Emailing Service - High Level Design

Requirements

- **Prioritized requirements**
  - Implementing **service registration and proxies**
  - Allowing User **registration, login (2FA) and profile creation.**
  - Set **preferences** for emails and **tagging** them.
  - Sending email with attachments.
  - Using keywords to search emails.
  - **Spam** and **virus** detection.
  - Making **contacts** and **groups**.

Capacity Estimation

Number of users: 2 Billion **Number of devices per user**: 2 **Number of users opting for 2-step verification**: 10% ~ 200M **Assume an attachment is on average** = 1 MB

- **Storage needed per day to store emails**
  - **Assumptions**
    - Number of characters: 200
    - Number of spam emails: 20
    - Number of marketing emails: 20
    - Number of important emails: 10
    - Percentage of emails that have attachments: 5%
  - Email storage = Number of emails * Number of characters * Users = 50 * 200 * 2000000000 = **20TB**
  - Attachments storage = Numbers of emails with attachments * Attachment size = 5% * 50 * 2B * 1MB = **5PB**
  - Storage needed without redundancy = **(5PB + 20TB)**
  - Taking redundancy into account = 3*(5PB + 20TB) = **15PB**
  - We can store hash of contents of emails and storing only one copy.
  - So, number of emails: 15
  - Total space required: 15PB * 15/50 = **4.5PB**
  - Compressing 50% of (old) emails = **2.5PB** per day
- **Storage needed per day to store profile data**
  - **Assumptions**
    - Number of characters in name: 15
    - Number of characters in DOB: 8
    - Number of characters in email address: 20
    - Percentage of users that have profile pictures: 10%

        - Size of profile picture: 100kB
    - Total data (without profile pictures) required = 2B * (15+8+20) = **100GB**
    - Data required to store profile pictures = 10% * 2B * 100kB = 20TB
    - Total data required (taking redundancy into account) = 3 * (20TB + 100GB) = **60TB.**
- **Processing power needed by virus checker service**
    - **Assumptions**
        - Time required to check each mail: 5 I/O operations
        - Time required for each I/O operation: 0.02 sec per MB
    - Total time required to check all emails = (1.5 * 10^9 MB) * (5 * 0.02 sec per MB) = 1.5 * 10^8 seconds = (1.5 * 10^8)/(24 * 3600) days = **1500 days**
    - We need 1500 virus checker processes to check all emails in 1 day.
    - Assuming we are running virus checker at 50% capacity and want to handle possible spikes in load, Number of virus checker processes required = 1500*4 = **6000**
- **Processing power needed by spam detector service**
    - **Assumptions**
        - Time required to check each email: 5 I/O operations
        - Time required for each I/O operation: 0.02 sec per MB
    - Number of emails = 2B * 15 = 30B
    - Size of each email = 200 bytes
    - Total email data = 30B * 200 bytes = 6 TB
    - Total time required to check all emails = 6 * 10^6MB * (0.02 sec per MB * 5) = 6 * 10^5 seconds = (6 * 10^5)/(24 * 3600) = **6 days**
    - Therefore, we need 6 processes to check emails in one day.
    - Assuming we are running spam detector at 50% capacity and want to handle possible spikes in load, Number of spam detector processes required = 6 * 4 = **24**
- **Cache storage required to store contact details**
    - **Assumptions**
        - Number of active users = 1% of total users = **20 million**
        - Each user appears in **10** contact lists.
        - Number of unique active users = **2 million**
        - Fault tolerance = **3**
        - Localized processing = **10**
    - Total cache storage required = 2 million * 100kB = **200GB**
    - Number of machines if we take 64GB machines = **4 machines**

  Total storage required taking fault tolerance and localized processing into consideration = 4 * 3 * 10 = **120 machines**

Requirement 1: Implementing service registry

Description

We need a gateway to receive external requests and route it to correct internal services. Whenever a service is switched on, it registers itself. So the registry maps the method to the service. We also need to implement service registry so that it checks if other services are operational or not.

Components required

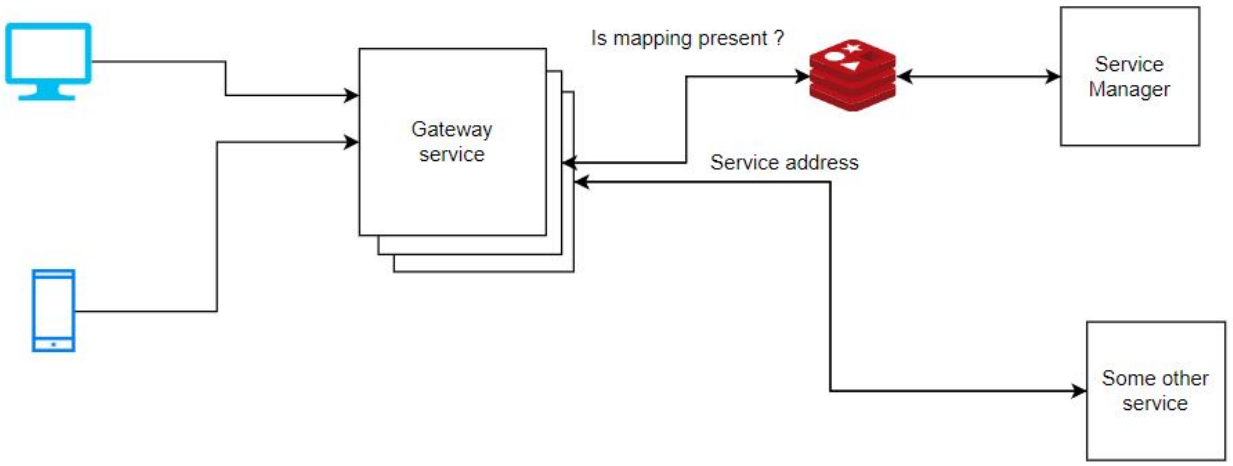
- **Distributed gateway service**

    - Blocks malicious IP addresses (Rate limiting).
    - Routes external requests.
    - Translate requests. (HTTP to other protocol).
- **Service Manager**
    - Keeps the registry which maps the methods to handlers.
    - It has a heartbeat mechanism that checks if the service is alive or not
- **Distributed cache**
    - Since the mapping does not change frequently we can store the mapping in cache.

Trade-offs

- **Storing registry in Gateway service v/s Storing service registry in service manager**
    - If we store the registry in the service manager then we can access it only through network calls (every time we get a request) which is comparatively slower than inter process calls.
    - If we store the registry in the Gateway service then it has to handle a lot of responsibilities. By storing registry in service manager we are decoupling the system and reduce load on one component.
    - **So we should implement service manager to store the registry**

Diagram



Requirement 2: Allowing users to login (2-FA) and register

We need to implement an auth service that allows users to log in using two-factor authentication and allows new users to register. We also need a profile service.

Components required

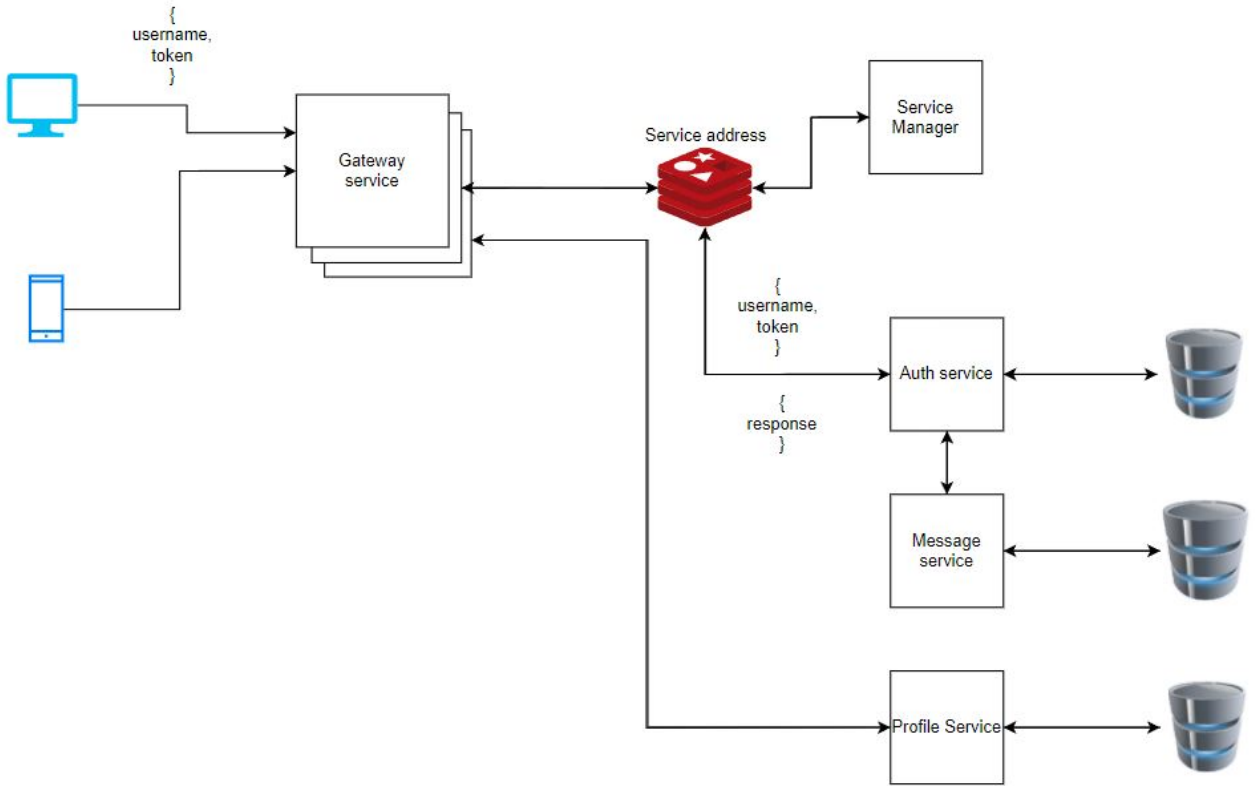
- **Auth service**
    - It checks if username exists in database and the password is valid.
    - It also needs to validate the one time code (within a fixed time interval), sent to user of two-factor authentication.

    - Furthermore, it also checks if the user is verified or not.
    - It also updates the cache every time user data is updated.
- **Message Service**
    - It sends the one time code to the user via email, SMS etc.
    - Furthermore, it has message templates for various cases.
- **Database**
    - For auth service it stores the name, encrypted password and one time code and the user secret token which is used to authorize user.
    - For message service it stores the templates.
    - Profile service database stores details related to user.
- **Profile Service**
    - It handles all the requests that involves creating and editing of profiles.
- **Distributed cache**
    - User token is stored in the cache. So instead of making API call to auth service every time we make a call to cache which is more efficient.

Trade-offs

- **Using in-memory cache in gateway service v/s using distributed cache**
    - If we are using in memory cache then we will have additional code and logic and more memory needs to be allotted which will result in bloated service.
    - If we are using in memory cache then there is cache duplication because gateway service is a distributed service, and it has multiple nodes. So updating cache will cause update fan out.
    - If we are using in memory cache then we can access it using in process call which is faster than network calls to global cache.
    - **So it is better to implement a global cache**

Diagram



Contract Registry

- We get data in JSON format, and we need to convert it to programming object.
- A contract tells the service how to convert JSON object to a programming object.
- Different services can have different contracts.
- We use contract registry to store all API contracts.
- Whenever there is a change in contracts services can pull the new code from contract registry. This can be done either manually or we can restart the service.
- API contracts should be language independent.
- Versioning contracts is important because it provides backwards compatibility, allows users to switch to new contracts whenever they want and, we can avoid breaking changes.

Requirement 3: Sending, Tagging and Searching emails

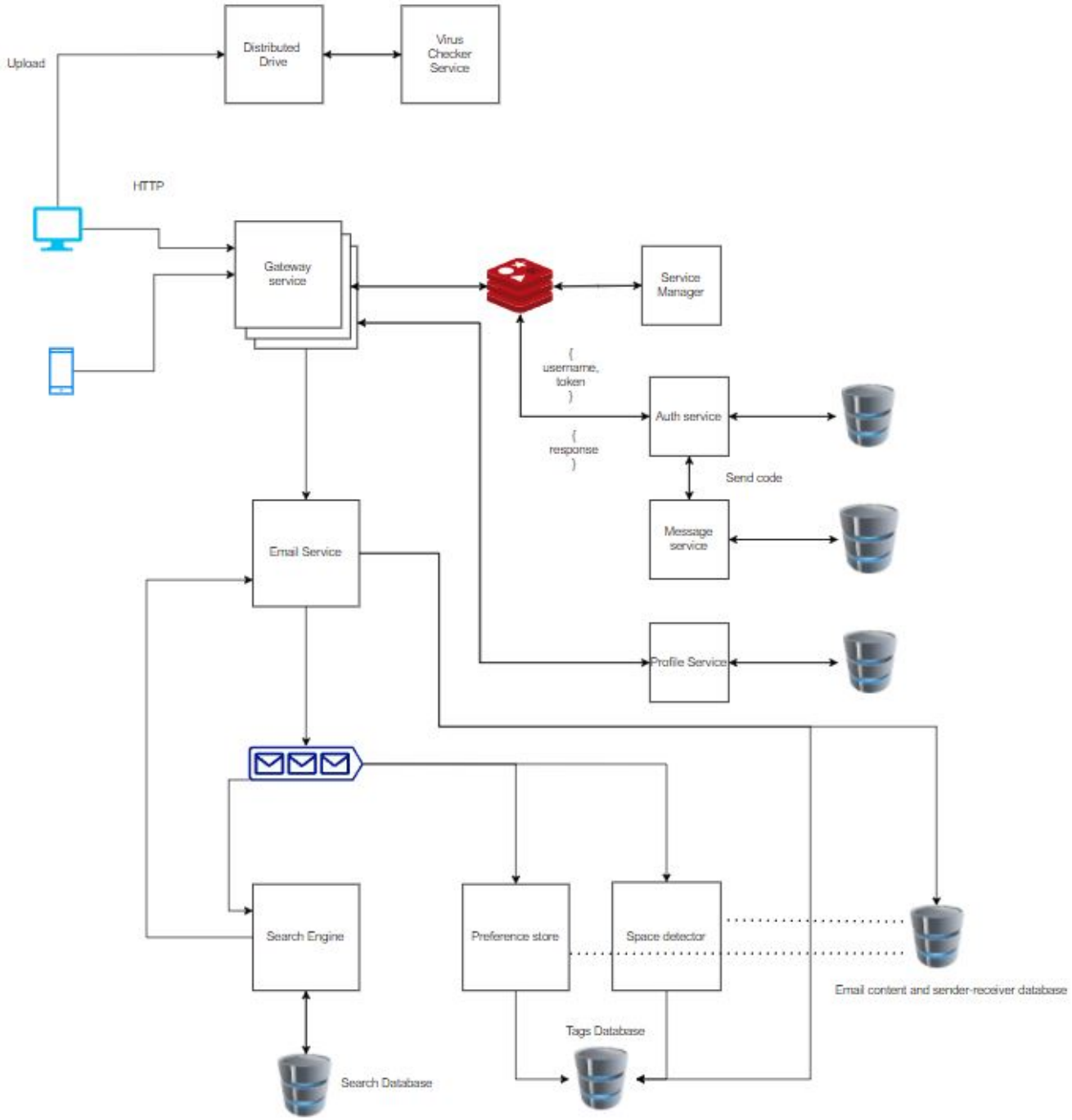
We need to implement services that can send emails and receive to/from same and different domains and tag them. We need to implement a search engine to find emails by keywords. Also, we need a spam detector and a virus detector service.

Components required

- **Email service**
  - It receives email content, sender and receiver address from the user and.
  - It also gets emails from the search engine service and sends it to user.
- **Message queue**
  - It receives email from the email service and sends it to preference and spam detector service.
- **Search Engine service**
  - It maps keywords in emails to their location.

    - It uses inverted index system to map content to its location.
- **Spam Detector service**
    - It checks the content/subject of the email and also the timestamps of emails to determine if the emails are spam or not.
    - It can check the emails in regular intervals (like cron job) or whenever there is a new email.
- **Message queue**
    - Whenever there is a new email, email service publishes an event to message queue. Different services like spam detector and search engine pulling events from message queue.
- **Virus Detector service**
    - It checks the content and attachments of emails for any virus.
- **Distributed File Service**
    - It stores all the attachments of emails.
- **Preference service**
    - It pulls emails from the message queue and assigns preference to emails.

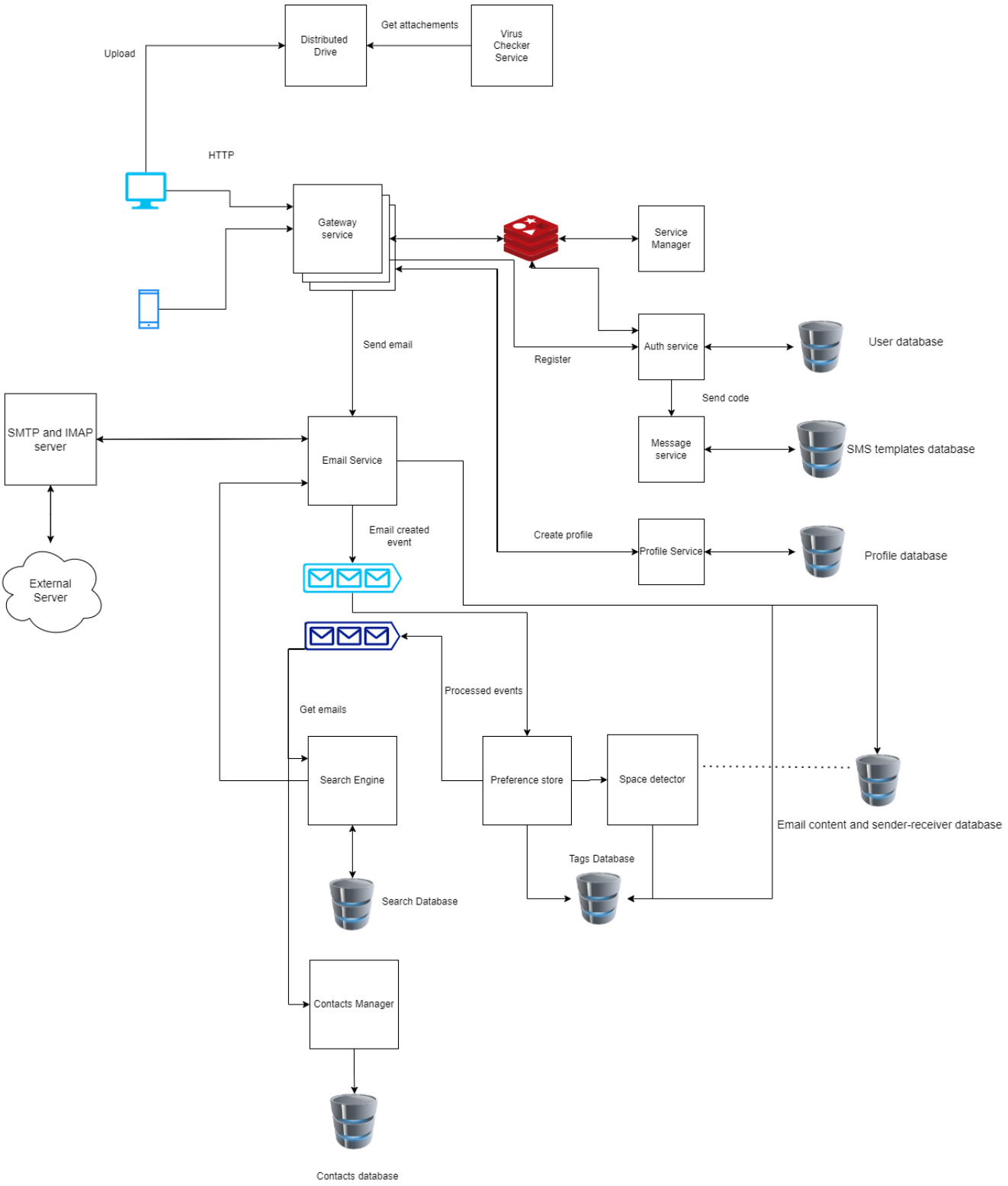
Diagram



Requirement 4: Managing contacts and groups

Components required

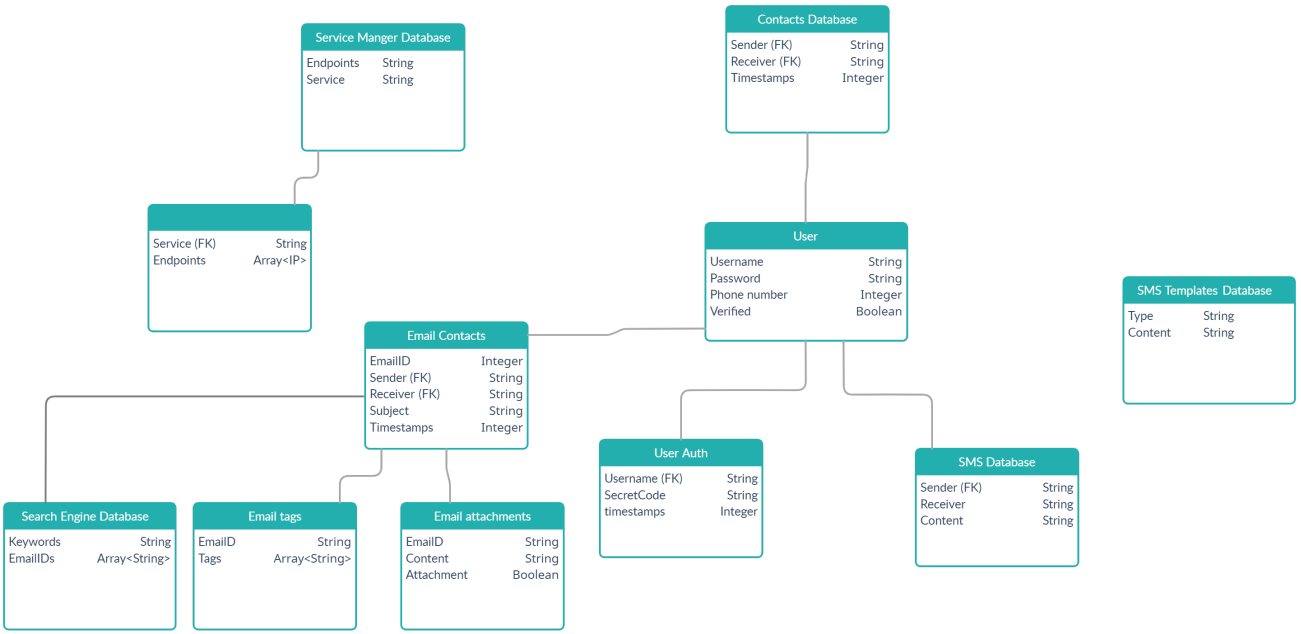
- **Contacts Service/ Contacts Manager**
  - It pulls processed emails from the message queue.
  - It keeps the mapping of sender to receiver.
- **Message queue**
  - The processed email events are pushed to this message queue.
  - Search Engine and Contacts manager service pull processed emails from this queue.
- **SMTP Server**
  - SMTP stands for Simple Mail Transfer Protocol. It sends emails to external server.
- **IMAP Server**
  - IMAP stands Internet Message Access Protocol. It receives emails from external server.



- **API Contracts**
  - **Gateway service**
    - void blockIPAddress(IPAddress, endpoints[] , duration)
  - **Service manager**
    - void Register(service, ipAddresses[], endpoints[])
    - Service routeRequest(service, request, apiEndPoint, user)
  - **Auth service**
    - void register(username, password, phoneNumber)
    - void login(username, password)
    - token verify(username, otp)
    - bool authenticateUser(usernamme, token)

        - void logout(username, token)
    - **Contact Registry**
        - void Register(service, contract)
    - **SMS Service**
        - void sendSMS(receiver, sendingService, smsTemplate , params)
    - **Profile service**
        - void createProfile(username, token, profilePictureURL, DateOfBirth, Gender)
        - void updateProfile(username, profile)
        - void deleteProfile(username, token)
        - Profile getProfile(username)
    - **Drive service**
        - void uploadFile(file, directory, uploader, accessControlList)
        - void deleteFile(file, directory)
        - File getFile(fileName, Directory, user, requestingActor)
        - File[] getFiles(fileNames[] , user, requestingActor)
    - **Contacts service**
        - void makeContact(sender, receiver)
        - void deleteContact(sender, receiver)
        - Group makeGroup(creator, members, name, groupPhotoURL)
        - void deleteGroup(groupID, groupMember)
        - void addMembers(groupID, user, members)
        - void updateGroup(groupID, user, groupName, groupPhotoURL)
        - User[] getUsersWithRoles(groupID, roles)
    - **Email service**
        - Email sendEmail(sender, receiver, content, attachments)
        - void deleteEmailFor(requesterID, emailID)
        - Email getEmails(receiver)
        - Attachement[] getEmailAttachements(emailID, requester)
    - **Search Engine service**
        - Email[] search(searchParams)

Database design



That's it for now!

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