國立交通大學

網路工程研究所

碩 士 論 文

即時交通資訊廣播車載網路系統
之雛形

A Prototype of VANET-TMC System

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摘要

智慧型運輸系統建立在傳統的傳輸架構上，結合了資訊系統的高度技術和改進。而發展於歐洲的調頻副載波即時交通資訊廣播 (RDS-TMC) ，透過廣播系統提供交通資訊給駕駛人。然而目前的 RDS-TMC 系統有若干缺點，例如最大訊息筆數的限制、只允許單方向的廣播方式等等。因此在本論文中，我們提出透過車載網路 (VANET) 傳輸 TMC 訊息的想法，稱為 VANET-TMC 系統。VANET-TMC 系統不只能提供雙向的溝通方式來達到互動式的交通資訊更新，也是一個具備可擴充性和地區性的服務。

關鍵字：智慧型運輸系統, 即時交通資訊廣播, 即時交通資訊廣播車載網路

A Prototype of VANET-TMC System

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Abstract

Intelligent Transportation System (ITS) combines high technology and improvement in information systems with the conventional transportation infrastructure. The European designed Radio Data System - Traffic Message Channel (RDS-TMC) is developed to provide traffic information to drivers via broadcast system. The current RDS-TMC systems have some drawbacks, e.g. the maximum message number constraint, one-way directional broadcasting. In this thesis, we propose to transmit TMC messages via vehicular ad hoc networks, called VANET-TMC systems. The VANET-TMC systems can not only provide bi-directional communications to interactively update traffic information but also give a scalable and localized services.

Keywords：ITS, traffic message channel (TMC), VANET-TMC

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蔡宗達 於

國立交通大學網路工程研究所碩士班

中華民國九十八年十一月

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Chapter 1

Introduction

1.1 Introduction

Intelligent Transportation System (ITS) combines high technology and improvement in information systems, communication, sensors, and advanced mathematical methods with the conventional transportation infrastructure. These technologies deal with the ability to *sense* vehicles in real-time through roadside units or Global Position Systems (GPS), to *communicate* large amounts of information more cheaply and reliably, to *process* this information through advanced information technology, and to use this information properly and in real-time in order to achieve better transportation network operations [1].

It is convenient to think of ITS in terms of six areas [1]: Advanced Traffic Management Systems (ATMS), Advanced Traveler Information systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO) Advanced Public Transportation

Systems (APTS), and Advanced Rural Transportation Systems (ARTS).

Recently, several ITS based methods have been proposed. In North America, Schultz [2] proposed advance warning for end-of-green indication at a high speed situation . The ITS project in Europe *[3]* is aimed to demonstrate the effectiveness of ITS on European roads. In [4], Chang and Chou proposed a rear-end collision warning system with a rear-end monitoring camera. Huang and Tan [5] proposed a future-trajectory-based cooperative collision warning system.

The European designed Radio Data System - Traffic Message Channel (RDS-TMC) is developed to provide traffic and travel information to drivers through FM-RDS system. It can also be transmitted on Digital Audio Broadcasting (DAB) or satellite radio. It allows silent delivery of high quality accurate, timely and relevant information, in the language chosen by the user and without interrupting normal services. RDS-TMC systems are now operational in many countries worldwide. It can be helpful for trip plans when data is integrated directly into a navigation system. However, the current RDS-TMC systems have some drawbacks, e.g. the limit message number in a time interval makes the system unscalable, one directional broadcasting resulting in lack of real-time interaction and large regional broadcast can not reveal localized dynamics.

In order to make a counterpart for RDS-TMC, we propose a new localized TMC system, called VANET-TMC systems, which transmits the TMC messages via vehicular ad hoc networks (VANETs). The VANET-TMC systems can not only provide bi-directional communications to interactively update traffic information but also give a scalable and localized services.

1.2 RDS-TMC

Radio Data System - Traffic Message Channel (RDS-TMC) [6] [7] [8] [9] provides event-orientated road end-user information messages. There are two important data structures, location table and event table, in TMC. Within RDS-TMC, locations are identified and referenced by their location code. As shown in fig. 1.1, there are three location types in the location table: area, path and point. An area may be a country, a region, a nation or a continent. A path represents a road segment consisting of a link of points with pre-defined direction. A point is an intersection of road segments. Event table is a table of event descriptions and parameters giving details of traffic problem (e.g. congestion caused by accident) and its severity (e.g. resulting queue length) or the weather situation.

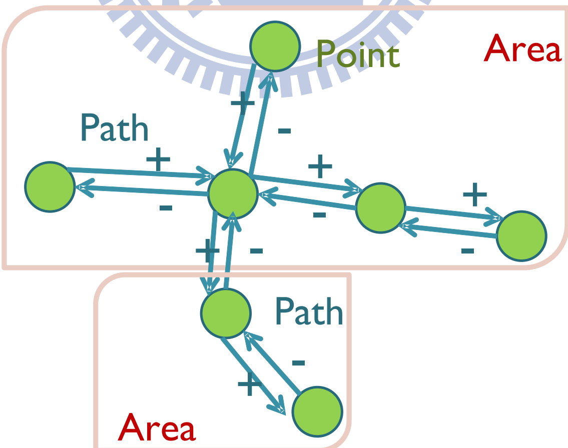

Figure 1.1: Location types in location table.

RDS-TMC comprises two message types, system messages and user messages. System messages contains details of parameters that the terminal needs to be able to find identify and decode the TMC message and are for message managements purposes. User messages contain the details of the traffic events. There are two categories of information within user messages: basic and optional information. Generally, basic information is present in all messages and optional information can be added in messages when necessary. User messages provide five basic broadcast items [6] including event description, location where a event occurs, direction of the event and extended road segments or point location affected by the event, event duration and diversion advise to a user whether or not choose an alternative route.

Optional information can be added to any message when there is any additional information need to add. The optional field is useful to give greater detail or can deal with unusual situations. Any number of additional fields can be added to each basic message, subject only to a maximum message length of five RDS data groups.

Within RDS-TMC, every terminal is expected to be able to store at least 300 RDS-TMC messages. Service providers have to ensure that the number of RDS-TMC messages that they have transmitted which have not been specifically canceled, or will have automatically expired, does not exceed the 300 maximum. This constraint limits the scalability of the system. In the other hand, since the TMC messages are transmitted via one way broadcasting, it is hard to reveal the traffic situations in real-time.

1.3 VANET-TMC

In order to enhance the ability of the TMC system, we propose to transmit TMC messages through vehicular ad hoc networks, called VANET-TMC. The system architecture of VANET-TMC is shown in Fig.1.2. The VANET-TMC system is comprised of on board units (OBUs) with digital map, road-side units (RSUs), local traffic server with local TMC database, global TMC database and traffic supervisor. Note that the global TMC database is in the county/state level. The TMC messages can be transmitted directly by broadcasting via broadband wireless access (BWA) or through multi-hop broadcasting by dedicated short range communication from OBUs/RSUs to OBUs. The local traffic server can update its local TMC database from global TMC database or interactive by bi-directional communications from RSUs and OBUs. We assume there is a local traffic server in each region and the region size is probably a town size. This ensures that the local traffic server can only collect the TMC message within its region. Therefore, the VANET-TMC system can not only provide interactive bi-directional communication to update the traffic events, but also make TMC service more scalable.

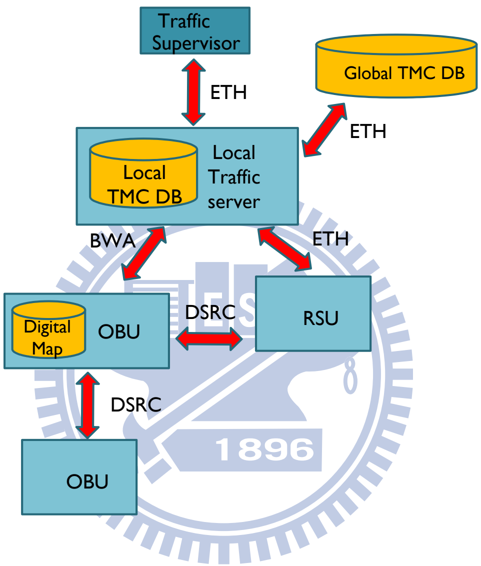

Figure 1.2: VANET-TMC system architecture.

Chapter 2

Related Work

2.1 TMC

2.1.1 What's is TMC

Radio Data System - Traffic Message Channel (RDS-TMC) is a solution of disseminating traffic and traveler information. From scratch, RDS-TMC is designed for transmission over the radio, and is developed first in Europe, based on a specification, Advice and Problem Location for European Road Traffic, Ver. C (ALERT-C) protocol. Now the technique is popular in Europe countries, Japanese, and even Taiwan.

ALERT-C defines the format of traffic message transmission and contains some issue of how radio transmits. Although in our project we don't transmit data by radio, the definition of format of traffic message is still good for use. The term TMC is defined as the use of this part in ALERT-C.

TMC provides event-orientated road end-user information messages. This means a TMC message is transmitted when something happened. TMC distinguishes between user messages and system messages. User messages are those potentially made known to the end-user, with some kind of in-vehicle equipments. System messages are of use only to the RDS-TMC terminal, for message management purposes.

The kernel objects of TMC is location table and event table. The location table [7] contains three geographical types: areas, paths, points. An area may be a country, a region, a nation or a continent. Each path and point will records the least defined area it belongs to. A path represents a freeway, a highway, a road or a street, which is consisting of double-linked points. Each point is normally a crossroad, and it is linked with positive offset and negative offset which indicates the next and and the last point to it respectively. The event table (Fig.2.1) contain events which is compatible to the specification of RDS-TMC [7]. All events are classified according to their attribution.

2.1.2 TMC User Message

The unit of TMC message is a group, each containing 4 blocks, or 64 bits. The message length is subject to a maximum of five TMC groups. A message of more than one group is called multi-group message. The first group of multi-group message is very similar to single-group one, but X_3 bit. The subsequent group of multi-group message contains free format. One extra group can convey a 28-bit-length free format. So a message can at most convey the free format of 112 bits.

CODE	EVENT_LIST	C	Explanatory_Notes
229	accident(s). Slow traffic	1	車禍
364	overturned vehicle(s). Slow traffic	1	翻車
213	vehicle fire(s)	3	火燒車
292	shed load(s). Slow traffic	1	路面有散落物
916	Road surface in poor condition	14	路面有坑洞
1984		0	併排停車
211	broke down vehicle(s)	4	車輛拋錨
122	heavy traffic	1	車多擁擠
108	queuing traffic	1	大排長龍
500	lane(s) closed	5	交通管制
1875	traffic lights working incorrectly. Danger	25	燈號不正常
1867	traffic lights not working.Danger	25	燈號不亮
724	roadworks. Slow traffic	1	施工
1034	clearance work. Danger	4	路面清掃
1084	house fire	12	火警
976	mud slide	12	坍方
932	flooding. Slow traffic	1	積水
977	grass fire	12	邊坡草皮燃燒
1136	heavy rain. Visibility reduced	16	大雨 能見度降低
1301	dense fog	16	濃霧
205	accident(s) involving hazardous material	3	危險原物料的意外事故
1772		0	晴天
1773		0	多雲
1774		0	陰天
1775		0	晴時多雲

Figure 2.1: RDS-TMC Event Table in part, provided by Institute of Transportation

TMC messages are consisting of user message and system message. Two categories of user messages are defined: basic and optional items. In principle basic items are present in all user messages. Optional information can be appended to basic user messages where necessary. The basic item uses the single-group format as shown in Fig.2.2, thus, as its name, using the group of a single size. Basic items contain five basic items [6]:

1. Event description: giving details of road event situation, general traffic problems and weather situations (e.g. congestion caused by accident) and where appropriate its severity (e.g. resulting queue length). All kind of event situations are defined in specific event table (in Taiwan,) compatible with the ISO 14819-2: Event and information codes for RDS-TMC.

2. Location: indicating the area, road segment or point location where the source of the problem is situated. All Location information is defined in specific location table (in Taiwan, this is defined by Institute of Transportation, MOTC, and is still in amended) compatible with the ISO 14819-3: Location referencing for ALERT-C.

3. Direction and Extent: identifying the adjacent segments or specific point locations also affected by the incident, and where appropriate the direction of traffic affected. The Direction indicates the direction of queue growth of traffic congestion; it is opposite to the direction of traffic flow affectd.

4. Duration: giving an indication of how long the problem is expected to last.

5. Diversion advice: showing whether or not end-users are recommended to find and

follow an alternative route.

Optional items can be added to any message using one or more additional TMC groups as shown in Fig.2.3 & 2.4. The optional addition can give greater detail or/and can deal with unusual situations. Any number of additional fields can in principle be added to each basic message, subject only to a maximum message length of five TMC groups.

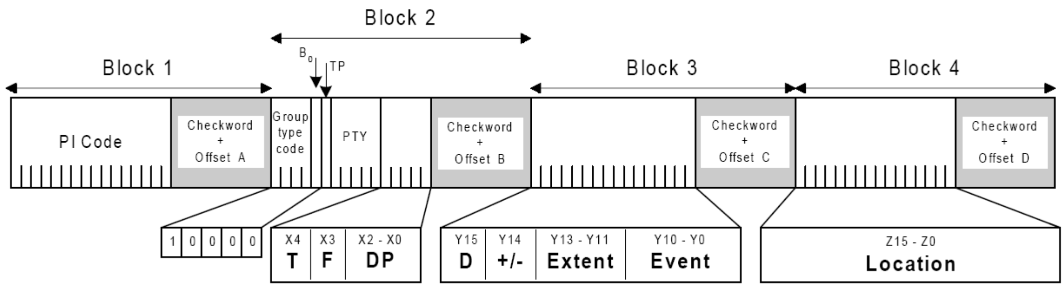

Figure 2.2: RDS-TMC single-group full message structure

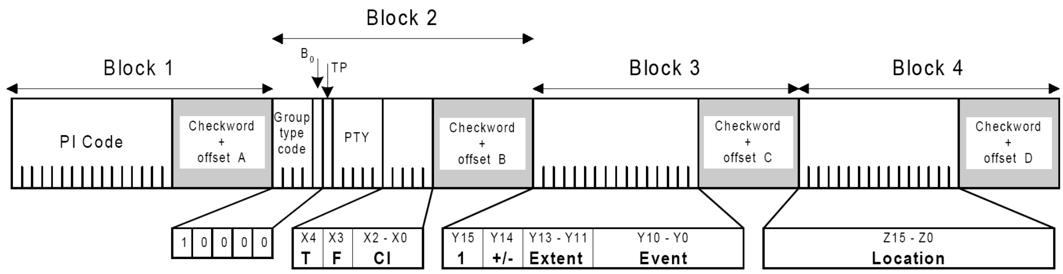

Figure 2.3: RDS-TMC multi-group message - first group

The optional items contain many extra details and control such as duration, speed limit advice, length of route affected, explicit start time, explicit stop time, additional event, detailed diversion and so on. Our presentation of traffic lights is implemented by using optional information. See section 4.2 for more details.

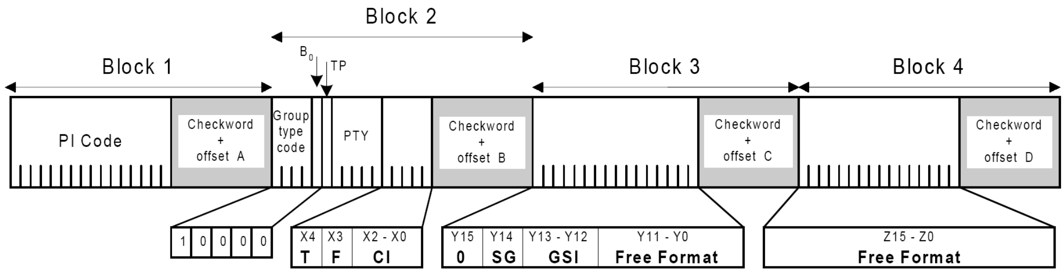

Figure 2.4: RDS-TMC multi-group message - subsequent group structure

2.1.3 TMC System Message

System messages consist of system information and tuning information. Tuning information is about the broadcast of radio. Because we don't use it, we omit it. The most important thing the system information can do is to indicate the secondary look-up database . We use the facility for presentation of traffic lights. See section 4.2 for more details.

2.1.4 Current Situation

TMC is based on Alert-C protocol. As its original name, Advice and Problem Location for European Road Traffic Ver. C, indicated, TMC is rooted in Europe. Thus the design of TMC is influenced by geographical and political considerations in Europe. The official forum of TMC can be found in the web site (http://www.tmcforum.com/en/home.htm). The web site lists lots of issues and FAQs about TMC.

In Taiwan, RDS-TMC is been tried to popularize in the northern area. Now some companies, like Garmin (Fig.2.5) and Mio (Fig.2.6), have begun to promote their in-vehicle equipments for receiving RDS-TMC messages. This is a profound benefit for drivers due to the real-time information of traffic and weather provided by RDS-TMC. But as we have indicated before, there are inevitable inherent drawbacks when carrying TMC messages via radio.

Figure 2.5: The screen of Garmin in-vehicle equipment

Figure 2.6: The in-vehicle equipment of Mio

2.2 The Law of Traffic

Our traffic lights have close relation to the Setting Rule of Traffic Signs, Lines, and Lights on Road. The rule is consisting of five chapters: general rule, traffic signs, traffic lines, traffic lights, and extra rule. The rule formulates omnifarious and detail items about traffic. Thus it's a great reference when manipulating something about traffic.

The rule has significant effect on our traffic light system. For example, article 194 of the rule defines all kinds of traffic lights and how they work (Fig.2.7). Article 212 specifies the general rules of how traffic lights are shown and placed at the road, and article 214 specifies in more detail how their displays are effected by each other.

The rule is the part of our specification not only because it defines all concrete components involving traffic, also because it defines how they are installed and how they work in the real situation.

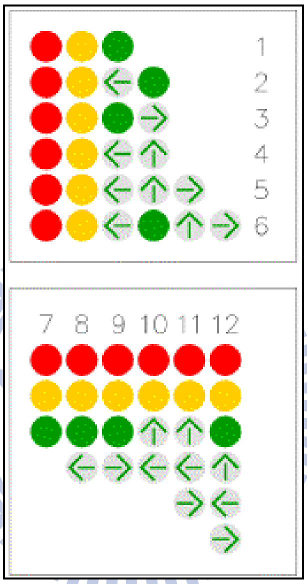

Figure 2.7: All kinds of traffic lights: (up) horizontal types and (down) vertical types

Chapter 3

System Architecture

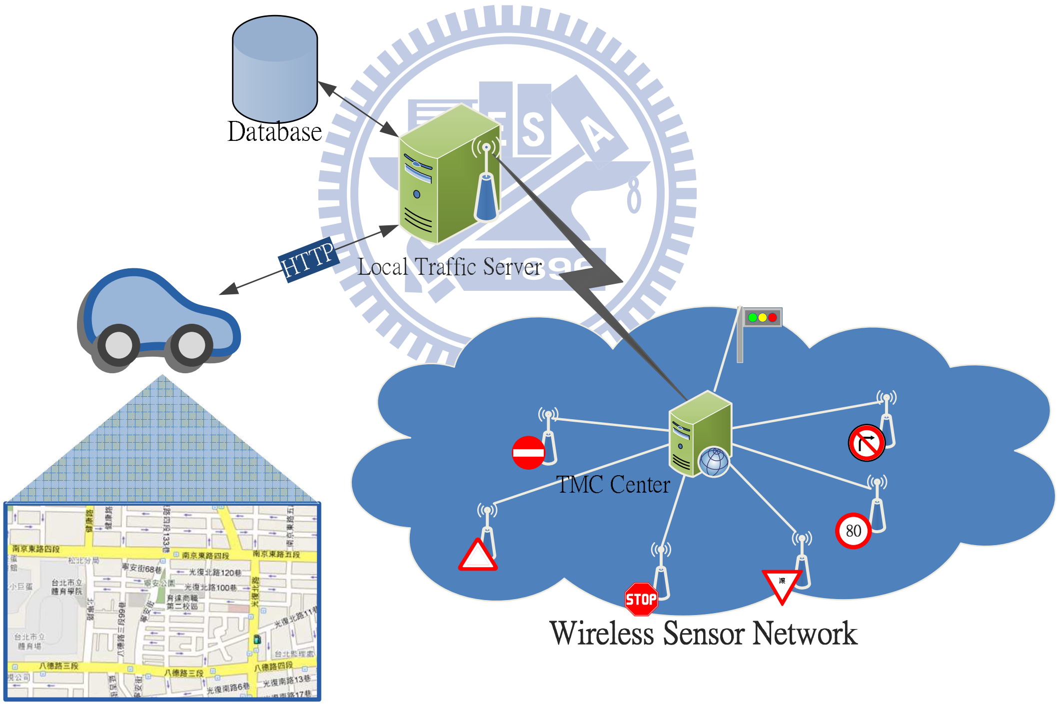

Figure 3.1: System Architecture

The figure above is the schematic diagram of system architecture. We'll discuss all components in the rest sections of this chapter. The figure explains how our system is built up and is worked.

3.1 Local Traffic Server

The local traffic server serves as a road side unit, providing functions of web server for users, accesses to database of TMC tables, and decode of TMC packages.

The web server plays a role of platform to show Google Map by its API. We use Google Map for our map source. One of advantages of using Google Map is the saving of cost setting mapping web. Because Google Map is a good free map source although map is normally commercial, not for free. The other advantage is that its abounded API can speed up the development of web applications of map. For example, with the API we can do something complicated easily just by shorter codes, for example, marking a point in the map, drawing a line in any position where the developer wants, and embedding a real photo at a mark.

The another role of local traffic server is accessing to database which contains TMC data (event table, location table) and TMC Messages. One situation is when a TMC message comes in, we need to decode the message, and then must lookup the event table and to location table from database to figure out what information the message carries. The other situation is when a user queries what TMC event happened around him/her, we need to lookup database containing whole TMC messages and to filter according to the user's geographical information. Then these TMC events will be displayed in the Google Map and be shown for users on the web. Accessing databases is a transparent action in the background, so users don't know actually how it works.

The local traffic server also decodes TMC messages. When a message comes, it will be decoded to get the information of the message. The information then will be inserts into proper database tables.

3.2 Database System

The database system contains two main parts: tables and GIS tools (PostGIS). Tables are consisting of four catalogues:

- Location Table & Event Table: The two tables are the official version from Institute of Transportation, MOTC.
- TMC Messages: Our defined table recording TMC event messages.
- Traffic Lights: Our defined table recording traffic lights on the road.
- User Information: Our defined table recording user information, like position and track.

Another important component is the GIS tools on the database. With the tools, we can calculate and analyzes some geographic data more easily. We will later discuss GIS tools more detail in the section §4.5.

3.3 TMC Center

In our system architecture, TMC Center is the controller of TMC event messages. It should verify the reliability of all TMC event messages. Then it encodes messages according ALERT-C protocol [6], and transmitting to the local traffic server. What need to be noticed is, in the prototype system, that the mechanism of verification is judged by human, such supervisors.

In Our system, TMC center provides an interface of easy use to encode TMC messages. In real world, these TMC messages are encoded by Institute of Transportation. Then these messages will be transported to Local Traffic Server for decoding and saving to the database.

3.4 Events and Traffic Lights

TMC events, which are defined by ALERT-C [7], and traffic lights are potential events. These events will all send to TMC center for encoding.

Traffic lights is not the part of TMC standard. It's one of important features in our system. For supporting representation of traffic lights, the reserved field of optional items of TMC format is used. Then traffic light table is build and put into database. And the icons of traffic lights also are put into map according to their states. For the detail of implementation, please see section 4.2.

Chapter 4

Implementation

This chapter introduces the issues of implementation more details.

4.1 User Interface

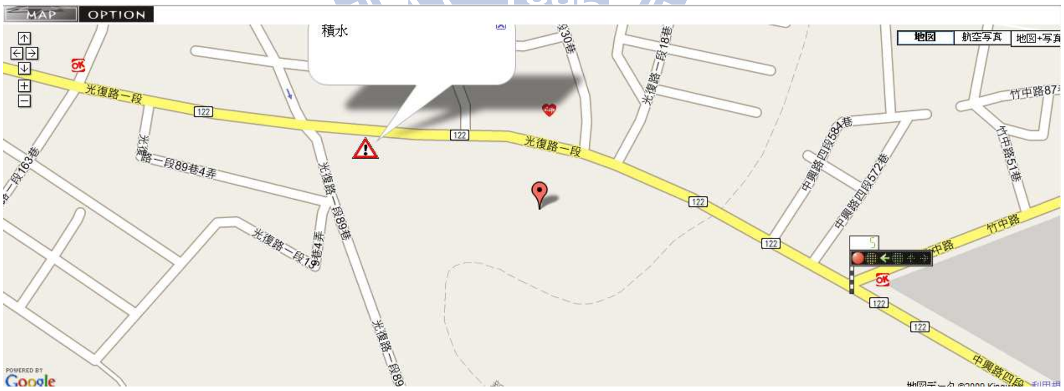

Figure 4.1: User Interface Using Google Map

Our goal of user interface is the intuitive representation of TMC events and traffic lights. The user are specified by special mark in the center of the map, and every events and traffic lights in the neighborhood of user is shown locally. As to the map, for now, we use Google Map for our source of map, but it is possible in the future to use digital map of Institute of Transportation instead. The Google Map is introduced at 4.3 subsection.

4.2 TMC Traffic Lights

4.2.1 Traffic Lights Presentation Using TMC

Our design of traffic lights uses TMC's optional format, which is a free format appending basic item. A free format leading by a label which identifies the content and the fields of free format. The label 15 is a reserved value for the field. we take advantage of this to define our traffic light format. The format definition is following.

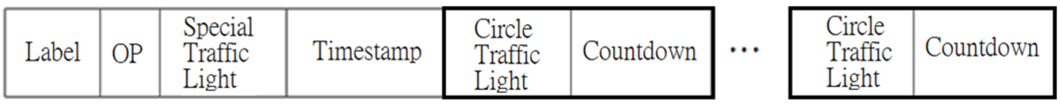

Figure 4.2: Traffic Light Format

The format is led by a label field of 4 bits, like any free format of TMC's optional item, and the label field equals 15.

The second filed is called OP of 2 bits, which defines the operations performed in database of traffic light. when OP filed equals zero , the action of traffic light is disabled, according to corresponding location point. If OP filed equals equals one, the new action defined by format of traffic light will be inserted or updated into the database of traffic light.

The third filed is the Special Traffic Light of 5 bits. The field specifies the type of special traffic light, if any.

The forth field is Timestamp of 17 bits. The field is defined the value of time in seconds since the midnight of that day when the TMC package is made.

The next fields are a sequence of a couple of Circle Traffic Light and Countdown.The six bits of Circle Traffic Light means red, yellow, left turn, green, straight, and right turn traffic lights respectively. Intuitively, a bit is set on means corresponding light is lit. This field forms a state of traffic light, and its next filed, Countdown, specifies its duration. A sequence of these two fields gives a complete description of a circle traffic light.

Following are some examples of encoding of traffic lights:

- Red light countdowns from 900 seconds, at 10:10:30:

  1111, 10, 00000, 01000111100010110, 100000, 1110000100

- Double flash red light, at 13:00:00 (special traffic light = 3):

  1111, 10, 00011, 10110110111010000

- Red light and left light countdown from 45 second, at 21:00:00:

  1111, 10, 00000, 10010011101010000, 100100, 0000101101

- Delete according traffic light from database:

  1111, 00

4.3 Map: Google Maps API

Our map is implemented by Google Maps API. It is a free service with an abundant API. The Google Maps API can embed Google Maps in our own web pages with Javascript. The API provides a number of utilities for manipulating maps and adding content to the map through a variety of services, allowing us to create maps applications on our user interface.

Developers are required to request an API key, which is bound to the website and directory entered when creating the key. The Google Maps API key is no longer required for API version three. Creating a customized map interface requires adding the Google Javascript code to a page, and then using Javascript functions to add points to the map.

4.4 Database

We use PostgreSQL for our database system. PostgreSQL is an object-relational database management system (ORDBMS). It is released under a BSD-style license and is thus free and open source software. As with many other open source programs, PostgreSQL is not controlled by any single company, but has a global community of developers and companies to develop it.

In the database, we define some tables such as event table and location table for TMC packet decode, traffic light table for traffic light, user information table for keeping user's position and so on, and message table, which records all TMC messages for user's query.

The reason why we use PostgreSQL is the benefit that we can add PostGIS, a GIS tool on our database. A GIS tool is a power tool for mapping web. We shall introduce GIS in the next section.

4.5 GIS Tool

A geographic information system (GIS) captures, stores, analyzes, manages, and presents data that is linked to location. In simplest terms, GIS is the merging of graphic map entities and databases.

PostGIS supports PostgreSQL for adding geographic objects to the database. Actually, PostGIS enables the PostgreSQL server spatially. PostGIS follows the OpenGIS "Simple Features Specification for SQL" and is compliant with the "Types and Functions".

With PostGIS, some spatial calculations can be made easily, like calculating the distance between the driver and the next crossroad, finding the user on which road segment, or searching all events surrounding the user within some distance.

Chapter 5

Conclusions and Future Works

Transporting TMC messages via radio has some limits: not localization, the lack of user's information, not interaction. In our system, we try to transport TMC messages via VANET to conquer these problems. As the title of the thesis stated, our system is just a prototype now. There are some aspect can be improved:

- Database Scalable: Because the density traffic light is greater than that of position of TMC location table, we may need to build up more other location tables. Considering salable of database, these tables will be good for use if we build up them by locality.

- Digital Map: Although, now we use google map for our map source, we may use the map provided by Institute of Transportation, Ministry of Transportation Communications instead, for more base-level control.

- Traffic Light: There are a great challenge to synchronize the time of traffic lights between the database and the real world. Besides, in this prototype system, we have not yet had the complete traffic light database, although we're now applying for it from HsinChu City Government.

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