416 Distributed Systems

Networks review; Day 2 of 2

And start of RPC

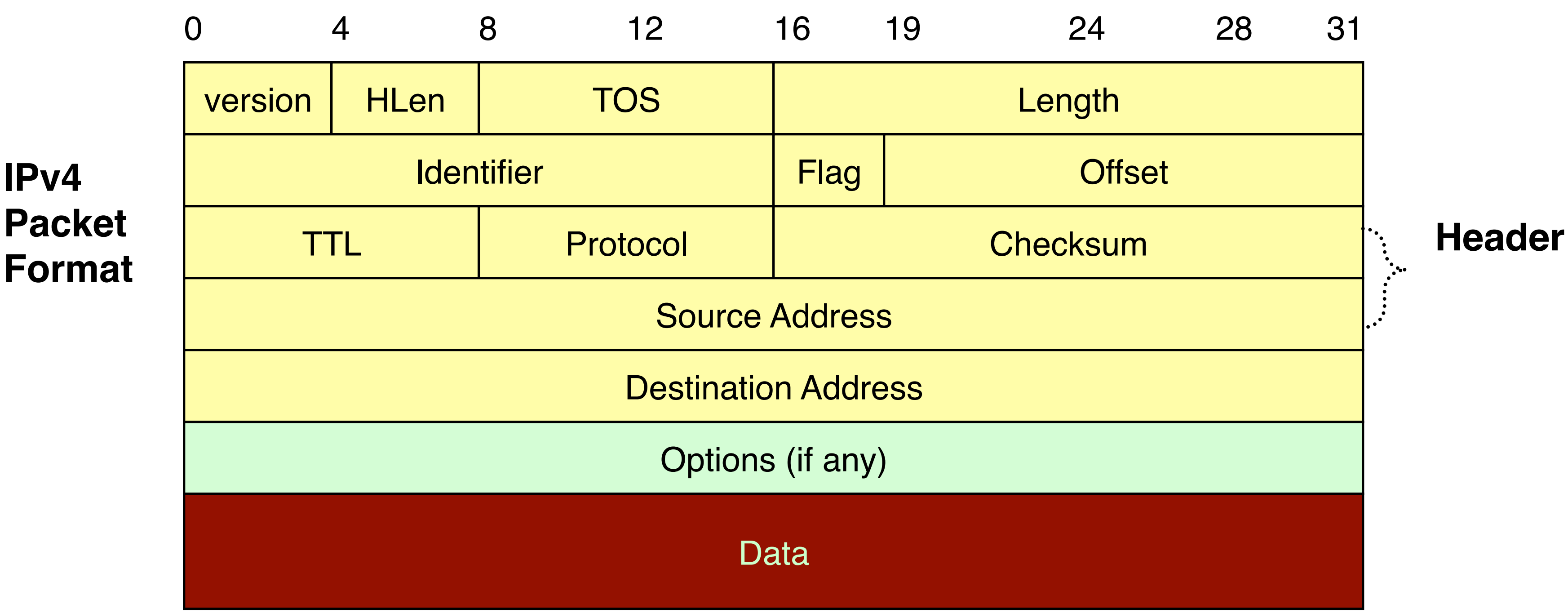
Jan 9, 2017

Last Time

- Modularity, Layering, and Decomposition
  - Example: UDP layered on top of IP to provide application demux ("ports")
- Resource sharing and isolation
  - Statistical multiplexing - packet switching
- Dealing with heterogenity
  - IP "narrow waist" -- allows many apps, many network technologies
  - IP standard -- allows many impls, same proto

IP Packets/Service Model

- Low-level communication model provided by Internet
- Datagram
  - Each packet self-contained
    - All information needed to get to destination
    - No advance setup or connection maintenance
  - Analogous to letter or telegram



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

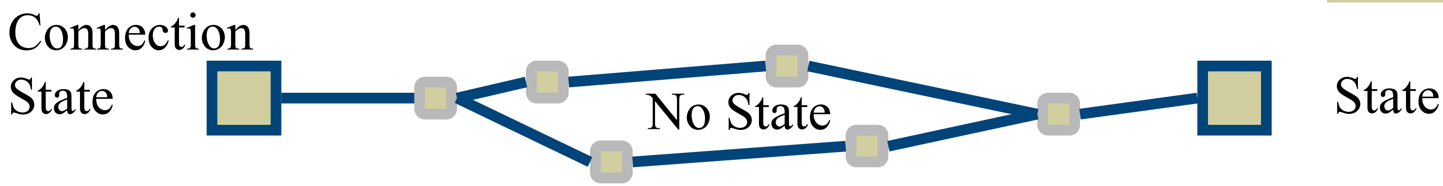
2. Support multiple types of services
3. Must accommodate a variety of networks
4. Allow distributed management
5. Allow host attachment with a low level of effort
6. Be cost effective
7. Allow resource accountability

Goal 1: Survivability

- If network is 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"
Net Engineering	Tough	Simple
Routing state	Maintain state	Stateless
Host trust	Less	More

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
- Tradeoffs
  - Less information available to the network
  - Must trust endpoints more

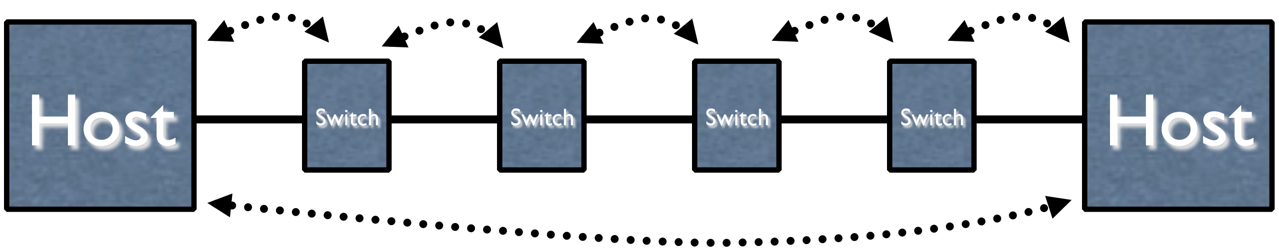
Networks [including end points] Implement Many Functions

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

Design Question

- If you want reliability, where should you implement it?

Option 1: Hop-by-hop (at switches)



Option 2: end-to-end (at end-hosts)

Options

- Hop-by-hop: Have each switch/router along the path ensure that the packet gets to the next hop
- End-to-end: Have just the end-hosts ensure that the packet made it through
- What do we have to think about to make this decision??

A question

- Is hop-by-hop enough?
  - [hint: What happens if a switch crashes? What if it's buggy and goofs up a packet?]

End-to-End Argument

- Deals with where to place functionality
  - Inside the network (in switching elements)
  - At the edges
- Guideline not a law
- Argument
  - If you have to implement a function end-to-end anyway (e.g., because it requires the knowledge and help of the end-point host or application), **don't implement it inside the communication system**
  - Unless there's a compelling performance enhancement

Further Reading: "End-to-End Arguments in System Design." Saltzer, Reed, and Clark.

Questions to ponder

- If you have a whole file to transmit, how do you send it over the Internet?
  - You break it into packets (packet-switched medium)
  - TCP, roughly speaking, has the sender tell the receiver “got it!” every time it gets a packet. The sender uses this to make sure that the data’s getting through.
  - But by e2e, if you have to acknowledge the correct receipt of the entire file... why bother acknowledging the receipt of the individual packets???

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- This is a bit of a trick question -- it's not asking e2e vs in-network. :)
  The answer: Imagine the waste if you had to retransmit the entire file because one packet was lost. Ow.

Internet Design: Types of Service

- **Principle**: network layer provides one simple service: best effort datagram (packet) 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
  - In fact, some underlying nets only supported reliable delivery (not best effort)
    - This made Internet datagram service less useful!
  - Hard to implement QoS without network support
  - QoS is an ongoing debate…

User Datagram Protocol (UDP): An Analogy

UDP	Postal Mail
• Single socket to receive messages	• Single mailbox to receive letters
• No guarantee of delivery	• Unreliable ☺
• Not necessarily in-order delivery	• Not necessarily in-order delivery
• Datagram – independent packets	• Letters sent independently
• Must address each packet	• Must address each letter

Example UDP applications
Multimedia, voice over IP

Transmission Control Protocol (TCP): An Analogy

TCP	Telephone Call
• Reliable – guarantee delivery • Byte stream – in-order delivery • Connection-oriented – single socket per connection • Setup connection followed by data transfer	• Guaranteed delivery • In-order delivery • Connection-oriented • Setup connection followed by conversation

Example TCP applications
Web, Email, Telnet

Why not always use TCP?

- TCP provides “more” than UDP
- Why not use it for everything??

Why not always use TCP?

- TCP provides "more" than UDP
- Why not use it for everything??

- A: Nothing comes for free...
  - Connection setup (take on faith) -- TCP requires one round-trip time to setup the connection state before it can chat...
  - How long does it take, using TCP, to fix a lost packet?
    - At minimum, one "round-trip time" (2x the latency of the network)
    - That could be 100+ milliseconds!
  - If I guarantee in-order delivery,
    what happens if I lose one packet in a stream of packets?
  - Has semantics that may be too strong for the app (e.g., Netflix streaming)

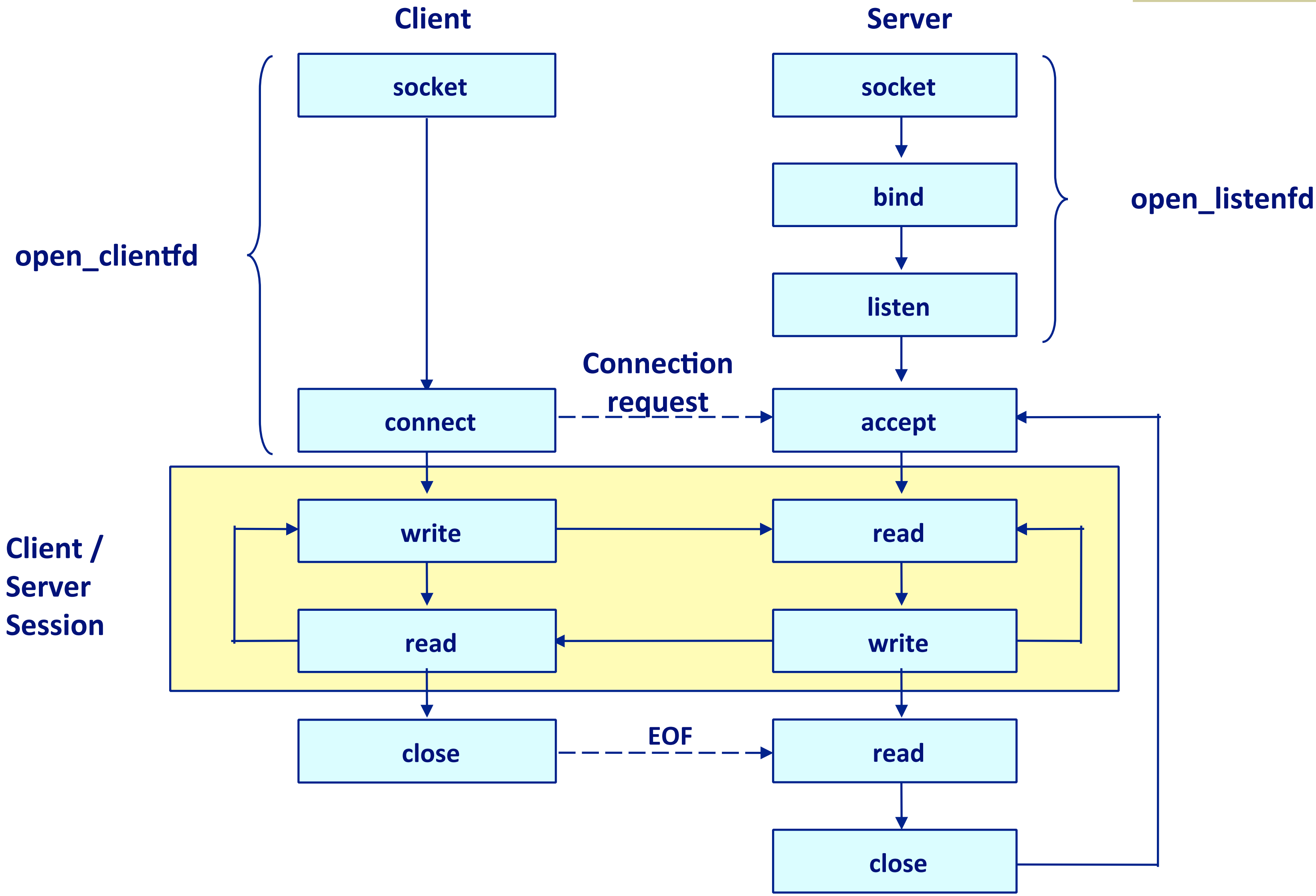
Design trade-off

- If you're building an app...

- Do you need everything TCP provides?
- If not:
  - Can you deal with its drawbacks to take advantage of the subset of its features you need?

    OR
  - You're going to have to implement the ones you need on top of UDP
    - Caveat: There are some libraries, protocols, etc., that can help provide a middle ground.
    - Takes some looking around

Socket API Operation Overview



Blocking sockets

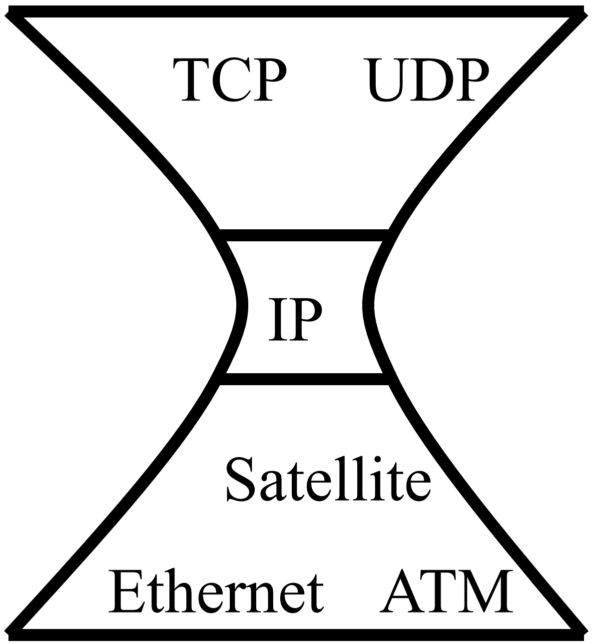
- What happens if an application write()s to a socket waaaaay faster than the network can send the data?
  - TCP figures out how fast to send the data...
  - And it builds up in the kernel socket buffers at the sender... and builds...
  - until they fill. The next write() call *blocks* (by default).
  - What's blocking? It suspends execution of the blocked thread until enough space frees up...

In contrast to UDP

- UDP doesn't figure out how fast to send data, or make it reliable, etc.
- So if you write() like mad to a UDP socket...
- It often silently disappears. *Maybe* if you're lucky the write() call will return an error. But no promises.

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

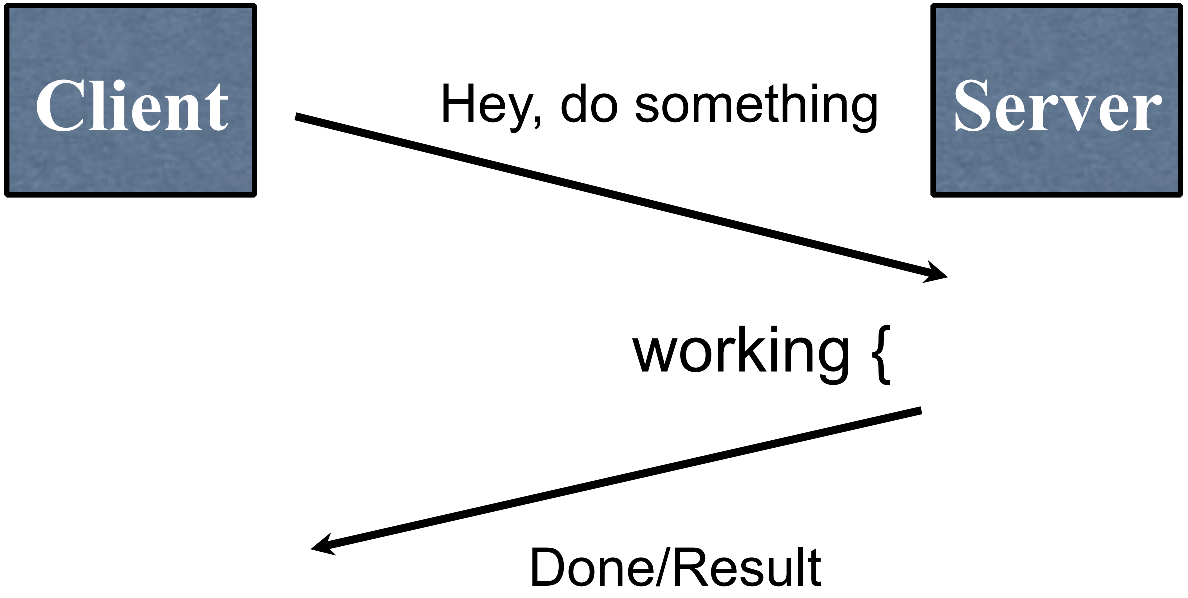


Summary: Minimalist Approach

- 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

RPC: Remote Procedure Calls

Common communication pattern



Writing it by hand (in C)

```
struct foomsg {
  u_int32_t len;
}

send_foo(char *contents) {
   int msglen = sizeof(struct foomsg) + strlen(contents);
   char buf = malloc(msglen);
   struct foomsg *fm = (struct foomsg *)buf;
   fm->len = htonl(strlen(contents));
   memcpy(buf + sizeof(struct foomsg),
          contents,
          strlen(contents));
   write(outsock, buf, msglen);
}
```

Then wait for response, etc.

RPC land

- RPC overview
- RPC challenges
- RPC other stuff

RPC

- A type of client/server communication
- Attempts to make remote procedure calls look like local ones

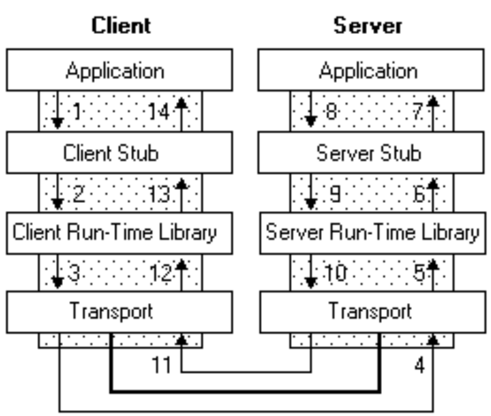


figure from Microsoft MSDN

```
{ ...
   foo()
}
void foo() {
  invoke_remote_foo()
}
```

Go Example

- Need some setup in advance of this but…

```
// Synchronous call
args := &server.Args{7,8}
var reply int
err = client.Call("Arith.Multiply", args, &reply)
if err != nil {
      log.Fatal("arith error:", err)
}
fmt.Printf("Arith: %d*%d=%d", args.A, args.B, reply)
```

RPC Goals

- Ease of programming
- Hide complexity
- Automates task of implementing distributed computation
- Familiar model for programmers (just make a function call)

Historical note: Seems obvious in retrospect, but RPC was only invented in the ‘80s.
See Birrell & Nelson, “Implementing Remote Procedure Call” ... or
Bruce Nelson, Ph.D. Thesis

Remote procedure call

- A remote procedure call makes a call to a remote service look like a local call
  - RPC makes transparent whether server is local or remote
  - RPC allows applications to become distributed transparently
  - RPC makes architecture of remote machine transparent

Emphasis on transparency

Remote procedure call

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Emphasis on transparency

What are some problems with this transparency?