Collaborative Real-Time Interactive Billboard Networks

by

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Online advertising and marketing nowadays has become more and more popular, and there are increasing number of companies that comes into the battle of this market. As everyone can see, advertisement is dispensable part for almost every website. When we are browsing the websites, we have access to various advertisements. Some of them are even based on our activities in the browser so that the advertisements can be more relevant to us, and consequently increase the impressions and click on the advertisements. To make this kind of advertising more efficient and profitable not only benefits the advertiser, but also helps websites and advertising technology vendors to grow.

There are many technology companies that provides the platform for websites and advertisers, where they websites can offer their advertisement spots and advertisers are able to pick their favorite places to render the advertisements. Since the process is very wide open on the Internet, it can involve huge amount of data which could be over million or even billion. Also most of advertising technology companies have real-time bidding system which really helps to activate the whole market and maximize the profit of advertisers, websites and themselves.

However, as the online advertising roaring up, it seems the billboard market is left behind. Compared to websites advertisement spots, billboard is much more physical and harder to operate. billboard owners are using different players and CMS(content management systems) to operate their billboards. Those CMS may be costly, for which billboard owners may be not willing to replace their existing system with other new methods. So it will be difficult and complicated to integrate different individual billboard operating networks together. But good news is people are choosing digital LED billboard over other kinds of billboards because it is easier to control and can provide more options to advertisers in terms of the type of advertisements. Therefore, i may be a good time to incorporate a system that helps to involve all the digital billboards under the hood and make outdoor billboard advertising as efficient as online advertising.

Firstly, in order to contain billboards as many as possible, we need one single place for billboard owners to show and describe their billboards, and meanwhile advertisers can are able to see those information and make their decisions based on the locations and the prices. Secondly, to be able to distribute the advertisement contents to the billboards, a hardware is required to install in the billboard so that it can communicate with the server and grab the content and the schedule. Thirdly, to increase the compatibility between different existing billboard management systems that billboard owners are using themselves, the hardware has to be an add-on device which does not interfere the original work flows. Finally,

the system should allow convenient interaction between advertisements and consumers so that the consumers can access the resources of the products or services which are being advertised, just like an end user clicking an advertisement on the Internet. Based on these four perspectives, a collaborative real-time interactive system for billboards is introduced and discussed.

Acknowledgements

I would like to thank my supervisor Professor Pin-Han Ho and my colleague Dr. Mohammed Liakat Ali. I really appreciate their supports and helps which make my MASc experience fruitful and fun.

Dedication

To my beloved parents.

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Chapter 1

Introduction

Online advertising has thrived for many years. The business model and the related technology has been very successful. However, in the outdoor advertising market, there are few companies trying to provide similar services which really connects billboard owners and advertisers in an efficient way. Billboard owners are maintaining their own networks and systems while advertisers takes fairly large amount of efforts to find the perfect locations for their advertisements.

It is consequently crucial to create such a online platform where billboard owners can offer their advertisement slots within a few click and advertisers can get rid of all the hassles to make tons of calls themselves. This thesis will introduce a collaborative real-time interactive system that may activate the advertising market of outdoor billboards.

As you can notice, the word that come first is collaborative. This can be seen in two different ways. The first one is to build a bridge between billboard owners and advertisers through Internet so that both of them could make transactions in a more modern way. Another way to see the word collaborative is that this system can break the barriers between different existing billboard networks who are using diverse management system. In the later chapters, I will explain more about how the barriers are broken by using a BlackBox(BB) that is invented for this system, which extremely increases the compatibility of the system.

Another thing that is worth to notice is that this system is a real-time system, which means everything is on the go. Billboard owners open slots of their billboard. Those slots are immediately available on the platform where advertiser can book them within just a few click if they are interested in. Furthermore, the advertisement contents are transferred

through Internet to the BlackBox, and the BlackBox will integrate the advertisement from server with contents from local CMS according the schedule provided by billboard owners.

In online advertising, if an end user visiting the website is interested in the content of the advertisement, the end user may click on that advertisement to enter the website of the product or the service. The actions of the end user are logged for this specific click which is associated with the particular advertisement spot, so that any feedback or benefit can be traced back to the spot. However, for billboard it is more difficult to let the potential consumers take actions on the advertisements immediately. So this is where Cyber-Physical media access(CPS) gets involved which allows users to drag the advertised information into their smartphones.

In the following sections, I will get into more details about this Collaborative Real-Time Interactive Billboard Networks.

1.1 Motivation

Advertising has been greatly evolved for the last 20 years since the Internet became an important part of people's daily life. And the online advertising is easy to operate and very efficient. All processes can be executed on the Internet. It is the modern way of advertising which is both time-saving and cost-saving. Many advertising technology companies provides services for both publishers and advertisers. publishers register their places for advertisements and advertisers buy or bid on the slot. Contents of advertisements are distributed really quick once the owner of the slot has been decided.

Nevertheless, in the world of billboard, it seems not as prosperous as the market of online advertising. Although digital billboard is getting more and more popular which makes the control of billboards easier, there are few companies are trying to make full use of it in order to simplify the process of outdoor billboard advertising. We think a model that is similar to online advertising could be introduced to billboard operation and advertising. In North America, there are many small independent billboard operators who are not generating enough revenues from their billboards. Billboard operators are looking for more orders of advertising while advertisers are seeking more exposure and matching customers. Also, there is no interactions between billboard advertisements and potential consumers in current billboard advertising model, which means after people see the advertisement on the billboard, it is hard to make further actions. So it is crucial and urgent to create a innovative billboard advertising platform on which selling and buying advertising slots, content distributions and consumer interaction are all taken care of.

1.2 Thesis Contribution

This thesis is presenting a system that makes billboard advertising more collaborative, real-time and interactive. To be more specific, the thesis proposes:

- A website where billboard owners can register their billboards and offer advertisement slots while advertisers can search the best locations and time slots for their advertisements, and upload advertisement contents to the server. All processes and transactions are done online. Furthermore, both billboards and advertisers can view the system generated report of the performances of their billboards and advertisements. The server also provides interfaces for BlackBox module to fetch and synchronize the schedule and advertisement contents. A simple version implementation of the website will be shown in later chapters.
- The BlackBox serves as a significant device placed in the billboard. One function of it to communicate with web server to retrieve necessary data for playing the advertisement contents from server. Another function is to act like an hot plugging adapter which can integrate the server contents with the local contents from CMS managed by the billboard owner, so that billboard owners can use our system without replacing their existing system.
- The Cyber-Physical media access(CPS) module will allow consumers who has our app on their smartphones to drag the advertisement information that they are interested in from the billboard remotely. This enables the direct and immediate interaction between consumers and billboard advertisements, just like clicking an advertisement on the Internet, which increases the efficiency and effectiveness of billboard advertising.

1.3 Organization of The Thesis

Chapter 2 reviews how the billboard advertising is currently operated and the past research about this, and also we will look into some concepts of online advertising which will be introduced into our billboard system. Chapter 3 presents the proposed billboard advertising platform and system in detail. The implementations of some parts of the system are discussed in chapter 4. And finally, a summary of the thesis and the further work and implementations of the system are presented in chapter 5.

Chapter 2

Background and Related Work

In this chapter, we brief the background and current status of billboard advertising and compare it with the thriving online advertising. Then we will go through some related research about billboard advertising.

2.1 Billboard Advertising and Online Advertising

2.1.1 Billboard Advertising

Billboard advertising is a way of advertising which uses billboards to present advertisement. It is designed to catch a person's attention and create a memorable impression very quickly, leaving the reader thinking about the advertisement after they have driven past it [8]. There are many types of billboard, which are painted billboard, digital billboard, mobile billboard, multi-purpose billboard, etc. Traditionally, billboards are painted with advertisements or covered with giant printed sheets. The advertisements on billboards were static and stay unchanged for a long time because it would take a lot of time and efforts to replace the advertisements on billboards. This was also not dynamic enough for advertisers to adjust their advertising plan if they found the location was not the right place for their advertisements or they found a better place but do not have enough budget to handle a new billboard. Furthermore, a static billboard advertisement that has not been changed for a long time tends to have less efficiency and impressions [7] since most people would get used to it after it is being presented for a period of time.

As digital products became more popular, digital billboard helps avoiding the hassle of changing advertisements on billboard because it can be controlled by computers. The

popular way to control digital billboards nowadays is by using a content management system(CMS). With CMS, billboard operators can remotely control their billboards via the Internet. More and more services emerge to help billboard operators to distribute contents while there are some companies help billboard operators to publicize their billboards so that they can attract more advertisers in order to increase the revenue.

Although the usage of digital billboard, CMS and other existing billboard services has made billboard advertising much more convenient and saving, it can be more dynamic. And we will talk more about how to make it more dynamic later. Now we are going to look into a fast developing area in the advertising industry which is online advertising.

2.1.2 Online Advertising

Online advertising began 20 years ago, after that it grew dramatically year by year [4]. Online advertising accounts for almost 9 percent of all advertising in the United States in 2009. The expansion of internet-based advertising is transforming the advertising business by providing more efficient methods of matching advertisers and consumers and is transforming the media business by providing a source of revenue for online media firms that compete with traditional media firms [1]. Also with the flying e-commerce business, the importance of online advertising is growing even faster, because consumers can experience quick shopping by just a few click of mouse while the transaction costs between sellers and consumers is significantly reduced.

Impressions is an important number of measuring the effectiveness of advertising. In online advertising, the concepts of "cost per mille"(CPM) and "cost per click"(CPC) are often used. CPM is the terminology for the cost of every 1000 viewers of the advertisement while CPC means the cost for every click on the advertisement. These concepts and models can be used for statistical purpose or in an online advertising bidding system where advertisers can bid on CPM or CPC for advertisement slots.

One thing that is worth to notice about online advertising is that for targeting the right consumers, it may gather data, such as browsing histories, online activities, so that some characteristics of the viewers can be obtained and analyzed. This is one mighty advantage that online advertising takes over other kinds of advertising, which extremely increases the effectiveness of advertising. But of course, this has some controversial privacy issues which may concern both consumers and those online entities who collect personal data.

As you can see, there some features of online advertising which billboard advertising does not have. For example, CPC only applies when consumers click on the advertisements. But in billboard advertising, this is unrealistic. Therefore, a way that can be counted

as a "click" should be invented so that billboard advertising has more choices of price models. Also, a click in online advertising means an interaction between consumers and advertisements. This concept should also be introduced into the billboard advertising which we will discuss in details in the later chapters.

2.2 Related Work

We find that early in 2002, a billboard advertising system is proposed, in which commercial advertisers may directly place advertisements onto selected billboards at selected times through direct access to a master network [5]. The system proposed in [5] seems to be the billboard management system or the content management system that are still being used today by most of billboard networks.

However, there are many similar systems in the market and different billboard operators may use different systems to manage their billboards. Although such a system takes the advantage of the Internet and simplifies the work load of both billboard operators and advertisers to some extent, imagine there are a large number of this kind of system, and advertisers may have to search through many systems in order to get an ideal billboard to present their advertisements. In order to solve this problem, either a unified platform is created where all billboards operators and all advertisers do their work, or a compatible solution is invented in order to allow each billboard network to stay unaffected and a new technology and platform can be incorporated upon the existing systems. Apparently, the solution with compatibility is more feasible under the current circumstances where billboard operators have invested a large amount of money on their management system and there are already a lot of advertisements being shown in those networks. Furthermore, the billboard advertising is not able to support much detail about the product or the service [6], and the consumers that are interested in the advertisement do not have a way to get further information about it instantly. This requires an invention to build connections between consumers and billboards.

2.3 Summary

This chapter we have gone through some background of both billboard advertising and online advertising. Obviously, some models and features only exist in online advertising, which we consider as the potential breakthroughs in the relatively slow developing billboard advertising industry. In addition, for the purpose of various existing billboard networks

to be able to coexist with the new platform which we are proposing, a highly compatible technology will also be created and bundled with the proposing system. Finally, the concept of interactions between consumers and billboards is introduced as well. The next chapter will present this new system in details.

Chapter 3

Collaborative Real-Time Interactive Billboard Networks

In this chapter, we will introduce each module of Collaborative Real-Time Interactive Billboard Networks. Just like what we have revealed in the former chapters, each adjective used before "Billboard Networks" has its purpose and meaning.

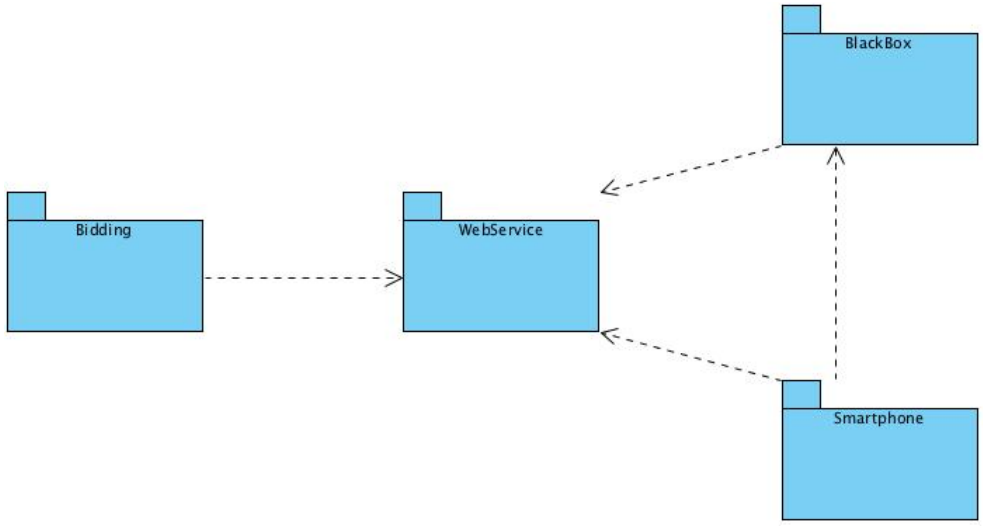

Figure 3.1: System modules

There are mainly three modules we will introduce in the following sections, including the web service for billboard owners, advertisers and consumers, the BlackBox technology

and the Cyber-Physical media access(CPS). Additional modules like bidding system is also in the plan of this system, but we will not dig into it in this thesis. Figure 3.1 illustrates the modules of this system. The arrows stand for the dependencies between each modules.

3.1 Web Service

This section will introduce the design of the web service for the three main roles that will use our system, which are billboard owners, advertisers and consumers. This web service serves as the user's access to the system. Users can use it to manage their specific resources based on their roles. In the following sections, we will go through each one by one.

3.1.1 Billboard Owner Service

The goal of the web service for billboard owners is to allow billboard owners to manage their billboard. To be specific, billboard owners provide their basic account information when they register with the system, including first name, last name, email address and so on. After they register and login, they can add existing billboards they have under their personal accounts. Once they register their billboards in the system. The initial status of the billboards is the *not ready* status which means the BlackBox that is in charge of communicating with the servers is not installed yet. Before the BlackBox is installed, no further functionality of the system can be used. Now assume that the status is *ready*, billboard owners can open advertisement slots on a particular billboard in the opening panel where some information of the opening, such as start time, end time, slot duration, quantity of opened slot, will be filled out. Of course, you can edit the information of billboards and openings as long as it does not affect the existing transactions with advertisers. The basic billboard owner service class diagram is shown in Figure 3.2.

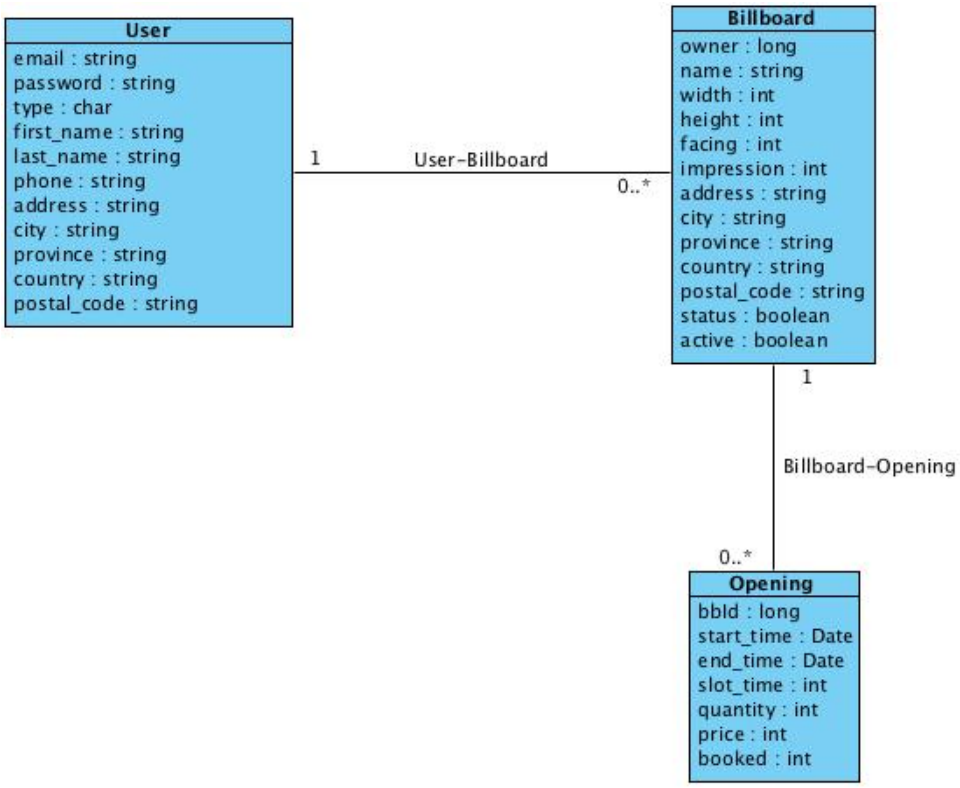

Figure 3.2: Billboard owner service class diagram

In the User class, we can see the *type* attribute. It is used to differentiate different roles. So the User here stands for billboard owner. In the class Billboard, there is an attribute *active* which signifies whether the billboard owner decides to use the BlackBox to incorporate the platform service. It is important for the owners to know that the platform will not hijack their billboards, it is an add-on service that helps to maximize the utility of the billboards. When the billboard owner decides to turn off the service, the *active* attribute changes to *false*, the advertisements that is showing based on the existing schedules stay unaffected. But the inactive billboard will not show up in the available opening list for advertisers. The relations of these three classes are simple, that is, one billboard owner can have multiple billboards and each billboard can have multiple openings.

3.1.2 Advertiser Service

The goal of advertiser service is to enable advertisers to buy advertisement slots that billboard owners provide. Once users register as advertiser, they can add and edit advertisement campaigns. For each advertisement, they can book slots from available opening list. In order to reach more target consumers, they can search opening slots based on various criteria. The basic advertiser web service class diagram is presented in Figure 3.3.

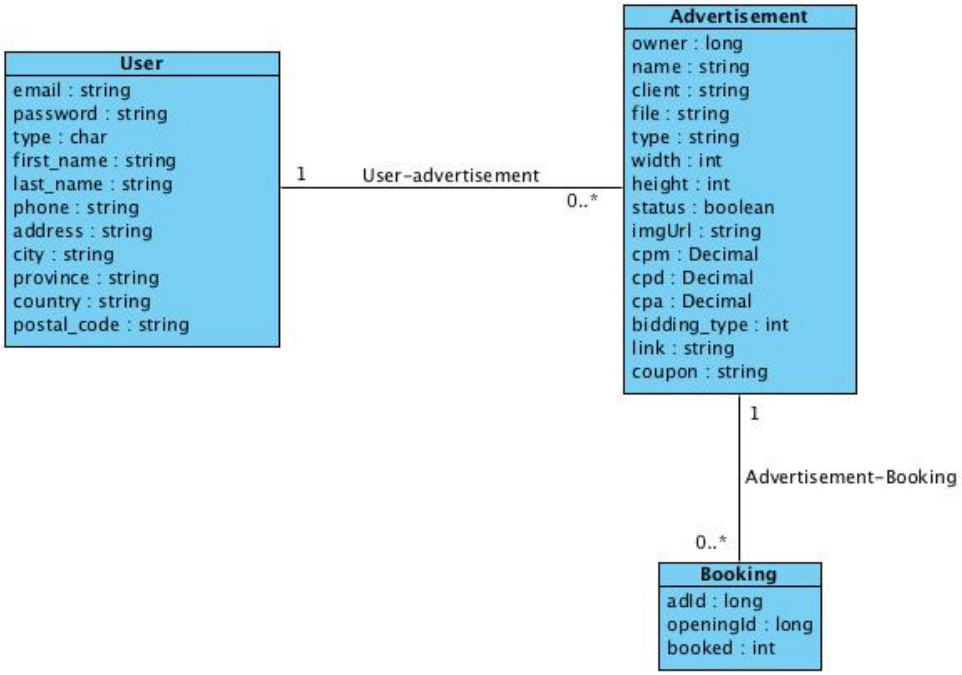

Figure 3.3: Advertiser service class diagram

Here the User class stands for advertiser role whose *type* attribute has different value from that of billboard owner role. The relations are similar to the relations in the billboard owner service. An advertiser can have multiple advertisement campaigns and each campaign can have multiple bookings of slots. In the advertisement class, besides the basic information, there is an *imgUrl* attribute for loading advertisement pictures on the web pages, and *cpm*, *cpd*, *bidding type* for the use in bidding module. As usual, attribute *cpm* meas cost-per-thousand impressions. Attribute *cpd* stands for cost-per-drag which is a completely new concept that we create in this system. There will be more explanations about the drag move when the user interaction module is introduced. Here you can as-

sume that it is a new type of price model for billboard advertising. Another attribute is *cpa* meaning cost-per-acquisition which has the same definition as that in online advertising. The reason we have *cpd* and *cpa* in billboard advertising is due to the invention of the user interaction with billboard in this system. Booking class is the relation entity between advertisement and opening. Their relation is illustrated in Figure 3.4.

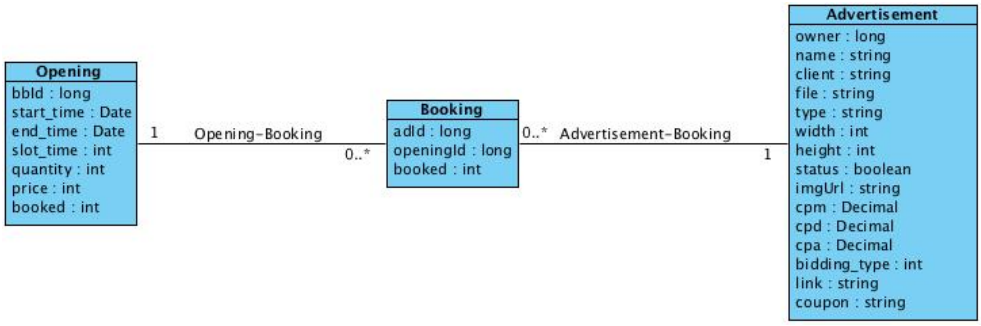

Figure 3.4: Relation Between Advertisement and Opening

3.1.3 Consumer Service

This is a brand new service in billboard advertising. The reason why we are able to provide this service in our system is that in our system we invent a new mode of interaction between potential consumers(people who see advertisements on the billboards) and billboards. Traditional billboard advertising has no such an interaction, so consumers may see the advertisements on the roads but forget it after a while. That makes the billboard advertising less effective. Imagine in online advertising, if users see the advertisements that intrigue them, they click them to access the advertiser website. The user interaction we use here intends to achieve this goal so that potential consumers can do the "clicking" on the billboard.

The technology we use for this service is utilizing the communication between the BlackBox and the smartphone. When users are interested in the advertisement being displayed on the billboard, they can obtain the advertisement information or even the coupons regarding this product or service into their smartphones via a dragging gesture. The detail of this technology will come later with the introduction of the BlackBox while this section just focuses on the web service for consumers.

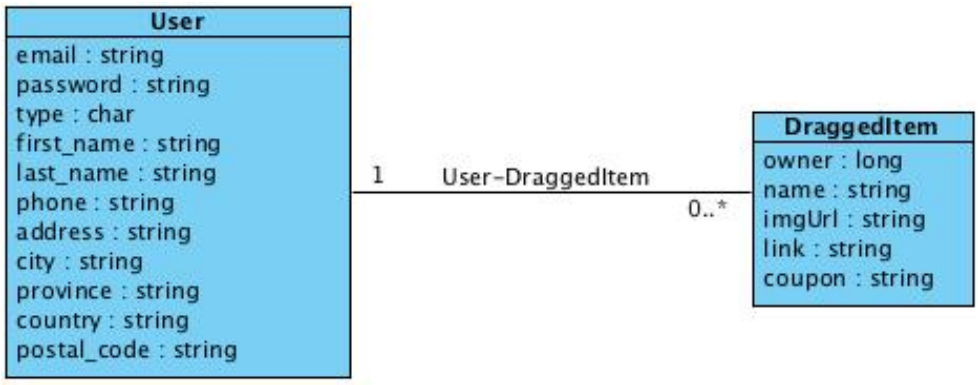

Figure 3.5: Consumer service class diagram

The intention of this web service is to synchronize and present the advertisements information, coupons that users have dragged from billboards so that further actions can be made, including accessing advertisers website from dragged information or even making transactions with or without coupons. This kind of interaction will increase the effectiveness of billboard advertising. Figure 3.5 is the basic class diagram of this service in which User stands for consumer.

3.2 BlackBox

As what has been mentioned in the former sections, in order to integrate with the platform service, a device is needed in the billboard to communicate with server via the Internet and put control on the contents that the billboard is displaying. The billboard advertisements are displayed periodically. For each advertisement, there is a duration time which means how long this advertisement displays on the billboard before the following advertisement shows up. Assume that a billboard owner has a billboard whose advertisement slots are not fully filled. He uses our platform to increase the utility of his billboard. After some advertisers are interested in the those free slots, they upload the advertisement contents. Here comes in the synchronization of advertisements and display schedules from server because the billboard needs to know where and when and what advertisements should be displayed. In this thesis, three different modes of the BlackBox are introduced.

3.2.1 Complete Control Mode

Complete Control Mode means the billboard gives control of all its advertisement slots to the BlackBox. This type of integration is suitable for the billboard owner who has a completely empty billboard or who does not have a content management system for their billboards. If billboard owners are not comfortable with the BlackBox taking over the billboard, this mode is not the right one for them. For the purpose of more transparency and letting the owner has the actual control over their billboards, other modes are invented, which will be explained soon.

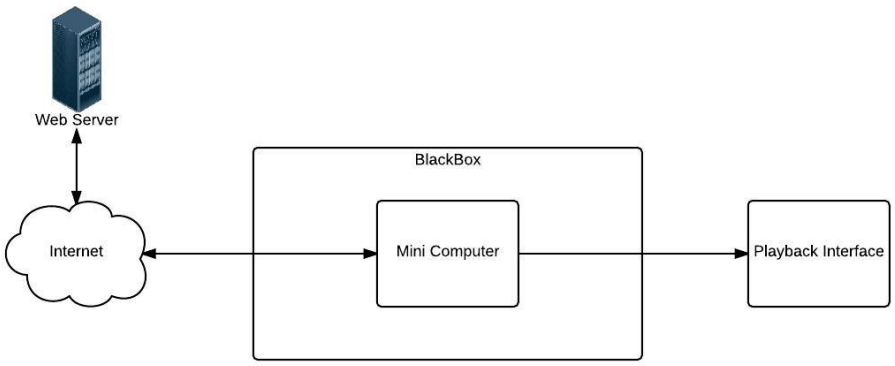

Figure 3.6: Complete Control Mode

Figure 3.6 shows how Complete Control Mode works. In this mode, billboard owner can just register this billboard using the web service of our system introduced in the last section, and after the BlackBox is installed in the billboard, the owner can leave it to our system to deal with the advertisement allocation. In the BlackBox of this mode, there is only one mini computer that has Internet access to communicate with server regarding the advertisement contents and display schedule. The output of the BlackBox is compatible with the playback interface of the billboard so that the owner does not have to do any modifications to the billboards.

3.2.2 Hardware Switching Mode

Hardware Switching Mode means the digital playback content is switched between the local contents controlled by billboard owners and the remote contents transferred from the web

server by a hardware switch for HDMI(High-Definition Multimedia Interface)/DVI(Digital Visual Interface)/VGA(Video Graphics Array) signal. Figure 3.7 shows how hardware switching mode works.

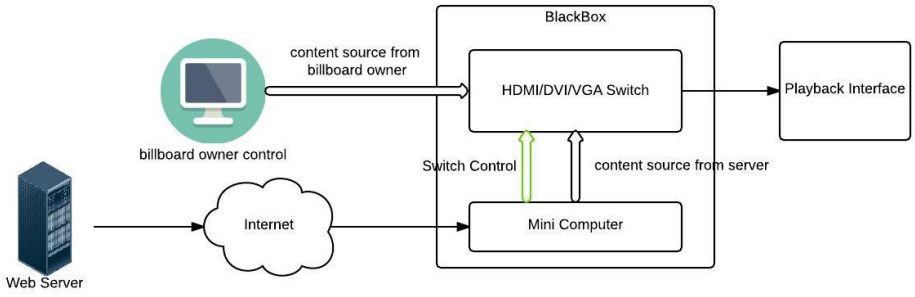

Figure 3.7: Hardware Switching Mode

Instead of having only mini computer inside the BlackBox, we have a HDMI/DVI/VGA switch connected to both advertisement content source from billboard owner and mini computer which contains contents from server. That is, we have two input sources for the switch and one output on the switch connected to the billboard playback interface. Mini computer has control on the switch according to the schedules of advertisements. The advantages of this mode is that the BlackBox does not have the access to the contents from billboard owners which just act as a data flow passing through the switch when it is the right time for it to show on the billboard. Thus, this mode gives the best protections to the advertisement contents from billboard owners. However, the hardware switch may have delay while switching which causes about 1 second black screen on the billboard.

3.2.3 Software Switching Mode

Software Switching Mode means we grab the display signal from the billboard owner input and store the data so that whenever it is the turn of billboard owner's content, the content data can be transferred to the output of the BlackBox. By using this technology, the hardware switch can be avoided because the contents from billboard owner and the contents from server can be considered as the same source arranged by the schedule that mini computer gets from the server. This is like the contents from billboard owner are buffered and put together with the contents from the server so that they can be output as a whole. Figure 3.8 illustrates the structure of this mode.

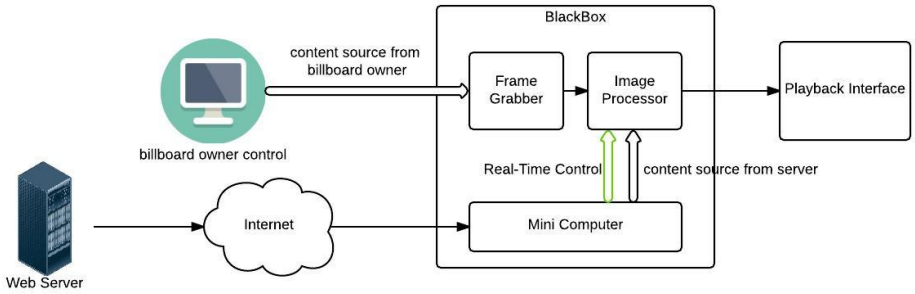

Figure 3.8: Software Switching Mode

The operations and controls of billboard owners also remain untouched, and the switch between two types of contents is seamless. But the problem of this mode is whether the billboard owners allows their contents to be stored and buffered by the BlackBox. Another problem is when the billboard owners decide to deactivate the service of the platform, the BlackBox should be turned off, which means the Frame Grabber and the Image Processor in Figure 3.8 would not be working. In this case, the BlackBox has to be removed which involves a little bit hassle for billboard owners.

3.3 Cyber-Physical Media Access

In traditional billboard advertising, there is no consumer interactions with the advertisements. The billboard is usually just for viewing. But it is important that the consumers can have instant activity with the advertisements which they are interested in because they may forget what they saw after a while. In our system, we invent a method to access the detail information of advertisements being displayed on the billboards using smartphones so that consumers can make further actions immediately, such as visiting or purchasing on advertisers' website, in which case, the advertisers can make more profits from their billboard advertisements.

A basic scenario is there is a billboard with the BlackBox installed which is connected to a wireless router. A user with a smartphone stands near the billboard and in the range of the wireless access. The BlackBox has the advertisement contents being displayed ready in its mini computer and keeps broadcasting the details of all advertisements and the tag of the displaying content via the wireless network. The files that are broadcast are the

smaller version of the displayed contents so that the time of transfer will not be too long. The tag stands for the id of the current content being displayed.

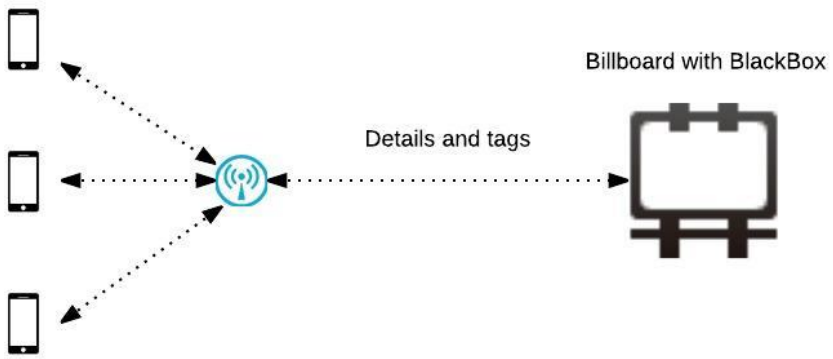

Figure 3.9: Cyber-Physical Media Access

Once the user's smartphone is connected to the same wireless network, the smartphone is one of the receivers of the broadcast of the BlackBox and starts to cache the transferred contents with content id from the BlackBox. When the user is interested in an advertisement being displayed, a dragging gesture can be made and the smartphone will look for the content based on the latest received tag. If the content file has been cached locally on the smartphone, the details of the corresponding advertisement will show up on the smartphone. Given the details, the user can make further actions. If the content is not found locally, the smartphone will wait until the content is available. Figure 3.9 illustrates the basic scenario of Cyber-Physical Media Access.

Inside the BlackBox, the following processes take place: one thread is responsible for constantly sending the advertisement details if the thread is not interrupted while the other thread is responsible for synchronizing the tag with smartphones if the thread is not interrupted. Figure 3.10 shows the Cyber-Physical Media Access activities inside the BlackBox.

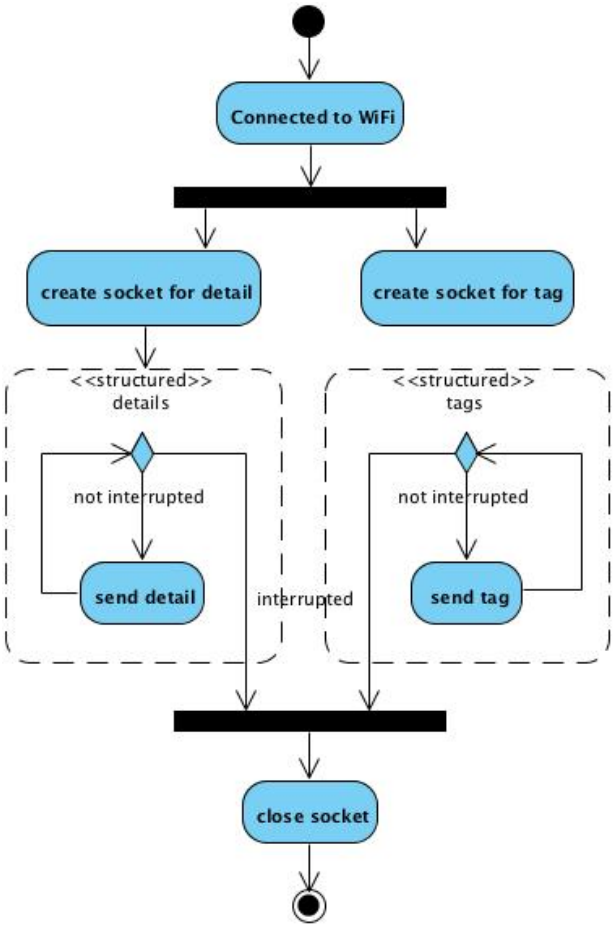

Figure 3.10: BlackBox Activity Diagram in Cyber-Physical Media Access

On the smartphone, there are three tasks to do concurrently. One is to receive the detail packets from the BlackBox. Then check if the detail has already existed locally on the smartphone. If it exists, we will disregard the packets and check the next detail. If it does not exist, we will cache the detail. Another task is to receive the tags packets from the BlackBox. We will always save the latest tag that we receive in order to track what is being displayed on the billboard. The third task is to detect the drag move. Once a drag move is detected, the smartphone will first check the latest tag to get the identity of the content being displayed on the billboard. Then it will check if the detail with that identity is ready. If it is not ready, wait until it is ready. Once it is ready, it will show up on the smartphone. Figure 3.11 explains how smartphone works in Cyber-Physical Media Access.

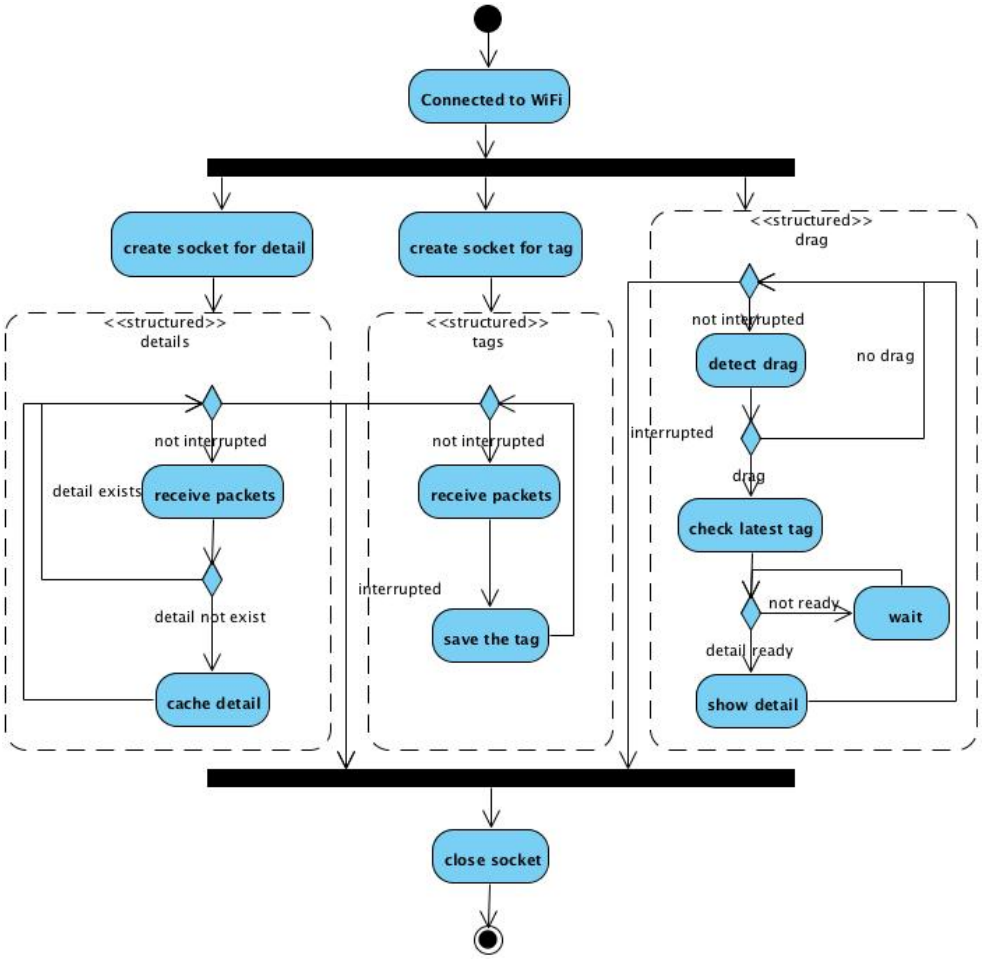

Figure 3.11: Smartphone Activity Diagram in Cyber-Physical Media Access

3.4 Summary

In this chapter, the structure and each main part of the Collaborative Real-Time Interactive Billboard Network is introduced and discussed. The proposed system contains four main modules, but in this thesis we focus on three of them which are the web service, the BlackBox and the smartphone interaction. The partial implementation of the system is discussed in the following chapter.

Chapter 4

Implementation of Collaborative Real-Time Interactive Billboard Networks

This chapter presents some implementations of the prototype of the web service and the BlackBox. In this implementation of the web service, there are only some basic functions for billboard owner and advertiser. Advanced functions and consumer service is still under construction. The implementation of the BlackBox is now just focusing on the synchronization of display schedules and advertisement contents. The Implementation of CPS is not part of this thesis.

4.1 Implementation of Web Service

This section presents the plans and work in different phases of the development. This implementation is based on a basic requirement. More functionality will be implemented in the practical production version.

4.1.1 Requirements

First of all, in order to enable customers to get to know about our services, we need a welcome page like many companies do to provide basic information and explanation about the services.

Then, for all web service users, no matter billboard owners or advertisers, they should be able to register and login. After they login, they should be allowed to modify their personal account information. So the first three functions should be:

- User register
- User login
- Edit account settings

The purpose of this prototype of billboard owner service is to enable billboard owner to:

- Register a new billboard
- Edit an existing billboard
- Add openings for a billboard
- Map view of billboards

Additionally, we could add a lot more features, such as the report regarding each billboard bookings, billings and revenues information. But here in this chapter the basic requirements listed above are targeted.

The purpose of this prototype of advertiser service is to enable advertiser to:

- Add advertisement campaign
- Edit an existing advertisement campaign
- Search openings of billboards based on some criteria
- Book advertisement slots for an advertisement campaign

Similarly, for advertisers, reports of real-time advertisement campaigns' performance and billings and more other features can be incorporated in the future.

4.1.2 Design

The first module to deal with is the welcome page which looks like Figure 4.1.

Figure 4.1: Welcome page layout

The second module to design is user registration and authentication. The overall process of this module is illustrated in Figure 4.2. When user is registering, there are some requirements that have to be met, such as the username or email has to be unique, password must match some format to increase the security level and some fields are required, and so on.

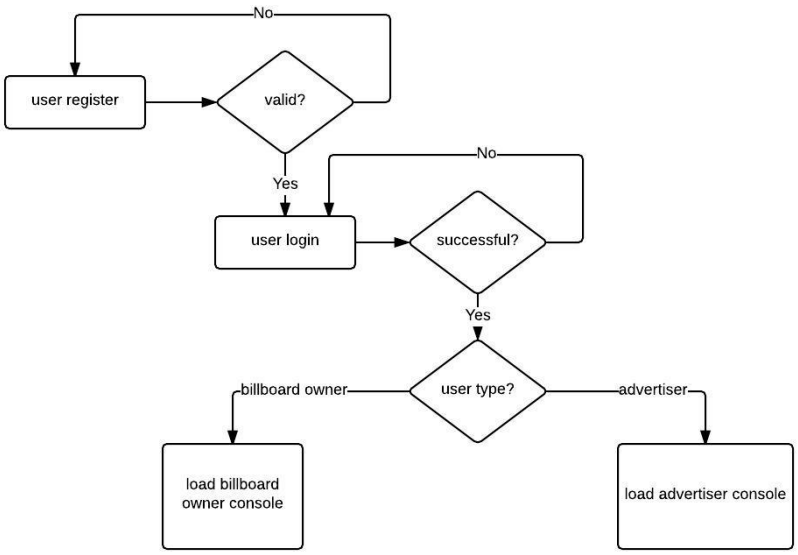

Figure 4.2: User Registration and Authentication

After the user successfully registers and logs in, the type of the user is checked so that the right page can be loaded for specific type of user. The user's type is stored as integers, that is, each user type is represented by an unique integer. For example, number 1 stands for billboard owner while number 2 stands for advertiser. So if the user type read from database is 1, the billboard owner console page is loaded; if it is 2, the advertiser console page is loaded. The main console of both billboard owner and advertiser is a page where there is a top navigation, a sidebar navigation on the left and a content area in the middle, shown as Figure 4.3.

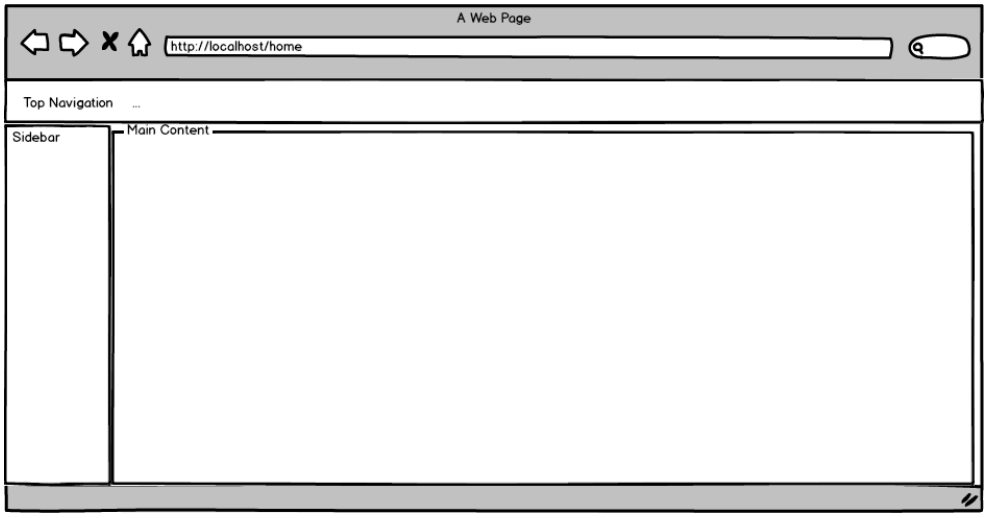

Figure 4.3: Main page layout

The third module to design is the billboard owner module. This module is loaded after the user logs in as a billboard owner whose user type is 1. Following the main page layout design in Figure 4.3, on the sidebar on the left, we put *Billboards* and *Account Settings* for the first level menu, and put *List Billboards* and *Billboard Map* inside the *Billboards* as a second level menu. When the menu are clicked, corresponding content appears in the main content area on the right. For each billboard listed, there is an edit billboard button which leads to the edit and opening panels, and a delete button. An add billboard button on the top of the list takes user to the panel of adding billboard.

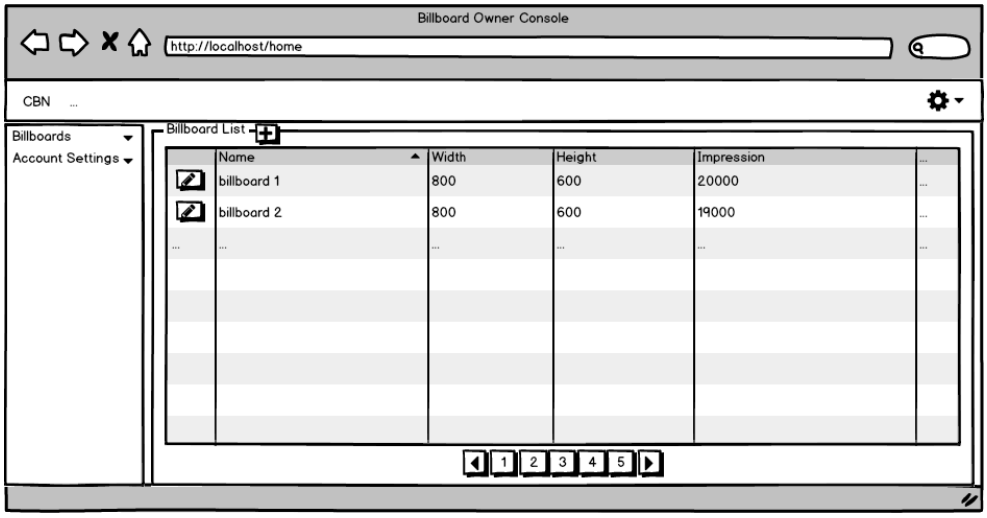

Figure 4.4: Billboard owner page layout

Figure 4.4 shows how it looks like in billboard owner user interface. Add billboard panel simply looks like Figure 4.5 and edit/opening panel is something like Figure 4.6.

The fourth module which is the advertiser module shares the same design style with the billboard owner module. It is loaded after the user logs in as an advertiser whose user type is 2. We put *Ads* and *Account Settings* as the first level menu, and *List Ads* as the second menu inside *Ads*. Also there are buttons for adding, editing and deleting advertisements. Booking panel is the place where advertisers can search and book available openings. Figure 4.7 and Figure 4.8 shows the layout of advertiser service and the booking panel respectively.

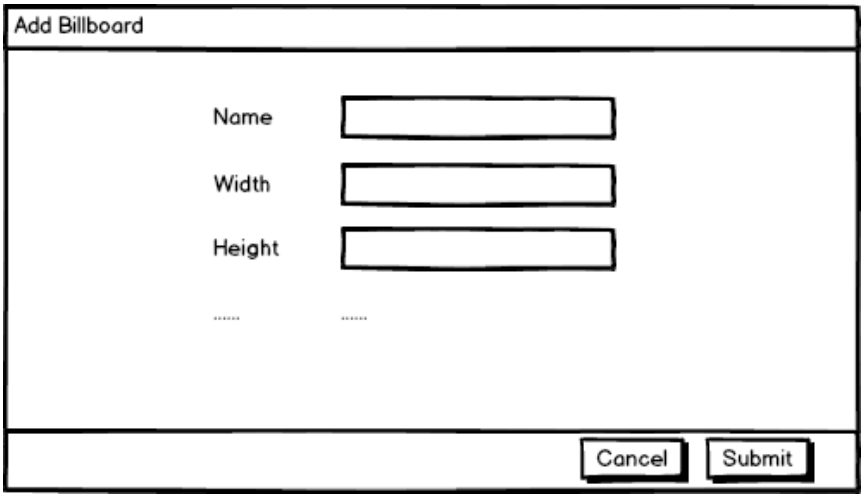

Figure 4.5: Add billboard panel layout

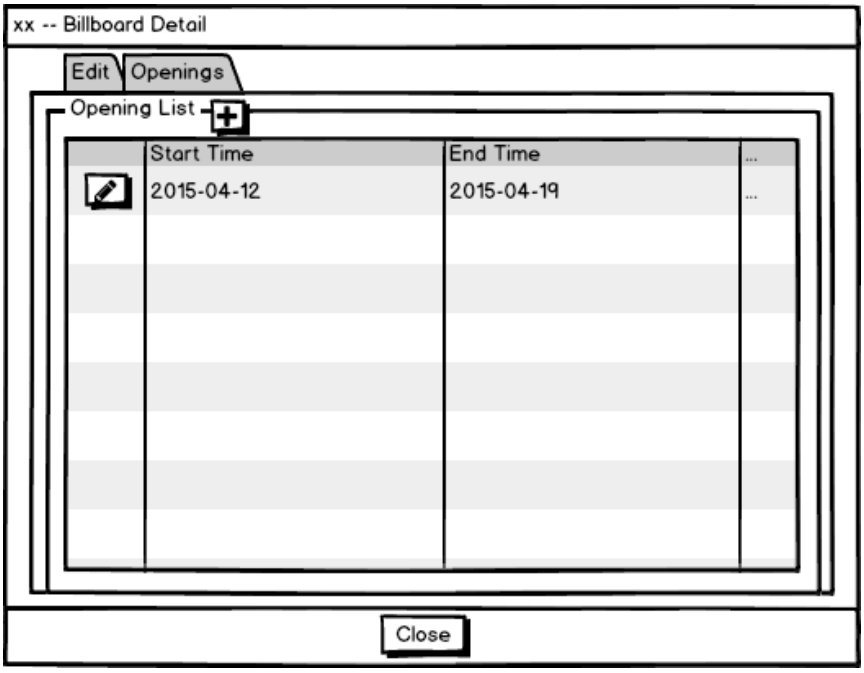

Figure 4.6: Edit/opening panel layout

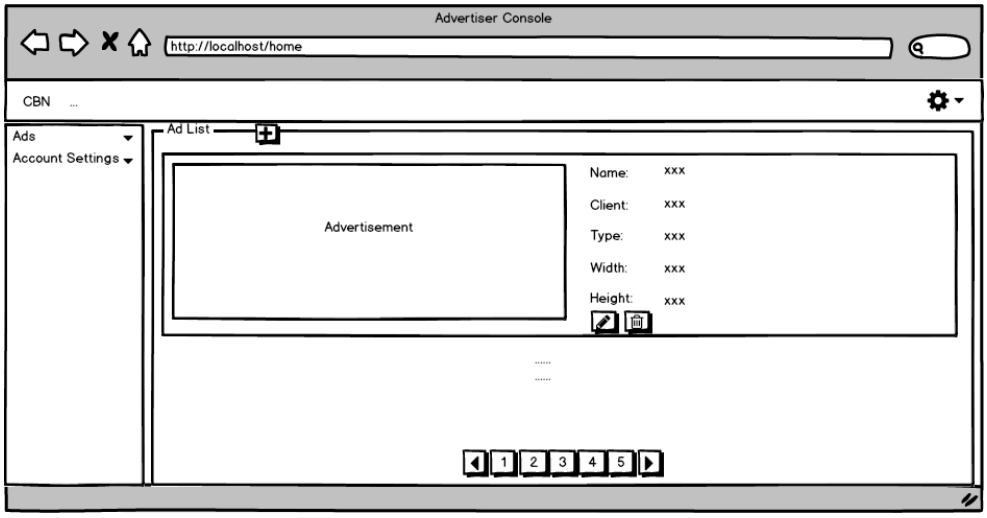

Figure 4.7: Advertiser page layout

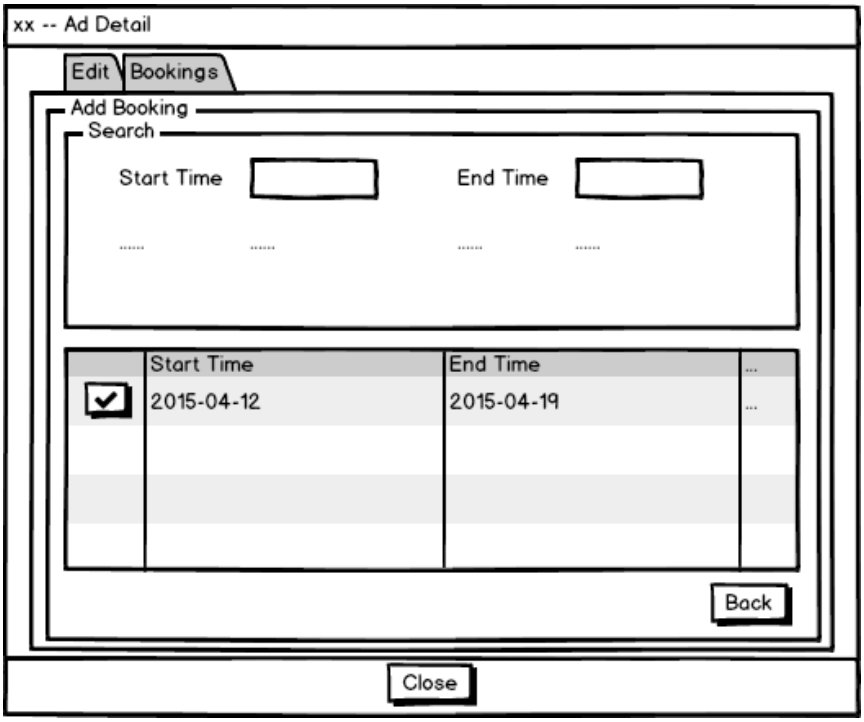

Figure 4.8: Booking panel layout

If billboard owners have multiple billboards, the name of the billboard belonging to the same billboard owner should be unique. But between different billboard owners, the billboard names do not have to be unique. Similar rule also applies on advertisement names. So when billboard owners are adding a new billboard or when advertisers are adding a new advertisement, the uniqueness of the name is checked while the name field is being filled. For the billboard map view, registered billboards are marked on the map which is implemented using Google Map API.

A high level scalable system architecture can be illustrated as Figure 4.9. However, there are a lot of cloud computing services available today, such as Amazon Web Services(AWS) and Heroku, which can help to automatically scale the system based on the usage.

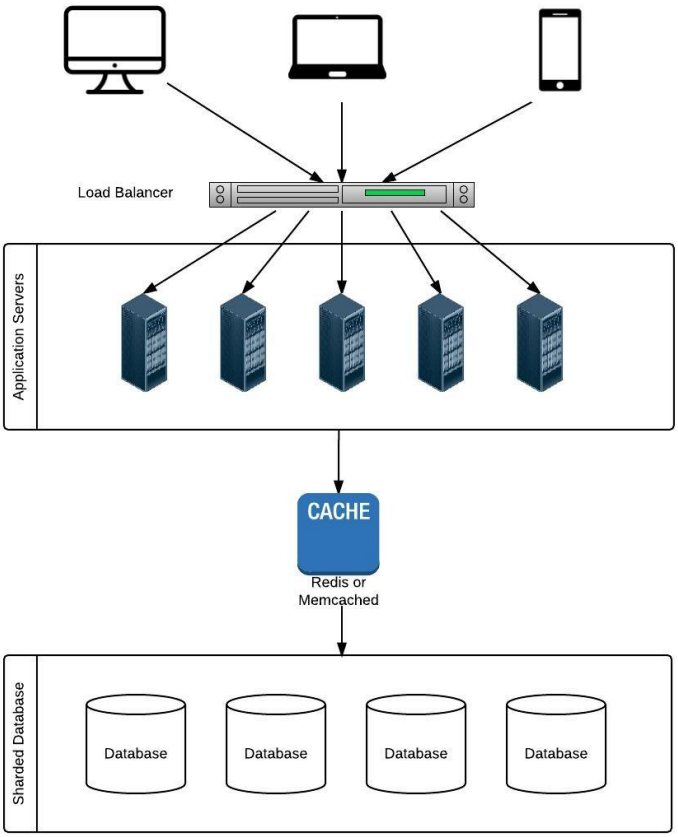

Figure 4.9: Scalable system architecture

In the application, the front-end talks to the back-end by the RESTful API which returns the resource objects as responses, usually in JSON format. It is based on the standard HTTP methods in which GET, POST, PUT, DELETE are used the most frequently. The RESTful API is really helpful to separate the development of the front-end and the back-end. For example, if the front-end needs the billboard list of a particular billboard owner whose id is 1. The corresponding URL for this is

GET /api/bbo/1/bb

bbo stands for billboard owner and *bb* stands for billboard. GET method is used here means retrieving resources rather than adding, updating or deleting resources. This URL returns the list of billboards that owned by billboard owner with id 1 in JSON format. Once the front-end receives the JSON response, it parses the response and loads the content on the page dynamically. Similarly if the information of a specific billboard with id 2 belonging to this billboard owner is needed, the URL looks like this

GET /api/bbo/1/bb/2

The RESTful API makes full use of HTTP methods to indicate the desired actions for some resources. For instance, to add a new billboard for this billboard owner, a POST request is issued:

POST /api/bbo/1/bb

To update an existing billboard, PUT method is used:

PUT /api/bbo/1/bb/2

To delete an existing billboard, a DELETE request is made:

DELETE /api/bbo/1/bb/2

As you can see, the RESTful API covers all the actions we need to deal with the target resources and the URL contains all the information that is needed for the request. And because it responds with JSON objects, the frond-end can be more independent upon the

back-end as long as it can parse JSON format, which means the front-end can be modified without changing anything on the back-end.

In the front-end, AngularJS, which is a very popular front-end framework, is chosen to deal with the logic and data while Bootstrap is used to deal with the page style and animations. For some unit tests, Karma is used. In the back-end, we use PHP and Laravel framework. PHPUnit, which has been integrated with Laravel framework, is selected to unit test the back-end code. The database is MySQL.

4.1.3 Development

This prototype of the web service is developed module by module. The first module is the welcome page. Following the design of the welcome page, we have the page that looks like Figure 4.10 and Figure 4.11.

Figure 4.10: Welcome page header

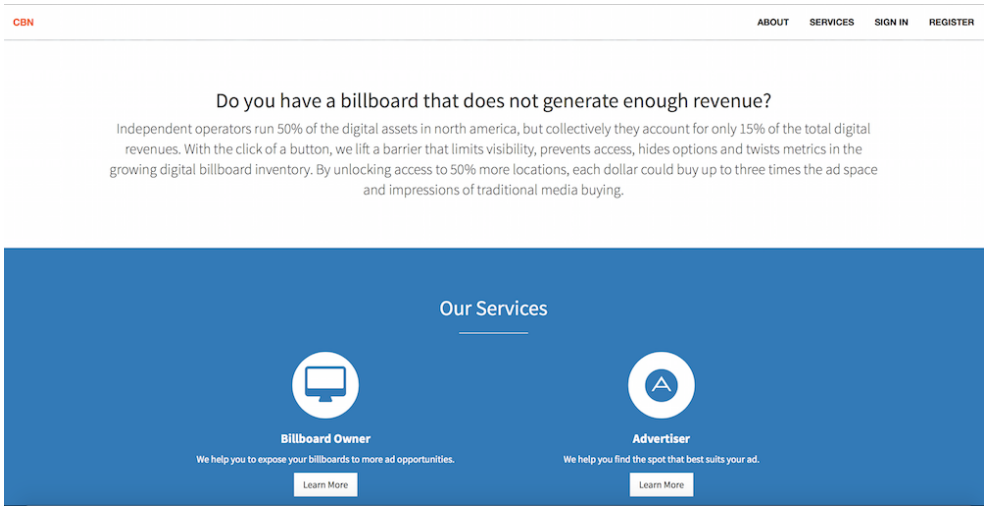

Figure 4.11: Welcome page About section and Service section

Once signed in as a billboard owner, the main console page for billboard owner is loaded as Figure 4.12. The layout of the page is controlled by HTML file while all the data is retrieved from the server by javascript making Ajax call.

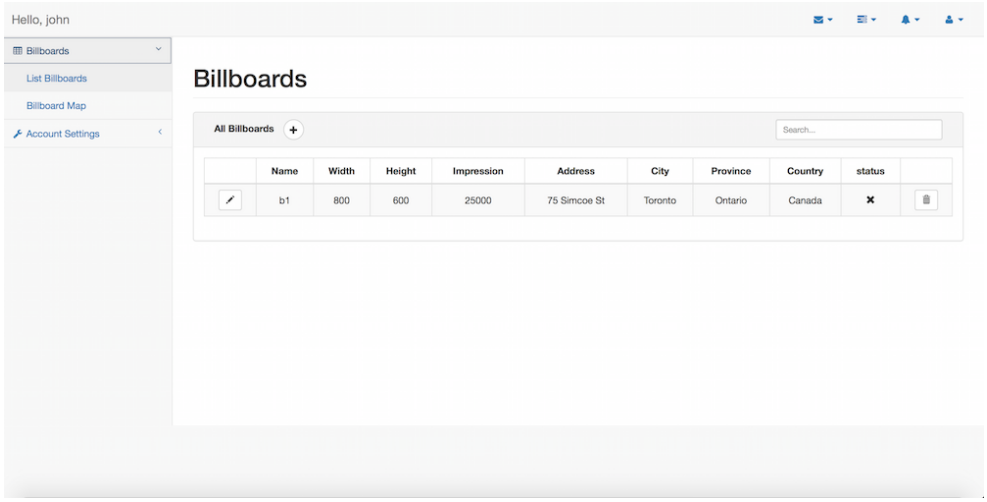

Figure 4.12: Billboard owner console page

When the add billboard button is clicked, a modal like Figure 4.13 shows up to provide a form for adding billboard.

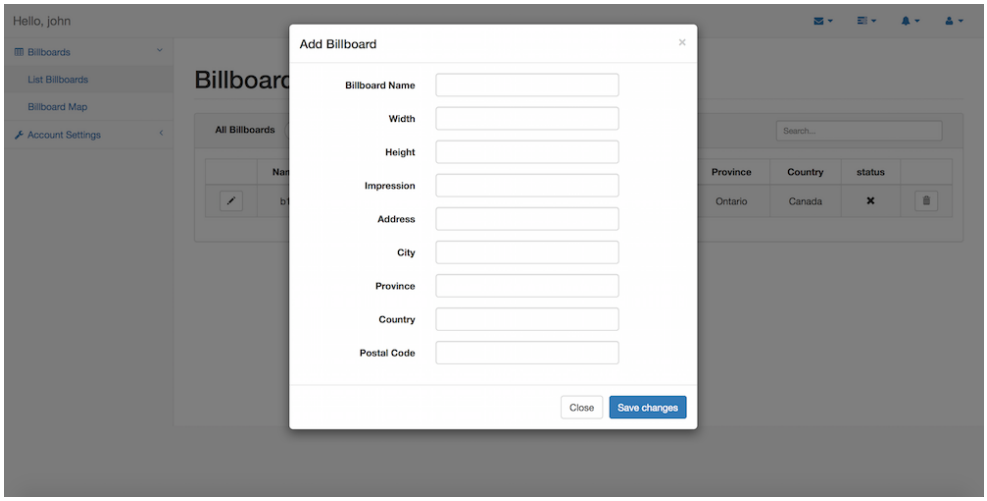

Figure 4.13: Adding billboard

While filling the form, the billboard name is checked by javascript making asynchronous request to the back-end to ensure there is no duplicate billboard name within one billboard owner account. Figure 4.14 illustrates this validation.

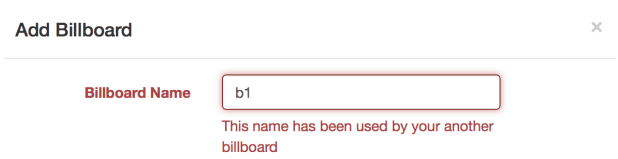

Figure 4.14: Billboard name uniqueness checking

When edit billboard button in Figure 4.12 is clicked, a modal of editing and openings is presented as Figure 4.15 shows. The basics tab is for editing billboard basic information and openings tab is for adding, editing and deleting openings for the specific billboard.

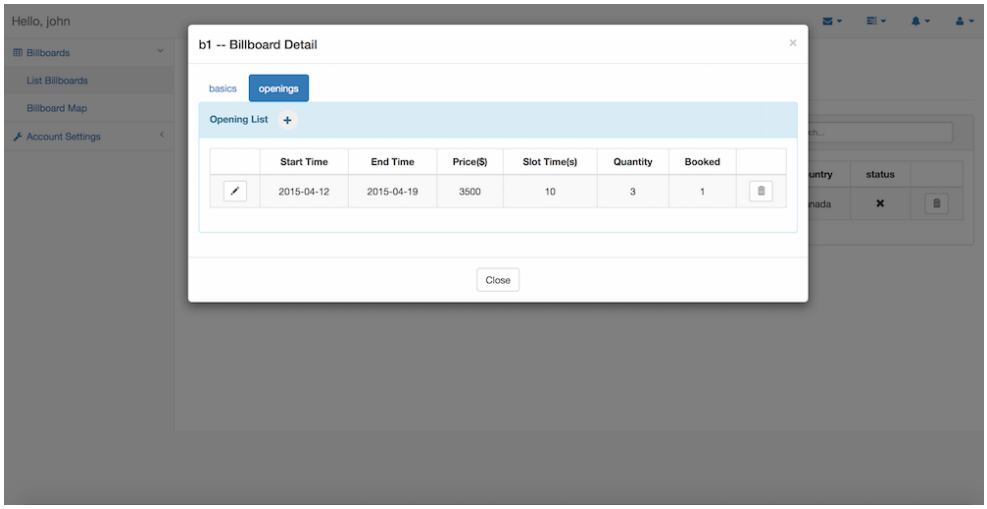

Figure 4.15: Editing billboard and openings

Billboard map is the place where billboard owners can overview their billboards in Google Map, like Figure 4.16.

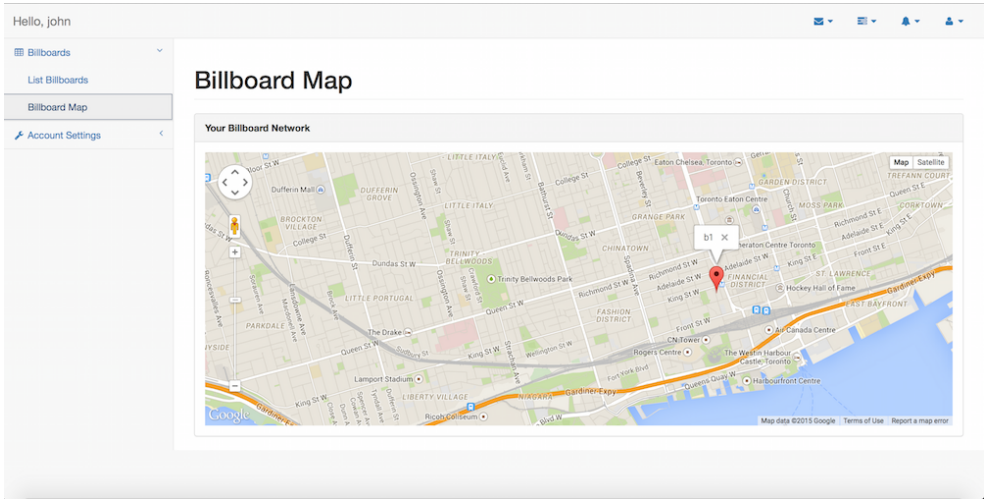

Figure 4.16: Billboard map

Logout button is available at the top right corner of the page. After logging out, the welcome page is shown. Likewise, after an advertiser logs in, the console for advertiser is loaded, which looks like Figure 4.17.

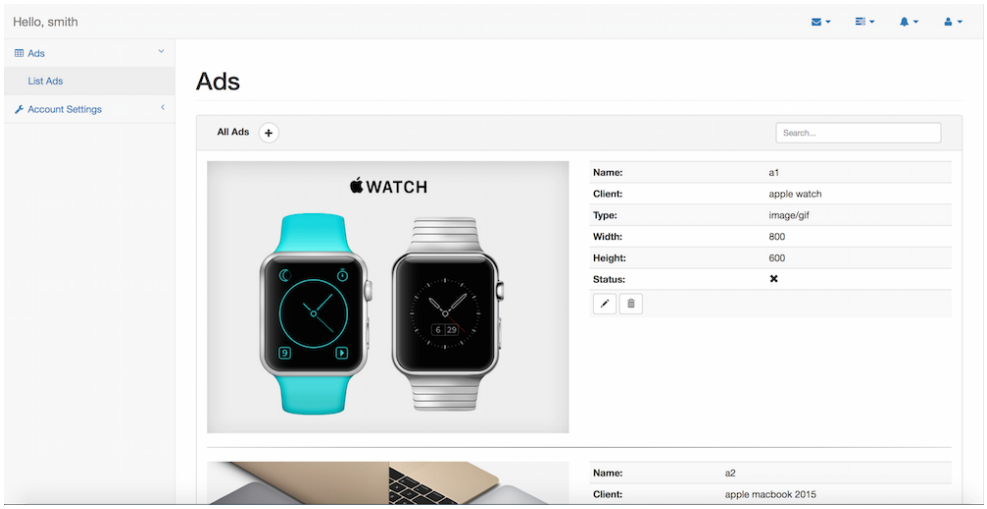

Figure 4.17: Advertiser console page

Besides the regular adding and editing advertisement panels, the booking panel is shown in Figure 4.18.

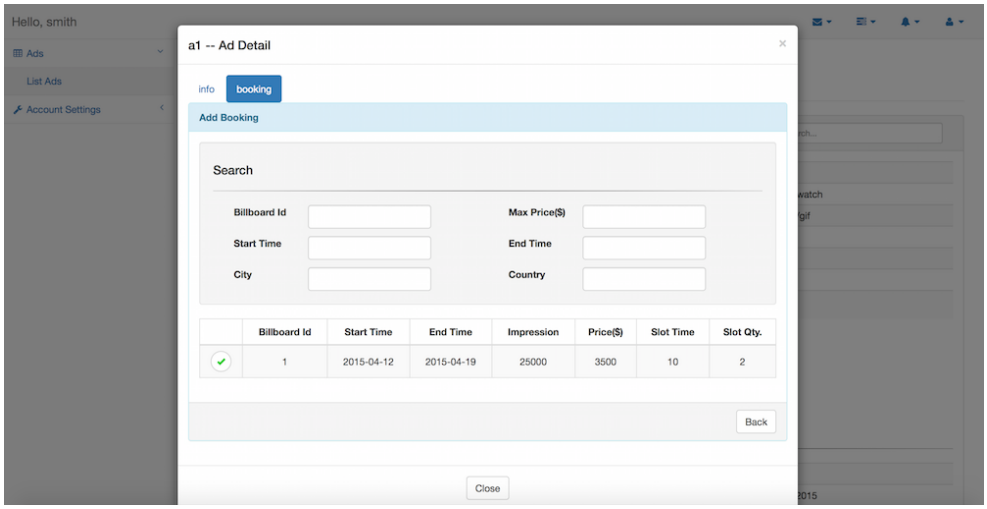

Figure 4.18: Searching and adding bookings

4.2 Implementation of the BlackBox

BlackBox is the core device that connects billboard with the server. Its functionality includes retrieving the advertisement contents and display schedules from server, and cooperating with other components, such as the hardware switch and the image processor discussed in the last chapter, to control the display of the billboard. This section discusses the implementation of the BlackBox prototype in hardware switching mode. In this prototype, computer monitors are used as billboards.

4.2.1 Requirements

The devices required in the prototype are two computers with monitors and two BlackBoxes. Each BlackBox is connected with a computer which acts like a local control device of billboard owner. A monitor is wired to the output of the BlackBox to present the displayed advertisement. On each computer, there is a program simulating the real billboard displaying advertisement and the advertisements are changed periodically every a few seconds. In the meantime, the BlackBox retrieves contents and schedule from the server and controls the hardware switch to output the contents according to the schedule.

4.2.2 Design

Inside the BlackBox, mini computer is a significant component for processing, controlling and storing the advertisement contents from server. In the prototype of the BlackBox, Raspberry Pi plays the role of mini computer. Raspberry Pi has a HDMI interface which can be used as one of the two inputs of the switch in the BlackBox. Another input should be exposed outside of the BlackBox so that the local computer control can be connected to it.

To control the switch, GPIO(General-purpose input/output) on the Raspberry Pi is used. The hardware design will not be discussed in this thesis.

There are two modules contained in the software on the BlackBox. One is real-time retrieve of advertisement contents and display schedule. The other is to display the contents based on the schedule. The real-time retrieve requires communication with server using HTTP protocol. A lot of languages can be used in this case, such as Python, Node.js and Java. These three languages also have library to access and control the GPIO. For displaying advertisements, Java Swing is used in this prototype.

4.2.3 Development

A BlackBox prototype is made and Figure 4.19 shows what it looks like. As you can see, inside the BlackBox, the HDMI output of the Raspberry Pi is converted to DVI signal which is one of the inputs for the switch under the Raspberry Pi. There are two DVI sockets outside of the shell of the BlackBox. One is for another input from the local computer and the other is the output of the BlackBox.

Figure 4.19: BlackBox

After the BlackBox is powered, the program of retrieving contents and schedule, the program of displaying contents using Java Swing and controlling the GPIO using the Pi4J library are run automatically. The result is shown in Figure 4.20.

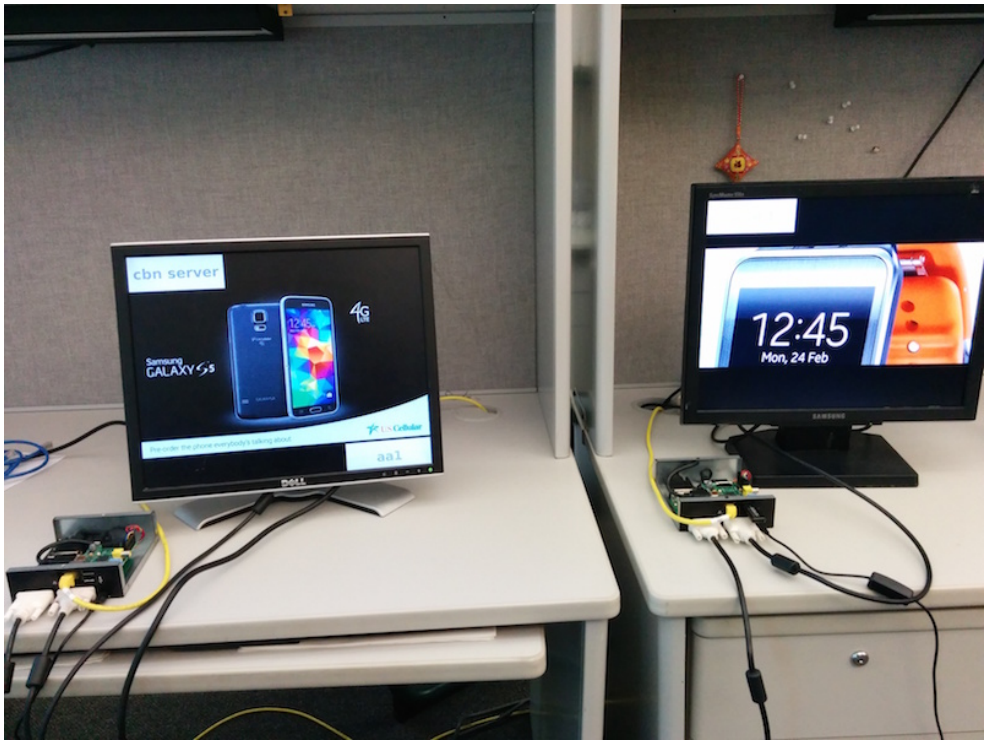

Figure 4.20: Display using monitors

4.3 Summary

This chapter explains the implementation details of the web service and the BlackBox prototype which only has limited and basic functions of the desired platform. There are a lot more features that can be integrated into the system in the future. The next chapter concludes this thesis and discusses some future work to do for further development.

Chapter 5

Summary and Future Work

Technology makes much difference in advertising industry, especially in online advertising. Billboard advertising has evolved to the new world where billboards are digital and can be easily controlled by computers and the Internet. However, it is still not that convenient for billboard owners to maximize the exposure of their billboards to the advertisers and for advertisers to choose the best locations for their advertisements without having to go through many different billboard networks. The proposed system in this thesis intends to beat this inconvenience and makes the life easier for billboard owners, advertisers and even consumers.

5.1 Thesis Summary

The core of this thesis is the proposal of the Collaborative Real-Time Interactive Billboard Networks. The gist of this system is to maximize the connections between billboard owners and advertisers, to automatically distribute advertisement contents in real-time without interfering the original operations of billboard owners, and to build interactions between billboards and consumers. The web service of the system enables billboard owners to manage their billboards and services conveniently while advertisers can use it to organize their campaigns and get real-time report. BlackBox not only provides a highly compatible way of distributing advertisement contents, but also maintains the billboard owner's full control of billboard operation. Cyber-Physical media access offers the possibility of immediate further actions by consumers on billboard advertisements, which increases the effectiveness of billboard advertising. Additionally, the prototype implementations of the web service

and the BlackBox are introduced and discussed, but more features can be integrated in the later development.

5.2 Future Work

This prototype of the web service and the BlackBox discussed in this thesis only provide very basic functions of the system. In order to make it a real product and service, there is still plenty of work to do. Besides continuous improvements of the current web service, a bidding system can be implemented and incorporated into the web service for advertisers to bid advertisement slots both manually and automatically based on the budget they provide. For BlackBox, it is necessary to invent a software maintenance system so that the BlackBox software can be updated automatically via the Internet when the new version is available. The scenario of the Cyber-Physical media access discussed in this thesis is basic. However, multiple billboards presenting in one area increases the complexity of the drag move of the smartphone because when the drag happens, it needs to determine which is the billboard that the consumer is interested in. This could be done by detecting the orientation and the azimuth angle of the smartphone at the moment of the drag move. But the precision could be a problem when the billboards facing the same direction are close.

5.3 Conclusion

A collaborative real-time interactive system for billboard advertising is proposed in this thesis, and we believe that it is an innovation in the billboard advertising industry and will make billboard advertising more convenient and efficient.

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