Globis Data Inc.

TP 14359E

Development and Demonstration of a System for Using Cell Phones as Traffic Probes

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Transportation Development Centre
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Transport Canada

by
Globis Data Inc.

February 2005

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Development and Demonstration of a System for Using Cell Phones as Traffic Probes

by
Barrie Kirk, P.Eng.
Keith Fagan, P.Eng
Roland Renner

February 2005

This report reflects the views of the authors and not necessarily those of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or suppliers' names appear in this report only because they are essential to its objectives.

This project is part of Canada's Intelligent Transportation Systems (ITS) R&D Plan, *Innovation Through Partnership*, funded by the ITS Office of Transport Canada under the Strategic Highway Infrastructure Program (SHIP).

The Transportation Development Centre of Transport Canada served as technical authority for this project.

Project Team

Globis Data Inc.	Barrie Kirk Keith Fagan Roland Renner
Bell Mobility	Adrian Vella Alex Wong Eric Corbeil
MIxpertS	Brian Watson
Profilium	Jay Gould Alex Miller Jimmy Hsu
University of Waterloo	Bruce Hellinga

Drivers for the tests and demonstrations:
Gordon Abry, Charles Berndt, Alexandra Dafoe, Catherine Dafoe, Michele Dathan, Olive Fagan, Frank Greene, Michelle Hupé, Carrie Kennedy, Melissa McNulty, Shauna Mullally, Mark Norris, and Globis Data team members.

Un sommaire français se trouve avant la table des matières.

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16. Abstract

The objective of the study was to determine the technical feasibility of using cell phones equipped with Assisted Global Positioning System (A-GPS) chipsets as traffic probes to measure the speed of traffic. A prototype system was developed and evaluated in Ottawa in the summer of 2004. The test program included positional accuracy, accuracy of the raw speed data, and accuracy of the traffic data on arterial roads and highways. The testing on the extended Highway 417 segment was very successful. Results indicated that significantly more sophistication must be built into the algorithms for arterial roads.

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16. Résumé

L'objectif de l'étude était de déterminer la faisabilité technique d'utiliser des téléphones cellulaires munis de puces A-GPS (système de positionnement global assisté) pour mesurer les débits de circulation. Un système prototype a été développé et évalué à Ottawa, au cours de l'été 2004. L'essai consistait à vérifier la précision des données de localisation, des vitesses brutes, et de l'information routière concernant de grandes artères urbaines et des autoroutes. Les essais menés sur le tronçon étendu de la route 417 ont donné d'excellents résultats. Les chercheurs ont en outre conclu à la nécessité d'élaborer des algorithmes beaucoup plus complexes pour les artères urbaines.

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- The Steering Committee formed by Transport Canada for this project: Madeleine Betts (Transport Canada), Roger Browne and Henry Wong (both with the Ministry of Transportation of Ontario), and Anne Pelletier and Michel Drouin (Transports Québec)

- All the members of the project team: Adrian Vella, Alex Wong, Eric Corbeil (all with Bell Mobility); Brian Watson (MIxpertS); Jay Gould, Alex Miller, Jimmy Hsu (Profilium); and Bruce Hellinga (the University of Waterloo)

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EXECUTIVE SUMMARY

Introduction

In response to a request for proposals from Transport Canada under the Intelligent Transportation Systems (ITS) Research and Development Plan, Globis Data Inc. and its team consisting of Bell Mobility, Profilium, the University of Waterloo, and MIxpertS Inc. proposed a project to develop, deploy and test a prototype system for the use of cell phones as traffic probes. This is the final report for that project.

The project is innovative because it leverages the capability to accurately determine the position of modern cell phones working with the Bell Mobility network. All cell phones currently sold by Bell Mobility have a built-in Global Positioning System (GPS) chipset that can, when augmented by the Bell Mobility network, determine their position to a relatively high degree of accuracy.

Project Overview

Globis Data is a start-up company that is focused on the currently under-addressed market of local drivers who wish to have advance notification of any impairment to their movement around the city, thereby allowing them to choose a route that will be more efficient at a specific time of day. These users are interested in the current speed of traffic along major routes, any congestion due to traffic volume, accidents or planned outages that might impair progress, weather conditions, etc.

Traffic congestion in major cities is steadily worsening, and there is strong interest by users in receiving more detailed real-time traffic information. To be able to satisfy this requirement, traffic information must be complete, accurate and timely. In addition, the information must be presented in a fashion that is readily available and can be safely delivered.

To meet this need, Globis Data is developing its D.R.I.V.E.S.™ service. Phase 1 versions of D.R.I.V.E.S. have been launched in Toronto and Montreal. There are two key factors underlying this project:

- Although the current level of traffic information from the Ministry of Transportation of Ontario, the ministère des Transports du Québec, and the City of Toronto is very useful, it is insufficient for a commercial service.

- Substantial expansion of government-owned traffic sensor networks is not feasible because governments simply do not have the resources to significantly expand their road sensor networks.

The solution is to find a technology that will allow traffic information to be gathered accurately and inexpensively. Many alternatives exist and Globis Data has examined a range of options for generating additional traffic data. Cell phones were determined to be the best option because there are a large number in use, they are a low-cost approach because they leverage the existing wireless infrastructure, and they are easily scalable and transportable to any market.

Literature Survey

A literature review was conducted to determine what relevant and useful information already exists. The survey included a broad literature search on the subject of cell phones as traffic probes, inputs from Globis Data's own files, and the *ITS Orange Book on Predictive Travel Time,* prepared by a team of sponsors that includes the ATLANTIC Project and ITS America.

Six projects were identified that use cell phones as traffic probes, all of which use network-based technologies:

- Cell-Loc of Calgary
- Applied Generics of Scotland
- Decell Technologies Ltd. of Israel
- U.S. Department of Transportation and Virginia Department of Transportation
- SFR, ASF and INRETS of Europe
- State of Maryland / Delcan / ITIS

No projects or studies were found that use A-GPS-enabled cell phones. The conclusion was that the current project appears to be very much on the leading edge of the technology. No information was identified that would help guide this project.

System Design

The system comprised the D.R.I.V.E.S. Ottawa server that hosted four custom-developed software applications. The interface to Bell Mobility's Location Based Services (LBS) platform used a Virtual Private Network operating over the public Internet.

The traffic between the Ottawa server and Bell Mobility's LBS platform, i.e., the requests for locations and the associated responses, used the Mobile Location Protocol, an industry standard developed by the Location Interoperability Forum.

The system determines the speed of traffic by polling ("pinging") each cell phone to determine its location, determining the distance travelled since the previous ping and the elapsed time, and then calculating speed based on distance/time. The actual speeds are then converted to one of three congestion values, which are displayed as colour-coded zones on a real-time traffic map:

- "Normal" = green = speed is greater than 80% of the posted speed limit
- "Somewhat slow" = yellow = speed is 40-80% of the posted speed limit
- "Very slow or stopped" = red = speed is less than 40% of the posted speed limit

Testing Methodology and Results

The initial testing program consisted of a series of tests with various numbers of cell phones being driven around the test route under different traffic conditions. Drivers and observers reported the observed traffic speed and made odometer and time reports that subsequently provided a calculated speed. The observed speeds and the calculated speeds were then compared to the map colour for each segment. The comparison was made with a 1 minute delay to account for latency in the system.

The cell phones appeared on the map in their expected positions according to driver reports. Also, the cell phones populated the map reliably. The overall comparison of actual map colours with the observed and calculated values, however, was disappointing in some respects, although there appeared to be explanations for some of the results. This led to a decision to perform additional tests on each stage of the process and to repeat the map colour performance for an extended highway section.

The additional testing program measured the accuracy of the prototype system in three ways:

1. The positional accuracy of the data from the LBS platform, i.e., the latitude and longitude data.

2. The accuracy of the raw speed data from the software.

3. The accuracy of the D.R.I.V.E.S. Ottawa real-time traffic map on highways.

The results show that each component of the D.R.I.V.E.S. software was verified in the testing: the accuracy of the location data from Bell Mobility, the calculation of traffic speed, and the transfer of this information to a map in three colour codes.

The additional testing on the extended Highway 417 segment was very successful. The analysis of the results of the initial testing identified a number of changes to the initial algorithms and the need for rigorous observation. Observations and calculations must be made consistently and accurately in order to complete testing successfully. Small measurement errors can have a large impact on the analysis with small zones.

The testing also confirms that significantly more sophistication must be built into the algorithms for arterial roads as well as a conceptual review. For example, should a D.R.I.V.E.S. map report vehicles as stopped because they are actually stopped at a traffic light? Or, alternatively, should the software average these results with the previous and subsequent yellow and green results to calculate an average speed, based on the rationale that the red time is part of the normal flow of traffic on the arterial road? Even more fundamentally, what is a “normal speed” on an arterial road with traffic lights? The current generation of the software defines normal as over 80% of the posted speed limit. For an arterial road with traffic lights, perhaps the threshold should be lower, say 50%.

Recommendations

The following recommendations are made:

1. That Globis Data, with key stakeholders in the transportation community, proceed with the development of the next generation system for the use of A-GPS-enabled cell phones as traffic probes.

2. That Globis and these stakeholders develop and review a list of possible follow-on projects. These could include a pilot system at a border crossing in southern Ontario, a large-scale deployment in Toronto, and other deployments.

3. That transportation management agencies evaluate the cost and operational issues related to the use of traffic data from cell phones.

SOMMAIRE

Introduction

En réponse à une demande de propositions lancée par Transports Canada en marge du Plan de recherche et de développement sur les systèmes de transports intelligents (STI), Globis Data Inc. et son équipe, constituée de Bell Mobilité, Profilium, l'Université de Waterloo et MIxpertS Inc., ont proposé un projet qui consistait à développer, déployer et essayer un système prototype permettant d'utiliser des téléphones cellulaires en tant que sondes pour surveiller les débits de circulation. Le présent document est le rapport final de ce projet.

Le projet est novateur, car il met à profit la capacité de positionner avec précision les téléphones cellulaires d'avant-garde reliés au réseau Bell Mobilité. En effet, chaque téléphone cellulaire actuellement vendu par Bell Mobilité possède une puce GPS intégrée qui lui permet, lorsque informée par le réseau Bell Mobilité, de connaître sa position avec un degré de précision relativement élevé.

Aperçu du projet

Globis Data est une jeune entreprise qui s'intéresse au créneau encore sous-exploité des conducteurs urbains, qui aimeraient être informés à l'avance des ralentissements susceptibles d'entraver leurs déplacements, afin d'opter pour l'itinéraire optimal à un moment précis. Ces utilisateurs veulent être informés de la vitesse des véhicules sur les grandes voies de circulation, des congestions routières dues à l'affluence de véhicules, à des accidents ou à des fermetures de routes susceptibles de ralentir leurs déplacements, des conditions météorologiques, etc.

La congestion routière est un fléau grandissant dans les grandes villes et les automobilistes valorisent au plus haut point l'accès à des données détaillées et en temps réel sur l'état de la circulation. D'où la nécessité d'une information routière complète, précise et à jour, et présentée sous une forme conviviale qui ne compromet pas la sécurité.

C'est pour répondre à ce besoin que Globis Data a entrepris le développement de son service D.R.I.V.E.S.MD. La version initiale de D.R.I.V.E.S. a été déployée à Toronto et à Montréal. Deux facteurs clés sont à l'origine du projet :

- Bien que l'information routière actuellement offerte par le Ministry of Transportation of Ontario, le ministère des Transports du Québec, et par la Ville de Toronto soit très utile, elle est insuffisante pour un service commercial.

- Il n'est pas possible d'étendre de façon substantielle les réseaux publics de surveillance routière, car les gouvernements n'ont simplement pas les ressources pour ce faire.

La solution est donc de trouver une technologie pour recueillir l'information routière. Plusieurs options existent. Après en avoir examiné quelques-unes, Globis Data est arrivée à la conclusion que les téléphones cellulaires constituaient la meilleure option, du fait de leur utilisation généralisée, du faible coût de l'approche – ils utilisent une infrastructure sans fil existante –, de leur caractère évolutif et de leur adaptabilité à n'importe quel marché.

Recherche documentaire

Une recherche documentaire a permis de faire le point sur l'information pertinente et utile qui existe sur le sujet. Elle a porté sur les articles traitant des téléphones cellulaires en tant que sondes de surveillance de la circulation, sur les propres dossiers de Globis Data, et sur le *Livre orange sur le temps de parcours prévisionnel*, dont l'élaboration a été parrainée par une équipe de spécialistes recrutés entre autres dans le réseau ATLANTIC et chez ITS America.

Cette recherche a permis de recenser six projets portant sur des téléphones cellulaires en tant que sondes de surveillance de la circulation, lesquels utilisent tous des technologies axées réseau :

- Cell-Loc, à Calgary
- Applied Generics, en Écosse
- Decell Technologies Ltd., en Israël
- Le U.S. Department of Transportation et le Virginia Department of Transportation
- SFR, ASF et INRETS en Europe
- État du Maryland / Delcan / ITIS

Aucun des projets ou études recensés n'utilisait des téléphones cellulaires à technologie A-GPS. Conclusion, le projet actuel se trouve à la fine pointe de la technologie. De plus, aucune information n'a été trouvée qui aurait pu être utile pour le présent projet.

Description du système

Le système s'articulait autour du serveur D.R.I.V.E.S. d'Ottawa, qui hébergeait quatre applications personnalisées. L'interface avec la plate-forme des services de géolocaliation (LBS, *location based services*) de Bell Mobilité était assurée par un réseau privé virtuel sur Internet.

Les communications entre le serveur d'Ottawa et la plate-forme LBS de Bell Mobilité, c.-à-d. les demandes de localisation et les réponses, étaient gérées par le Protocole de localisation des postes mobiles, une norme industrielle élaborée par le Forum d'interopérabilité de localisation (LIF, *Location Interoperability Forum*).

Pour établir l'état de la circulation, le système capte les impulsions de chaque téléphone cellulaire, puis détermine la distance parcourue depuis la dernière impulsion et le temps écoulé; il suffit ensuite de calculer la vitesse en divisant la distance par le temps. Les vitesses ainsi obtenues sont converties en «valeurs de congestion», qui s'affichent selon des codes de couleur sur une carte de la circulation en temps réel. Voici la signification de ces codes :

- «mouvement de la circulation régulier» = vert = vitesse supérieure à 80 % de la limite de vitesse permise
- «mouvement au ralenti» = jaune = vitesse égale à 40-80 % de la limite de vitesse permise
- «circulation très ralentie ou interrompue» = rouge = vitesse inférieure à 40 % de la limite de vitesse permise

Méthode d'essai et résultats

Les premiers essais mettaient en jeu des téléphones cellulaires (en nombres plus ou moins grands) circulant sur un parcours donné dans différentes conditions de circulation. Les conducteurs et les observateurs rendaient compte des vitesses observées et consignaient les données de l'odomètre et les temps de parcours, qui servaient ensuite à calculer la vitesse. Les vitesses observées et calculées étaient alors comparées aux couleurs des tronçons représentés sur le plan de la ville. Les comparaisons se faisaient avec une minute de retard, à cause de la latence du système.

Les téléphones cellulaires figuraient sur le plan à leur position prévue, d'après les comptes rendus des conducteurs. De plus, ils se répartissaient de façon fiable sur le plan. Toutefois, les comparaisons des couleurs affichées avec les valeurs observées et calculées ont été décevantes à certains égards, même si ces résultats s'expliquent en partie. Il a donc été décidé de soumettre chaque étape du processus à de nouveaux essais et de reprendre les comparaisons entre les couleurs affichées et les vitesses réelles pour un tronçon étendu d'une autoroute.

Le programme d'essais complémentaires a consisté à mesurer la précision du système prototype à trois égards :

1. La précision des données de localisation transmises par la plate-forme LBS, c.-à-d. la latitude et la longitude.

2. La précision des données de vitesse brute transmises par le logiciel.

3. La précision de l'information en temps réel affichée par le réseau D.R.I.V.E.S. d'Ottawa.

Le bon fonctionnement de chaque composante du logiciel D.R.I.V.E.S. a été vérifié : précision des données de localisation de Bell Mobilité, calcul de la vitesse des véhicules, et transfert de cette information sur un plan, selon trois codes de couleur.

Les essais complémentaires menés sur le tronçon étendu de la route 417 ont été couronnés de succès. L'analyse des résultats des premiers essais a révélé la nécessité de certaines modifications aux algorithmes initiaux et d'une observation plus rigoureuse. Pour que les essais soient valables, il est important que les observations et les calculs soient uniformes et exacts. En effet, de petites erreurs de mesure peuvent avoir d'immenses conséquences lorsque l'analyse porte sur des zones restreintes.

Les essais ont aussi confirmé la nécessité d'algorithmes beaucoup plus complexes pour les grandes artères urbaines, de même que le besoin d'une revue conceptuelle. Par exemple, la carte D.R.I.V.E.S. doit-elle considérer que des véhicules sont immobilisés du simple fait qu'ils sont arrêtés à un feu rouge? Autre possibilité, le logiciel doit-il additionner ces résultats aux résultats «jaunes» et «verts» précédents et subséquents pour établir une vitesse moyenne, en admettant que le temps d'arrêt au feu rouge doit être inclus dans le calcul du débit normal sur l'artère? Encore plus important, qu'est-ce qu'une «vitesse normale» sur une artère urbaine comportant des feux de circulation? La version actuelle du logiciel définit comme «normale» une vitesse supérieure à 80 % de la vitesse permise. Pour une artère urbaine à carrefours signalisés, ce seuil pourrait être abaissé, disons à 50 %.

Recommandations

Les chercheurs ont formulé les recommandations suivantes :

1. Que Globis Data s'allie à des intervenants clés du milieu des transports pour développer une nouvelle génération du système qui permettra d'utiliser les téléphones cellulaires à puce A-GPS intégrée en tant que sondes pour surveiller la circulation.

2. Que Globis et ces intervenants développent et revoient une liste de projets subséquents possibles. On peut penser au déploiement d'un système pilote à un poste frontière du sud de l'Ontario et à un déploiement à grande échelle à Toronto, entre autres.

3. Que les organismes de gestion des transports évaluent les coûts et les enjeux opérationnels reliés à l'utilisation de données de circulation recueillies à l'aide de téléphones cellulaires.

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GLOSSARY

A-GPS	Assisted GPS
ATLANTIC	**A** **T**hematic **L**ong-term **A**pproach to **N**etworking for the **T**elematics and **I**TS **C**ommunity
E-911	Enhanced 911
DAB	Digital Audio Broadcasting
FCC	Federal Communications Commission (U.S.)
FHWA	Federal Highway Administration (U.S.)
GPS	Global Positioning System
GSM	Global System for Mobile Communication
ITS	Intelligent Transportation Systems
IVR	Interactive Voice Response
LBS	Location Based Services
LIF	Location Interoperability Forum
MLP	Mobile Location Protocol
NRCan	Natural Resources Canada
PTT	Predictive Travel Time
SMS	Short Message Service
TDOA	Time Difference of Arrival
VPN	Virtual Private Network
XML	Extensible Markup Language

1 INTRODUCTION

1.1 General

In response to a request for proposals from Transport Canada under the Intelligent Transportation Systems (ITS) Research and Development Plan, Globis Data Inc. and its team consisting of Bell Mobility, Profilium, the University of Waterloo, and MIxpertS Inc. proposed a project to develop, deploy and test a prototype system for the use of cell phones as traffic probes. This is the final report for that project.

The project is innovative because it leverages the capability to accurately determine the position of modern cell phones working with the Bell Mobility network. All cell phones currently sold by Bell Mobility have a built-in Global Positioning System (GPS) chipset that can, when augmented by the Bell Mobility network, determine their position to a relatively high degree of accuracy.

1.2 Report Overview

Following this Introduction, the report comprises five chapters and two Appendices:

- **Project Overview** describes the background to the project, the objectives and scope, the project team and the work plan.

- **Literature Survey** reports on a survey of relevant literature and related projects.

- **System Design and Deployment** describes the overall system architecture, the hardware elements, the software and algorithms, and some of the issues that arose during the design phase.

- **Results** addresses the testing methodology, the results, the analysis of those results, and conclusions.

- Finally, there are the project's **Conclusions and Recommendations**.

- Appendix A is a **Profile of Globis Data Inc**.

2 PROJECT OVERVIEW

2.1 Background to the Project

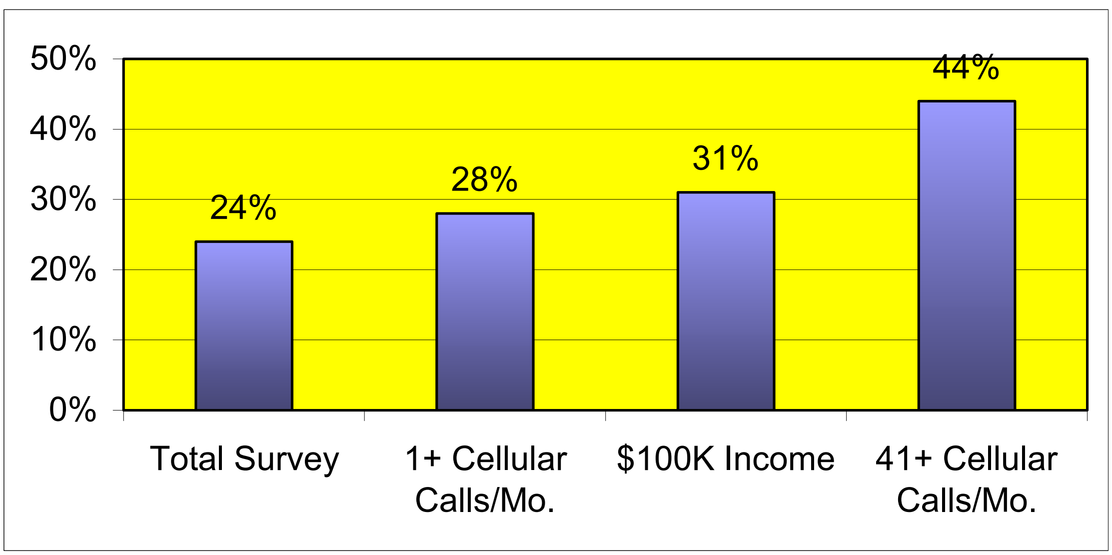
Globis Data is a start-up company that is focused on the currently under-addressed market of local drivers who wish to have advance notification of any impairment to their movement around the city, thereby allowing them to choose a route that will be more efficient at a specific time of day. These users are interested in the current speed of traffic along major routes, any congestion due to traffic volume, accidents or planned outages that might impair progress, weather conditions, etc.

Traffic congestion in major cities is getting worse, and there is strong interest by users in receiving more detailed real-time traffic information.

In a U.S. survey conducted by Driscoll-Wolfe, 28% of respondents making one or more cell-phone calls per month said they would be willing to pay US$4.95 a month for a location-based traffic information service [1].

Figure 2-1: Results of Market Research

"Would you be willing to pay $4.95 a month for a location-based traffic information service?"



In addition:

- Research by Microsoft indicates that three out of five consumers want real-time traffic updates.
- Canadian market research shows a similar high level of interest in better real-time traffic information.

- Discussions between Globis Data and government transportation agencies in Canada also indicate that there is interest in broadening the geographic scope of existing traffic monitoring infrastructures at a lower cost for the data than the existing fixed loop method. These agencies are interested in the potential use of cell phones as traffic probes.

To be able to satisfy all these requirements, traffic information must be complete, accurate and timely. In addition, the information must be presented in a fashion that is readily available and can be safely delivered.

To meet this need, Globis Data is developing its D.R.I.V.E.S.™ service. Phase 1 versions of D.R.I.V.E.S. have been launched in Toronto and Montreal:

- D.R.I.V.E.S. Toronto (www.drives.toronto.ca) is supported by the Ministry of Transportation of Ontario (MTO) and the City of Toronto, both of which are providing traffic data at no charge for the Phase 1 service.

- D.R.I.V.E.S. Montreal (www.drives.montreal.ca) was deployed with partial funding from Transport Canada under the *Intelligent Transportation Systems Deployment and Integration Plan*. The project is also supported by the ministère des Transports du Québec (MTQ), which is currently also providing traffic data at no charge.

- Both the Toronto and Montreal D.R.I.V.E.S. services are currently provided to the public at no charge.

- Screen shots of both services are contained in Appendix A.

One critical element is the amount of traffic data available to the user. There are two key factors underlying this project:

1. Although the current level of traffic information from MTO, MTQ and the City of Toronto is very useful, it is insufficient for a commercial service.

2. Substantial expansion of government-owned traffic sensor networks is not feasible because governments simply do not have the resources to significantly expand their road sensor networks.

The solution is to find a technology that will allow traffic information to be gathered accurately and inexpensively. Many alternatives exist and Globis Data has examined a range of options for generating additional traffic data, including fixed probes such as loops and microwave, and floating probes such as dedicated GPS devices, taxi dispatch systems, bus fleet monitoring systems, toll transponder tags, 802.11b technology, network-based cell-phone systems, and a cell-phone system that uses handsets equipped with Qualcomm's Assisted Global Positioning System™ (A-GPS).

The fixed-probe options are expensive (from both a capital and operating perspective) and have the significant disadvantage of requiring access to the right of way. Obtaining access to a right of way for installation and maintenance is generally difficult and there are important restrictions that would affect the quality of a D.R.I.V.E.S. service. Traffic probes based on bus and taxi monitoring have a key weakness in that taxis and buses often use separate lanes from regular traffic. A system based on toll transponder tags, such as those on Highway 407 around Toronto, would involve proprietary technology that would not be easily transportable to other markets.

A closer look at the use of cell phones as traffic probes included an examination of both network-based and handset-based location methods; these are described in Section 2.2.3.

2.2 GPS, A-GPS, and Cell-Phone Location Methods

To fully understand the cell-phones-as-traffic-probes project, a basic knowledge of three key background topics is required:

- GPS
- A-GPS
- Network- and handset-based location methods

The requirement to determine cell-phone locations originated with the U.S. Federal Communications Commission (FCC), which mandated that commercial wireless carriers be able to locate cell phones when a user dials 911. This capability, known as Enhanced-911 or simply E-911, has triggered a large amount of research and development (R&D) into various methodologies that would meet the FCC's stringent location accuracy. This R&D has also branched out into non-emergency commercial services that can leverage this capability.

Industry Canada has not mandated the use of E-911 in the wireless networks, but Canadian wireless carriers are aware of the probable future requirement to implement E-911 in Canada, and they are also aware of the emerging opportunity for commercial Location Based Services (LBS). Bell Mobility is currently the only Canadian carrier to have implemented LBS in Canada.

2.2.1 GPS

The Global Positioning System (GPS) is a worldwide, satellite-based positioning system that was developed by the U.S. military. GPS units receive signals from several satellites in the constellation of GPS satellites. These signals contain highly accurate timing information that allows the receiver to calculate its latitude and longitude with precision.

A wide range of military, commercial and consumer GPS products are available.

2.2.2 Assisted GPS

The implementation of A-GPS differs from regular GPS in two fundamental ways:

1. The calculation of the position based on the information received from the satellites is done not in the handset but in the network at a dedicated location.

2. A-GPS technology (such as Qualcomm's, which is used by Bell Mobility) uses an embedded chipset in each handset and a location server (which can be located anywhere in the network) to help the GPS receiver find weak GPS signals. This results in significant improvements in availability, sensitivity, and position fix times. This also enables A-GPS handsets to operate in indoor or blocked environments at signal levels not detectable by conventional GPS receivers [2].

This A-GPS approach can be used in all of today's cellular solutions: 800/900 MHz, 1800/1900 MHz, CDMA, WCDMA, TDMA, PDC/PHS, GSM/GPRS and IDEN.

The following steps illustrate how the location server obtains a position from a handset:

- A 911 call centre or commercial user starts the process by requesting that the location server provide the location of a handset.

- The location server makes a rough determination of the handset location, usually identifying the cell the phone is in. The server sends a message to the handset that includes:
    - A request that the handset provide the basic information from the GPS satellites; this will allow the server to determine the handset's latitude and longitude.
    - Key information on which GPS satellites should be used to provide the best location accuracy.

- The handset reads the data from the selected GPS satellites and sends this data to the requesting server.

- Software within the server applies sophisticated error-correcting routines to the data, merges it with network data, and calculates the latitude and longitude of the handset.

- This information is sent either to a third party for further processing, to a 911 call centre, or back to the user for display on the handset.

The advantage of this A-GPS approach is that a “fix” can be made very rapidly (in the order of seconds instead of the normal GPS fix that can take minutes). In addition, the enhanced sensitivity of A-GPS means that the system is more robust and a fix can be made where traditional GPS signals could fail, e.g., in urban canyons, indoors, or where there are a limited number of signals from GPS satellites.

2.2.3 Network-based and Handset-based Location Methods

There are two primary methods for establishing the location of a cell phone: network-based and handset-based.

1. **Network-based** methods use one of several types of network triangulation and/or trilateration. The advantage is that these methods use standard, non-GPS handsets. However, there are three major disadvantages of network-based systems:
   a. They are relatively inaccurate.
   b. Additional hardware and/or software is generally required at the cell towers, and this extra equipment is expensive.
   c. Because of the above two reasons, wireless carriers are generally moving toward handset-based solutions, which makes this approach more expensive and therefore less attractive for non-carriers such as Globis Data.

2. **Handset-based** methods use GPS receivers in the handset to determine the position of the handset. This approach is far more accurate than network-based approaches and no additional equipment is required at the cell towers. In addition, wireless carriers are implementing this approach, which provides an opportunity to leverage existing investments. There are two sub-categories:
   a. GPS, in which the handset has the processing capability to determine its own latitude and longitude.
   b. A-GPS, in which a location server helps the GPS receiver find the signal and process the data.

2.2.4 Conclusions

It was concluded that A-GPS is the best option for D.R.I.V.E.S. for the following reasons:

- A-GPS solutions are considerably more accurate and cost significantly less than those using network-based technologies.

- A-GPS solutions are more robust and more accurate than standard GPS systems.

- There are a large number of A-GPS cell phones in use in Canada; as of November 2004, an estimated 1.6 Million Bell Mobility customers use A-GPS-enabled cell phones.

- It is a low-cost approach because it leverages the existing wireless infrastructure and investment.

- The solution is easily scalable and transportable to any market.

2.3 Project Objective and Scope

The purpose of this project was to develop, deploy and test a prototype system for the use of A-GPS-enabled cell phones as traffic probes.

The scope of the project is defined by the following:

- The prototype system used up to 14 cell phones circling both ways around a 15 km loop covering the west end of Ottawa, Ontario, and Gatineau, Quebec.

- The project demonstrated the ability to accurately determine the position of cell phones via the wireless carrier's network.

- The project also demonstrated the ability to process the position data, derive traffic speed information, and display traffic conditions on a real-time map on a web site.

- Because this project was a feasibility trial, a basic set of algorithms was used, with the expectation that the project would help define the more sophisticated algorithms that would be needed in a commercial implementation.

Within the system developed for the project, the project computer polled ("pinged") the Bell Mobility LBS server to obtain cell-phone position information. Custom-developed software then geofenced the position data to the specific routes of interest, converted this data into traffic speed vector, and displayed the resulting traffic map on a private page on Globis Data's web site.

Although not part of the project, an add-on component was included: the delivery of traffic information via Interactive Voice Response (IVR). This component was self-financed by Globis Data and its partner Vocantas Inc.

2.4 Project Team

To accomplish the above, Globis Data assembled a team that included three other companies and a university:

- **Bell Mobility** provides a complete range of innovative wireless communications solutions including voice, data, e-mail, and web browsing. Bell has deployed an LBS platform to support the development and marketing of a range of LBS services such as MyFinder.[1] For this project, Bell Mobility provided access to its LBS platform, technical support to assist with integrating the project computer to the LBS platform, and the cell phones.

- **MIxpertS** has developed much of the software for D.R.I.V.E.S. Toronto and Ottawa. For this project, it developed the software that implements the algorithms and creates the D.R.I.V.E.S. Ottawa traffic map.

- **Profilium** is a leading provider of wireless infrastructure solutions that bridge mobile communications and LBS. It developed and supplied the software to request the cell-phone location data from Bell Mobility's LBS platform.

- **Dr. Bruce Hellinga** of the **University of Waterloo** has conducted advanced research and provided technical support in the areas of traffic data analysis and statistical hypothesis testing. His role was to develop the algorithms that define the way that cell-phone location data is converted to traffic speed.

2.5 Work Plan

The project work plan is shown in Table 2-1.

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[1] MyFinder finds the location of the user's mobile device (with their consent) within Bell Mobility's coverage area and allows the user to look up information for services such as restaurants, gas stations, hotels, hospitals, banks or theatres.

Table 2-1: Project Work Plan

Work Package	Objective	Tasks
1.0 Project Initiation	Develop a detailed plan for the project	1.1 Project start 1.2 Develop detailed project plan 1.3 Hold project initiation meeting
2.0 Development of detailed technical plan	Develop a detailed technical plan for the system	2.1 Develop detailed technical plan 2.2 Circulate and review 2.3 Finalize technical plan
3.0 Development of algorithms	Develop the algorithms that will form the basis for the software that will convert cell-phone location data to traffic speed	3.1 Develop algorithms 3.2 Review 3.3 Revise as required
4.0 Software development	Develop software that will convert cell-phone location data to traffic speed	4.1 Develop software 4.2 Review 4.3 Revise as required
5.0 Equipment testing	Test network equipment for provision of cell-phone locations	2.1 Develop test plan 2.2 Conduct test on LBS platform
6.0 Integration	Integrate LBS platform and new software, and test	6.1 Plan integration 6.2 Integrate 6.3 Conduct preliminary testing 6.4 Refine hardware and/or software design as required
7.0 Development of detailed test plan	Develop plan to test accuracy of the prototype system	7.1 Develop test plan 7.2 Review 7.3 Revise as required
8.0 Test	Compare actual traffic speeds with those obtained from the prototype system	8.1 Conduct tests 8.2 Review results
9.0 Project management	Conduct ongoing project management activities	9.1 Hold biweekly project management meetings 9.2 Submit monthly reports to Transport Canada
10.0Promotion	Promote the project	10.1 Issue news release #1 10.2 Issue news release #2
11.0Final report	Prepare project report for Transport Canada, including key chapters on: • Performance of the prototype • Cost to deploy in a major city	11.1 Prepare draft of project report 11.2 Circulate and review 11.3 Finalize and submit project report 11.4 End of project

3 LITERATURE SURVEY

At the start of the project, a literature review was conducted to determine what relevant and useful information already exists. The survey included:

- A broad literature search on the subject of cell phones as traffic probes, with inputs from Globis Data's own files.

- The *ITS Orange Book on Predictive Travel Time* [3], a recent and comprehensive review of projects, developments and issues related to Predictive Travel Time (PTT). It was prepared by a team of sponsors that includes the ATLANTIC Project[2] and ITS America. PBS&J, a U.S. consulting company, coordinated the preparation of the *Orange Book* and Globis Data contributed to it.

3.1 Projects that Use Cell Phones as Traffic Probes

Six projects were identified that use cell phones as traffic probes; however, all of these use network-based technologies:

1. **Cell-Loc** of Calgary has developed a system for measuring traffic speeds using Time Difference of Arrival (TDOA) and evaluated this technology with financing from Transport Canada. This TDOA approach is not being implemented by the wireless carriers [4].

2. **Applied Generics** of Scotland has also developed a solution using a particular attribute of the GSM-based system whereby the signal strength from a number of adjacent cell towers can provide a rough order of magnitude positioning. Using this capability and a proprietary map-matching technique, the Applied Generics system can get a positional fix on a vehicle. Used in an iterative fashion, this technique can position a vehicle on known roads [5].

3. **Decell Technologies Ltd**. in Israel provides a service using technology based solely on the existing mobile network infrastructure. Decell enables mobile network operators to deliver personalized real-time route guidance to driving mobile subscribers. Its technology uses existing cell towers along major routes and uses the GSM capability of relative signal strengths to determine a user's position between towers. The service then uses traditional cell-phone delivery mechanisms to provide traffic status information about the driver's route [6].

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[2] The ATLANTIC Project (**A** **T**hematic **L**ong-term **A**pproach to **N**etworking for the **T**elematics and **I**TS **C**ommunity) is a project supported by Transport Canada, the Ministry of Transportation of Ontario, Transports Québec, the US DOT, and the European Commission. ATLANTIC successfully brought together world ITS experts to pool knowledge, share information and promote solutions for transport.

4. **U.S. Department of Transportation** and the **Virginia Department of Transportation** helped fund a feasibility test of deriving traveller information from cell-phone usage. The technology under development by AirSage, Inc. of Marietta, Georgia, could help provide travel time information on a wide variety of roadways, including both freeways and major arterial roadways [7].

   The goal of the test was to determine the viability of providing real-time, area-wide traffic information through cellular-based traffic probes. The final evaluation report for the project concluded that "it appears that the costs of the cellular based system can be competitive with other technologies"; however, the project did not produce results as accurate as hoped due to several factors, including problems with geolocation accuracy.

   AirSage's technology only requires the installation of two different software packages. One piece resides on the carrier's system and taps into all data on the network – including, potentially, the identification and location of individual callers. That module then extracts data from the cellular company's network in a non-intrusive manner, strips out the identity of individual callers, and then communicates movement records back to AirSage. The second software piece, which is resident at AirSage, aggregates data from multiple cell-phone carriers, performs geospacial analysis and mapping, and merges GIS data as well as the carriers' operational data.

5. **SFR, ASF** and **INRETS** have teamed under a US$1 million European project funded 50 percent by SERTI and managed by the French Department of Transport. The team's objective is to locate and measure speed and direction of cars carrying wireless devices (cell phones) in order to provide road traffic operators with velocity and direction of travel on all roadways within any given service area. The project examines only network-based positioning [8].

6. **State of Maryland / Delcan / ITIS** and other organizations are partnered in a project for traveller information services. This project is examining cellular probe data [9].

3.2 Overview of the *Orange Book*

Within the *Orange Book*, there is a clear recognition that travel predictions and forecasts rest on the ability to capture the current travel conditions. It identifies several related major programs and projects:

- The U.S. Intelligent Vehicle Initiative could lead to systems for data to aid travel time predictions and/or provide dissemination methods.

- Transport Direct, a U.K. initiative, aims to provide the traveller with all the information required before and during a trip.

- The U.S. Federal Highway Administration’s Traffic Estimation and Prediction Software (TREPS) program is applying the concept of dynamic traffic assignment to traffic management and may also yield advancements for PTT.

- The Japanese “IP Car” (where IP stands for Intelligent Probe) project aims to facilitate advances in logistics and improvements in traffic management.

- Vehicle Relayed Dynamic Information (VERDI) is a floating car system implemented jointly by German telematics service providers. VERDI uses GPS receivers in cars linked to a control centre via a GSM network.

- The Welsh Assembly Government has investigated floating car data, but felt there was an insufficient fleet of floating vehicles in Wales for this approach to be viable. Wales is now moving toward a hybrid system using loops and licence plate recognition systems.

- The Scottish Executive has signed a five-year contract for the supply of a journey time and traffic delay service on Scotland’s roads. This uses information on the road system and historical data on delays that are regularly experienced.

- TravInfo in the San Francisco area uses a combination of the FasTrack AVI transponder system and loop detectors.

- SmartRoute Systems, owned by Westwood One, has a local traffic and weather information service that uses traffic data collected by 2,000 reporters, 65 fixed-wing aircraft, 35 helicopters, and thousands of traffic cameras throughout the U.S.

- Mobility Technologies, based in Pennsylvania, has a “Traffic Pulse Network” that uses RTMS sensors.

- TrafficCast, based in the U.S., is a wholesaler of traffic and travel time information using a database of historical travel times linked to real-time highway conditions.

The conclusion is that although there is broad interest in estimating travel times, there is no initiative or project in the *Orange Book* that proposes to use GPS-enabled cell phones as traffic probes.

3.3 Conclusions

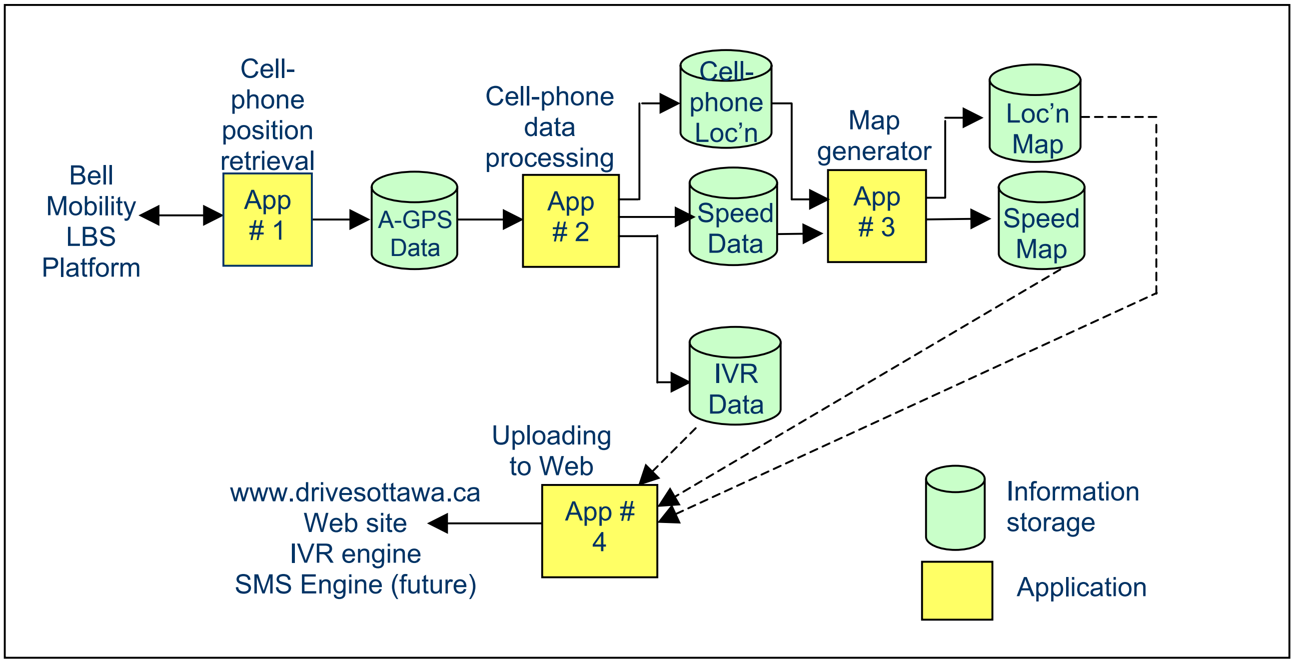
There is great interest in predicting travel times and there are many ways to measure traffic speeds. There are six known projects that use cell phones as traffic probes, but they all use network-based technologies. The use of A-GPS-enabled cell phones as traffic probes involves a very different set of issues and there is no other known project addressing this subject. The current project therefore appears to be very much on the leading edge of the technology. No information was identified that would help guide this project.

4 SYSTEM DESIGN AND DEPLOYMENT

4.1 System Architecture

Figure 4-1 shows the main elements of the architecture.

Figure 4-1: System Architecture



Each of the applications was designed by one of the project team partners and was written to be a stand-alone element in the architecture. The architecture was designed in advance of the contract and provided to each partner to ensure a common vision of the provision. However, no constraints were placed on the partner as to how the code was to be written or the language in which it was to be coded other than to specify the requirements that a high-quality index was to be maintained and that adequate management techniques had to be incorporated to allow for code maintainability and adjustments to certain parameters during the course of the testing phases.

The system architecture used during this trial was an extension of that already in effect for the current two D.R.I.V.E.S. services in Toronto and Montreal. By using the same basic architecture, both time and project funds were saved by the re-use of the current software kernels.

The project goals were to not only prove the feasibility of the use of cell phones as traffic probes, but also to explore the various elements of the methods used for the data retrieval, processing and presentation. Therefore, each module was designed to be as close to standalone as possible for maximum flexibility, and this allowed each module's operation and characteristics to be evaluated before the processed data was passed to the next stage.

A key part of the architecture was the interface with Bell Mobility. There were three elements:

1. The underlying communications link was the public Internet.

2. Security was provided by deploying a secure Virtual Private Network (VPN) operating over the Internet between VPN routers operated by Bell Mobility and Globis Data.

3. The traffic between the D.R.I.V.E.S. Ottawa server and Bell Mobility's LBS platform, i.e. the requests for locations and the associated responses, used the Mobile Location Protocol (MLP), an industry standard developed by the Location Interoperability Forum (LIF).

4.2 Hardware Elements

The architecture of the cell-phone data-gathering solution was designed to fit into the pre-existing Globis Data D.R.I.V.E.S. service and to be seamlessly integrated with the current hardware. Doing it in this fashion meant that no additional hardware needed to be purchased and the current network management tools could be utilized.

Figure 4-2: Hardware Elements of the System

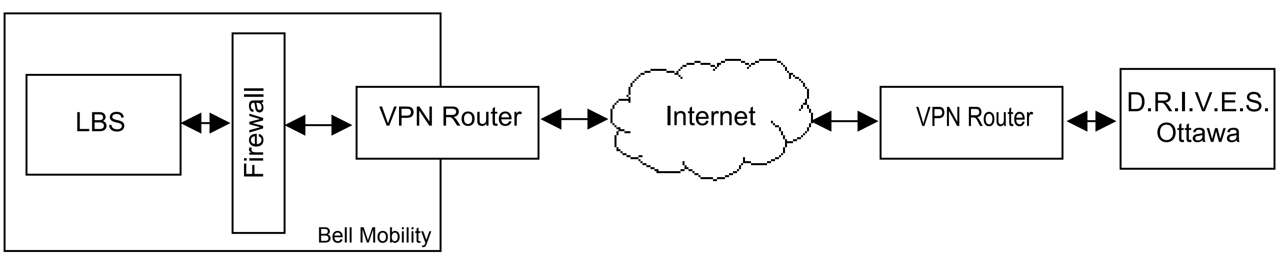


Figure 4-2 shows the hardware elements that were used in the system:

- A computer to host the applications

- Routers with VPN capability; one was supplied by Globis Data for the Ottawa node, and one by Bell Mobility at the LBS location

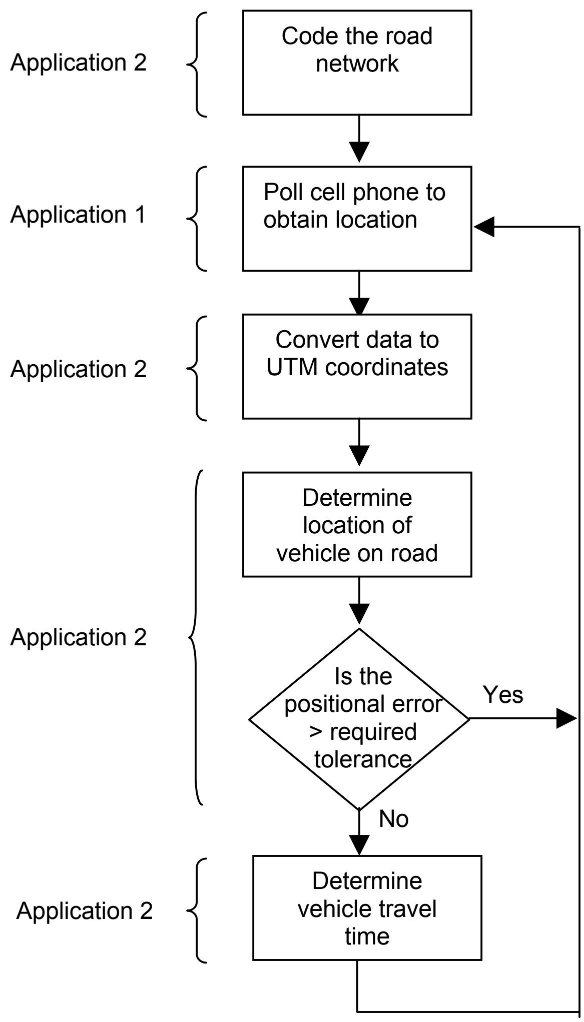
- The Bell Mobility LBS platform

All of the software applications written for this project were hosted on the single Globis Data computer located as one of the elements within the total D.R.I.V.E.S. network.

4.3 Overview of Software and Algorithms

The flow chart in Figure 4-3 provides an overview of the process and algorithms used to determine the position and traffic speed information.

Figure 4-3: Algorithm Flow Chart



There were four software applications, as shown in Figure 4-1; these are described as follows.

Application 1

Application 1, developed by Profilium, requests and retrieves the cell-phone A-GPS data on a flexible schedule and places the results in a datafile that can be accessed and archived.

Access to Bell Mobility's LBS is tightly controlled and any developer has to demonstrate to Bell Mobility the quality of the developed software as well as the secure nature of the connection before access is allowed to the operational platform.

The actual access protocol used is the Mobile Location Protocol (MLP) version 1.2 developed by the Location Interoperability Forum (LIF). The developer needed to become very familiar with the elements of this protocol prior to the development of this application. LIF's MLP is XML based and is carried through a secure VPN link between Globis Data's project computer and Bell Mobility's LBS platform. After the completion of the initial testing, Bell Mobility requires that developers establish a VPN connection to the lab before the final acceptance testing and before the application is allowed to retrieve data from the operational LBS platform.

Table 4-1 describes the functionality of this application module.

Table 4-1: Application 1 Inputs and Outputs

INPUT	OUTPUT
Probe IDs	Location request (XML)
Pinging frequency	Create A-GPS log entries
Accuracy requirement	LBS Error messages
VPN access ID / password	LBS Location response (XML)
Location response (XML)	

Note: All inputs are manually entered and are easily changed

Application 2

Application 2, written by MIxpertS, accesses the location data from the A-GPS log and applies the appropriate algorithms to verify its usefulness for further processing. It then converts the data into a standard structure for further processing.

This application applies georeferencing to the data and develops the probe location data file while at the same time developing the average speed for the segment of road based on predetermined instructions. The development of IVR data, while not a prime intent of this project, is a logical derivative of this application module.

The algorithms supplied by the University of Waterloo select (or discard) data that is outside a predetermined set of criteria and identify the road segment the data applies to.

The A-GPS positional information uses the regular constellation of GPS satellites. However, cell phones are not always in optimal locations to be able to see the necessary numbers of satellites to provide accuracy to the best possible resolution. The data is therefore supplemented by positional data obtained from triangulation based on the cell phones' strongest signal. The result is that there is an uncertainty of position. This uncertainty is used in two ways:

- First, location data with a radius of uncertainty greater than a predefined threshold is filtered out and not used. A balance was achieved between the data points to be included and those to be discarded due to inaccurate position reports. Globis Data expects to be able to tighten the threshold in the commercial deployment of this technology.

- The second part of the algorithms dealt with allocating data points to the correct road segments. The selected method uses a classical orthogonal approach whereby the position was allocated to a road segment and a place on the segment that is closest to the cell-phone. The vector from the cell-phone to the closest road segment and the road segment itself meet in a right angle. If this approach resulted in an ambiguous location (i.e. intersected two segments at an equal distance from the cell-phone) then other algorithms resolved this ambiguity through the analysis of the previous data.

Table 4-2 describes the functionality of this application module.

Table 4-2: Application 2 Inputs and Outputs

INPUT	OUTPUT
A-GPS data from each probe	Speed log datafile
Accuracy requirement	Location log datafile
Required algorithms	Data file in XML format for IVR delivery
Road segment definitions	Updates the cell-phone location database
Posted speed definitions	
Colour/speed definitions	

Application 3

Application 3, developed by MIxpertS, develops the presentation maps and (when required) provides an extrapolation capability for missing data. The type and details of the map are flexible and are chosen to provide a minimum of download time for the user (i.e., minimum file size).

The application determines the speed of traffic by polling ("pinging") each cell phone to determine its location, determining the distance travelled since the previous ping and the elapsed time, and then calculating speed based on distance/time. The actual speeds are then converted to one of three congestion values, which are displayed as colour-coded zones on a real-time traffic map:

- "Normal" = green = speed is greater than 80% of the posted speed limit
- "Somewhat slow" = yellow = speed is 40-80% of the posted speed limit
- "Very slow or stopped" = red = speed is less than 40% of the posted speed limit

Table 4-3 describes the functionality of this application module.

Table 4-3: Application 3 Inputs and Outputs

INPUT	OUTPUT
Speed log datafile	Completed speed map
Location log datafile	Completed location map
Extrapolation capability (with on/off switch)	
Map details: ▪ Base map ▪ Line width ▪ Georeferenced data ▪ Objects ▪ Scaling	
Colour definitions	

Application 4

Application # 4, written by Globis Data, uploads various files to the Globis Data web site every minute. Some of these files are used by the web site itself, and an XML file is downloaded to the IVR engine.

4.4 System Design and Deployment Issues

The software modules were delivered on time and in good quality; this enabled the project to stay on schedule.

System design and deployment issues were minimized through the preparation of technical data sheets that defined the system architecture, requirements, and protocols for the various modules. However, as with any software development project, there were a few interpretation issues, and testing revealed the need for a few additional features that were not included in the original specification.

Some minor and unexpected errors occurred during the early testing; these needed resolution before the formal testing phases could begin. A few representative items are listed in Table 4-4.

Table 4-4: Examples of Problems Encountered[3]

Problem	Resolution
Frequent random system reboots	The immediate assumption was that one of the applications was causing the random system crashes – but this was not the case. It was finally determined to be an incompatible memory problem. Additional RAM had been purchased and installed that turned out to be incompatible with the original vendor's type.
No data on Highway 417	Data was being discarded because the distance threshold in application #2 was set too low.
A stopped car could cause the traffic zones in both directions to show red	One reason the test route was chosen was because the route included both highways and arterials, some of which have traffic lights. When a car was stopped at a traffic signal, the software became "confused" as to which direction the car was travelling in and had a tendency to paint the traffic zone red in both directions. The problem was resolved by adding a historical record to the data showing the past direction for each vehicle.
No data in some zones	Some zone boundaries were close enough to each other that it was possible for a vehicle moving at the posted speed to traverse a zone without getting pinged. The zone extrapolation feature uses a set of algorithms to colour the zone based on adjacent zone colours, thereby compensating for the missing data. For the detailed testing, this feature was turned off to allow for a more accurate evaluation of the probe data.
Installation and operation of the VPN secure data link	There were some configuration problems due to different terminology between the Cisco routers used by Bell Mobility and the Linksys router used by Globis Data.

[3] Figure 5-1 shows a map of the test route; this may be useful to the reader in understanding the observations in Table 4-4.

5 RESULTS

5.1 Overview of Testing Program

The initial testing program consisted of a series of tests with various numbers of cell phones being driven around the test route under different traffic conditions. The map was successfully painted green, yellow and red through the location of the cell phones and the operation of the D.R.I.V.E.S. system as illustrated in Figures 5-4 and 5-5.

Note: the convention for colour coding the traffic zones was:

- Green: traffic is moving at 80% of the posted speed limit or better;
- Yellow: traffic is moving at 40-80% of the posted speed limit;
- Red: traffic is moving at less than 40% of the posted speed limit.

The next question was to determine the accuracy of these results. In order to do this, three parameters were recorded and compared:

1. The times and colours of the map results.
2. Drivers and observers in the vehicles reported the ***observed*** traffic speed in a zone (map segment) at a specific time.
3. Drivers and observers in the vehicles also made odometer and time reports that subsequently provided a ***calculated*** speed that was compared to the colour indicated on the map for that zone at the same time.

Each time and zone for which the calculated and observed reports were available was compared with the corresponding map colour. The comparison was made with a 1 minute delay to account for latency[4] in the system.

Tables 5-2, 5-3 and 5-4 compare the map or system result to the observed and calculated results. In Table 5-2, for example, there were 45 green map results, 86 yellow map results, and 31 red map results for which there were corresponding observations and calculations. An accuracy of 100% would be indicated if the map results had been supported by 45 observed reports of green, 86 observed reports of yellow and 31 calculated results of red. This was not the case. The results actually showed:

- For the 45 green map results, there were 40 *observed* green reports for the same zone at the same time, 4 yellow reports, and 1 red. The *calculated* results showed 23 green, 16 yellow, and 6 red results.

- For the 86 yellow map results, the *observed* reports were 56 green, 24 yellow and 6 red for the same zone at the same time. The *calculated* results showed 29 green, 41 yellow, and 16 red results.

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[4] The overall system comprised a number of processes, including the D.R.I.V.E.S. Ottawa software modules, the Bell Mobility LBS platform, and the pinging process to the cell phones. Each had a small delay that contributed to a total system delay or latency.

- For the 31 red map results, there were 15 *observed* green, 3 yellow, and 13 red reports for the same zone at the same time. The *calculated* results showed 6 green, 12 yellow and 13 red results.

The cell phones appeared on the map in their expected positions according to driver reports. Also, the cell-phone traffic data populated the D.R.I.V.E.S. map reliably. However, the overall comparison of actual map colours with the observed and calculated values was disappointing in some respects, although there appeared to be explanations for some of the results.

This led to a decision to perform additional tests on each stage of the process and to repeat the map colour performance for an extended highway section. The additional testing program measured the accuracy of the prototype system in three ways:

1. The positional accuracy of the data from the LBS platform, i.e., the latitude and longitude data.

2. The accuracy of the raw speed data from the software.

3. The accuracy of the D.R.I.V.E.S. Ottawa real-time traffic map on highways.

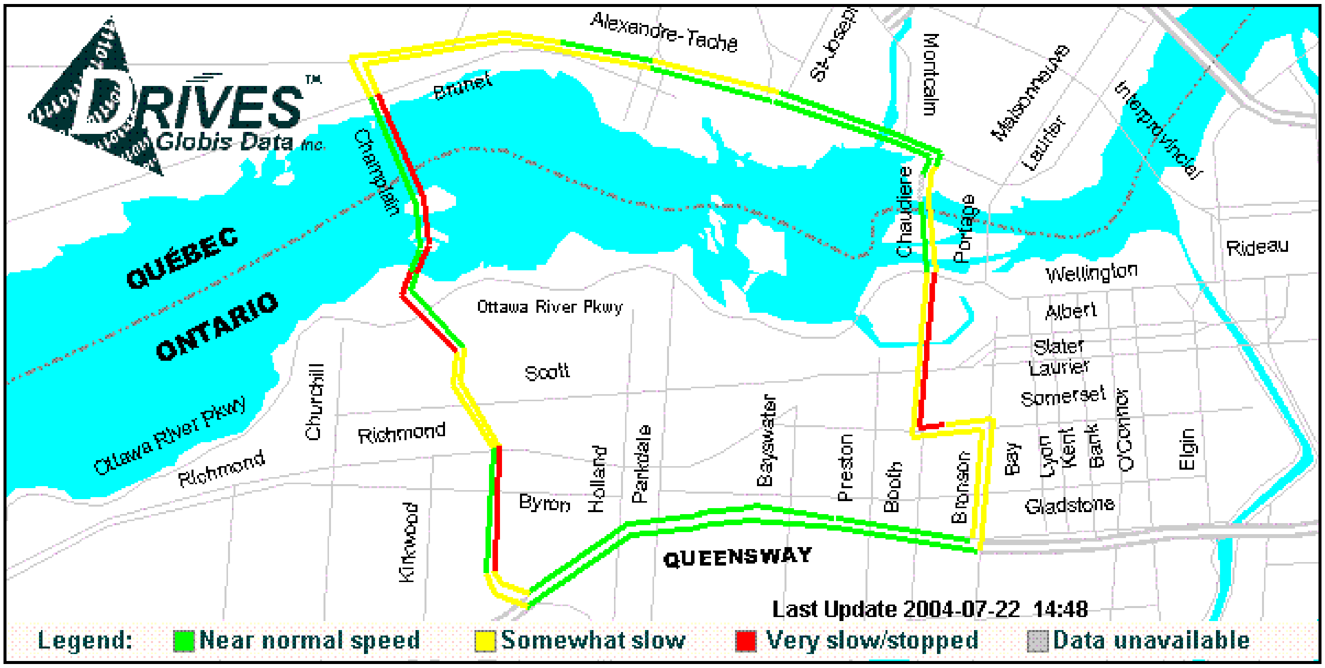
Sections 5.2 through 5.5 address the results of the initial testing program and these additional topics; each section includes the methodology, results and analysis, and conclusions. Section 5.6 summarizes the conclusions from the entire testing program.

5.2 Initial Testing Program

5.2.1 Methodology

Testing took place on three days: July 9, July 14, and July 22, 2004. A number of cell phones were used on each occasion and placed in vehicles that were driven around the test route shown in Figure 5-1. The test route included both a limited-access highway (417) and arterial roads. The scope of these tests is shown in Table 5-1. The tests on July 22 involved 14 phones and cars (see photo in Figure 5-2). Bell Mobility's LBS platform identified the location of each cell phone. This data was used to feed the D.R.I.V.E.S. system that calculated the speed of the vehicles and painted the information onto the D.R.I.V.E.S. map for the Ottawa test route.

Figure 5-1: Map of Test Route



Note: Highway 417 (the Queensway) is a limited-access highway; all the other roads on the test route are arterials. The total distance is 15 km.

Table 5-1: Scope of Initial Tests

Date (2004)	# Phones	# Vehicles	Test Objective
July 9	2	1	Highway 417
			Arterials Counterclockwise
			Arterials & Hwy 417 Clockwise
July 14	4	2	Arterials
			Full Route Clockwise
			Full Route Counterclockwise
July 22	14	14	Full Route – 2 circuits light traffic
			Full Route – 2 circuits heavy traffic

Figure 5-2: Drivers for the Initial Tests

From left to right: Gordon Abry, Keith Fagan, Olive Fagan, Alexandra Dafoe, Melissa McNulty, Shauna Mullally, Catherine Dafoe, Mark Norris, Charles Berndt, Carrie Kennedy, Michele Dathan, Michelle Hupé. Missing from the photo: Frank Greene, Roland Renner.

Figure 5-3 shows the notebook computer and 1X cell phone that was used as the field control centre during the testing. The computer was linked to the D.R.I.V.E.S. Ottawa server via pcAnywhere.

Figures 5-4 and 5-5 are screen shots from the D.R.I.V.E.S. Ottawa computer during the tests on July 22, 2004.

Figure 5-3: Control Centre During Field Testing

Figure 5-4: Traffic Map During Testing on July 22, 2004 at 14:48

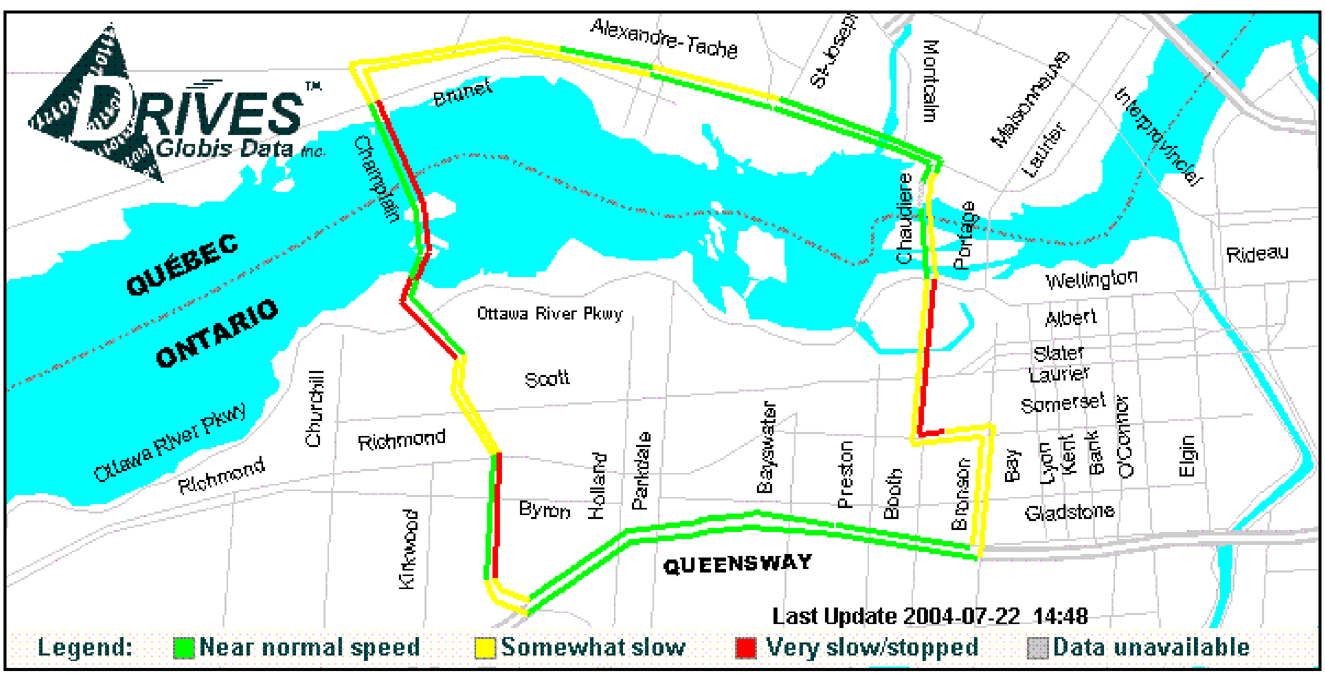
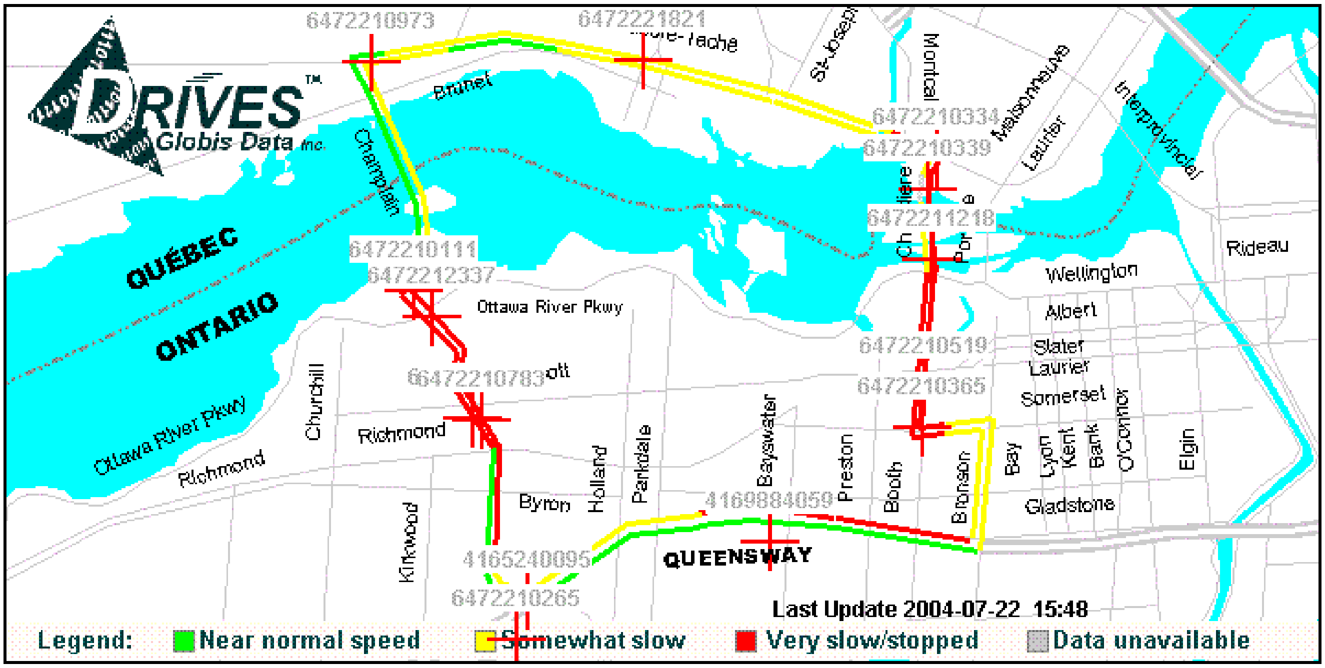


Figure 5-5: Traffic Map Showing Cell-phone Positions on July 22, 2004 at 15:48



5.2.2 Summary of Results

Table 5-2 (and 5.3 and 5.4) shows the correlation between the colours on the D.R.I.V.E.S. map and the observed and calculated traffic conditions. It refers to three different types of test data:

1. Map results, i.e., the colour of the zone(s) on the D.R.I.V.E.S. map. A one minute lag was incorporated into the analysis to account for the estimated latency in the system.

2. Observed results, i.e., the car's instantaneous speed at a certain time as determined by the car's speedometer. There was a minimum of one observation point per zone.

3. Calculated results, i.e., the car's average speed as determined by recording the odometer reading and time at certain points and dividing the distance travelled by the elapsed time.

In each of these results tables, columns one and two show the number of zones on the map that were green, yellow and red (45, 86 and 31, respectively, in Table 5-2). The third column shows how many of these zones were recorded by the observer as green, yellow or red. For example, of the 45 green zones on the map, 40 were observed to be green, 4 yellow, and 1 red. Similarly, the fourth column shows how many of these zones were calculated as green, yellow or red based on the car's distance travelled and elapsed time.

Table 5-2 shows that there were significant differences between the map result and both the observed and calculated results. There were also significant differences between the observed results and the calculated results. The reasons for this are discussed in Section 5.2.3. These results led to the decision to perform additional tests to obtain additional data.

Table 5-2: Results of Initial Tests

Colour	Map Result	Observed	Calculated
Green	45	40	23
Yellow		4	16
Red		1	6
Green		56	29
Yellow	86	24	41
Red		6	16
Green		15	6
Yellow		3	12
Red	31	13	13

5.2.3 Evaluation of Results

A number of qualifications must be made to the results of the testing:

- First, the test data is not suitable for statistical analysis due to differences in the tests and the limited number of observations.

- Second, the observed results and the manually calculated results are sensitive to differences in interpretation by different observers and small errors in measurement. Some of the manually calculated speeds are not possible and others not likely. In other words, the quality of the actual measurements and observations is less than perfect, so that in comparing the D.R.I.V.E.S. calculation to the observed and calculated results, the latter may be wrong.

- Finally, the results indicate a number of issues for these tests, some of which can be addressed by small modifications to the software. Others can be reduced or eliminated by using a larger number of cell phones in a commercial level service.

In more detail:

- The segments on the D.R.I.V.E.S. map that showed green correlated well with the observed data and somewhat less so with the manual speed calculations.

- Yellow map segments were confirmed in 27% of the observations and were more generally observed as green, although 6 red results also occurred. For the calculated results, the confirmation of yellow was considerably better but still only at about 50% with a sizeable number of both green and red results.

- For the zones on the D.R.I.V.E.S. map that were red, the observations and calculations indicated red and also many green and yellow zones.

The tests included both highway and arterial traffic. Stop lights on arterial roads generate red zones on the map because sequential pings indicate that the vehicle is stopped. While this is correct in one sense because the vehicle is actually stopped, it may not indicate that traffic flow is red. The stopped vehicles are part of the normal flow of traffic on arterial roads. An averaging process over a few minutes should reduce the number of false red zones and bring the results into line with observed results.

Pinging cell phones that are entering or leaving a limited-access highway can also result in false red or yellow results. With a larger number of cell phones, the existing algorithms are expected to eliminate these results.

The number of yellows that are observed and calculated as green remains an issue for further research. To some extent these may be observation and calculation errors, but further research is required to identify the source of this error pattern.

Highway results were isolated and analyzed separately (Table 5-3). Generally, the results were slightly better than the overall results, but the same pattern of errors as identified above remained. A review of the software showed that some of the calculated result errors could be because of averaging of speed results from the arterial roads at the highway exit points. For example, one incorrect red map segment was painted due to the vehicle being stopped for a red light just before the Bronson entrance to Highway 417.

Table 5-3: Results of Initial Tests – Highways Only

Colour	Map Result	Observed	Calculated
Green	17	17	8
Yellow		0	7
Red		0	2
Green		9	4
Yellow	15	5	9
Red		1	2
Green		1	0
Yellow		1	1
Red	2	0	1

5.2.4 Conclusions

The D.R.I.V.E.S. software consistently paints a map green, yellow, and red even when a small number of cell phones are being pinged. The results are based on a combination of observations, calculations and results on both arterial roads and Highway 417. We can expect that the results on arterial roads will have problems due to over-reporting of red results and possible observation bias to report after acceleration to normal speed.

Globis Data decided to test the separate components of the system and to repeat the final comparison of observations and calculations over a longer portion of the 417. Several improvements were also made to the testing process. These included calibration of test vehicle speedometers, making the highway segments long enough to receive multiple pings and carefully setting reporting marks for the observations and calculations.

5.3 Positional Accuracy

In order to fully understand the various components for using cell phones as traffic probes, it was decided to check the positional accuracy of the A-GPS system. Reliable positional accuracy will be a key component in the commercialization of this technology, in the selection of the appropriate algorithms for positional determination, and in the elimination of the effect of traffic on adjacent roads.

5.3.1 Methodology

A Natural Resources Canada (NRCan) station marker in Ottawa was selected; it had easy access and its position was known to within ±1 mm in both a northing and easting position.

Four phones were set up directly on top of the marker (see Figure 5-6) and 250 data points were collected. The resulting positions (latitude and longitude) were logged by the software and the results transferred into an Excel spreadsheet for further analysis. Using known spherical geometry calculations, the apparent distance between the cell phones and the reference station marker were calculated.

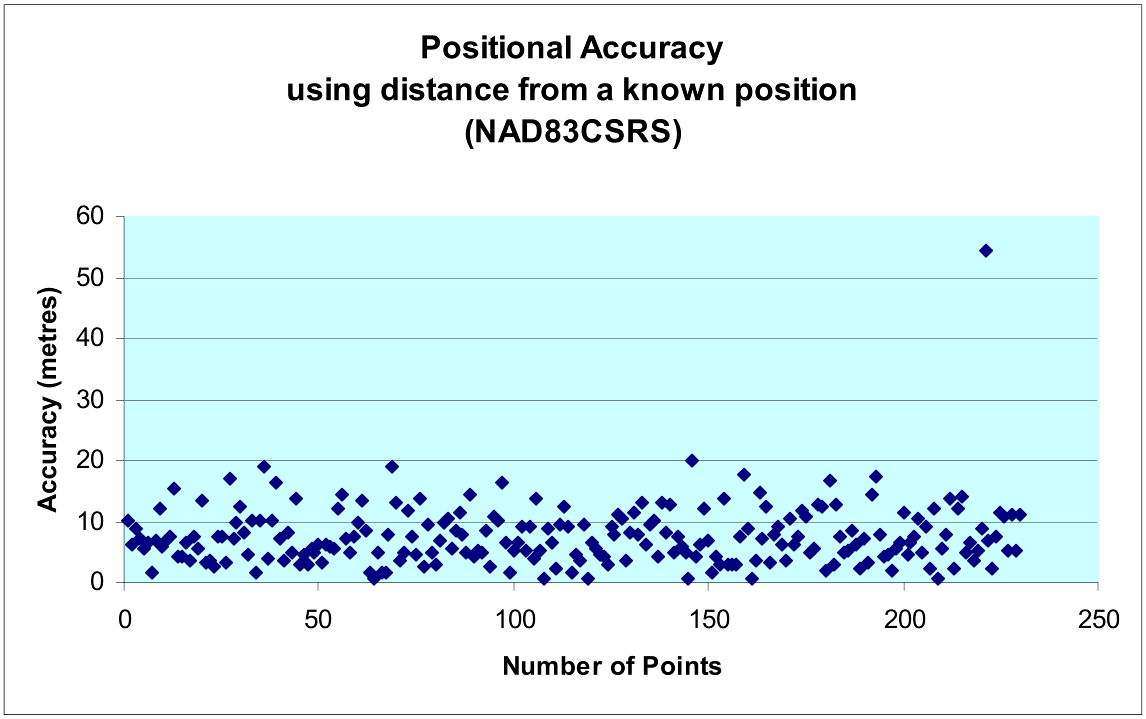
Figure 5-6: Photos of the Positional Accuracy Test Site

It should be noted that the horizontal datum used for the reference position used the NAD83CSRS standard, whereas the reference used for the A-GPS positions is the WAC84 standard. A comparison of these two standards showed that the introduced error is zero metres for the longitudinal positions, and less than 0.0001 m (at a latitude of 45 degrees) for the latitudinal. This level of error is insignificant for this project.

5.3.2 Results and Analysis

As can be seen from Figure 5-7, the average accuracy was approximately 7 m, and over 99% of the results had an accuracy better than 20 m.

Figure 5-7: Results of Positional Accuracy Test



There will be occasional locates that have an accuracy worse than 20 m due to effects such as building blockage and/or vehicle blockage. However, GPS locates have a Dilution of Precision (DOP) factor, which the Bell Mobility LBS provides to Globis Data as a “radius of uncertainty” associated with each locate. Globis Data’s software filters out locates that have a radius of uncertainty greater than X metres, where X is programmable. This filters out any poor quality locates. Also, the initial deployment for this technology will likely be on highways where building blockage will not be much of a factor -- although it is recognized that vehicle blockage will still be a factor. Finally, as mentioned earlier, A-GPS is more robust than regular GPS and provides improved accuracy.

5.3.3 Conclusions

The consistent worst-case accuracy was better than 20 m; this is very acceptable for using cell phones as traffic probes. It means that the D.R.I.V.E.S. system can easily discriminate between adjacent roads that are as little as 50 m apart and the data can be presented in a graphical mapping format.

5.4 Accuracy of the Raw Speed Data
5.4.1 Methodology

The objective of this part of the evaluation was to determine the accuracy of the “raw” speed data from the software. The raw speed is defined as the actual speed in km/h as determined by the D.R.I.V.E.S. Ottawa software and prior to the application of algorithms. The raw speed is calculated by distance/time, based on two pings 30 seconds apart. (The algorithms determine whether the vehicle is on a highway/road of interest, which zone it is in, and the zone colour based on all vehicles in the zone at that time.)

The approach to this part of the testing was as follows:

- Calibrate the speedometers on the two cars used for this test, based on the time to travel a route measuring exactly 4.55 km. A speedometer adjustment formula was developed for each vehicle and this formula was applied to all speedometer readings.

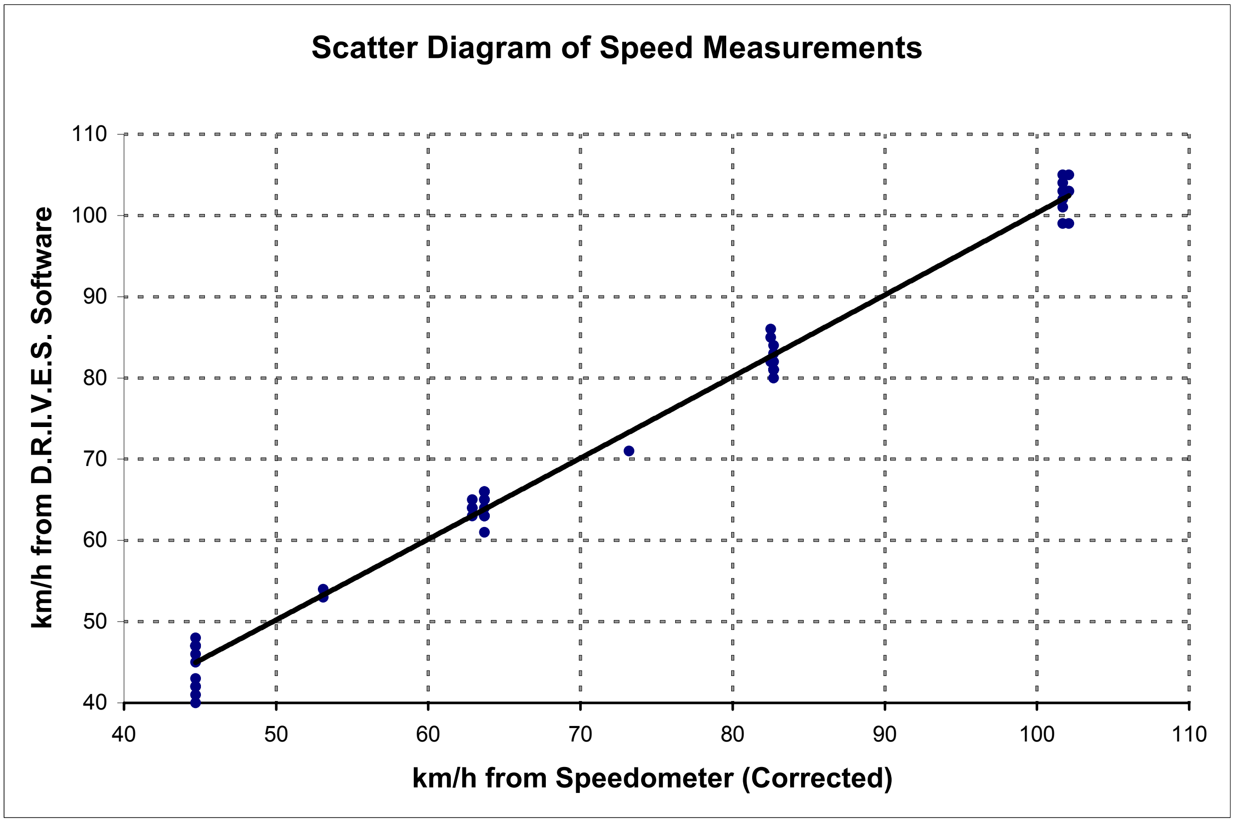
- Drive along Highway 417 at a constant speed and record:
  - The precise time as displayed on the D.R.I.V.E.S. Ottawa server,
  - The car’s speedometer reading, and
  - The speed as determined by the software (this speed was automatically logged by the software with a date and time stamp).

- Repeat the second step for various speeds.

5.4.2 Results and Analysis

The test provided 51 data points. These were used as source data for Figure 5-8, a scatter diagram that shows the relationship between the two sources for the speed data.

Figure 5-8: Scatter Diagram Showing the Accuracy of the Speed Data



Notes:

1. The parameter “km/h from Speedometer” incorporates the adjustment factor resulting from the speedometer calibrations.

2. The trend line is a second order polynomial generated automatically by MS Excel; the formula is $y = 0.0002x^2 + 0.9716x + 1.1282$. The low value of the second order coefficient shows that the line is basically linear with an offset at zero of just over 1 km/h and a slope of 0.9716. This illustrates that the D.R.I.V.E.S. Ottawa system is quite accurate.

To further investigate the variation between the two sources of speed data, a second scatter diagram was developed; Figure 5-9 shows the percentage variation at various speeds.

Figure 5-9: Percentage Variation in Speed at Various Speeds

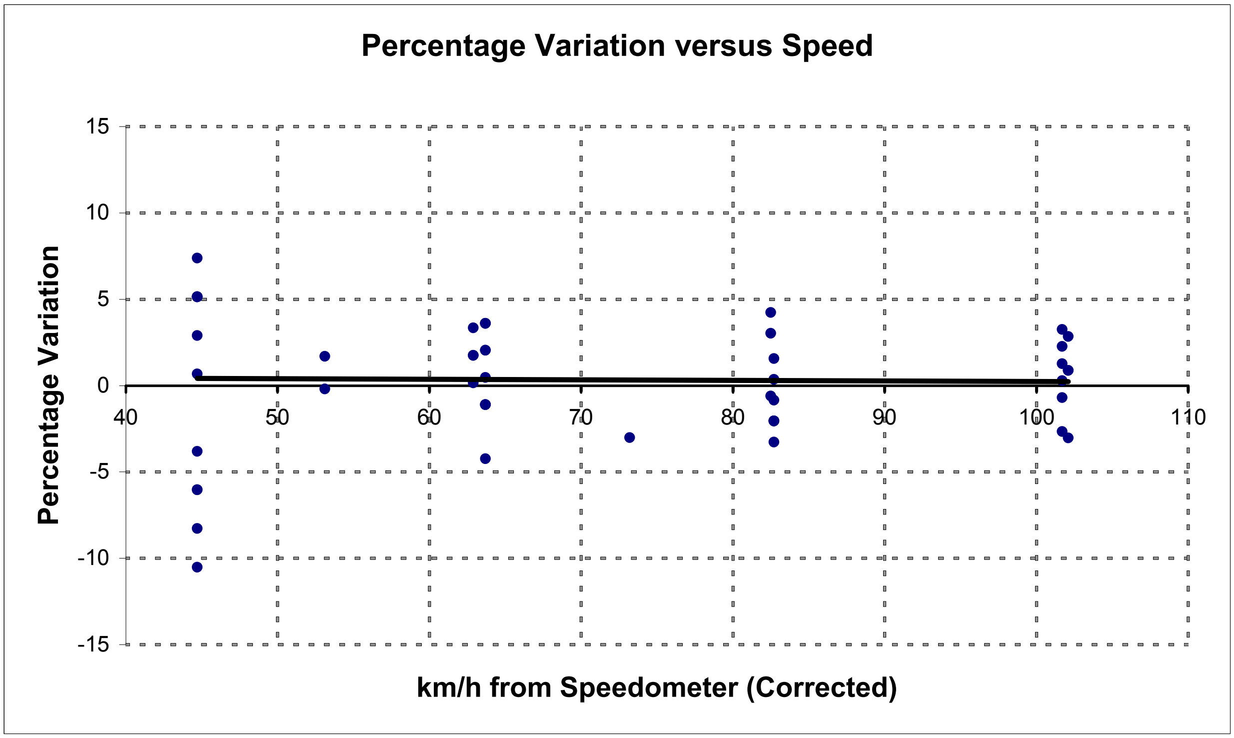


Figure 5-9 shows:

- The errors are fairly evenly distributed on each side of the horizontal 0% line.
- The average of all errors across all speeds is consistently less than 1%.
- The range of data points at just over 100 km/h is from +3.2% to – 3.0% relative to the corrected speedometer readings.
- The range of data points at 45 km/h is from +7.4% to –10.5% relative to the corrected speedometer readings.

This accuracy is certainly sufficient for determining the speed of traffic, especially as the algorithms incorporate an averaging function.

Figure 5-9 also shows that at lower speeds, the spread between the data points increases. This raises an important question: why is the system less accurate at lower speeds? The answer lies in some simple mathematics:

- At 45 km/h, there is a worst-case variation of 10.5% between the calculated speeds and the corrected speedometer readings.
- At 45 km/h, a car travels 375 m every 30 seconds (the interval used for pinging Bell Mobility's LBS).
- The positional accuracy tests in Figure 5-7 show that the worst-case positional error for over 99% of the data points is 20 m (although the mean error was 7 m).

- In a true worst-case situation in which a pair of pings are worst case in opposite directions, the maximum error in determining the distance travelled would be 40 m.
- The worst case percentage error in distance travelled is therefore 40 x 100/375, i.e. 10.7%.
- This means that in the same worst-case situation, the calculated speed would also be out by 10.7%. This theoretical value is very close to 10.5%, the worst measured error at 45 km/h.

In other words, at lower speeds, the distance travelled between pings is less and the impact of the GPS positional inaccuracy is greater. Increasing the time between pings would, of course, increase the distance travelled and reduce this effect, but there are trade-offs with other factors.

5.4.3 Conclusions

There are two main conclusions from this test:

1. The average of all errors at each speed is consistently less than 1%.

2. The range of data points varies from +3.2% to – 3.0% at just over 100 km/h, to +7.4% to –10.5% at 45 km/h.

This range of errors is certainly accurate enough for determining the speed of traffic.

5.5 Accuracy of the D.R.I.V.E.S. Map on Highways

5.5.1 Methodology

An 18 km portion of Highway 417, from Eagleson Road to Bronson Avenue in the west end of Ottawa, was defined for a highway-only test. The zones were somewhat larger than the zones for the previous test to allow for more pings to the same cell phone while within the zone. Reporting points for observation and odometer readings were predefined to ensure more consistent measurement and small observation intervals eliminated to reduce the potential impact of small distance errors creating large speed calculation errors. Tests were run on October 8 and October 12, 2004. The first test consisted largely of normal traffic with a few reductions of speed. The second test was held in the morning rush hour and more yellow and red zones were reported.

5.5.2 Results and Analysis

The test results were essentially perfect except for one no-data report. (The number of calculated speeds does not match the map result and observed columns because calculation data was not taken on all of the runs.)

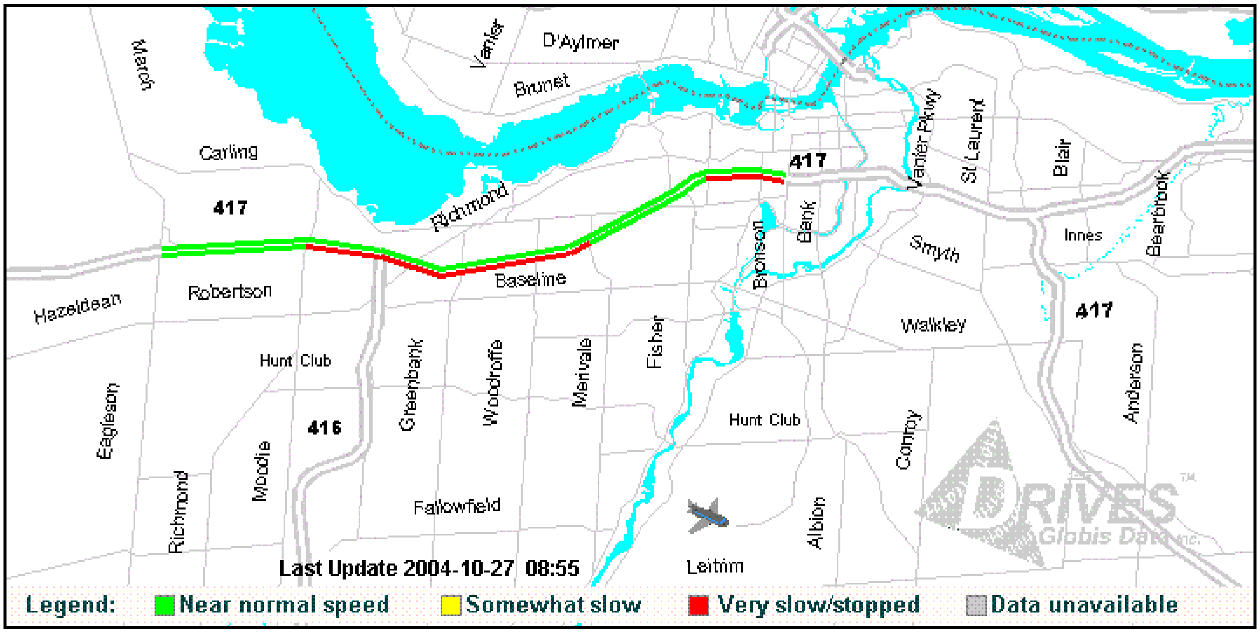
The results in Table 5-4 show that only one yellow observation was observed as green, but in fact, the results are even better than they appear. The map colour changed consistently approximately 40 seconds after a report of an observed traffic speed change. Especially at slower speeds, this sometimes resulted in changes in the map colour while the test vehicle was in the zone. This was reported by observation. The one yellow result observed as green also had a brief period of time as yellow. There were a number of other occasions where the map briefly changed a zone from green to yellow and then back. These were confirmed by observation.

Table 5-4: Results of Highway-Only Tests

Colour	Map Result	Observed	Calculated
Green	42	42	34
Yellow		0	0
Red		0	0
Green		1	0
Yellow	4	3	4
Red		0	0
Green		0	0
Yellow		0	0
Red	2	2	1

Figure 5-10 shows the D.R.I.V.E.S. Ottawa traffic map during a demonstration conducted during the morning rush hour on October 27.

Figure 5-10: Traffic Map of Highway 417 on October 27, 2004 at 08:55



5.5.3 Conclusions

The D.R.I.V.E.S. software performed to near 100% accuracy, with the exception of the single no-data zone. The observation of 40 second latency was significantly better than had been anticipated. The D.R.I.V.E.S. software accurately reflected changes in speed while the vehicle was within a specific zone.

This confirms that the D.R.I.V.E.S. software successfully describes the speed of traffic on highways.

5.6 Conclusions from the Entire Testing Program

Each component of the D.R.I.V.E.S. software has been verified in the testing: the accuracy of the location data from Bell Mobility, the calculation of traffic speed, and the transfer of this information to a map in three colour codes.

The additional testing on the extended Highway 417 segment was very successful. The analysis of the results of the initial testing identified a number of changes to the initial algorithms and the need for rigorous observation. Observations and calculations must be made consistently and accurately in order to complete testing successfully. Small measurement errors can have a large impact on the analysis with small zones.

The testing also confirmed that significantly more sophistication must be built into the algorithms for arterials; there should also be a conceptual review of the approach to arterials. For example, should a D.R.I.V.E.S. map report vehicles as stopped because they are actually stopped at a traffic light? Or, alternatively, should the software average these results with the previous and subsequent yellow and green results to calculate an average speed, based on the rationale that the red time is part of the normal flow of traffic on the arterial? Even more fundamentally, what is a “normal speed” on an arterial with traffic lights? The current generation of the software defines normal as over 80% of the posted speed limit. For an arterial with traffic lights, perhaps the threshold for “normal” should be lower, say 50% and above.

6 COST TO DEPLOY

The following are some estimates of the cost to deploy D.R.I.V.E.S. in a commercial environment:

- Globis Data's capital cost to develop the next generation D.R.I.V.E.S. platform for highway coverage and deploy it in one major city in Canada is approximately CAN$400,000.

- The cost to deploy the system in additional cities or other locations (such as border crossings) is less than this, but it is not possible to estimate the cost at this time.

- There are additional costs to create the business infrastructure required, such as implementing the marketing plan, developing and deploying customer authorization and billing systems, etc. The cost of this is highly dependent on both the strategy used and the choice of partner(s). It is not possible to estimate these costs at this time.

- The wireless carrier also has costs, including possible changes to the LBS platform, implementing a "privacy firewall", the operation of the LBS platform, and (if the carrier also sells the service) changes to the billing system and customer contract. These costs cannot be estimated at this time, but they could be recovered: a) by a capital contribution, or b) through fees paid for the use of the LBS platform, or c) in a combination of the two approaches.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The design, development and deployment stages went relatively smoothly. There were no major problems or issues, only minor issues related to configuration, the interfaces between the software modules, a memory compatibility problem within the computer, etc. All of these were quickly resolved.

The testing phase showed that it is clearly feasible to use A-GPS-enabled cell phones as traffic probes. The detailed evaluation of the results showed that the D.R.I.V.E.S. map is accurate enough to use for measuring and reporting on traffic speeds on highways. The algorithms developed for this feasibility trial were intentionally basic and the results showed that more complex algorithms are required for tracking and reporting traffic speeds on arterials.

These results, coupled with the result from the literature search, show that Globis Data is a world leader in the field of A-GPS cell phones as traffic probes. To the best of Globis Data's knowledge, nobody else is working in this field.

7.2 Recommendations

The following recommendations are made:

1. That Globis Data, with key stakeholders in the transportation community, proceed with the development of the next generation system for the use of A-GPS-enabled cell phones as traffic probes.

2. That Globis Data and these stakeholders develop and review a list of possible follow-on projects. These could include a pilot system at a border crossing in southern Ontario, a large-scale deployment in Toronto, and other deployments. (A Toronto deployment could be designed to overlap part of COMPASS;[5] this would enable a comparison of traffic conditions from the two systems.)

3. That transportation management agencies evaluate the cost and operational issues related to the use of traffic data from cell phones.

[5] COMPASS is a freeway traffic management system developed and operated by the Ontario Ministry of Transportation to respond to traffic congestion problems on urban freeways.

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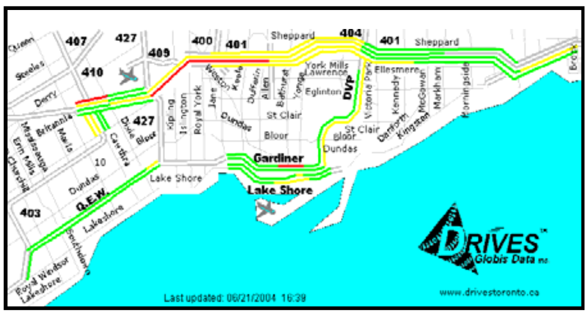
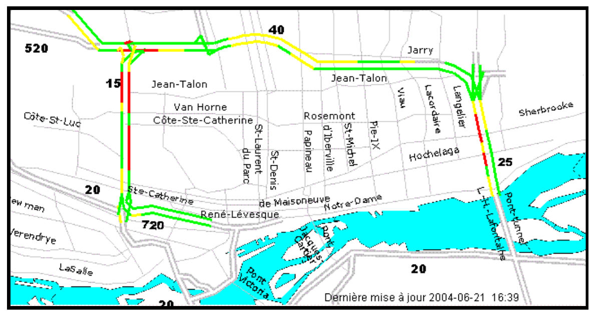
APPENDIX A: PROFILE OF GLOBIS DATA INC.

Move into the Fast Lane with D.R.I.V.E.S.

D.R.I.V.E.S.™ is a real-time traffic information service created by Globis Data Inc. The company's market comprises consumers and professionals, fleet operators, and government transportation agencies. These drivers and organizations require prompt notification of any traffic slowdown around the city, thereby allowing them to choose a quicker route.

Globis Data has developed and launched Phase 1 versions of D.R.I.V.E.S. in Toronto (www.drivestoronto.ca) and Montreal (www.drivesmontreal.ca). The current D.R.I.V.E.S. network uses a fully automatic system of traffic sensors, specialized software and communications. The data is collected from loop sensors embedded in the highway by the Ministry of Transportation of Ontario, the City of Toronto, and Transports Québec. The information is therefore accurate, available 7/24 in all weathers, and always up to date within a few minutes.





Cell phones as Traffic Probes

To build on the above, Globis Data has become a world leader in the development and deployment of a system that uses Assisted GPS-enabled cell phones as traffic probes. Based on Globis Data's pioneering work in this area, the company filed a patent application with the U.S. Patent and Trademark Office in March 2004.

During 2004, Globis Data and its team consisting of Bell Mobility, MIxpertS, Profilium, and the University of Waterloo successfully developed, deployed and tested a prototype system in Ottawa. This demonstration system, which is the first of its kind anywhere in the world, was financed by Transport Canada under its Intelligent Transportation Systems (ITS) R&D Plan, part of the Strategic Highway Infrastructure Program.

A Global Opportunity

Independent market research has demonstrated the need for traffic information and shown that people are willing to pay for it. The key issue is that traffic information services generally have been inaccurate and stale by the time they reach the users. Globis Data has created an approach that delivers accurate information within 1-2 minutes of real time without requiring massive investments in infrastructure. The approach is scalable and can be implemented anywhere in the world. Globis Data estimates revenue of over CAN$50 million in the second year of operation with appropriate funding and marketing capability.

D.R.I.V.E.S. Market Vision

Globis Data's plans call for the merging of traffic data from the cell phones-as-traffic-probes system and the existing loop data. The vision for D.R.I.V.E.S. is:

- Multiple markets
  - Consumers (commuters, sales people, other professionals who drive extensively)
  - Fleet operators
  - Government traffic management agencies
  - Other traffic information providers; outside Canada, Globis Data will market the platform rather than traffic information services

- Multiple Canadian cities
  - Toronto, Montreal, Vancouver, Ottawa-Gatineau
  - Border crossings
  - Inter-city corridors, e.g. Highway 401 in Ontario; and southern Ontario

- Multiple distribution technologies
  - Interactive Voice Response (IVR)
  - Real-time maps on the Internet
  - Text messages to cell phones
  - Integration with in-vehicle navigation systems
  - "Push" products based on a user's location
  - Digital Audio Broadcasting (DAB)

- Multiple channels to market
  - Direct sales by Globis Data
  - Distributors

- Multiple revenue models
  - Advertising supported
  - Subscription based ($4.95 - $9.95/mth)
  - Charge per use
  - Technology licensing

For more information, contact:

Globis Data Inc. Tel: 613-271-1657
300 Earl Grey Drive, Suite 222 Fax: 613-592-4640
Kanata ON K2T 1C1 E-mail: info@globisdata.ca

Globis Data Inc.