (in switching elements)
  - At the edges
- Argument:
  - There are functions that can only be correctly implemented by the endpoints – do not try to completely implement these elsewhere

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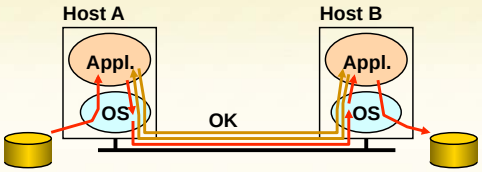
Example: Reliable File Transfer



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

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E2E Example: File Transfer

- If network guaranteed reliable delivery
  - The receiver has to do the check anyway!
    - E.g., network card may malfunction
- Full functionality can only be entirely implemented at application layer; no need for reliability from lower layers
- Is there any need to implement reliability at lower layers?

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Discussion

- Yes, but only to improve performance
- If network is highly unreliable
  - Adding some level of reliability helps performance, not correctness
  - Don't try to achieve perfect reliability!
  - Implementing a functionality at a lower level should have minimum performance impact on the applications that do not use the functionality

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2. Types of Service

- Best effort delivery
- All packets are treated the same
- Relatively simple core network elements
- Building block from which other services (such as reliable data stream) can be built
- Contributes to scalability of network

- No QoS support assumed from below
  - Accommodates more networks
  - Hard to implement without network support
  - QoS is an ongoing debate…

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Types of Service

- TCP vs. UDP
  - Elastic apps that need reliability: remote login or email
  - Inelastic, loss-tolerant apps: real-time voice or video
  - Others in between, or with stronger requirements
  - Biggest cause of delay variation: reliable delivery
    - Today's net: ~100ms RTT
    - Reliable delivery can add *seconds*.
- Original Internet model: "TCP/IP" one layer
  - First app was remote login…
  - But then came debugging, voice, etc.
  - These differences caused the layer split, added UDP

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3. Varieties of Networks

- Minimum set of assumptions for underlying net
  - Minimum packet size
  - Reasonable delivery odds, but not 100%
  - Some form of addressing unless point to point
- Important non-assumptions:
  - Perfect reliability
  - Broadcast, multicast
  - Priority handling of traffic
  - Internal knowledge of delays, speeds, failures, etc.
- Much engineering then only has to be done once

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The "Other" goals

- 4. Management
  - Each network owned and managed separately
  - Will see this in BGP routing especially
- 5. Attaching a host
  - Not awful; DHCP and related autoconfiguration technologies helping.
- 6. Cost effectiveness
  - Economies of scale won out
  - Internet cheaper than most dedicated networks
  - Packet overhead less important by the year
- But…

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7. Accountability

- Huge problem.
- Accounting
  - Billing? (mostly flat-rate. But phones are moving that way too - people like it!)
  - Inter-provider payments
    - Hornet's nest. Complicated. Political. Hard.
- Accountability and security
  - Huge problem.
  - Worms, viruses, etc.
    - Partly a host problem. But hosts very trusted.
  - Authentication
    - Purely optional. Many philosophical issues of privacy vs. security.
  - Greedy sources aren't handled well

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Other IP Design Weaknesses

- Weak administration and management tools
- Incremental deployment difficult at times
  - Result of no centralized control
  - No more "flag" days
  - Are active networks the solution?

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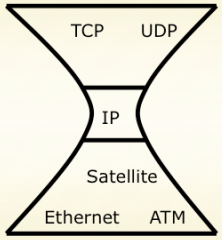
Summary: Internet Architecture

- Packet-switched datagram network
- IP is the "compatibility layer"
  - Hourglass architecture
  - All hosts and routers run IP
- Stateless architecture
  - No per flow state inside network



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Summary: Minimalist Approach

- Dumb network
  - IP provide minimal functionalities to support connectivity
    - Addressing, forwarding, routing
- Smart end system
  - Transport layer or application performs more sophisticated functionalities
    - Flow control, error control, congestion control
- Advantages
  - Accommodate heterogeneous technologies (Ethernet, modem, satellite, wireless)
  - Support diverse applications (telnet, ftp, Web, X windows)
  - Decentralized network administration
- Beginning to show age
  - Unclear what the solution will be → probably IPv6
- Discussion: what are the implications for distributed system design?

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