Web Servers

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Type	Lecture
Week	9
Lecture #	1
Lecture URL	https://youtu.be/OxWnwAmoJiQ
Notion URL	https://21f1003586.notion.site/Web-Servers-842fe13b76254cecad47416847ce471a

Web Server

Simplest possible HTTP server

- Open port 80 in "listen" mode — wait for incoming connections
- If incoming connection, read text, look for request
- Send back a response

Blocking connections with Flask

- Flask in “non-threaded” mode
  - https://replit.com/@nchandra/FlaskBlocking#main.py
- vs. Threaded mode
  - Default operation of Flask

Threaded Web Server

- Threaded server
  - Accept incoming request
  - Immediately start a thread to handle request
  - Go back and listen for the next request
- Limitations
  - Each thread consumes resources
  - Depends on the OS for handling parallel / concurrent execution
- **NOTE:** Threads are concurrent — parallelism depends on the hardware

Blocking server

- Client blocks until server responds
- Can be back for interactivity
- Need not block other clients
  - Depends on threading

Long running tasks

Example: face recognition on uploaded photos

- User uploads photos
- Server runs face detection on each photo
- Then face recognition against known database
- Alert when match found

Face recognition task problems

Blocking

- User uploads photo, but gets no response till task complete
- Cannot navigate away, do not know the response

Threading

- Only one user can upload a photo at a time?
- Large photos block server for a long time
- Uncontrolled thread creation drags down server performance

General Problem

- Should web server directly run compute intensive tasks?
    - Or stick to handling application logic, rendering, file serving?
- Can tasks be handed off to outside servers?
    - Specializeds for types of compute
    - Different scaling algorithms than web
- How should web server and compute servers communicate?
    - Automatically handle scaling
    - Allow easy task distribution

Asynchronous Task Frameworks

Goals:

- User can define set of tasks
- Web server can “dispatch” tasks to be executed later
- Asynchronous completion and updating possible

When to use?

- Response to user does not depend on execution of the task
    - Example: send email — can display a “sending” message and later update the status
- Example of when NOT to use:
    - API fetch: response must be based on result of API query
    - async task will not help since you will need to block and wait for response

- NOTE: this is NOT the same as async of the frontend
  - Async frontend with UI reactive update is still useful
  - But the frontend process should return with the correct response

Requirements

- Messaging / Communication system
  - Message queues
  - Brokers / Backends
- Execution system
  - Threads / Coroutines / greenlets ...
  - Concurrent models
  - Can be in another language, runtime, ...

Example: Celery for Python

Message Queues

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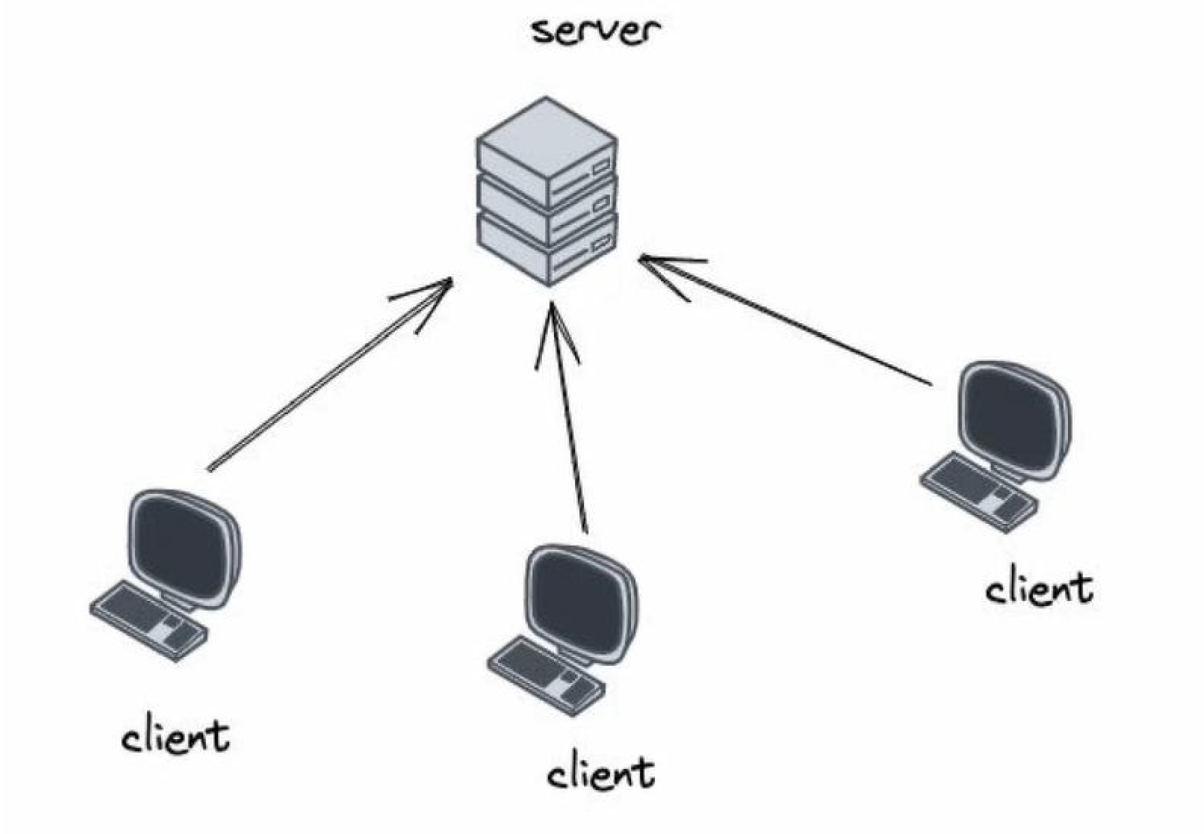
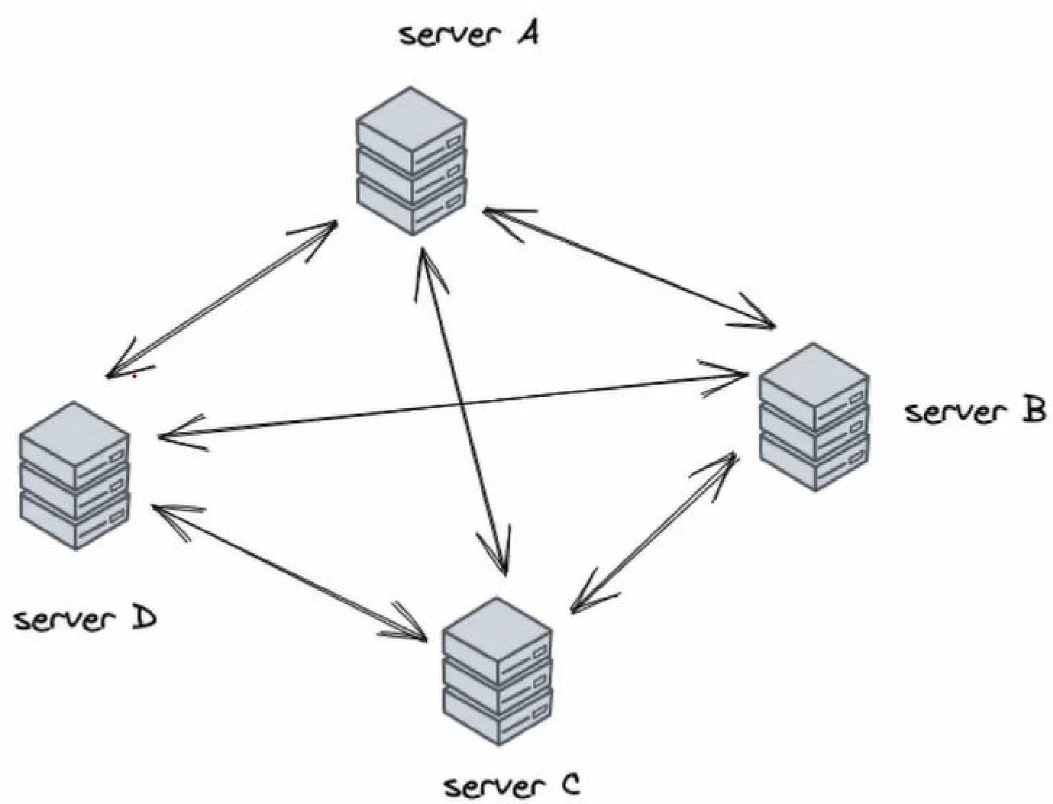
Client-Server



Server-Server



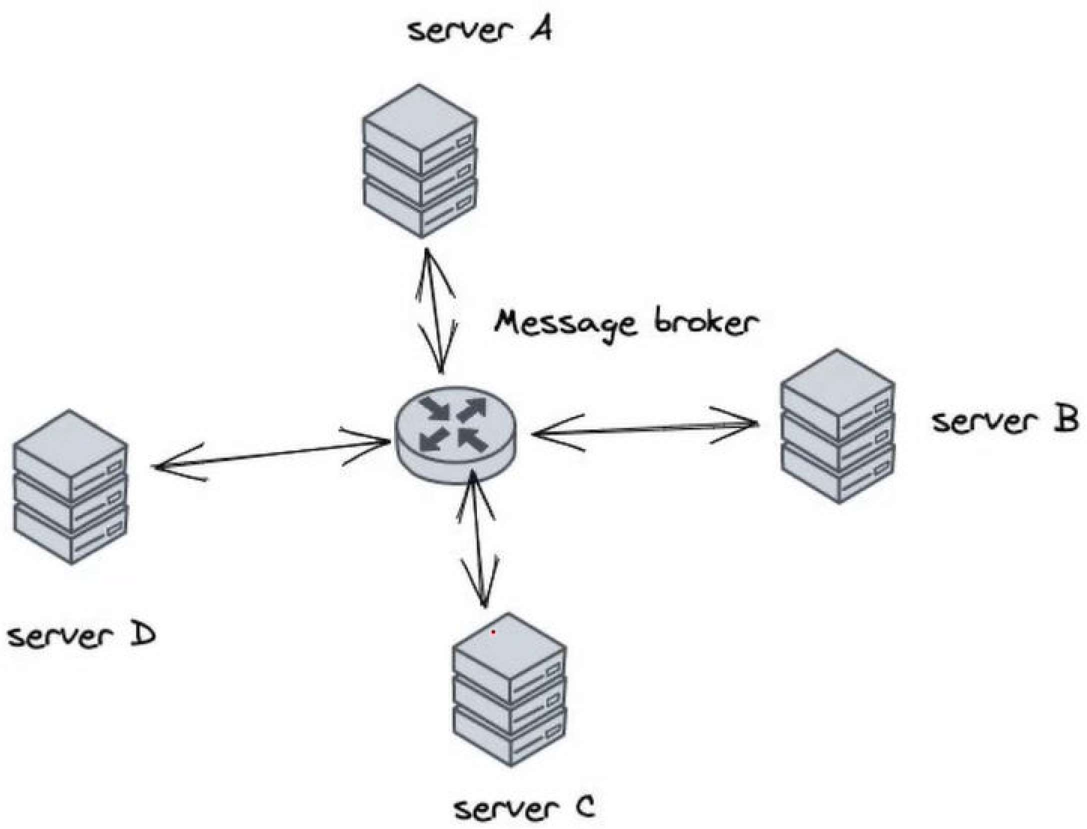
Communication between servers

- Many-to-many
  - Point to Point: too many connections
- Scaling
  - Add new servers
- Asymmetric
  - Not all servers need to talk to all others
  - Some produce messages, other consume
- Failure tolerance
  - Offline servers — failover
  - Busy servers — retry

Messaging

- Communicate through message queues or brokers
- **Decouple** message from execution
  - Server for execution sends a message — another server picks it up
- **Asynchronous** communication
  - No need to wait for response — or response may be delayed
- **Dataflow** processing
  - React to presence of messages
  - Automatically adjust to the rate of processing determined by activity
- **Ordered** transactions
  - First-in-first-out

Message Broker



Potential Benefits

- Scalability
  - Can easily add servers to consume messages as needed
- Traffic spikes
  - Messages retained in queue until processed — may be delayed, but not lost
- Monitoring
  - Easy point of reference for monitoring performance: number of messages unprocessed
- Batch processing
  - Collect messages into a queue and process them at one shot

Variants

- Message Queues
  - Mostly point to point: producer → queue → consumer
- Pub/Sub: Fanout

  - Producers publish without knowing who will read, multiple subscribers consume
- Message Bus
  - Analogy to hardware bus: multiple entities communicate over shared medium, addressable
- APIs/Web services
  - Direct point to point — communicate between services directly: less resilient, no storage
- Databases
  - A messages is a piece of information: store in databases — not normally well suited

Advanced Message Queueing Protocol — AMQP

- Standard similar to HTTP, SMTP
  - Details of how to connect, initiate transfers, establish logical connections
- Many open-source implementations
  - RabbitMQ, Apache ActiveMQ etc
- Broker
  - Manage transfer of messages between entities
  - “Message exchange” intermediary — clients always talk to the exchange
- RabbitMQ
  - Well suited for complex message routing

Redis

- In-memory database
  - Key-value store
  - Not originally designed for messaging at all
- Pub/Sub pattern
- Very high performance due to in-memory
  - But lacks persistence — data lost on shutdown

- Excellent for small messages
    - Performance downgrades for large messages

Summary

- Distributed systems need messaging
- Complex messaging patterns are possible
    - Point-to-point
    - Publish/Subscribe
- Many messaging systems exist
    - One more service to install and maintain
    - Useful at scale or for long running tasks
- Most useful in context of task queues

Asynchronous Tasks with Celery

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Task Queues

How can we manage large numbers of long running tasks without interfering with the ability to respond to user requests

- User request handler pushes task into a queue

    - First in, First out → Give priority in the order that tasks are issued or can have separate priorities
- Separate queue managers to handle execution of tasks and returning results

Asynchronous → in general no guarantees of timely response

Asynchronous Task Execution

- Language supported:
    - Python asyncio
    - JS async/await
- Guarantees of completion
- Reliable against server failure
- Ability to auto retry

General Principles

- Pushing a task onto a queue should be faster than executing the task
    - Else not worth using a queue — just finish the task
- There should be enough worker resources to empty the queue eventually
    - Else build up backlog and eventually overflow

Potential problems

- Problems like any other distributed systems
- Deadlock and related issues
    - Message system does not accept messages: block or lose data?
- Buffer sizing, overflows

Scenario: Push Queue

- Client pushes task onto server queue
- Server should start the operation “immediately”
    - May be delayed based on availability of resources, etc.
- Closer to “real-time” operation
- Example:

    - Update friend list in social media application: push updates to DB for all friends
    - Send emails: push emails onto queue to be sent out individually

Scenario: Pull Queue

- Clients can push tasks at any time
- Server “polls” queue at regular intervals
- Better suited to “batch-mode” operation
    - Generally not real-time
- Example:
    - Batch update of high scores in gaming server: periodic updates
    - Dashboard updates — process many log entries in batch and update periodically

Pull mechanisms

- Polling
    - Periodically check on state of queue
    - CPU / network intensive — repetitive function calls
- Long poll
    - Server keeps connection open until data present
    - Client blocks until data received

Examples: High End

- Google AppEngine
    - TaskQueue — APIs
- Tencent cloud
- AWS
    - SQS — Simple Queue Service — Messaging
    - Worker tasks implemented separately

Examples: General Use

- Celery — Python library
- RQ — Redis Queue
- Huey, Django-carrot, ...

We are mostly interested in Python APIs, but exist for most langauges

- Messaging systems are language independent
- Task queue builds on top of message system + language

Celery

- Python package for handling asynchronous tasks
- Requires a separate broker for messaging
- Also a backend for collecting and storing results
- Multiple celery instances can “auto-discover” through the messaging system
- Abstracts away the messaging system to focus on tasks

Using Celery

- Problem: Multiple moving parts
    - Message broker
    - Result collector
    - Celery instance to run workers
    - Actual code
- Installing and managing needs care
- Use when needed
- Can use on platforms like replit
    - Requires a little extra work