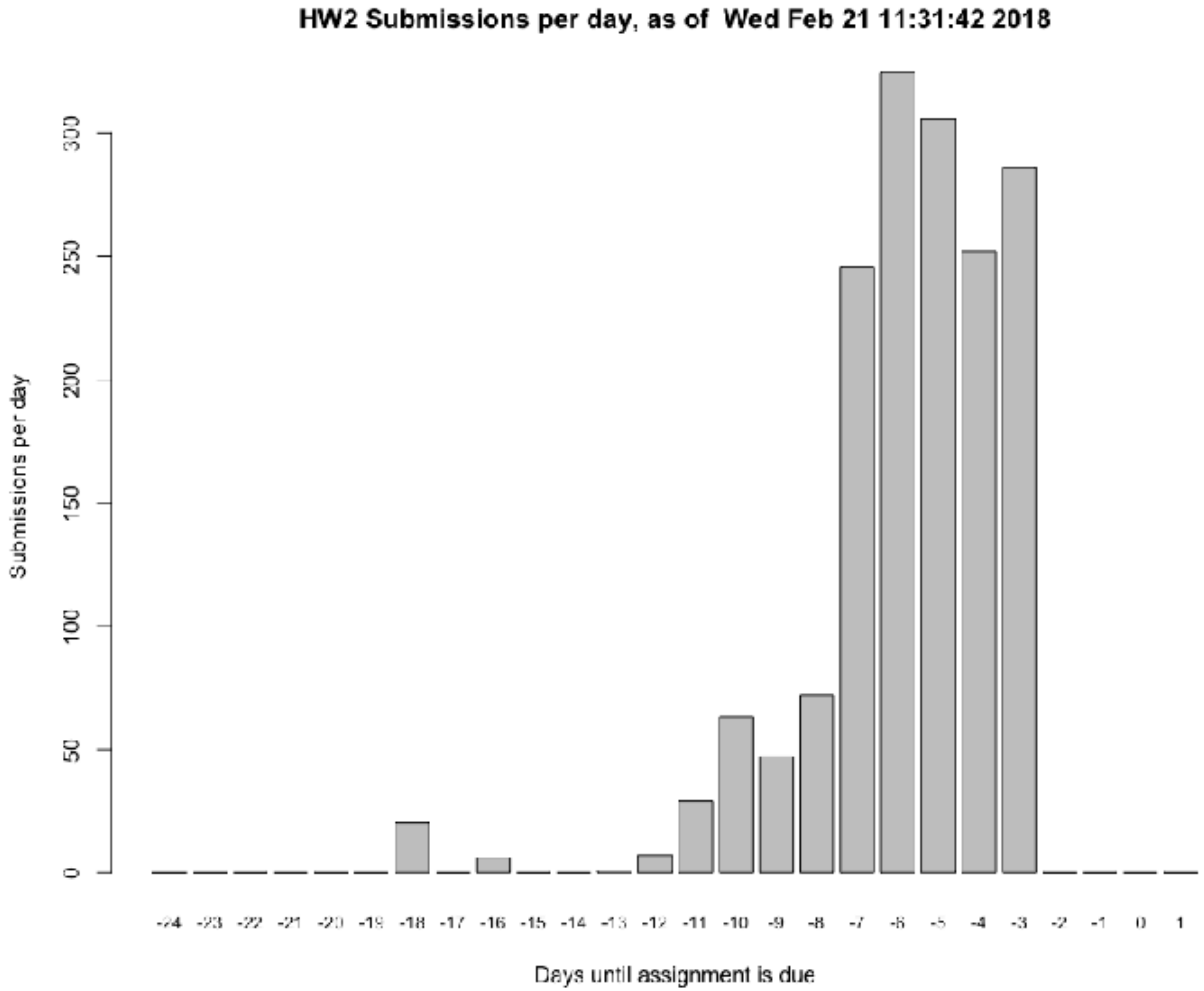
Web Services & Asynchronous Programming

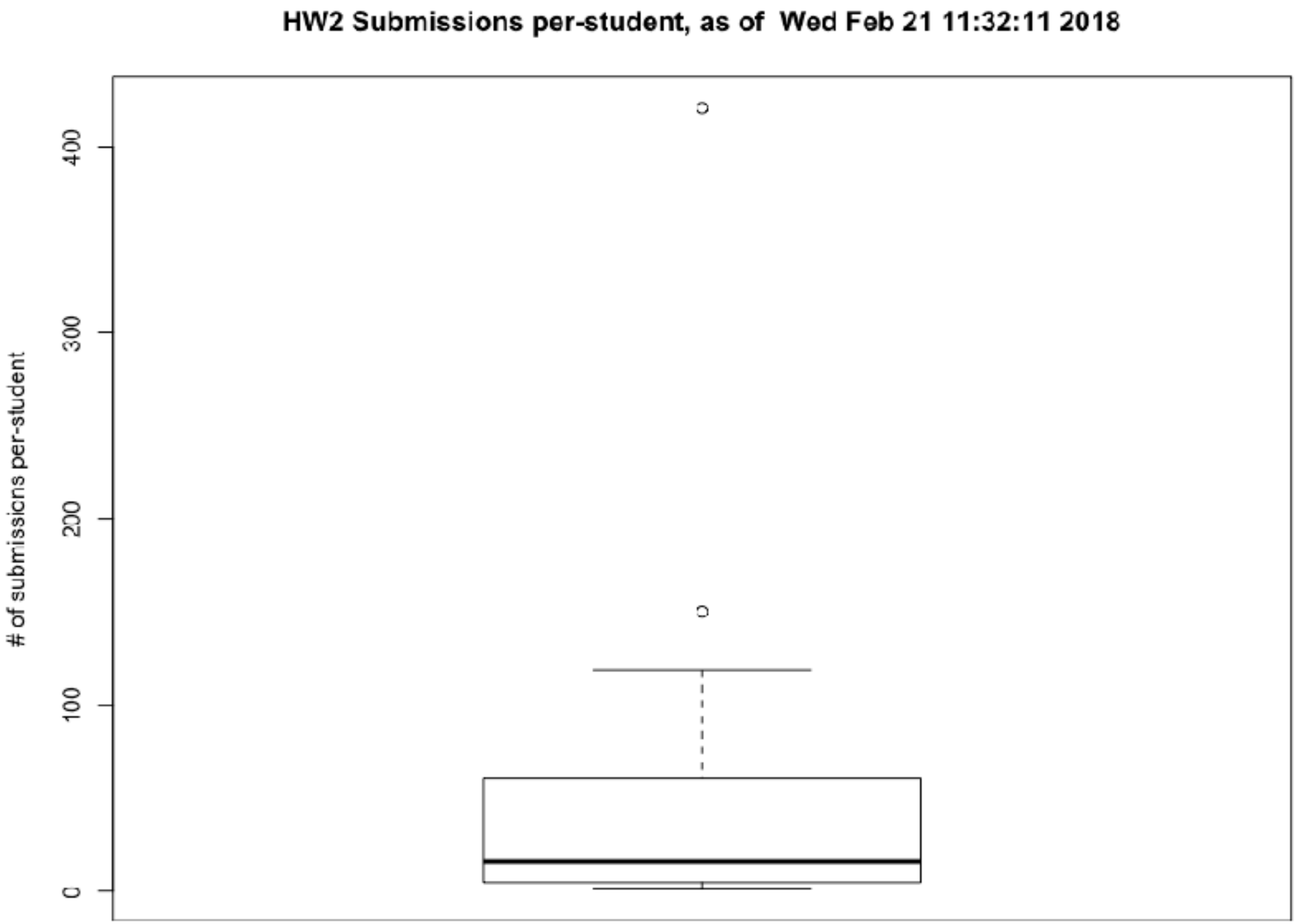
CS 475, Spring 2018
Concurrent & Distributed Systems

GEORGE MASON UNIVERSITY

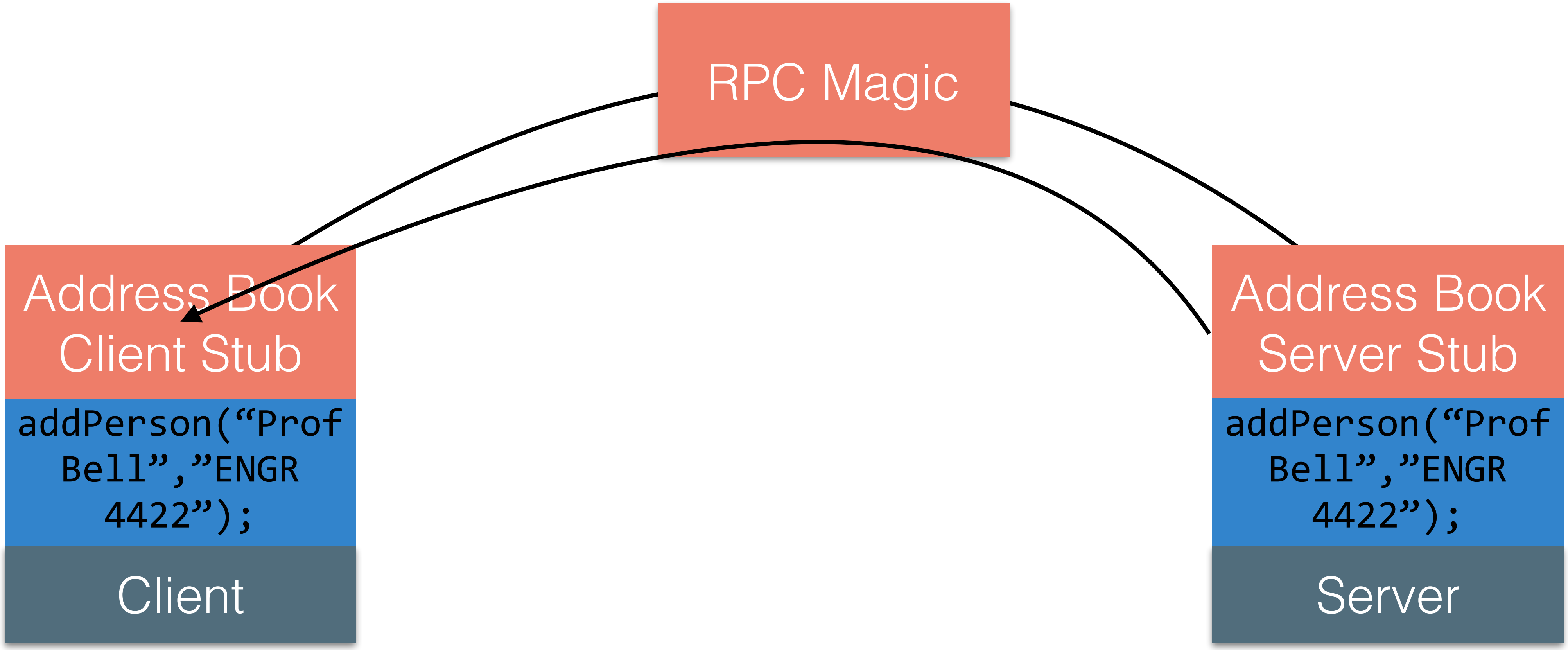
HW2 Discussion



HW2 Discussion



Review: Remote Procedure Calls


RPC Magic
Address Book Client Stub
addPerson(“Prof Bell”,”ENGR 4422”);
Client
Address Book Server Stub
addPerson(“Prof Bell”,”ENGR 4422”);
Server

Review: Shared Fate

- Two methods/threads/processes running on the same computer generally have **shared fate**
- **They will either both crash, or neither will crash**

Review: Split Brain

- When two machines in a distributed system can’t talk to each other, they might start believing different things
- Two sides can not reconcile view of world because they can’t talk to each other
- We call this a **split brain** problem

Review: RPC

- Procedure calls
  - Simple way to pass control and data
  - Elegant transparent way to distribute application
  - Not only way…
- Hard to provide true transparency
  - Failures
  - Performance
  - Memory access
  - Etc.
- How to deal with hard problem: give up and let programmer deal with it

Announcements

- HW3 is out!
  - http://www.jonbell.net/gmu-cs-475-spring-2018/homework-3/
  - Handout will be posted Friday
- Today: Web Services
  - FYI - XML/RPC + SOAP
  - (For real) REST

Announcements

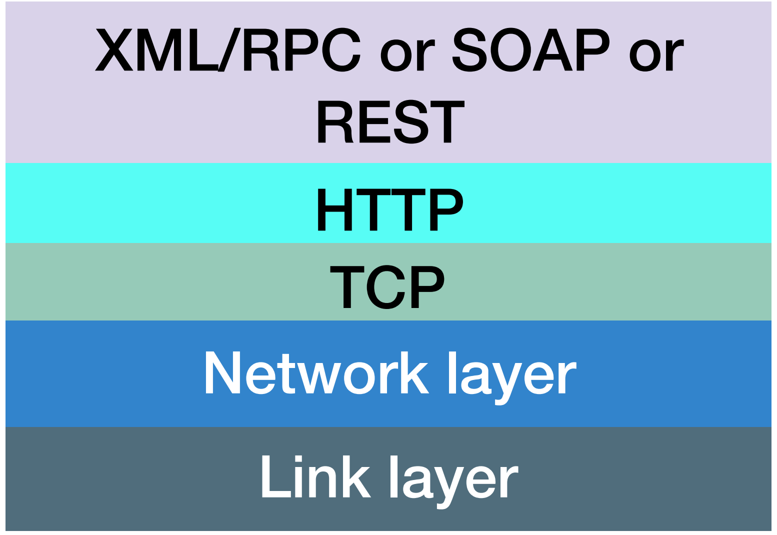
- FYI - What are you doing next year?
    - Not graduating yet: You’ve almost reached the end of the line for classes - Research?
    - Graduating: Consider the opportunity to graduate again?
        - Great new-ish program at GMU:
            - Do you have a GPA of 3.30?
            - You are pretty much guaranteed to be admitted to MS-CS!

RPC on the Web

- How do we do RPC on the web?
- Challenges for scaling up (more clients) and out (heterogeneous clients)
  - Need to get beyond RMI (it's Java only)
  - How do we find API endpoints?
  - How do we format requests?
  - How do we encode data?

Web Services

- At a high level: any application that invokes computation via the Web
- Several standards:
  - XML/RPC
  - SOAP
  - REST
- All are implemented over HTTP as a communication protocol



XML (Extensible Markup Language)

- For a long time, the standard solution for describing information exchange in heterogeneous systems
- XML documents have elements, and elements are demarcated with tags

```
<AccountList>
<Account> 729-1269-4785 </Account>
<Account type="checking"> 729-1269-4785 </ Account>
</AccountList>
```

- **Markup language** like HTML but not simply for displaying pages
  - Can be read by programs and interpreted in an application-specific way

JSON (JavaScript Object Notation)

- XML is a markup language, with a schema
- JSON is instead a **data interchange format**
- Only specifies how to represent objects as strings

```
{
    "accounts": [{
                 "id": "729-1269-4785"
                 }, {
                 "id": "729-1269-4785",
                 "type": "checking"
                 }]
}
```

- Less verbose than XML
  - Less bytes to send the same data
  - Usually faster to parse

XML/RPC

- A specification for generic RPC, using XML as an interchange format

```
<?xml version="1.0"?> <methodCall>
    <methodName>SumAndDifference</methodName> <params>
        <param><value><i4>40</i4></value></param>
        <param><value><i4>10</i4></value></param> </params>
</methodCall>
```

- Recall - XML is a markup language — tags and parameters
- Protocols (like in this case, XML/RPC) define what tags mean (e.g. methodCall)

XML/RPC

- Very simple specification
  - http://xmlrpc.scripting.com/spec.html (it's ~ 2 pages)
- Does not have a standard way to specify interfaces or generate stubs
  - Compare to: RMI @Remote interfaces
- No standard for extending protocol, adding authentication, sessions, etc

SOAP

- Written in XML
- Extension to XML-RPC
- Defines mechanism to pass commands and parameters for RPC (like XML-RPC)
- Also defines standard for describing the services and interfaces (WSDL, or Web Service Definition Language)
- WSDL can be used to automatically generate stubs for client/server

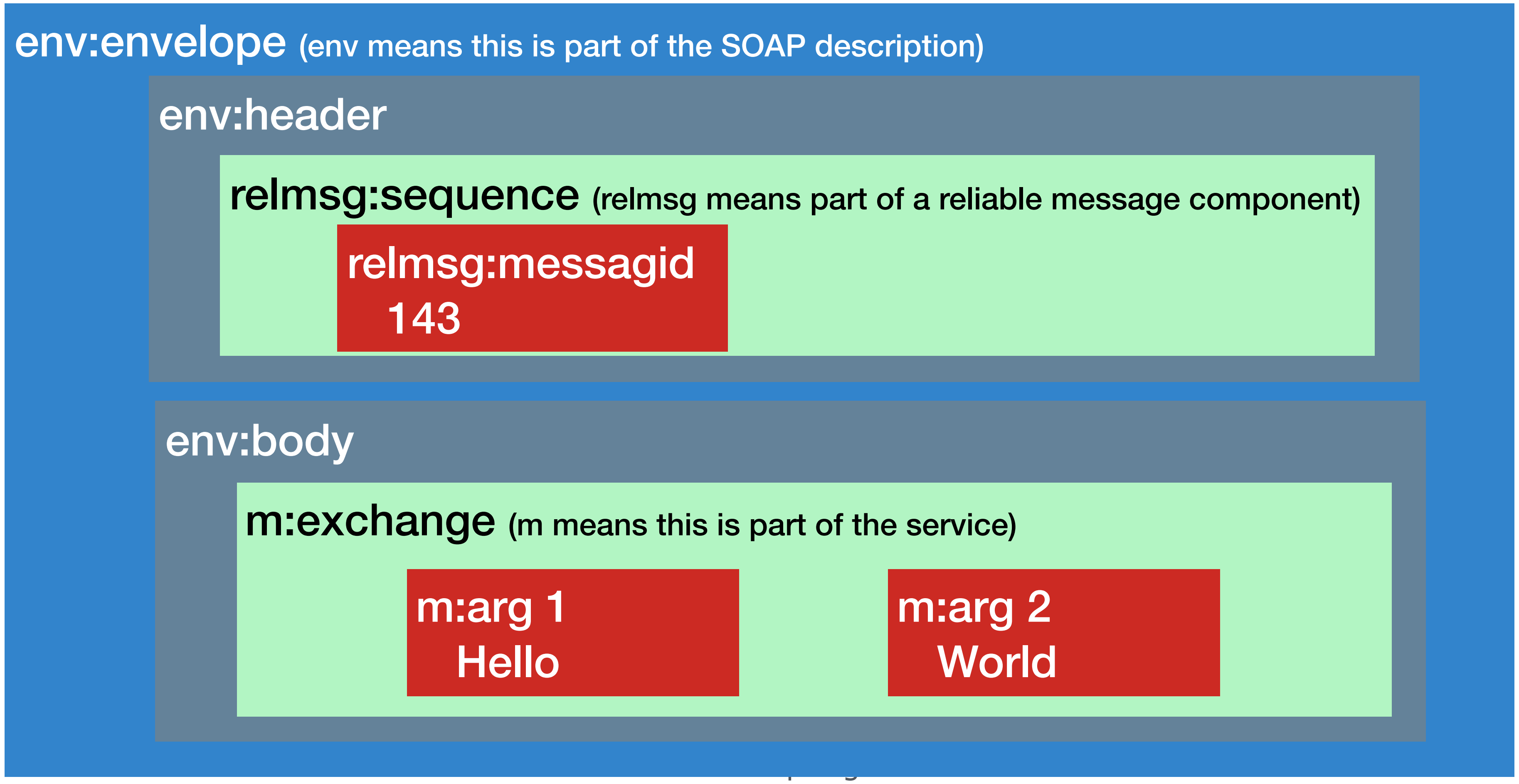
WSDL

- Written in XML
- Defines a web services:
  - Operations offered by the service (what)
  - Mechanisms to access the service (how)
  - Location of the service (where)

```
<definitions name="MyService">
    <types>data types used</types>
    <message>parameters used</message>
    <portType>set of operations performed</portType>
    <binding>communication protocols and data formats used</binding>
    <service>set of ports to service provider endpoints</service>
</definitions>
```

SOAP

- SOAP protocol defines how RPC are sent over a network
    - WSDL defines how a given service uses SOAP
- SOAP packs messages into an envelope with a header and body
- Envelope abstraction allows SOAP extensions to do more stuff (authentication, etc)



env:envelope (env means this is part of the SOAP description)

env:header

relmsg:sequence (relmsg means part of a reliable message component)

relmsg:messagid 143

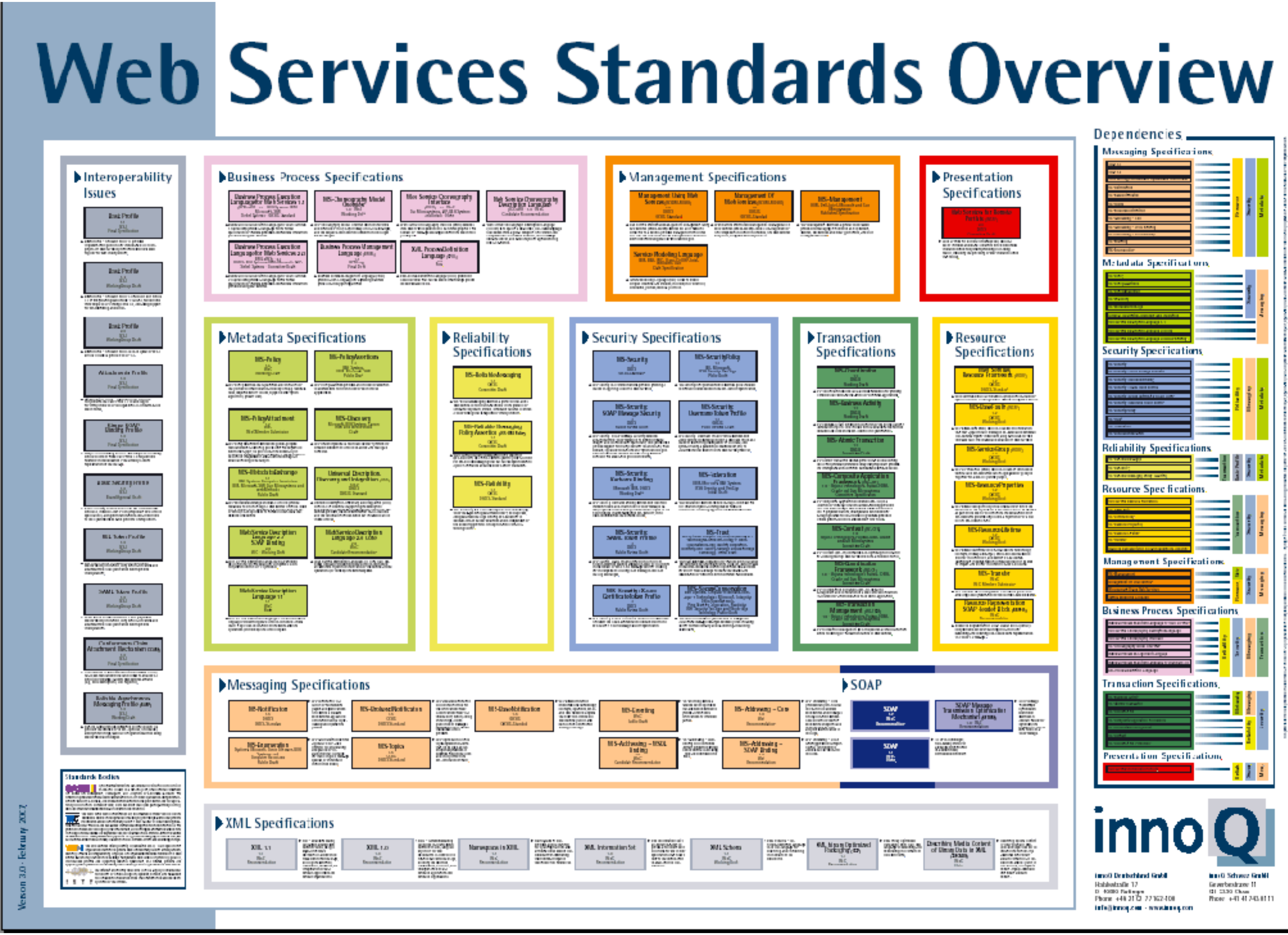
env:body

m:exchange (m means this is part of the service)

m:arg 1 Hello

m:arg 2 World

Web Services Standards Overview



Interoperability Issues

Business Process Specifications

Management Specifications

Presentation Specifications

Metadata Specifications

Reliability Specifications

Security Specifications

Transaction Specifications

Resource Specifications

Messaging Specifications

SOAP

XML Specifications

Standards Bodies

Dependencies

Messaging Specifications

Metadata Specifications

Security Specifications

Reliability Specifications

Resource Specifications

Management Specifications

Business Process Specifications

Transaction Specifications

Presentation Specifications

SOAP

- SOAP has LOTS of extensions (60+)
  - Reliable messaging
  - Security
  - Addressing
  - Transactions
- SOAP supports a lot of complexity **in the protocol itself**
- Problem: just to get a minimal, small example working, you need to do a lot of boilerplate

REST: REpresentational State Transfer

- Defined by Roy Fielding in his 2000 Ph.D. dissertation
- “Throughout the HTTP standardization process, I was called on to defend the design choices of the Web. That is an extremely difficult thing to do... I had comments from well over 500 developers, many of whom were distinguished engineers with decades of experience. That process honed my model down to a core set of principles, properties, and constraints that are now called REST.”
- Interfaces that follow REST principles are called RESTful

Properties of REST

- Performance
- Scalability
- Simplicity of a Uniform Interface
- Modifiability of components (even at runtime)
- Visibility of communication between components by service agents
- Portability of components by moving program code with data
- Reliability

Principles of REST

- Client server: separation of concerns (reuse)
- Stateless: each client request contains all information necessary to service request (scaling)
- Cacheable: clients and intermediaries may cache responses. (scaling)
- Layered system: client cannot determine if it is connected to end server or intermediary along the way. (scaling)
- Uniform interface for resources: a single uniform interface (URIs) simplifies and decouples architecture (change & reuse)

Uniform Interface for Resources

- Originally files on a web server
  - URL refers to directory path and file of a resource
- But… URIs might be used as an identity for any entity
  - A person, location, place, item, tweet, email, detail view, like
  - *Does not matter* if resource is a file, an entry in a database, retrieved from another server, or computed by the server on demand
  - Resources offer an *interface* to the server describing the resources with which clients can interact

URI: Universal Resource Identifier

- Uniquely describes a resource
  - https://mail.google.com/mail/u/0/#inbox/157d5fb795159ac0
  - https://www.amazon.com/gp/yourstore/home/ref=nav_cs_ys
  - http://gotocon.com/dl/goto-amsterdam-2014/slides/StefanTilkov_RESTIDontThinkItMeansWhatYouThinkItDoes.pdf
  - Which is a file, external web service request, or stored in a database?
    - It does not matter
- As client, only matters what actions we can *do* with resource, not how resource is represented on server

HTTP Actions

- Idea: define operations by using existing HTTP action verbs
- Describes what will be done with resource
  - GET: retrieve the current state of the resource
  - PUT: modify the state of a resource
  - DELETE: clear a resource
  - POST: initialize the state of a new resource

URI Design

- In theory, URI could last forever, being reused as server is rearchitected, new features are added, or even whole technology stack is replaced.
- “What makes a cool URI?
  A cool URI is one which does not change.
  What sorts of URIs change?
  URIs don't change: people change them.”
  - https://www.w3.org/Provider/Style/URI.html
  - Bad:
    - https://www.w3.org/Content/id/50/URI.html (What does this path mean? What if we wanted to change it to mean something else?)
- Why might URIs change?
  - We reorganized our website to make it better.
  - We used to use a cgi script and now we use node.JS.

URI Design

- URIs represent a contract about what resources your server exposes and what can be done with them
- Leave out **anything that might change**
  - Content author names, status of content, other keys that might change
  - File name extensions: response describes content type through MIME header not extension (e.g., .jpg, .mp3, .pdf)
  - Server technology: should not reference technology (e.g., .cfm, .jsp)
- Endeavor to make all changes backwards compatible
  - Add new resources and actions rather than remove old
- If you must change URI structure, support old URI structure **and** new URI structure

Example URI Design

- The candy web service!
- Tracks information about candy
- http://api.jonbell.net/candy/twix
  - GET this URI to find out about twix bar
  - POST to the URI to set up a new twix bar
  - DELETE this URI to eat a twix

Describing Responses

- What happens if something goes wrong while handling HTTP request?
  - How does client know what happened and what to try next?
- HTTP offers response status codes describing the nature of the response
  - 1xx Informational: Request received, continuing
  - 2xx Success: Request received, understood, accepted, processed
    - 200: OK
  - 3xx Redirection: Client must take additional action to complete request
    - 301: Moved Permanently
    - 307: Temporary Redirect

https://en.wikipedia.org/wiki/List_of_HTTP_status_codes

Describing Errors

- 4xx Client Error: client did not make a valid request to server. Examples:
  - 400 Bad request (e.g., malformed syntax)
  - 403 Forbidden: client lacks necessary permissions
  - 404 Not found
  - 405 Method Not Allowed: specified HTTP action not allowed for resource
  - 408 Request Timeout: server timed out waiting for a request
  - 410 Gone: Resource has been intentionally removed and will not return
  - 429 Too Many Requests

Describing Errors

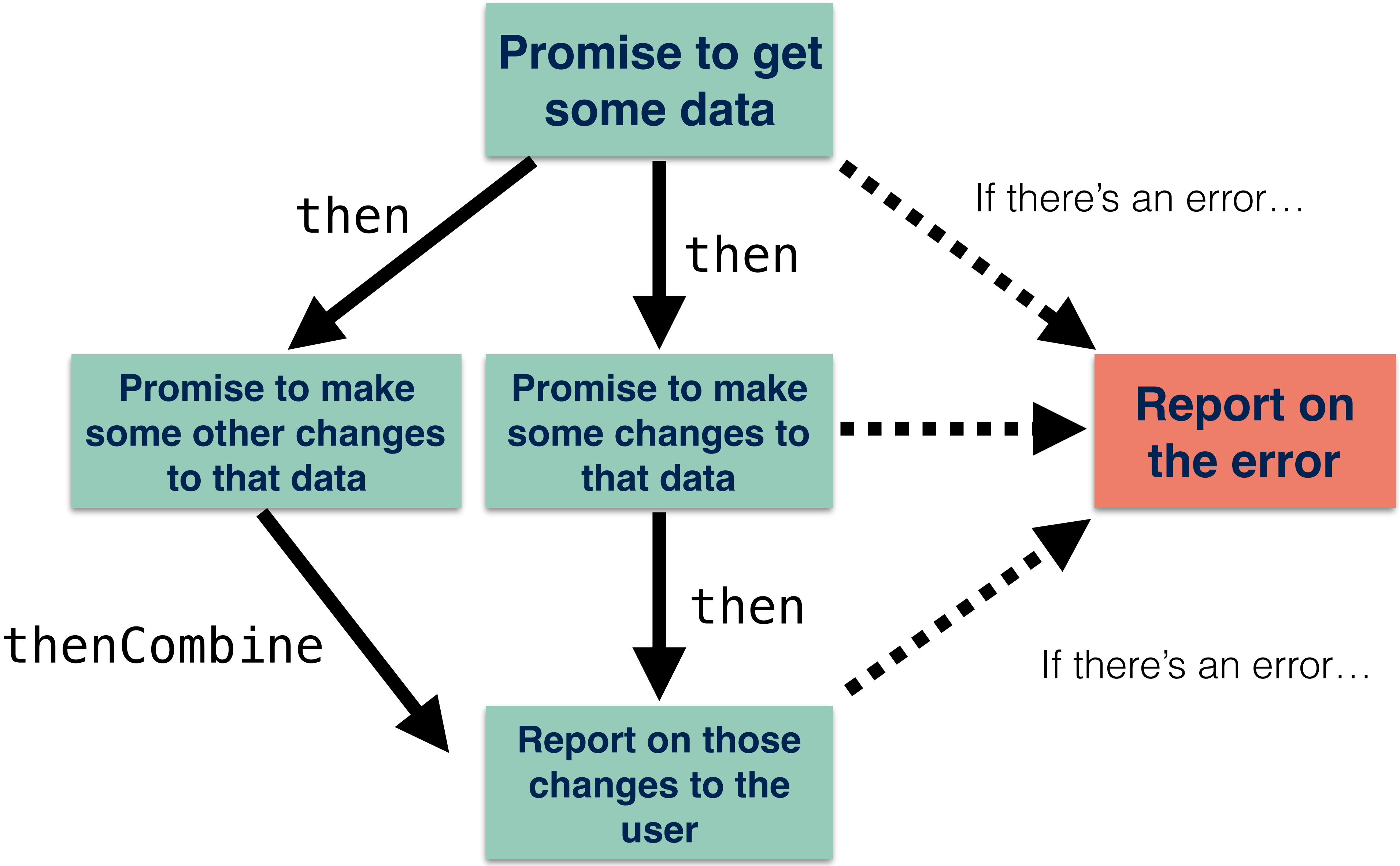
- 5xx Server Error: The server failed to fulfill an apparently valid request.
  - 500 Internal Server Error: generic error message
  - 501 Not Implemented
  - 503 Service Unavailable: server is currently unavailable

Async programming

- Interacting with web services begs for asynchronous programming
- Example:
  - Get a list from GitHub's API of the top 10,000 Java projects
  - As that list starts coming in, start requesting information on each commit of each of those projects
  - As that information starts coming in, request more information on each commit

Async Programming

- We probably **really** want to do this concurrently, but implementing it is tricky
- This is what promises are made for!!!



Promise to get some data

then

then

If there's an error…

Promise to make some other changes to that data

Promise to make some changes to that data

Report on the error

thenCombine

then

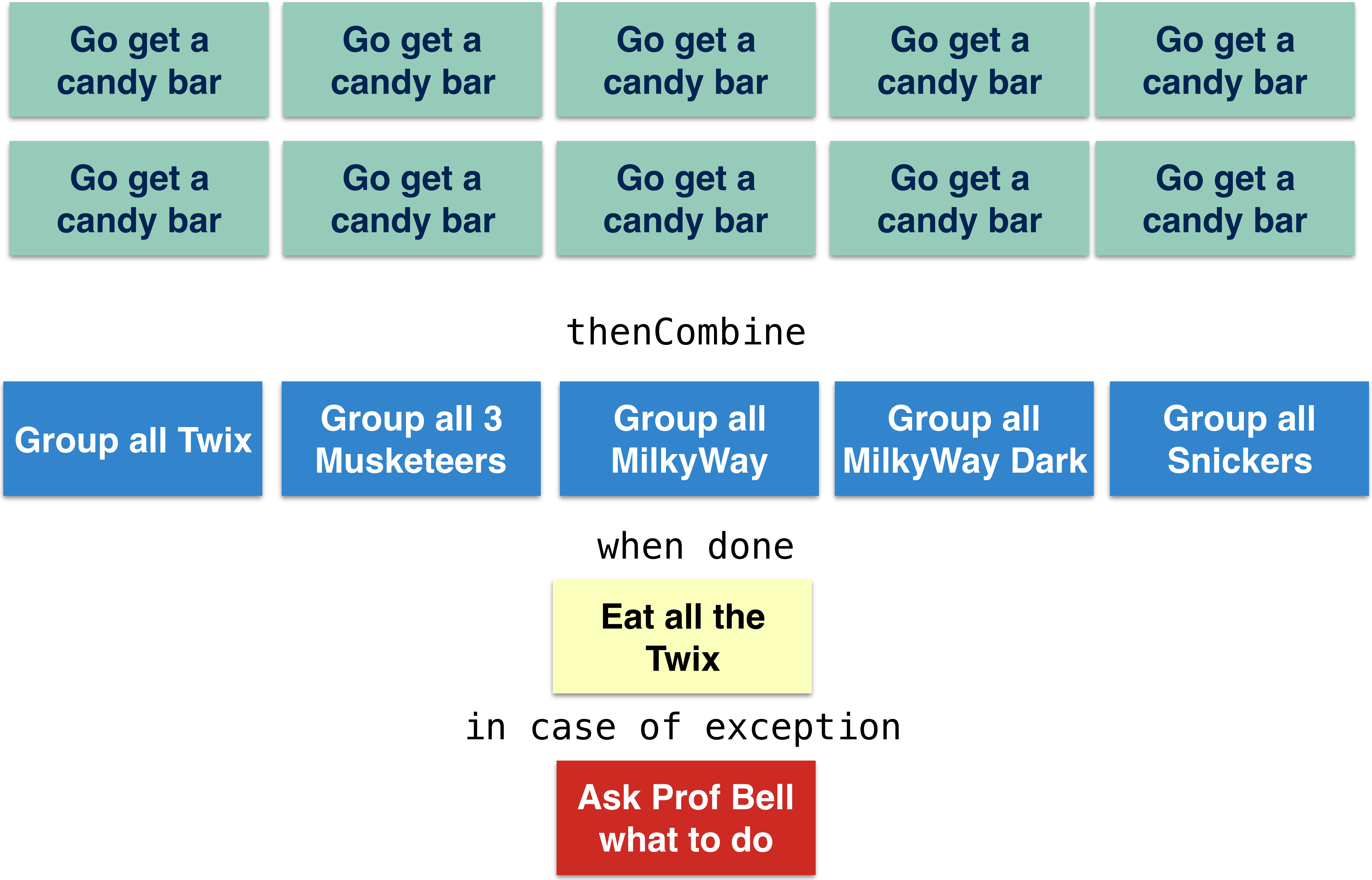
If there's an error…

Report on those changes to the user

Async Programming Activity

- Case study (not GitHub): the Candy API

Async Programming Activity



Go get a candy bar | Go get a candy bar | Go get a candy bar | Go get a candy bar | Go get a candy bar

Go get a candy bar | Go get a candy bar | Go get a candy bar | Go get a candy bar | Go get a candy bar

`thenCombine`

Group all Twix | Group all 3 Musketeers | Group all MilkyWay | Group all MilkyWay Dark | Group all Snickers

`when done`

Eat all the Twix

`in case of exception`

Ask Prof Bell what to do