Designing OO and Web APIs

CSCI 4448/5448: Object-Oriented Analysis & Design

Lecture 39

Acknowledgement & Materials Copyright

- I'd like to start by acknowledging Dr. Ken Anderson
- Ken is a Professor and the Chair of the Department of Computer Science
- Ken taught OOAD on several occasions, and has graciously allowed me to use his copyrighted material for this instance of the class
- Although I will modify the materials to update and personalize this class, the original materials this class is based on are all copyrighted © Kenneth M. Anderson; the materials are used with his consent; and this use in no way challenges his copyright

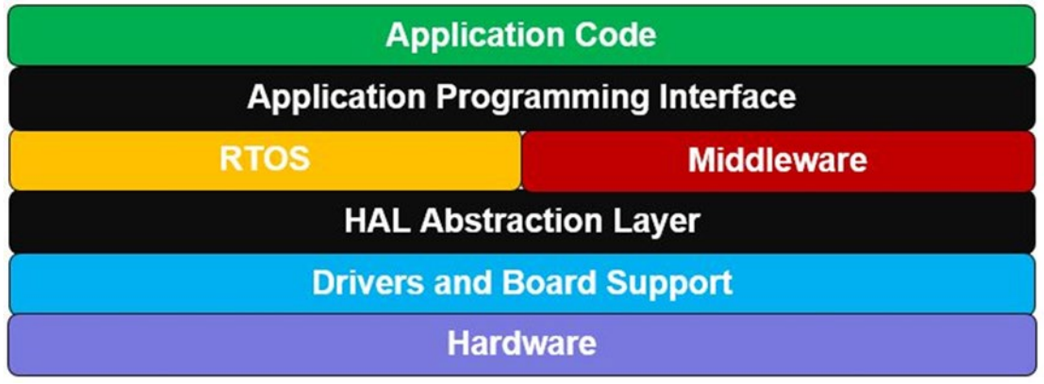
- Some bits taken from my EID API lecture
- Some from Joshua Bloch's lecture on API design
  - http://fwdinnovations.net/whitepaper/APIDesign.pdf
  - Also see Bloch's Effective Java book
- Martin Fowler – he's back

Why APIs?

- Consider making a device that hangs on the wall…
- In practice, a device may be created without any user interface, OR
- Not all functions provided by the device may be available in its user interface – so to…
  - Configure the device
  - Diagnose issues
  - Provide inputs
  - Gather logs or output data
  - Use extended functions
  - Connect to other systems

- …it may be necessary to connect to the device via a program or Web-based API – Application Programming Interface – defined for that purpose
- The same holds true for any software elements you are providing an interface to for others to use – you expose an API for connecting
- Recall that even the properties and methods exposed by a class for use form an interface (an API of sorts)

What is an API



- An API (Application Programming Interface) is a set of selected functionality defining interactions between a subsystem or a service and their clients
  - It provides an abstraction layer (much like the Façade pattern) to provide only the subsystem or service functionality needed by clients
  - And it provides encapsulation of the details of elements of the subsystem that a client doesn't need to know
- In a firmware system, APIs may be thought of as analogous to Hardware Abstraction Layers (HALs), which
  - Protect higher level elements of the system from having to know details of underlying hardware implementations and
  - Allow that underlying hardware to be changed without severely impacting the implementations above

Code to an Interface (not an Implementation)

- Again, remember we are not talking specifically about a certain kind of interface here – like a Java Interface
  - We would like the clients of our interfaces to focus on the functionality we expose in the interface
  - We would like code that implements a REST API or a Java Interface (or a set of abstract class methods) to consider just the specific transactions that need to be modeled and provided
  - The interface defines the interaction
- And we'd like to maintain the Interface Segregation Principle
  - Small, cohesive interfaces
  - Reduce the impact and frequency of changes

Types of APIs

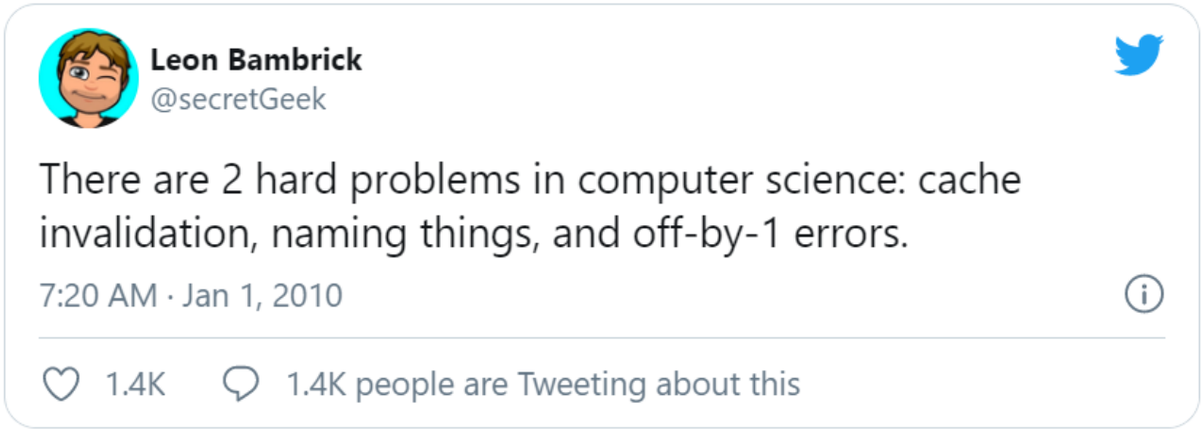
- Certainly, the set of methods provided by a Java class, for instance, can be considered an API
  - What methods are made available
  - What attributes are needed to pass data, etc.
- APIs can also be independently defined using standard Web-based API approaches such as
  - RPC – Remote Procedure Calls
  - REST – REpresentational State Transfer (used in a “RESTful” API)
  - or other RESTless custom command syntax
- In Web-based APIs, both clients and servers would have to reference the defined API to pass data between each other

Importance of API Design

- APIs can be though of as a company's asset
  - Customers invest when they use them
  - Once an API is made public, it likely will stay public, important to get it right
  - Bad APIs cause support issues, customer loss
- All programmers are API designers
  - Modular code communicates through interfaces
  - Once a module is in use, it becomes harder to change the API
  - Thinking in terms of interfaces improves code quality

- From How to Design a Good API and Why it Matters - Bloch

- Good APIs
  - Clear naming
  - Easy to learn and use, even without documentation
  - Hard to misuse
  - Using the API makes code easier to read and maintain
  - Can be extended
  - Developed with the audience in mind
- Most API designs are over-constrained
  - You can't allow for all users/usage



General OO API Principles

- The API should do ONE THING well
  - Easy to recognize by name
    - Standard and self-explanatory names
    - Should make code readable
  - Easy to explain the functionality
- May need to split/merge to get the right fit of functional cohesion
- APIs should be as small as possible
  - Focus on key requirements
  - You can add later, but it’s hard to remove once published
- Keep implementation details out of the API
- Minimize accessibility
  - Maximize information hiding
- APIs must be documented
  - Classes: what is an instance representing?
  - Methods: the contract
    - Pre- or post-conditions
    - Side effects
  - Parameters: units, formats
- Use API-friendly elements
  - Generics, varargs, enums, defaults

- From How to Design a Good API and Why it Matters - Bloch

Fluent Interfaces

Consider…

```
private void makeNormal(Customer customer) {
        Order o1 = new Order();
        customer.addOrder(o1);
        OrderLine line1 = new OrderLine(6, Product.find("TAL"));
        o1.addLine(line1);
        OrderLine line2 = new OrderLine(5, Product.find("HPK"));
        o1.addLine(line2);
        OrderLine line3 = new OrderLine(3, Product.find("LGV"));
        o1.addLine(line3);
        line2.setSkippable(true);
        o1.setRush(true);
    }
```

Simple to write the constructors, setters, and addition methods, but…

Fluent Interfaces continued

A fluent version of the same code:

```
private void makeFluent(Customer customer) {
        customer.newOrder()
                .with(6, "TAL")
                .with(5, "HPK").skippable()
                .with(3, "LGV")
                .priorityRush();
    }
```

Fowler describes this as almost an internal Domain Specific Language, but certainly it makes for an API that's readable and flows, but it takes more work to design and implement

https://martinfowler.com/bliki/FluentInterface.html

Minimal vs. Humane Interfaces

- Minimal Interface: an API that allows the client to do everything they need to do, but keeps the capabilities at the smallest reasonable set of methods that will do the job
- Humane Interface: Find out what people want to do and design the interface to make it easy to do the common case
- Getting the last item from a list:
- In Java

  `aList.get(aList.size-1)`
- In Ruby

  `anArray.last`

  (Ruby also has a `.first`)

  https://martinfowler.com/bliki/HumaneInterface.html

Java – Service Provider Interfaces

- SPI (Service Provider Interfaces) - A method of formatting classes as services for clients or consumers
  - Creates an easy plug-in interface for multiple implementations
  - Structures a jar file with the SPI elements
- To access an SPI service, you drop the SPI jar file on the classpath for your application
- https://docs.oracle.com/javase/tutorial/sound/SPI-intro.html

- Four elements to a Java SPI
  - Service
    - Interfaces and classes for accessing functionality
  - SPI
    - Interface or abstract class to reach the service
  - Service Provider
    - A concrete implementation of the SPI
  - ServiceLoader
    - Provides lazy loading of implementations as needed, using an internal cache
- Standard Java SPIs
  - TimeZoneNameProvider
  - JsonProvider
- https://www.baeldung.com/java-spi

Web-based APIs

- RPC
- RESTful
- RESTless/Custom

RPC-based APIs

- Web-based RPC is generally characterized as a single URI (Uniform Resource Identifier) on which many operations may be called, usually solely via an HTTP POST (a REST command)
- Examples include
  - XML-RPC (http://xmlrpc.com/) →
  - SOAP (Simple Object Access Protocol) (https://www.w3.org/TR/soap/)
- You pass a structured request that includes the operation name to invoke and any arguments you wish to pass to the operation; the response will be in a structured format

```
POST /xml-rpc HTTP/1.1
Content-Type: text/xml

<?xml version="1.0" encoding="utf-8"?>
<methodCall>
   <methodName>status.create</methodName>
   <params>
      <param>
         <value><string>First post!</string></value>
      </param>
      <param>
         <value><string>mwop</string></value>
      </param>
      <param>
         <value> <dateTime.iso8601> 20140328T15:22:21
                  </dateTime.iso8601>
         </value>
      </param>
   </params>
</methodCall>
```

Considerations of RPC-based APIs

- Advantages
  - One service endpoint, many operations
  - One service endpoint, one HTTP method (usually POST)
  - Structured, predictable request format, structured, predictable response format
  - Structured, predictable error reporting format
  - Structured documentation of available operations
- Disadvantages
  - You cannot determine via the URI how many resources are available
  - Lack of HTTP caching, inability to use native HTTP verbs for common operations; lack of HTTP response codes for error reporting requires introspection of results to determine if an error occurred
  - "One size fits all" format can be limiting; clients that consume alternate serialization formats cannot be used, and message formats often impose unnecessary restrictions on the types of data that can be submitted or returned

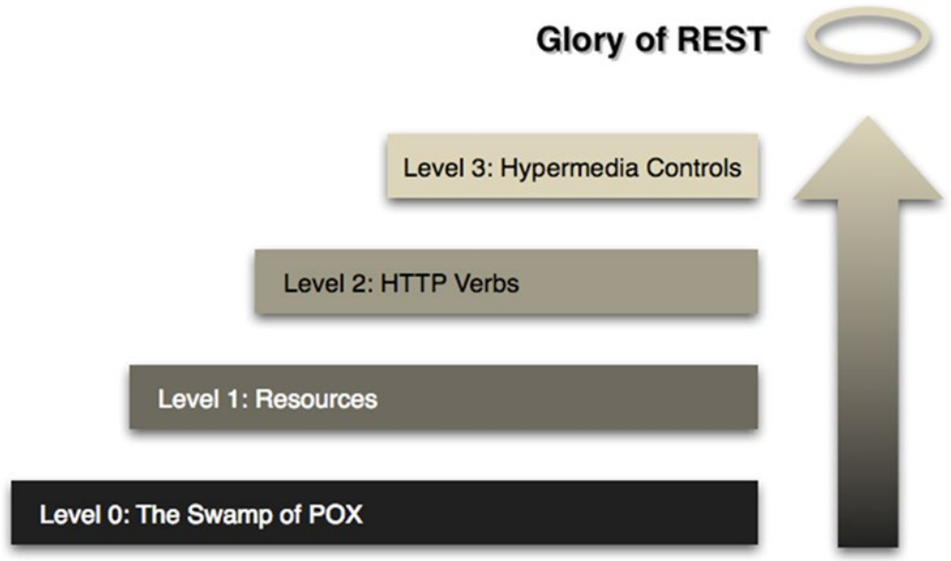
- https://apigility.org/documentation/api-primer/what-is-an-api

RESTful/REST-based APIs

- Most common Web-based API approach in modern systems
- REST leverages HTTP's strengths, and builds on URIs as unique identifiers for resources
- Rich set of HTTP verbs for operations on resources (PUT, GET, POST, DELETE, PATCH, OPTIONS, HEAD, others)
- Clients can specify representation formats they can render, and request those from the server (if the server can provide)
- Linking between resources to indicate relationships (e.g., hypermedia links, such as those found in plain old HTML documents)
- REST API implementations can vary in complexity and completeness

- https://apigility.org/documentation/api-primer/what-is-an-api

- 4 Levels of the Richardson Maturity Model (yes, another Fowler article)
  - https://martinfowler.com/articles/richardsonMaturityModel.html



- POX = Plain Old XML transfers
- Hypermedia controls – more dynamic command structures for enhanced resource provision

A good RESTful API

- A good REST API
  - Uses unique URIs for services and the items exposed by those services
  - Uses the full spectrum of HTTP verbs to perform operations on those resources, and the full spectrum of HTTP to allow varying representations of content, enabling HTTP-level caching, etc.
- Provides relational links for resources, to tell the consumer what can be done next

- Design questions for REST APIs
  - REST does not dictate any specific formats
  - What representation formats will you provide, how will you report failed requests?
  - REST does not dictate any specific error reporting format (suggests using standard HTTP Codes)
  - Which HTTP methods will be available for a given resource; how do you respond to a failed request?
  - Authentication – web APIs are generally stateless, and should not rely on features like session cookies
  - Credentials – HTTP authentication, or OAuth2, or create API tokens?

RESTful API Design Best Practices

- Documentation (->SDK)
  - API, Endpoints, Functions (often automatically generated) – technical reference
  - Usage examples and tutorials – first steps for new users, how-tos, examples of typical operations
  - Validate the documentation with outside users
- Stability and Consistency
  - Include a version number in the API from the beginning
  - Ok to maintain version for additions, but not for changes
  - Internal consistency – all functions should work the same way
  - Publicize changes, changelogs, and document difference in versions
- Flexibility
  - Allowing for easily identifying supported output formats: JSON, YAML, XML
  - Ex: /api/v1/widgets.json
  - Allowing for multiple standard input formats
- Security
  - Use standard approaches
  - Token-based authentication (SHA-1 token)
  - SSL & OAuth2
  - Identify whitelisted (allowed) and blacklisted (security required) functions
  - Verify/validate access to key resources
  - Validate all input
- Ease of Adoption
  - Have others try to program/connect to the API to verify ease of use and operations
  - Use standard approaches, JSON, SOAP, REST, etc.
  - Provide language specific examples and/or libraries
  - Tools for generating libraries from APIs
    - Alpaca: Node.js, Python, Ruby, PHP
    - Apache Thrift: Node.js, Python, C++, Java, C#, many others
  - Provide for simple sign up, support and bug reporting

- https://www.toptal.com/api-developers/5-golden-rules-for-designing-a-great-web-api

Tools for RESTful API Design

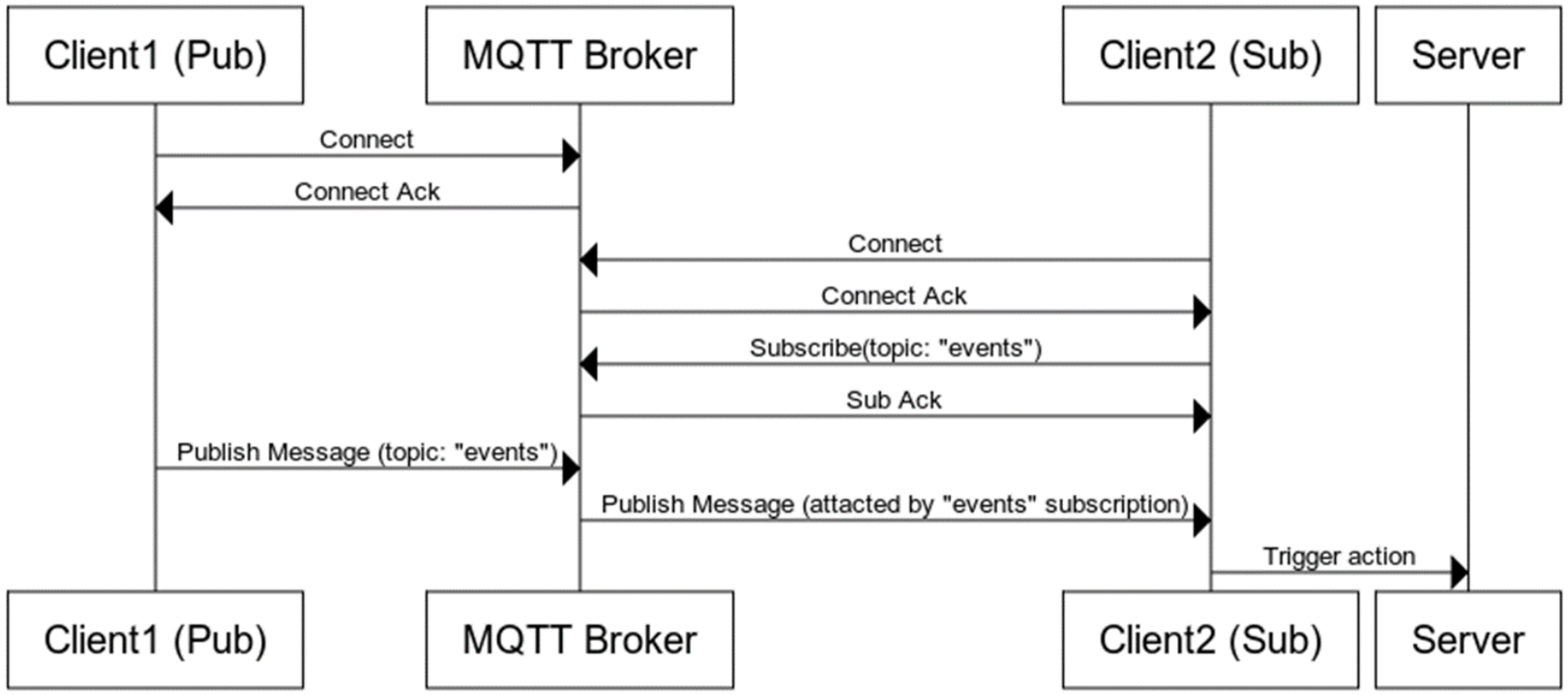
Nice basic RESTful API example for Python: https://realpython.com/api-integration-in-python/

- Swagger (https://swagger.io/)
  - Open source and commercial
  - OpenAPI 3.0 specification
- Open source elements include Swagger Editor, Codegen, and UI for documentation
- Easy to create the definition of the API and then generate
  - Server stubs
  - Client SDKs
  - Documentation
- Try here:
  - https://editor.swagger.io/

- RAML (https://raml.org/)
  - Open source
  - Design, build, test, document, and share APIs
- AWS API Gateway
  - https://aws.amazon.com/api-gateway/
  - Typical of API tools from Cloud services

Example of a Custom API - MQTT

- Commands: Connect, Publish, Subscribe, Unsubscribe, Disconnect
- Topics – Specially formatted labels for grouping of application messages, matched against subscriptions to forward the messages
- Publish messages under specific topics
- Subscribe/Unsubscribe to/from Topic filters
- Built on top of TCP/IP but not RESTful



Summary

- APIs and Interfaces, broadly considered
- Best practices for interface designs
- APIs for OO language classes/methods/attributes
  - Fluent, minimal, humane interfaces
  - Java SPIs
- Web-based APIs
  - RPC
  - REST
  - Custom

Next Steps

- New discussion topic is up (looking for your feedback on the class), please post your responses to topics for Participation grading!
- Due Monday 7/19
  - Graduate Pecha Kucha – presented in class by teams on 7/20 and 7/21 – sign up sheet at
    - https://docs.google.com/document/d/193mP7K5zSR6FiYGgS0QOAYOJgsesI1HXZL1Aas3WijI/edit?usp=sharing
- Bonus points for attendance during Pecha Kucha sessions on 7/20, 7/21
- Due Wednesday 7/21
  - Project 7 with recorded demo
  - Graduate Final Research Presentation – turned in for reading/review, not presented (in person or by recording)
  - Quiz 6
- Final Exam – optional, available on Friday 7/23 to Saturday 7/24
- Upcoming lectures/activities:
  - Monday 7/19 – APIs, Anti- & Other Patterns
  - Tuesday 7/20 – 2 Pecha Kuchas, Final Review
  - Wednesday 7/21 – 6 Pecha Kuchas
  - Thursday 7/22 – Other than OOAD, Class Wrap-up
- How to find Bruce:
  - Post the question on the class Piazza site (often, if you have a question, others might as well)
  - Find me during office hours on Zoom at https://cuboulder.zoom.us/j/3844137608 on Tuesday 4-5 PM, Wednesday 10-11 AM, Thursday 3-4 PM
  - Make an appointment to see me via Zoom at https://brucem.appointlet.com
  - Email me at bruce.r.montgomery@colorado.edu