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Lecture 9: API Design

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Implementing Features

- Features often implemented a standalone services.
- Services can be accessed through an API.
  - e.g., web APIs generally use REST interfaces.
- Good API design is crucial to creating a feature reusable in many clients.

REST

- REST is a web-based API format.
  - Services provide resources (through URLs) designed to be consumed by programs rather than by people.
  - Design Principles:
    - Stateless
    - Resource-Based (URI)
    - Uniform Interface (GET, PUT, POST, DELETE)
    - Links describe relationships
    - Cacheable and monitorable using standard internet tools

Today's Goals

- Creating REST APIs.
  - Web services with common invocation methods.
- REST API design practices.
- Designing Reusable APIs.
  - Features that can be substituted for other features.

Hypertext Transfer Protocol (HTTP)

HTTP

- Communication protocol for networked systems.
  - Defines how to exchange or transfer hypertext between nodes in a network.
  - How your computer accesses a webpage.
- Defines an API based on requests.
- Requests performed using **verbs**.
  - I **get** a page, **post** an update, **delete** a photo, **put** up information.

Retrieving Information (GET)

- User types into the browser: http://www.amazon.com
- The browser creates an HTTP request (no body)
- The HTTP request identifies:
  - The desired action: GET ("get me resource")
  - The target machine (www.amazon.com)

Updating Information (POST)

- The user fills in a form on a webpage.
- The browser creates an HTTP request with a body containing form data.
- HTTP request identifies:
  - The action: POST ("here is some updated info")
  - The target machine (amazon.com)
- The body contains data being POSTed (form data)

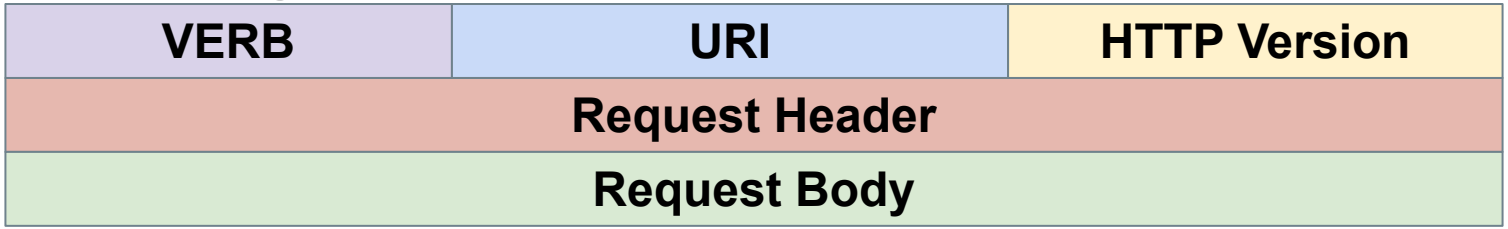
The HTTP API

- HTTP provides a simple set of operations.
- Based on the idea of CRUD (Create, Retrieve, Update, and Delete)
  - **PUT:** “Here is some new info” (Create)
  - **GET:** “Give me some info” (Retrieve)
  - **POST:** “Here is some updated info” (Update)
  - **DELETE:** “Get rid of this info” (Delete)

Additional Verbs

- **HEAD**
  - “Give me the metadata”
- **TRACE**
  - “Show me what changes have been made”
- **OPTIONS**
  - “What verbs have you implemented for this resource?”
- **PATCH**
  - “Apply partial resource modification”

Anatomy of an HTTP Request



- <VERB> is one of the HTTP verbs, <URI> is the resource location
- <Request Header> contains metadata
  - Collection of key-value pairs of headers and their values.
  - Information about the message and its sender like client type, the formats client supports, format type of the message body, cache settings for the response, and more.
- <Request Body> is the actual message content (JSON, XML).

HTTP Request Examples

VERB	URI	HTTP Version
Request Header		
Request Body		

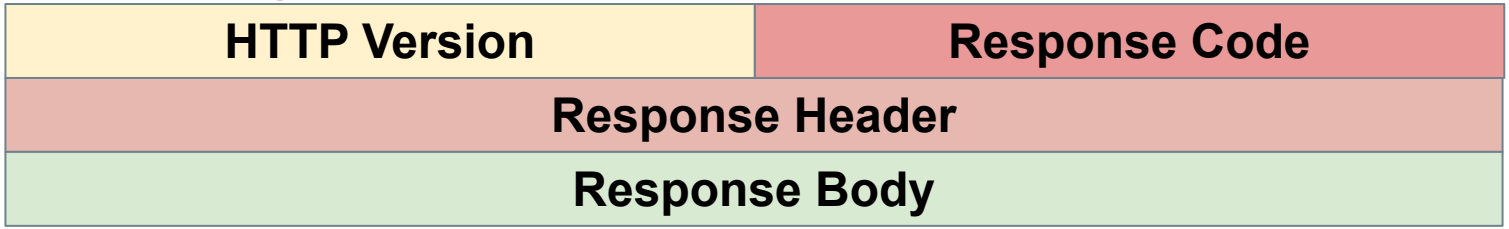
GET:

```
GET http://www.w3.org/Protocols/rfc2616/rfc2616.html HTTP/1.1
Host: www.w3.org, Accept: text/html,application/xhtml+xml,application/xml; …,
User-Agent: Mozilla/5.0 (Windows NT 6.3; WOW64) AppleWebKit/537.36 …,
Accept-Encoding: gzip,deflate,sdch, Accept-Language: en-US,en;q=0.8,hi;q=0.6
```

POST:

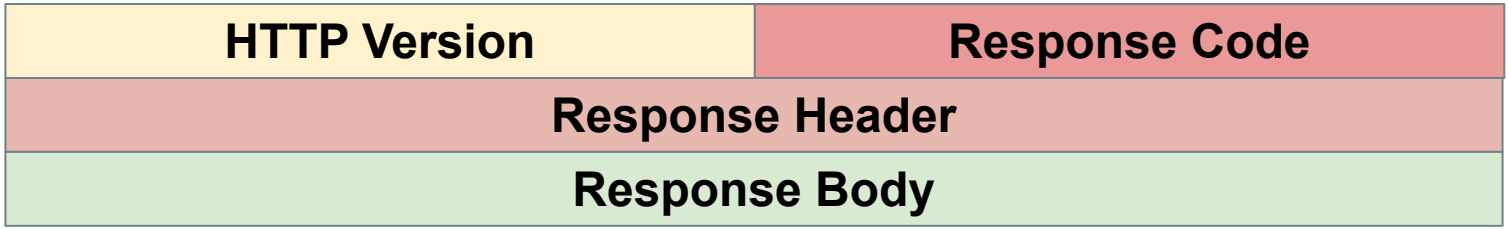
```
POST http://MyService/Person/ HTTP/1.1
Host: MyService, Content-Type: text/xml; charset=utf-8, Content-Length: 123
<?xml version="1.0" encoding="utf-8"?>
<Person><ID>1</ID><Name>M Vaqqas</Name>
<Email>m.vaqqas@gmail.com</Email><Country>India</Country></Person>
```

Anatomy of an HTTP Response



- <Response code> contains request status. 3-digit HTTP status code from a pre-defined list.
- <Response Header> contains metadata and settings about the response message.
- <Response Body> contains the representation if the request was successful.

HTTP Response Example



HTTP/1.1 200 OK

Date: Sat, 23 Aug 2014 18:31:04 GMT, Server: Apache/2, Last-Modified: Wed, 01 Sep 2004 13:24:52 GMT, Accept-Ranges: bytes, Content-Length: 32859, Cache-Control: max-age=21600, must-revalidate, Expires: Sun, 24 Aug 2014 00:31:04 GMT, Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"> <html xmlns='http://www.w3.org/1999/xhtml'> <head><title>Hypertext Transfer Protocol -- HTTP/1.1</title></head> <body> …

HTTP Status Codes

- Common Responses:
  - 200 Ok (succeeded)
  - 201 Created (a new resource)
  - 202 Accepted (not completed)
  - 204 No Content (fulfilled request, nothing to return)
  - 205 Reset content (reload page)
  - 301 Redirection: moved permanently
  - 400 Bad request
  - 401 Unauthorized
  - 404 Not found

Representational State Transfer (REST)

Representational State Transfer

- A Client references a resource using a URI.
- A **representation** of the resource is returned.
  - Receiving the representation places the client in a new **state**.
- When user selects a link in `Boeing747.html`, it accesses another resource. New representation places client into another state.
  - Client application **transfers** state with each resource access.

The Core Idea

- REST modeled after natural workflow of the net.
  - Design pattern for web services.
  - A well-designed web app behaves as a network of web pages (a virtual state-machine).
  - User progresses through application by selecting links (state transitions).
    - Resulting in next page (the next state) being transferred to the user and rendered.

REST - Not a Standard

- Not a standard, but an architectural pattern.
  - You can't bottle up a pattern.
  - You can only understand it and design your web services based on it.
- REST does prescribe the use of standards (**reuse**):
  - HTTP, URL
  - XML/HTML/JPEG/etc. (Resource Representations)
  - Frameworks like Hydra offer advice for designing generic, reusable REST interfaces.

Verbs in REST

- Verbs describe actions that are applicable to nouns
- Using different verbs for every noun would make widespread communication impossible.
  - Some verbs only apply to a few nouns.
- In REST, we use **universal verbs.**
  - All RESTful services offer the same interface.
  - Based on HTTP requests and responses.

REST Fundamentals

- Services offer **resources**.
- All resources have a unique **URI**.
  - URIs tell a client that there's a concept somewhere.
  - Clients request a specific representation of the concept from the representations the server makes available.
- HTTP **verbs** are used to retrieve or manipulate resources in a clear, universal manner.

Representation Formats

- Client and server should be able to comprehend data.
  - Structured content often JSON or XML
- Representation should completely represent resource.
  - If partial representation needed, break into subresources.
  - Smaller representation = easier to transfer = less time required to create representation = faster services.
- Representation should be capable of linking resources to each other via URIs.

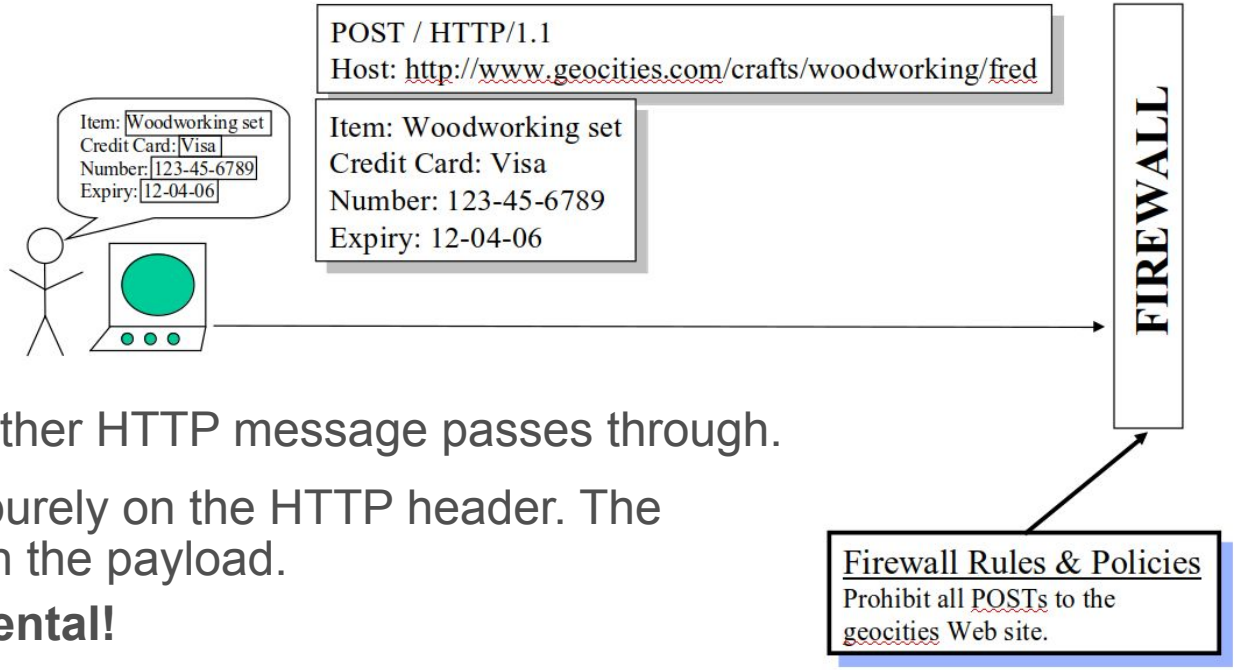
Verb Guarantees

- GET, OPTIONS, TRACE, and HEAD are **safe.**
  - Should not change the resource in any way.
  - Be careful - no technical limitations ensuring safety.
- PUT and DELETE are **idempotent**.
  - Repeated requests have same effect as a single request.
  - Safe operations are also idempotent.
  - POST is *not* idempotent.

Elements of Web Architecture

- **Firewalls** decide which HTTP messages get out, and which get in.
  - These components enforce web *security*.
- **Routers** decide where to send HTTP messages.
  - These components manage web *scalability*.
- **Caches** decide if saved copy of resource used.
  - These components increase web *performance*.

Firewalls



- Firewall decides whether HTTP message passes through.
- All decisions based purely on the HTTP header. The firewall never looks in the payload.
  - **This is fundamental!**
- This message is rejected.

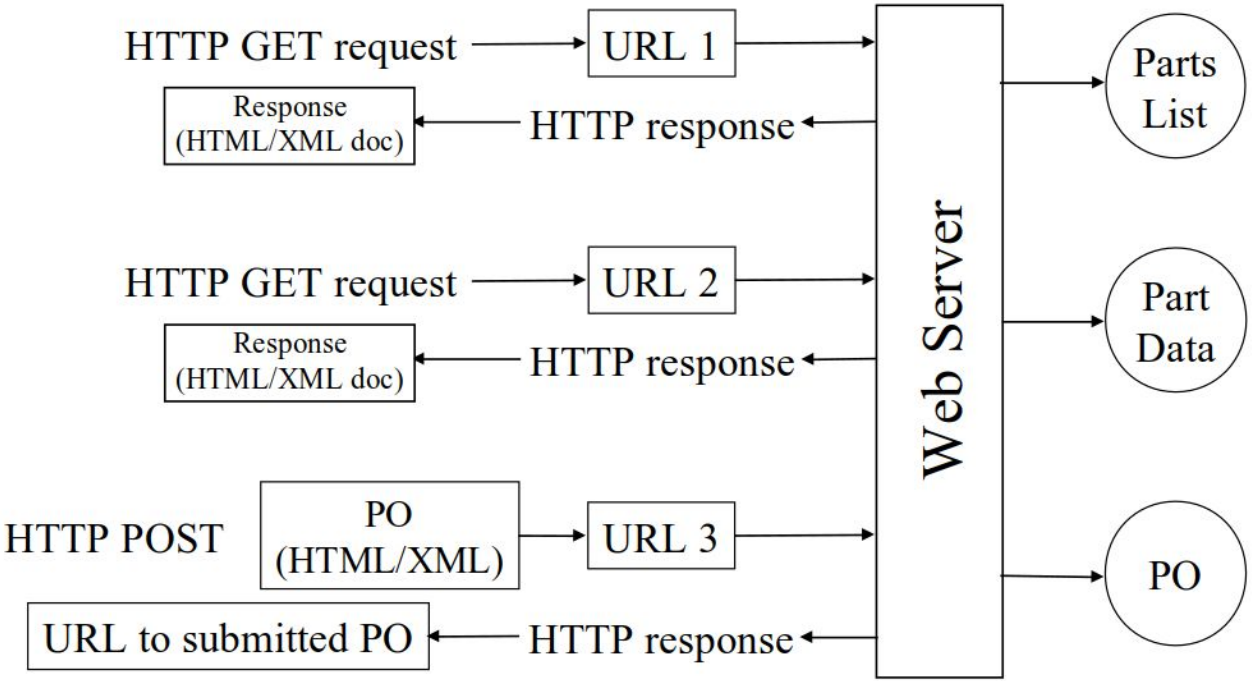
Privacy of Content

- Firewalls, routers, caches base decisions only on HTTP header.
  - **Should never examine the request body.**
- Letter analogy: Postal service doesn't look inside your letter (this is illegal), they just act based on addressing on the outside.
  - The content should not matter, just the metadata.
  - Protects privacy of data.

The Parts Depot Web Store

- Parts Depot, Inc wants to deploy a web service to enable its customers to:
  - Get a list of parts.
  - Get detailed information about a particular part.
  - Submit a Purchase Order (PO).
- How would you architect this?
  - Let's discuss the RESTful way to design this.

The RESTful Way



Retrieving a List of Parts

Service: Get a list of parts

- Web service offers a URL to parts list **resource**.
- Client posts GET request to URL to get parts list:
  - http://www.parts-depot.com/parts
- **How** the web service generates parts list is completely transparent to the client.
  - **Enforces loose coupling.**

REST Fundamentals:

1. Create a resource for every service.
2. Identify each resource using a URI.

Data Returned: Parts List

```
<?xml version="1.0"?>
<Parts>
    <Part id="00345" href="http://www.parts-depot.com/parts/00345"/>
    <Part id="00346" href="http://www.parts-depot.com/parts/00346"/>
    <Part id="00347" href="http://www.parts-depot.com/parts/00347"/>
    <Part id="00348" href="http://www.parts-depot.com/parts/00348"/>
</Parts>
```

- Contains links to detailed information about parts.
- Client transfers state by choosing among alternative URLs in a response.

REST Fundamental:

Data that a service returns should link to other data.

- **Design data as network of information**
- **Contrast with OO design, which says to encapsulate information.**

Retrieving Details on a Part

Service: Get detailed information about a particular part

- Web service makes available a URL to each part resource.
- A client can request information on a specific part by posting GET request to http://www.parts-depot.com/parts/00345

Data Returned: Part 00345

```
<?xml version="1.0"?>  <Part>
    <Part-ID>00345</Part-ID>       <Name>Widget-A</Name>
    <Description>This part is used within the frap assembly</Description>
    <Specification href="http://www.parts-depot.com/parts/00345/specification"/>
    <UnitCost currency="USD">0.10</UnitCost>
    <Quantity>10</Quantity>
</Part>
```

- Data is linked to still more data. Part specification may be found by traversing the link.
- Response allows client to get more detailed information.

Let’s take a break!

Designing Services with REST

Designing Services With REST

- Destination URL placed in HTTP header.
  - Firewalls, routers, caches make decisions based on information in the HTTP Header.
  - Infrastructure will not work if destination not in URL!
- HTTP header should identify **final** destination, not intermediate destination.

Designing Services With REST

- Client requests should be **idempotent** – multiple calls should lead to the “same” response.
- Server responses are “idempotent”, but only in terms of the meaning of information and not necessarily the content.
  - Think of a URL that always returns the current time…

PUT and POST

- PUT is idempotent, POST is **not**.
  - Multiple POSTs may create multiple resources.
- PUT requires a full resource ID path.
  - Client creates resource.
- POST does not require full resource ID path.
  - Server notifies client of resource location.
  - Post can still be used for resource updates.

PUT and POST

- PUT http://MyService/Persons/
  - Won't work. PUT requires a complete URI.
- PUT http://MyService/Persons/1
  - Insert a new person, PersonID=1, if it does not already exist or update existing resource with the payload.
- POST http://MyService/Persons/
  - Insert new person (using the payload), generate new ID.
- POST http://MyService/Persons/1
  - Update the existing person where PersonID=1

Handling POSTs

- Other methods are idempotent, but POST creates new resources.
- Multiple POSTs of same data must be harmless.
  - Put message ID in a header or in the message body.
  - This renders multiple posts harmless.
    - Prevents “multiple charge” issue with web stores.

Handling POSTs

- Many ways to do this:
  - Exact: client or server-side unique transaction ID.
  - Heuristic: check and remove “likely duplicates”.
- Wasted IDs are irrelevant.
  - Duplicated POSTs are not acted on by the server
- Server must send back same response original POST got, in case the application is retrying because it lost the response.

Idempotence

- What does this mean, strictly speaking?
  - Call to server must return the same thing each time?
  - No side effects?
- What about changing data?
  - Time-of-day service.
  - Each GET call returns a new time. Is this RESTful?
    - As long as the **resource is constant**.
    - The value does not need to be constant, just how we access it.

Statelessness

- Each request contains all information needed to service the request.
- No client state is held on the server.
  - Benefits in scalability and availability.
  - Performance may be worse (multiple requests may be needed to get information).

Well-Structured URIs

- Avoid using spaces. Use _ (underscore) or – (hyphen) instead.
- Remember that URIs are case insensitive.
- Stay consistent with naming conventions.
- URIs are long lasting.
  - If you change the location of a resource, keep old URI.
  - Use status code 300 and redirect the client.

Well-Structured URIs

- Avoid verbs for resource names unless resource is actually an operation or a process.
  - Bad URIs:
    - http://MyService/FetchPerson/Mike
    - http://MyService/DeletePerson?id=Mike
  - Good URI:
    - http://MyService/Persons/Mike
    - You can apply verbs to this resource.

Food For Thought

What if Parts Depot has a million parts, will there be a million static pages?

http://www.parts-depot/parts/000000

http://www.parts-depot/parts/000001

...

http://www.parts-depot/parts/999999

Food For Thought

- URLs are **logical**.
  - Express what resource is desired, not physical object.
  - Changes to the implementation of the resource will be transparent to clients (loose coupling!).
- All parts stored in a database. Web service will receive URL request, parse it for ID, query the database, and generate the response document at runtime.

Food For Thought

Physical URLs

http://www.parts-depot/parts/000000.html
http://www.parts-depot/parts/000001.html
...
http://www.parts-depot/parts/999999.html

Logical URLs

http://www.parts-depot/parts/000000
http://www.parts-depot/parts/000001
...
http://www.parts-depot/parts/999999

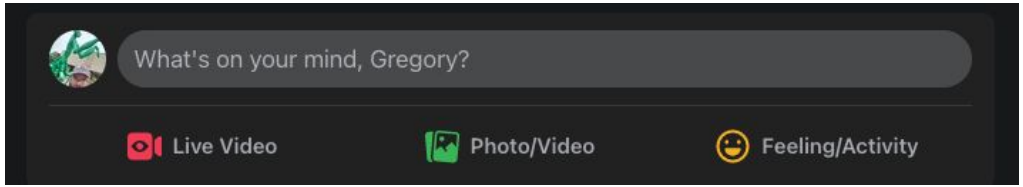
- Physical URLs point to HTML pages.
  - If there are a million parts,we don't want a million HTML pages.
- Changes to how these parts data is represented will effect all clients that were using the old representation.

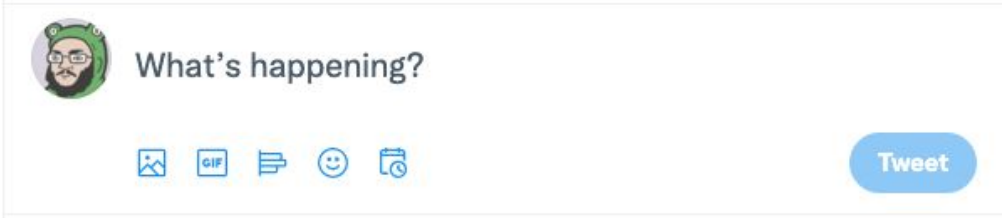
Designing Reusable APIs

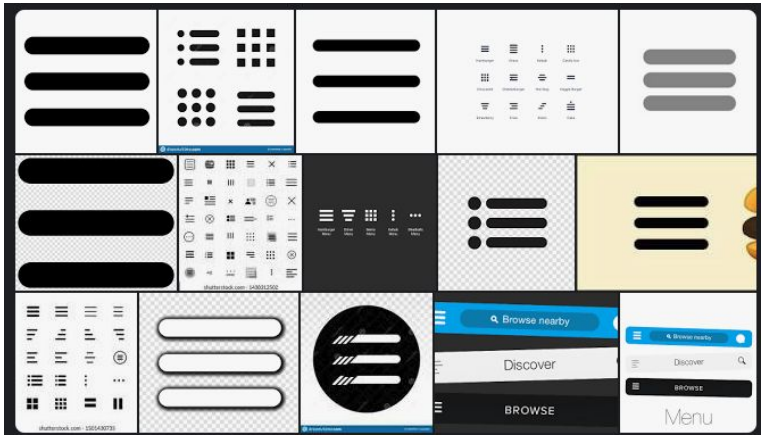
Adapted from Verborgh, R. and Dumontier, M. (2018), “A Web API ecosystem through feature-based reuse”, Internet Computing, IEEE, Vol. 22 No. 3, pp. 29–37.

Human-based Interaction

- Well-designed websites base user interaction on common interaction patterns.
- Interaction patterns are *reused* across the web.







Code-based Interaction

- API reuse is difficult, as similar APIs often have very different interfaces.
  - Different number of HTTP requests to perform a task.
  - Different JSON bodies.
- A client can’t easily swap an API that posts a photo to Facebook for one that posts to Twitter.

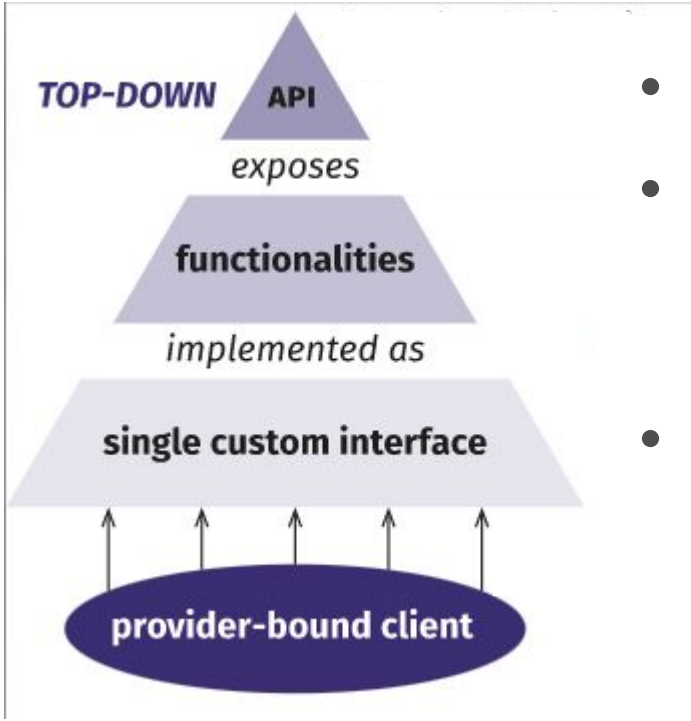
Designing Reusable APIs

- APIs should be reusable in many applications.
  - However, they often require custom code, and rarely share interaction patterns.
  - Result: # of APIs grows rapidly.
- API design should center around common interaction patterns.
  - Like human-based interaction.

Designing Reusable APIs

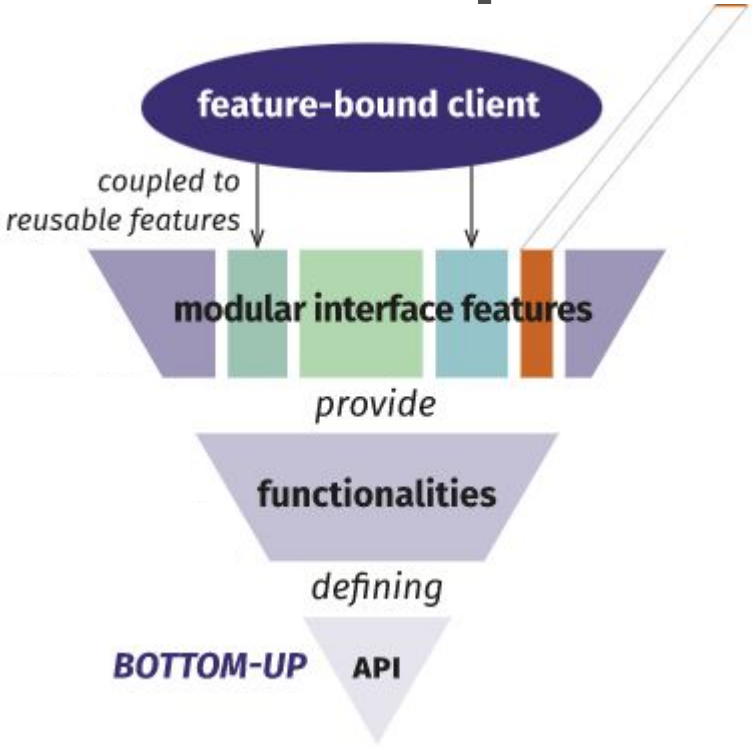
- Individual APIs *are* reusable.
  - We can use one to post a photo to Facebook.
- *However, APIs are often not substitutable.*
  - If we want to post photos to Facebook or Twitter, the APIs can't be swapped.
  - We should be able to choose and swap APIs that perform the same kind of functionality.

Top-Down API Design



- API is monolithic.
- Clients couple to specific interface to interact with lower-level parts.
- Only clear invocation mechanisms are parameter names and types.

Bottom-Up API Design



- A feature offers interface to a common function type.
  - Search text, upload file, update status, etc.
  - Should be simple, self-describing.
- Clients couple to select features, not entire API.
- APIs reuse features.
  - Whole API may not be identical.

1: Web APIs Consist of Features with Common Interfaces

- A web service should be split into features with their own interfaces.
  - Accessing/updating/sorting list of items, pagination, updating a status, uploading a photo, search.
- Features can be optionally selected by client or enabled/disabled by server.
  - Clients only affected by changes to selected features.
  - Clients can make use of only what they need.

1: Web APIs Consist of Features with Common Interfaces

- **OpenSearch** specifies a common format for performing search and publishing the results.
- Also specifies a format for auto-completion of partial search terms.

2: Partition Interface for Feature Reuse

- If a feature is available elsewhere, reuse it in your API instead of implementing it yourself.
  - Clients could perform task with any API offering feature.
- If designing a new feature, make it available separately for reuse.
  - Feature-specific repository, documentation.
- Prioritize reuse when possible, make new functionality available as features.

2: Partition Interface for Feature Reuse

- Atom defines XML format for representing collection of items.
  - E.g., blog posts
  - Could create feature for “post a blog entry” that uses Atom as a generic representation.
  - “Post to Facebook”, “Post to Twitter” could use same shared input format.

```
<?xml version="1.0" encoding="utf-8"?>
<feed xmlns="http://www.w3.org/2005/Atom">

  <title>Example Feed</title>
  <link href="http://example.org/"/>
  <updated>2003-12-13T18:30:02Z</updated>
  <author>
    <name>John Doe</name>
  </author>

  <entry>
    <title>Atom-Powered Robots Run Amok</title>
    <link href=
      "http://example.org/2003/12/13/atom03"/>
    <updated>2003-12-13T18:30:02Z</updated>
    <summary>Some text.</summary>
  </entry>

</feed>
```

3: API Responses Should Advertise Relevant Features

- Server should include or link to supported features.
  - Support indicated in header of HTTP response or inside response body.
  - Can indicate which optional parts are implemented.
- Clients can determine whether API offers needed features at runtime.

3: API Responses Should Advertise Relevant Features

- Hypermedia: Embed links to resources within JSON body of HTTP response.
- Ex: GET call to entry point returns links to accessible resources.
- GitHub API uses hypermedia to broadcast functionality.

GET /

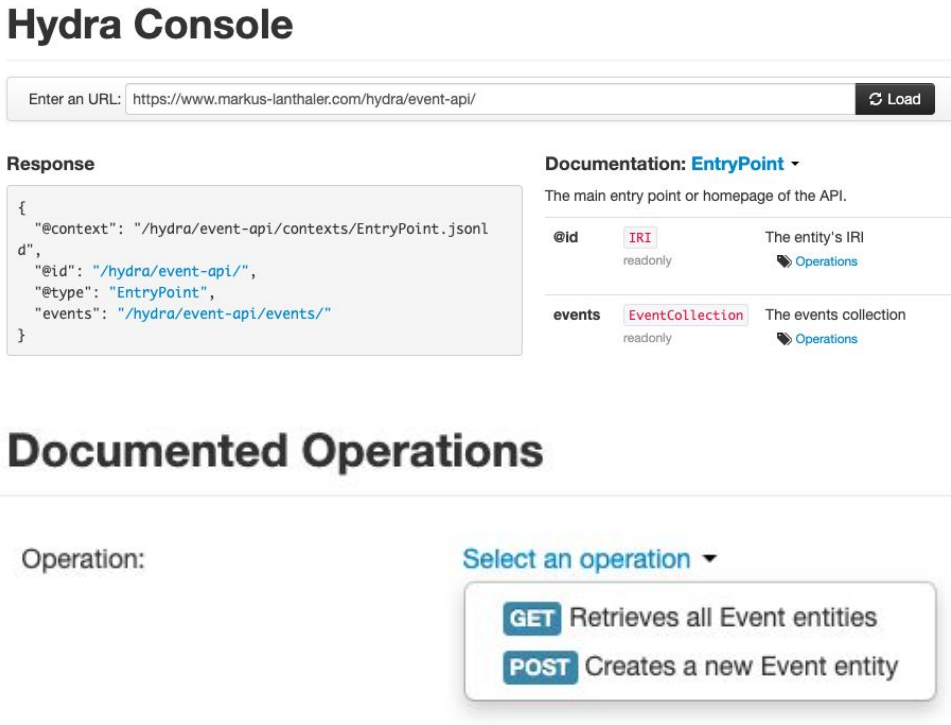
```
{
    "version": "1.2.3",
    "description": "Example API to
manage orders",
    "links": [
        { "rel": "orders",
          "href": "/orders" },
        { "rel": "customers",
           "href": "/customers"},
        { "rel": "customer-by-id",
           "href": "/customer/{id}"},
        { "rel": "customer-by-email",
          "href": "/customer{?email}"},
        ...
    ]
}
```

4: Features Describe their Functionality and Invocation

- When queried, a feature should describe its functionality and how it is accessed in a standard form (e.g., hypermedia, JSON schema).
  - Reduces need to find documentation on an API.
  - APIs implementing a feature do not need to use same URL structure/parameter names.
- Client can query feature for details at runtime.

4: Features Describe their Functionality and Invocation

- Hydra is a standard for generic APIs.
  - Includes ways to describe functionality and invocation.
- Hydra Console infers details from Hydra APIs and renders documentation.



We Have Learned

- REST is a web-based API format.
  - Services provide resources (through URLs) designed to be consumed by programs rather than by people.
  - Design Principles:
    - Stateless
    - Resource-Based (URI)
    - Uniform Interface (GET, PUT, POST, DELETE)
    - Links describe relationships
    - Cacheable and monitorable using standard internet tools

We Have Learned

- APIs should be designed to be reusable.
  - APIs should be split into features.
  - Features should have a common interface with compatible features with separate implementations.
  - The overall API should be partitioned into these separate features with their own interfaces.
  - APIs should advertise available features.
  - Features should broadcast their functionality and invocation details.

Next Time

- System-Level Test Design

- Assignment 3 - due tonight
- Assignment 4 - December 12
  - Modularization and design patterns
  - Any questions?

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