Intelligent Fleet Management System with Concurrent GPS & GSM Real-Time Positioning Technology

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Abstract

Fleet management system is a rapid growing industry. This system helps institutions to manage vehicle fleet efficiently and effectively through smart allocation of resources. In this project, an intelligent fleet management system which incorporates the power of concurrent Global Positioning System (GPS) and Global System for Mobile Communications (GSM) real-time positioning, front-end intelligent and web-based management software is proposed. In contrast to systems which depend solely on GPS positioning, the proposed system provides higher positioning accuracy and is capable to track the target at areas where GPS signals are weak or unavailable. The terminal is powered by Front-End Intelligent Technology (FEI), a comprehensive embedded technology that is equipped with necessary artificial intelligence to mimic human intelligence in decision-making for quicker response, better accuracy and less dependence on a backend server. With less dependency on the backend, large scale fleet management system can be implemented more effectively. The proposed system is successfully implemented and evaluated on twenty vehicles including buses and cars in Universiti Teknologi Malaysia (UTM). Results from the test-bed shown that user can monitor and track the real-time physical location and conditions of their vehicles via Internet or Short Message Service (SMS). The web-based fleet management software also helped the user to manage fleets more effectively.

I. Introduction

In this project, an intelligent fleet management system which incorporates the power of concurrent Global Positioning System (GPS) and Global System for Mobile Communications (GSM) real-time positioning, front-end intelligent and web-based management software is proposed. An intelligent front-end terminal is developed and installed in targeted vehicles. This terminal communicates with the fleet management control centre through GSM channels. User monitors and controls the system through web-based software. GPS and GSM positioning is incorporated to provide worldwide vehicle tracking capability. The terminal is powered by Front-End Intelligent Technology (FEI), a comprehensive embedded technology that is equipped with necessary artificial intelligence to mimic human intelligence in decision-making for quicker response, better accuracy and less dependence on a backend server. With less dependency on the backend, large scale fleet management system can be implemented more effectively especially for Intelligent Transport System application such as Dynamic Congestion Charging, Dynamic Speed Monitoring Enforcement and etc. The terminal is connected to the vehicle's onboard computer to gather data such as mileage, fuel consumption, driving speeds and battery level. By combining the real-time data from vehicle tracking and onboard computer, the driver's driving behaviors can be studied. Web-based fleet management software is developed as the interface between the terminal and user. This software enables the user to monitor the fleets and accomplish a series of specific tasks in the management of fleets such as driver assignments, maintenance alerts and vehicle acquisitions and disposals. In addition, to secure the security of both the driver and fleet, emergency panic button, anti-theft mechanisms and virtual geo-fencing features are incorporated in the proposed system. The proposed system is successfully implemented and evaluated on twenty vehicles including buses and cars in Universiti Teknologi Malaysia (UTM). Results from the test-bed shown that user can monitor and track the real-time physical location and conditions of their vehicles via hybrid General Packet Radio Service (GPRS) and Short Message Service (SMS). The web-based fleet management software also helped the user to manage fleets more effectively.

With the power of Front End Intelligence, the terminal will processed all the information at the remote terminal according to user defined configuration and hence, the overall system wireless

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connectivity architecture is being optimized for low-bandwidth with possibly intermittent wireless connectivity. iFM terminal only transmit event information would be transmitted immediately using GPRS and/or SMS, whereas positioning reporting could only be sent over at defined session. Nevertheless, since the terminal with front end intelligent technology, it is possible for user to configure different reporting method for each terminal dynamically that fit their application.

Section 2 contains a brief background on iFM, operational services software and the front end technology. Section 3 consists of a description of UTM project and in Section 4 we discuss Key Performance Indicator (KPI) monitoring within UTM project. We provide a description of the trial iFM applications in Section 5, as well as results of the testing of these applications. We conclude in Section 6 and discuss future plans for the iFM system.

II. Background

A. Related Research

Since May of the year 2000, the accuracy of the GPS [1] could be less than 15 meters [2], [3], [4], [5], [6] because of the up lift of Selective Availability. However, using GPS in densely populated major cities, like Kuala Lumpur & etc are not an efficient method because satellite signals are always reflected, deflected and blocked by tall and large buildings. In such cases, blind spots in GPS become a serious problem.

Because of the blind spot problem, hybridization positioning approach is utilizing concurrent GPS and the GSM positioning technologies; GSM positioning used to overcome the blind spot problem of the GPS positioning, so as to provide a better location service for fleet management.

There are several technologies [12] available for cellular phones positioning. They are either Network based or Mobile station based [11]. Nevertheless, these methods utilized the signal attenuation, angle of arrival (AOA), time of arrival (TOA), time difference of arrival (TDOA), enhanced observed time difference (EOTD), and time advance (TA) to locate unmodified cellular phones. Basically, all of these methods are based on knowing the location of reference points and then relating them to the location of the mobile phone. TOA, TDOA and observed time difference (OTD) are all time-based methods that take the propagation time from mobile phone to base station (or from base station to the mobile phone in case of OTD). As the time for the signals to reach mobile phone is known in the Time Division Multiple Access (TDMA) network system, this information can be exploited for location estimation.

As the positioning technology of both GPS and GSM are mature enough and available for civil use, Positioning accuracy and availability would be the major task in this investigation.

B. Front End Technology

For Intelligent Transport System, we need to consider large scale implementation; we shall consider the implementation of iFM for large number of fleet which maybe more than 1,000,000 fleets. Hence, it is very important to have the iFM terminal that designed with front end intelligent technology to reduce the necessary processing requirement at the backend. The front end intelligent technology is powered by distribute processing capability, i.e., there will be multiple processor to process different tasks such as GSM related information to be process independently from GPS related information and then combine into a single table, with this approach, the iFM terminal will be able to parallel perform complex task to ensure fast response especially to perform concurrent GPS and GSM positioning. Front End Intelligent enabled the iFM terminal to be configured individually according to requirement dynamically at the most possible optimized operation communication cost.

III Concurrent GPS and GSM positioning system concept and technique

Concurrent GPS and GSM positioning system is a superior hybrid positioning technology that designed for high accuracy and high availability. The principal of proposed concurrent positioning is to make the most of GPS positioning and Mobile Station based GSM positioning. Both positioning is first be processed independently and then being validated by Positioning Validation (PV) before system being determine what should be the finalized position as shown in Figure 1.

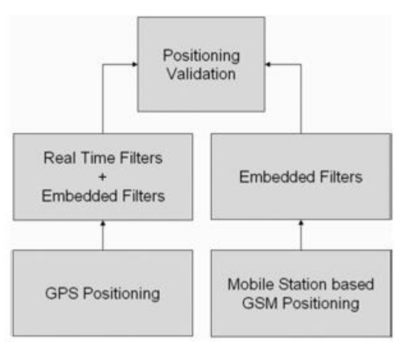

Fig 1. Concurrent Positioning Concept

For GPS positioning, there are various filters [7] technique to remove those less accurate positions can improve the quality positioning data. Since Fleet Management focus a lot of real time application, hence, commonly used model-based Kalman filter techniques [9], [10] is chosen. On top of that, three embedded filters have been introduced to further remove unwanted potential false positions, these new embedded filters are:

- Speed Spike Filter to remove any position reported with speed of 150% increase from the defined increasable speed per second, see Figure 3.
- Distance Spike Filter to remove any position reported with distance of 150% increase from the definable increasable distance per second See Figure 4.
- Bearing Filter to remove any position reported with 180 degree reverse direction from next reported position within 1 second See Figure 5.
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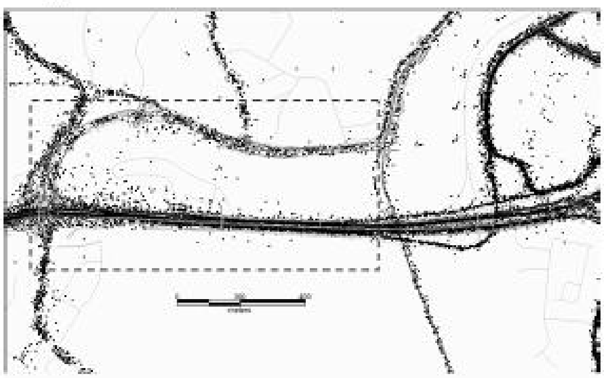

Fig 2. Repeat 100 trips typical GPS reported position over Federal Highway, Petaling Jaya, Malaysia

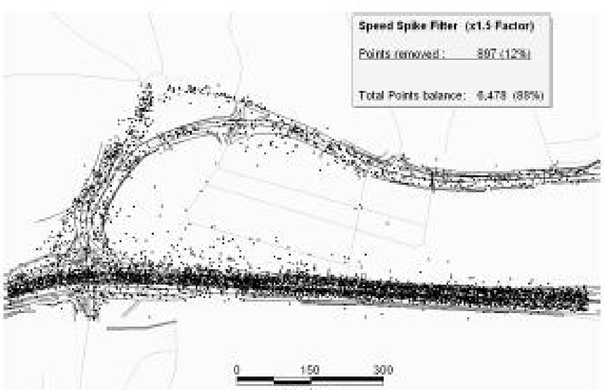

Fig 3. Speed Spike Filter (X1.5 Factor over next position) GPS reported position over Federal Highway, Petaling Jaya, Malaysia.

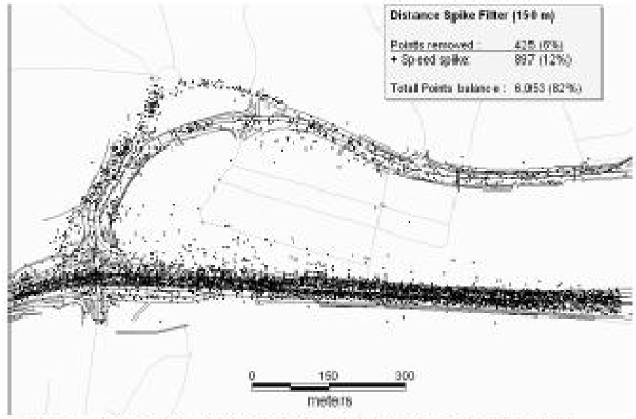

Fig 4. Distance Spike Filter (X1.5 Factor over next position) GPS reported position over Federal Highway, Petaling Jaya, Malaysia.

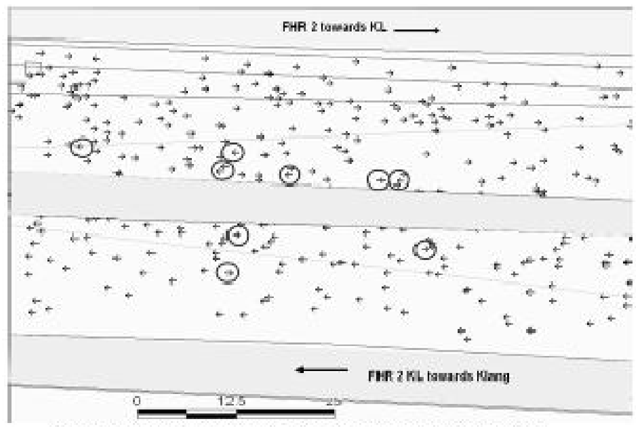

Fig 5: Bearing Filter (180 degrees against next position) GPS reported position over Federal Highway, Petaling Jaya, Malaysia.

For GSM positioning, we have choose the readily available information that Mobile Station (MS) can read using AT command. We have collected information of Cell-ID (CI), Timing Advance (TA) and received signals' level (RXLEV) **CI+TA+NMR** (Network Measurement Report) for computation using formula as below.

TA gives a distance estimation between Base Transceiver Station (BTS)s and MS straight

TA-distance = (TA-value + ½) · dTA
dTA = ½ · 3.69μs symbol period · 3e8 m/s
= 554m

Assumption:

- Omnidirectional cells: estimated position = BTS position
- Sectored cells: estimated position = intersection of antenna azimuth and TA-distance

NMR contains measured RX levels from serving cell and neighboring cell(s)

Modeling of propagation loss:

Hata's Formula $L = A + B \log10(d/\text{km})$

L: decibel path loss

A: offset loss

B: distance exponential

Calculate distance d to BTSs based on measured path loss L':

$$d/\text{km} = 10^{\wedge}((L' - A) / B)$$

It is important to highlight that the GPS positioning normally use as primary positioning in rural area while GSM positioning to be used in urban area where it can compensate the lost of GPS position [8] due not possible of direct line of sight or GPS positioning drifting during idle/stationary/non moving state. GSM positioning will be very useful to validate the poor quality of GPS positioning.

Stationary position is always the challenge and hence, it is necessary to ensure the positioning validity by analyzing both independent reported positioning via Positioning Validation (PV) process. PV can eliminate GPS drifting effect of non moving object by validating GSM positioning for not detecting of 3 changing main serving Cell ID and the previous detected/locked cell ID is not one of the current detected neighbors Cell ID list as shown in Figure 6.

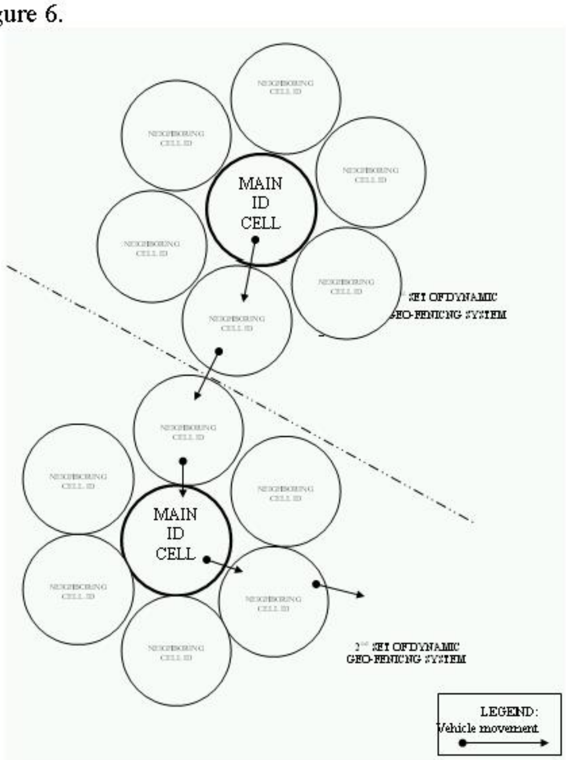

Fig 6. Illustration of Positioning Validation using GSM Positioning Technology

IV The performance or results of the concurrent GSM and GPS positioning

With the effective embedded filters, the accuracy has been greatly improved from 56m to 15m as shown in Figure 7 as in Two Dimensions (2D), Figure 8 as in Distribution Statistic Chart of positioning accuracy of +/- 3.82m in 2D While Figure 9 shown the Three Dimensions (3D) Distribution Statistic Chart. Figure 10 shown the sample web report of intelligent Fleet Management with Concurrent GPS and GSM Positioning record.

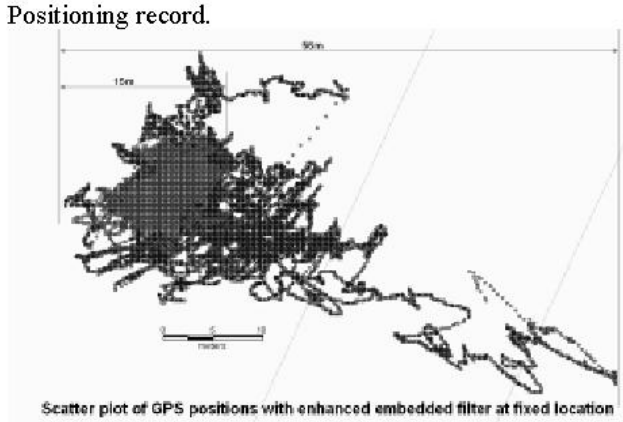

Fig 7 Accuracy of GPS reported positions shown great improvement from 56m to 15m after the embedded filter

For 95% confident, the accuracy of the concurrent GPS and GSM positioning is =/- 3.82m as shown below:

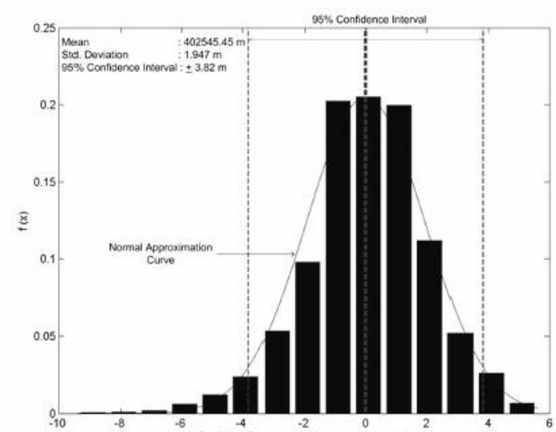

Fig 8. 95% confident position accuracy after embedded filter is +/- 3.82m

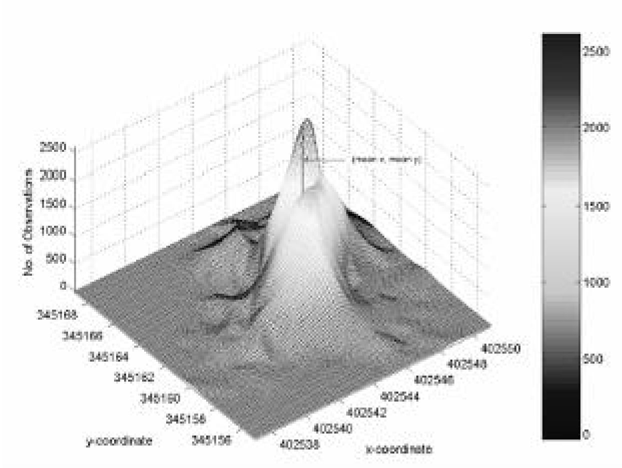

Fig 9. GPS positioning accuracy in 3D after embedded filters

Fig 10. Concurrent GPS GSM positioning data captured

V Case study

The project R&D was initiated under Industrial Grant Scheme (IGS) funded partially by Ministry of Science, Technology and Innovation (MOSTI) and now it is partially by Malaysia Technology Development Corporation (MTDC) under Commercial Research Development Fund (CRDF). The Wireless Communication Center in University Technology Malaysia, Sekudai designed a prototype of iFM technology to monitor real-time vehicle performance. The trial was implemented over 20 vehicles including buses and private cars. The Management Console will be the software platform. iFM terminal as shown without casing in Figure 11 which provide both digitals and analog interface with vehicle's wiring to gather and generate data such as mileage, fuel consumption, driving speeds and battery level. By combining the real-time data from vehicle tracking and status, the driver's driving behaviors can be studied. Web-based fleet management software is developed as the interface between the terminal and user. Figure 12 shows the useful Dashboard to provide user an easy and direct overview all the vehicle status. While the Figure 13 shows journey record overlay on Google. This software enables the user to monitor the fleets and accomplish a series of specific tasks in the management of fleets such as driver assignments, maintenance alerts and vehicle acquisitions and disposals. In addition, to secure the security of both the driver and fleet, emergency panic button, anti-theft mechanisms and virtual geo-fencing features are incorporated in the proposed system.

The proposed system is successfully implemented and evaluated on twenty vehicles including buses and cars in Universiti Teknologi Malaysia (UTM). Results from the test-bed shown that user can monitor and track the real-time physical location and conditions of their vehicles via Internet or Short Message Service (SMS). The web-based fleet management software also helped the user to manage fleets more effectively.

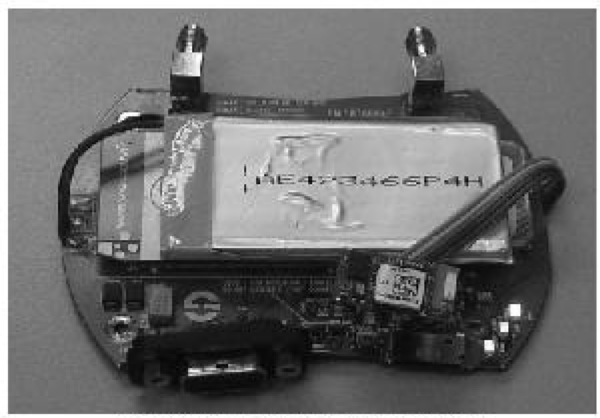

Fig 11. The device without casing

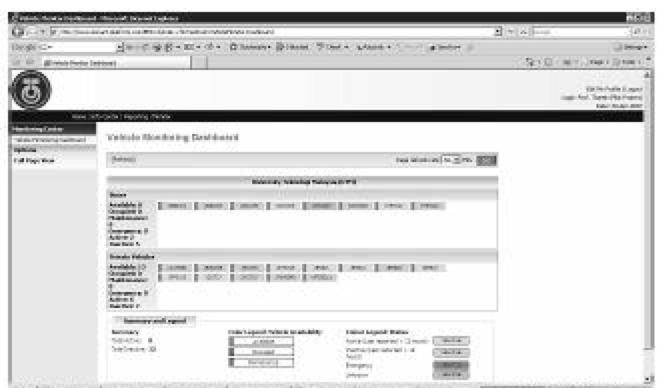

Fig 12. The web enabled Dashboard for overview of the fleet under the monitoring

Fig 13. Reporting position overlay on Google Earth page

VI Conclusion & Future Works

From the iFM trial, the concurrent GPS and GSM positioning is capable to enable seamless positioning throughout rural and urban area as GSM positioning are able to compensate the GPS blind spot problem in metropolitan areas. By fine tuning embedded filter and the dynamic position mapping, we shall able to improve the GSM positioning estimation when GPS signal is not available, more accurate job order automation capturing improve simplified daily operation and enabled better accuracy of Real Time Key Performance Indicator monitoring report generation.

By improving the GPS positioning via embedded filters, overall hybrid positioning accuracy will be improved too and hence the accuracy of such hybrid positioning method will out performs the other proposed methods in metropolitan areas. Based on our trial data, the accuracy shown +/- 3.82m with 95% confident, thus, it is believed that there are still rooms for improvement.

As for the future works, our focus will be on antenna design as it is where the signal first reach the device as well as to replace the existing GPS module with a better sensitivity GPS module which equipped with better real-time applications classically approached by model-based Kalman filter techniques [9], [10] so as to increase the accuracy of the overall positioning accuracy algorithms. Furthermore, power emissions and the pitch and yaw angles are different for each antenna, and these factors can affect the signal strength being received by the device. These factors should be considered to improve the accuracy for location estimation in our algorithms.

Nevertheless, the trial shown the Hybrid Positioning method with concurrent GPS and GSM positioning can be useful for intelligent Fleet Management system.

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