Distributed Applications

Georgia Tech

Week 7

Design Principles for Distributed Applications

"A Distributed Application is a system in which the crash of a machine you've never heard of can cause your program to break."

~ Famous Quote, sometimes attributed to Peter Deutsch

Design Principles for Distributed Applications

- First step: getting the protocol right
- What's the right protocol?
- One that's:
  - Inherently reliable: either party can tell if something's gone wrong
  - Easily parseable: simple to write clients and servers
  - Highly efficient: requires sending as few messages as possible
  - Structurally simple: easy to debug

The Seven Fallacies of Distributed Computing

- *Definitely* attributed to Peter Deutsch
- Assumptions that people make that result in bad distributed applications:
  - The network is reliable
  - Latency is zero
  - Bandwidth is infinite
  - The network is secure
  - Topology of the network doesn't change
  - There is one administrator
  - Transport cost is zero

What This Means in Practice:

The network is reliable	Don't assume that data you send will be received, that a server or client you're talking to will always be alive, etc.
Latency is zero	It takes time for a recipient to get your message! Don't assume transmission is instantaneous.
Bandwidth is infinite	You must make messages as small as possible.
The network is secure	Don't assume that clients that connect to you will have good intentions. Guard against evil!
Topology of the network doesn't change	Don't assume that hosts will retain the same IP address; don't assume that routes between hosts won't change
There is one administrator	You can't "reboot" the Internet, to upgrade clients and services to a new protocol at the same time.
Transport cost is zero	Sending bytes across a network is expensive, relative to doing local computation. Trade computation for transmission whenever possible.

Why It's Important to Get It Right the First Time!

- Once you deploy a service (for real), the protocol is largely set in stone
  - Why? Because if you change it, you have to change *every other client in existence* to speak the new protocol
  - HTTP is only at version 1.1 (which came out early...), and will likely never see 1.2
- The protocol, to a large extent, determines what you can build on top of it
  - Example: in our IM system, impossible to (easily) send text before the chat is created... because the protocol doesn't support it
  - Example: in most email systems, impossible to "retract" a sent message... because the SMTP protocol doesn't support it
  - You can fake certain things, but often difficult. The underlying infrastructure constrains what you can build on top of it

Common Protocol Design Idioms

- *Request/response/notification*
  - Client sends a *request*
  - Server replies with a *response*
  - Server may also send *notification* asynchronously
- Often uses a *sequence number* at the front to allow easy message processing, pipelining of requests and responses
- Example:
  - Client sends request 101, request 102, request 103, ...
  - Server replies with response 101, response 102, response 103, ...
  - Allows clients to have multiple requests "in flight" at once, pair up responses as they come in

Common Idioms for Delimiting Messages

- "Stuffing"
  - Example: SMTP: each header on a line by itself, multiline data begins with "DATA" and ends with "."
  - Client: you don't need the entire message assembled before you start sending it
  - Server: easy to process, but also slow to process: you have to "look" at every line to see if you're at the end.
- "Counting"
  - Example: HTTP: messages indicate how many bytes they contain
  - Client: need to know the length of the entire message before you can send it
  - Server: don't need to examine every byte to process it; just get the length and read this much
- "Blasting"
  - Example: FTP: open an entirely new socket for sending a file; blast the file across and then close it
  - Client: no need for parsing at all
  - Server: no need for parsing at all. Expensive if you're sending lots of small files though (need to set up, tear down socket for each one)

Common Idioms for ASCII Encoding

- Most ASCII-encoded protocols are *line oriented*
- Example: SMTP
  - Textual headers (FROM, SUBJECT, DATE, etc.)
  - Each header consists of *name : value* followed by a carriage return
  - Message body starts with DATA, then message body, then a "." on a line by itself to terminate
  - If message body contains "." on a line by itself anyway, it's replaced by ".." and then decoded on the receiver
- HTTP uses essentially the same format
- Very easy to parse, as long as you're not sending complex data types
- Very easy to debug

Common Idiom: Reply Codes

- Reply messages from a server often contain structured codes to indicate what happened.
- Defined as a part of the protocol spec, intended to allow very easy parsing
- SMTP: 3 digit codes at start of replies
  - 1st digit: success or failure
  - 2nd digit: the subsystem of the mail server that is responding
  - 3rd digit: the situation that occurred
- HTTP: same deal
  - Error 404 anyone?

Debugging ASCII-Oriented Protocols

- You can *telnet* to a server that speaks an ASCII protocol to talk to it directly

telnet <u>www.cc.gatech.edu</u> 80
Trying 130.207.7.237...
Connected to rhampora.cc.gatech.edu.
Escape character is '^]'.
GET /index.html HTTP/1.0

Blank line indicates end of request

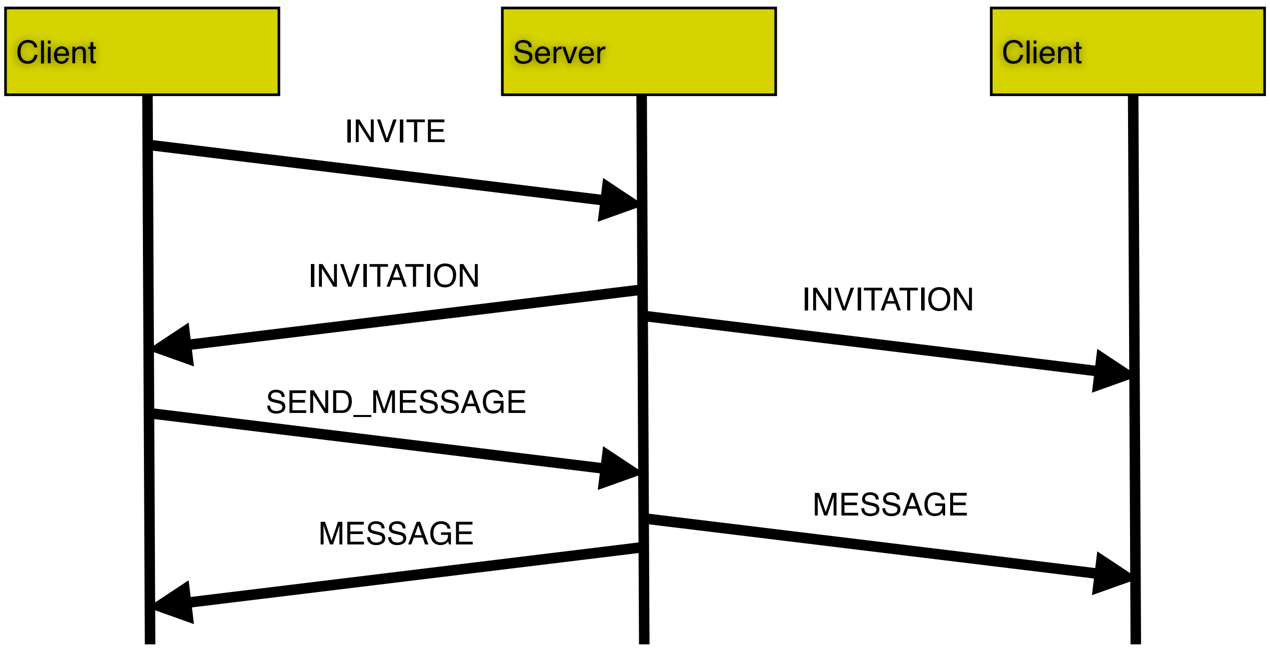
HTTP/1.1 200 OK
Date: Wed, 16 Feb 2005 14:55:22 GMT
Server: Apache/2.0.46 (Unix) mod_ssl/2.0.46 OpenSSL/0.9.7a
Last-Modified: Mon, 14 Feb 2005 12:01:38 GMT
ETag: "e97772-7573-69118c80"
Accept-Ranges: bytes
Content-Length: 30067
Connection: close
Content-Type: text/html

<HTML><HEAD><TITLE>Georgia Tech - College of Computing</TITLE><META

Protocol Design Techniques

- "Lo-fi prototypes for protocols"
- Fence sketches
- Shows interactions among hosts involved in a protocol exchange
- Time starts at the top of the sketch, goes down
- There's even software to create these for you

Examples



Client
Server
Client
INVITE
INVITATION
INVITATION
SEND_MESSAGE
MESSAGE
MESSAGE

Dealing With Errors

Networking Errors, Other Errors

- From last week: *defensive programming*
  - Would like to ensure that a server can't crash your client
  - Would like to ensure that a client can't crash your server
- How do you do this?
- One good tool: *exceptions*
- Built into the Jython language
  - Also available in some form in many other languages: Java, C++, ...

What Are Exceptions?

- A way to skip out of an arbitrarily large chunk of code when an error happens
- Sort of a structured "super-goto"
- Any sort of runtime error that happens in your program may *raise* an exception
  - Meaning: it's telling you that something has gone wrong
- By default, exceptions are not *caught*
  - Meaning: they simply cause your program to quit
- Jython provides a way for you to *catch* these exceptions, and *handle* them with your own code
  - Meaning: you can write code to recover from errors that may occur
- Exceptions are not just for network programming! All sorts of errors cause exceptions to be raised!

Example

```
list = [1, 2, 3]
print list[158]

Traceback (innermost last):
   File "<console>", line 1, in ?
IndexError: index out of range: 158
```

- This message is telling you than an exception--called *IndexError*--was raised, but not caught

Example with Exceptions

```
list = [1, 2, 3]
try:
    print list[158]
except IndexError:
    print "Dummy! You used a bogus index!"
```

```
Dummy! You used a bogus index!
```

Anatomy of an Exception

- New keyword: *try*
  - Specifies the start of a block of code that might cause exceptions you'd like to handle
- New keyword: *except*
  - Specifies the end of the block of code that might cause exceptions, and the beginning of your *exception handler*
- There are different types of exceptions.
  - Example: IndexError caused by list index out of bounds
  - Other operations define their own types of exceptions
  - You specify in the *except* statement which types you're handling
- If an exception is raised, control passes to the handler, and then to the next statement after that
- If no exception is raised, control continues to the except keyword, then skips the except clause, then continues to the next statement after that

What Good Does This Do You?

- In the previous example, not much
  - The index problem was a *logic* error, caused by an actual bug in the program
  - Pretty much you'd just want to exit; the developer will need to find and fix the bug to make the program right
- Other sorts of exceptions are *not* caused by logic errors though
- Examples:
  - You're trying to connect to a server and the server is down
  - You're trying to write to a server and it crashes
- Caused not by bugs in your program, but by changes in the external situation

More Exception Syntax

- Syntax of *except* statement:
  - except ExceptionType, exceptionInstance

  - except: keyword in the Jython language
  - ExceptionType: indicates the type (class name) of the exception you want to catch
    - Can just use "Exception" as the type to catch everything
    - Can have multiple except statements, each of which catches a different type of exception
  - exceptionInstance: an object that provides more details about the exception
    - Optional
    - Use it to print out more details about what specifically went wrong

A More Realistic Example

```
import sys
import java.net as net

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

success = 0
while not success:
    # let the user type in a hostname. They might type something bogus!
    hostname = sys.stdin.readline()
    try:
        s.connect(hostname, 80)              # try to connect
        success = 1                          # if no exception, we were successful
    except net.UnknownHostException:     # if the name is bogus, we'll get an exception
        print "The hostname you entered," hostname, "is not valid."
```

Detecting Read/Write Errors

- socket.send(), socket.recv() raise *java.net.SocketException* if they fail

```
import java.net as net
try:
    socket.send(”hello”)
except net.SocketException, ex:
    socket.close()
    print “Error while trying to send data:” + str(ex)
    # do whatever other cleanup is necessary here
```

Good Design When Using Exceptions

- In general, wrap any operations that commonly fail: opening files, socket calls, etc.
- If there's no way you could ever possibly recover--and the only suitable response is to exit--then you could just let the default exception handler be used
- If you've got a function that might raise lots of exceptions, may be better to wrap the *call* to the function, rather than having lots of handlers *inside* the function
- Don't catch too much: you don't *want* to catch exceptions that flag programmer errors