Enhancing Transportation Service in the Local Community Using Fleet Tracking and Data Management

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ABSTRACT

This project demonstrates that basic mobility management tools such as fleet tracking and data management can provide more efficient operations when applied to small transportation providers. These smaller scale providers are often connected to facilities such as councils on aging, assisted living facilities and university campuses providing student transportation. They have clients such as the elderly, disabled, people of low income, and college students. These providers often do not need and cannot afford commercial expensive mobility management software systems. In addition, they are often staffed by non-technical, part-time employees and volunteers, and thus, are unlikely to adopt or deploy theses systems without assistance.

This study develops and presents a generic tracking system that is readily and easily deployed by small transportation providers. It is low cost but effective. A generic architecture is designed with the core capabilities of fleet tracking and data management. Its implementation targets open source software, free Internet hosting, low equipment costs and low global position system (GPS) service costs. The generic system has been applied to three fleets and software has been customized for three small local transportation providers. The application has a lasting value as the open source is ready for deployment to other small transportation providers.

Keywords: Mobility Management, Fleet Tracking, GPS, Small Communities, Decision Support Systems, Transportation Access, Elderly

INTRODUCTION

This study demonstrates an economical deployment of GPS phone technology and software that enable fleet tracking of vehicles and centralizes dispatching of data. It provides mobility management enhancement tools for three small transportation providers: the New Bedford Council of Aging (NBCA), Community Care–A–Vans (CCAV) and the DartVan, a university campus transportation provider to students. While the three transportation providers differ from each other in organizational size and mission, their core objective remains the same: to provide special transportation services for people in need, such as the elderly, disabled, low income, unemployed and students.

All three transportation providers in this study are looking for ways to provide increased services with existing resources and without increasing costs. The objective of this study is to assist these providers in the deployment and adoption of a few chosen low cost mobility management tools that can increase transportation services by improving efficiency of operations. It is anticipated that not only will providers use their available resources more effectively, but will also gain the advantage of an archived database. This data, such as mileage and number of trips, will now be automatically documented and can be used for grant and report writing for future acquisition of available funding. Further more, there is also a need by these transportation providers to be more efficient in organizing their dispatch data such as client, driver , and schedule information. This kind of data can be integrated to the archived database into one seamless process.

The NBCA (http://www.gnbcoast.org/index.php) is a small transportation service that provides trips to seniors and the disabled in the New Bedford, Massachusetts region. The fleet includes 6 small vans. The routes of their vehicles change daily, due to the dial-a-ride nature of their required transportation services. Because of budget constraints, expensive, traditional commercial tracking hardware as well as the accompanied software programs are beyond the reach of the NBCA.

The CCAV (www.communitycare-a-vans.org) is a local transportation provider with a larger fleet of 26 vans. It operates a pickup service similar to the NBCA. In addition to its dial-a-ride services, however, the CCAV also has fixed scheduled routes, providing services that pick up riders on a particular day of the week at a specified time of day and brings customers to set destination sites. This service is given to people that are unable to transport themselves on their own due to physical or mental impairments. The CCAV also operates on a low budget.

The University of Massachusetts campus transportation system, the DartVan, (http://www1.umassd.edu/publicsafety/dart) includes a fleet of 4 small vans that travel solely on the UMass Dartmouth campus and provide transportation for students as well as staff and faculty. Although the vans are operated during evening and nighttime hours, these vans are driven by students during the daytime hours only. The campus police are responsible for operations, for dispatching and for the employment of drivers.

The project developed three customized login protected web-based vehicle tracking and data management decision support systems (DSS). For development purposes, each website is currently housed on a server in the UMass Dartmouth Intelligent Transportation Systems (ITS) Laboratory. In the future, it will be moved to the UMass Dartmouth Datacenter, which is a more secure facility with backup systems that keep functioning even with electrical blackouts.

The requirements for the three different providers are displayed in the Table 1. The scope represents the number of vehicles and the radius of operations. The needs include the major reason why each organization wants to track their vehicles. The expertise represents the level of computer finesse each operator possesses in order to utilize this new technology.

TABLE 1: Requirements for the three agencies

Org.	Regional Coverage	Needs	Expertise
NBCA	6 vehicles within the City of New Bedford	Real time scheduling	Low
CCAV	26 vehicles within a 40 mile radius of Taunton	Dispatch & Data-Management	Medium
DartVan	4 vehicles restricted to on-campus travel	Increased Ridership & Regulation of student-drivers	Medium

BACKGROUND

Fleet tracking and data management systems are systems that reveal vehicle locations to fleet managers for the purpose of facilitating decision making and operations. Vehicle tracking systems have many applications for a wide spectrum of working areas including but not limited to delivery services, transportation, construction, taxi, fire fighting and public as well as private security [1].

Vehicle Tracking Systems have been used by the urban transit providers in recent years. The needs for these providers due to high demands of transportation accessibility have gone beyond vehicle tracking. Such additional needs include add-on GPS supplements to assist dead zone scenarios, dispatch initiative voice calls, text messaging, automatic destination announcements, and several others [2].

Rural transit providers are beginning to also have demands for vehicle tracking systems for the prediction of bus arrival times and to ensure that the buses do not deviate from their routes [3]. Various tracking technologies are out there and the cost of installation and subscriptions vary [3].

Choosing a vehicle tracking system is greatly contingent upon the application scenario and the scope of the tracking project. Depending on the geographical dimensions of the area within which vehicles are required to be tracked, the environmental settings of that area, the required precision of the reported vehicle positions and the sensitivity of the application to the real-time component of the tracking system different integration of tracking methods may prove to be suitable. Our goal is to design a core vehicle tracking system with basic functionality that fits the needs of the small non-profit transportation providers with minimal cost.

The whole vehicle tracking process is a combination of several technologies and can be classified into three basic sub-processes. The first sub-process is acquiring the location information of the vehicle being tracked. The second sub-process is forwarding the location information to the data center where both the queries and the query responses are gathered for further processing. The existing wireless networks are usually a good candidate for this. Finally, the last sub-process is processing the data and rendering the results in the desirable interface. Additionally, if necessary, it is possible to improve the precision of the determined location by taking advantage of several methods [2].

The first sub-process which is acquiring the vehicle location information is the most challenging stage in vehicle tracking. Different methods have been developed to address this challenge. Some of these methods are stronger than others in terms of the precision they render, although they have their own limitations as well. In practice, the stronger methods usually shape the backbone of the solution and other methods are available to fill for them in case of their temporary failure or as a tool to enhance the degree of accuracy and precision.

Vehicle location gathering can be done by deploying sensors in the vehicle and having them gathering the required data. LORAN (LOng RAnge Navigation) sensors were one of the very first in-vehicle sensors being used for this purpose. LARAN is a terrestrial radio navigation system that uses low frequency radio waves to determine the location of the vehicles. The system is based on the time difference between the reception of signals flooded by a pair of radio transmitters deployed in fixed and known locations across roads. This time difference locates the vehicle in an imaginary hyperbolic line. Theoretically, adding a second application of the same principle can make the location of the vehicle known while in practice, one more transmitter would be enough as it could form a pair with each one of the transmitters of the first pair.

After emerging new technologies like Global Positioning System (GPS) LORAN was gradually replaced with other in-vehicle sensors mostly due to not being available globally, its lack of coverage in the areas that where it existed and its decreased accuracy in urban areas [1][4]. However, using LORAN as a backup for GPS is an option which has directed attentions to it again [5].

The GPS system is composed of a number of satellites orbiting the earth every 12 hours. This number can be different, anywhere from 24 to 34 and is always prone to changing as old satellites retire and new ones fill for them. At present there are 27 satellites orbiting the earth in six different plates. Among these 24 are working and 3 are spares, in case of failure. The distribution of these satellites is set in a way that four of them are visible from any location on the earth given that there are no obstructions. Vehicles that are required to be tracked have to carry GPS receivers. At least four satellites should be visible to a GPS receiver to fix the location of the car and do time synchronization. The accuracy of the solution will improve with additional visible satellites.

The GPS system owes its popularity to its ubiquity, accuracy and rather low cost. However, using GPS can impose its own limitations depending on the tracking application scenario. The most important problem is the blockage of satellite signals that happens often in dense urban areas due to existence of large buildings. Buildings can further cause multipath effect by deflecting and distorting of satellite signals [6]. However, the GPS system is still reliable for a good percentage of the time.

The next sub-process is choosing the medium to transmit the location data to a remote site. There are several communication systems that can accomplish transmission of data such as Analog Radio Data, Digital Radio, Dedicated Short Range Communications (DSRC), Broadband Wireless Networks, Wireless local Area Networks (WLAN), Mesh Networks, Text paging, Satellite Communications, Cellular Data Communications, and commercial telecommunications as described in the Federal Transit Administration (FTA) state of art report in [7].

The final sub process involves capturing and storing the transmitted data in a computer database. Records in the database can be displayed as visual representations of the vehicles on a Decision support system (DSS) using a Geographic Information System map. There are various mapping interface that could be plugged in to the DSS such as Google Maps, Mapstraction, Microsoft Virtual Earth, and OpenLayers.

This paper presents an overview of the system architecture design which includes the hardware or cell phones, the server cluster, the browser user interface, and user data-entry-forms for each of the three transportation providers.

SYSTEM ARCHITECTURE

To achieve the dual design goals for low cost in deployment/operation and ease of use/maintenance, we have developed a generic system with the core capabilities of fleet tracking and data management selected from the Automatic Vehicle Location (AVL) system recommended by Transit Cooperative Research Program (TCRP) [3]. Figure 1 depicts the architecture with three components: GPS Cellphones, a Browser User Interface (BUI), and a Server Cluster.

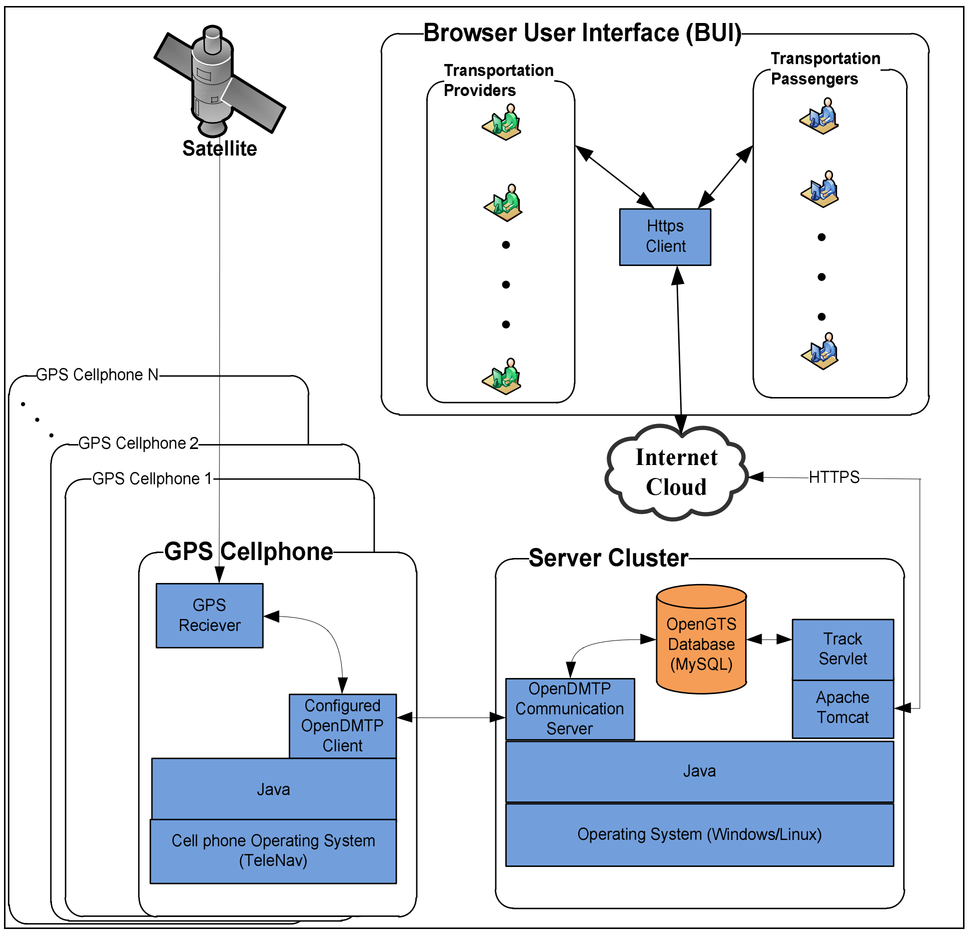


FIGURE 1: System Architecture

The choice of *GPS Cellphones* for fleet tracking fulfills the goal for low cost in deployment/operation, as discussed in the previous section on background. A Web-enabled *Browser User Interface (BUI)* achieves the goal for ease of use/maintenance. A

Server Cluster implements mobility management and data management customized for each transportation provider while hiding the technical complexity from the system users.

Each GPS Cellphone installed on a vehicle contains a *GPS Receiver* that obtains its geographic location and motion information from a satellite. The GPS Cellphone sends such information to the Server Cluster, which has pre-configured the cellphone, via a communication protocol. A protocol is an agreement between *Client*, GPS Cellphone in this case, and *Server* in order to understand each other. We have chosen the Open Device Monitoring and Tracking Protocol (OpenDMTP) for its compatibility and at no cost [8]. Both the *Configured OpenDMTP Client* in each GPS Cellphone and the *OpenDMTP Communication Server* in the Server Cluster are written in Java. *Java* is a high level object-oriented programming language suitable for device control and portable across platforms [9]. For our project, the *platform/operating system* (basic software managing the hardware resources and providing a user interface to the device) of GPS Cellphones is Motorola TeleNav, and that of Server Cluster is Microsoft Windows or Linux.

The Server Cluster stores the fleet tracking information on a database for customized processing. We have targeted to open source software packages for no cost and ready customization. The Open GPS Tracking Software (OpenGTS) [10] is customized and configured to store the information in the *OpenGTS Database* format and to display spatial data on a map system such as free Google Maps. Data management is implemented with *MySQL*, a database query language [11].

Both *Transportation Providers* and *Transportation Passengers* interact with the system via the Web-enabled Browser User Interface (BUI) over the Internet. Our BUI is user friendly with access control on the privileges to view the OpenGTS Database for fleet locations and other information. BUI and Server Cluster communicate via *HTTPS* (Secure HyperText Transfer Protocol) [12]. *Apache Tomcat* [13] in Server Cluster is an open source Web server, upon which the *Track Servlet* has been implemented. *Track Servlet* is a small program plug-in the server.

Figure 2 illustrates the installation of the system's hardware. The GPS Cellphones have been installed on the vehicles being tracked. Due to the line-of-sight requirement by the GPS Receivers from the satellite, the cellphones are placed close to the windows or windscreen. A data service plan is acquired for each cellphone as OpenDMTP Client to communicate with Server Cluster via the cellular network towers relayed to the Internet.

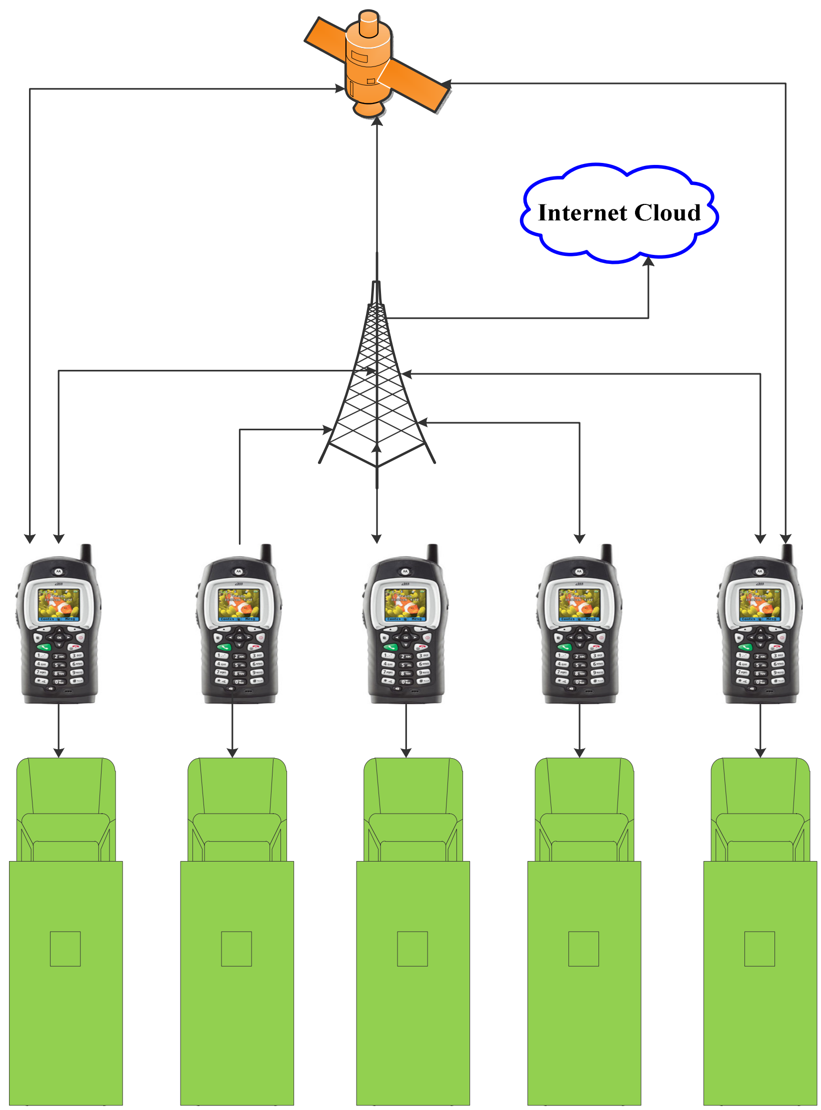


FIGURE 2: Conceptual System Installation

GPS CELLPHONE

Two types of GPS cellphones are considered for the system: regular and assisted. Regular GPS cellphones communicate directly with a satellite. Location finding is only based on the satellite. The problem with this type of phones is that satellites require a line of sight. In case where no line of sight is seen, location is lost. An example of regions with no line of sight includes underground tunnels. Assisted GPS (AGPS) can determine its location with cellular network towers when there is no line of sight from the satellites. However, AGPS requires smart computations and trades off speed with reliability.

We choose Motorola i355 for three reasons. First, it uses AGPS for better location tracking reliability. Secondly, it comes with a software development kit, on which we can customize the system easily. Lastly and the most importantly, it is very inexpensive, less than $20 when we purchased on eBay this year. Nextel/Sprint offers good data service plan that costs $70 for the first phone with an unlimited data transmission and $10 for each additional phone. Figure 3 shows Motorola i355.

FIGURE 3: Motorola I355 GPS Cell Phone.[14]

Recalling Figure 1 in the Architecture section, OpenDMTP Client runs on each cellphone to communicate with OpenDMTP Server in Servier Cluster. This is another cost-saving choice as OpenDMTP is an open communication protocol targeted towards devices that have low processing, storage, and networking capability [8]. Such devices include cell phones, PDAs, GPS Receivers, and various probing micro devices. Most of these devices use the OpenDMTP communication protocol primarily for sending location and monitoring information such as longitude, latitude, speed, temperature, and pressure. The communication protocol is open to the public that leads to ease of customization and high compatibility compared to closed proprietary protocols. OpenDMTP is not intended for time constrained systems. Data can only be transmitted once in a minute or two. This time constraint is sufficient for fleet tracking systems. OpenDMTP is also event driven, which transmits data based on those events important to a particular application. Event-triggers help to decrease the cost of transmitting unnecessary data. For example, it would waste resources to send the same location of a vehicle all night when the vehicle is parking. One only needs information when it is in motion.

The OpenDMTP Client program periodically probes the GPS Receiver for location, time, and speed information. Then it sends the information to OpenDMTP Server based on the events configured. Table 2 lists the configuration parameters to the OpenDMTP Client.

TABLE 2 : OpenDMTP Client Configuration Parameters

Parameter	Units	DESCRIPTION	Optional	Set at Runtime
Dmtp-Access	N/A	Sets the OpenDMTP Server address, port number, account and device.	NO	NO
DMTP-gps-minspd	km/h	This sets the minimum speed by which the vehicle being tracked is in motion. Any speeds less than this speed is automatically set to zero.	YES	NO
DMTP-mot-start	km/h	This is the minimum speed that the vehicle has to be moving in order to be registered as a vehicle in motion. This always has to be at least equal to the DMTP-gps-minspd parameter.	YES	NO
DMTP-mot-inmotion	s	This is the time interval between data transmissions to the server when the vehicle is in motion. This value cannot be less than 60 seconds according to the OpenDMTP specifications.	YES	Yes
DMTP-mot-stop	s	This is the number of seconds to wait for after the vehicle is not moving before reporting a stopped event. This is crucial for avoiding false stops such as stop signs and traffic lights.	YES	NO
DMTP-mot-dorm-rate	s	This is the time interval between transmissions to the server when the vehicle is not in motion.	YES	YES
DMTP-mot-exspeed	km/h	This is the speed threshold at which an excess speed event can be triggered.	YES	NO

BROWSER USER INTERFACE (BUI)

The Browser User Interface (BUI) is a visual medium between the fleet tracking application and the transportation providers and passengers, achieving the design goal for ease of use by non-technical people. Figure 4 samples the four categories of BUI screens: Map, Geo Zone Admin, Account Admin, and Reports.

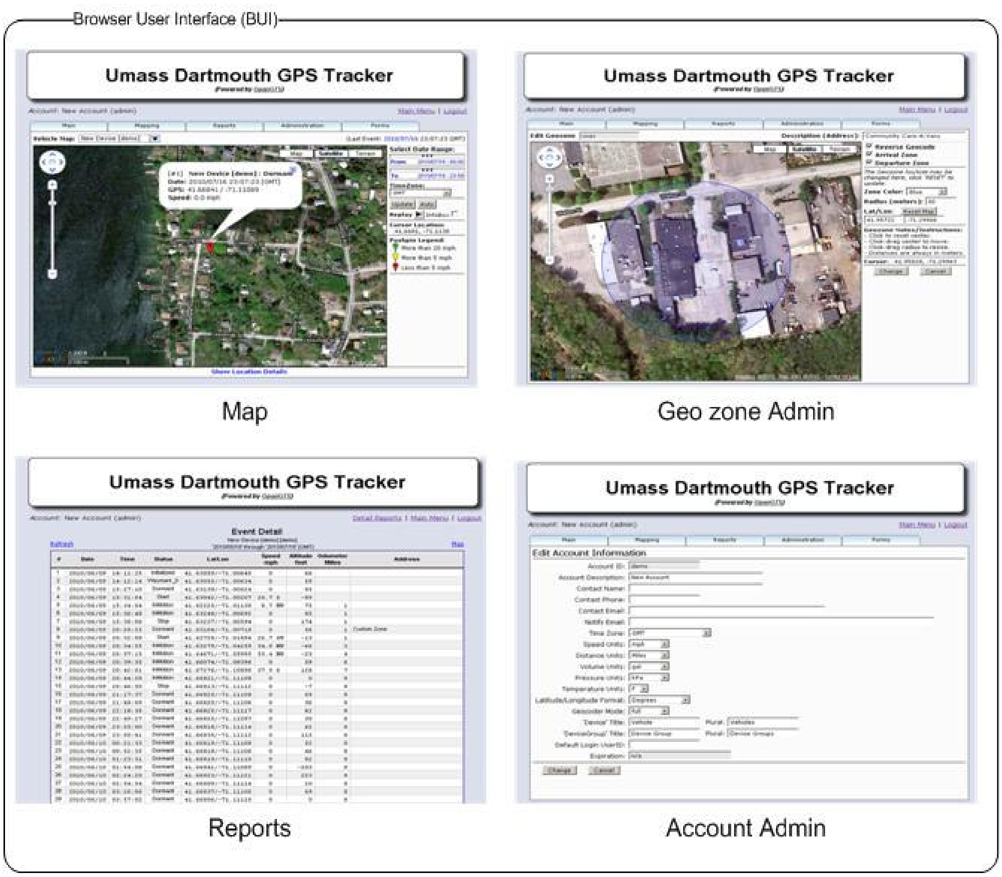


FIGURE 4: Snapshots of Fleet Tracking System

The Map screen displays the fleet or vehicles being tracked on a map background. OpenGTS supports a vast variety of map plug-ins such as Google maps and Open maps. The vehicles appear as icons located in the map with their status such as speed, location, and mileage being displayed on the fly. With a quick glance, one would know the locations of the fleet for the last 2 minutes.

Geo Zone Admin allows a privileged user to administer ranges of spatial location on the map as surveillance perimeter for the fleet. Any vehicle leaving the perimeter would trigger a notification to the Map screen, which is also recorded.

Reports screen archives the data of tracked vehicles. Such historical information can be utilized for budget proposal, future planning, dispute resolution, etc.

Account Admin manages the data for the whole process including drivers, customers, appointments, and etc.

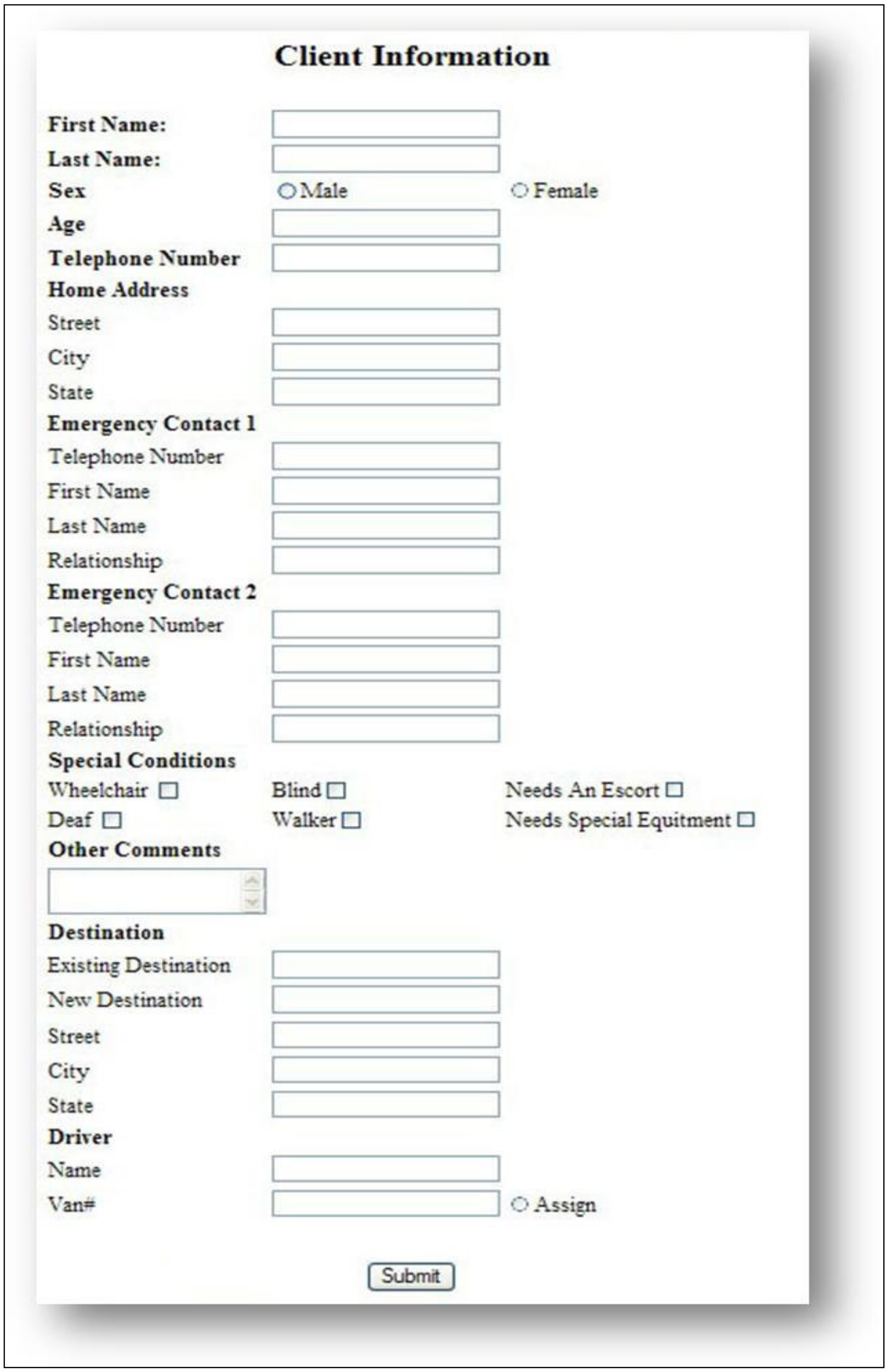
As indicated in Figure 1 of the Architecture section, HTTPS Client is used to control access for security and privacy of the system.

DATA MANAGEMENT IN SERVER CLUSTER

The Server Cluster offers transparent and seamless fleet tracking perceived by the transportation providers and the transportation passengers. While OpenGTS is effective for managing fleets, it is limited to the whole process involving all the parties of transportation. We have added data management functionality to the Server Cluster. It manages customers, drivers, appointments, and hotspot destinations to integrate tracking and scheduling.

The small transportation providers manage their data with individual computer forms such as Excel files. Inconsistency among operators' files and human editing errors cause confusion. We offer a centralized database, where transportation provider personnel such as operators, dispatchers, and drivers can enter information via a web form, and our system keeps the consistent records visible by all personnel. Access control is implemented for security and privacy of the database. Currently, we offer four kinds of forms: Client, Appointment, Driver, and Destination.

The Client-Form as shown in Figure 5 takes client personal information such as name, age, address and so on. This information is also vital to enforce pricing policies such as the exemption of charges for citizens over 90 years of age.

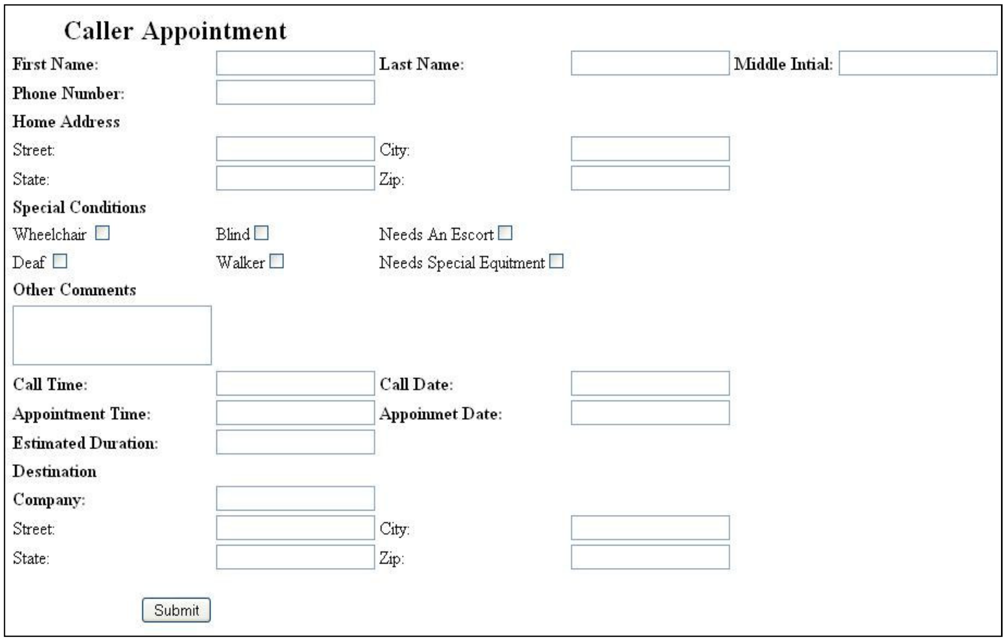


Client Information

First Name:
Last Name:
Sex Male Female
Age
Telephone Number
Home Address
Street
City
State
Emergency Contact 1
Telephone Number
First Name
Last Name
Relationship
Emergency Contact 2
Telephone Number
First Name
Last Name
Relationship
Special Conditions
Wheelchair Blind Needs An Escort
Deaf Walker Needs Special Equitment
Other Comments
Destination
Existing Destination
New Destination
Street
City
State
Driver
Name
Van# Assign
Submit

FIGURE 5: Client-Form

Figure 6 records appointment calls received by the dispatcher. Information required includes destination and time of the appointment. The Appointment-Form also includes comments about the nature of the trip such as wheel chair requirement or door-to-door assistance requirements. This informs the driver ahead of time of the client needs.



Caller Appointment

First Name: Last Name: Middle Intial:

Phone Number:

Home Address

Street: City:

State: Zip:

Special Conditions

Wheelchair Blind Needs An Escort

Deaf Walker Needs Special Equitment

Other Comments

Call Time: Call Date:

Appointment Time: Appoinmet Date:

Estimated Duration:

Destination

Company:

Street: City:

State: Zip:

Submit

FIGURE 6: Appointment-Form

The Driver-Form in Figure 7 contains the information about the drivers such as their name, vehicle, and schedule. This is critical for the dispatcher to determine which drivers are available at any given time to pick up passengers.

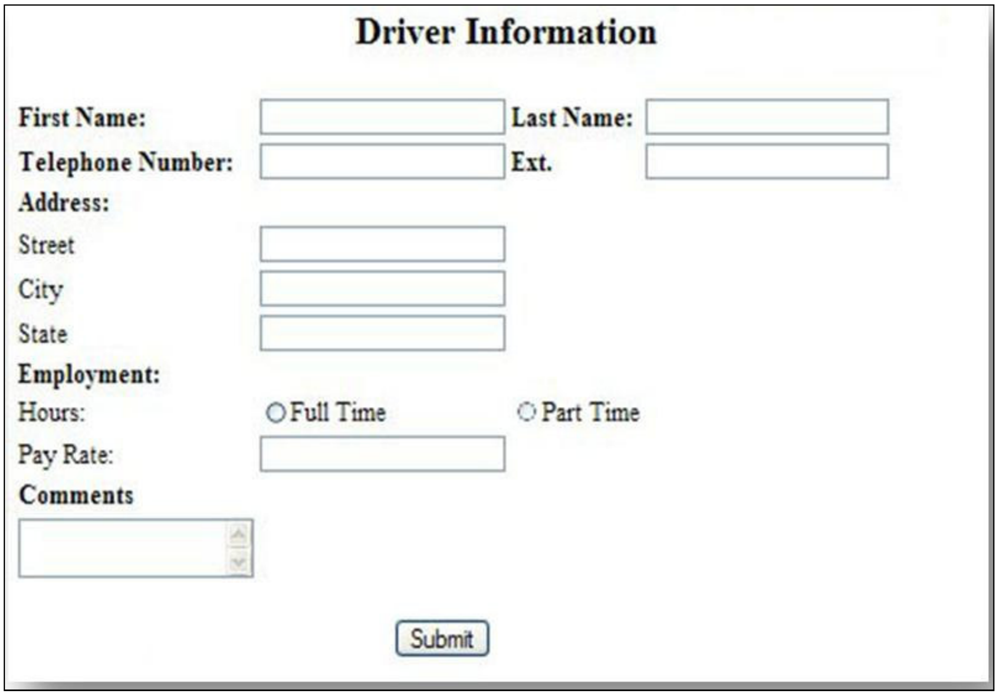
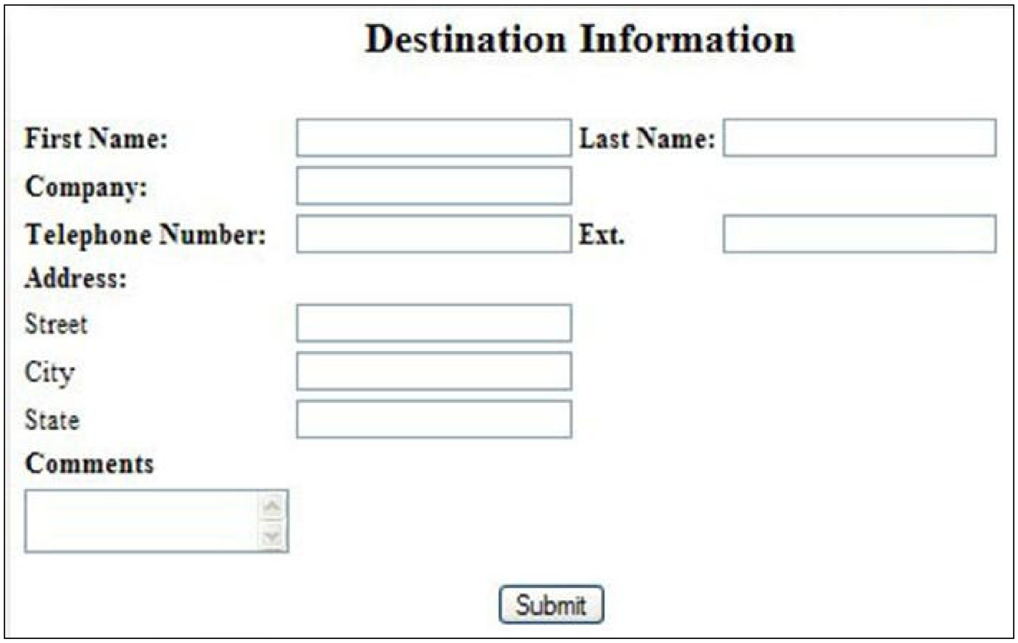


FIGURE 7: Driver-Form

The Destination-Form as shown in Figure 8 marks frequently used destination sites. It associates hotspot names to these addresses, natural to drivers' language of locations.



Destination Information

First Name: **Last Name:**
Company:
Telephone Number: **Ext.**
Address:
Street
City
State
Comments

Submit

FIGURE 8: Destination-Form

Introducing the forms and a secure database system enabled the transportation provider personnel to have data readily accessible, secure, and comprehendible. Also, viewing data on the web facilitates filtering and search mechanisms to get relevant data being targeted. This saves time, improves operations and enables planning. For instance, and as has been mentioned, one of the NBCA's pricing policies is that elderly passengers that are 90 years old do not get charged. It is easier to generate this particular charge for each appointment automatically when using a centralized database. This leads to robustness of the system which is one of the powerful features of having data centralized.

RESULTS, BENEFITS & CONCLUSIONS

By carefully choosing two applications from among the many mobility management tools available, operations were improved for three small transportation providers in the local community: the New Bedford Council of Aging (NBCA), Community Care–A–Vans (CCAV) and the DartVan, a university campus transportation provider to students. This study demonstrates an economical deployment of GPS phone technology and software that enables real-time fleet tracking of vehicles. The project also demonstrates that with proper design, an increase in efficiency of scheduling and dispatching can occur. Finally, centralization of the database generates reliable reports for these providers.

The system, demonstrated to all three transportation providers, included a GPS cell phone installed in vehicles and a website display of real-time tracking on a map viewable via internet accessible computers. Providers were able to login, view the map, enter the forms, and generate reports of the archived data such as time-of-day, vehicle location, vehicle speed and geozone. On the map, they were also able to easily identify their vehicles, speed, mileage, and landmarks. Search engines and filtering to generate the reports was also demonstrated. As a result of this project, the three transportation providers found the functionality of the system satisfactory.

The observed benefits of the mobility management tools for each of the three small transportation providers vary somewhat. With the deployment of real-time tracking, this project facilitates *smart-pickups* where dispatchers alert drivers of new sensible pickup locations while in-route, or add pickups that are a short time/distance away. This is a benefit for both the NBCA and the CCAV providers. The display of the vehicle's location is clearly visible on the computer monitor, easy to read and displays information that aids in navigation such as the street names. In this project, googlemaps was utilized as the underpinning mapping interface.

In addition, both providers find that real-time fleet tracking has also demystified riders' complaints concerning vehicles who fail to appear (no-shows) or pickups designated as late by the customer. The software keeps a detailed chronicle or track record in the computer of the vehicles' locations, speeds and times of day. Also, when there are unavoidable delays, seniors can be notified via a phone call and given an accurate pickup time. Because the vehicles' locations are known, more precise estimation of delays in pickup can be approximated. Real-time tracking of vehicles also adds an element of safety, for both operators and riders. If an accident were to occur, the vehicle's exact location would be known and emergency services could be informed immediately.

The DartVan's and the CCAV's set routes have additional benefits which included an increased efficiency. For instance, when a particular pickup point suddenly has extra clients, more than expected, and larger than the capacity of a single vehicle, dispatchers may divert a nearby van to pick up the remaining passengers. Furthermore, the pickup schedule can now be calibrated using route history to increase the accuracy of the estimated time of arrival for the route. Monitoring the vans in-route will also help increase the quality of the ridership as drivers can be held accountable for any off route detours or other delays.

There are several improvements to operations of the DartVan that are now realizable and that are important to customers as well as to the campus police. Vans can now work on schedule more reliably so that students know when to expect them. Student drivers no longer leave the campus area or stop at one spot for long periods of time without the fleet tracking system alerting the campus police.

During operations of the DartVan vehicles, police on campus were able to use geozones to detect times when the vans inappropriately left the university campus grounds. They were also able to use the reports to detect speeds in excess of 25 mph, the on-campus speed limit. This was important to them because the police are also in charge of public safety. The Driver-Forms were the most beneficial to the DartVan, allowing the police to monitor student-driver performance real-time.

Both the NBCA and CCAV are now able to synchronize data more effectively among personnel. For example, at the NBCA, one staff member schedules vehicle trips to medical appointments, while another staff member schedules vehicle personal-trips, such as grocery shopping. Each of them maintains their Excel files when receiving requests.

Overlapping shifts of staff members cause confusion. As a result of centralizing the data management and capability process, with one appointment form for each targeted object, the data conflicts were reduced. Each staff member can now schedule trips of all types. They can receive calls, record data into the database, all in the same manner. The CCAV, on the other hand, had established forms on their website to accept requests for pickups. The request went through the email to be analyzed. If the request was feasible, then it was accepted by the dispatcher. They had shared folders across CCAV location sites. But this was not efficient and not very secure. The CCAV was able to utilize the new system to speed up this process using a centralized database.

Additional functionality was achieved for all the small transportation providers, but the most beneficial of all, is staffs' ability to search or filter the growing database for information pertaining to a specific trip or client. Furthermore, reports are easily constructed. Archived data and search engine tools facilitate daily, weekly, monthly or yearly reports. This additional capability will enhance the proposal writing process for future funding of these agencies.

Expanding the capability in data management and real-time fleet tracking brought an increase in capacity to the transportation services of these smaller non-profit providers. The elderly, disabled, unemployed, and students in the southeastern Massachusetts region were able to receive more effective transportation services. This project demonstrates that mobility management tools do not have to be expensive and thus are economical for smaller transportation providers.

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