IEMS 5780 / IERG 4080
Building and Deploying Scalable Machine Learning Services

Lecture 10 - HTTP and Web Applications

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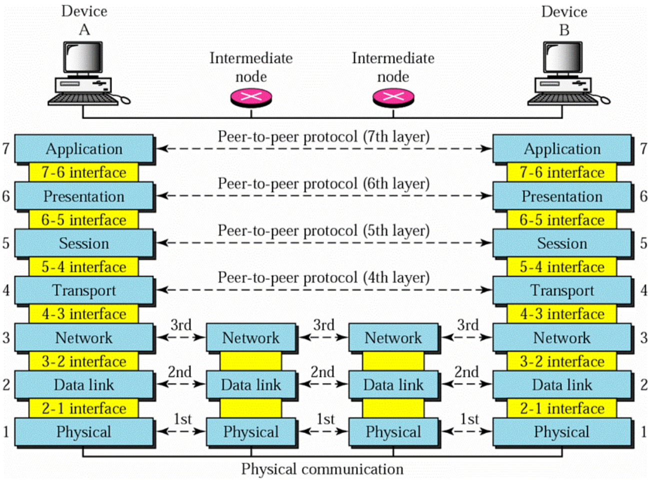
The Hypertext Transfer Protocol (HTTP)

The OSI 7-Layer Model



TCP vs. HTTP

- TCP is a streaming protocol for exchanging data between computers on the Internet (which is based on the IP protocol)
- Using TCP on the application level can be difficult
- Having an **application layer** protocol simplifies the development of a particular type of applications, and can also introduce some standards
- HTTP defines several things for communication between Web clients and servers
  - Uniform Resource Locators (URLs)
  - HTTP methods
  - HTTP headers
  - HTTP status codes
  - ...

History of HTTP and the Web

- Tim Berners-Lee, credited as the inventor of the World Wide Web, created the original HTTP protocol and HTML (Hypertext Markup Language) in 1990 at CERN for combining the Internet and hypertext

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OWN!!
NeXT

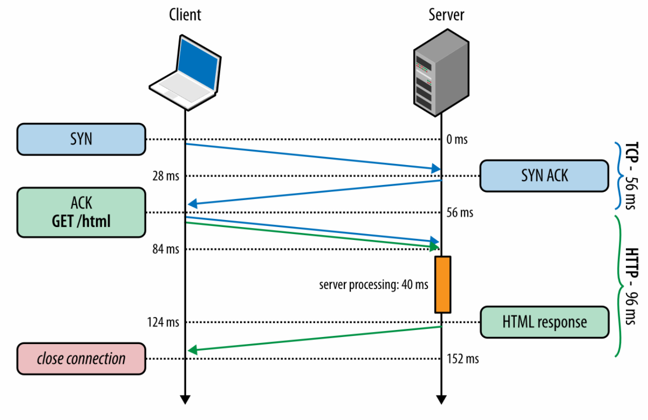
History of HTTP and the Web

- History of the Web - World Wide Web Foundation
- Tim Berners-Lee: The next Web of open, linked data
- info.cern.ch - The first Website in the history!
- Tim Berners-Lee is the recipient of the 2016 Turing Award

HTTP

- HTTP is an application protocol for transferring hypertext and other file formats over the Internet
- Current widely used version: **HTTP/1.1** (standardized in 1997) RFC 2616
- HTTP/2 specification was published as RFC 7540 in May 2015
- **Client-Server model**:
  - Client (e.g. Web browser) sends an HTTP request to a URL
  - Server prepares and returns the requested resources
- Read https://www3.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html

HTTP



- Reference: https://hpbn.co/http1x/

HTTP

- **HTTP** is an application protocol designed on top of the **TCP protocol**
- Once the TCP connection is established, the client can send a request to the server

```
GET / HTTP/1.1
Host: www.cuhk.edu.hk
Accept-Language: fr
(\r\n)
```

- The first line specifies the method (`GET`), the path (`/`), and the HTTP version
- The second line specifies the server name (domain name)
- From the second line onwards, these are **headers** of the requests
- The last empty line indicates end of the header

HTTP

- Another example with data sent to the server

```
POST /contact_form.php HTTP/1.1
Host: developer.mozilla.org
Content-Length: 64
Content-Type: application/x-www-form-urlencoded

name=Joe%20User&request=Send%20me%20one%20of%20your%20catalogue
```

- Content-Length specifies the lenght of the data sent to the server (64 bytes in this case)
- The content (data) follows the empty line
- (Ref: https://developer.mozilla.org/en-US/docs/Web/HTTP/Session)

HTTP Request

An HTTP request has the following components

- URL - the unique identifier of the online resource
- Method/Verb – the action of the request (e.g. GET something?)
- HTTP Version – the version of the protocol you are using
- Headers – the metadata of the request
- Body – Data to be sent to the server

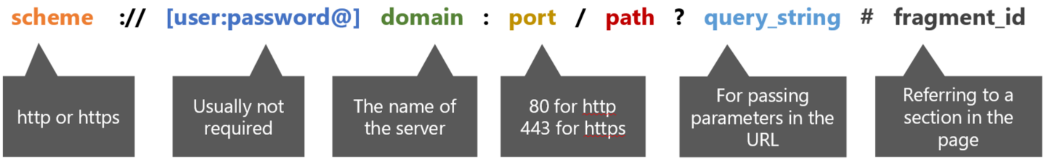
HTTP Response

An HTTP response has the following components

- Status Code – indicate whether the request is successful
- HTTP Version - the version of the protocol you are using
- Headers – metadata of the response
- Body – data of the resource requested

Uniform Resource Locator (URL)

- A specific type of URI (Uniform resource identifier)
- It implies the means to access a resource
- Syntax of a URL:



scheme :// [user:password@] domain : port / path ? query_string # fragment_id

http or https

Usually not required

The name of the server

80 for http
443 for https

For passing parameters in the URL

Referring to a section in the page

URL Examples

- CUHK Homepage

  http://www.cuhk.edu.hk/chinese/index.html
- YouTube Video

  https://www.youtube.com/watch?v=Q93o1yBr-Mc
- Apple Daily

  http://hkm.appledaily.com/list.php?category_guid=4104&category=daily
- Instagram API

  https://api.instagram.com/v1/users/self/feed?access_token=ACCESS-TOKEN
- Wikipedia

  https://en.wikipedia.org/wiki/Python_(programming_language)#Libraries

HTTP Methods

Indicate the **desired action** to be performed on the resource identified by the URL

- **`GET`** – retrieves data from the server
- **`HEAD`** – asks for a response same as GET, but without the body
- **`POST`** – asks the server to accept data enclosed in the request and apply it to the resource
- **`PUT`** – asks the server to store the data under the supplied URL
- Other methods: **`DELETE`**, **`TRACE`**, **`OPTIONS`**, **`CONNECT`**, **`PATCH`**

HTTP GET

An example of GET:

- https://www.youtube.com/watch?v=Q93o1yBr-Mc
- Retrieve a YouTube video page providing the value of the parameter v
- It has no effect on the resource to be retrieved, it simply retrieves a copy of the resource
- `v=Q93olyBr-Mc` is the query string

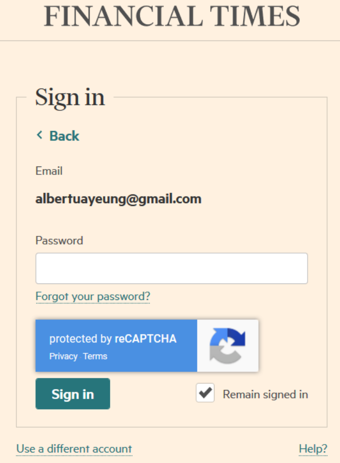
Query String

- Each parameter and its value are specified by **name**=**value**
- Parameters are separated by ampersand **&**
- The maximum amount of information that can be passed to the server using the query string depends on the maximum length allowed for an URL (The limits of different browsers are different, usually at about 64K characters)
- NOT for passing sensitive data (e.g. password) (*Why?*)

HTTP POST

An example of POST:

- https://www.ft.com/
- After filling in the user name and password and clicking on the **Sign in** button, the data will be sent to the server using the **POST** method
- Usually used for submitting a form (e.g. online forms, leaving comments, etc.)
- The username and password will be put in the **body** of the request and sent to the server



FINANCIAL TIMES

Sign in

‹ Back

Email

albertuayeung@gmail.com

Password

Sending Binary Data

- Recall that HTTP is a **text protocol** (i.e. everything sent using HTTP are assumed to be characters)
- If you want to send files (binary data), you need to **encode** the binary data first before sending
- In an HTML form, set **`enctype=multipart/form-data`**
- Setting enctype="multipart/form-data" tells the server that the data are split into multiple parts, one for each file, plus one for the textual data in the form body.
- Ref: https://developer.mozilla.org/en-US/docs/Web/Guide/HTML/Forms/Sending_and_retrieving_form_data

```
<form method="post" enctype="multipart/form-data">
    <input type="text" name="name">
    <input type="file" name="file">
    <input type="submit" value="Send!">
</form>
```

HTTP Headers

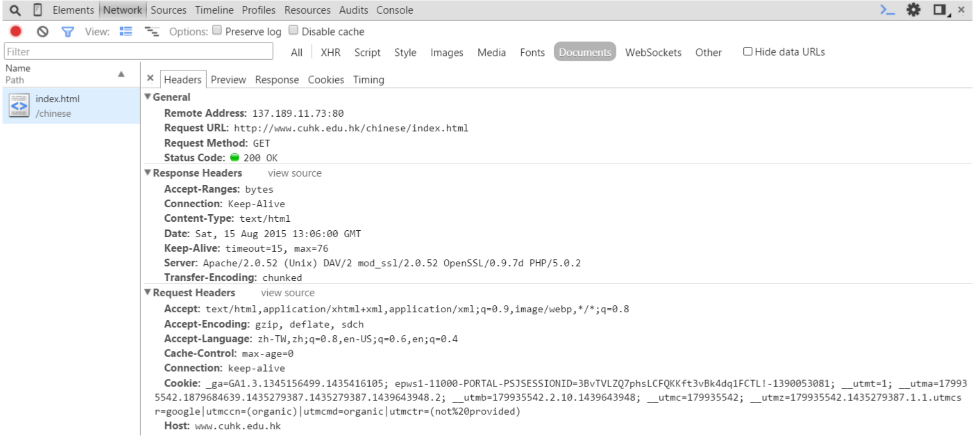
Headers contain metadata about the request/response, such as:

- Identity of the client
- Type of the content (e.g. plain text, HTML, CSS, image)
- Encoding of the content (e.g. ASCII, utf-8)
- Expiry date/time of the content
- Cookies
- ...
- (For a list of HTTP request and response header fields,

  see: https://en.wikipedia.org/wiki/List_of_HTTP_header_fields)

Checkng HTTP Headers

- Use the developer's tools in Firefox or Chrome:



```
▼ General
    Remote Address: 137.189.11.73:80
    Request URL: http://www.cuhk.edu.hk/chinese/index.html
    Request Method: GET
    Status Code: ● 200 OK
▼ Response Headers      view source
    Accept-Ranges: bytes
    Connection: Keep-Alive
    Content-Type: text/html
    Date: Sat, 15 Aug 2015 13:06:00 GMT
    Keep-Alive: timeout=15, max=76
    Server: Apache/2.0.52 (Unix) DAV/2 mod_ssl/2.0.52 OpenSSL/0.9.7d PHP/5.0.2
    Transfer-Encoding: chunked
▼ Request Headers      view source
    Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
    Accept-Encoding: gzip, deflate, sdch
    Accept-Language: zh-TW,zh;q=0.8,en-US;q=0.6,en;q=0.4
    Cache-Control: max-age=0
    Connection: keep-alive
    Cookie: _ga=GA1.3.1345156499.1435416105; epws1-11000-PORTAL-PSJSESSIONID=3BvTVLZQ7phsLCFQKKft3vBk4dq1FCTL!-1390053081; __utmt=1; __utma=17993
  5542.1879684639.1435279387.1435279387.1439643948.2; __utmb=179935542.2.10.1439643948; __utmc=179935542; __utmz=179935542.1435279387.1.1.utmcs
  r=google|utmccn=(organic)|utmcmd=organic|utmctr=(not%20provided)
    Host: www.cuhk.edu.hk
```

HTTP Headers

HTTP headers are sets of **key-value pairs** (field names and values)

- Some of the **request header keys**:
  - **Accept**: the preferred format of the resource (e.g. text/html, application/json, application/xml)
  - **Accept-Language**: the preferred language of the resource (e.g. zh-TW, zh-CN, en-US)
  - **User-Agent**: the type of browser or device (e.g. indicate whether the client is on a PC or on a mobile)
- Some of the **response header keys**:
  - **Content-Length**: length of the content of the resource
  - **Content-Type**: format of the resource (e.g. text/html)
  - **Last-Modified**: the time when the resource was last changed
  - **Server**: The name of the Web server serving the resource

For a more exhaustive list of header fields: https://en.wikipedia.org/wiki/List_of_HTTP_header_fields

HTTP Status Codes

HTTP Status code is included in a HTTP response to indicate the outcome of an HTTP request

- The different categories of HTTP status codes:
    - **1XX**: Informational
    - **2XX**: Successful
    - **3XX**: Redirection
    - **4XX**: Client-side error
    - **5XX**: Server-side error

Examples of HTTP Status Codes

- **200**: OK

  Everything is OK, results should be in the response

- **301**: Moved Permanently

  The client should send request from the URL provided instead

- **403**: Forbidden

  The client is not authorised to access the resource

- **404**: Not Found

  The resource cannot be found

- **500**: Internal Server Error

  Some problem with your server application

Stateless Protocol

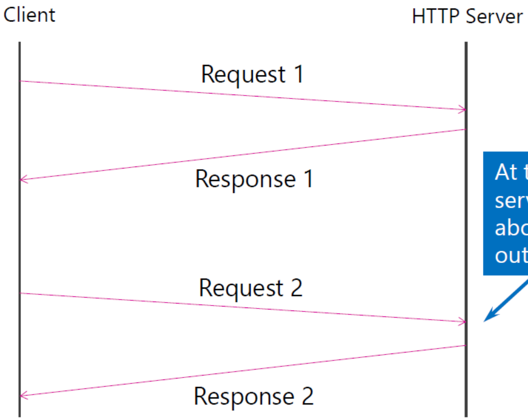
- HTTP is a **stateless protocol**
- The server does not retain information about clients between requests
- The state of the communication is maintained **on the client side**
- Each request is considered independent
- No session information stored on the server-side

Stateless Protocol

In order to let the server know that the client has done something before, the client has to include some information in the request (header or content)

Example:

- The client has already logged in
- The client has filled in a form but some fields are missing



At this point, the server knows nothing about the content and outcome of Request 1.

Accessing HTTP Resources in Python

- As mentioned, HTTP runs on top of TCP, so you can use sockets to request data from an HTTP server

```python
import socket

# Create a socket and connect to CUHK's web server on port 80
s = socket.socket(socket.AF_INET,socket.SOCK_STREAM)
s.connect(("www.cuhk.edu.hk", 80))

# Create an HTTP request and send it to the server
req = "GET / HTTP/1.1\nHost: www.cuhk.edu.hk\nAccept-Language: en\n\r\n".encode("ascii")
s.sendall(req)

# Read the HTTP response from the server
resp = s.recv(2048)
print(resp)  # "HTTP/1.1 200 OK\r\nServer: 02_1517723009\r\n..."
```

Accessing HTTP Resources in Python

- In practice, you should use modules such as **`http.client`**, **`urllib.request`** or **`requests`**
- The first two can be found in the standard library, while **`requests`** is a third party package

```
import http.client

# Create an HTTP connection to www.cuhk.edu.hk
conn = http.client.HTTPConnection("www.cuhk.edu.hk")
conn.request("GET", "/")

resp = conn.getresponse()
print(resp.status, resp.reason)  # should print 200 OK

page = resp.read()
# page now contains the HTML source code of the Web page
```

Accessing HTTP Resources in Python

- Using `urllib.request`:

```
from urllib import request

with request.urlopen('http://www.cuhk.edu.hk/') as response:
   page = response.read()
```

- Install `requests` by `pip3 install requests` and then you can import the module

```
import requests

response = requests.get("http://www.cuhk.edu.hk")
page = response.content()
```

Web/HTTP Servers

HTTP

- **HTTP** is an application protocol designed for transmitting Web pages and other documents over the Internet
- HTTP is also based on the **client-server model**
- In this lecture, we will introduce:
  - How does an HTTP server (Web server) works?
  - How do we create network applications that use HTTP for communication

Web Servers

What does a basic **Web server** do?

- It is responsible for **serving** Web pages and other documents to Web clients (in most cases the Web browsers)
- Each incoming **request** asks for a file stored in the machine running the Web server (identified by a **path**)
- THe Web server loads the content of the file and sends it to the client
- In the most basic form, a Web server serves **static** content

Web Servers

A simple HTTP server's pseudo-code

```
Open socket, listen at port 80
While true:
    Accept socket connection from client
    While read == true:
        Read request data
    Process request data
    Output response
    Close connection
```

A Simple Web Server in Python

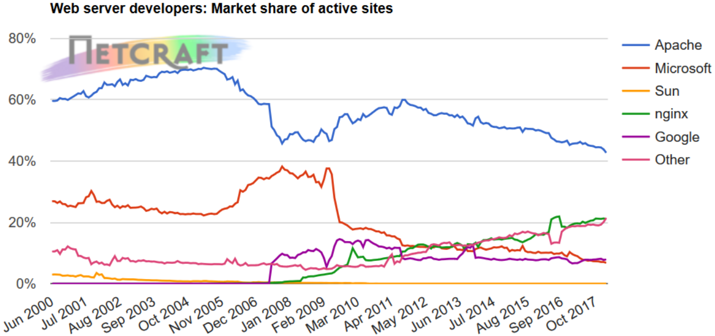
- Python comes with a class **`HTTPServer`**, which is a subclass of **`TCPServer`**
- You can run a simple Web server using the command below, which will start serving content under the folder in which you execute the command

```
$ python3 -m http.server
Serving HTTP on 0.0.0.0 port 8000 ...
127.0.0.1 - - [16/Feb/2018 14:54:32] "GET / HTTP/1.1" 200 -
...
```

- By default it listens on all network interface, and on port 8000. Use **`--help`** to check how you can configure the server

Common Web Servers

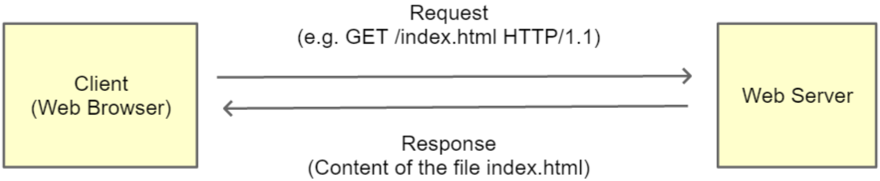
- Many off-the-shelf Web servers can be found. Examples are Apache, Nginx, and Lighttpd



- Ref: https://news.netcraft.com/archives/2018/02/13/february-2018-web-server-survey.html

Functions of a Web Server

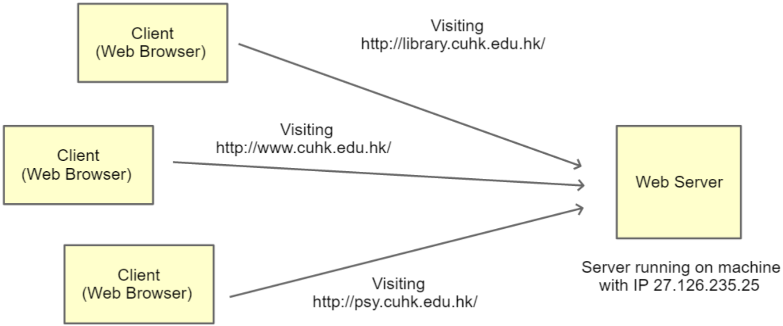
Serving Static Content


Request
(e.g. GET /index.html HTTP/1.1)
Client
(Web Browser)
Web Server
Response
(Content of the file index.html)

Functions of a Web Server

Manage Multiple Domains (Virtual Hosting)

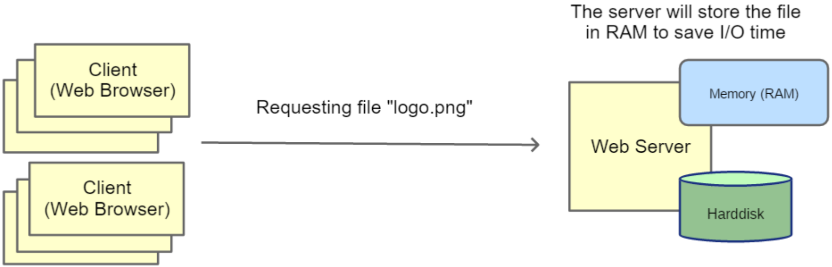
- Assume that the three domains all map to the same IP address
- The Web server needs to determine what to server given the domain in the request



Functions of a Web Server

Caching

- When some files are frequently accessed by the clients, a Web server can keep the contents in the RAM to avoid repeated I/O


The server will store the file in RAM to save I/O time
Client (Web Browser)
Client (Web Browser)
Requesting file "logo.png"
Web Server
Memory (RAM)
Harddisk

Other Functions

- HTTP Authentication (restrict access using username and password)
- Executing serer-side scripts
- URL redirection / URL Rewriting
- Reverse proxying (redirect requests to application servers)
- Traffic control
- ...

Types of HTTP Servers

In order to **server multiple clients** more efficiently, there are different implementations using different concurrent programming methods

- **Multi-threading**: Create a new thread to handle a new request
- **Multi-processing**: Create a new process to handle a new request
- **Pre-fork Workers**: Create a pool of workers (either processes or threads) in advance to handle new requests
- **Event-driven** / **asynchronous** approach

Nginx

- A web server "with a strong focus on high concurrency, performance and low memory usage"
- A free and open source software developed by Igor Sysoev (a Russian software engineer)
- Use an event-driven (asynchronous) approach to hand HTTP requests Avoid waiting for blocking system calls (e.g. read from socket, read from file in memory or from disk)
- Addition functions such as reverse proxy with caching, load balancing, and support other new protocols such as SPDY or WebSocket

Serving Dynamic Content

HTTP Servers vs. Application Servers

- For running a Website with mostly **static content**, a Web server is sufficient
- However, building an application or service involves more complex server-side logic, and very often you will need to generate content dynamically. Examples:
    - Loading the **profile page** of a user in a Web application
    - Providing **personalized** recommendations
    - Applications requiring updating data stored in a **database**
    - A Web application that provides language translation **services**
    - ...
- You need an **application server**!

HTTP Servers vs. Application Servers

- These two types of servers have different requirements

HTTP Servers

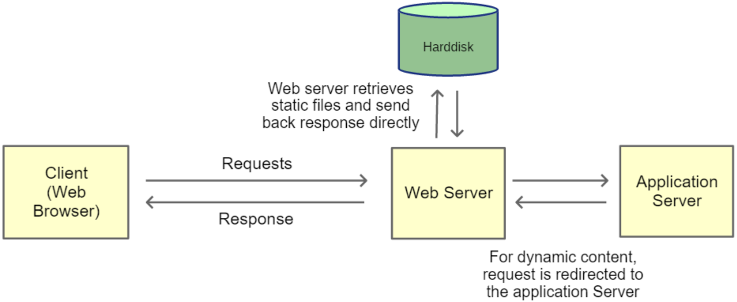
- Has to be stable and secure
- Serve static files or content quickly
- Be configurable
- Be able to handle many requests at a time (concurrency issues)
- Be language agnostic

Application Servers

- Execute business logic
- Development using high-level languages is usually more efficient
- Interface with other components to execute the business logic (e.g. database, message queues, other Web services)

HTTP Servers vs. Application Servers

- If your application uses **HTTP**, then a Web server will help you handle most of the common HTTP-related functions
- You can focus on the implementation of the **logic** of your application
- The Web server will send requests to the application server for carrying out computation or for retrieving dynamic content


Harddisk
Web server retrieves static files and send back response directly
Client (Web Browser)
Requests
Response
Web Server
Application Server
For dynamic content, request is redirected to the application Server

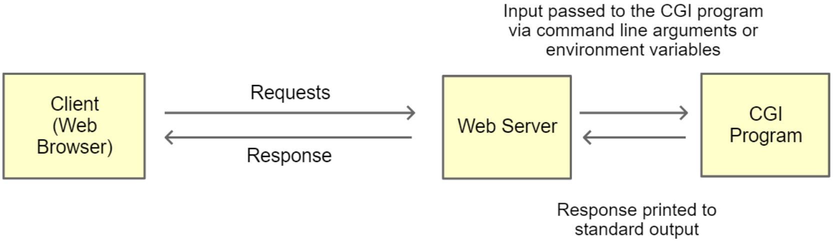
Interface with Application Servers

How does a Web server communicates with an application?

- via executing **console applications** (e.g. CGI)
- via plug-in or **modules** (e.g. mod_php in Apache)
- via **TCP** connections (e.g. FastCGI)
- via other specific **programming interfaces** (e.g. WSGI)

Common Gateway Interface (CGI)

- A standard protocol for interfacing external application with a Web server
- **CGI programs** are executable programs that run on the Web server machine
- The Web server creates a new process by executing the CGI programs
- CGI programs print response to the **standard output**, which will be collected by the Web server to produce the final response to the client.


Input passed to the CGI program via command line arguments or environment variables
Client (Web Browser)
Requests
Response
Web Server
CGI Program
Response printed to standard output

Limitation of CGI

- For each request to invoke a CGI program, a new process is created, which will be terminated at the end of the execution
- The **overhead** to start and terminate the process can be huge
- Consider Assignment 2 in which we use SqueezeNet for object recongition:
- In a sample run:
  - Time to import Tensorflow, Keras and SqueezeNet, and to load the pre-trained model: **2.03 seconds**
  - Time to process one image and generate predictions: **0.14 seconds**

Beyond CGI

- CGI is suitable only for relatively simple tasks or when the overhead of starting the process is small
- To reduce **overhead**, it is necessary to:
    - Do initialization only once
    - Pre-load data and logic necessary for the tasks
- In other words, it is desirable to have a **persistent** process running to serve incoming requests
- Some solutons: FastCGI, SCGI, Python's WSGI

Web Server Gateway Interface (WSGI)

- WSGI refers to the Web Server Gateway Interface (See also PEP 3333)
- Specify the interface through which a Web server and an application communicate
- If an application is written according to the specification, it will be able to run on any server developed according to the same specification
- Applications and servers that use the WSGI interface are said to be **WSGI compliant**

Why WSGI?

- Web servers are not capable of running Python applications
- For Apache, there is a module named **mod_python**, which enables Apache to execute Python codes
- However, **mod_python** is
  - not a standard specifications
  - no longer under active development
- Hence, the Python community came up with **WSGI** as a standard interface for Python Web applications

Why WSGI servers and WSGI applications?

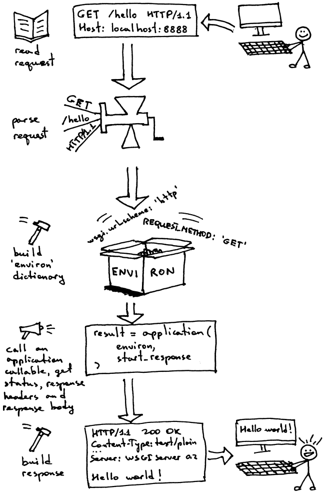
- It is an example of **de-coupling**
- Applications focus on how to get things done (e.g. business logic, updating databases, serving dynamic content, etc.)
- Servers focus on how to route requests, handle simultaneous connections, optimise computing resources, etc.
- As an application developer, you can focus on developing the functions and features, without worrying about how to interface with the Web server

WSGI Flow

When there is a new request

1. The server invokes the application
2. Parameters are passed to the application using environment variables
3. The server also provides a callback function to the application
4. The application processes the request
5. The application returns the response to the server using the callback function provided by the server

Ref: https://ruslanspivak.com/lsbaws-part2/



```
GET /hello HTTP/1.1
Host: localhost:8888
```

```
result = application(
    environ,
    start_response
)
```

```
HTTP/1.1  200 OK
Content-Type: text/plain
...
Server: WSGI server 0.2

Hello world!
```

Example

- A simple WSGI-compatible application that returns "Hello World"

```
def application(environ, start_response):
    start_response(‘200 OK’, [(‘Content-Type’, ‘text/plain’)])
    yield ‘Hello World\n’
```

- **`environ`** contains parameters that the server passes to the application (e.g. parameters in the query string)
- **`start_response`** is a callback function provided by the server, the application uses it to return the HTTP response

Web Frameworks

- You do not need to directly implementing the WSGI interface in your application, as there are many **Web frameworks** that will help you development an application more easily
- In this course, we will talk about Flask
  - Relatively easy to pick up
  - Debug mode that assists your development
  - Many plugins and modules
- Other options:
  - Django: A comprehensive Web framework following the model-view-controller (MVC) architectural pattern
  - Bottle: A micro-framework like Flask, but more lightweight and requires no dependencies on other modules
- For more, see https://wiki.python.org/moin/WebFrameworks/

Developing Web Applications using Flask

Flask

- Flask is a Python framework for developing WSGI compatible Web / HTTP applications
- To use Flask, install it using **pip**:

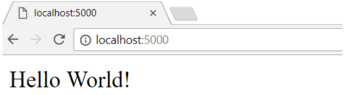
```
$ pip3 install Flask
```

- A Flask "Hello World" Application

```
from flask import Flask
app = Flask(__name__)

@app.route('/')
def hello_world():
    return 'Hello World!'

if __name__ == '__main__':
    app.run()
```

Flask

```python
from flask import Flask

# Create a Flask application
app = Flask(__name__)

# Define a new route at "/"
@app.route('/')
def hello_world():
    return 'Hello World!'

if __name__ == '__main__':
    # Run the application at
    # the default port (5000)
    app.run()
```



Hello World!

Routes

- Define different routes (paths) for different functions
- An HTTP request to a particular path will invoke the corresponding function

```
from flask import Flask
app = Flask(__name__)

@app.route('/')
def index():
    return 'Index Page'

@app.route('/hello')
def hello():
    return 'Hello World'
```

Note: If you define the url with a **trailing slash**, like `@app.route('/about/')`, accessing it without a trailing slash will cause Flask to redirect to the canonical URL with the trailing slash. However, if you define the url without a trailing slash, like `@app.route('/about')`, accessing it with a trailing slash will produce a **404 "Not Found"** error.

Dynamic Routes

- You can change part of the path to be a variable that can be used to change the behaviour of a function
- Specifiy **`<variable>`** in the route, and let the function receive an argument:

```python
@app.route('/user/<username>')
def show_user_profile(username):
    message = "Hello {}!".format(username)
    return message

# Use <type:variable> to restrict the data type
@app.route('/post/<int:post_id>')
def show_post(post_id):
    message = "This is Post {:d}".format(post_id)
    return message
```

GET and POST Requests

- By default, a route only answers to HTTP **GET** requests
- You can change this by providing the methods explicitly when defining the route

```
from flask import request

# Accepts both GET and POST method
# Perform different tasks depending on the method
@app.route('/login', methods=['GET', 'POST'])
def login():
    # request is an object containing information
    # about the request received from the client
    if request.method == 'POST':
        # Check user's username and password
        ...
    else:
        # Presents the login form
        ...
```

Passing Data to the Application

- Your app will almost always need to pass some data to the server
- In the query string when using GET (e.g. the ID of a news article)
- In the HTTP body when using POST (e.g. the username and password for signing in)
- You can access the data submitted from the client using the **`request`** object in Flask

```
@app.route('/get_news', methods=['GET'])
def get_news():
    news_id = request.args.get("news_id")
    ...

@app.route('/like_news', methods=[POST'])
def like_news():
    news_id = request.form.get("news_id")
    ...
```

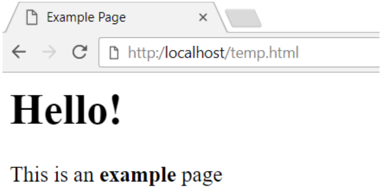
Generating Response

- Response can be classified into two types:
  - **Human-readable** (e.g. Web page coded in HTML)
  - **Machine-readable** (e.g. XML, JSON)
- Your application may need to return both types of response, depending on which functions get called
- Many Websites provide different both types of response (**Web pages** and **APIs**)
- For example, consider https://openweathermap.org/:
  - Web page showing the weather of Hong Kong
  - API Response containing weather information of Hong Kong in JSON format

One Page Introduction to HTML

- Hypertext Markup Language (HTML) is used to describe the structure of a Web page, and informs the Web browser how the page content should be **displayed**
- It is commonly used with JavaScript and Cascading Style Sheets to create the user interface of a Web page

```
<html>
    <head><title>Example Page</title></head>
    <body>
        <div>
            <h1>Hello!</h1>
            This is an <b>example</b> page
        </div>
    </body>
</html>
```



Hello!

This is an **example** page

JavaScript Object Notation (JSON)

- JSON is a data format commonly used for data exchange
- It has the same syntax as the definition of an object in JavaScript
- Can be directly converted into Python dictionaries or lists using the `json` module
- A JSON file with a list of students taking a course:

```
[
    {
        "first_name": "Peter",
        "last_name": "Chan",
        "student_id": "12345678"
    },
    {
        "first_name": "May",
        "last_name": "Wong",
        "student_id": "23456789"
    }
]
```

JSON

- JSON is basically made up of **lists** and **dictionaries**
- You can convert JSON to and from Python data structures using the `json` module

```
import json

# Converts a string of JSON into Python data structure
data_str = '[{"x": 1}, {"x": 3}, {"x": 5}]'
data = json.loads(data_str)
# Now data[0]["x"] is 1

# Serialize a Python list to a JSON string
data_str = json.dumps(data)
```

Generating HTML Response in Flask

- In Flask, you can return HTML directly as a string

```
@app.route('/')
def index():
    return """
        <html>
            <head>
                <title>My Homepage</title>
            </head>
            <body>
                Welcome!
            </body>
        </html>
    """
```

Generating HTML Response in Flask

- More conveniently, you can use HTML templates that are stored under a **`templates`** folder

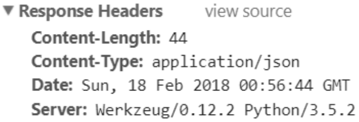
```
from flask import render_template

@app.route('/')
def index():
    # return the content of index.html
    return render_template('index.html')
```

- Flask uses the **`Jinja2`** template engine, which is very powerful for generating dynamic HTML pages
- See http://flask.pocoo.org/docs/0.12/quickstart/#rendering-templates for some examples

Generating JSON Response in Flask

- When you are developing an API, you will probably need to return data in JSON format
- You should use the `jsonify` function provided by Flask, which will set the `Content-Type` header in the response to `application/json`

```python
from flask import jsonify

@app.route('/get_news', methods=['GET'])
def get_news():
    news_id = request.args.get("news_id")
    articles = get_news_from_db(news_id)
    return jsonify(status="OK", data=articles)
```



```
▼ Response Headers      view source
    Content-Length: 44
    Content-Type: application/json
    Date: Sun, 18 Feb 2018 00:56:44 GMT
    Server: Werkzeug/0.12.2 Python/3.5.2
```

Example

- Let’s assume we are developing an API for finding the sum of two numbers:

```python
from flask import jsonify

@app.route('/add', methods=['GET'])
def add():
    # Retrieve values of a and b from query string
    a = request.args.get("a", 0, type=int)
    b = request.args.get("b", 0, type=int)
    sum = a + b

    # Return a JSON response
    return jsonify(status="OK", sum=sum)
```

- Output of sending a HTTP GET request to the path **/add?a=5&b=6**:

```json
{
    "status": "OK",
    "sum": 11
}
```

Testing a Flask Application

- You can test your application by simply execute the python script, for example:

```
$ python app.py
 * Running on http://127.0.0.1:5000/ (Press CTRL+C to quit)
```

- By default, Flask will execute the app using an **internal Web server** on port 5000, and the APIs can only be accessed from within the same machine (note the **127.0.0.1** address)
- You can change the address and port by using the arguments in the `run()` function. For example:

```
app.run(host="0.0.0.0", port=8080)
```

Enabling Debug Mode

- For testing and debugging purposes, you can enable the DEBUG mode of Flask by

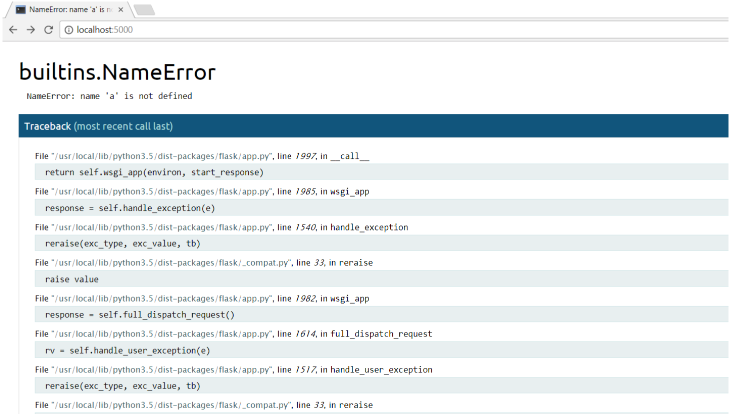
  `app.run(debug=True)`

- When you execute the script again, you will see

```
$ python app.py
 * Running on http://127.0.0.1:5000/ (Press CTRL+C to quit)
 * Restarting with stat
 * Debugger is active!
 * Debugger pin code: 211-226-346
```

Enabling Debug Mode

- If some exceptions occur during the execution of the Flask application, you will see a debug interface. For example:



builtins.NameError

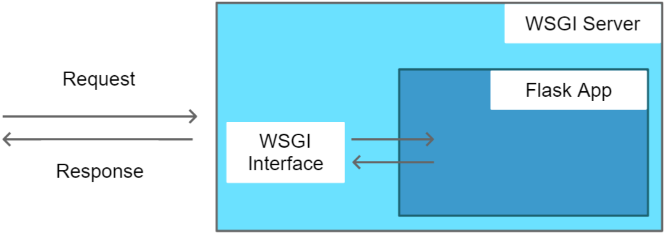
```
NameError: name 'a' is not defined
```

Traceback (most recent call last)

```
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1997, in __call__
  return self.wsgi_app(environ, start_response)
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1985, in wsgi_app
  response = self.handle_exception(e)
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1540, in handle_exception
  reraise(exc_type, exc_value, tb)
File "/usr/local/lib/python3.5/dist-packages/flask/_compat.py", line 33, in reraise
  raise value
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1982, in wsgi_app
  response = self.full_dispatch_request()
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1614, in full_dispatch_request
  rv = self.handle_user_exception(e)
File "/usr/local/lib/python3.5/dist-packages/flask/app.py", line 1517, in handle_user_exception
  reraise(exc_type, exc_value, tb)
File "/usr/local/lib/python3.5/dist-packages/flask/_compat.py", line 33, in reraise
```

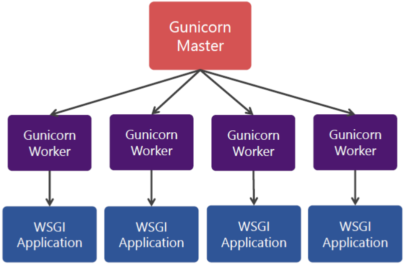
Deploying Flask Applications

- The internal Web server of Flask is only for **testing** and **development** purposes
- For deploying the application for production use, you need a proper HTTP WSGI server to **host** your application
- The HTTP WSGI server will load your application on start up, and route requests to the application



Gunicorn

- Gunicorn is a Python WSGI HTTP Server for Unix / Linux systems.
- It acts as a **container** of a WSGI application
- It manages one or more instances of the application (multiple workers)
- Architecture of Gunicorn
    - A **pre-fork worker** model
    - A master process managers the workers
    - Each worker process runs a **copy** of your application



```
$ pip3 install gunicorn
```

Gunicorn

- Basic Usage (See Documentation)

```
$ gunicorn [OPTIONS] $(MODULE_NAME):$(VARIABLE_NAME)
```

- For example:

```
$ gunicorn app:app -b localhost:8000 -w 4
```

- A Flask app called `app` defined inside a file called `app.py`
- Running on port `8000` on `localhost`
- Create **4** worker processes

Number of Workers

- Depends on your application's design and also the configurations of the server (e.g. number of cores of CPUs)
  - In general: **2n + 1**, where n = number of cores
  - Based on the assumption that half of the workers are doing I/O while half of the workers are doing computation
- There are **TWO** main types of Gunicorn workers
  - **Sync Workers**: Default type – handles a single request at a time
    - Suitable for applications that do not do something that consume an undefined amount of time or resources
  - **Async Workers**: For non-blocking request processing
    - Use this if your application has I/O bound operations (i.e. need to wait for I/O events to finish)

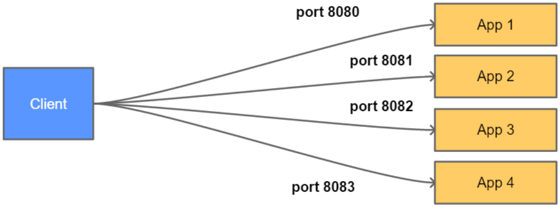
Example

```python
from flask import Flask
import time
import random
app = Flask(__name__)

@app.route(“/sleep/”)
def go_sleep():
    x = random.randint(1,3)
    time.sleep(x)
    return str(x)

if __name__ == "__main__":
    app.run()
```

- If you use sync workers, a worker can only serve a new request after one request has been finished
- Using async workers (e.g. gevent or eventlet), a worker will switch to serve another request while one is waiting for I/O (or any other blocking operation)

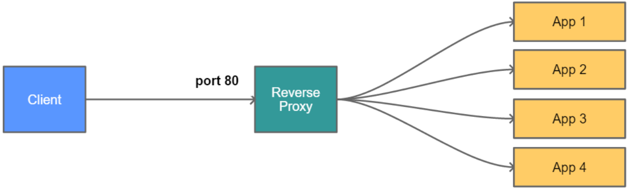
Running Multiple Applications

- It is common to have multiple applications running on the same machine
- If we allow clients to connect to each applications directly, we need to specify different port numbers



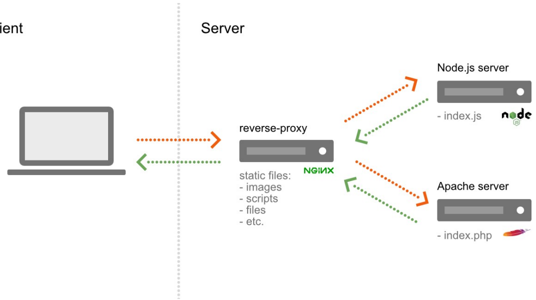
Reverse Proxy

- To make it easier for the client to make requests, we usually use a **reverse proxy server** to relay requests to different applications
- Clients always send requests to a **Web server on port 80**, which will **redirect** requests to different apps depending on the **URL**



Nginx as a Reverse Proxy

- **Nginx** is a Web server but can also be configured as a reverse proxy server
- It can proxy requests to another HTTP server or even a non-HTTP server
- It supports the following non-HTTP protocol: FastCGI, uwsgi, SCGI, memcached
- It can also serve **static pages** more efficiently, and also act a **cache**



Ref: https://medium.com/@francoisromain/setup-node-js-apache-nginx-reverse-proxy-with-docker-1f5a5cb3e71e

Configuring Nginx

- Nginx can be configured by editing the configuration files
- In Ubuntu, configuration files are usually stored under **`/etc/nginx/`**
- A main configuration file named **`nginx.conf`**
- One or more configuration files for each of the sites hosted by the server (see **`/etc/nginx/site-available`** and **`/etc/nginx/site-enabled`**)
- Examples and references: http://nginx.org/en/docs/http/load_balancing.html

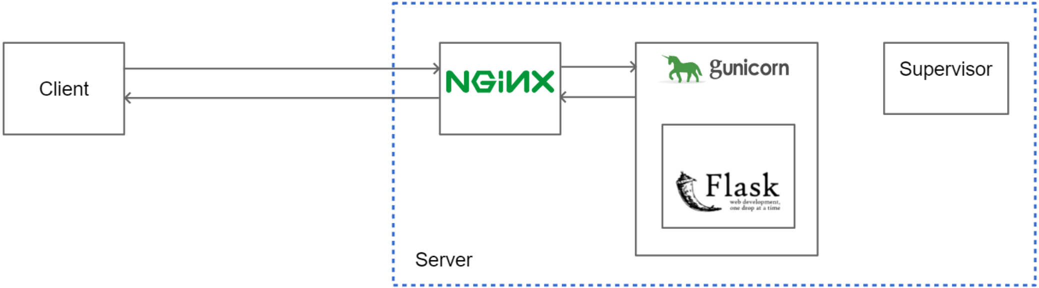
Supervisor

- Usually, we control the gunciorn process using Supervisor
- It is a **process control system** can be used to control and monitor other programs
- It can be used to **start/stop** a process, or automatically **restart** a process if it terminates
- Install via `pip3 install supervisor`
- An example config file (put under `/etc/supervisor/conf.d/`):

```
[program:myapp]
command = /home/albert/myapp/env/bin/gunicorn app:app -b localhost:8080
directory = /home/albert/myapp
user = albert
autostart = true
autorestart = true
stdout_logfile = /home/albert/myapp/log.txt
redirect_stderr = true
```

Summary

- Deploying a **Flask** app using **Nginx**, **Gunicorn** and **Supervisor**



End of Lecture 10