CS3217 Final Report: Sotravel

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Overview

The sotravel application is designed to aid the startup sotravel.me manage their trips.

Context

Sotravel.me organises group adventure travel for young adults. The aim of the startup is to allow young adults to go on adventurous trips such as skiing or diving and make friends in the process. The company has a ski trip slated for April 2023. The goal of the application is to allow trip hosts to publish events within the trip and invite participants to these within-trip events, track the physical location of participants, and allow trip hosts and participants to communicate with each other.

Features and Specifications

Host features

- Log in/Register with Telegram
- View all traveller locations on a map (in real-time)

Traveller features

General

- Log in/register with Telegram
- Switch between active trips

Events

- Allow travelers to create events
- Allow travelers to RSVP to events
- Create and send out event to people nearby, friends only or selected people

Profile

- Allow travelers to update their profile with social information

Friends

- Allow travelers to view friends on the trip and message them on Telegram

Map

- Depending on where the user is at, load the correct map. Mountain map vs street map.
- View all nearby traveller locations on a map (in real-time)

In-app instant messaging

- Provides an easy means of communication between group members
- Helps to ensure a degree of privacy as users do not need to share more personal information like Telegram handle or phone number

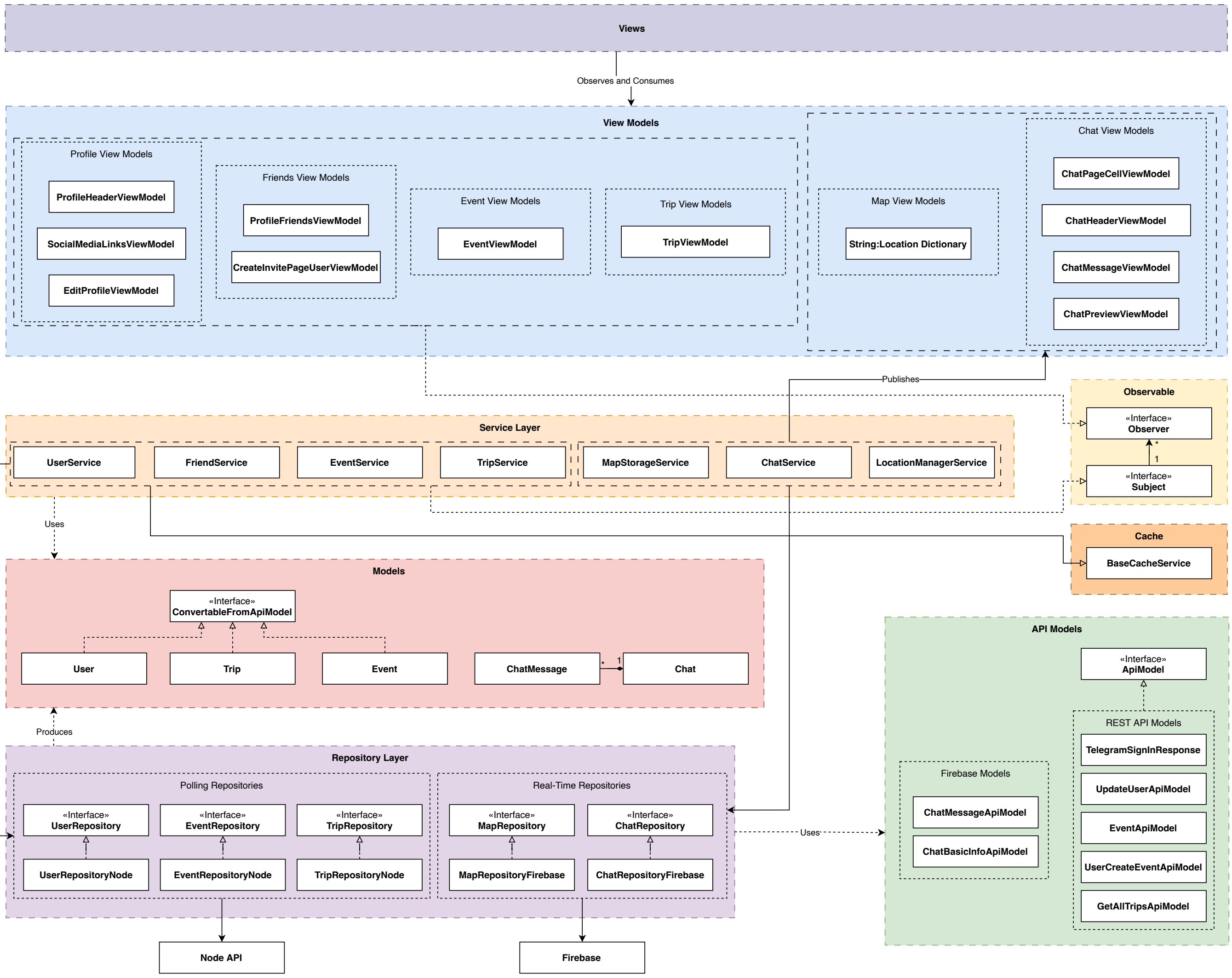
User Manual

Please see User Manual

Designs

We will break down the applications design into 2 parts, the backend and frontend. For ease of understanding, the backend specifically refers to the part of the codebase that does not directly deal with the views. This can be thought of as the components that do not directly deal with the views. The frontend is the set of components that do deal with the views (and presentation more broadly).

Overall architecture



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The overall architecture can be seen above. We can categorise the system into the following components

- Repository and API models
- Models
- Service and ViewModels
- Views

The respositories handle retrieving/updating information from the data store. In our case, the repositories communicate with Firebase as well as a backend REST API written in NodeJS.

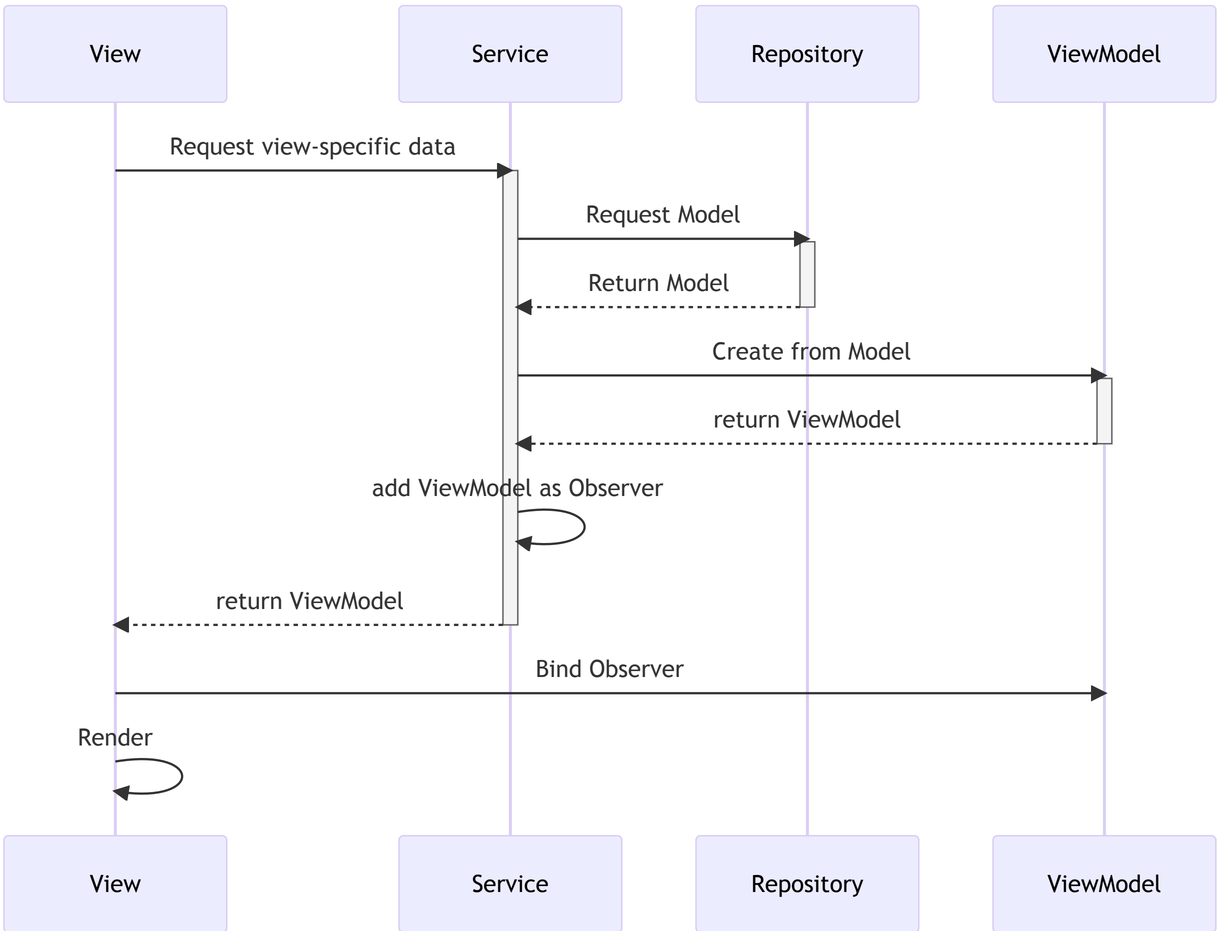
The Models are the internal representation of key information within the trip. The API models (which are representations of data from the data source) are converted into models which are used as the source of truth for the Service layer and the front end.

The Service layer consumes the models and publishes ViewModels which contain view-specific information. The ViewModels contain only the information required for a specific View. Thus, they prevent irrelevant information from being leaked to the View.

The Views consume the ViewModels and set up an observer relationship with them. This allows the views to be updated when a ViewModel is updated, without repeatedly setting the values of UI elements such as text boxes. In effect, this allows for a 1-way binding relationship.

Flow of data

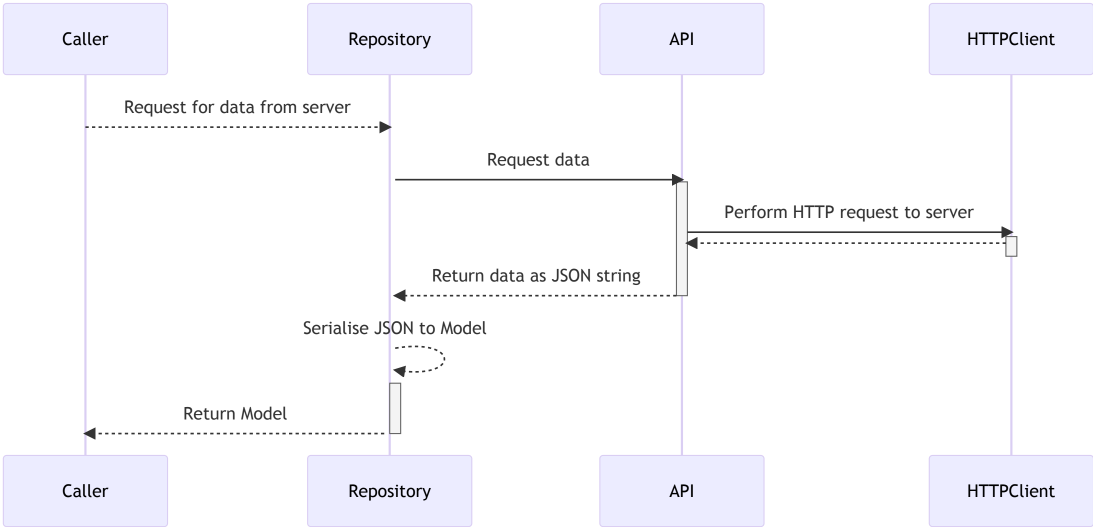
The backend of the application adopts a 3 layer architecture approach. A generic model of how the backend obtains data is shown below



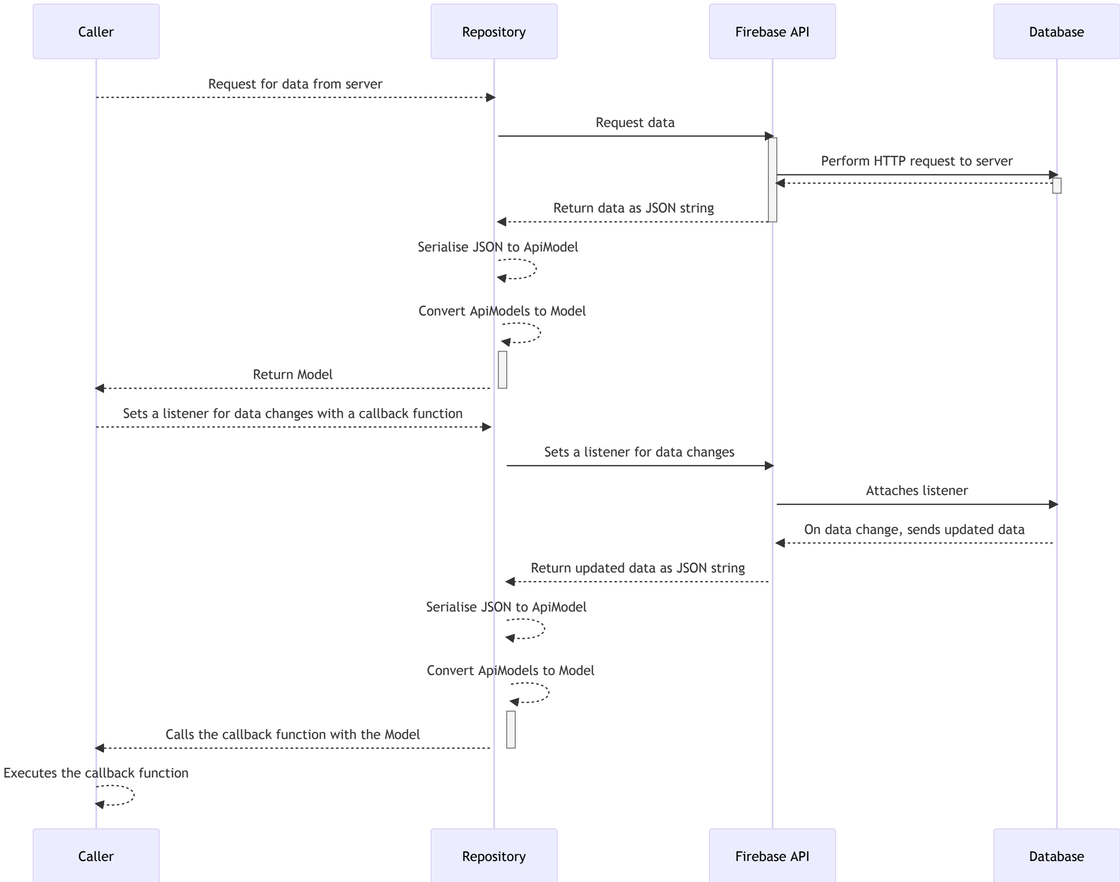
The high level idea is as follows:

- A repository for each data model exists to retrieve information from a data access layer. The repository conforms to an interface so that it can easily be swapped out later in favour of a repository that pulls information from a different data source.

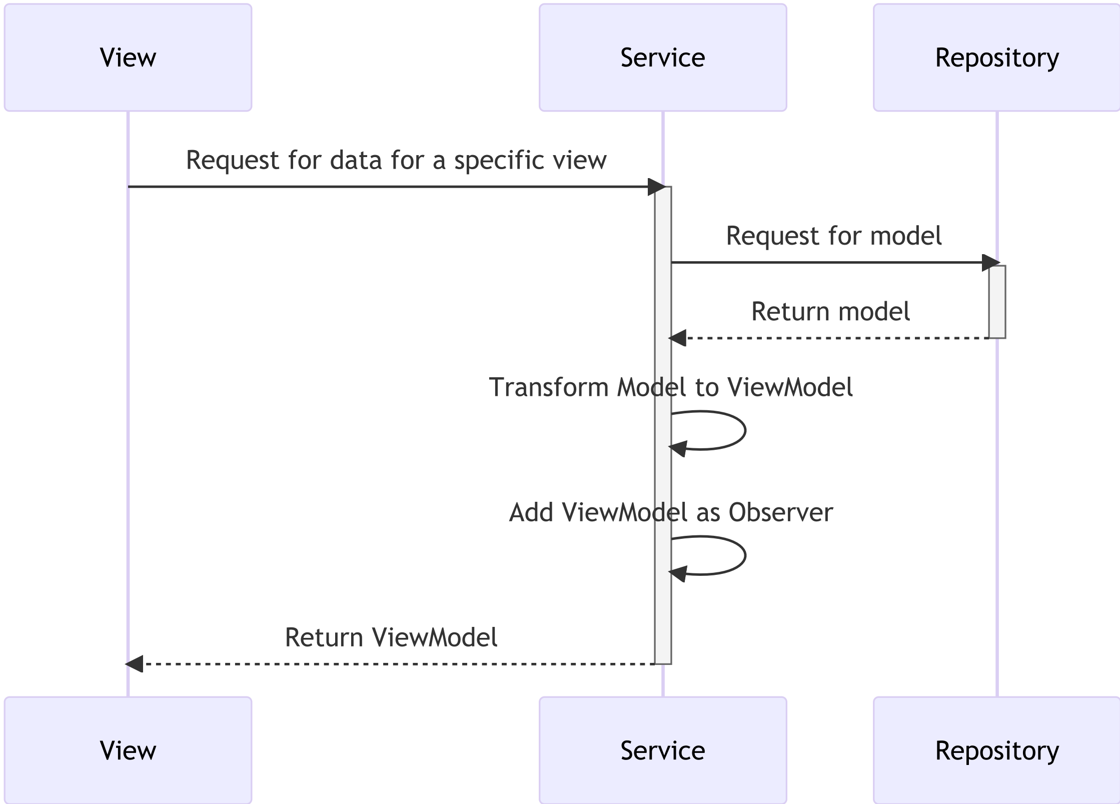
- The diagram below shows how a repository gets data from a REST API



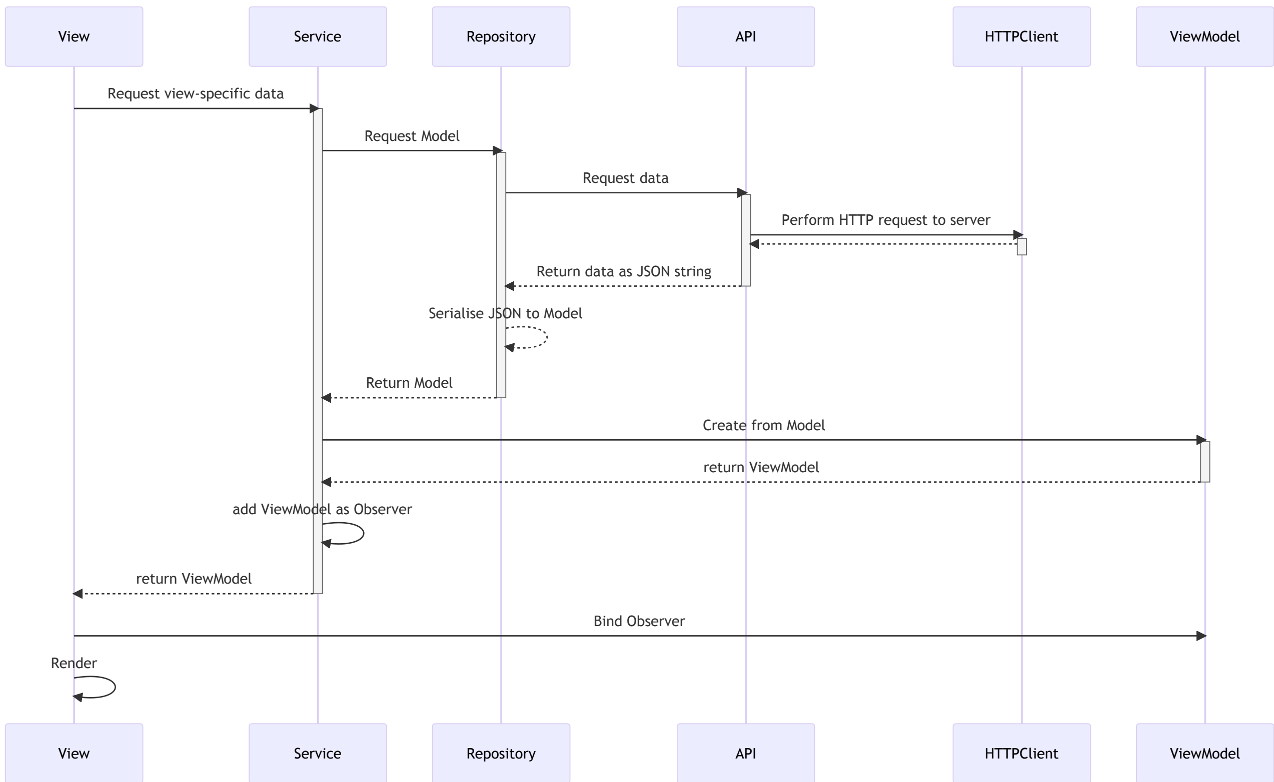
- The way a repository gets data from a (Firebase) database is similar, but also attaches a listener so as to get notified of any data changes:



- A service exists for that data model. It contains a dependency-injected repository. The service converts the model into a view model which the view can consume
- A view contains a reference to a service which generates a view model. The view observes the viewmodel to reflect changes to the data.



The 3 layers put together show how data is called from each layer



The `Repositories` for each model conform to an interface and are dependency injected into each `Service`. Dependency injection is done through property wrappers. This allows for the following benefits:

- Repository implementation can easily be changed. Today we suffix many of the concrete implementations with "Node" since our data source is essentially a Node API, but in the future the data source may change

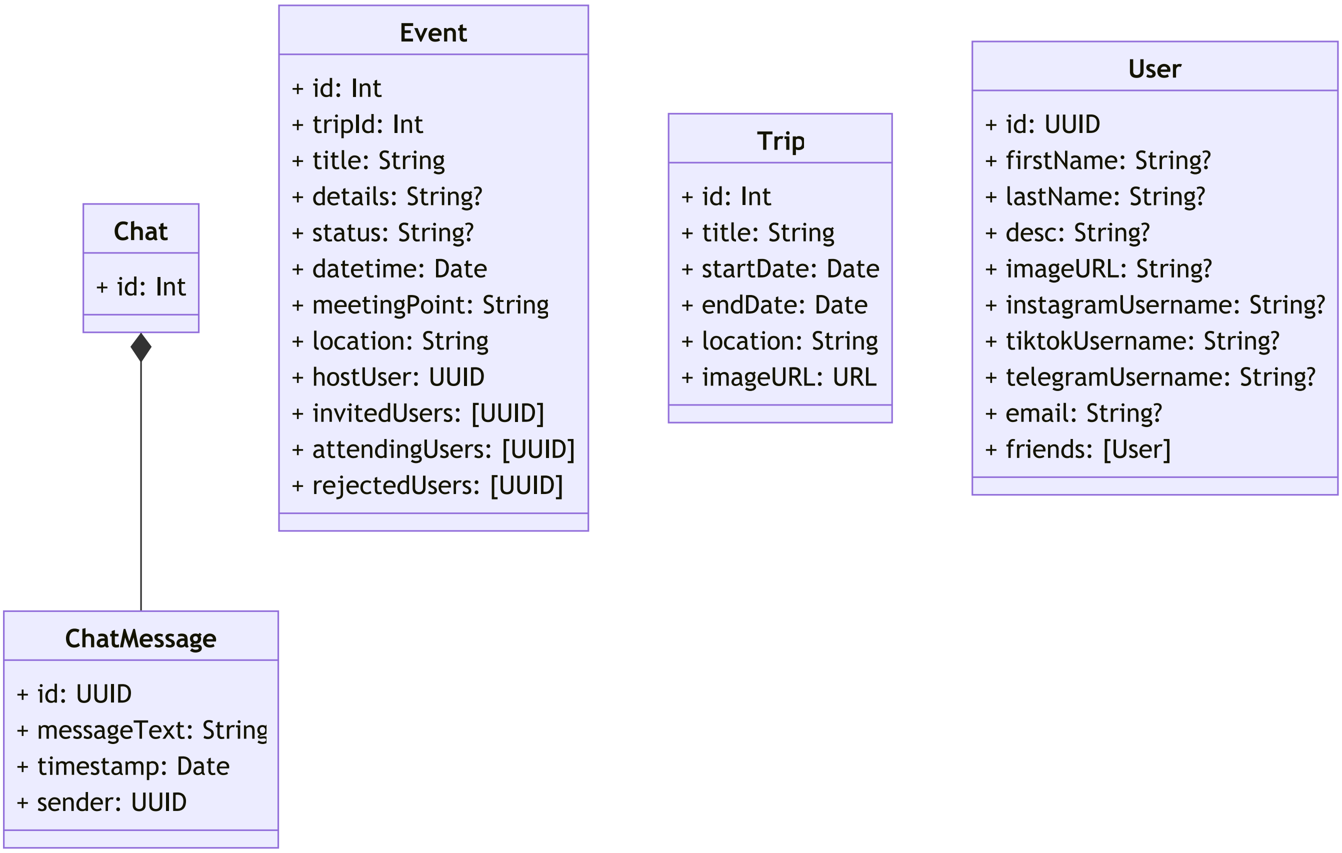
- Dependencies are not injected through constructors, preventing a "carrying" effect where each layer needs to pass dependencies down
- Testability is greatly increased as dependencies can easily be replaced with stubs/mocks. We already use such stubs/mocks of repositories such as the `UserRepository` to provide mock data during testing.

Frontend

The frontend is relatively straightforward, following an MVVM architecture. A `Service` is injected into each `View`, and the `View` observes a `ViewModel` returned by a `Service`. When the service is requested to provide new information, it obtains the information required and notifies the ViewModels observing it that there has been a change. The ViewModels then update themselves and these changes propagate to the View since the View is observing the ViewModel. Greater detail on how the Observers are set up can be found below under the section Service-ViewModel observer relationship

Models

The application has 5 key models it makes use of. They are defined below.



These models are enough to ensure that all the key data for the application can be derived.

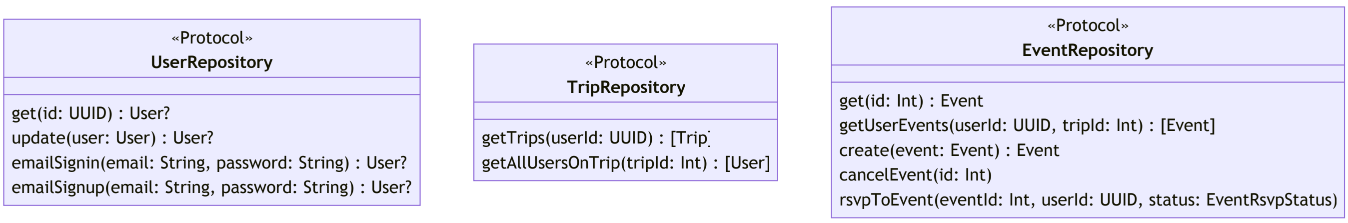
Repositories

The application makes use of 5 repositories. These repositories primarily perform CRUD operations on their respective models, and persist those changes to their respective persistent storage services (Firebase or REST API.)

All of them except `MapRepository` produce the models seen above. `MapRepository` listens for user coordinates and produces use of built-in datatype `CLLocation` instead. As a result, to avoid bloat, an encapsulating model does not exist for the information produced by the `MapRepository`.

Pull Repositories

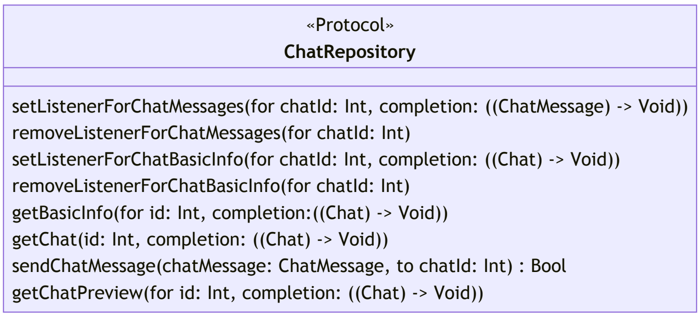
`UserRepository`, `TripRepository` and `EventRepository` pull information from a server when requested. In other words, they operate on a polling/pull basis.

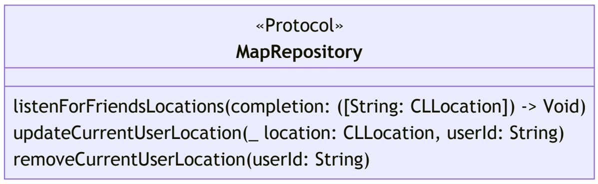


Push Repositories

On the other hand, `ChatRepository` and `MapRepository` operate on a push basis, with information pushed to them from the real-time data store. To register changes in the data, they take in delegates to update their respective callers when there is a change in data.

These delegates are termed as `completion` handlers, and are passed in to the respective repository functions that listen for changes in data on the database's side.





Data conversion

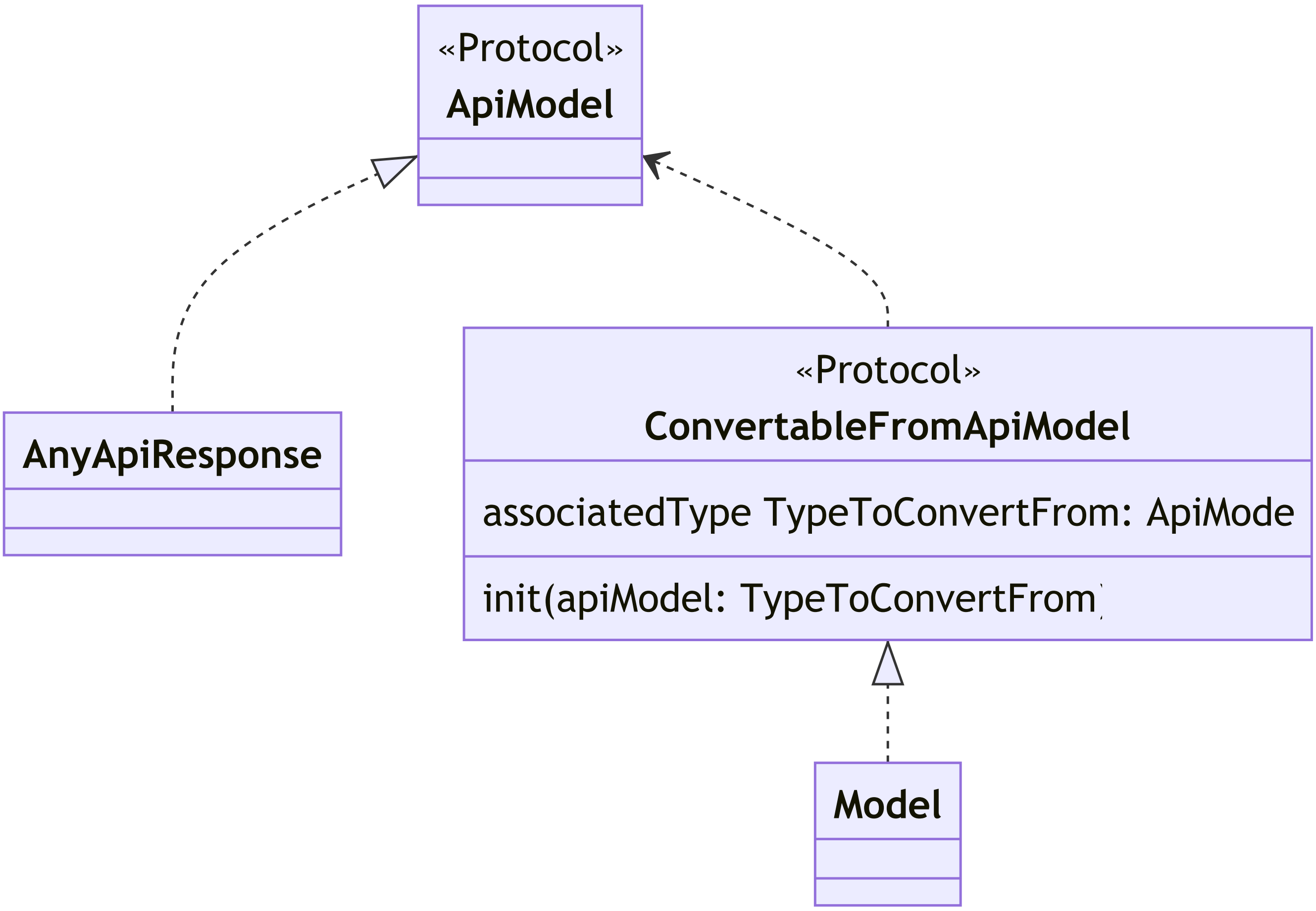
The repositories work in terms of `APIModels`, which are Swift classes that represent the JSON response returned by the server. However, the application itself fundamentally works in terms of `Model`s which mirror the data consumed by the application. Thus, the repositories needed essentially perform the following tasks:

1. Retrieve relevant data as JSON string from server
2. Decode JSON string into API Model type
3. Handle JSON decoding errors if any
4. Convert API Model Type into Model type
5. Return Model to caller

In particular, steps 2-5 were repetitive steps that every respository method needed to implement. Writing the same code to perform these tasks resulted in a lot of code reuse. Thus a generic `DecoderHelper` was created that made use of Swift's associated types and type inference to convert `APIModels` into `Models`

We linked the `APIModels` and `Models` through protocols `ConvertableFromApiModel` and `ApiModel`. The `ConvertableFromApiModel` protocol specified a constructor that would allow the `Model` to be initialised from an `ApiModel`.

The relationship between these protocols and classes can be seen below:



One major benefit of using associated types here is that it allows the `Model`'s constructor to specify which specific sub-type of `ApiModel` it is able to convert. This improves type safety within the application and prevents issues such as a User model trying to be initialised from an Event API model.

The code snippet that handles this conversion can be found in the file DecoderHelper.swift. It has been replicated below as well:

```
static func decodeToClass<ReturnType: ConvertableFromApiModel>(data:
String, location: String = #function, line: Int = #line) throws ->
ReturnType {
        do {
            let responseModel = try
JSONDecoder().decode(ReturnType.TypeToConvertFrom.self, from:
Data(data.utf8))
            return try ReturnType(apiModel: responseModel)
        } catch is DecodingError {
            let modelName = String(describing: ReturnType.self)
            let prefix = constructErrorPrefix(location: location, line:
line)
            throw SotravelError.message(
                "\(prefix) Unable to decode json at \(location) to \
(modelName). The JSON string is \(data)")
        } catch {
            throw error
        }
    }
```

A similar snippet exists to decode into lists instead of singular types as well.

Services

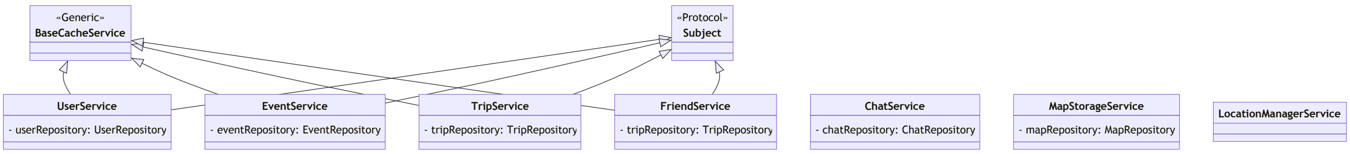
There are 7 main services used in the application:

- UserService
- EventService
- TripService
- FriendService
- ChatService
- MapService
- LocationManagerService

Most services interact with their respective repositories for data storage purposes (e.g `UserService` interacts with `UserRepository`). However, there are 2 main excpetions:

- `LocationManagerService` interacts with the built-in `CLLocationManager` which interfaces with the device's GPS module
- For better coherence, `FriendService` interacts primarily with `TripRepository` to return the users who are going on a specific trip

Each of the services can be seen below, alongside the Repositories they hold a reference to



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Of the 6 services, `UserService`, `EventService`, `TripService` and `FriendService` are observed by the `ViewModels` they serve. Since these services create the `ViewModel`s, they register the `ViewModel`s as observers which are notified when the underlying `Model`(s) change. We explain this in detail in the section Service-ViewModel observer relationship

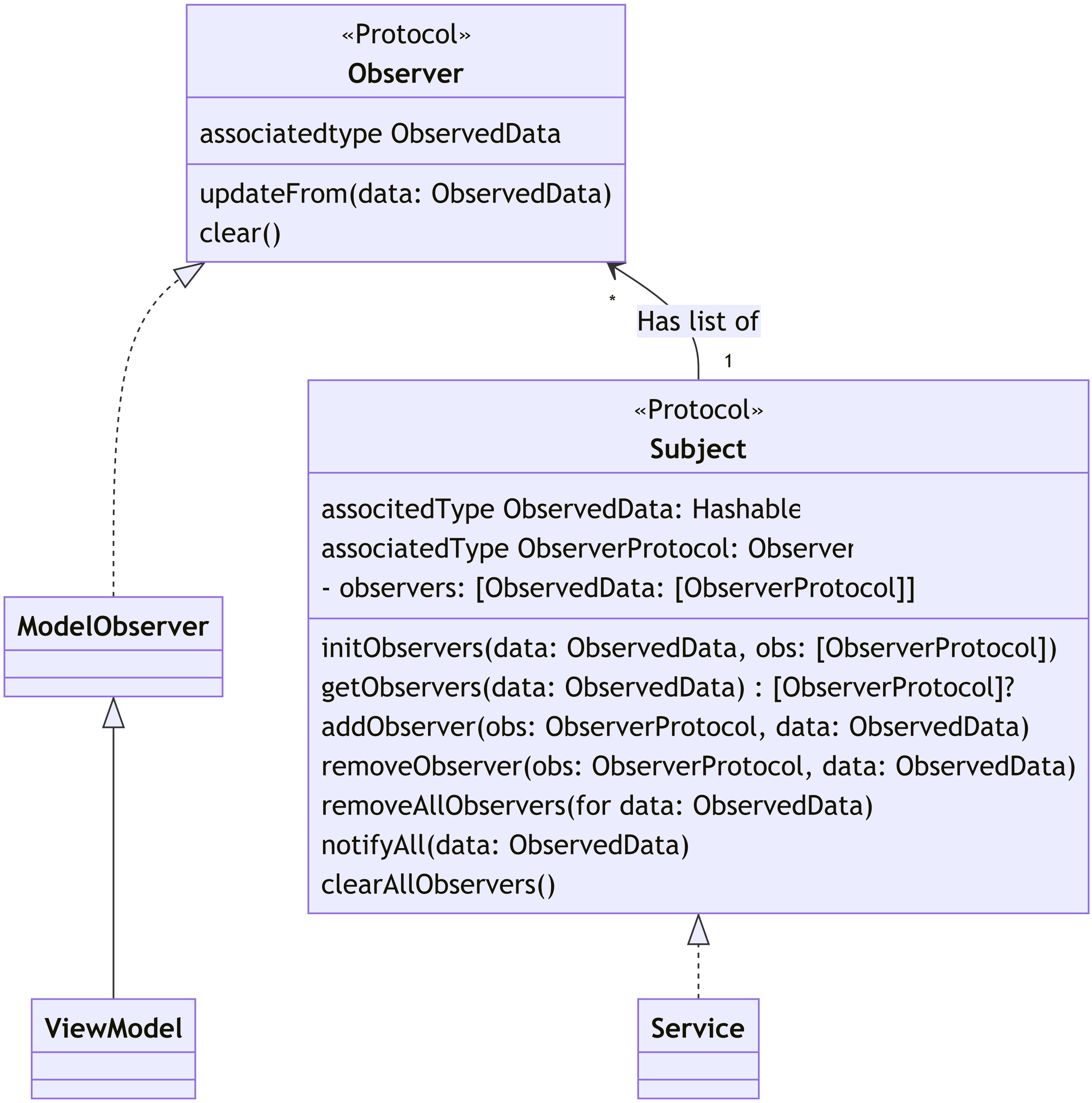
In addition, the same 4 Services also work with models that may regularly need to be retrieved but that information does not necessarily need to be up to date. To reduce the frequency of calls to the backend, they subclass the `BaseCacheService` class and ensure that data retrieval is attempted from a local cache first. This has improved the speed of the application, resulting in a better UX. We explain this in detail in the caching section.

Service-ViewModel observer relationship

To decouple the `Service` from the `ViewModel`s it serves, an observer pattern was set up so that the `ViewModel` can observe the `Service` from whom it pulls data. This ensures that

- `Services` don't hold direct references to the `ViewModel`s who rely on it, decoupling them through the observer abstraction
- The responsibility of updating the `ViewModel` is passed back to the ViewModel, instead of the `Service`

The pattern is set up as shown below:



The observer pattern allows for the `Service` to inform its observers (typically other `ViewModels`) through the `notifyAll` method that it's relevant data has changed. Since the `Service` can then call the Observer's `updateFrom` method, the observers can then perform an update within themselves with the new data recieved.

Notice that the `Observer` and `Subject` class make use of the Swift Associated Types feature to ensure the protocol is kept generic. This means that any Service implementing the `Subject` protocol can dictate the type of the data being observed, as well as the type of Observer. This allows for complex observer relationships to be set up where the type of the data being observed does not necessarily need to match the class implementing the observer pattern.

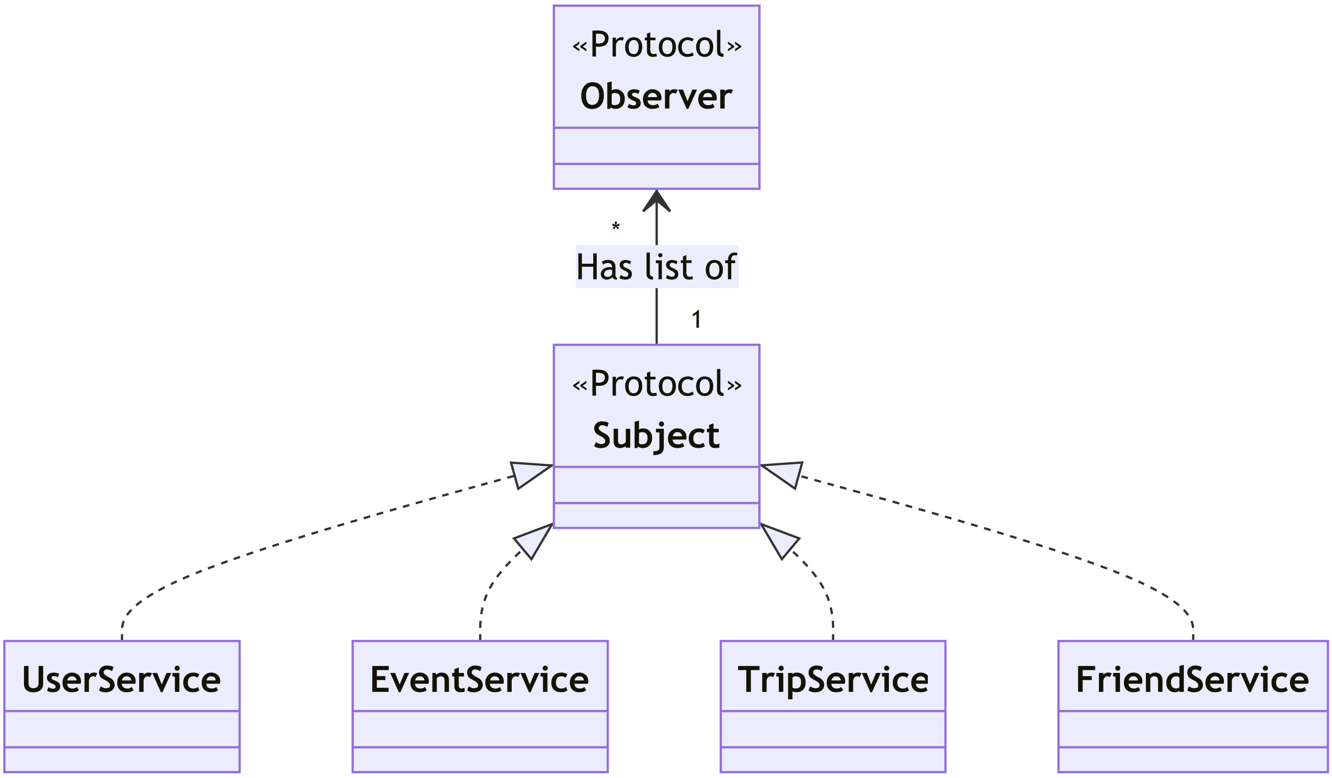
The `Service`s which have the Observer protocol implemented are the following:

- UserService

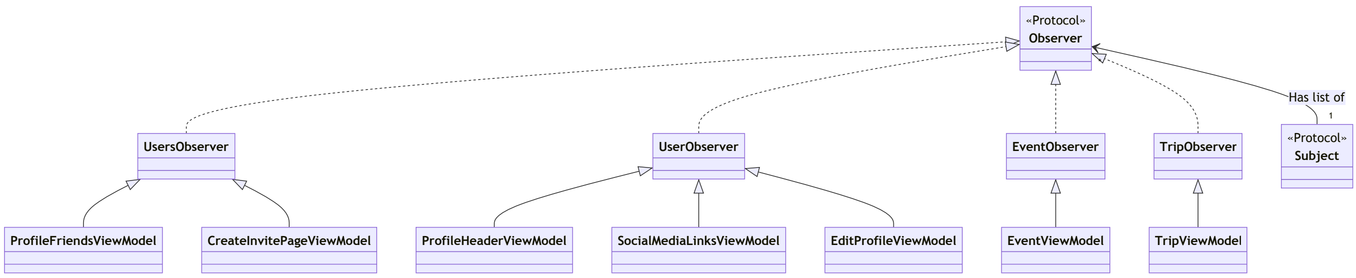
- EventService
- TripService
- FriendService

The association between these `Service`s and the `ViewModel`s which rely on them can be seen in the two diagrams below

The first diagram shows which `Service`s implement the Subject protocol:



The next diagram shows which `ViewModel`s implement the Observer protocol:

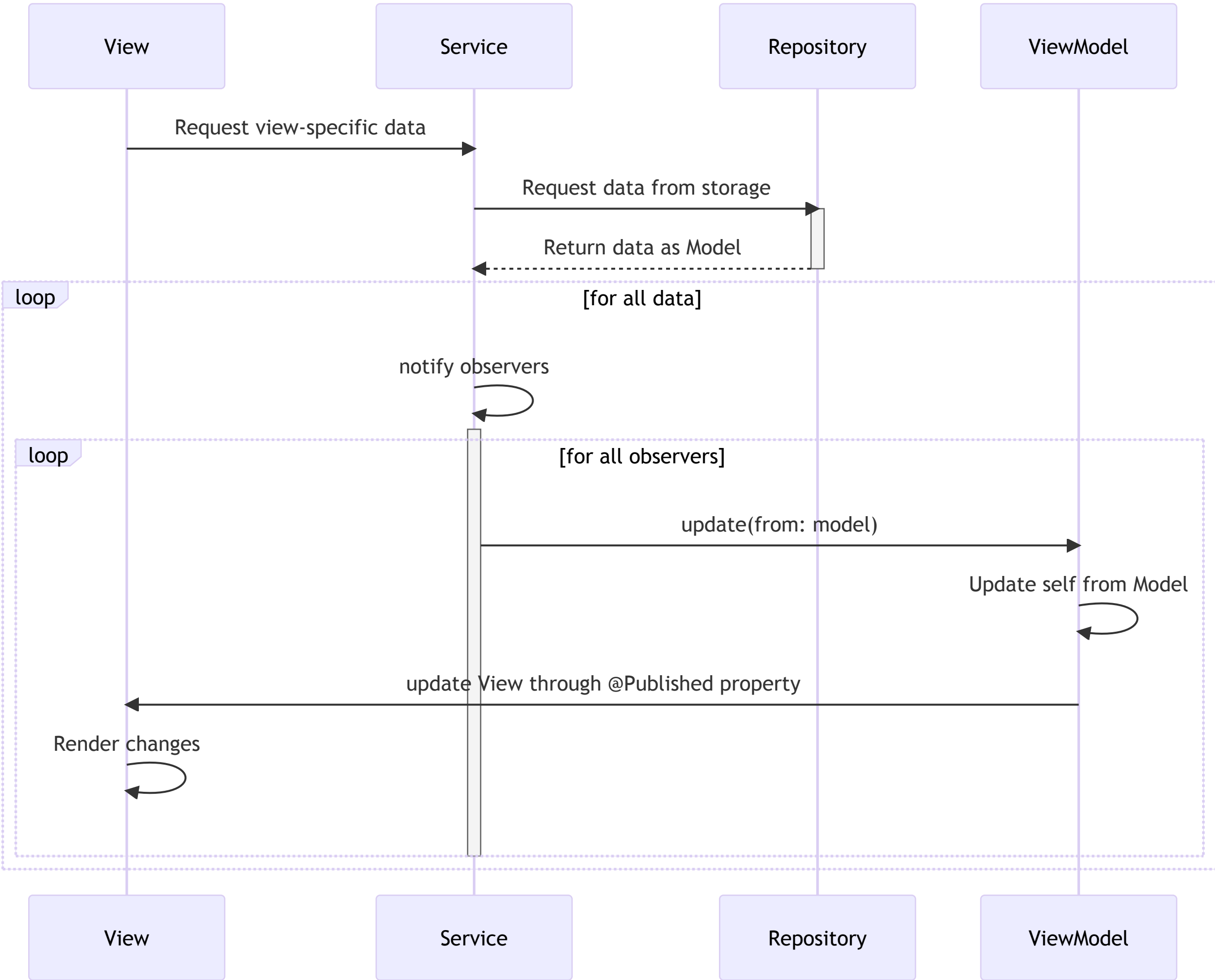


Note: Methods have been ommitted for simplicity

For a sample on how a service implements the Observer protocol, please see Structure of User Service and Observer

Updating data

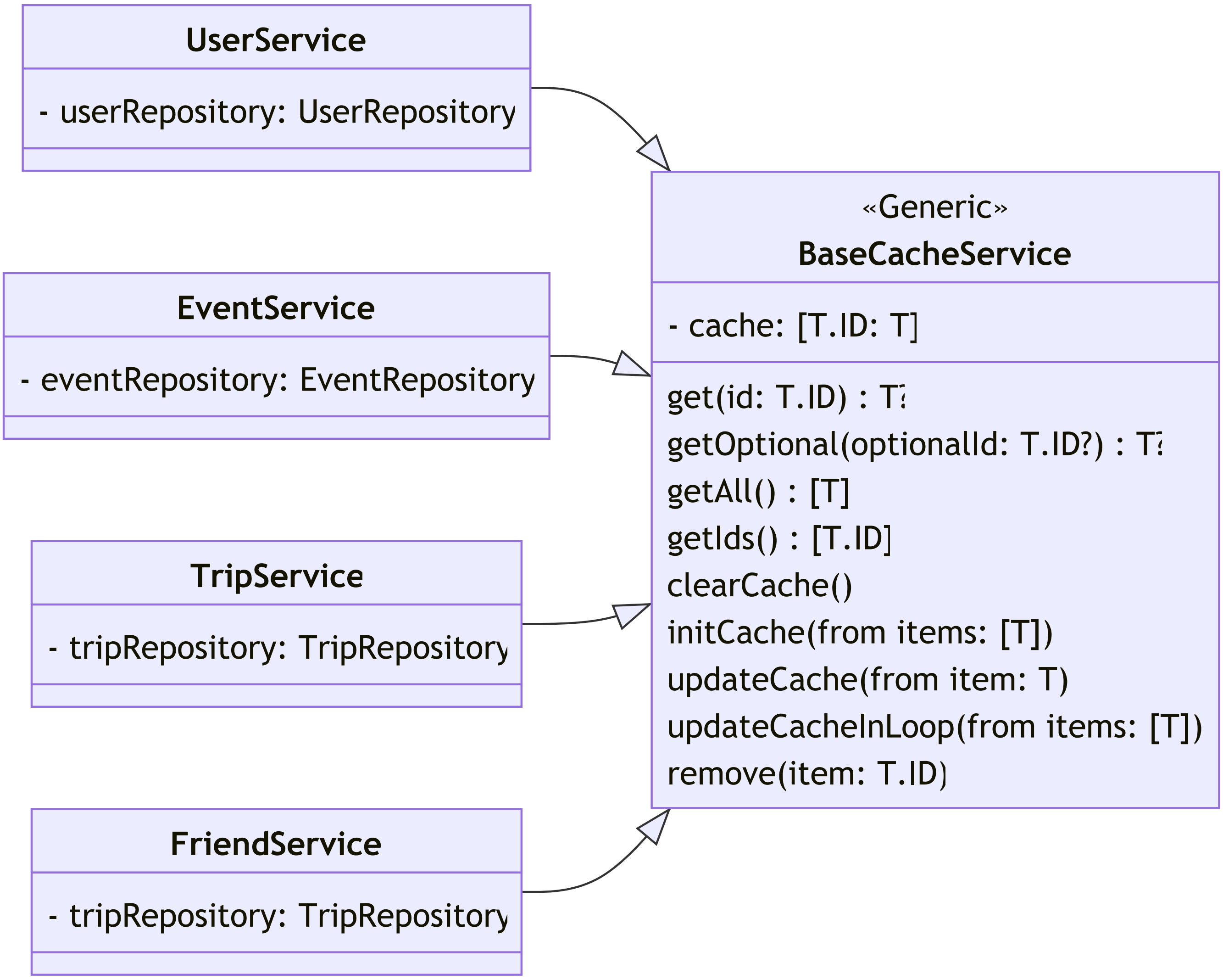
We've provided a diagram showing how the `ViewModel` is registered as an observer of the service under flow of data. However, when a model is updated by the service, the observer pattern allows the `ViewModel`s to be notified of a change without a new `ViewModel` being instantiated. This is because the observer pattern allows the `Service` to directly notify observing `ViewModels` that the associated underlying model has changed. We demonstrate how that interaction works in the diagram below:


View
Service
Repository
ViewModel
Request view-specific data
Request data from storage
Return data as Model
loop
[for all data]
notify observers
loop
[for all observers]
update(from: model)
Update self from Model
update View through @Published property
Render changes
View
Service
Repository
ViewModel

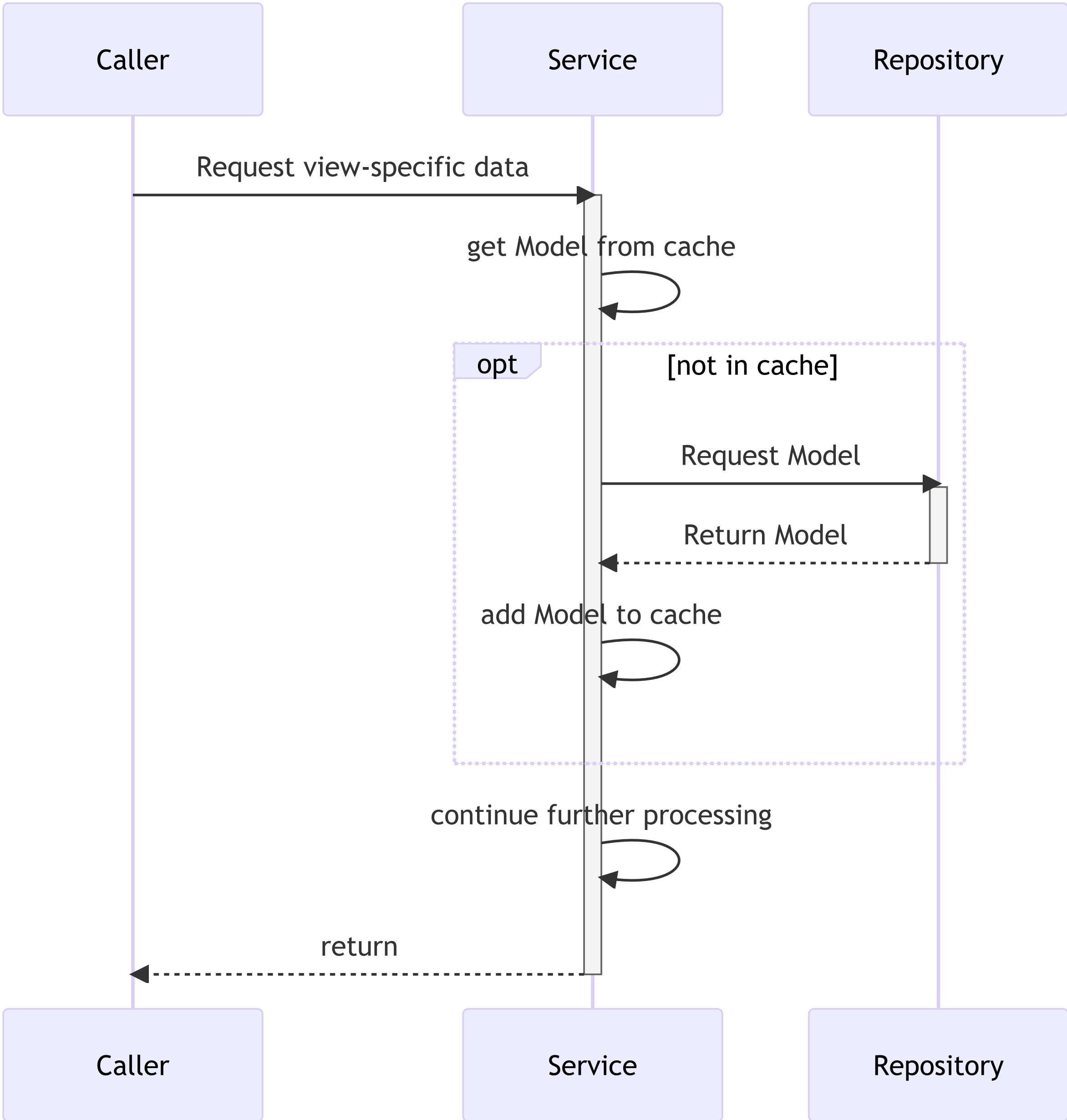
Caching

We've implemented a custom caching layer that allows for data to be cached and retrieved without a network call. Specifically, we cache the `Model`s associated with `UserService`, `EventService`, `TripService` and `FriendService`. The models associated with these services do not change frequently or in real time, and thus it is acceptable to cache their values. A `reload` function also exists in each of these services to pull fresh data from the server should it be required.

A class diagram showing which classes implement the `BaseCacheService` can be seen below:



In general, the workflow for working the Cache layer is as follows:



One of the key benefits of introducing the cache at the `Service` layer is the following: Multiple `ViewModel`s rely on the same model, and thus if we cache the model, we avoid unnecessary network IO to produce those `ViewModel`s

A class was used instead of a protocol because the `BaseCacheService` was set up as a generic class with default implementations of all the methods within the class. This allows the the `BaseCacheService` to easily be subclassed and provide extensive caching functionality to any class that extends from it.

Live location sharing

The live location sharing is one of the key features of the application. The goal is to allow the user to update their location and save that to the database, as well as allow the user to view the live locations of all of their friends.

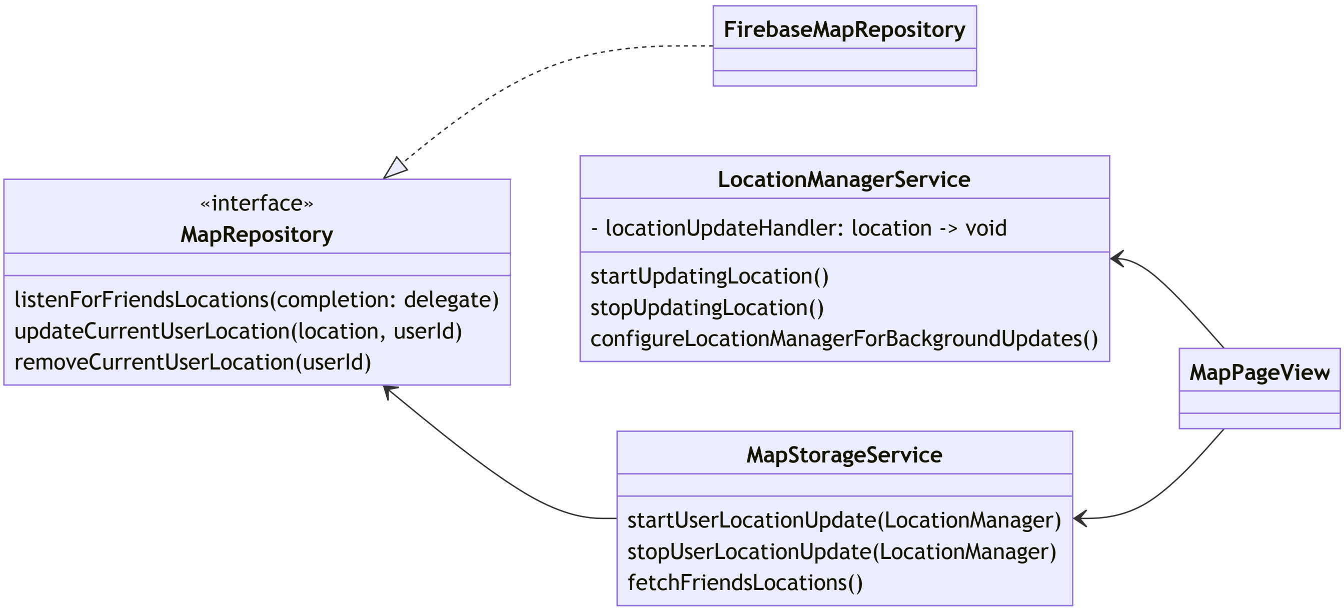
Location Management: Key responsibilities

The location management functionality has three key parts:

1. Getting the user's current location via GPS
2. Persisting the user's location to the real-time database
3. Pulling all the friends' locations onto the map

Part (1) is handled by the `LocationManager` while parts (2) and (3) are handled by the `MapStorageService` which relies on the `MapRepository`.

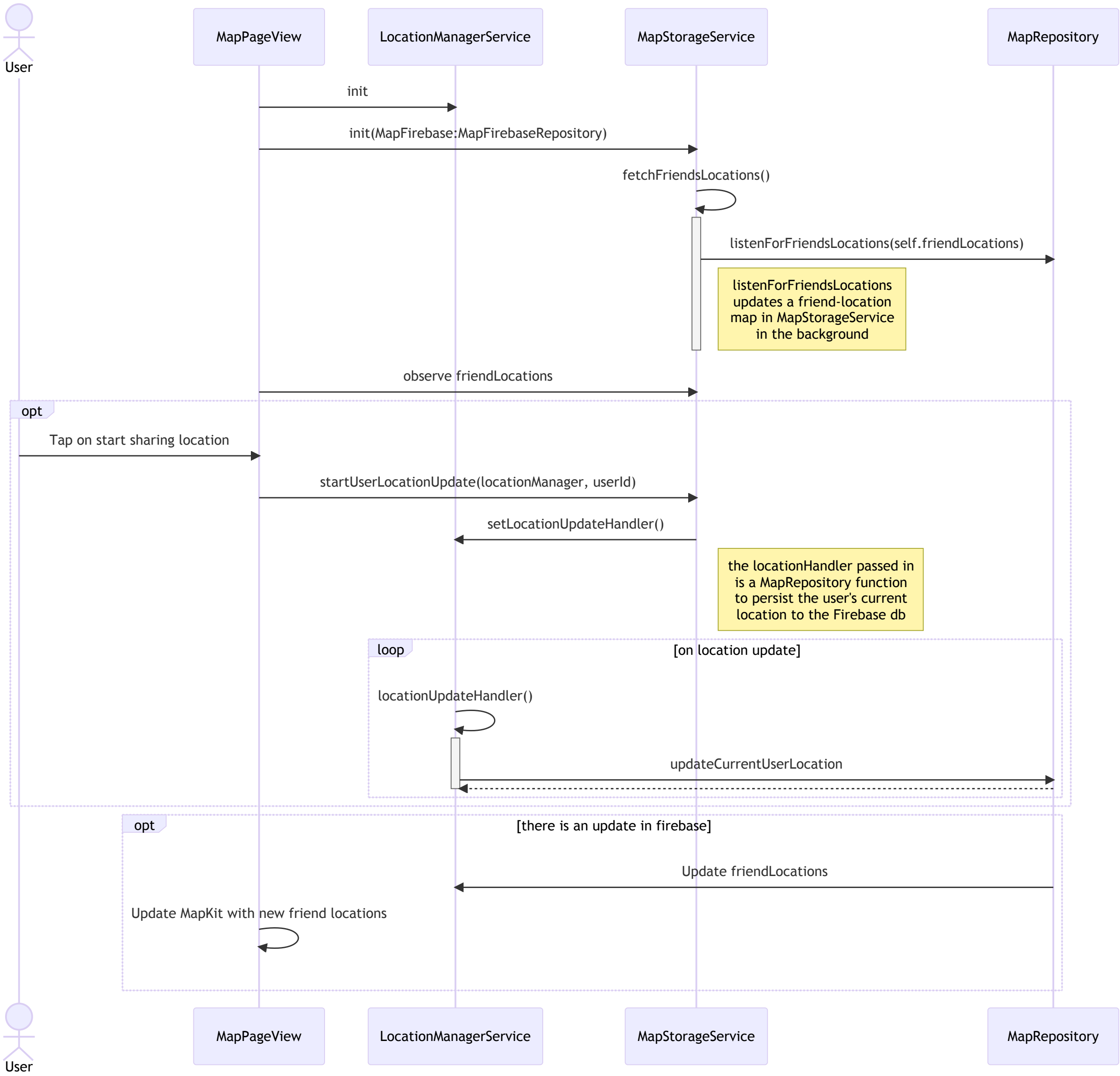
The class diagram for how these 3 key classes interact with the `MapView` is shown below:



Location Management: Flow of data

The `LocationManager` resolves the user's current location via GPS, while the `MapStorageService` sends and receives information from the persistent data store. The delegate pattern is employed here, where the `MapStorageService` passes a delegate function to the `LocationManager` to call to when the user's location is updated. This allows the app to easily swap out the desired behaviour when the user's location changes, decoupling it from the GPS service itself as well as allowing flexibility on the actions to be taken when the user is moving around.

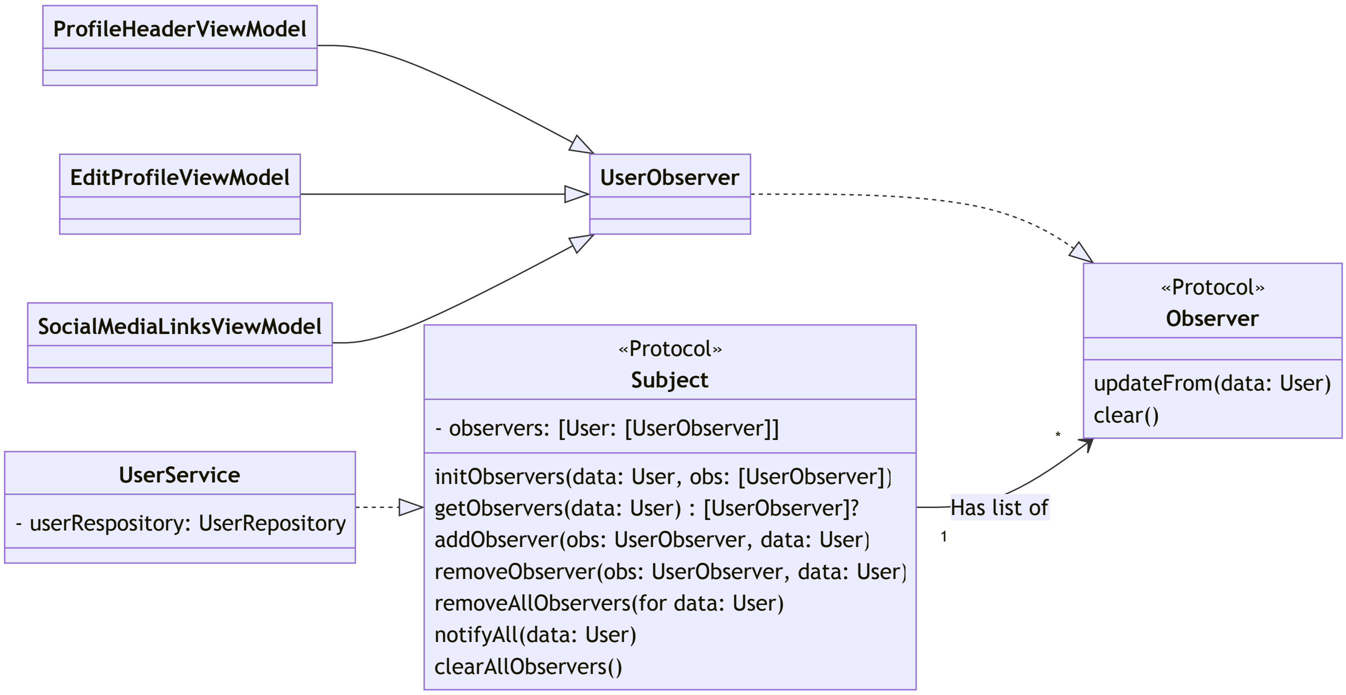
The flow of how the user's GPS coordinates are stored in the data storage as well as how friends' locations are retrieved and updated on the map can be seen below:



Sample Interactions

Structure of User Service and Observer

This section aims to explain how the UserService is structured with respect to the Observer protocol. The diagram below shows an example of how the observer pattern is set up within the `UserService`. The associated types within the protocols have been resolved to concrete types to aid the understanding of the diagram.

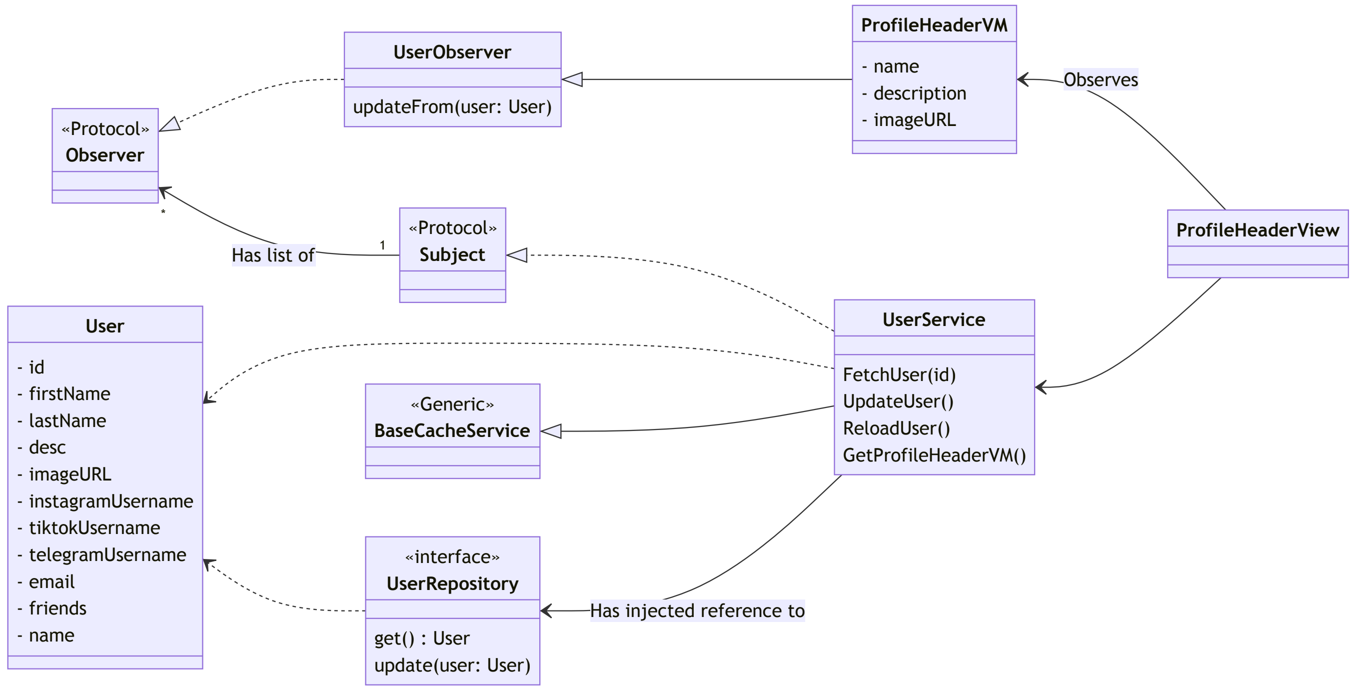


Since the `UserService` and the `ViewModels` that rely on it (`ProfileHeaderViewModel`, `EditProfileViewModel`, `SocialMediaLinksViewModel`) are not directly linked (rather, they are linked through the `Observer`-`Subject`) relationship, it is easy to scale and add more ViewModels that rely on the `UserService`. A new ViewModel can easily be created, subclass the `UserObserver` class, and register itself with the `UserService` to be notified when a model changes.

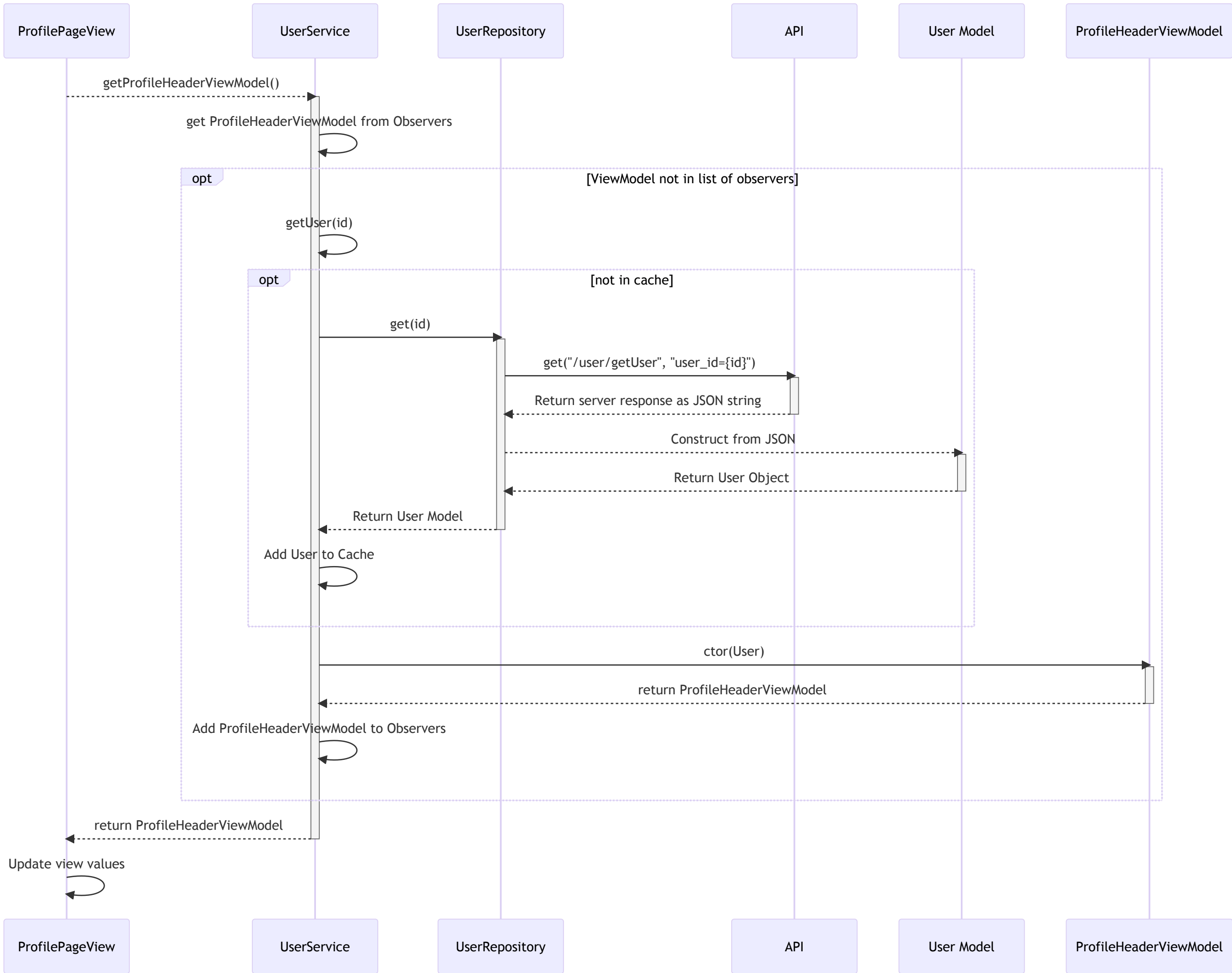
Get User Profile

This section aims to explain how the `ProfileHeaderViewModel` is populated.

The `ProfileHeaderViewModel` is derived from the `User` model. It gets its information from the `UserService` and `UserRepository` classes. The interaction between them can be seen below.



The following diagram aims to illustrate how the `ProfileHeaderViewModel` would be populated when it is first called. It shows the full lifeline onf the information being retrieved and the how the Observer relationship is set up, as well as how the cache is used as a first attempt to get the User.

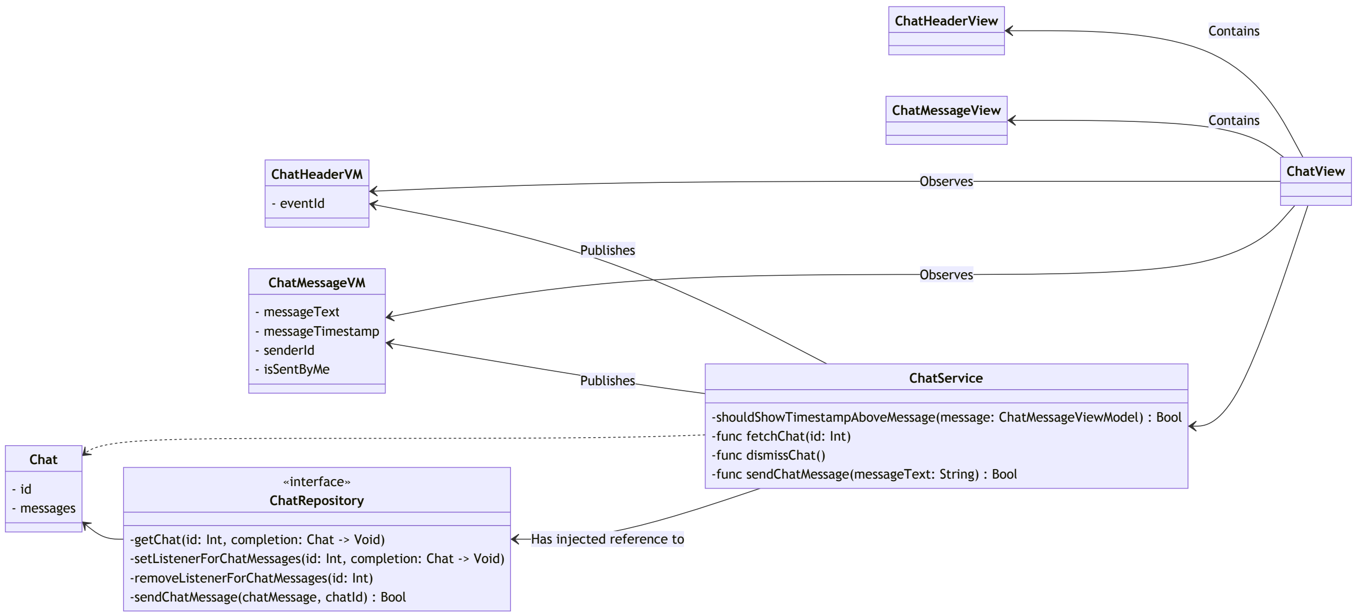


Notice how the cache and observer protocol come together here. The `UserService` first attempts to retrieve the requested `ProfileHeaderViewModel` from the set of Observers. If it does not exist, it then proceeds to consruct the `ProfileHeaderViewModel`. The `User` model is first attempted to be retrieved from the cache. Should it fail, it then proceeds to get the `User` from the repository. Following that, it constructs the `ProfileHeaderViewModel`, and sets it up as an observer to the `UserService`. This ensures that when the underlying `User` changes, `ProfileHeaderViewModel` can easuly update too.

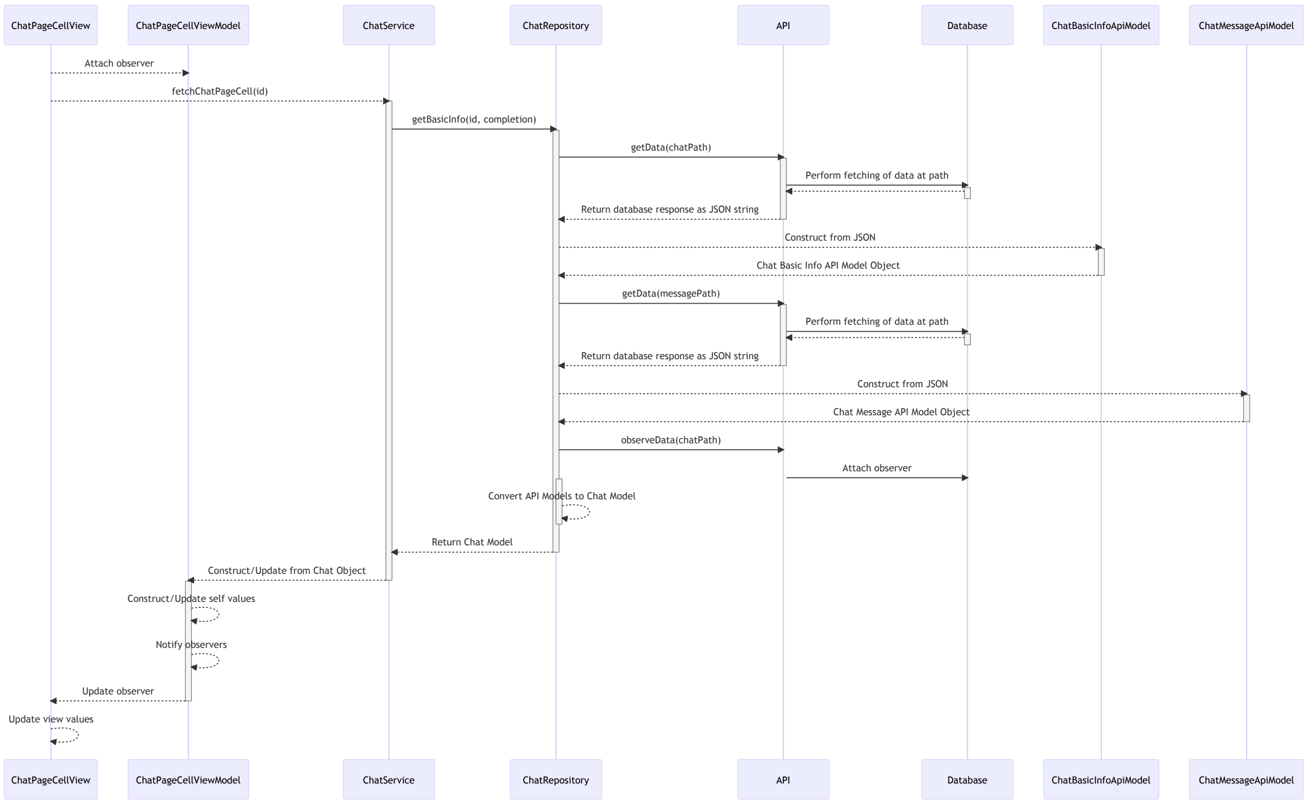
Get Chat Page Cell

This section aims to explain how the `ChatPageCellViewModel` is populated.

The `ChatPageCellViewModel` is derived from the `Chat` model. It gets its information from the `ChatService` and `ChatRepository` classes. The interaction between the classes can be seen below.



The following diagram aims to illustrate how the `ChatPageCellViewModel` would be populated when it is first called. It shows the full lifeline of the information being retrieved and how the Observer relationship is set up.



The `ChatRepository` class first gets the basic data of the `Chat` and constructs it into a `ChatBasicInfoApiModel`, the fields of which correspond to how it is stored in the database. Then, it gets the message from the message ID and similarly constructs it into a `ChatMessageApiModel`. A small difference with the above section is that the `ChatRepository` also attaches a listener with a callback function to the database. What this does is to let the database know to execute the callback function (with the new data) whenever the data along that path is updated.

Error handling

Backend

The app defines a custom `SotravelError` class which is thrown at all layers. If exceptions caught are from other function calls (e.g. decoding JSON throws a `DecoderError`) the enforced convention is to wrap the error within a `SotravelError` and throw that instead. There are custom types defined such as `NetworkError` and `AuthroizationError`, with more to be added as more development takes place.

The key benefit of this is that errors being bubbled up will only be of one specific type, with a finite set of reasons. This will make it easier to design an error handler at the presentation layer that only needs to know of a single (or a few) fixed error types.

Ideally, we hope to ensure that there is an exception handler that automatically triggers when errors are bubbled to the view layer.

Frontend

We created the `ViewAlertController` as a reusable component that all views can make use of to display errors. This component will show a specified error message and contain buttons to dismiss the message. By centralising to a singular component to display errors, we follow the DRY (don't repeat yourself) princple and abstract the error dialog to one location.

Design Patterns Utilised

Observer pattern

The observer pattern was utilised to prevent tight coupling between the `ViewModel`s and `Service`s. Instead of using the existing `@Published` property which still resulted in the `Service` holding a reference to the `ViewModel`, we mde use of a custom implementation of the Observer pattern to ensure loose coupling and ease of extensibility between `ViewModel`s and `Service`s.

Alternative implementation: `Model` as `Subject`

One alternative implementation we considered was making the Model the subject and the ViewModel the observer. In this approach, the Model would implement the Subject protocol, and the ViewModel would implement the Observer protocol. When the Service updates the Model, the ViewModel observing the subject would automatically get updated.

Pros of the alternative implementation:

Clear separation of concerns: By making the Model the subject, the responsibility of managing its state and notifying observers would be delegated to the Model, while the ViewModel would focus on handling updates and presentation logic. This separation would make the codebase easier to maintain and extend.

Easier testing: The alternative implementation would make it easier to write unit tests for the ViewModel and Model without having to mock or stub the Service, resulting in more reliable and comprehensive test coverage. Increased modularity: Since the ViewModel would only interact with the Model, it would be easier to swap out the Service implementation without having to modify the ViewModel. This would allow for greater flexibility and modularity in the application architecture.

Cons of the alternative implementation:

Increased complexity: By moving the observer logic into the Model, the Model would become more complex, potentially making it harder to understand and maintain.

Performance considerations: Having the Model notify observers directly could lead to performance issues if there are many observers or if updates are frequent.

Potential for circular dependencies: If not implemented carefully, this approach could introduce circular dependencies between the Model and the ViewModel. Proper architecture and design patterns would need to be employed to prevent this issue.

Comparison with the current implementation

In the current implementation, the UserService implements the Subject protocol, and the ViewModel implements the Observer protocol. This approach has several advantages that make it a better choice for the given application:

Simplified Model: The current approach keeps the Model simple and focused on representing the data structure, while the UserService takes care of managing observers and updates. This separation of concerns allows for a more streamlined data model, which can be easier to understand and maintain.

Centralized observer management: The current implementation centralizes the management of observers in the UserService. This can be beneficial for consistency and maintainability, as it allows you to easily modify the observer management logic without having to touch the Model or ViewModel. Better encapsulation of service logic: By keeping the observer management in the Service, the current implementation ensures that service-related logic is isolated from the Model and the ViewModel. This encapsulation can make the overall architecture more robust and less prone to bugs, as it reduces the chances of inadvertently introducing side effects or dependencies between different components.

Less risk of circular dependencies: In the current approach, the Service is responsible for managing observers and updating the ViewModel, which reduces the risk of introducing circular dependencies between the Model and the ViewModel. This can make the overall architecture more stable and easier to reason about. While the alternative implementation offers some benefits in terms of separation of concerns, easier testing, and increased modularity, the current implementation has several advantages that make it a more suitable choice for the given application. The current approach simplifies the Model, centralizes observer management, encapsulates service logic, and reduces the risk of circular dependencies, leading to a more stable, maintainable, and robust application architecture.

In conclusion, considering the specific requirements and priorities of the Sotravel application, the current implementation with the UserService as the subject and the ViewModel as the observer is the better choice. This approach provides a streamlined and robust architecture that simplifies the data model, centralizes observer management, and isolates service-related logic, leading to a more stable and maintainable application.

Decision to not to use Observer pattern for chat

The decision to not use the Observer pattern for chat came down to 3 main concerns:

Complexity: Adding the Observer pattern for chat would greatly increase the complexity of the current chat service. In addition, the added complexity would decrease the overall readability of the code. Part of this stems from the polling nature of the chat repository (the callback function needed from the Service), which was not a factor for the other services.

Separating Model and ViewModel: The implementation of the chat service cleanly separates the Model and the ViewModel, with neither needing to "know" about the other. This allows for the Service to function as the "bridge" between the two, thus changes to either the Model or the ViewModel can be handled in a single place. Implementing the Observer pattern in chat entails that the ViewModel know about certain aspects of the Model, which might make it difficult for future changes of either.

Performance: This was what we considered to be the biggest issue, and which does not affect the other Services as much. As chat needs to be sorted (either in the chat page cells or in the chat messages), implementing the Observer pattern means that the ViewModels need to be sorted every time they are required. With a large number of messages, as might very likely be the case, this constant sorting presents a huge performance concern. In contrast, keeping to the same approach allows us to maintain a sorted array that can be taken as-is, without needing to be sorted each time.

Delegate pattern

We extensively made use of the delegate pattern. There are 2 main places these were used

1. Completion handlers which were passed in to `Service`s
2. Obtaining updates from the real-time database

The delegate pattern allowed loose coupling between classes which were trying to obtain information, and classes which could provide it. By passing in a completion delegate, it also allows asynchronous method calls to return immediately, and act on the result of the call later.

At the UI level, this ensures that the UI is not blocked while waiting for an action to complete. When dealing with the real-time database, this pattern ensures that the functionality encapsulated within the completion handler can be asynchronously handled by the Firebase SDK when a change is detected.

Repository pattern

The repository pattern has been invaluable in designing the application. It provides the core of the infrastructure persistence layer. By conforming to the repository pattern where we have one repository per model, it makes the application easier to reason about. It is immediately clear from the name of the repository which model will be prodiuced by it.

In addition, the repository pattern has made testing the application as well as concurrent development much easier. The team set up Mock Repositories and used those while waiting for the infrastructure layer to be created and tested. In addition, it ensured that logic was easily testable since a mock repository could easily be injected into the core logic when required.

Adapter pattern

The repositories served a dual purpose, acting as an adapter between the JSON provided by the REST API or Firebase SDK and the Models used by the application. Since all conversion into Models happens at the Repository layer, it ensures that there is a single source of truth that the upper layers (Services, ViewModels, Views) can work with.

Proxy pattern

The Repositories make use of the `NodeApi` class which acts as a proxy to the `AsyncHTTPClient` library. The `NodeApi` creates a single point of communication to the REST API, and handles important pre-request tasks such as adding the user's Authorization Token, converting dictionary data into a JSON, etc. It also handles errors originating in the `AsyncHTTPClient` library, and re-wraps them as `SoTravel` errors. This ensures that unexpected exceptions are rewritten into types that the rest of the codebase is able to handle.

The proxy also ensures that the `Repositories` are not overloaded with extra tasks improving cohesion of the class.

Facade pattern

The `Service` and `Repository` act as a facade between the complexities of API calls and JSON decoding. They act as a single point of contact for the `ViewModel`s and `View`s to obtain the information to be displayed.

Good Practices

Dependency Injection

We dependency inject dependencies using the Resolver library as well as through EnvironmentObjects. This allows each class to operate using the interface of the dependency rather than the concrete type. Using DI has the following key benefits for us:

- Easily swap implementations out for testing. We frequently replaced our repositories with mock versions of them for testing or while awaiting bugfixes on the repository
- Dependency management in one place: By using Resolver, we were able to manage all our dependencies in the `Repositories+Injection.swift` and `Services+Injection.swift` file. This provided a central location to dictate how each dependency was resolved into its concrete type.

View Composition

View composition refers to the practice of creating reusable components that can be combined to build complex user interfaces. This approach allows developers to break down large and complex UI designs into smaller, more manageable pieces. These components can then be reused across different parts of the application, resulting in a more consistent and maintainable codebase.

In our example, we use view composition to create reusable components such as ProfileImageView, LoginButtonView, and SafariView:

1. ProfileImageView: This component is a reusable image view that displays the user's profile picture. It is used in various parts of the application, such as the event, chat, and profile pages. By encapsulating the functionality and styling of the profile image within a single component, we can easily reuse it across different pages without duplicating code. This not only saves development time but also ensures a consistent look and feel throughout the application.

2. LoginButtonView: This component is a reusable button view used for both email and Telegram login. By creating a single LoginButtonView component, we can reuse it in multiple places, ensuring that the button's appearance and behavior remain consistent across different login methods. This approach adheres to the DRY (Don't Repeat Yourself) principle, which is a cornerstone of clean code and good programming practices.

3. SafariView: This component is a reusable web view that can be used whenever the application requires displaying a web page. Currently, it is used during the Telegram login process. By encapsulating the web view functionality within the SafariView component, we can reuse it in other parts of the application where a web view might be needed. This not only simplifies the code but also ensures that any future updates to the web view behavior will be automatically propagated to all instances of the component.

Async-Await and asynchronous processing

Most functions within the application are async functions, greatly improving code readability. Since the result of an async call is right next to the caller, there is no need to hunt for the the completion closure of method to process the result of an async call. While completion closures do exist within the codebase, they are only between the View <--> Service interface as async calls are not allowed within the main thread.

We also make use of `TaskGroups` to perform large blocking operations concurrently. The best example of this is in the `FriendService#getUsersFromUserIds` method where we concurrently resolve a list of UserIds to User objects using `withThrowingTaskGroup`. This has greatly sped up the friend retrieval process, with a roughly 20x improvement in speed.

Roles and contributions

1. Azeem Vasanwala

    - Designed project architecture using 3-layer architecture and MVVM pattern, to allow for scalability and maintainability.
    - Implemented repository pattern: Required deep understanding of data model and data manipulation, and allows for easy extension with new data sources or changes to existing data model.
    - Implemented all polling repositories: Worked with Sotravel team to understand API specifications, and implement generic repositories to serve higher layers. Repositories performed key CRUD operations assisted by a generic REST API.
    - Developed generic transformers to map APIModels to Models to reduce boilerplate
    - Implemented dependency injection: Required careful planning of component interactions and dependencies, but allows for easy extension with new components or changes to existing ones.
    - Implemented asynchronous processing: Structured all repository layer calls to follow async-await pattern allowing client libraries to perform concurrent processing. Resulted in 20x increase in some functions without blocking the user interface.
    - Created diagrams to help visualize project architecture and data flow, which required translating complex technical concepts into easily understandable diagrams, and helps communicate project structure to other developers and stakeholders for easier collaboration and maintenance over time.

2. Wang Rizhao

    - Implemented real-time map feature: Developed an interactive and dynamic map that displays and updates relevant information in real-time, enhancing user experience.
    - Mastered Apple's MapKit API: Gained expertise in utilizing Apple's MapKit API for iOS applications, enabling seamless integration of mapping features.
    - Devised efficient synchronization between user device state and real-time database: Ensured data consistency between the user's device state and the real-time database by implementing effective synchronization techniques.
    - Integrated data from real-time database and REST API: Combined information from various sources, such as real-time databases and REST APIs, to provide users with a comprehensive view of the map data.
    - Developed all necessary views: Created custom UI elements and views to support the map feature, maintaining a visually appealing and user-friendly interface.
    - Created reusable components for view composition: Developed modular and reusable UI components that can be easily integrated into multiple parts of the application, reducing code duplication and improving maintainability.

3. Zhang Weiqiang

    - Collaborated with Azeem on designing a scalable project architecture using the 3-layer approach and MVVM pattern, promoting separation of concerns, modularity, and

maintainability.
- Implemented the service layer, focusing on:
  - Encapsulating business logic and adapting to changing requirements.
  - Integrating a generic caching system that improves performance and efficiency by storing frequently accessed data in memory and reducing database queries.
  - Incorporating the observer pattern to enable flexible communication between the service layer and other components, promoting a modular and event-driven architecture.
- Developed several user-friendly and responsive views, ensuring an accessible and appealing user experience that encourages adoption and contributes to the project's success.
- Encapsulated a `ViewAlertController` class to handle situations where a view needs to display an alert, streamlining the process of alert management and improving user experience.
- Optimized interaction between views and the service layer by implementing data bindings and event-driven mechanisms, guaranteeing seamless and efficient data flow between the presentation and service layers and ensuring application responsiveness and performance as the project grows.

4. Neo Wei Qing

   - Implemented the service layer for chat, focusing on encapsulating business logic and extensibility for future development and changing requirements. Also considered varied approaches in an effort to improve performance and efficiency, in particular for the large amounts of chat messages that would inevitable come in.
   - Updated and refactored a number of views to better abstract out internal program logic and to ensure that the view is only concerned with what is to be presented to the user.
   - Implemented real-time updating for chat and chat previews in other views, which involved several design patterns related to callbacks and polling, while simultaneously optimising for performance and scalability.
   - Developed the data structure for chat that would enable easy conversion of data from the ApiModel to the Model and finally to the ViewModel. Implemented the repository layer for chat to better serve this function and perform key operations such as listening and updating.
   - Ensured that the links to chat from other components, such as chat previews were properly handled and exposed several functions that made it easy for chat to be seamlessly integrated in with the main portion of the app.
   - Created some diagrams to help visualize project architecture and data flow in particular for the repository portion as that used a different repository pattern from other parts of the app.
   - Conformed to the scalable project architecture as proposed by Azeem and Weiqiang, with benefits as described above.

Reflection

Evaluation

Our team met most of the targets we have set at the start of the project. Thanks to our 3-layer structure that we have adopted early on in the project and the use of dependency injection to mock repositories, we were able to work in parallel despite the large number of discrete components in the project. Towards the end of the project with feedback from Prof Leong, we were able to develop further good abstractions to reduce coupling and make it easier to extend on the application without modifiying too many classes. This also provided the additional benefit of most changes happening closer to the View/ViewModel layer once the Repositories and Services were set up, proving that our design philosophy encapsulated good layering and modularisation.

Towards the end of the project we did spend time rewriting some of our abstractions and introducing project-level efficiencies to improve the speed of the application as well as maintainability. Two of the key contributions to this was the development of the cache and observer protocol to reduce coupling and reduce unnecessary network IO for items that did not *need* to be up to date.

That being said, we are proud of our application and the fact that we managed to launch it to the app store. There are some things that still need to be fully integrated such as the push notifications and some further deep linking. We're glad that the application handled the scale at STEPs with over 600 users in the community trip without any major hiccups.

Lessons

We learnt the importance of not working in a silo depsite components that seem to be isolated from each other. This was an issue in the first sprint that we quickly resolve moving forward, with check-ins every other day to improve communication and ensure everyone is on the same page.

We also did our best to follow idiomatic swift principles to ensure that the application is maintainable and scalable within the iOS platform. While many of us came from backgrounds in different languages, we learnt to embrace and utilise Swift's type system and protocol oriented approach to programming to create powerful and reusable abstractions.

Things we were unable to implement

- **Push notifications:** We were unable to implement push notifications in the application as it requires the provisioning of an iOS Developer certificate. To save cost we had purchased a single user's Apple Developer Account instead of an Enterprise account. While we got Firebase Cloud Messaging (FCM) working on Rizhao's device, we realised the rest of us could not build and deploy the application as it was tied to Rizhao's Apple account. Should we have purhcased the more expensive enterprise certificate, we could have been enrolled in a "team" that let all of us make use of FCM. However, since we were unwilling to spend addtional money on this, we didn't merge the FCM PR
- **Ski specific features:** We were unable to complete the ski map feature due to the requirement of manually adding ski lift data, which we currently do not possess, into Mapbox. This issue presents more of a logistical challenge rather than an engineering one, which falls outside the scope of this

module. As a result, we have decided to focus on other aspects of the project that align more closely with our engineering objectives.
- **RSVP to events via telegram:** While this was an intial goal, we realised that for larger trips telegram's TOS would result in our service being rate-limited or blocked for spamming. Not wanting to lose our account, we opted to not blast a message to everyone on telegram to avoid being blacklisted and reduce spam for users. We will still continue to implement the deeplink so that the host can still send event RSVP links on Telegram without the bot. In addition, this feature is also out of scope of the module's aims for software engineering.

Tests

Testing Strategy

We used white and black box testing to write an exposition of the test cases we wish to use. Due to time limitations and a requirement to have the app live for an ongoing trip, we didn't have time to write explicit test cases. The exposition of our test cases can be found here. We used white box testing to test explicit pathways such as testing if information was added to a the cache, was cleared from the cache, etc. We used black box testing to test application flows such as navigation, redirects, etc.

In addition, we found it hard to write explicit test cases for the real-time synchronisation across firebase. Consequently, we relied on manual testing with multiple devices to ensure that the chat and location functionality work as intended.

We have an existing backend server using RESTful APIs which is developed by the Sotravel team. The backend server's APIs were manually tested using Postman to ensure that the APIs work as intended.