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REAL-TIME TRAFFIC INFORMATION VIA MOBILE AD-HOC NETWORKS

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ABSTRACT

Currently it is possible to use the internet in selected urban areas such as Los Angeles or Houston to view a real-time map of vehicular traffic flow velocities on major arteries using a laptop computer display. Also for a monthly fee traffic information distributed over a Traffic Management Channel (TMC) can be integrated with automobile navigational systems to provide alternate routing capability. Both of these techniques involve a monthly charge and are limited in information they provide and areas they cover. This investigation provides an architecture and a vision to provide more fine grained real-time traffic conditions that works over a wider range of geographical areas providing situational awareness information to motorists using the infrastructure of a mobile ad-hoc network. The idea is similar to a time lapse weather satellite photograph that gives the user the raw information and allows them to use it to make decisions in the manner that best suits their individual situation.

Keywords: information technology, mobile ad-hoc networks

1. INTRODUCTION

Imagine you are driving down a highway and see a traffic jam ahead. This usually happens just after you have just passed the last exit possible to avoid the traffic jam. What is lacking here is a basic situational awareness. In the past people have used private radio systems in an informal manner to distribute basic information but this can only provide limited and unreliable information at best. Many organizations are currently involved in the development of various types of intelligent traffic control systems. For example the US Department of Transportation is spearheading many of these efforts in the area of intelligent transportation systems (USDOT, 2009). As another example, the city of Los Angeles uses computer traffic control systems to control traffic lights to optimize traffic flow (Li, 1998). This type system however is very expensive to implement and maintain.

Right now on the internet in a number of metropolitan areas such as Los Angeles and Houston it is possible to pull up a map of the area and see basic summary information on traffic flow in the main streets. This also has been integrated into Global Positioning System (GPS) routing systems. This may be effective in some cases however automobile routing systems sometimes come up with inferior and or impractical solutions as anyone who has used one will tell you. The Traffic Message Channel (TMC) is a technology for delivering traffic and travel information to drivers. It is typically digitally coded using the FM-RDS system on conventional FM radio broadcasts. When data is integrated directly into a navigation system it gives the driver the option to take alternative routes to avoid vehicular traffic congestion.

Figure 1. Navigational Map of Irvine California Showing Individual Vehicle Locations

The intent of this paper is to investigate how a WiFi or peer-to-peer mobile ad-hoc or mesh network might be used to gather and disseminate real time traffic information (Zong, 2001). The advantage would be that it would not be dependent on a subscription. If you buy the required software and hardware it would be a free extension of the GPS system. The idea is to give you the big picture, like a satellite weather photograph which you can zoom in to whatever level of detail you want and so you can make the decisions about what to do with the information.

2. OVERVIEW

The basic idea is to overlay a real-time and highly granular view of existing traffic in terms of individual vehicles (shown as red circles in Figure 1). This could be done by a stand alone device or built into a navigation system. Each device would have to have some way to distinguish itself as an individual without compromising the privacy of that individual. In the most basic of systems it would simply show a vehicle as a circle on the map. This information is constantly and dynamically changing and updates must be disseminated in an efficient manner. The refresh rate will have to depend (perhaps dynamically) on the network topology and the number of vehicles participating. The data becomes outdated rapidly however it may still be useful. The information should be displayed in such a way that maximizes the usefulness to the user. Obviously the map is not perfect it only shows the subset of vehicles who have chosen to participate in the information sharing.

The kind of information needed to provide this capability can be obtained through the use of a Mobile Ad-hoc Network (MANET) or WiFi mesh network (Wang, 2003) (IETF, 2009). WiFi mesh networks can cover more geographic area and users than previous generations of wireless networks by relying on sophisticated routing technology to increase range and network capacity. Routers accomplish this by spreading a wireless signal across a geographic area including a number of vehicles - extending the range far beyond the range of a single wireless router. Instead of relying on a single large antenna to cover every user, each radio in an open-mesh network cooperates to find the best path to carry a user's traffic. As they operate, the network reevaluates available routing paths constantly, resulting in enhanced network connectivity and availability. The WiFi open-mesh networking platform is capable of providing service to thousands of simultaneous users.

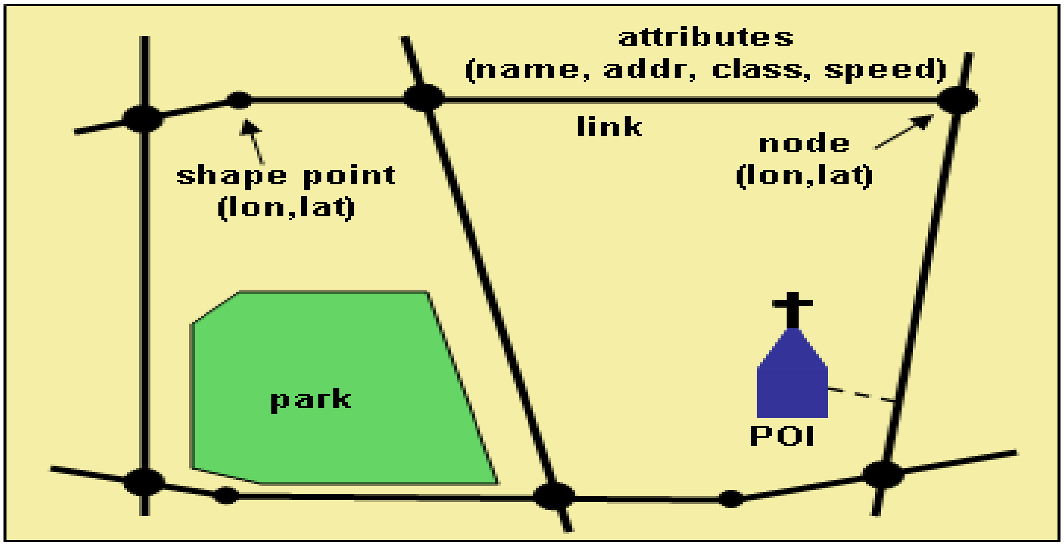

Figure 2. Standard Representation of Navigational Maps

3. MOTIVATION

Peer to peer information sharing is common over the internet. If an information sharing device could be made cheap enough it would provide value to the user (for example if it was integrated into an existing Global Positioning System (GPS) navigational system). Privacy issues could be addressed by assigning a random ID code to each user (for example the SHA-1 hash of their location and time when they joined the network). Billions of dollars could be saved in worker productivity, accidents, and energy by implementing various intelligent transportation system capabilities such as this. All of this is technologically feasible and it appears it could be implemented with relatively little development effort which raises the question of why this has not been implemented already. The reason for this probably has something to do with the business model. Why should some manufacturer sell a box for a small one-time profit when they can charge a hefty monthly fee for a subscription-based traffic and alternate routing service.

4. PROTOCOL FOR EFFICIENT INFORMATION DISSEMINATION AND DISPLAY

One of the most challenging problems that needs to be addressed to create an ad-hoc information sharing network is the protocol for dissemination of all this rapidly changing information in an efficient manner. There is a lot of information and it is constantly changing. Perhaps the most efficient method is to send some kind of ID number, time stamp and GPS location in a small packet. Each vehicle records the information and then passes it to its neighbors with a UDP (User Datagram Protocol) packet where no connection is required. Vehicle location and velocity information are automatically overlayed onto a geographic map as in Figure 2. Information can be added to the map as an icon using the Standard Interchange (SIF) format (SIF, 2009):

type1,label,node1,z1,node2,z2,class,number of shape points,number of lanes,speed

where type represents the type of icon (church, park, vehicle), icon label, shape,etc. The parameters z1 and z2 give spacing information between different icons. Longitude and latitude information must also be specified to know where to place the icon. Alternatively, instead of placing individual icons for each vehicle, the information could be displayed as color coded regions according to vehicular traffic speed. This would make the information easier for the user to interpret at a glance (given that GPS screen sizes are still relatively small at this time).

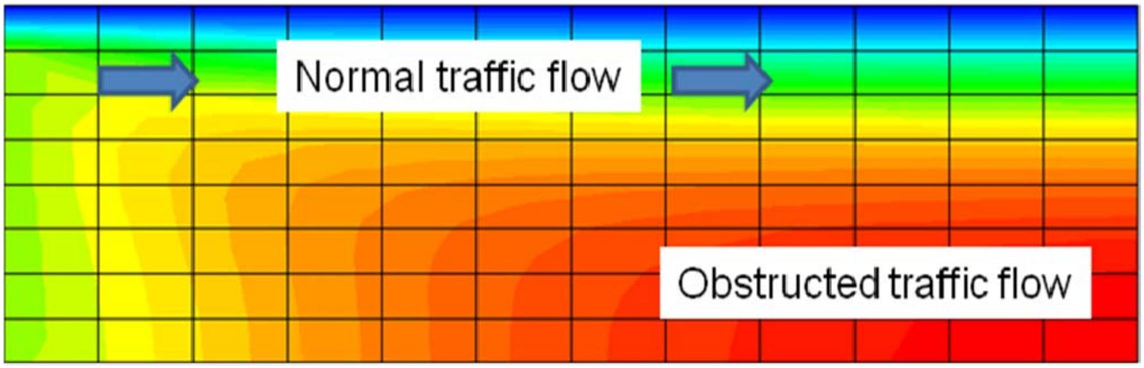

Figure 3. Laminar Flow of Vehicular Traffic Around Disabled Vehicle or Accident

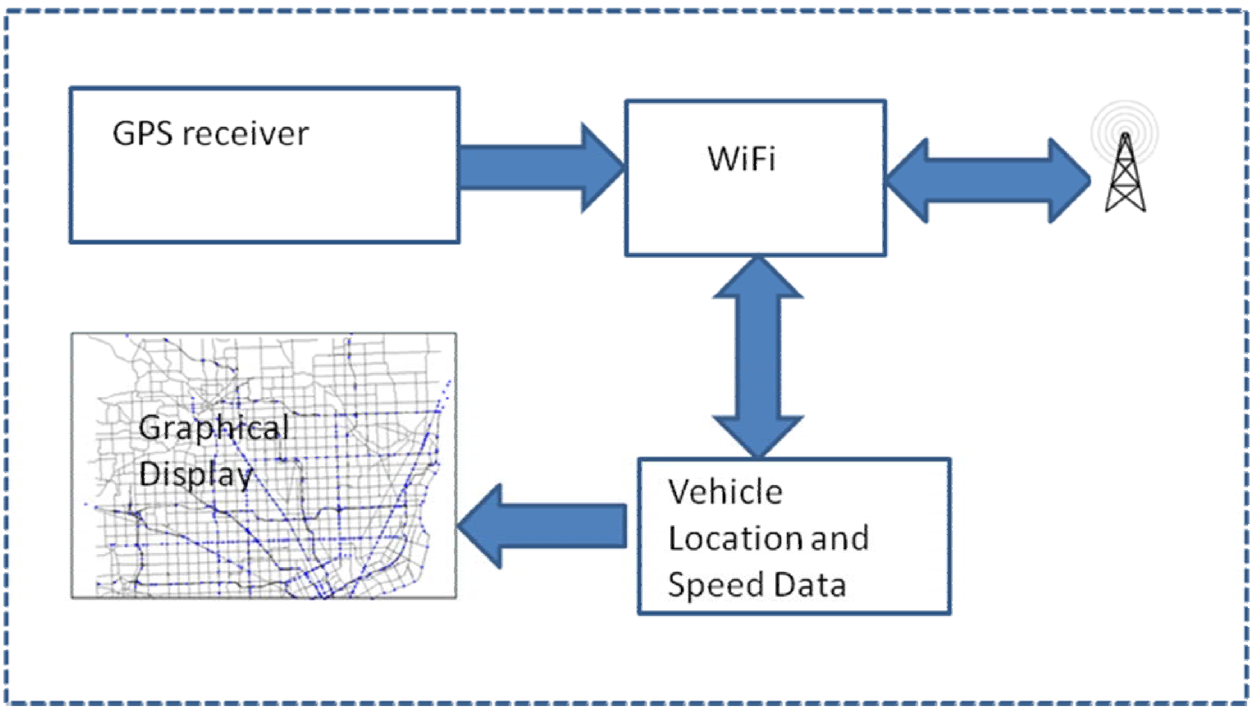

Figure 4 Architecture of Individual Stand-Alone Ad-hoc Networking Device

5. SYSTEM ARCITECTURE

An architecture for the proposed information sharing mobile ad-hoc network system is shown in Figure 4. The basic idea is to create a device which can be carried in a vehicle or attached to a vehicle and performs the following functions.

1. provides a Global Positioning System (GPS) receiver capability

2. calculates latitude, longitude and speed using GPS

3. sends this information with a timestamp to other devices

4. displays the information on a map and refreshes it at an appropriate rate

The diagram of Figure 4 represents a device that can be stand alone or it could be fully implemented by a program running on a laptop (iNAV, 2009). GPS receivers can now be bought for less than a hundred dollars that connect to a laptop via USB or Bluetooth. The system should be designed as a plug-and-play setup and configuration. Every device should work out of the box without the user having to enter any information with the possible exception of the Service Set ID (SSID) (which can also be hardwired). All device manufacturers should use the same SSID even if the device is made by different vendors to maximize the information usefulness. An ad-hoc network of client devices is called an IBSS (Independent Basic Service Set). In an ad-hoc network the SSID is chosen by the client device that starts the network and broadcasting of the SSID is performed in a pseudo-random order by all devices that are members of that network.

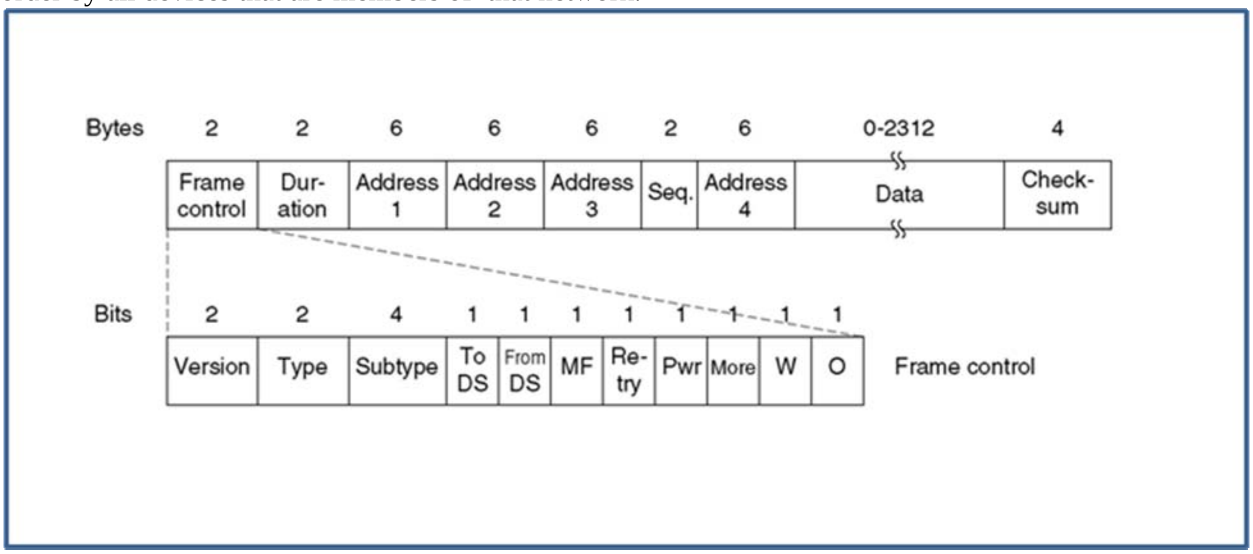

Figure 5. 802.11 Frame Structure

The whole system might be viewed more as a wireless sensor network as opposed to a WiFi network access point. Also because the data to be shared is distributed among many small packets and speed of dissemination is of the essence for real time situational awareness it is a major challenge in terms of contention as the number of nearby vehicles and distance can vary widely by location and time of day. In this proposed system architecture there is no real concern about routing and some form of flooding or gossiping is used for simplicity. It can be made to adapt to the situation based on the number of nearby neighbors and refresh rate. Fortunately if an individual packet is lost it doesn't matter the next packet will refresh the information.

The information to be transmitted is minimal and takes up about 60 bytes: 20 bytes for the ID number (output of 160 bit SHA-1 hash), 9 bytes for latitude, 9 for longitude, 8 bytes for date DD:MM:YYYY, 8 bytes for time HH:MM:SS and 3 bytes for speed (0-999 mph so that it will also work on the autobahn). Information to be transmitted is carried in the data section of the standard 802.11 frame shown in Figure 5. As seen in Figure 5 the 802.11 frame overhead is on the order of 32 bytes and the data to be transmitted takes about 60 bytes which gives about 100 bytes per frame. It is possible to reduce this further by not sending the speed since average speed can be computed from successive GPS location data and timestamps. However, due to round off error this could be misleading in some cases so speed should be included to enhance the data integrity of the system.

Throughput and refresh rate limitations can be estimated as follows. At 10 ns per bit transmission time each packet would take 10 microseconds. At 1% efficiency the throughput could approach 1000 packets of information per second. Assuming extremely inefficient routing of 1 percent for flooding (very conservative) this could represent information for about 1000 vehicles distributed to all participants every minute. Since this information is streaming in real time the refresh rate can be increased or decreased as appropriate. With processor speed rising and data storage price falling this it appears that a range of updating from once per minute to once per second could potentially be achieved.

Figure 6 shows the standard National Marine Electronics Association (NMEA) message format used to communicate between GPS satellites and GPS devices (NMEA, 2009). The NSV fields are from individual satellites and can be stripped out after the latitude and longitude are calculated. In this manner the same syntax can be used in the data section of the 802.11 frame to maximize compatibility and interoperability with other GPS devices.

```
$<CR><LF>
MRK,0<CR><LF>
ZDA,123336.8069,17,06,2001,13.0<CR><LF>
GLL,2924.11158,N,1211.07392,W, 75.97,M<CR><LF>
VTG,218.7,T,2.38,H,0.18,V<CR><LF>
SGD,-1.0,G,-1.0,M<CR><LF>
SYS,3T,9<CR><LF>
ZEV,0.28745E-006<CR><LF>
NSV,2,00,000,00,0.0,00.0,00,00,D<CR><LF>
NSV,7,00,000,00,0.0,00.0,00,00,D<CR><LF>
NSV,28,00,000,00,0.0,00.0,00,00,N<CR><LF>
NSV,1,00,000,00,0.0,00.0,00,00,D<CR><LF>
NSV,13,00,000,00,0.0,00.0,00,00,D<CR><LF>
NSV,4,00,000,00,0.0,00.0,00,00,N<CR><LF>
NSV,25,00,000,00,0.0,00.0,00,00,N<CR><LF>
NSV,0,00,000,00,0.0,00.0,00,00,N<CR><LF>
NSV,11,00,000,00,0.0,00.0,00,00,D<CR><LF>
NSV,0,00,000,00,0.0,00.0,00,00,N<CR><LF>
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Figure 6. NMEA 0183 Protocol Specification

6. INFORMATION ASSURANCE AND PRIVACY ISSUES

Users of this type of network may be willing to risk some privacy in exchange for the benefits they receive (similar to a free email account). However, to make the system more acceptable it may be required to anonymize the identity of the individual. This could be done by randomly choosing an ID as follows. Each node enters the network with a temporary session ID that can be based on the SHA-1 hash of their current location and time. This preserves the identity of the individual as there is no information to identify the user. Also it is computationally infeasible to take the output of the SHA-1 hash function and derive the users location or time of entry information (and even if it were possible the information could not be easily traced to a specific individual).

There is also a risk of the compromise to information integrity and this can manifest itself in a number of ways. For example in April 2007 research about RDS-TMC was presented at the CanSecWest security conference by two Italian security researchers (Barisani, 2007). The presentation, titled Unusual Car Navigation Tricks, raised the point that RDS-TMC is a wireless cleartext protocol and showed how to build a receiver and transmitter with cheap electronics capable of injecting false and potentially dangerous messages into the system.

7. SUMMARY AND CONCLUSIONS

This work presented an overall architecture and vision for information sharing real-time traffic via a mobile ad-hoc network and gave an overview of the types of algorithms that need to be developed. A method for sharing real time traffic data is described. It appears that this can currently be accomplished with the relatively modest development effort. However it requires buy-in by a critical mass of people. Each device manufacturer should design and test for interoperability to maximize the information sharing potential. This capability could be built into existing navigation systems with an option to disable it for those who value privacy. The privacy issue is addressed using the SHA-1 hash of the users GPS location and timestamp at the time of joining the network. Fine tuning of parameters will clearly be required. A proof of concept could be done on a laptop computer in peer-to-peer mode. There are many questions to be answered yet clearly the technology is there and is feasible.

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