**Community Based Train Locating System (CBTLS)**

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Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Name of the Student Signature of the Student

Date:

Supervised by

Name of the Supervisor Signature of the Supervisor

Date:

Dedication

This thesis is dedicated to my parents, Mr. D.S. Senevirathna and Mrs. A.P.P Karunasingha for their endless love, encouragement and support.

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Abstract

Rail transportation has been considered as a main mode of transportation in Sri Lanka since a long time. Therefore it is very important to support and enhance railway transportation as an alternative method of transportation. With the advancement of information technology, over the time there has been many attempts to enhance the quality of train transportation, but despite of them there are some major concerns for the train passengers in Sri Lanka remaining up to date unsolved.

The main objective of this project is to propose and implement a crowd - sourced real time train tracking system based on GPS named Community Based Train Locating System (CBTLS), for the benefit of train passengers and train transportation of Sri Lanka aiming to address the major concerns and enhance the railway transportation service.

CBTLS is a community based (crowd - sourced) system, therefore the data is retrieved from the train passengers, and then organized, processed and analyzed by the system, and resulting information and predictions using is given back to the train passengers from the system.

The proposed system consists of a native Android mobile application and a Web application. Any train passenger with a smart mobile device or a computer would be able to access the system through internet, update the train locations, compartment details, and view current and/or last known locations of a train, view analysis, predictions and suggestions on train schedules. Only the master data would be inserted into the system initially and the rest of the data required for system’s functionality is captured from the train passengers, hence the system is community based.

As an additional feature, a location aware alarm clock is integrated into the native android application, for the use of passengers to indicate when their destination has been reached.

Other than train passengers, the system consists of an administrative functionality as well. System administrators hold responsibility to control and overview the user accounts created by train passengers and manage static master data.

With this system, it is expected to facilitate train passengers to make better travelling decisions by providing required information for them.

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Chapter 1

CBTLS – Community Based Train Locating System

1. Introduction

This chapter mainly focuses on the motivation, aims and objectives of the community based train locating system. Here it is described some of the key problematic areas in the current train transportation system that could be observed in Sri Lanka, mainly in the train passengers perspective, hence identifying the problem to be addressed. At the same time, it is briefly explained the proposed method of addressing the problem in this chapter.

1. Background and Motivation

In today’s context, in city areas, especially around and in city of Colombo, a heavy traffic congestion could be observed daily on the roads, and it has become one of the major concerns in country as well. School students, University Students, Government and public sector employees, and general public have been facing a crisis when it comes to travelling in and out from Colombo daily.

As the study done by A. Kumarage indicates, there can be different approaches available to solve this issue involving both short term and long term strategies. One of the key and less time and resource consuming approach would be to enhance and develop already existing alternative methods of transportation for general public. The valuable man hours and other resources which are wasted on roads daily could be easily preserved by introducing proper alternative methods of transportation and by enhancing the efficiency, reliability and quality of currently available public transport systems [1].

As it indicates in the work by Jayasinghe and Pathiranage, it is very important to support and enhance railway transportation as an alternative method of transportation[2].

When considering such already available alternative transportation methods, Rail transportation has been considered as a main mode of transportation in Sri Lanka since a long time.

The significance of enhancing train transportation service has been indicated in the annual report 2012 of Central Bank of Sri Lanka. In the annual report 2012 of Central Bank of Sri Lanka, it has indicated that the Sri Lanka Railway has a great potential to improve their current services for both passengers and freight, and it will cause the city traffic congestion to be reduced to a great extent. Further, the report indicates that is has been already identified that the current issues in the service like inadequate coverage, lack of carriages, and most importantly the key point “inefficiency”. It indicates that due to the said issues, general public are to seek for other modes of transportation, causing heavy traffic congestion, and ultimately leading to loss of productive man hours and energy utilization[3].

As mentioned above, the productive man hours, energy could be saved, and the heavy traffic congestion could be avoided to a certain extent, especially around city areas, by enhancing rail transportation service. The current issues mentioned above, inadequate coverage and lack of carriages should be addressed by providing required physical infrastructural resources for the service.

The issue “inefficiency” could be considered as a main reason for general public to consider other modes of transportation in place of trains. The main objective of the system proposed here (CBTLS) would be to provide a means for the general public to use this “inefficient service” efficiently.

When considering the statistics provided by Ministry of Internal Transport - Sri Lanka, which is given in the table below, no. of passengers who has chosen train, increasing annually[4].

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2010 | 2011 | 2012 | 2013 |
| Total trips operated (Both passenger and Goods trains) | 116,912 | 119,392 | 121,782 | 122,269 |
| No.of Passengers Carried (in millions) | 101.45 | 96.11 | 106.05 | 118.71 |
| Length the passengers carried on (Km in million) | 4,352.83 | 4,574.19 | 5,039.45 | 6,257.38 |

Table 1.1 - Sri Lanka Railways - Operational Statistics[4]

Considering data shown in Table 1 above, the important figure in this context would be the “No.of Passengers Carried”. The variation of this figure is given below,

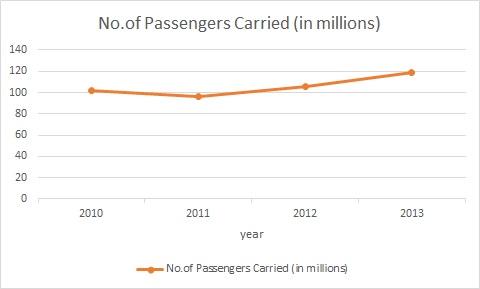


Figure 1.1 - No.of Passengers Carried (in millions) over 2010 - 2013 period

The increased number of passengers over the years indicates the increasing demand for the train as a mode of transportation.

In order for Sri Lanka Railway Service to draw and retain more passengers with their service, there are several issues which need to be immediately addressed. Delay of Trains in Sri Lanka is a very common situation, which train passengers have to face daily. It has turned in to be an unavoidable scenario over the time and the train passengers who are frequently using the service, have got used to it. As a transportation service, railway should maintain its reliability, and it’s important in country’s economic aspects as well. The mentioned issues here should be resolved within Railway Department of Sri Lanka after doing a proper analysis of the causes, but the aim of the proposed system (CBTLS), here is to facilitate the train passengers to use this existing inefficient service efficiently with the aid of the system.

Usually, a train might get delayed from few minutes to many hours in Sri Lanka and in certain commonly observable scenarios, trains gets cancelled as well. This is without any prior notification for the train passengers. According to media, even in recent history in Sri Lanka, in such situations clashes has occurred among the passengers and the railway administration. But the problems still remain unresolved to date.

A fixed schedule is maintained by the Railways department of Sri Lanka on train arrival and departure, it is available online as a web application and also as mobile applications. The major issue with the static schedule is, it does not get updated based on potential delays and cancellations.

As a result the commuters face many problems and waste time and energy that could have been used more productively. For people who are using trains for their daily travelling, there’s no means of recovery of their time in scenarios which trains are delayed or cancelled.

If the passengers could know beforehand, whether the train they expect to travel is on time or not, preferably before coming in to the station, they would be able to make a better decision on their method and time of transportation. An ideal situation for them would be to know the current location of the train.

In railway administration’s point of view, if they could collect the train details on each and every schedule daily, along the entire route, that data could be used to analyse the existing issues in the system, the reasons for the train delays, locations where trains gets delayed. Then that analytical information can be used to identify the issues, find solutions to them and finally enhance the service.

Similarly, such information is important for passengers as well, especially when deciding which train to travel on, since the expected time of arrival at the destination indicated in the railway’s timetable would be somewhat different from the actual time of arrival.

There are passengers who uses trains for their daily travelling, or frequently, who are much familiar with the railway system, specially the stations. There are some passengers who might seldom use railway transportation, especially like tourists. Such people might not be aware of the location of destination stations they want to travel to.

Such scenarios could be observed while travelling in train, people get in to the wrong train, which will not stop at their destination station, or people who have missed their destination station.

Usually in train stations in Sri Lanka, an announcement is made when a train is arrived in the station, indicating the next set of stations in where it would stop along with the final destination. But these announcements are not very clear sometimes, and most of the time is in Sinhala language only in smaller stations. Therefore people like tourists, who are not familiar with Sinhala language, would face issues when finding the correct train and destination stations. If there was a way for them to get an indication when they are reaching their destination, it would be a great help and they would grow in confidence to use railway service more frequently.

1. Aims and Objectives of the CBTLS

The expected outcome of this research is to provide a comprehensive software application solution - named as Community Based Train Locating System (CBTLS), for the train passengers in Sri Lanka, which would help them for an efficient usage of current train transportation service in Sri Lanka.

CBTLS would be aiming at enhancing the usage of rail transportation service in Sri Lanka for passengers, by introducing new features for them which are not available in current systems as given below,

* Facility for the passengers to update train’s current location actively or passively
* Searching and locating trains in real time
* Providing information about the passenger density in each compartment of the selected train
* Predicting and suggesting most suitable train to take based on destination, and time of arrival at destination desired by the passenger.
* Analysis of data collected over a period on a given train, and indicate more accurate travelling times.
* Location based alarm to indicate if the passenger has reached the destination.

The proposed system will also be an enhancement and combination over the features available in currently available systems for the same purpose.

Additionally, the CBTLS would facilitate the storage and analysis of historical data related with each train by storing them in a centralized database. With this facility, authorized users would be allowed analyze patterns of train travelling daily, hence the delays could be observed.

As a community based system, it would allow registered users to post their comments, criticisms and suggestions regarding a selected train. Authorized users would be allowed to view these comments, criticisms or suggestions by the passengers.

1. CBTLS Implementation – how will it address the issues

The proposed system would be consist of a web application and a mobile application. Web application would cater as the backend for the mobile application, while facilitating all the functionalities available in the mobile application as well. Web application backend and native android mobile application would communicate through a REST (Representational State Transfer) API (Application Program Interface).

When it comes to the web application, when actively updating train locations and compartment details (while travelling in the train), the user’s location would be tracked through the web browser in contrast to the native android application, in which the location would be gathered through GPS and the Network Location Provider of Android.

Initially, the available static train schedule details from Sri Lanka Railways would be inserted to the system as master data. This data would be considered as a base line through the rest of the application. For this purpose, the data integration module is available in the system and the web service available from Railway Department through Information and Communication Technology Agency of Sri Lanka (ICTA) is used.

A proper database structure is defined in order to store these kind of master data and the data received from passengers on each occurrence of this train schedule. Design of this data structure is a key part of the system.

A location aware android mobile application consisting of a train details (location, compartment details) update and a train details view part would be developed for the use of passengers.

Considering train details update part for the system from passengers,

* A simple user interface would be provided for them to indicate if a selected train has arrived or not at their location, when updating the train locations, it could be done in two ways in the system
  + Actively update – The passengers who are already on board the train could actively update the train’s location. This could be done once or else a facility is available for the users to keep updating the location automatically along the entire journey. In this process, the train location would be determined based on user’s current location
  + Passively update – The passengers or anyone who’s aware of train’s location (e.g. People who live around train stations, rail roads) could use this facility to update train’s location, and in this process, the train location would not be determined based on user’s current location, rather it would be determined based on last train station, along with the data, if train is in the station, moving or stopped after the station.
* The data inserted would be validated against the predefined geo coordinates of the selected rail route, before accepting into the system.
* A simple user interface would be provided for passengers to indicate the passenger density of their current compartment, or the overall density in the entire train. Sometimes a user may not aware of the current compartment number he is in, in such situations, a general indication could be updated. The total number of compartments is also retrieved from user, therefore an average number would be indicated as the total number of compartments in the given train turn.
* The crowd density states are predefined as levels – Low, Medium, High, Very High, and user can easily select the compartment number and select a level and update.
* The compartment number could be selected within a given range, and in the same way, total number of compartments in the train could also be selected.
* Since these data is updated by general public, there’s a great possibility for entering inconsistent and inaccurate data in to the system, and to clean such data validations are placed in every possible scenario.
* The train passengers could setup a location aware alarm using the native android application, by choosing the destination train station and at which time the alarm should notify – before a certain distance to the destination station, at the train station or after the train station.
* A user interface would be provided for passengers to enter their comments/suggestions/criticisms into the system regarding a selected train, this is supposed to be cater as a review for other passengers. This data is stored on a train schedule basis rather than a single occurrence of a train schedule, this data could be provided to the users along with other analytical data available regarding the train schedule.
* Using this application, passengers would be able to mark their frequently used train schedules as “Favorites”, and after that they would have easy access to the most frequently used train schedules, rather than searching always.
* A user will have to login to the system to use certain customized functionalities like favorites, and also to update train locations. A single user account could be created using a user name and a password, and using that, a user can log in to the system using any android mobile device. With this design, the user’s preferences would be saved across multiple android devices and/or web application.

Considering data view part of the system for passengers,

* A UI would be provided to search for a train, this is similar to the functionalities of existing systems, that’s is to select a start station, end station and if preferred a date and a time range. With the given criteria, a set of train schedules will be loaded, from master data obtained from Sri Lanka Railway services.
* With the “Favorites” facility, for regular passengers this search functionality could be skipped and the required train schedules could be directly loaded to the system.
* The rest of system’s functionality will mainly base on the schedule selected here.
* The passengers would be able to view last known location of the train to the system (must have been reported by another passenger), for a selected train, together with the crowd density details reported for each compartment.
* The scheduled time for the train to reach the user’s station (or the nearest station for the user), and the general deviation of it along the time, and predicted reaching time would be displayed for the passenger.
* When viewing details reported by other passengers, an indicator about the confidentiality would also be displayed for the passenger

A web application would be developed specifically for the admin functionalities like maintaining master data, moderating user comments in addition to the functions available in the mobile application. It would also provide the analytical functions related with data mining, in order to analyze the patterns of transportation of a single train. This would allow the authenticated users to determine any delays at specific points of journey. The same set of users would be able to see the feedback from passengers regarding the selected trains.

The mobile application would be a native android application, and the web application would be developed mainly based on Java EE. Spring and Hibernate Frameworks are used in the web application, and for the UI, bootstrap and JQuery is used.

Railway transportation service has been popular among various types of passengers. Based on how frequently the train has been used, various types of passengers can be categorized roughly as below,

* Daily Users - train is used as the main method of transportation daily

e.g.:-

* + Workers in both private and government sectors, travelling daily to the working places
  + School students,
  + University students
* Weekly users - train is used as the main method of transportation weekly

e.g.:-

* + Workers, of whom the working places are in Colombo, travelling from faraway places like Galle, Kandy, and Anuradhapura.
* Occasional users - train is used as the main method of transportation occasionally

e.g.:-

* Tourists

When the passenger type - daily users is considered, it can be observed most of the time their travelling pattern has been similar along time. The train, the compartment, sometimes even the seat row which is being used to travel has been the same. The system which is proposed here has mainly targeted this passenger type.

Other user types also could be highly benefitted through this system, since its features like location aware alarm, and analysis of train schedules.

When the factors mentioned above, the importance of rail transportation, and the increasing demand and usage of rail transportation in Sri Lanka, are considered, any contribution to enhance it as a service for general public would be of great value. The system proposed here has been aimed to be a contribution for that.

1. Structure of the Dissertation

The next chapter (Chapter 2) describes the review of similar systems currently available and the similar systems proposed to address the same issue. There are several systems available currently for the same purpose as CBTLS – to enhance Railway Transportation system in terms of efficiency and reliability, also there are researches done for the same purpose. Some of these were reviewed before proposing the CBTLS and the review details are indicated in this chapter.

After that in Chapter 3, the technologies adapted in this CBTLS system would be explained. The overall architecture of the system, and the reasons to justify the selection of technologies would be described here.

Chapter 4 would describe the proposed CBTLS system’s approach to address the efficiency and reliability issues in current railway transportation system which are described in detail in the section above “aims and objectives of CBTLS”, along with the technologies adapted which is described in Chapter 3.

In chapter 5, system design is described for the community based train locating system. The wireframes for the mobile UI, the class diagram, ER diagram and the sequence diagrams are included and described in this chapter. Also the modules available in the system and the interaction among them is also described in detail here.

Chapter 6 would describe the implementation details each module which was described in chapter 5. Here the details about software, hardware used for the system is mentioned, and at the same time details of critical algorithms used in system are described.

In Chapter 7 the evaluation methods used for this system will be described in detail. The design of the questionnaire, selection of users and final results would be described in this chapter.

Chapter 8 is about the overall achievements of CBTLS, problems that had to be addressed while developing the system, and limitations of CBTLS and how it could be enhanced further in the future.

1. Summary

In this Chapter 1, the motivation behind the proposed system, Community Based Train Locating System (CBTLS) has been described in detail, that is to enhance facilitate more efficient usability of current train transportation for train passengers despite of the issues observed in the current railway transportation system in Sri Lanka. The aims and objectives of the system is described in detail as to address the identified issues, and how the system is designed to address the identified issues. Finally, The structure of the dissertation has been indicated in this chapter.

The following chapter – Chapter 2 is mainly about reviewing currently available and proposed approaches to resolve the issues identified in the railway transportation system in Sri Lanka.

Chapter 2

Current approaches available to address the Issues in Railway Transportation System

1. Introduction

Railway Transportation service in Sri Lanka is owned by the government of Sri Lanka and functions as a public service offered to citizens by Sri Lanka railways Department. To use this public service efficiently, the availability, and easy access of information regarding the service is a critical factor for train passengers. Based on the available information, the passengers would be able to make decisions on their travel plans.

Since the railway transportation service in Sri Lanka is owned by the public sector of the country, the government authorities have been seeking methods to improve the efficiency of this service. The main objective of such efforts is to provide a better service to the train passengers.

According to the work done by G. Bradley, it suggest that in most of countries the governments have already recognized the potential and importance of the implementation of Information Communication Technology in the key areas of their services for general public. At present, Information Communication Technology is playing a key role as a main tool used to enhance the quality and allow easy access to government services with the aim of providing a better and efficient service for the general public[5].

As a result, e-Government and m-Government like concepts have been introduced to use Information Communication Technology as an interface to provide services offered by the public sector as well as to distribute the required information to general public of the country.

As it is indicated in the work by S.Rainford, at present, in Sri Lanka most of the key public services has been integrated with ICT already and as a still ongoing project, rest of the services are also planned to be integrated in the future. As an example, public services like revenue license issuance, wildlife bungalow reservation service are already available as e-Services, furthermore public information services like the exam result publishing service, vehicle information service, and train schedule information service are available as e-Services. Through the currently available service, public has access to the static train schedules[6].

Based on this e-Service provided by Sri Lanka railways Department, with the support of Information and Communication Technology Agency of Sri Lanka (ICTA), there are several applications build, both mobile and web applications for the benefit of train passengers. Some of these systems are reviewed in this section.

In addition to the currently available system, there are some proposed systems available for the purpose of enhancing the railway services, and they would be also reviewed here.

1. Currently Available Systems for general public in railway transportation services

When the currently available methods of information retrieval by train passengers are considered, certain drawbacks could be seen in them. A list of such services that could be found online is listed below

1. eService by The Department of Railways [7]

This is the main service offered by Department of Railways, with the support of Information and Communication Technology Agency of Sri Lanka (ICTA), even for CBTLS, the master data was obtained from this system. The backend for this service is hosted as a web service, and same service is used in both mobile and web applications. Here the web application is analysed and the mobile application is reviewed in the section below.

This provided e-Service can be accessed via the given url here - <http://www.eservices.railway.gov.lk/schedule>.

Same service has been implemented as several different mobile applications and they are listed after this.

This service is aimed mainly at displaying the static train schedule for the users – anyone who has access to the service. According to the instructions given in the service below are the steps to use this service and information which could be obtained from it.

An enquiry can be placed by providing start and destination stations. This service allows viewing Train schedules with time/ station details and ticket prices according to the search criteria.

In this service, mandatory details to search for train would be start and end railway stations as in schedules.

Search Train Schedule Procedure in the system is given as below,

* Start station should be selected from drop down menu –mandatory.
* End station should be selected from drop down menu –mandatory.
* If required Start and end time can be selected, otherwise if the date is current date, train schedules would be displayed from next available train.
* If required to search for a train on different date other than current date, a search date from the calendar could be selected.
* After clicking on ‘Search’ button, a list of train schedules would be displayed.

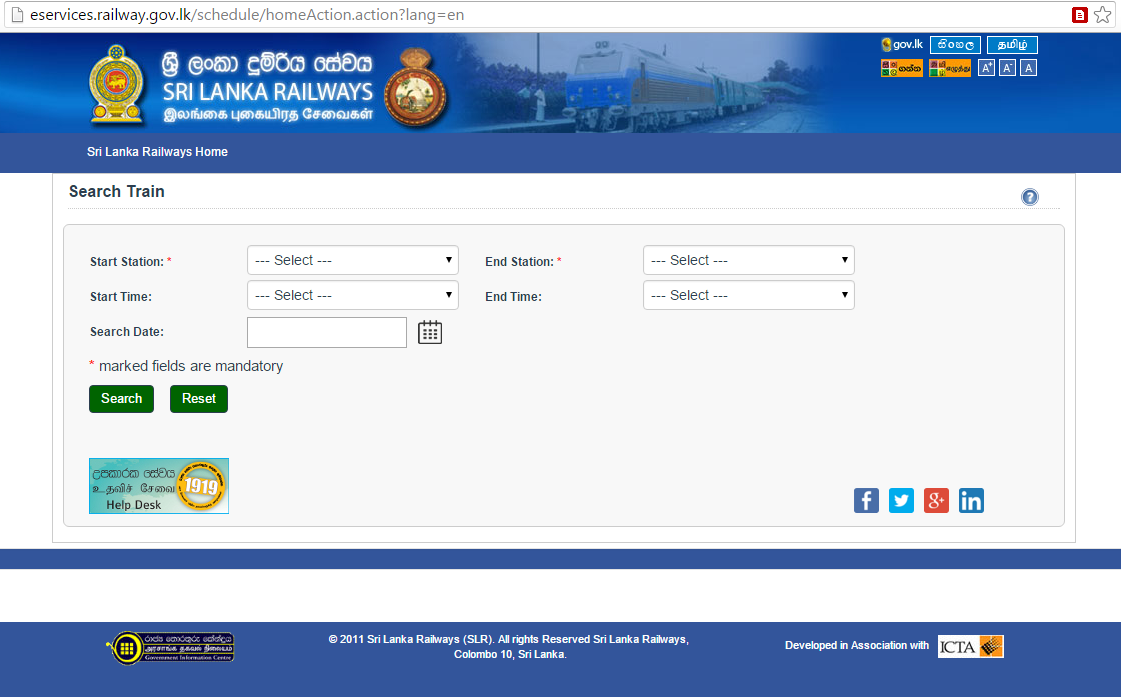


Figure 2.1 – Initial Screen of e-Service Offered by Railway Department[7]

The above System will display Train time table with following details

* Direct Trains
* Arrival time
* Departure time
* Destination/ Time
* End station/ Time
* Frequency
* Name
* Type
* Available Classes &
* Train number
* Connecting Trains(if available) – Same as above details
* Ticket Prices
* Class name
* Price (Rs.)
* Total Distance

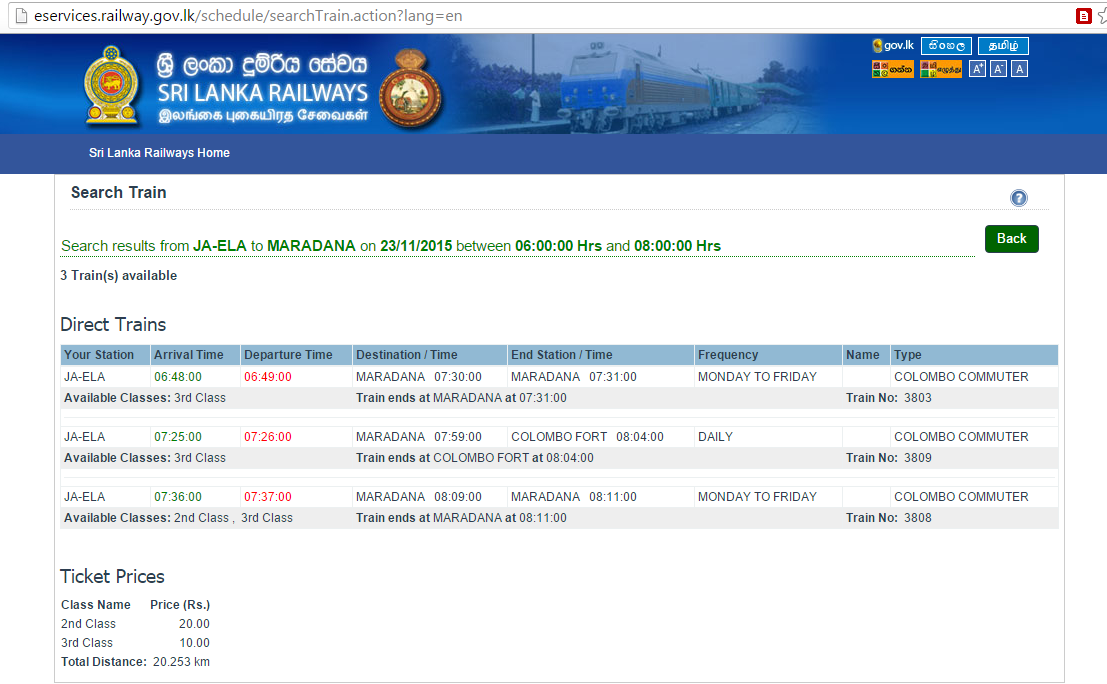


Figure 2.2 – Train Detail Screen of e-Service Offered by Railway Department[7]

Drawbacks as observed,

In this system, only the static schedule data is displayed, and there’s no way of confirming if the train is available or not in real time. The system does not offer a method to view train delays. And there’s no way to locate the trains in real time.

1. Android Mobile Applications available in the Google Play marketplace;

* Sri Lanka Train Schedule [8]

This application is provided by Railway Department of Sri Lanka with the help of Information and Communication Technology Agency of Sri Lanka (ICTA). As mentioned in the above section, this is the mobile presentation of the service offered by government. This application can be installed in android mobile devices, as same as the web application, it requires an active internet connection to work.

The application is available in google play store in the following location: - <https://play.google.com/store/apps/details?id=lk.icta.mobile.apps.railway>

The following information is available in the google play store regarding the application, ,  
*“Sri Lanka Train Schedule application is developed under the initiative of delivering government e-services which are connected to Lanka Gate through smart phone mobile interface. From this application you can get Train Schedule and Ticket Price information from Sri Lanka Railways.”*[8]

Drawbacks as observed,

In this system, only the static schedule data is displayed, and there’s no way of confirming if the train is available or not in real time. The system does not offer a method to view train delays. And there’s no way to locate the trains in real time.

* Train Schedules of Sri Lanka [1]

Train Schedules of Sri Lanka Provided another mobile user interface for the same service as above.

* + Additional features are added to add train schedules to favorites and to store last 10 searches in history.
  + Accessed via : - <https://play.google.com/store/apps/details?id=com.aselalee.trainschedule>
  + Drawbacks as observed,

In this system, only the static schedule data is displayed, and there’s no way of confirming if the train is available or not in real time. The system does not offer a method to view train delays. And there’s no way to locate the trains in real time.

* Train Guide - Sri Lanka [2]
  + Provided another mobile user interface for the same service as above.
  + Additional features are added as search history to be available offline access, and the location awareness to find the nearest train station.
  + Accessed via : - <https://play.google.com/store/apps/details?id=k.dw.timetable>
  + Drawbacks as observed,

In this system, only the static schedule data is displayed, and there’s no way of confirming if the train is available or not in real time. The system does not offer a method to view train delays. And there’s no way to locate the trains in real time.

In addition to the mobile applications indicated here, there are several more applications, but all of them share the same basic set of features and therefore share same drawbacks.

1. GPS based train movement tracking system by Sri Lanka Railway with University of Colombo [3]

The GPS based train movement tracking system by Sri Lanka Railway has been developed with the association of University of Colombo – Sri Lanka. This system could be accessed via - <http://www.slrail.info/>

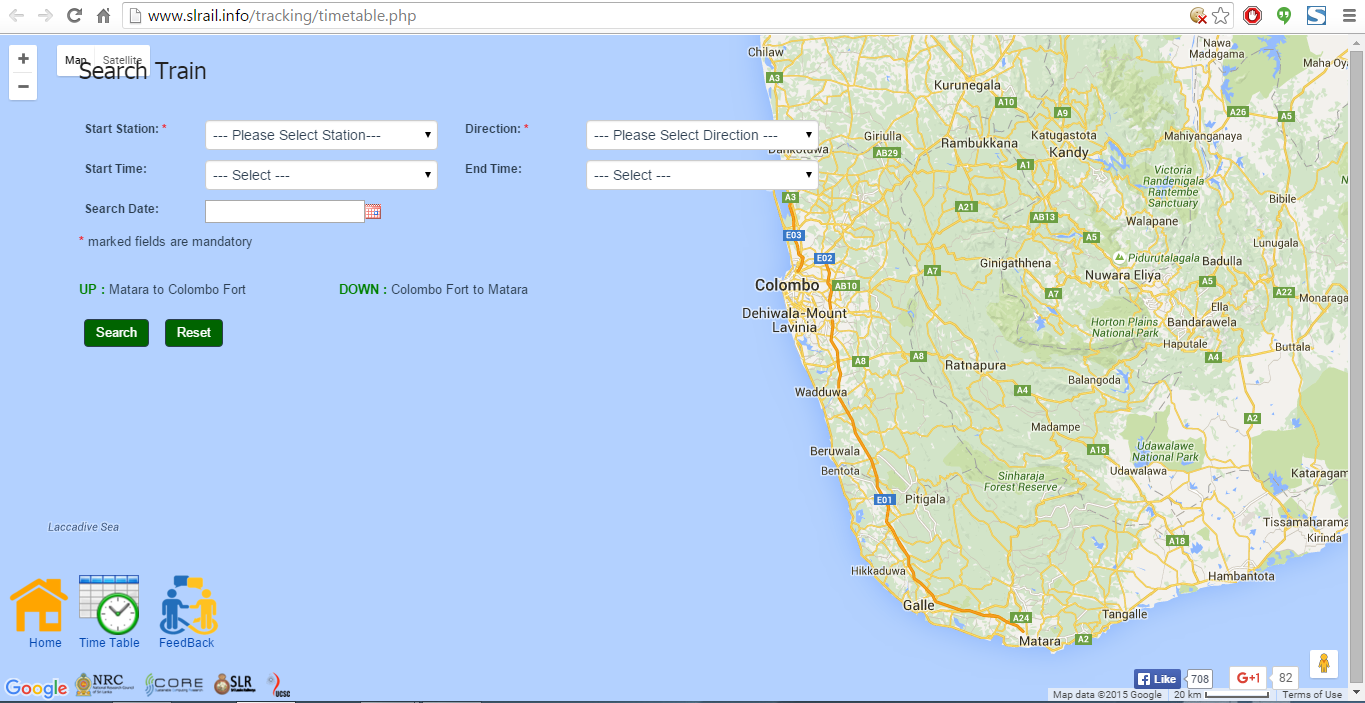


Figure 2.3 – Search Train Screen of GPS based train movement tracking system by Sri Lanka Railway with University of Colombo [7]

The system is implemented only for Coastal Line, and the current location of the train could be seen on a map. An enquiry can be placed by providing start position and destination stations. This is the only available system to show current location of trains in Sri Lanka.

Drawbacks as observed,

* Implemented only for Coastal Line and currently the system does not show the live train details, system maintainace is not properly in place as it is observed.

1. A proposed system - GPS/GSM based train tracking system – utilizing mobile networks to support public transportation [4]

“The paper presents a solution implemented at Sri Lanka, to provide an intelligent train tracking and management system to improve the existing railway transport service.

The solution is based on powerful combination of mobile computing, Global System for Mobile Communication (GSM), Global Positioning System (GPS), Geographical Information System (GIS) technologies and software. The in-built GPS module identifies the train location with a highest accuracy and transfers the information to the central system via GSM.

The availability of this information allows the Train Controller to take accurate decisions as for the train location.

Location data can be further processed to provide visual positioning using maps granting a wholesome view on train location.

Positioning data along with train speed helps the administration to identify the possible safety issues and react to them effectively using the communication methods provided by the system. Additionally, the location information can be used to facilitate accurate scheduling with regard to train arrival and departure on each station.” [4]

This system is a comprehensive solution for the current issues observed in the train transportation system. But it mainly focuses on train administrative staff rather than the passengers, and also the cost of implementation and infrastructure cost will be large. This system should be implemented within the railway department itself.

1. GPS based tracking system for trains in Sri Lanka [5]

“The main objective of this project is to develop a system to electronically monitor the movements of trains in Sri Lanka. This system will be set up inside the control center of the Sri Lanka Railway Department as an auxiliary system, to be used by the technical staff. The system is developed keeping the cost at a minimum at all possible times. Since the main function of the system is to track the location of the trains, it is named as the 'trianTracker'” [5]

The main disadvantage of the proposed system here is, it is available for the train control staff only. The main objective of the CBTLS is to provide train location information to the general public.

1. Summary

There are several number of solutions which are already implemented and also proposed to address the same issues which CBTLS is trying to address. As indicated above, each one of them are having its own unique features which is beneficial for the train passengers as well as train controlling staff. But the lack of one comprehensive system, including all good features of all above systems is still a pending requirement.

The many mobile application which are available in Google Play, are based on same service offered by Information and Communication Technology Agency of Sri Lanka (ICTA) and Sri Lanka Railways, therefore all of them share the same issue, not having real time updated data.

CBTLS is addressing this issue by keeping data from ICTA and Sri Lanka Railways as master data, and get updated on them through the community. By maintaining its own data store, CBTLS is capable of handling the issues which other systems described above are not able to handle.

In contrast to the systems mentioned above, the implementation cost would be minimum for CBTLS.

The following chapter – Chapter 3 will describe the tools and technologies used to implement the CBTLS.

Chapter 3

CBTLS – designed to cater real time data

1. Introduction

In the previous chapter, various existing systems and proposed systems to address the same issues which CBTLS is supposed to solve were analyzed. Each of their features and disadvantages were listed.

In this chapter, the technologies, and architectural features will be described regarding the proposed community based train locating system. CBTLS should be designed in a way to allow unlimited number of users to access the system. The system will receive data from a large number of users simultaneously, and therefore should be capable of handling such large amounts of requests through the web clients as well as the mobile clients.

When considering the mobile application, the system requires internet access to operate its functionality properly, but at least the cached static data of recent searched should be available in the mobile device as well. Therefore a temporary database would be stored in mobile device as well. A more detailed description of such concerns and technologies adapted to address them are described in this chapter.

1. Design Considerations

Following design considerations were made during the design process of CBTLS.

1. UI Considerations

* For the web application - Model View Controller (MVC) Pattern – The Spring MVC is used for this purpose. Because of this both mobile and web client could be catered using same services, since the presentation layer is separated from the business layer.
* User Language Preference and option to change - labels shall support all three languages and shall be shown to the user in the selected language. This localization is a must for the web application and mobile application since a wide range of users would be accessing the system, and one of systems main objective is to address the issue of unawareness due to linguistic issues.
* Internet Browser Support – The application will support Internet Explorer 9, Firefox 20 and Google Chrome 28. The web application would support all the main browsers and their latest versions. For this purpose, a UI framework like bootstrap would be used.
* Mobile device support – native android mobile application would support earliest possible android version, in order to cater as much as devices. The standard screen sizes would be developed, in order to cover the majority of devices properly.
* JQuery based AJAX framework will be used for populating data in dependent dropdown rather than refreshing the whole page. In web application, for the sake of limiting the calls to server, only the required parts of pages would be refreshed through ajax calls.
* Segregate Look and Theme – The application will have CSS (cascaded style sheet) for storing font, colour, table styles etc. This would certainly make the core application logic decoupled from application look and style. The mobile application and web application would be developed in a way look and feel would be similar for both.

1. Data Model Design

* The physical data model is done considering MySQL database.
* The model has assumed soft deletion of entities compared to hard delete.
* Although, in this sample application which would be implemented MySQL is used, but in a real world application, a NoSQL solution would be preferred since CBTLS would have to cater a huge amount of real time data access and process, and as well as huge amount of data analysis.

1. Uses of Design Pattern

A number of design patterns would be used. The Business component uses Data access Object (DAO) pattern, Factory Pattern, Singleton Pattern. The presentation layer uses MVC pattern.

1. Connection Pooling

The connection object is obtained by lookup from the data-source defined in the application configuration file of spring and Hibernate integration. Connection pool is used for obtaining database connections & those connections are released back to the pool after usage. This process is handled automatically with the introduction of Hibernate as Object Relational Mapping and data access framework to the system.

1. Transaction and rollback

Connections will be fetched from connection pool in Business layer and passed as parameter to DAO layer. In case database exception occurs in DAO layer that will propagate up to Business layer and the transaction will be rolled back. So business classes will have entry and exit points of transactions. In case of transactions involving multiple DAO layer, the business layer ensures that same connection object is passed to all. Any create/update operation will be done in a single transaction – so that if anything goes wrong within a transaction, then the whole operation will be rolled back.

1. Concurrent access

Since data in CBTLS will be concurrently accesses with a large frequency, Version column will be used on all tables to handle concurrent updates and to avoid data being overwritten from other sessions. This is the concept of optimistic locking of database records.

1. Clustering support

Business classes are stateless and singleton in nature. Thus application supports single instance or cluster environment deployment. Since business classes will generate single stateless instance in each JVM of clustering, it does not affect session affinity capabilities of the load-balancer, if used.

Also all value object classes will implement Serializable interface to ensure no hindrance occurs if and when session replication is enabled.

1. Logging Facilities

Log4j logging framework will be integrated to capture log into file system for any kind of operation in the system. But in production, logging level would be set as ERROR to avoid performance deterioration because of capturing huge amount of log.

1. Audit Facilities

Every transaction table will have two audit columns namely "Created By", "Created Date" – to track who has created/updated a particular entry in table and when that is happened. Also for every transaction table, there will a corresponding audit table to capture all the audit trail data for any modification of data in the main table.

1. Security

The web application is secured with Spring security framework and only authorized users will be able to access the system, and even the authorized users will have restrictions when it comes to system’s functionality.

1. Detailed Software Architecture

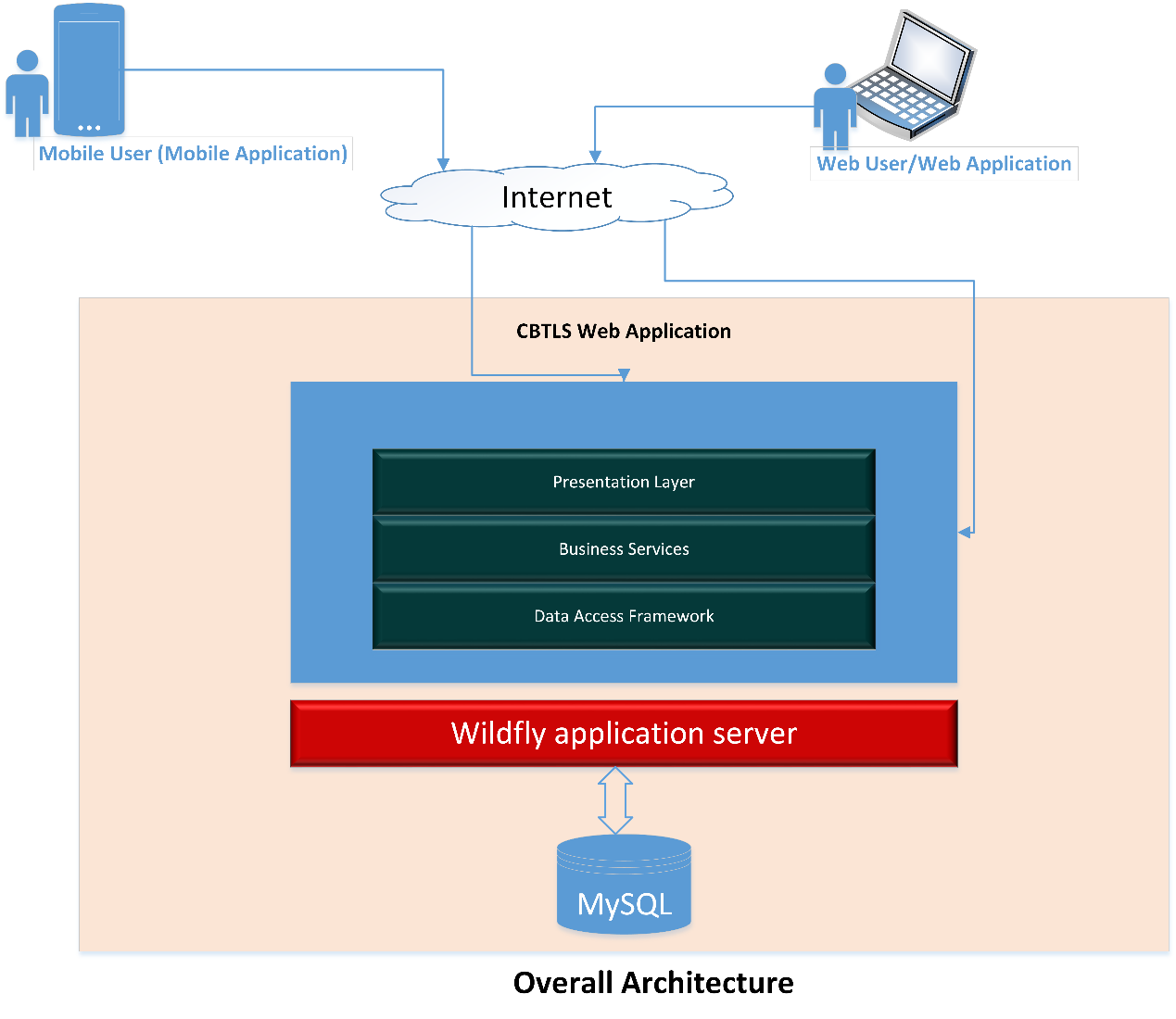


Figure 3.1 – Overall Architecture of CBTLS

|  |  |
| --- | --- |
| **Component** | **Description** |
| CBTLS Web application | Used by the general public through web clients and as well as mobile clients |
| Wildfly Application Server | Application server which hosts the CBTLS Web application |
| MySQL | Relational database to store CBTLS data |
| Mobile User/Mobile Application | Native android application which would communicate with the web application |
| Web user/Web application | Web application as the client itself |

Table 3.1 – Each component of Overall Architecture of CBTLS

1. Technology Stack

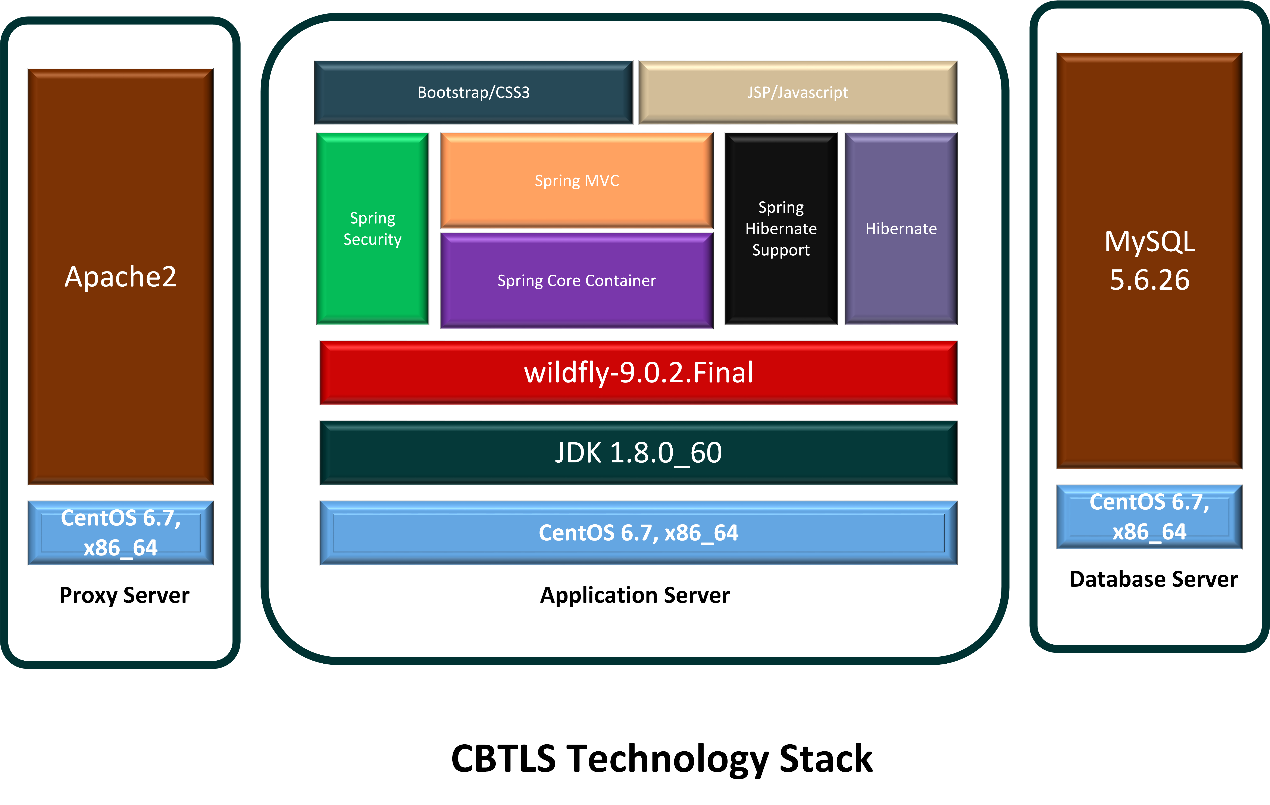


Figure 3.2 – Technology Stack

|  |  |
| --- | --- |
| **Component** | **Description** |
| Proxy Server | The physical server dedicated to handle requests from client and do load balancing, which is crucial in systems like CBTLS |
| CentOS 6.7,x86\_64 | 64 bit CentOS- a linux operating system as the OS in servers |
| Apache2 | To be used as the proxy server |
| Application Server | The dedicated physical server/servers to handle application server - WildFly |
| JDK 1.8.0\_60 | Java framework version 8, on top which CBTLS is implemented and will execute,. |
| Wildfly Application Server | Application server which hosts the CBTLS Web application |
| Spring security | A component in Spring framework, integrated to CBTLS to handle user authentication related security tasks easily |
| Spring Core container | Included in CBTLS to handle Inversion of Control and dependency Injection and for the integration of Spring MVC, spring security and spring hibernate support. |
| Spring MVC | Included in CBTLS to separate presentation layer from business logic, so it will be able to cater both mobile and web clients, or any other client |
| Spring hibernate support | Used to integrate Hibernate ORM mapping framework into spring context, and also to handle database transactions automatically |
| Hibernate | Used as an ORM tool and database access |
| Bootstrap/CSS | To style the UI and maintain consistent look and feel across different browsers |
| JSP/Javascript/jQuery | To view and modify data from client’s web browser |
| MySQL | Relational database to store CBTLS data |

1. Summary

In this chapter the technologies used and design considerations were described, the reasons to use the selected technologies in the implemented system was also described.

In the following chapter, the approach to implement CBTLS will be described.

Chapter 4

Implemeting CBTLS for real time information

1. Introduction

In the previous chapter the design considerations and technologies used to implement CBTLS was described.

In this chapter the implementation plan for the CBTLS for demonstration purpose is described. Along with that, the deployment environment for the CBTLS is also described.

1. Implementation Plan

For the research purpose, only a single train route would be selected to initially implement the system. Of that train route, train schedules would be selected to cover both weekdays and weekends, for office times where the trains are mostly crowded, and to cover regularly crowded times.

Initial data of selected train schedules would be fed to system so the users would be able to look up schedules initially. But the proposed system is based on data provided by general public (the community of train passengers). The most challenging part of the system would be to validate the received data before it gets displayed for other users.

For this validation purposes, and for data analytical purposes, geo coordinations of train stations along the selected route, and the geo coordinates of the selected rail route would be have to be inserted into the system.

The system would be consisted with a web application and a mobile application. Mobile application would be used to collect data about trains from passengers and the same is used to display data upon enquiries. The mobile application would be a native, location-aware application for Android which would support geo locating the user. Therefore this mobile system would only be available for android users.

The user location would be acquired through GPS and Android's Network Location Provider. Although GPS is most accurate, it only works outdoors, it quickly consumes battery power, and doesn't return the location as quickly as desired. Android's Network Location Provider determines user location using cell tower and Wi-Fi signals, providing location information in a way that works indoors and outdoors, responds faster, and uses less battery power. Therefore, to obtain the user location in this application, both GPS and the Network Location Provider are to be used.

The web application would also contain all the features of mobile application, except for the facility to provide the location of the train or the compartment details. The general public would be able to search for trains, get the estimation and predictions. At the same time they could provide feedback on each selected trains.

In the web application, there would be a part with restricted access for admin functionalities which would be described in detail in below sections.

1. Deployment View

The following diagram illustrates the deployment environment for the CBTLS, required resources and networks.

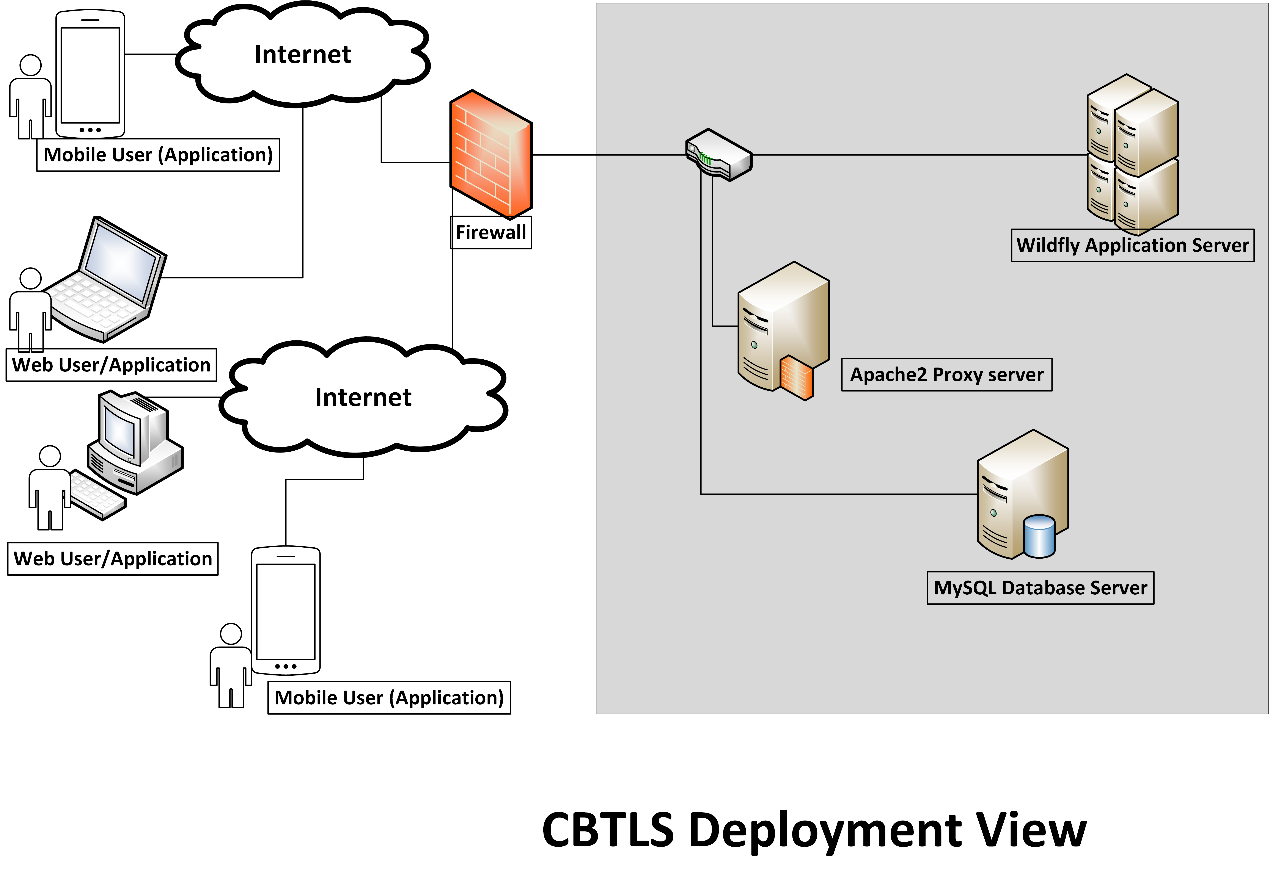


Figure 4.1 – CBTLS Web Application Deployment Diagram

Above figure depicts the deployment architecture of the servers and the services required for the CBTLS Application.

Apache2 – Proxy Server running as the load balancer

Wildfly Application Server – Hosts the CBTLS application

MySQL database – Database service which stores the CBTLS application data.

1. Summary

In this chapter the implementation plan for the CBTLS for demonstration purpose is described. Along with that, the deployment environment for the CBTLS is also described.

In the next chapter analysis and design part of CBTLS would be described along with diagrams to aid.

The design diagrams would be incorporated in to this document.

Chapter 5

Analysis and Design of CBTLS

1. Introduction

In the previous chapter, implementation plan of CBTLS application for the demonstration purpose was described.

In this chapter detailed design of CBTLS would be illustrated. For the design purposes, the UI wireframes of mobile application, the Entity relationship diagram of CBTLS, the class diagram of CBTLS, sequence diagrams related with mobile application functionalities are illustrated below.

1. UI Wireframes of CBTLS mobile application

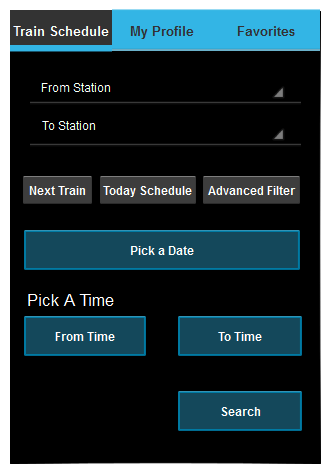


Figure 5.1 – CBTLS mobile application initial UI wireframe

This would be the initial UI loaded to the mobile user, and this can serve as other existing system to search for train schedules. This UI was built to preserve that functionality and user experience. From here, by picking a start station and an end station, and an optional date and time range, users can search for train schedules.

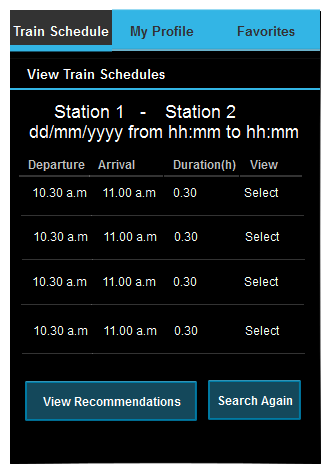


Figure 5.2 – CBTLS mobile application view train schedule wireframe

Once the schedules are search, they will be get listed like in the above figure, up to this level, system behaves as an ordinary existing train schedule searching mobile application. Through this UI, advances features like recommendations, and real time location UIs could be accessed.

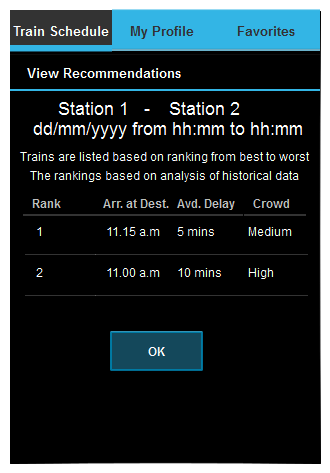


Figure 5.3 – CBTLS mobile application view recommendations wireframe

Here through an internal algorithm, system will order the train schedules for user, the considered facts are included like daily delay, crowd density, time of arrival at destination.

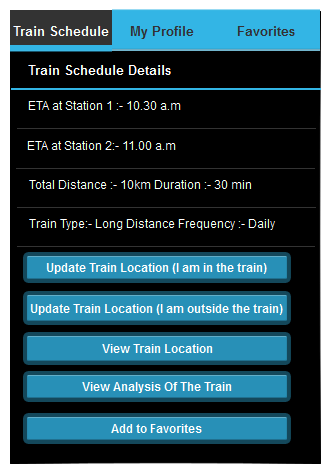


Figure 5.4 – CBTLS mobile application view train schedule details wireframe

This UI provides access to the other major UIs as indicated.

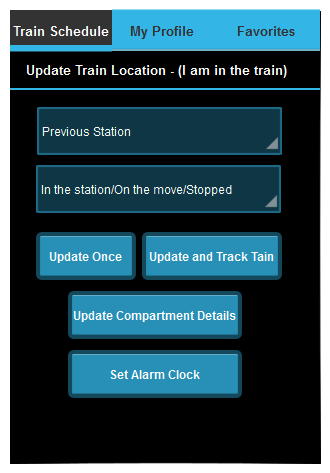


Figure 5.5 – CBTLS mobile application active update train location wireframe

Using this UI, the user could update the current location of the train.

Rest of the UIs wireframes are listed below,

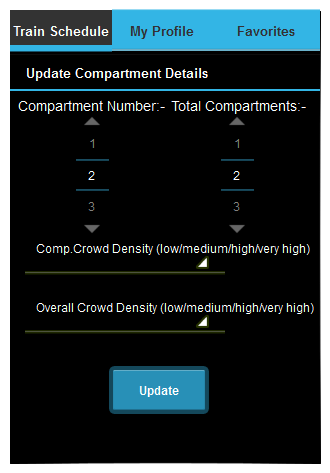


Figure 5.6 – CBTLS mobile application active update compartment details wireframe

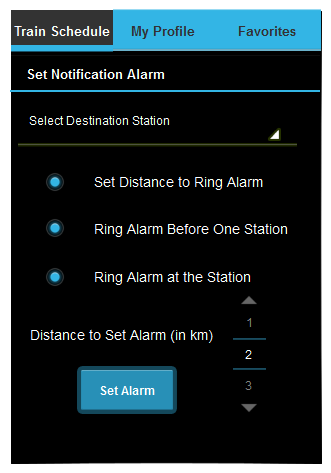


Figure 5.7 – CBTLS mobile application set notification alarm wireframe

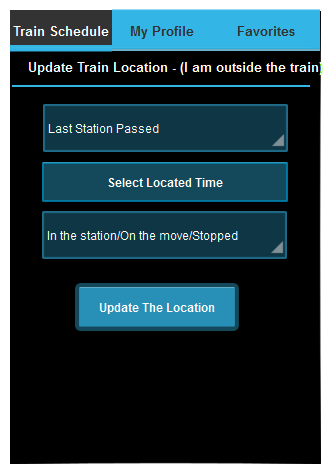


Figure 5.8 – CBTLS mobile application passive update train location wireframe



Figure 5.9 – CBTLS mobile application view real-time train location wireframe

The train locations will be indicated in a map, for current trains.

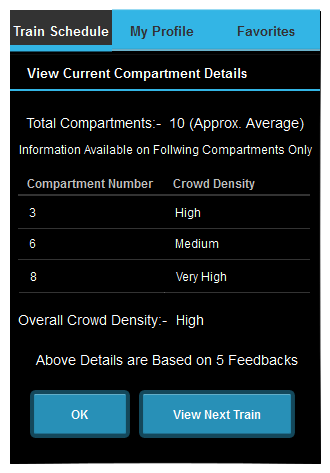


Figure 5.10 – CBTLS mobile application view compartment details wireframe

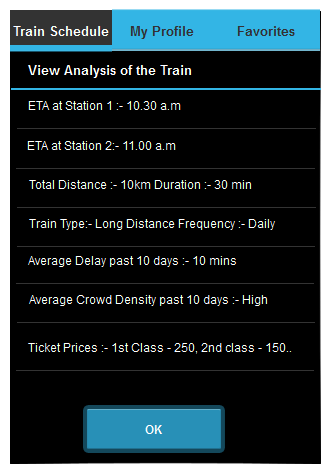


Figure 5.11 – CBTLS mobile application view analysis of train wireframe

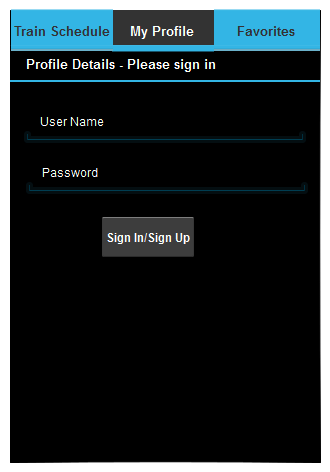


Figure 5.12 – CBTLS mobile application user login wireframe

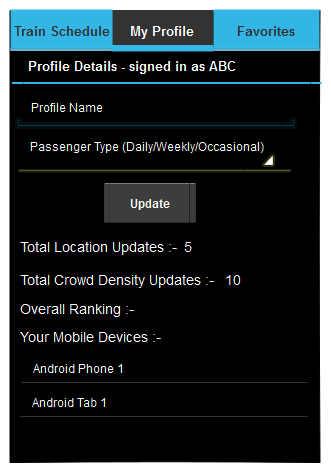


Figure 5.13 – CBTLS mobile application user profile details wireframe

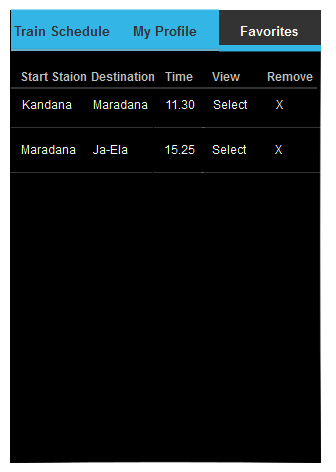


Figure 5.14 – CBTLS mobile application favorite trains wireframe

1. Entity relationship diagram of CBTLS

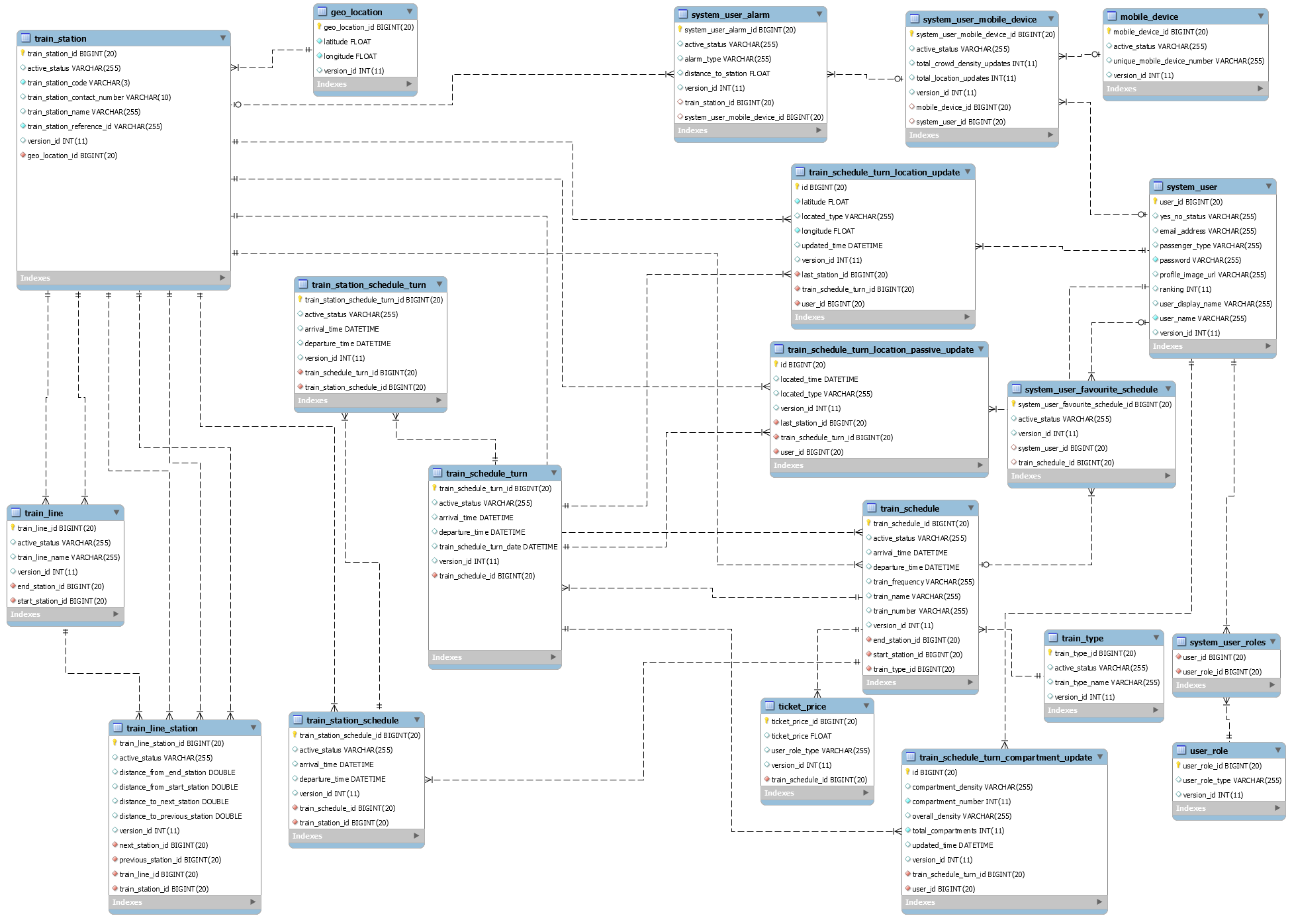


Figure 5.15 – CBTLS ER diagram

1. Class diagram of CBTLS

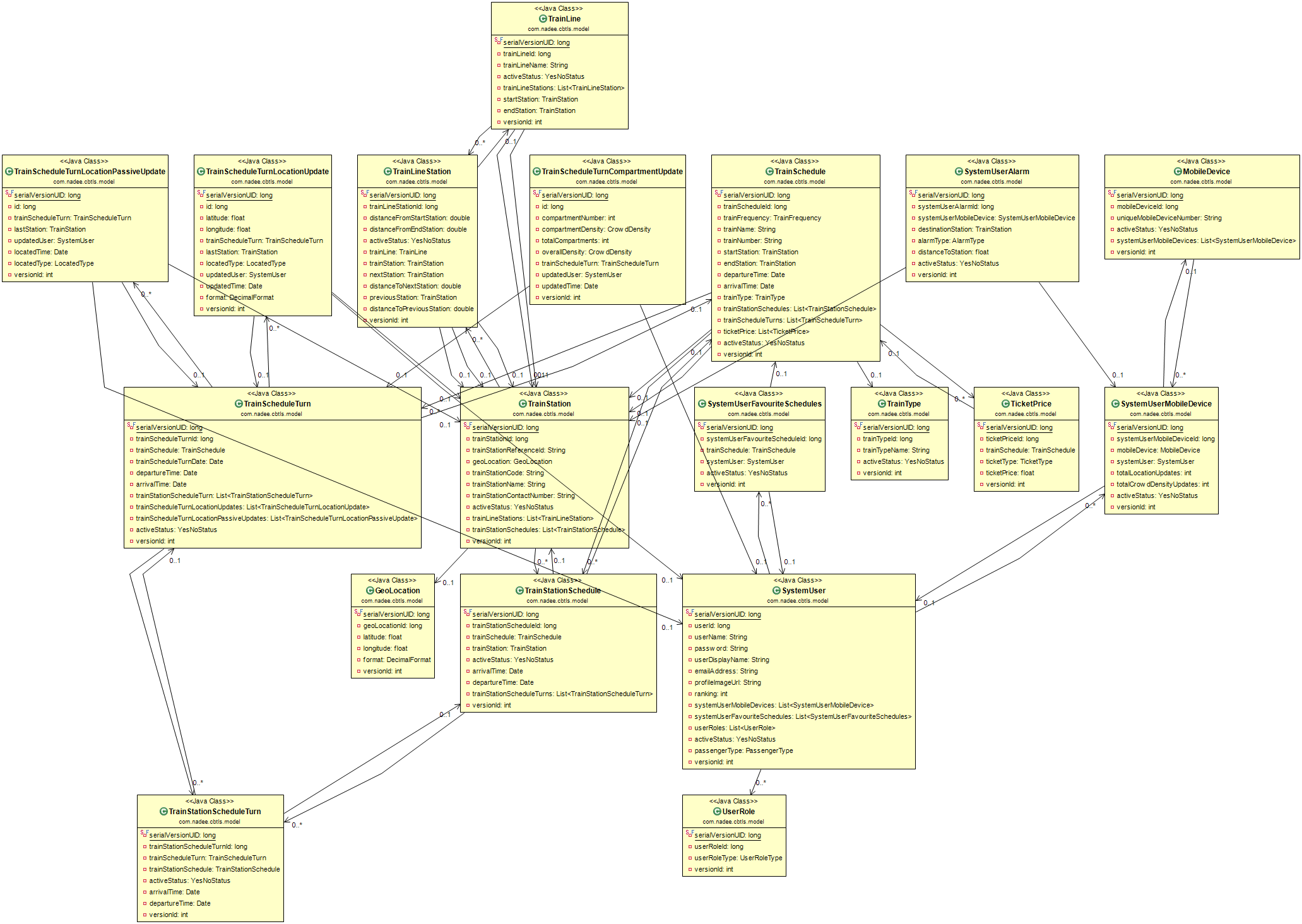
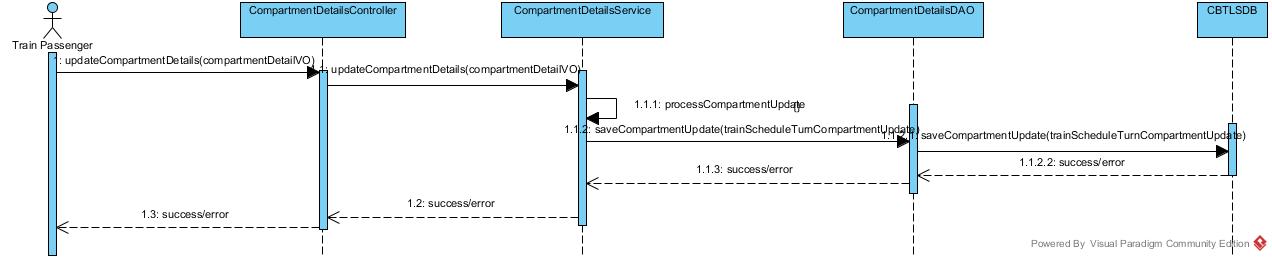
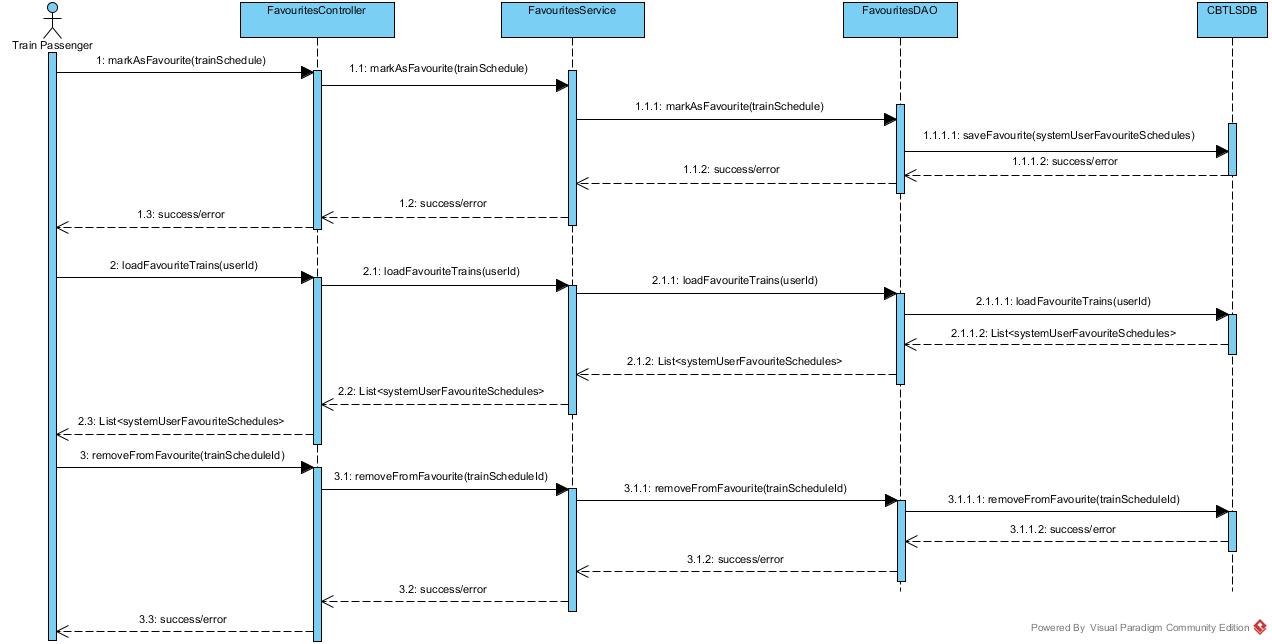


Figure 5.16 – CBTLS Class diagram

1. Sample Sequence Diagrams of CBTLS





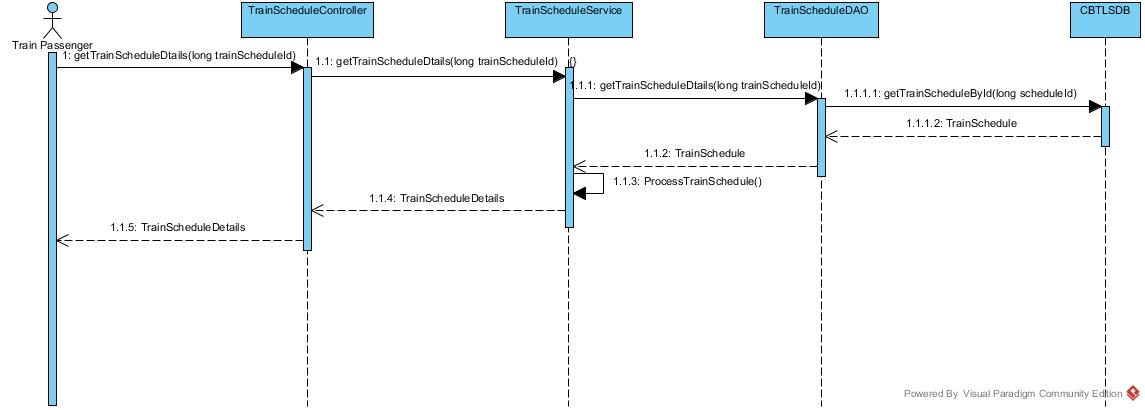


Figure 5.16 – CBTLS Sample Sequence diagrams

1. Summary

This chapter was mainly focused on design diagrams and design details of CBTLS.

Chapter 6

Discussion

The party whom are mainly benefited by this system would be the passengers. With the currently available systems, they are only capable to see the train schedules. This new system will provide the following information to a passenger, regarding a selected train.

* Indication if the train is available or not (for current trains).
* The current position of the desired train.
* The crowd density in each compartment.
* Suggestions for trains based on destinations and time of reaching destinations together with user’s location and the most nearby station of boarding the train
* Facility to provide the passenger’s suggestions, comments and criticisms regarding a selected train
* A location aware alarm to indicate when the desired destination is reached

The above features would allow a passengers to save the waiting time at the stations for a train. It would also allow to select an alternative method of transportation, in case a train is not available for the desired time, or the train has been delayed or cancelled. This can save many productive man hours for the country. Through the facility to provide their feedback regarding the train, passengers would be able to convey their suggestions, comments and criticisms for other passengers, and possibly for some responsible authority.

A set of authorized users for the web application, would be able to analyze patterns of train transportation and to identify the points where delays occur. The past stored data could be also analyzed and studied to provide a better train transportation service which will serve the need of passengers better.

The main risk for the system would be the possible inaccuracy and reliability issues of the data retrieved from the passengers. The inaccuracy could be reduced by through validation, but the reliability of data could only be determined through the amount of similar data retrieved from different sources. To enhance the reliability,a grading system for users could be introduced.

The location awareness of the mobile application for passengers would require GPS or Android's Network Location Provider activated in the mobile application. Also the application would require an active internet connection to use this application. These could be considered as limitations of the system, since some users would not be agreed with these terms.

All the existing and proposed systems mentioned currently available, would require an involvement from Sri Lanka Railways (SLR), mainly for locating trains. It has been done by placing a GPS tracking device inside the train. In this CBTLS, there won’t be a requirement for any involvement of SRL, since the data is expected to be fed by train passengers.

For the passengers, to use the mobile system, it would require an android mobile device with either GPS or Android's Network Location Provider activated, and an active internet connection.

For the web application, it would require a high performance server to host the application to handle the expected large amount of requests, since this is accessed by general public. At the same time, since the current locations of trains should be updated at regular intervals, requests for locations updates would be sent frequently to the server.

For the demonstration purposes for this research, a single rail route would be selected, and the geo locations along the route would be required to be inserted into the system as master data. The existing train schedules also would be inserted. A set of randomly generated mock data also would be inserted to the system to demonstrate the analytical part of the system. To demonstrate location-aware mobile application, a mock GPS client would be used.

References

|  |  |
| --- | --- |
| [1] | A. Leelaratne, "Google Play - Train Schedules of Sri Lanka," Asela Leelaratne, 14 October 2014. [Online]. Available: https://play.google.com/store/apps/details?id=com.aselalee.trainschedule. [Accessed 22 11 2015]. |
| [2] | "Google Play - Train Guide - Sri Lanka," K Mobiles, 30 August 2015. [Online]. Available: https://play.google.com/store/apps/details?id=k.dw.timetable. [Accessed 22 11 2015]. |
| [3] | "Sri Lanka Railways," [Online]. Available: http://www.slrail.info/. [Accessed 22 11 2015]. |
| [4] | D. Jayakody, M. Gunawardana, N. W. Surendra, D. G. Jayasekara and C. Upendra, "GPS/GSM based train tracking system – utilizing mobile networks to support public transportation.," Phanindhra Nath, 2011. |
| [5] | N. Gunasekara, "GPS based tracking system for trains in Sri Lanka," University of Moratuwa, Colombo, 2006. |
| [6] | "Search Train," 2011. [Online]. Available: http://eservices.railway.gov.lk/schedule. |
| [7] | "Statistics, Ministry of Internal Transport," Ministry of Transport & Civil Aviation Sri Lanka, 28 10 2015. [Online]. Available: http://www.transport.gov.lk/web/index.php?option=com\_content&view=article&id=141&Itemid=113&lang=en. [Accessed 22 11 2015]. |
| [8] | "Economic and social infrastructure - Central Bank of Sri Lanka - ANNUAL REPORT 2012," 2013. [Online]. Available: http://www.cbsl.gov.lk/pics\_n\_docs/10\_pub/\_docs/efr/annual\_report/AR2012/English/7\_Chapter\_03.pdf. [Accessed 22 11 2015]. |
| [9] | B. N. Gamage, "Google Play - Sri Lanka Train Schedule," ICTA Sri Lanka, 03 April 2014. [Online]. Available: https://play.google.com/store/apps/details?id=lk.icta.mobile.apps.railway. [Accessed 22 11 2015]. |
| [10] | S. Rainford, "e-Sri Lanka: An Integrated Approach to eGovernment," ICT Agency of Sri Lanka, Kirimandala Mawatha Colombo 5, Sri Lanka, 2006. |

[1] A. Kumarage, “Urban traffic congestion. the problem and its solutions,” 2002.

[2] A. B. Jayasinghe and N. Pathiranage, “Centrality measures’ as a tool to identify the transist demand at railway stations: the case of railway network, Sri Lanka,” 2015.

[3] “Economic and social infrastructure - Central Bank of Sri Lanka - ANNUAL REPORT 2012,” CENTRAL BANK OF SRI LANKA, ANNUAL REPORT 2012, Mar. 2013.

[4] “Statistics, Ministry of Internal Transport,” *Ministry of Transport and Civil Aviation - Sri Lanka*, 28-Oct-2015. [Online]. Available: http://www.transport.gov.lk/web/index.php?option=com\_content&view=article&id=141&Itemid=113&lang=en. [Accessed: 13-Mar-2016].

[5] G. Bradley, International Association for Development of the Information Society, and Albert-Ludwigs-Universität Freiburg, Eds., *Proceedings of the IADIS International Conference ICT, Society and Human Beings 2010: part of the IADIS Multi Conference on Computer Science and Information Systems 2010 ; Freiburg, Germany, July 29 - 31, 2010*. Lisboa: IADIS Press, 2010.

[6] S. Rainford, “e-Sri Lanka: An integrated approach to e-government case study,” *Reg. Dev. Dialogue*, vol. 27, no. 2, pp. 209–218, 2006.

[7] ICTA, “Sri Lanka Railways - Train Schedule,” *Sri Lanka Railways*, 2011. [Online]. Available: http://eservices.railway.gov.lk/schedule. [Accessed: 13-Mar-2016].

[8] G. Bhashitha Nadun, “Sri Lanka Train Schedule - Android Apps on Google Play,” *Google Play*, 04-Mar-2014. [Online]. Available: https://play.google.com/store/apps/details?id=lk.icta.mobile.apps.railway. [Accessed: 13-Mar-2016].