SlugTransit: A Location-Based Public Transportation Management System

James Koshimoto
Computer Engineering Department
University of California, Santa Cruz
jkoshimo@soe.ucsc.edu

Matt Bromage
Computer Engineering Department
University of California, Santa Cruz
mbromage@soe.ucsc.edu

Vladislav Petkov
Computer Engineering Department
University of California, Santa Cruz
vladi@soe.ucsc.edu

Katia Obraczka
Computer Engineering Department
University of California, Santa Cruz
katia@soe.ucsc.edu

ABSTRACT

In this paper, we describe *SlugTransit*, an on-line location-based system which allows public transportation systems to be managed in a cost-effective manner while improving overall system's usability and user satisfaction. *SlugTransit* vehicles report their location in real-time to *SlugTransit* base stations; vehicle location information is then uploaded and stored in a database. Software updates and log file retrievals are done through *SlugTransit* gateway's. Through a visual, Web-based interface, system operators as well as users have access to current location information in real-time. This capability enables operators to better manage the transportation network, improving efficiency and, at the same time, user satisfaction.

Categories and Subject Descriptors

H.4.3 [**Information Systems**]: Communications Applications

General Terms

Design, Experimentation, Management

Keywords

Location-based, Transportation Management System

1. INTRODUCTION

The increasing availability of portable computing devices as well as ubiquity of wireless communication infrastructure have sparked the development and deployment of a wide-range of new applications and services. "Location-based" applications are a notable example of these new class of applications which use location information to provide a variety of services. In this paper, we describe *SlugTransit*, an on-line location-based system which allows cost-effective management of public transportation services while improving their overall usability and user satisfaction. *SlugTransit* vehicles report their location in real-time to *SlugTransit* base stations; vehicle location information is then uploaded and stored in a database. Software updates and log file retrievals are done through *SlugTransit* gateway's. Through a visual, Web-based interface, system operators as well as users have access to current location information in real-time. This capability enables operators to better manage the transportation network, improving efficiency and, at the same time, user satisfaction. Users are also able to look up real-time bus schedule information available on-line which provides them with a higher-quality user experience.

The name *SlugTransit*[1] refers to the current instantiation of the system which is being used to manage the UC Santa Cruz campus transportation service. Currently, *SlugTransit* consists of ten bus nodes, five base station nodes, and one gateway node.

SlugTransit is also part of *Scorpion*[4], a heterogeneous, disruption-tolerant, wireless networking testbed that can be used by researchers to test their protocols in a real-world environment under realistic conditions. To this end, *SlugTransit* nodes can communicate among themselves through a separate wireless network. Mobility traces collected from *SlugTransit* vehicles can also be used as realistic traces to drive simulations when evaluating disruption-tolerant network (DTN) protocols.

2. RELATED WORK

There has been significant work on location-based services for a variety of applications. In the specific case of transportation management, one notable service is NextBus, a

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[1]The name SlugTransit was inspired by UC Santa Cruz's mascot, the banana slug.

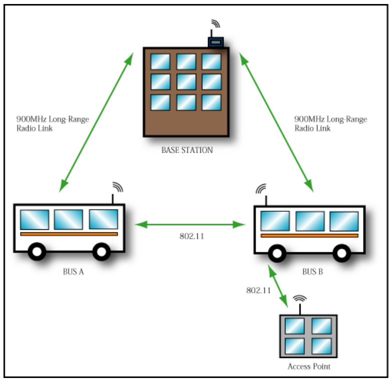

Figure 1: *SlugTransit* system overview: location information from vehicle nodes is sent to the base station through a 900MHz network. A separate 802.11 network is used for vehicle-to-vehicle communication.

system used by the Bay Area Rapid Transit (BART) [7]. NextBus provides time-of-arrival using current location information. It uses cellular communication to transmit vehicle location. Each bus is equipped with a cellular modem and at specific intervals, it sends its location to a centralized server. Although cellular technology provides wide coverage, the cost of maintaining a cellular link per vehicle can get prohibitively expensive. In fact, based on the contract between NextBus and BART, the total cost for a seven year contract connecting four BART stations is estimated to cost approximately $1,000,000 [2]. *SlugTransit*, on the other hand, does not require any maintenance fee; its one-time cost is for setting up the 900MHz infrastructure and to install the tracking device on to the buses.

Another system to be pointed out is UMass's DieselNet[5] whose main purpose was to serve as a networking research testbed. DieselNet vehicles transmit location information through 802.11b WiFi radios in a disruption-tolerant manner. This means that location information traverses from bus to bus until it gets to a centralized location. This is one of the main differences between DieselNet and *SlugTransit*, where location information is transmitted through a dedicated 900MHz network where connectivity is guaranteed. This ensures minimum delay in providing up-to-date vehicle location information to operators and users.

3. SYSTEM OVERVIEW

Public transportation can be disturbed by several factors including traffic situations, vehicle breakdowns, route changes, "hot spots", etc. *SlugTransit* aims at providing users and system operators with on-line up-to-date vehicle location information to ensure efficient and high-quality service.

SlugTransit vehicles are outfitted with nodes equipped with a GPS tracking device and a 900MHz long-distance radio to track vehicles on their routes. Location data is collected using the GPS device and beaconed out through the 900MHz radio. Location data is then received by base stations, which also uses a 900MHz network to relay it to a centralized server.

This data is then made available through a visual Web-based interface; we have also made it available on portable

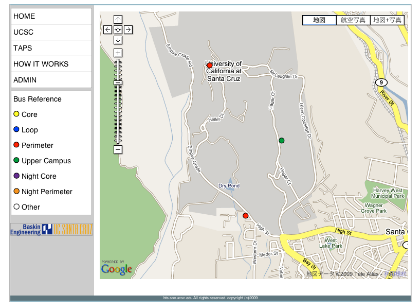

Figure 2: *SlugTransit* user interface based on the Google Maps API

mobile devices, specifically the iPhones, using the Google Maps API [8] [2]. Through the *SlugTransit* interface, users and operators can access exact location of vehicles from nearly anywhere and plans can be made accordingly even when problems occur.

SlugTransit vehicles are also equipped with 802.11 WiFi radios providing a separate network dedicated to vehicle-to-vehicle communication. This network is intended as a way to test and evaluate wireless network protocols, specifically protocols designed to operate in connectivity-challenged network scenarios. It can also be used to communicate with other nodes in the *Scorpion* [4] testbed. Additionally, *SlugTransit* vehicles can collect GPS-rich data sets to be used in trace-driven simulations of wireless network protocols as well as statistical studies of user mobility. The 802.11 network is also used for pushing software updates and collecting log files through a gateway node (described in detail in Section 6).

In summary, *SlugTransit* is able to relay up-to-date vehicle location information reliably and thus reflect the dynamics of the day-to-day operation of a public transportation service. It is instrumental at helping system operators provide high-quality service to users in a cost-effective way. Figure 1 shows the system overview of *SlugTransit*.

4. GRAPHICAL USER INTERFACE

The graphical Web-based user interface (shown in Figure 2) is a key part of the system. *SlugTransit*'s Web site is available to anyone with Internet access. However, a portion of the Web site is meant to be accessible only by service operators and is thus password protected. *SlugTransit* maps are also accessible using smart phones such as the iPhone.

4.1 Transportation System User Interface

Users access real-time vehicle location information through a Web site created using the Google-Maps API. In the current implementation, the Web site refreshes every 2.5 seconds to offer up-to-date location of vehicles. Location information is displayed on the map in color-coded dots depending on which route the vehicle is on. This is the same on an iPhone. The server will detect the iPhone and direct the user to the appropriate page and display the map with the current location of all of the vehicles. Figure 3 shows the iPhone interface.

[2]The Google Maps API provides the ability to embed Google Maps into Web sites using JavaScript; it also comes with abundant map manipulation utilities.

Figure 3: *SlugTransit* User Interface for the iPhone

4.2 System Operator Interface

System operators are also provided with a Web site and given administrator privileges to, e.g., configure route information for each vehicle. These updates show up on the main Web site (accessible to users of the transportation service) in real-time.

5. HARDWARE

SlugTransit hardware is based on a Mini-ITX [10] computer running Linux and depending on the type of node, it is equipped with different external devices as follows:

- **Vehicle Node:** GPS tracking device, 900MHz radio, and three 802.11a/b/g WiFi radios.
- **Base Station Node:** 900MHz radio.
- **Gateway Node:** 802.11a/b/g WiFi radio.

5.1 900MHz Radio

AC4790 900MHz transceiver radios from Aerocomm [1] are used to populate the 900MHz network. The AC4790 uses frequency hopping spread spectrum in the 900MHz ISM band to provide high-performance communication, while following the FCC part 15.247 regulations. Therefore, it does not have FCC licensing issues allowing *SlugTransit* to be usable by any public transportation provider/operator in the United States.

5.2 GPS Tracking Device

Pharos' iGPS-500 [9] receiver collects vehicles' GPS coordinates. The NMEA-0183 standard protocol is used and the 'GGA' message containing 3-Dimentional location and accuracy data, is extracted from the output message to provide the longitude and latitude corresponding to the vehicle's current location. This device connects through USB and thus can be connected through an available USB port.

5.3 802.11a/b/g Radios

Atheros 802.11a/b/g WiFi radios[3] are used to enable communication between vehicles and *Scorpion* testbed nodes. The radios are also used for software updates and collecting log files. They are configured to be on the same subnet to enable communication between them. Figure 4 shows a snippet of a GPS log file collected on June 10th 2009.

```
...
1243005797 36.989944 -122.066994
1243005798 36.989922 -122.067055
1243005799 36.989891 -122.067123
1243005800 36.989861 -122.067184
1243005801 36.989830 -122.067253
1243005802 36.989796 -122.067337
1243005803 36.989758 -122.067398
1243005804 36.989719 -122.067467
1243005805 36.989681 -122.067513
...
```

Figure 4: Snippet of a GPS log file on June 10th 2009.

6. CURRENT DEPLOYMENT

Currently, *SlugTransit* has been deployed in the UCSC campus and used by UCSC campus transportation service. As of now, there are a total of ten buses outfitted with vehicle nodes, five base stations that are deployed to provide a campus wide coverage, and a gateway node installed at the bus depot that performs software updates and log retrieval.

6.1 Vehicle Node

Vehicle nodes are installed in the cabinet located above the bus driver's seat. Since the Mini-ITX computer has one of the smallest form factors available in the market, it allows easy installation on the bus without cramming the bus driver's area. The power is connected through three input wires on the M3-ATX power supply [6]: Battery +, Battery -, and ignition. This power supply is designed for use in a vehicle and it can handle an input voltage from 6V - 24V to accommodate engine cranks, under-voltage and over-voltage situations. It also takes care of power challenges when installing a computer in a vehicle. Generally when vehicles are powered off, the computer connected to the battery still consumes power and drains the battery. To avoid this, this power supply has an 8-bit micro-controller unit that cuts-off the power completely after some pre-defined time.

6.2 Base Station Node

Base station nodes are deployed throughout campus to provide a 900MHz coverage over all bus routes. The current deployment allows maximum coverage around campus with minimal number of base stations. The approach used to choose the best location to deploy base stations depended on how high the building is, if the site had Internet connectivity, and the range of the 900MHz radio. Each site's 900MHz range was checked around campus using a 900MHz transceiver to determine the approximate range in order to provide optimal coverage. Additionally, the deployment was done in such a way as to allow a small overlap between neighboring base stations to avoid drop outs by allowing smooth hand-offs between base stations. Figure 5 shows the approximate 900MHz coverage.

This infrastructure also allows the bus operators to use the system without any monthly maintenance fee. Compared to coverage using a cellular technology, where each communication device usually comes with a monthly service charge, the maintenance fee scales with the number of participating vehicles and thus can get overwhelmingly ex-

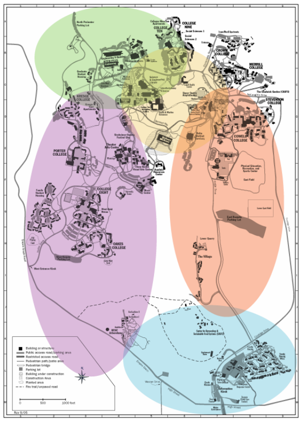

Figure 5: Approximate 900MHz coverage.

pensive. In *SlugTransit*, once the infrastructure is installed, no additional maintenance fees are needed.

6.3 Gateway Node

A gateway node has been installed in an office near the gas station in the bus depot. During a normal day, a bus comes into the bus depot to fill up their gas at least once a day. When the bus is turned on, a series of scripts are activated and start communicating with the gateway node. (This is discussed in further detail in Section 7.) Since every bus comes into the bus depot, it allows prompt updates of software and log files to be uploaded.

7. MANAGEMENT

Vehicle nodes are updated via bash scripts along with the usage of an SVN repository. When a vehicle starts its engine, the vehicle node detects that it was turned on and initiates a boot up script. Once the boot up script launches, it invokes a series of other scripts that are responsible for executing different tasks. One of the script's main task is to start the update process, which is done by making an update call to the SVN repository. The update procedure is quite simple and this script executes a command to compare its revision number against the SVN repository's revision number to check for any updates. If there exists files with a newer revision number, the bus node will download the new files through the gateway node and then finishes the update procedure.

Since these nodes do not have continuous access to the Internet, the updates are done only when it has contact with the gateway node. A gateway node acts as a bridge to the Internet for vehicles. In order to check if vehicles are in contact with the gateway node, one of the scripts make an attempt to ping the gateway node on boot up and if it is successful, the script goes on to the update procedure. Otherwise, it skips updating and continues booting up the node. The ping command is useful to avoid any delays when vehicles turn on because vehicles are not in contact with the gateway node at all times.

8. CONCLUSION

In this paper, we describe *SlugTransit*, an on-line location-based system which allows cost-effective management of public transportation systems while improving their overall usability and user satisfaction. *SlugTransit* vehicles report their location in real-time to *SlugTransit* base stations; vehicle location information is then uploaded and stored in a database. Software updates and log file retrievals are done through *SlugTransit* gateway's. Through a visual, Web-based interface, system operators as well as users have access to current location information in real-time. This capability enables operators to better manage the transportation network, improving efficiency and, at the same time, user satisfaction. Users are also able to look up real-time bus schedule information available on-line which provides them with a higher-quality user experience.

We have also described the current *SlugTransit* deployment aiming at helping manage UCSC's campus transportation services. As future work, we plan to expand the current deployment to include other vehicles that are part of UCSC's transportation network (e.g., disability vans, bicycle shuttles, etc.). We also plan to deploy *SlugTransit* in the Santa Cruz Metropolitan region.

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